SYSTEMIC BARRIERS TO NITROGEN REDUCTION IN THE DUTCH LIVESTOCK SECTOR:

A MISSION ORIENTED INNOVATION SYSTEM APPROACH

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Table of contents

Summary

Current Dutch nitrogen levels damage biodiversity Natura 2000 nature areas and are in breach with the EU *Birds and Habitats Directive* and *Natura 2000 directive.* In 2019, as a juridical failure of the previous nitrogen regulations, the Netherlands faced *the nitrogen crisis.* This immediately pressured the government to take action and explore how to decrease these emissions. To restore biodiversity in natural areas, the livestock sector should reduce its nitrogen emissions substantially, since it accounts for 58% of the total Dutch emissions. In addition, the government proposed a mission “In 2050 the system of agriculture and nature will be net climate neutral,” of which nitrogen reduction is a prerequisite. This research uses the currently introduced *mission-oriented innovation system (MIS)* framework to investigate the implicit mission of decreasing nitrogen emissions in the livestock sector. This research aims to gain insight into the complexity of the problem and to identify the systemic barriers for decreasing nitrogen emissions in the livestock sector. Semi-structured expert interviews and desk research are used to perform a qualitative framework analysis. The following steps are performed in this research; *problem-solution diagnosis, structural analysis, system function analysis,* and finally, *systemic barrier analysis.* The final step identified multiple barriers that hamper the reduction of nitrogen emissions in the livestock sector. Most barriers are related to the ambiguity about future regulations and insecurity that they generate for farmers, making them more resistant to change. Future policies should account for more certainty and security, to increase the willingness to change among farmers, since they are the most important factor related to pursuing the mission. The isolated approach on nitrogen was both perceived as an advantage since it provided more detail and a limitation because many environmental problems are interrelated. The use of the MIS framework guided this research and provided insight into the complexity of the problem.

Keywords: nitrogen crisis, ammonia, livestock, mission-oriented innovation system, systemic barriers

1. Introduction

Nitrogen deposition has been recognised as a threat to global biodiversity (Stevens et al, 2018). Biodiversity loss is exceeding the planetary boundaries (Steffen et al, 2015). Nitrogen deposition alters nutrient ratio in the soil and increases soil acidity, consequently, certain plants overgrow others and biodiversity is lost (De Vries et al, 2011). Next to damaging the environment, nitrogen emissions can form particular matter, which causes damage to human health as they are linked to asthma and chronic respiratory diseases (De Vries, 2021). The nitrogen that causes harm to the environment and human health is nitrogen in the form of ammonia (NH3) and nitrogen oxides (NOx). These gaseous compounds flow to the atmosphere where they travel with the wind-flows and descend as nitrogen deposition. Additionally, nitrogen emissions are involved in the formation of secondary particulate matter.

The Netherlands is a nitrogen hotspot compared to other EU countries (TNO, 2019). In 118 of 162 Dutch nature reserves, so-called Natura 2000 or N2000 areas, nitrogen levels exceeded the safe ecological limits (Schmidt & Smidt, 2018). Dutch nitrogen levels are not only exceeding safe boundaries, causing damage to the environment and human health, they are also in breach with the EU *Birds and Habitats Directive* and *Natura 2000 directive* (RIVM, 2020). As a consequence of the juridical failure of the Dutch policy to alleviate nitrogen emissions (PAS), the Netherlands called out the so-called nitrogen crisis (Stokstad, 2021). As a juridical consequence, all licences obtained during the PAS were declared invalid and all construction projects were put on hold (Schut, 2020).

In order to restore and maintain a healthy ecosystem and human health in the Netherlands, nitrogen deposition must decrease. The most recent numbers from the RIVM (2021) found that in 2019, 43% of the total nitrogen emissions derived from agriculture, 20% from industry, transport and construction, and the remaining part derived from neighbouring countries. From all Dutch emissions, 58% of nitrogen emission derives in the form of ammonia, which originates from animal manure (TNO, 2019). The largest share of ammonia emissions from manure comes from cattle farming (49%), followed by pig farming (15%) and chicken farming (8%). The Netherlands counts 4 million cows, 12 million pigs and 100 million chickens (Agrimatie, 2021), which together is four times more biomass of livestock per square meter compared to the rest of Europe (Stokstad, 2021). This explains partially why the Netherlands emit more ammonia than other European countries.

Several research and policy reports have shown that in order to decrease overall nitrogen deposition, nitrogen emissions from livestock must decrease (Remkes, 2020; Lesschen et al, 2020). Political parties, governmental institutions and scientific disciplines accept this fact. However, when politicians first started to debate the question of how to decrease these emissions, they did not agree on how to solve the nitrogen crisis in livestock. The strategies on one political side propose highly technological measures such as innovative barn systems. On the other side, the solution was proposed to decrease the number of livestock animals. In particular, this last proposal by the Dutch social liberal party D66 enraged farmers and led them to protest (Rooijen, 2019). The misalignment of the proposed solution is not only visible in politics but can be perceived in policy briefs, news articles and even in scientific articles. The conflicting views on suitable measures make the pathway to reaching the nitrogen goals for the livestock sector, until now, inadequate.

The mission

A committee, Remkes, was set up to advise the government on how to tackle the nitrogen crisis. Remkes advised that "50% reduction of nitrogen emissions is sufficient to reach nitrogen levels below the critical deposition value (KDW) for most Natura 2000 areas" (Remkes, 2020). A few months later, Carola Schouten, minister of agriculture, nature, and food quality, proposed a 26% reduction of nitrogen emissions, since more reduction was not "financially and socially achievable" (NOS, 2020). Next to specific nitrogen-related goals for the livestock sector, the Dutch government proposed a mission for the whole agricultural sector: "In 2050 the system of agriculture and nature will be net climate neutral." This mission included several submissions relevant for the case of nitrogen and livestock: "Restore and utilize biodiversity," "Sustainable livestock farming," and "Emission reduction in soil and land use in agriculture" (Ministerie Economische Zaken en Klimaat, 2019). These are ambitious missions that can not be achieved if the livestock sector continues emitting nitrogen in current quantities. This makes the decrease of nitrogen emissions from livestock an *implicit* mission that needs to be fulfilled for the sake of the nitrogen crisis and the fulfilment of the other missions. Combining the nitrogen advice of Remkes (2020) and the agricultural (sub)missions from the ministry of economic affairs and climate, this research investigated the following implicit mission: “50% decrease of nitrogen emissions from livestock farming in 2030.”

In order to reach the lower nitrogen limits, restore ecosystems and improve human health, we must investigate the barriers that inhibit the fulfilment of these missions. Nonetheless, the nitrogen problem of the livestock sector is a highly complex issue and requires a non-traditional approach (Remkes, 2020). In this research, the *mission-oriented innovation system framework (MIS)* is used to deal with the complexity of the problem. The five steps in this framework will elaborate on different sub-questions which eventually lead to the main research question:

> *What systemic barriers inhibit the decrease of nitrogen emissions in the livestock sector?*

The following sub-questions are addressed:

1. *How do different problems contribute to nitrogen emissions in the livestock sector and what solutions are relevant for the decrease of nitrogen emissions in the livestock sector?*
2. *What actors, institutions, interactions and infrastructure are involved in formulating and pursuing the missions?*
3. *Which system functions contribute negatively to the functioning of the MIS: decreasing livestock-originated emissions?*

Before the sub- and the main questions are addressed, the theoretical will explain the most relevant concepts. Followed by the analytical framework, in which the steps of MIS are operationalized. The methodology explains the use of expert interviews for this research. Nest, the results are presented by the four steps of the MIS. The limitations and implications are presented in the discussion, followed by the conclusion of this research.

2. Theoretical framework

2.1 Innovation systems

The 21st century is known for many challenges that are formulated in missions. An example of a mission as proposed in the introduction is: “In 2050, the system of agriculture and nature will be net climate neutral” (Rijksoverheid, 2019). Missions are useful because they can mobilize resources and people and steer social and technical innovations in a sustainable transition (Janssen, 2020). Recently, a new way to study missions emerged that can be used to identify barriers that inhibit the fulfilment of a mission. This approach, *mission-oriented innovation system (MIS),* is a new approach to studying *innovation systems.*

Innovation systems is a way to study the complex environment in which innovation takes place and can be defined as “all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion and use of innovations” (Edquist, 1997, p.14). There are multiple approaches to innovation systems, each with another scope and purpose (Granstrand & Holgersson, 2020). A mission-oriented innovation system (MIS) is a recently proposed framework to understand the innovation system focused on the mission, in order to find barriers and formulate policies (Hekkert et al., 2020). Mission-oriented policies (MIP) enable pathways towards mission fulfilment. In order to formulate MIP, the current functioning of the mission-oriented innovation system needs to be analysed.

Four dimensions of a MIS differentiate this framework from other innovation or transition frameworks and justify its use for this research. First of all, MIS focuses on a *mission* with an underlying set of technological and social solutions (Wesseling & Meijerhof, 2020). Secondly, MIS focuses on the *wickedness* of missions. Wickedness indicates that both a mission’s problems and solutions are contested, highly complex and involve uncertainty (Wanzenböck et al., 2020). Thirdly, MIS are *temporal and embedded.* Proper missions should be time-bound on the medium to long terms, e.g. 10-30 years (Mazzucato, 2018) and missions are embedded into other innovation systems (Wesseling & Meijerhof, 2020) since relevant solutions are already being developed. Lastly, missions provide *directionality*. This is different from other transition frameworks like the multi-level perspective framework, which focuses on bottom-up innovation and transformation without a clear direction (Wanzenböck et al., 2020).

These four dimensions are found in the mission-oriented innovation system of this research. Although the mission proposed in the introduction is implicit, it provides directionality. The mission is temporary, as the Dutch government has proposed nitrogen deposition targets for 2025, 2030 and 2035 (Rijksoverheid, 2020) and agricultural missions for 2050 (Rijksoverheid, 2019). Although the nitrogen problem is not new, no total solution has been proposed yet due to conflicting interests different actors have. This study will provide more information on just how complex and wicked this problem is.

2.2. Structural components, system functions and systemic barriers

Innovation systems consist of four structural elements: actors, institutions, interactions and infrastructure (Wieczorek & Hekkert, 2012). *Actors* fulfil different roles and are delineated into different categories based on their role in economic activity: civil society, government, NGOs, companies, knowledge institutes, and legal and financial parties. *Institutions* are divided into soft and hard institutions. Soft institutions are common habits, routines and shared concepts, hard institutions are rules, norms and strategies. *Interactions* or *networks* are relations between actors. *Infrastructure* is divided into physical, knowledge and financial infrastructure. Whether the innovation system is performing well is determined by certain processes, which are called system functions. The following system functions are proposed in Wesseling & Meijerhof (2020): *entrepreneurial activities (F1), knowledge development (F2), knowledge diffusion (F3), problem directionality (F4a), solution directionality (F4b), reflexivity (F4c), market formation (F5), mobilisation of resources (F6), creation of legitimacy (F7)*. A definition of these system functions can be found in Table 1 in section 3.3.

An innovation system approach can help identify system failures and barriers (Granstrand & Holgersson, 2020), defined here as obstacles that hamper the decrease of nitrogen emissions in the livestock sector. This mission is studied by the use of structural-functional analysis of the MIS. Barriers to system functioning are therefore called *systemic barriers* or *systemic problems* and indicate weaknesses that pertain to the system structure (Kieft et al, 2017) and hinder the development and functioning of the system (Wieczorek & Hekkert, 2012). Wieczorek & Hekkert (2012) propose that if the system has weak functions, the systemic barriers are related to either the presence or capability of one or more of the structural elements: 1) actors, 2) institutions, 3) interaction or 4) infrastructure.

3. Analytical framework

The structure of this research is based on the MIS approach and follows five steps (Wesseling and Meijerhof, 2020). The first three steps aim to answer the sub-questions, which form the pre-study for step 4, the analysis of the systemic barriers. Step 5 is not part of the results section since policy suggestions are mentioned in the discussion.

1. Problem-solution diagnosis
2. Structural analysis
3. System function analysis
4. Systemic barriers analysis
5. Identification of systemic policy instruments

3.1 Problem-solution diagnosis

The first step of studying the mission-oriented innovation system is to investigate and identify the different problems and solutions relevant to the mission. *Problem-directionality* is about the different societal problems included and the mission's formulation. *Solution-directionality* concerns the solutions that are found promising in fulfiling the missions.

The following sub-question is answered in the problem-solution diagnosis:

1. *How do different problems contribute to nitrogen emissions in the livestock sector and which solutions are relevant for the decrease of nitrogen emissions in the livestock sector?*

3.2 Structural Analysis

After describing the problems and solutions subjected to the missions, the second step maps the structural element involved in formulating and pursuing the mission. This includes the relevant actors, institutions, networks and infrastructure. A distinction is made between the mission arena and the overall MIS. *The mission arena* consists of all actors that are engaged in formulating the mission and governing its implementation. The pursuit of the mission, however, depends on a larger group: *the overall MI*S. These are all the actors, institutions, interactions and infrastructures that are related to legitimizing, developing and adopting the mission's solution.

The following sub-question is answered in the structural analysis:

2. *What actors, institutions, interactions and infrastructure are involved in governing and pursuing the mission?*

3.3. System functions analysis

The system functions are mapped in table 1. The first column shows the name of the system function and the second column its interpretation. In the third column, diagnostic questions are proposed that guide the data collection and system function analysis. System functions are analysed based on their ranks during the data collections. The ranks are between 1 and 5 and indicate the fulfilment of the system functions.

1. very weak system functioning
1. weak system functioning
2. moderate system functioning
3. strong system functioning
4. very strong system functioning

The following question is answered in the system-function analysis:

2. *How are the different system functions performing?*

Table 1: *System functions and their interpretation (Wesseling & Meijerhof, 2020), complemented with diagnostic questions and indicators that guide this research.*

SYSTEM FUNCTION	MIS INTERPRETATION	DIAGNOSTIC QUESTION
SF1: Entrepreneurial activities	Experiments with (clusters of) solutions to enable learning; entering markets for new solutions; engaging in business model innovations to the diffusion of solutions.	→ Are experiments to develop existing and new solutions to decreasing nitrogen in the livestock, conducted sufficiently rapidly to complete the mission?
SF2: Knowledge development	Learning by searching and by 'doing', resulting in the development and a better understanding of new technical and social knowledge on problems and solutions, through R&D, social and behavioural science research.	→ Is there sufficient knowledge developed about the problem and the potential solutions?
SF3: Knowledge diffusion	Stakeholder meetings, conferences, governance structures, public consultations, mission progress reports and other forms of disseminating technical and social knowledge for the mission's solutions and societal problems.	→ Is knowledge of the problem and solutions regarding nitrogen emissions in livestock farming diffused among stakeholders?
SF4a Problem directionality	The direction provided to stakeholders' societal problem conceptions and the level of priority they give it.	→ How do stakeholders prioritize the problem of livestock-originated nitrogen in relation to other problems?
SF4b Solution directionality	The direction provided to the search for technological and social solutions, as well as the coordination efforts needed to identify, select and exploit synergetic sets of solutions to the mission.	→ How do stakeholders support potential solutions?

SF4c Reflexivity	Reflexive monitoring, anticipation, evaluation and impact assessment procedures, which provides the analytical and forward-looking basis for redirecting the system's problem framing and search for solutions based on lessons learned and changing context.	→ Is the decrease of nitrogen in livestock monitored?
SF5: Market formation	Creating niche markets and upscaling support for technical and social solutions; phasing out or destabilizing markets for practices and technologies harmful to the mission.	→ Are formal or informal policies supporting the diffusion of solutions to decreasing nitrogen in livestock and are stakeholders adopting them?
SF6: Resources mobilization	Mobilization of human, financial and material resources to enable all other system functions	→ How much (financial) resources are mobilized for the decrease of livestock-originated nitrogen?
SF7: Creation of legitimacy	Creating legitimacy for prioritizing the problem and the development and diffusion of its solutions.	→ Do all stakeholders support the nitrogen problem the livestock has? and what solutions gain the strongest support or opposition?

3.4 Systemic barriers analysis

As proposed in section 2.2 of the theoretical framework, the weakness can be caused by problems regarding the presence or capabilities of the structural elements related to that specific system function (Wieczorek & Hekkert, 2012). The system function analysis indicates problems to each system function. These problems are related to the presence, capability or quality of one of the structural elements. An example of this mechanism is shown in table 2. The last step is to identify the systemic barriers that are superior to the systemic problems. This is done by mapping all systemic problems, find overlap and aggregate into main systemic barriers.

The main research question is answered in the systemic barriers analysis:

What systemic barriers inhibit the decrease of nitrogen emissions in the livestock sector?

Table 2: *Systemic problems based on functional–structural analysis of an innovation system. Adjusted from Wieczorek & Hekkert (2012).*

SYSTEM FUNCTION	STRUCTURAL ELEMENT	SUB-CATEGORY	TYPE OF PROBLEM	PROBLEM
F1: Entrepreneurial activities	Actors	Government Farmers	Presence	
			Capability	
	Institutions	Hard Soft	Presence	
			Quality	
	Interactions	Networks Actor ↔ Actor	Presence	
			Quality	
	Infrastructure	Financial **Physical** Knowledge	**Presence**	**Farmers have no money to experiment**
			Quality	

4. Methodology

In order to obtain all relevant information required for analysing the MIS, five expert interviews are conducted because they can answer questions directly related to the system functions. Information from the interviews is complemented with desk research in order to increase the validity of the claims that are made (Bogner et al., 2009).

4.1 Expert interviews

Table 3 gives an overview of the anonymized interviewees' profiles. The experts were asked to rank every system function between 1 and 5. Additional questions were asked to elaborate on the expert's answers. The interviews are therefore considered semi-structured. The duration of the interviews varied between 25-50 minutes. The interviews were held online via Microsoft Teams after contacting them by email or phone. The interviewees were informed about the aim of the research and were verbally asked for consent to record and process the interview. The recordings are stored safely and are destroyed after the final deadline. This is in line with the ethical issues proposed in Bryman (2014).

Table 3: Organisation, function and expertise of experts

REFERENCE	ORGANISATION AND FUNCTION	EXPERTISE	DATE
EXP1	*Utrecht University*, researcher and assistant professor	Biodiversity conservation, transitions from conventional farming to more sustainable farming	2/6/2021
EXP2	*Wageningen university and research, Dairy campus integraal aanpak*, project manager	connecting science to practice for sustainable dairy farming projects.	2/6/2021
EXP3	*Utrecht University*, researcher and assistant professor	Nature inclusive dairy farming, policy and governance for agricultural transformations	3/6/2021

EXP4	*Centrum voor landbouw en milieu (CLM).* Consultant and project manager	Water quality, ammonia and climate, Economic calculations.	7/6/2021
EXP5	*Wageningen University and Research, Dairy farm de Marke, kringloopwijzer* Researcher and project manager	Collecting data Communicating about science and practice developments in dairy farming, sustainable dairy farming.	9/6/2021

4.2 Qualitative Coding

The information gathered during the interviews is processed and assessed by the use of qualitative coding. Qualitative coding is about "how you define what the data you are analysing are about" (Gibbs, 2007). The analytical framework formed the basis for this coding process. This is called *framework analysis* and is considered *structured coding* (Gale et al., 2013). Next to the fixed categories, additional categories are added for more overview. These *semi-structured coding* provided a convenient way of collecting, analysing, and interpreting the expert data and within the existing framework. Interviews were colour-coded in google documents, in which each step and category of the framework was ascribed a certain colour. In addition, colour-coding is used for the systemic barrier analysis, where systemic problems regarding system functions were aggregated into main barriers.

4.3 Desk research

Desk research was done both prior to and after conducting the interviews. Prior desk research was required to gain an understanding of the problem and to be able to ask adequate questions to the experts. After the interviews, desk research complemented the insights from experts. Information was searched for in google search engine and google scholar, using Dutch or English keywords relevant to that section. E.g. varieties of the following keywords '*experimenten verminderen stikstof veehouderij'* generated relevant information for the function *entrepreneurial activities*.

4.4 Reliability and validation

Targeting experts rather than random people of a certain group is a non-probability sampling technique. This research did not intend to replicate previous research or to be replicated, therefore, non-probability sampling is a sufficient method Furthermore, the results of this research can not be generalized for other missions or countries, since it concerns a specific mission in the Netherlands.

Two use of two data sources, namely, expert interviews and pre-existing research, increased the reliability of this research. Furthermore, the reliability is influenced by the choices made during interviewing and coding. The coder minimized distortion by sticking to the categories that emerged from the pre-existing MIS framework from Wesseling and Meijerhof (2020). In their research, a case study was incorporated, which showed that coding was a valid method that generated knowledge about the system and the barriers subject to the mission.

5. Results

5.1 Problem solution diagnosis

1. *How do different problems contribute to the mission? and what solutions are relevant for decreasing the nitrogen emissions in the livestock sector?*

5.1.1 Problem diagnosis

In the introduction, the following mission is proposed: *50 % decrease of nitrogen emissions from the livestock sector in 2030.* The problems subjected to this mission are multidimensional and either led to the mission or make it hard to fulfil.

Environmental aspect

When animal faeces and urine are mixed together, ammonia is formed. This is emitted to the atmosphere and can form nitrogen deposition, which causes multiple environmental problems like eutrophication and biodiversity loss (De Vries et al., 2011). More details are described in the introduction.

Juridical aspect

With the help of different laws and regulations and the deployment of technologies, the Netherlands already decreased ammonia emissions from livestock by 67% between 1990 to 2013 (EU, 2021). Although this is a large decrease, the emissions that remain, still exceed the National Emission Ceiling (EU, 2021). In 2019, the council of state (Raad van State) declared the PAS regulation, the formal law to alleviate nitrogen emissions, invalid. The law was in conflict with the EU habitat directive that declared that projects could not be licensed if they could potentially harm nature habitats (Raad van State, 2019). All handed permits had to be licensed again through the Wet Natuurbescherming (Wnb) and an Area-specific Nitrogen Approach was proposed with more focus on local nitrogen deposition in N2000 areas (Aanpak Stikstof, 2021).

Political aspects

The government acknowledges that nitrogen emission from the livestock sector must decrease. The views on how much, and more importantly, how this decrease must be realized are, however, contrasting. This is reflected by the program parties for the house of representatives election in 2021. The statement ranges between "decrease livestock with 75%"(Partij van de Dieren) and "do nothing and withdraw from the EU" (Forum voor Democratie) (Bloemhof, 2021).

Economic aspect

The Netherlands' second and third-largest agricultural export groups are dairy and eggs products (€8.3 billion) and meat products (€8.6) and is the biggest exporting country of animal products in the EU (CBS, 2021). Although the Netherlands is a small country with a dense population, it produces more than it consumes which results in a *positive trade balance.* This was achieved through a process called *intensification*, which encompasses that more output is generated with the same amounts of input, in terms of animals, land and labour (Udo et al., 2011). As a consequence, the number of animals on a farm increased, and the number of farms decreased (CBS, 2021). The current economic activity of the livestock sector is of large interest to some actors in this discussion. Decreasing nitrogen emissions will cost a lot of money, however, not decreasing entails costs. In April 2020, Schouten, minister of agriculture, allocated nearly three billion euros to restore Natura 2000 networks (Aanpak Stikstof, 2020). Although this is a substantial amount, they do not think if it is enough to restore nature (Hofs, 2020).

Social aspects

The nitrogen crisis in 2019 stirred up farmers to protest. They wanted to draw attention to their position in society, the continuously changing regulations, and the lack of empathy and respect for farmwork (Rooijen, 2019). The trust index for farmers reached its bottom in the first month of 2020 (Agrimatie, n.d.). Next to problems for farmers, residents that live close to large pig and chicken barns experience extreme stench (van Hoof, 2020) and respiratory issues (de Vries, 2021).

5.1.2 Solution diagnosis

As mentioned in the introduction, different measures can decrease nitrogen emissions in the livestock sector. With help of the desk research and interview analysis, different measures, strategies and solutions have been identified which potentially can decrease nitrogen emissions. An overview can be found in Appendix 1.

Manure injection, low emission floors and air scrubbers are the most prominent technological measures to decrease ammonia emissions. A combination of these technological measures has already decreased ammonia emissions by 67%. The technologies can still be improved and optimized for each sub-sector in livestock farming. E.g in cattle farming, responsible for 50% of ammonia emissions, air scrubbers are less suitable since they only decrease emissions in closed barns systems, which is uncommon in cattle farming. For dairy farming, low emission floors and grazing are proposed as measures for nitrogen reduction. In the meadow, urine is locally separated from faeces, thus reducing the formation of ammonia. At the same time, the ground is fertilized and less manure is left to process (Schils et al, 2019). An additional benefit is that less feed has to be imported, thus improving the circularity of the farm. Nitrogen fines, nitrogen rewards and nitrogen taxes are economic measures that in a way will favour farmers who decreased nitrogen emissions. However, these measures are not (yet) implemented, since they are complex and cause undesirable effects, f.e. increasing the price of daily products for consumers. Buying out farms near Natura 2000 areas effectively reduces the amount of nitrogen that deposits in these areas, and is in a set of measures proposed by the government (Hofs, 2020). However, farmers can only be bought out voluntarily. Extensity farms, e.g. transitioning a conventional farm to organic, is also proposed as measure by the government. However, it is unclear if organic farming really decreases ammonia emissions. Some research indeed indicates a decrease (Plomp & Migchels, 2021), but other research shows a decrease in nitrogen emissions in organic farming (Bikker et al, 2013) especially for chickens and pigs.
There is a another group of solution. This direction “stresses that a transition towards sustainable agriculture requires more than improving agribusiness as usual” (Elzen et al., 2017). This *agricultural transition, agro-food sustainability transition* or *agroecological transition* argues that the technical solutions can not solve the problem. It proposes that the number of animals should be decreased.

Different technological and management measures should be combined in order to decrease the most nitrogen emissions. However, they are hard to compare with *agroecological transition.* The underlying belief regarding transition proposals is that technology is not enough to solve all the related agricultural-environmental problems, while on the other hand, technology measures have proved to be very effective in decreasing nitrogen emissions.

5.2 Structural analysis

2. *What actors, institutions, interactions and infrastructure are involved in governing and pursuing the missions?*

5.2.1 Mission area

The following actors are involved in governing the mission of decreasing nitrogen emissions in livestock: The ministry of agriculture, nature and food (LNV), the house of representatives, the twelve provincial governments, committee Remkes, LTO and other farmer interest organisations, and non-governmental environmental organisations. The ministry of economic affairs and climate (EZK) is involved in formulating the agricultural missions for 2050. This is explained in more detail in the introduction.

5.2.2 Overall MIS

Actors

The most important actors in pursuing the mission are livestock farmers, farmers interest groups, environmental interest groups, farmers' advisors, veterinarians, suppliers of feed and barns, veterinarians, universities, research projects, consumers, supermarkets, value chain actors.

Institutions

There are hard institutions in the form of regulations, policies and requirements, of which there are numerous concerning livestock farming. Livestock farmers have to request a licence if they want to start a farm or if they want to expand,or change. These licences regard environmental and nature permits. The request is based on the Act Ammonia and livestock (Wav), the Act Odour Nuisance and livestock (Wgv), and an assessment regarding a particular matter (Infomil, n.d). In the Wav, codes for certain barn systems are complemented with ammonia emissions in kg per animal. Specific requirements regarding housing are sharpened every few years.

The most relevant soft institutions relevant to decreasing ammonia emissions is that the Netherlands is a highly agricultural-productive and efficient country. An international campaign “farming the future” was launched by the Netherlands, which is about the aim of “a sustainable food system that can boost production, the economy, and help us to restore nature and biodiversity.”(Farming The Future, n.d).

Interactions

An important network of these missions is the network of 116 demonstration farms on which there is experimented with decreasing ammonia and methane emissions simultaneously (integraal aanpakken, 2021). This project is funded by the government, but there are multiple projects with the aim of connecting science and practice, and communicating what works to other farms (EXP2, 2021). Next to projects, interest organizations are important for interactions among actors. An important farmer organisation is LTO, which protects the interest of (livestock)farmers in politics, and serves as a network for individual farmers. Additionally, there are multiple newspapers and websites specifically for (livestock)farmers, on these platforms, the latest news is shared (Erisman & Verhoeven, 2019).

Infrastructure

Physical infrastructure relevant to this mission is available agricultural land, Natura 2000 areas, the number of animals, the availability of qualitative barns including low-emission floors and air scrubber, and the animal feed, either imported or produced in the Netherlands. The knowledge infrastructure relevant to the missions are scholars with knowledge about nitrogen emissions in livestock, and environmental, social and economic knowledge relevant for pursuing this mission. Wageningen University and Research (WUR) and other universities, Louis Bolk Institute, and the ministry of LNV, generating relevant knowledge about sustainable livestock farming. Part of the knowledge infrastructure are the livestock consultants.

Financial infrastructure is about the budget the government reserved for solving the nitrogen crisis and decreasing emissions from livestock. In 2020, minister Carola Schouten divided the total of €5 billion for the nitrogen crisis into €633 milion for technical measures, 175 million for farmers who want to make a sustainable transition, €1.8 billion for buying out farmers near N2000 areas and the remaining part for restoring damaged nature areas (Hofs, 2020). Apart from the budget the government reserved, the financial resources farmers themself have available for making adjustments is very important. The financial resources farmers have available is very limited. For most farmers, most of their financial capital is captured in their land, buildings and animals and they have limited financial resources on their savings account (Melkvee, 2018). One out of three chicken and pig farmers lives under the poverty line and earns less than the minimum wage (Nieuwe Oogst, 2019).

5.3 Functional Analysis

The experts ranked the functions between 1 (weak) and 5 (strong). An overview is provided in figure 1. The expert's insights are used to discuss the strengths and weaknesses of each function. The weaknesses are related to problems that are either related to the capability, quality or the absence of a structural component. The systemic problems are mapped in appendix 2.

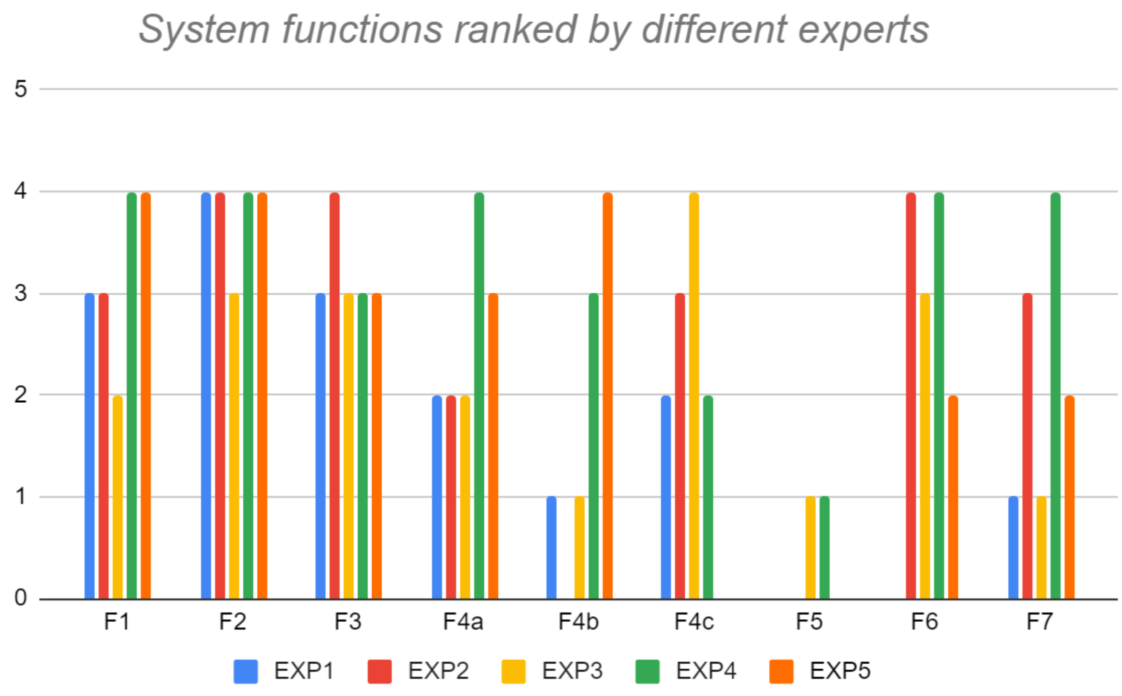

Figure 1: *Bar chart of the system functions ranked by the experts.*

5.3.1 Entrepreneurial activities

Farmers see the urgency, but not much potential to experiment with decreasing ammonia emissions (EXP1, EXP2, EXP5, 2021). Since April 2021, the provinces Gelderland, Limburg, Noord-Brabant and Overijssel have a policy that allows innovation experiments in livestock farming (Damen, 2021). Farmers mostly implement emission-low barn systems if they want to expand, in order to get a nitrogen permit, or if they have to renew old barns, who do not meet the criteria anymore (EXP2). Farmers can join research projects in which they experiment on their farm to reduce ammonia (and methane) e.g. the network of pilot farms (Integraalaanpakken, n.d). Farmers who are engaged in such projects, or who are experimenting with sustainable measures themselves can be considered *the coalition of the willing* or *peloton* (EXP1, EXP2, EXP3, 2021). Erisman & Verhoeven (2019) indicate that for circular farming, including dairy farming, about 15% is considered as the *peloton*. This number is not equally compatible with the peloton since circular farming involves more than nitrogen emissions, but it does give some indication. They also indicated that the largest share of farmers (65%) operates according to the regulations, but do not go any further.

5.3.2. Knowledge development

Most experts did not consider knowledge development as a problem regarding the mission. The details of the problem are known and solutions are available to a large extent although technical solutions are still being optimized. Two main problems regarding knowledge development have been identified. The first problem is a knowledge gap regarding actual emissions on farms (EXP4, 2021) (see F4c for more), and the second problem is a knowledge gap regarding agricultural system change. Knowledge about the social, economical and political aspects of this so-called *agroecological transition*, is underexplored (EXP3, 2021).

5.3.3. Knowledge diffusion

Most experts regarded knowledge diffusion as moderately fulfilled. The network of pilot farms is an important part of knowledge diffusion in dairy farms, as the network allows farmers and science to come together and share their knowledge. Knowledge diffusion towards farmers goes through laws and regulations, trade journals and sector associations (Erisman & Verhoeven, 2019) and value chain actors (EXP2, EXP4, 2021). Additionally, there are many reports and policy recommendations focused on policymakers. The problem regarding knowledge diffusion is not the diffusion itself, but rather the adoption of knowledge. According to the *diffusion of innovation theory* (Rogers, 1962), innovators and early adopters consist of 15% of the population. *The diffusion of innovation theory* can also be applied to farmers (Diederen et al, 2003). This share of early adopters corresponds to the share of the peloton indicated by

Erisman & Verhoeven (2019). 16% of the population are considered laggards (Rogers, 1962), a group that regarding these missions are rather identified as deniers (they deny the existence of the nitrogen problem). They are sceptical of change, and often they refer to the past in their arguments (Rogers, 1962). Laggards are not only part of the population among livestock farmers and other kinds of advisors, there are also conservative parties in politics that deny the existence of the problem. Another problem regarding knowledge diffusion is the weak interaction between the public and science. Knowledge diffusion about the importance of decreasing nitrogen in livestock is important because the public influences the house of representatives, and since they make decisions.

5.3.4. Problem directionality

In *knowledge diffusion* and *entrepreneurial activities,* two groups have been identified, the peloton and the deniers. The group between these extremes, however, form the largest share, which according to Erisman en Verhoeven (2019) group make up 65%. This group acknowledges there is a problem but 1) do not know how to improve it (EXP4, 2021), 2) do not think it is up to them to solve (EXP5, 2021), or, 3) do not think it is on the scale that is proposed (EXP2, 2021). The deniers hold back the overall directionality of the problem.

The government, an important actor in problem directionality, is divided into these three categories. However, since there is a juridical urgency to solve the nitrogen crisis, the government as a whole prioritizes this. The government points predominantly at the livestock sector, which makes sense by looking at the share of emissions (EXP4, 2021; Remkes, 2020). However, it can be argued that the government does not acknowledge the core of the problem, the surplus of manure in the Netherlands. Most solutions are formulated regarding innovative technologies or decrease emissions only near N2000 areas and do not consider the option of fewer livestock-animals in the Netherlands.

3.3.5. Solution directionality

According to the experts, the following solutions are considered suitable for nitrogen decrease in livestock farming: less protein in the feed (EXP5, 2021), grazing and different feed (EXP2, 2021), outcome-oriented regulations instead of activity-oriented regulations (EXP4, 2021), or changing the way of farming and transforming the agricultural system (EXP1, EXP3 2021).

These solutions are described in more detail in appendix 1. The variety of opinions among the experts already indicates that there is no consensus about solutions. There are many more management or technological adjustments and innovations that can potentially decrease nitrogen, but there is no clear direction of solutions agreed upon.

5.3.6. Reflexivity

Most knowledge about emissions is calculated by the use of models and are not actually measured. RIVM uses the model AERIUS which many farmers distrusted and they argued that their share of nitrogen emissions was overestimated (EXP3, 2021; NOS, 2020). Although the commotion led to the conclusion that the model used by RIVM was sufficient (Hordijk et al., 2020), it is odd that policy decisions are based on models only (EXP1, 2021). “There are 18000 dairy farms and only on 18 of them emissions are truly being measured” (EXP2, 2021). Expert 4 started measuring ammonia emissions at a farm that invested in a low emissions floor, which according to the model (RAV) decreased emissions up to 9kg/cow. The emissions turned out to be 14.5 kg/cow because the floor shovel was not scraping at the right frequency and the rubbers were worn out, two problems that are easy to solve. “This was a fluke, but on the other 18.000 farms, we do not know whether the implemented measures really reduced ammonia emissions.” This anecdote describes the importance of measuring the emissions on a farm, something which has also been mentioned in the advisory report from the committee Remkes (2020) and Hordijk et al. (2020).

5.3.7. Market formation

All experts indicated that financial incentives would motivate farmers to improve their farms. This should not be marketed with an extra nitrogen-low label, since there are already many labels and consumers would not be willing to pay more (EXP1, EXP4, 2021). Although farmers can request subsidies for sustainable barn renovations, farmers currently do not receive money if they actually decrease their nitrogen emissions (Rijksoverheid, 2021). Most farmers are joint with large corporations that process and sell their products. Since these corporations do not pay farmers more if they decrease their ammonia emissions (EXP4, 2021). For example, FrieslandCampina communicated to pay €1,00 per 100 kg extra to farmers who let their cattle graze on the meadow, and between €0,125 and €2,0 extra to farmers, based on their score on a sustainable development indicator (Friesland Campina, n.d.). Nitrogen is part of this sustainable development indicator, but is only one out of many indicators and it is not a high incentive.

5.3.8. Availability of resources

The ministry subjected €5 billion to nitrogen decrease in the livestock sector (NOS, 2020), €633 million is allocated to subsidize new barn technologies and €175 million to subsidies for farmers that want to switch to nature-inclusive or organic (Hofs, 2020). According to EXP2 and EXP5 this amount is sufficient for the measures for nitrogen decrease, but not for within the time span that is proposed (2030). The availability of financial resources from the government is a matter of priorities, say EXP1 and EXP3 (2021). However, farmers themselves have insufficient resources available to make large investments that decrease nitrogen emissions. In 2016, the Rabobank announced that one third of its dairy farmer customers faced financial problems (Runhaar, 2017). Even if they do have financial resources, they rather invest in something that is profitable (EXP1, EXP5).

5.3.9. Creation of legitimacy

EXP1 and EXP3 referenced the *creation of legitimacy* as the main problem regarding insufficient nitrogen decrease in livestock farming. "The problem is highly politicalized and polarized, this causes an impasse" (EXP1, 2021). The legitimacy will be highly influenced by the ruling government, and thus the formation of the cabinet (EXP3, 2021). However, the pressure on the livestock sector will rise (EXP3, 2021). Most stakeholders see that something must change, although it is unclear how. EXP2 and EXP5 (2021) pointed out that creating legitimacy for farmers is a matter of providing direction and security. Additionally, EXP4 (2021) pointed out that sustainability-shaming decreases the legitimacy for farmers, and de-motivates them.

5.4 Systemic barrier analysis

In part 5.3 the systemic problems per function are identified and mapped in appendix 2. They are assembled into themes by making a mind map, which is also added in the appendix. From these themes, the systemic barriers are formulated. The word main is used to indicate that these are, in this research, considered the most influential regarding mission fulfilment. Additionally, the barriers identified are connected and are depicted in figure 2.

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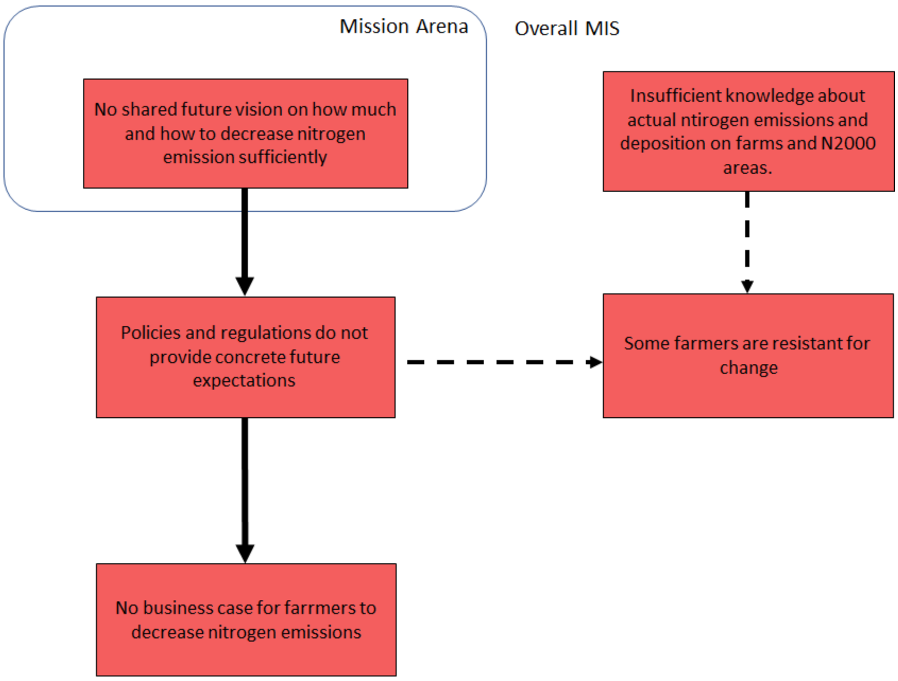

Figure 2: *Systemic barriers and their connection.*

The first barrier identified is part of the mission arena and is *the absence of a shared vision on how much and how to decrease nitrogen in the livestock sector*. The surplus of nitrogen emissions from livestock farming is acknowledged by the government from the moment it became a juridical problem. Most governmental actors, therefore, agree on decreasing the nitrogen emissions in livestock farming. However, there is no consensus on how much decrease and consequently how this decrease will take place. Additionally, the core of the problem - the surplus of manure in the Netherlands - that causes not only nitrogen deposition but many environmental problems, remains untouched. The absence of a shared future vision is reflected in *the current policies and regulations*, which do not provide *a concrete vision of what is expected of livestock farmers within a certain period.* These regulations do not provide security, e.g. "If you take this measure you can continue farming." (EXP5, 2021). Currently, the regulations are sharpened every few years, and give no guarantee that improvements made today will fall within regulations within a few years. This insecurity for future regulations makes it hard for farmers to take more measures than what is already required. The third barrier is the *lack of a business case for farmers to decrease nitrogen.* If farmers choose to invest in nitrogen reducing measures, like the newest emission-low barns systems, they might receive subsidies, but they do receive extra money for their products, not from corporations that buy, process and sell their livestock-products, nor from the government. Another barrier is the *lack* *of knowledge regarding actual nitrogen emissions from farms and deposition in N200 areas.* The emission-factors in the models are estimates, and do not represent actual emissions. This ambiguity about the emissions nurse resistance to change amongst farmers. To take some of this disbelief away and to increase knowledge about effective measures, more knowledge about actual emissions on farms and depositions in nature areas is required. The last barrier is *the resistance to change and decrease nitrogen emissions* amongst a share of the livestock farmers. Most farmers want to continue farming, future insecurity caused by changing regulations and the absence of financial incentives endanger the viability of their farms. Ambiguity about the models provide a justification to farmers to not worry about nitrogen emissions on their farms.

6. Discussion

6.1 Interpretation of key findings.

This research followed the mission-oriented innovation system framework to generate insight into 1) the multidimensionality of the problem and the variety of solutions, 2) the structural elements of the system and 3) the performance of nine system functions. With help of expert interviews and desk research, these steps added up step 4, in which the five barriers have been identified. The first barrier is the absence of a shared future vision on how much decrease in emissions should be realized and how this should be done. This is reflected in the second barrier, the current policies and regulations that do not include concrete expectations. The third barrier is the lack of a business case for farmers to decrease nitrogen emissions The fourth barrier is the lack of knowledge about exact emissions on farms and deposition in nature areas. The insecurity about future expectations for farmers and the ambiguity about the emission-share of livestock cause that farmers are more resistant to change. This is the final barrier that inhibits the decrease of nitrogen emissions.

Previous research to systemic barriers for nature-inclusive dairy in the Netherlands identified five barriers of which two correspond with the barriers identified in this research: the importance of financial rewards and the lack of a concrete future vision on the problem and solutions (Runhaar et al, 2020). This overlap is not surprising. Dairy farms make up a large share of the total dutch livestock farms. Furthermore, Runhaar et al. (2020) used a technical innovation system approach (Hekkert et al, 2007) and mission-oriented innovation systems (Wesseling & Meijerhof, 2020) elaborates on this approach. Wesseling & Meijerhof (2020) investigated a case study about sustainable shipping. One of the identified barriers was the lack of a business case to adopt radical sustainable innovations. The absence of a business case is identified as a barrier to nitrogen decrease in livestock farming as well. The most surprising barrier identified is the lack of knowledge about exact emissions on farms and Natura 2000 areas. This is important to measure the progress of the mission, take away scepticism amongst farmers and gain insight into which measures generate the most reduction.

6.2 Limitations of key findings

Several limitations of this research are related to the use of expert interviews. First of all, the number of interviews (5) was enough to obtain relevant insights although more interviews with a wider variety of experts would have added to the multidimensionality of the analysis. Secondly, the use of interviews as the main source for determining the system function is not objective. This limitation was partly accounted for by combining the results with scientific literature and policy documents. The third limitation addresses the use of the MIS framework. The original framework consists of five steps, the last step involving the formulation of mission-oriented policies. Due to time constraints, it was not possible to propose comprehensive policies, which is step 5 of the MIS framework. However, section 6.4 of the discussion proposes some guidelines for policies regarding nitrogen reduction in livestock farming. The final limitation of this research is regarding the focus of this research. Decreasing nitrogen emissions in the livestock sector is very important to solve the nitrogen crisis, but it does not make the livestock sector instantly sustainable. Nitrogen deposition is only one of the many harmful environmental consequences of livestock farming. Climate change, soil degradation and deforestation are environmental problems that livestock farming contributes to. Solutions for nitrogen decrease should therefore be assessed on multiple impacts. Luckily, some solutions that are identified have beneficial impacts on other problems. For example, reducing the number of animals would benefit most environmental problems since a decrease in total animals will generate both less nitrogen and methane emissions. Less food is required to feed all the animals, which will decrease deforestation.

6.3 Scientific implications

This research adds to the scientific literature and public debate about the nitrogen crisis. It focused on the barriers to nitrogen reduction in livestock farming, which has not been researched before. It is of juridical and environmental urgency that these barriers will be overcome. Therefore, more in-depth research is required about these barriers, how they are perceived by different actors, and most importantly, how they can be overcome. Furthermore, *agroecological transformations* should further explored and specified as possible solutions for nitrogen reduction and other problems.

The *mission-oriented innovation system framework* is a working paper (Wesseling & Meijerhof, 2020). This could be perceived as a shortcoming, since it is not yet peer-reviewed. However, this framework builded upon other innovation system frameworks, which have been acknowledged widely by innovation scholars. Additionally, the unique focus on missions made the MIS framework suitable for this specific research. This thesis thus tested the applicability of this framework. The framework is considered useful to explore and research missions, e.g the missions the Dutch ministry proposed. This research formulated an implicit mission, which did not cause problems and proved to suit the framework. Furthermore, the framework left some room for incorporating other methods, which is considered a strength.

6.4 Policy implications

The barriers identified in this research can be used to search for and formulate suitable policy instruments that will guide the mission in the right direction. This is part of the MIS framework but has not been covered in this thesis. During the interviews, a few important points were mentioned that should be considered when designing policy instruments. First of all, not every livestock farm is the same. Process- or activity-oriented policies are not always favoured. Outcome-oriented policies in which farmers get more freedom would increase legitimacy for farmers (EXP4, 2021). Secondly, farmers need a future perspective. Policies should be designed and formulated with some more social security so that farmers would know what is expected of them in 5, 10 or 20 years. This would increase the willingness of farmers to change (EXP5, 2021). Lastly, it should be avoided that policy instruments for decreasing nitrogen emissions increase other environmental problems (EXP2, EXP3, 2021).

7. Conclusion

This paper aimed to gain insight into the problem, the solutions and structural elements, and investigate barriers related to the implicit mission of decreasing nitrogen emissions in livestock farming. Expert interviews and desk research were used as input for the steps of the MIS approach. This added up to answering the following question: *What systemic barriers inhibit the decrease of nitrogen emissions in the livestock sector?*

Environmental, economic, social and juridical aspects make this problem very complex. Many different technological and management solutions are proposed for nitrogen decrease. However, some scientists argue for an agricultural system change. Two actors were considered extremely important for this mission; the government, since they make the policies and regulations, and the livestock farmers, since they have to generate the decrease of nitrogen emissions. The following systemic barriers are identified; 1) the lack of a shared future vision on how much and how to decrease nitrogen emissions, 2) the current policies and regulations that do not account for future expectations, 3) the lack of financial incentives for farmers to decrease nitrogen, 4) insufficient knowledge about actual emissions and depositions. The last three barriers cause uncertainty and insecurity about the future of farmers and cause 5) resistance to change.

Due to the juridical urgency of nitrogen decrease, the government is urged to take action to overcome these barriers. Hopefully, this mission will be accomplished so that it can become an example of how the Dutch agricultural is transitions towards a more sustainable system.

Bibliography

Aanpak Stikstof (n.d). Over de kamerbrief van 24 april 2020: structurele aanpak. https://www.aanpakstikstof.nl/themas/natuurherstel/vragen-en-antwoorden/over-de-kamerbrief-van-24-april-2020-structurele-aanpak

Aanpak Stikstof (n.d.) Waarom is er een stikstofprobleem? https://www.aanpakstikstof.nl/waarom-is-er-een-stikstofprobleem/vragen-en-antwoorden

Agrimatie (n.d.). Ontwikkeling veestapel. Retrieved on May 4th. https://www.agrimatie.nl/ThemaResultaat.aspx?subpubID=2232&themaID=2286&indicatorID=2922

Agrimatie (n.d.) Vertrouwen varkenshouder sterk toegenomen. Retrieved on July 1st. https://www.agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2255&themaID=2527

Bikker, P., Harn, J. V., Groenenstein, C. M., Wit, J. D., Bruggen, C. V., & Luesink, H. H. (2013). Stikstof-en fosforexcretie van varkens, pluimvee en rundvee in biologische en gangbare houderijsystemen. *Wageningen University and Research.*

Bloemhof, L. (2021, March 9). Partijen blijken vooral verdeeld over toekomst Nederlands boer. *NOS.* https://nos.nl/artikel/2371982-partijen-blijken-vooral-verdeeld-over-toekomst-van-nederlandse-boer

Bogner, A., Littig, B., & Menz, W. (2009). Introduction: Expert interviews—An introduction to a new methodological debate. In Interviewing experts (pp. 1-13). Palgrave Macmillan, London.

Bryman, A. (2016). Social research methods. Oxford university press. ISBN: 9780199689453

CBS (2021). Landbouw; gewassen, dieren, grondgebruik en arbeid op nationaal niveau. https://opendata.cbs.nl/#/CBS/nl/dataset/81302ned/table

CBS (2021). Nederland grootste vleesexporteur van de EU. https://www.cbs.nl/nl-nl/nieuws/2021/25/nederland-grootste-vleesexporteur-van-de-eu

Damen, F. (2021, May 25). Experimenteerruimte voor innovatie in de veehouderij. *Omgevingsweb.*https://www.omgevingsweb.nl/nieuws/experimenteerruimte-voor-innovatie-in-de-veehouderij-2/

de Vries, W. (2021). Impacts of nitrogen emissions on ecosystems and human health: A mini review. Current Opinion in Environmental Science & Health, 100249.

de Vries, W., Erisman, J. W., Spranger, T., Stevens, C. J., & van den Berg, L. (2011). Nitrogen as a threat to European terrestrial biodiversity. The European nitrogen assessment: sources, effects and policy perspectives, 436-494.

Diederen, P. J. M., van Meijl, H., Wolters, A., & Bijak, K. (2003). Innovation adoption in Agriculture: Innovators, Early Adoptors and Laggards. Cahiers d'economie et sociologie rurales, 67, 30-50. http://www.inra.fr/esr/publications/cahiers/pdf/diederen.pdf

Edquist, C. (Ed.). (1997). Systems of innovation: technologies, institutions, and organizations. Psychology Press.

Elzen, B., Augustyn, A. M., Barbier, M., & van Mierlo, B. (2017). Agroecological transitions: changes and breakthroughs in the making. *Wageningen University & Research.*

Erisman, J. W. & Verhoeven, F. (2019). Kringlooplandbouw in de praktijk: Analyse en aanbevelingen voor beleid. https://www.louisbolk.org/downloads/3417.pdf

European commission (n.d). Reduction of National Emissions https://ec.europa.eu/environment/air/reduction/index.htm

Farming the Future (n.d.) Farming the future. https://farmingthefuture.nl/

Friesland Campina (n.d.) Melkprijssystemetiek. https://www.frieslandcampina.com/nl/onzeboeren/eigendom-van-leden-melkveehouders/melkprijssystematiek/

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. BMC medical research methodology, 13(1), 1-8.

Gibbs, G. R. (2007). Thematic coding and categorizing. Analyzing qualitative data, 703, 38-56.

Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. Technovation, 90, 102098.

Hekkert, M. P., Janssen, M. J., Wesseling, J. H., & Negro, S. O. (2020). Mission-oriented innovation systems. Environmental Innovation and Societal Transitions, 34, 76-79.

Hekkert, M.P., Suurs, R. a a, Negro, S.O., Kuhlmann, S., Smits, R.E.H.M. (2007). Functions of innovation systems: A new approach for analysing technological change. Technol. Forecast. Soc. Change 74, 413–432. https://doi.org/10.1016/j.techfore.2006.03.00

Hofs, Yvonne (2020, April 27). De stikstof crisis, bijna vergeten: miljarden lossen het conflict niet op. *De Volkskrant.* https://www.volkskrant.nl/nieuws-achtergrond/de-stikstofcrisis-bijna-vergeten-miljarden-lossen-het-conflict-niet-op~b97c66cb/

Hordijk, Leen & Erisman, Jan Willem & Eskes, Henk & Hanekamp, J.C. & Krol, Maarten & Levelt, P.F. & Schaap, Martijn & Vries, Wim & Visser, Auke. (2020). Niet uit de lucht gegrepen Eerste rapport van het Adviescollege Meten en Berekenen Stikstof. 10.13140/RG.2.2.19588.68489.

Huijsmans, J. F. M., Schröder, J. J., Vermeulen, G. D., De Goede, R. G. M., Kleijn, D., & Teunissen, W. A. (2008). Emissiearme mesttoediening: ammoniakemissie, mestbenutting en nevenaspecten (No. 195). *Plant Research International.*

Integraal Aanpakken (n.d.). *Integraal aanpakken.* https://www.integraalaanpakken.nl/nl/integraalaanpakken.htm

Janssen, M. (2020). Utrecht University launches 'Mission-oriented Innovation Policy Observatory'. *Utrecht University.* https://www.uu.nl/en/news/utrecht-university-launches-mission-oriented-innovation-policy-observatory#:~:text=8%20June%202020-,Utrecht%20University%20launches%20'Mission%2Doriented%20Innovation%20Policy%20Observatory',and%20tackle%20complex%20societal%20challenges.

Kieft, A., Harmsen, R., & Hekkert, M. P. (2017). Interactions between systemic problems in innovation systems: The case of energy-efficient houses in the Netherlands. Environmental innovation and societal transitions, 24, 32-44.

Lesschen, J. P., Reijs, J., Vellinga, T., Verhagen, J., Kros, H., de Vries, M., ... & Daatselaar, C. (2020). Scenariostudie perspectief voor ontwikkelrichtingen Nederlandse landbouw in 2050 (No. 2984). Wageningen Environmental Research.

LTO (2021, May 25). Gezamenlijk voorstel boeren-, natuur-, en ondernemersorganisaties om uit de stikstof impasse te komen. *Land- en Tuinbouworganisatie Nederland.* https://www.lto.nl/gezamenlijk-voorstel-boeren-natuur-en-ondernemersorganisaties-om-uit-stikstofimpasse-te-komen/

Mazzucato, M. (2018). Mission-oriented innovation policies: challenges and opportunities. Industrial and Corporate Change, 27(5), 803-815.

Melkvee (2018). Bijna 20 procent agrariërs is miljonair. https://www.melkvee.nl/artikel/138741-bijna-20-procent-agrariers-is-miljonair/

Nieuwe Oogst (2019). Een of de drie boeren heeft minder dan minimum loon. https://www.nieuweoogst.nl/nieuws/2019/05/15/een-op-drie-boeren-heeft-minder-dan-minimumloon

Ministerie voor economische zaken en klimaat (2019). Missies voor topsectoren. https://www.rijksoverheid.nl/documenten/publicaties/2019/04/26/missies

NOS (2020). Kabinet hakt knoop door, 5 miljard voor stikstof aanpak. https://nos.nl/artikel/2331599-kabinet-hakt-knoop-door-5-miljard-voor-stikstofaanpak

NOS (2020). Zuivelfonds komt met alternatieve stikstof cijfers, verschil lijkt verklaarbaar. https://nos.nl/artikel/2323872-zuivelfonds-komt-met-alternatieve-stikstofcijfers-verschil-lijkt-verklaarbaar

NOS (2020, Oktober 10). Schouten presenteert stikstofwet: 'meer reductie lastig haalbaar'. https://nos.nl/artikel/2352142-schouten-presenteert-stikstofwet-meer-reductie-lastig-haalbaar

Ploegmakers, H., Raaphorst, K. M. C., Kooij, H. J., & Aarts, M. N. C. (2020). Analyse debat kringlooplandbouw: Eindrapport.

Plomp, M., & Migchels, G. (2021). Quick scan stikstofproblematiek en biologische veehouderij: Mogelijke bijdrage van de biologische sector aan oplossingsrichtingen voor ammoniakproblematiek (No. 1306). *Wageningen Livestock Research.*

Raad van State (2019, May 29). PAS mag niet als toestemming basis voor activiteiten worden gebruikt. https://www.raadvanstate.nl/@115651/pas-mag/

Remkes, J. W., van Dijk, J. J., Dijkgraaf, E., Freriks, A., Gerbrandy, G. J., Maij, W. H., ... & Vet, L. E. M. (2020). Niet alles kan overal: Eindadvies over structurele aanpak op lange termijn. *Adviescollege Stikstofproblematiek.*

Rijksoverheid (2020, October 10). Stikstof Aanpak: sterkere natuur, perspectief voor de bouw. https://www.rijksoverheid.nl/actueel/nieuws/2020/10/13/stikstofaanpak-sterkere-natuur-perspectief-voor-de-bouw

RIVM (2016). Veehouderij heeft een effect op longfunctie omwonende. *Rijksinstituut voor Volksgezondheid en Milieu.* https://www.rivm.nl/nieuws/veehouderij-heeft-effect-op-longfunctie-omwonenden

RIVM (n.d.). Stikstof. https://www.rivm.nl/stikstof

Rogers, E. (1962). Diffusion of Innovations.

Rooijen, L. (2019, September 30). Dit is waarom boeren gaan protesteren. *Boerderij*.https://www.boerderij.nl/dit-is-waarom-boeren-gaan-demonstreren

Runhaar, H. (2017). Governing the transformation towards 'nature-inclusive'agriculture: Insights from the Netherlands. *International Journal of Agricultural Sustainability,* 15(4), 340-349.

Runhaar, H., Hekkert, M., Wojtynia, N., Vermunt, D. (2020). Five barriers to more nature-inclusive dairy farming. https://www.uu.nl/en/news/five-barriers-to-more-nature-inclusive-dairy-farming

Schils, R., Philipsen, B., Hoekstra, N., Holshof, G., Zom, R., Hoving, I., ... & van den Pol-van Dasselaar, A. (2019). Amazing grazing: A public and private partnership to stimulate grazing practices in intensive dairy systems. *Sustainability*, *11*(20), 5868.

Schmidt, A. M., & Smidt, R. A. (2018). Scientific analysis of the status of designated Natura 2000 areas and the protection of nitrogen-sensitive species and habitats: Dutch contribution (No. 2880). Wageningen Environmental Research.

Schut, G. (2020, June 30). Zo klimt de bouw uit de stikstofcrisis. *Technisch weekblad.* https://www.technischweekblad.nl/nieuws/zo-klimt-de-bouw-uit-de-stikstofcrisis

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223).

Stevens, C. J., David, T. I., & Storkey, J. (2018). Atmospheric nitrogen deposition in terrestrial ecosystems: Its impact on plant communities and consequences across trophic levels. *Functional ecology*, *32*(7), 1757-1769.

Stokstad, E. (2019). Nitrogen crisis threatens Dutch environment—and economy. Science, 366(6470), 1180-1181. https://doi.org/10.1126/science.366.6470.1180

TNO (2019). Factsheet emissie en depositie van stikstof in Nederlands. https://www.tno.nl/nl/over-tno/nieuws/2019/10/factsheet-stikstofemissie/

Udo, H. M. J., Aklilu, H. A., Phong, L. T., Bosma, R. H., Budisatria, I. G. S., Patil, B. R., ...& Bebe, B. O. (2011). Impact of intensification of different types of livestock production in smallholder crop-livestock systems. *Livestock science*, 139(1-2), 22-29.

Van den Broek, W. (2009). Emissiearme vloer, wie komt met wat. *Wageningen University and Research.* https://edepot.wur.nl/14441

van Hoof, N. (2020, June 10). Olga kan raam niet open zetten en de was niet buiten hangen door stank van varkens. *Omroep Brabant.* https://www.omroepbrabant.nl/nieuws/3215728/olga-kan-het-raam-niet-openzetten-en-de-was-niet-buitenhangen-door-de-stank-van-varkens

Veeteelt (2020). Uitkoop piekbelasters van start. https://veeteelt.nl/nieuws/uitkooppiekbelasters-kan-van-start

Vonk, J., van Pul, W. A. J., Schols, E., & de Groot, G. M. (2012). Naleeftekorten bij luchtwassers in de intensieve veehouderij: Effect op emissiereductie) van ammoniak.

Wanzenböck, I., Wesseling, J.H., Frenken, K., Hekkert, M.P., Weber, K.M., 2020. A framework for mission-oriented innovation policy: Alternative pathways through the problem–solution space. Sci. Public Policy 1–16. https://doi.org/10.1093/scipol/scaa027

Wesseling, J. H., Meijerhof, N., & Nederland, O. (2020)Development and application of a Mission-oriented Innovation Systems (MIS) approach. https://www.uu.nl/sites/default/files/Wesseling%20and%20Meijerhof%202020_working%20paper.pdf

Wieczorek, A. J., & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. Science and public policy, 39(1), 74-87.

WUR (n.d.), Vijf vragen over minder eiwit in veevoer. https://www.wur.nl/nl/nieuws/Vijfvragen-over-minder-eiwit-in-veevoer.htm

Appendix 1: Overview of different solutions

SOLUTION	DESCRIPTION	PHASE	ADVANTAGE	DISADVANTAGE	SOURCE
TECHNICAL MEASURES					
Air Scrubber	Air with ammonia compounds flows through a machine with chemicals that clears ammonia out of the air	Already implemented in many pig barns, some chicken farms and very few cattle stables.	Less stench for local residents, less ammonia to the atmosphere. If used correctly, reduction between 70-95%.	Expensive (although subsidies were possible till 2016). Only possible in closed barns (so in general not for cows).	Vonk et al., 2020
Low emission floor	Urine is drained away quicker than feces, reducing the contact moment with those. This inhibits the formation of ammonia.	Implemented mainly for cattle	Possible in open barns, can decrease ammonia formation up to 40 %.	Expensive If not managed well, it will not work optimally and emissions reduction will not be reached.	Van den broek, 2009
Emission-low manure application	Manure is injected in the ground instead and or	Obligatory since 1988-1994	reduces ammonia emissions during application of manure.	It does not work on every type of ground type. It can harm nutrients in the soil.	Huijsmans et al., (2008)

	diluted with water. Less ammonia is emitted to air.		effectiveness between 5-60%	There is too much manure to process all.	
MANAGEMENTAL MEASURES					
More grazing	Letting cows graze more on pasture helps prevent mixing of urine and feces.	More grazing for cattle since 2015	Not expensive. 5% reduction of ammonia (at least). Improves animal health. Less feed is required → cheaper.	More effort, less overview and cows can be milked less frequently.	Schils et al., 2019
Change feed	If less protein is feeded to the cow, and milk production remains stable, less ammonia leaves the cow.	already being implemented for cows.	less protein in the manure → less ammonia. estimation of 10% reductions. No additional cost, possibly decreased cost	Can decrease animal health, milk production or milk quality.	Wageningen University and Research (n.d)
Buying out farms	Relocating farms near N2000 areas to minimize local nitrogen deposition	The government proposed this in 2020. Especially pig	It is voluntary, farmers receive a substantial amount of money.	Expensive for the government. Since it is voluntary, peak emittes can	Veeteelt (2020).

		(500 already) but also chicken and cows	Very effective for local decrease of nitrogen deposition.	not be forced. Farmers are mad since they can not start a farm anywhere else in this regulation	
Fewer animals on each farm	Decrease in number of animals decreases the amount of manure.	Not implemented systematically. Can be a consequence of permits and regulations	less ammonia emissions, since less manure is produced. Being able to farm with more care per animal.	Less profitable for a farmer if the farm is designed for a certain amount of cows. A lot of resistance in politics	Ploegmakers et al., 2020.
Nitrogen rights	Every farmer gets nitrogen rights, which limits the amount of nitrogen a farmer can emit.	Already implemented through Wet ammoniak en veehouderij (WAV).	Farmers are obligated to decrease nitrogen emissions, they can choose how.	If farmers improved their emissions, they could increase their farms. Therefore, in the end, it does not always lead to lower emissions. “It is odd that you receive the right to pollute”	Infomil (n.d)

POLICY MEASURES					
Outcome-oriented regulations	Similar to nitrogen rights. communicate a maximum amount of nitrogen that can be emitted per kind of farmer, and let them decide which package of measures they use.	Similar to nitrogen rights, this is more preferred.	Willingness to change for farmers increases.	More difficult to measure and check	EXP4, 2021
Activity-oriented regulation	Obligatory use of certain technologies	Implemented for some technologies in some sectors	If a technology is very effective, making it obligatory will decrease ammonia emissions on each farm	Will not fit every farm. If not managed well, it does not add to decrease. Difficult for small businesses.	EXP4, 2021
Transition farms to organic	Conventional livestock to organic farming.	Included in the policy proposal 2020 for decreasing nitrogen in livestock farming.	Ecological is often less animals, thus less manure. Farmers receive more for its products.	Ammonia emissions per cow will not decrease. For cows, they remain similar, for chicken and pig they	Bikker et al., 2013

		Subsidies will come available.	Improved animal welfare.	increase with about 25% and 100%.	

Appendix 2: Systemic problems per system function and per theme.

SYSTEM FUNCTION	STRUCTURAL ELEMENT	SUB - CATEGORY	TYPE OF PROBLEM	SYSTEMIC PROBLEM
F1: Entrepreneurial activities	Institutions	Hard	Quality	Current strict regulations leave less room for experiments.
	Institution	Network	Quality	Current pilot projects to which farmers can apply, only attract farmers that are willing to change.
	Infrastructure	Financial	Presence	Most farmers do not have the financial resources to make large investments and experiment with new technologies.
F2: Knowledge development	Infrastructure	Physical	Presence	Lack of nitrogen emissions measurement points and devices.
		Knowledge	Presence	There is missing knowledge about the actual emission reduction nitrogen reducing practice generate.
		Knowledge	Quality	Insufficient knowledge about how to transform the agricultural system in the Netherlands accounting for social, economical and political dimensions.
F3: Knowledge development	Actors	Deniers	Capability	New insights regarding nitrogen emissions and solutions are not adopted, holding back the diffusion of knowledge.

	Interaction	Public ↔ Science	Presence	Interaction between the public and science is weak: General public doesn't know what solutions are relevant for solving the nitrogen crisis
F4a: Problem directionality	Actors	Government	Capability	The government as a whole does not acknowledge the core of the problem: a surplus of manure in the Netherlands.
		Deniers	Capability	Deniers of the problem decrease overall problem directionality.
	Interaction	Deniers ↔ other actors	Quality	Deniers of the nitrogen problem do not have fructuous interaction with other actors.
	Institution	Hard	Quality	Problem directionality is not captured in the regulations.
F4a: Solution directionality	Actors	Government	Capability	The government did not propose a clear pathway towards mission fulfilment
	Institutions	Soft	Presence	There is no consensus about the suitable solutions.
		Hard	Quality	Buying out peak emitters is the only practical-solution proposed to decrease nitrogen emissions of livestock farming.

	Infrastructure	Knowledge	Quality	The literature about agricultural transitions is hard to apply in real-life.
F4c: Reflexivity	Institutions	Hard	Quality	Permits are licences based on emission calculation in ‘AERIUS'. The real emissions can be higher (or lower).
	Infrastructure	Knowledge	Presence	Knowledge about actual nitrogen emissions is missing
		Physical	Presence	Insufficient measurement points on farms and N2000 areas.
F5: Market formation	Actors	Value chain actors	Capability	These actors do not reward farmers that improve nitrogen emissions.
	Institution	Hard	Quality	Farmers can receive subsidies if they want to make changes. Nitrogen reduction is not part of the subsidies farmers receive.
	Infrastructure	Financial	Presence	There is no funds for livestock farmers who decrease their ammonia emissions.
		Knowledge	Quality	Knowledge gap: what would be the best mechanism to financially reward or punish livestock farmers to decrease nitrogen?

F6: Mobilization of resources	infrastructure	Financial	capability	The proposed subsidies for technological and management measures are insufficient to decrease nitrogen emissions to the target.
F7: Creation of legitimacy	institution	Soft	presence	No social and financial security for farmers.
	interaction	Public ↔ Farmers	Quality	Citizens criticize farmers for being polluters.
	Infrastructure	Knowledge	Presence	Uncertainty about the future of livestock farms.

Figure 3: *Systemic problems mapped into themes. Mind map made in* *https://lucid.co/* .