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Impact of sustainable manure management: An exploration into the social and economic effects of the adoption of sustainable manure management on Dutch dairy farms

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Abstract

Insufficient animal manure management is one of the big contributors to the nitrogen crisis, which became a national phenomenon in the Netherlands in 2019, through leakage of ammonia from animal manure into Dutch soil. Sustainable Manure Management (SMM), as researched in this study, is a strategy which aims to limit ammonia emissions from cow manure to surround air, soil and water. SMM is one of the key strategies that need to be developed to overcome the nitrogen crisis. Aside from the issue being prevalent in the Netherlands, excessive global nitrogen deposition has a detrimental effect on air, water, soil, and human health worldwide. It was observed that although plenty of research was conducted on the environmental impact of SMM, little to no research was done on the social and economic impact of SMM. Very few studies have been conducted which present an approach to evaluating the social and economic impacts of novel sustainable technologies in the agricultural sector. As a consequence, little is known about the overall sustainability (from the economic, social and environmental perspective) of SMM. Therefore, the aim of this study was to research the economic and social effects of SMM on Dutch dairy farmers and relevant stakeholders. SMM was defined in this research as technologies implemented at the stable of Dutch dairy farms and verified by the state through the Regeling Ammoniak and Veehouderij (Rav). The economic analysis was performed based on the Sustainability Assessment of Farming and the Environment (SAFE) framework, to assess the impact of different types of SMM on economic well-being of Dutch dairy farmers. The environmental impact of these different SMM systems were considered, to be able to distinguish what SMM performed best regarding economic and environmental impact. The social analysis was performed based on a Social Life Cycle Assessment (S-LCA) to assess the impact of SMM on workers on Dutch dairy farms, the local community and dairy processing companies. For both analyses a set of indicators was proposed, including Performance Reference Points (PRP's) for the economic analysis. To obtain indicator values, structured interviews were conducted with 15 Dutch dairy farmers who apply SMM as defined in this research. It was found that economic effects vary greatly depending on the type of SMM applied. Emission reducing floors had a strong negative impact on economic well-being of Dutch dairy farmers, and with many doubts about its environmental performance this is not a promising solution. Other SMM had more positive effects, with a combination of a mono-digestor with a manure scraper and a sealed basement being the optimal solution regarding economic wellbeing as well as environmental impact. Results of the social analysis highlighted social impacts on selected stakeholders to generally be positive, with strongest positive effect on the local community. Results also highlighted that more research was needed on the stakeholder 'worker' as well as 'government' which is a stakeholder that was not covered in this research. From a theoretical perspective, general indicators were tailored to this specific field of research, through which this study presents an approach for full investigation of the sustainability of SMM, whereas prior only the environmental aspect of sustainability was covered. From a practical perspective, this study allows policy makers to be more effective in the granting of subsidies for SMM, as it has shown which SMM methods show strong performance in terms of overall sustainability, and which SMM show weak performance and should therefore be disregarded.

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1. Introduction and Problem Statement

The Dutch nitrogen crisis became a national phenomenon in 2019 and has caused massive protests and uncertainty in the business sector since (van Dijke, 2023). Its status as a national problem was initiated by a decision of the Dutch council of state to dismiss permits based on the PAS (Programma Aanpakking Stikstof). Insufficient animal manure management is one of the big contributors to the nitrogen crisis, through leakage of ammonia from animal manure[1] into Dutch soil (Stokstad, 2019). The Dutch government decided that before 2030, farmers will have to decrease their nitrogen emissions by 40% (NOS, 2022). On a global scale, excessive nitrogen deposition can lead to problems such as air quality degradation, damaging human health, degrading sensitive ecosystems and more (Liu et al., 2020). Sustainable animal manure management is one of the key strategies that need to be developed to overcome the nitrogen crisis, as lots of environmental profit can be gained from it (Migchels & de Vries, 2020).

Sustainable Manure Management (SMM) is a strategy which allows the handling of byproducts of animal production in a way that limits their impact on the quality of air, water, soil, plant, and animal resources (Malomo et al., 2018). The primary way in which SMM limits this impact, is through prevention of nutrient leakage (mostly nitrogen) into the soil (Mosquera et al., 2017). It is estimated that in the Dutch dairy industry, a reduction of 25-40% ammonia emissions is possible without the need for an increased price of the final products, which are dairy and meat products (Migchels & de Vries, 2020). New nitrogen regulations[2] are forcing Dutch farmers to quickly adapt to changing nitrogen demands (ZLTO, 2022). In face of this changing environment, manure management is becoming increasingly important to reduce environmental impacts of livestock (Gebrezgabher et al., 2013).

Policies are in place which limit the amount of nitrogen allowed in the soil of a farmer (Hoes et al., 2022). Derogation is a process which allows deviation from an official law or rule with permission from the European Union (deLoonwerker, n.d.) Through derogation, farmers with abundant grassland could legally ask for permission to use more animal manure in the grassland as here it has a lower leaking rate compared to other types of land (Hoes et al., 2022). In 2022, the Netherlands' nitrogen committee announced a three-year reduction of the derogation, exacerbating the limitations in using animal (Hoes et al., 2022). Once again, this puts pressure on Dutch farmers to adopt alternative SMM methods. If the quantity of manure exceeds the permissible limit, the farmer is obligated to remove it, which could incur costs ranging from €5 to €14 per m^3 (Hoes et al., 2022). To prevent these additional costs, farmers are increasingly being forced to adopt technologies that allow SMM.

The primary aim of environmental policies in general is to make a positive impact on the environment (Jongeneel et al., 2009). To evaluate the success of an implemented policy, an overall understanding of its holistic impacts (environmental, economic and social) is needed rather than just indications of environmental consequences. Despite the focus on environmental impact, all holistic impacts need to

[1] Animal manures are the solid, semisolid, and liquid by-products generated by animals grown to produce meat, milk, eggs, and other agricultural products for human use and consumption (Shober & Maguire, 2018). In animal manure, ammonia is formed which ends up as a nitrogen source in soil. In this research, focus will be on cow manure, which accounts for 80% of the total manure in the Netherlands(Hoes et al., 2022).

[2] Nitrogen regulations concern a set of measures that the Dutch government has taken in the agricultural, industrial, construction, traffic, and transport sector (Rijksoverheid, n.d.). The aim of these regulations is a 50% decrease in total nitrogen emissions before 2030 (NOS, 2022).In this research, focus will be on the measures taken in the agricultural sector. For this sector, a 40% decrease in nitrogen emission is aimed for by these regulations (NOS, 2022).

be addressed to achieve a sustainable pathway for development (Soltani et al., 2021). In this research, not the environmental policies are investigated but the technology adopted as a consequence of them, which is SMM. There has been previous acknowledgement for the need of a clear framework to evaluate the social and economic impact of environmental policies (Jongeneel et al., 2009). To evaluate the success of an implemented policy, an overall understanding of its impact is needed rather than just indications of environmental consequences.

Dairy farms[3] are big contributors to the nitrogen crisis in the Netherlands (Yang et al., 2022). Twenty years ago, dairy farms were responsible for about 50% of national ammonia emission (Rougoor & Van der Schans, 2001). Due to SMM, in 2011 ammonia emissions had been reduced by more than 50% since 1990 (Vellinga et al., 2011). However, to facilitate the preservation of natural habitats in the Netherlands, a reduction of 70-85% compared to 1990 was needed (Vellinga et al., 2011). As the number of dairy farms in the Netherlands started to grow again in 2014, ammonia emissions increased as well (Mons, 2019). Because of this high contribution to ammonia emissions combined with an increasing demand for dairy, relevance of SMM was estimated to be high for Dutch dairy farms. Dutch dairy farms were therefore selected in this research.

There are multiple moments in the nitrogen cycle at which ammonia can leak from farms into the environment (Fowler et al., 2013). This research will focus on ammonia leakage from the stable at which dairy cows are kept. One reason for this is the high amount of ammonia which leaks into the environment at the stable if no SMM is applied, which van der Schans et al., (1999) estimated to be about 40% of the total amount of ammonia leakage at farms. The second reason is that for reduction of this leakage certain equipment is needed, which requires an investment from the farmers (Rijkswaterstaat Ministerie van Infrastructuur En Waterstaat, 2023). This will make the economic investigation performed in this research more relevant.

Since the introduction of the new Common Agricultural Policy (CAP) in the Netherlands in 2022 the focus has shifted more towards an environmental view with the aim of limiting nitrogen concentrations in Dutch soil (NL Times, n.d.). In cooperation with other Dutch firms WNF-NL developed a Dutch Biodiversity Monitor (BDM) for dairy farming (van Doorn & Jongeneel, 2020). The DBM measures the contribution that farmers make to biodiversity on the farm and beyond through Key Performance Indicators (KPIs) (van Doorn & Jongeneel, 2020). In this way, a farmer's impact on biodiversity can be easily monitored, and financial rewards can be more accurately distributed amongst the farmers that effectively contribute to combatting biodiversity loss. What is lacking is a clear analysis of the overall impact that these new regulations and the new societal demands regarding sustainability have in terms of social impacts[4] and effect on economic well-being[5] of these farmers. This is the problem that this research aims to tackle. By incorporating frameworks from other studies and applying them in this novel context, a new and more complete understanding is obtained of the current well-being of Dutch dairy farms and the effect that sustainable manure management has on them.

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[3] A dairy farmer is a person who owns, or works on, a dairy farm and takes care of cows that produce milk which is used in dairy products (Hussain, 2021). The number of Dutch dairy farms is expected to decline by 33% before 2030, while dairy consumption is slightly increasing (WUR, 2020). Therefore, much innovation is demanded from Dutch dairy farmers.

[4] Social impacts are the positive changes that organizations and individuals make within their communities, addressing needs and challenges that society faces (Forgeard, 2024).

[5] Economic well-being defined as having present and future financial security, regarding people's consumption possibilities and their command over resources (OECD, 2013).

The aim of this research is to gain an understanding of the social and economic effects of the uptake of SMM on Dutch dairy farms. An investigation will be made into the social impacts felt by relevant stakeholders due to the adoption of SMM, as well as an investigation into the effects of the adoption of SMM on economic well-being of Dutch dairy farmers. Dutch dairy farms with SMM systems operating at the stable will be investigated to obtain knowledge about the social and economic impact of the implementation of the SMM system. Much is known about the environmental impact of SMM (Mosquera et al., 2017) (Regeling Ammoniak En Veehouderij, 2023), but a lack of research into the social and economic effects is prevalent. This research will thus contribute to the scientific body of knowledge by providing a more complete understanding of the social and economic effects of SMM on farmers and thereby on society. In addition to this, frameworks will be presented with indicators to quantify social and economic impacts, thereby presenting an approach to social and economic analysis of SMM.

Innovations should be studied in the context of the triple bottom line (people, planet, profit) to gain an understanding of the innovations' success in contributing to sustainable development (Miller, 2020). As the environmental impact (planet) of the implementation of SMM has been extensively researched, as explained above, investigation into the social and economic pillars (people, profit) was needed for a more complete understanding. This research will provide the investigation into the social and economic effects needed to gain a broad understanding of the effect of the implementation of SMM on Dutch dairy farmers. In this way, this research will contribute to a broad understanding of the impact of SMM on Dutch dairy farmers, which was mostly restricted to understanding of the environmental impact only before this research. In the practical sense, this research will allow for more well-founded choices related to sustainable manure management, because it will differentiate between different types of SMM and investigate their economic and environmental performance. In this way, subsidies towards farmers as well as investments in research and development related to sustainable manure management can be distributed more accurately, and more effectively.

2. Research Design

The first phase of this research consists of research question formulation. Following is thorough literature research on SMM to gain a deep understanding of the topic, its context and relevant concepts. In the literature review, it is demonstrated that a knowledge gap exists in this field, which this research will aim to fill. Following this, an overview is made of the stakeholders affected by the implementation of SMM. Building on this, an overview is given of frameworks used in other studies to analyze social and economic impacts of novel technologies/policies. The methodology section builds on the information retrieved in the literature review, and develops a framework that will be used to execute the empirical research. The empirical part of this research consists of a set of structured interviews conducted with Dutch dairy farmers that apply SMM technologies as indicated in Table 1. Only Dutch dairy farmers will be interviewed, and only ones that apply SMM technologies as indicated in Table 1. In these interviews, the social and economic effects of SMM on selected stakeholders are explored. The qualitative and quantitative data that is collected in these interviews will be analyzed. Data will be normalized and analyzed using Excel. Using the data of the interviews together with the data found in literature review, conclusions will be drawn about the social and economic impact of SMM on Dutch dairy farmers. Figure 1 visualizes the research framework as described above.

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Figure 1: Overview of the research design of this research, with the stages of the research and a short indication of what is done at each stage of the research.

3. Research Question

3.1 Central Research Question

As explained in the introduction, the aim of this research is to gain a broader understanding of the impact of SMM on farmers' quality of life. Therefore, the following central research question will be answered in this research:

What are the economic and social effects of the adoption of SMM practices on Dutch dairy farmers and relevant stakeholders?

The scope of the research was limited to Dutch dairy farmers only to limit the scope and improve the quality of the conducted research. As explained in the introduction, farmers were chosen as the agricultural sector is one of the biggest contributors to the nitrogen crisis. The choice for Dutch farmers was made because the nitrogen crisis is a big issue in the Netherlands, and this was therefore a relevant focus group. Lastly, dairy farmers were selected because of their big contribution to the nitrogen problem in the Netherlands, as also explained in the introduction.

3.2 Sub Research Questions

1.1 What is the effect of different sustainable manure management systems on the economic well-being of Dutch dairy farmers?

1.2 What are the social impacts of the adoption of sustainable manure management on Dutch dairy farmers and relevant stakeholders?

4. Preliminary Literature Review

Literature review was conducted to gain an overall understanding of the topic and relevant concepts. The following sections give an overview of the data extracted from the literature, which was considered useful for this research. For an explanation of the overall search strategy applied to obtain valuable literature, see Method of Literature Review.

4.1 Sustainable Manure Management

As mentioned before, the focus of this research will be on sustainable manure management methods that operate at the stables of Dutch dairy farms. Mosquera et al. (2017) made an overview of current measures used to reduce ammonia emissions from livestock farming. In this research, a differentiation was made between measures that were registered in the Regeling Ammoniak and Veehouderij (Rav) and measures that were not yet approved and published in the Rav. Only manure management methods that are registered in the Rav and thereby verified by the state will be considered in this research. Hereby, the scope of this research is limited, and the validity and environmental impact of the researched SMM systems can be easily verified. Rav mentions 40 different systems which can be applied in the stable of dairy farms (Regeling Ammoniak En Veehouderij, 2023). Mosquera et al., (2017) grouped these systems into eight categories, which are shown in Table 1. The categories have been determined by how commonly they are used by farmers. Mosquera et al. (2017) observed that almost all farmers which apply SMM at the stable have a SMM system in place which can be classified into one of these eight categories. Table 1 shows an overview of these eight categories as grouped by Mosquera et al. (2017). By providing this overview, it is clarified what types of SMM methods are investigated in this research.

Category	**Combination of adaptations**
A	-Frequent and complete disposal of manure and urine into basement -Limit air transfer between stable and manure storage basement
B	-Frequent and complete disposal of manure and urine into basement -Limit air transfer between stable and manure storage basement -Lowering ammonia content in manure
C	-Frequent and complete disposal of manure and urine into basement -Limit air transfer between stable and manure storage basement -Influence chemical interaction between ammonia and ammonium
D	-Frequent and complete disposal of manure and urine into basement -Influence chemical interaction between ammonia and ammonium
E	-Frequent and complete disposal of manure and urine into basement -Lowering ammonia content in manure -Reducing the surface area covered with manure
F	-Lowering ammonia content in manure
G	-Reducing the surface area covered with manure
H	-Cleansing air in the stable using a combination of a chemical washer and mechanical ventilation

Table 1: Overview of measures, included in the Rav, used at stables of dairy farms to reduce ammonia emissions. Categorization of measures is based on how commonly the combination of measures is used by farmers.

4.2 Knowledge Gap

In the introduction it was stated that much research has been done into the environmental impact of SMM, whereas the social and economic impact have barely been investigated. This section will give an overview of the current literature regarding the impact of sustainable manure management.

Method of Literature Review gives an overview of how literature review was performed in this study. When using search strings as stated in Method of Literature Review, the results were often studies that investigate the environmental impact of SMM. Some examples:

- Köninger et al. (2021) reviewed 407 published papers to explore the relationship between manure management and soil biodiversity. An investigation was made into what practices achieve SMM, and how it affects the environment. When investigating what practices achieve SMM, solely environmental indicators were researched, such as soil biodiversity (Köninger et al., 2021).
- In a meta-analysis by Tuomisto et al. (2012) 71 papers were reviewed to examine the environmental impact of different types of farming, in which nutrient losses (nitrogen leaching and ammonia emissions) were a key indicator of environmental impact. Again, the environmental impact of animal manure management practices was reviewed through a large-scale meta-analysis.
- Wei et al. (2022) stated that there was a worldwide focus on reducing the environmental impacts of animal manure management and conducted a study into the nitrogen excretion rates of different SMM methods.

While reviewing the available literature on SMM, it becomes clear that environmental impact is the focus. When conducting literature with search strings as shown in Method of Literature Review, it becomes apparent that studies into the social and economic effects of SMM are limited. Especially in the context researched in this study, dairy farms in the Netherlands, no in-depth knowledge is present about the social and economic impact of SMM. This is the knowledge gap that this research aims to tackle.

4.3 Stakeholder Selection Review

Literature was reviewed to identify and compare stakeholder selection processes applied in similar research. Gebrezgabher et al. (2013) identified four stakeholders involved in manure management practices in the Netherlands: Provincial government, farmers, dairy processing companies and academic groups. Provincial government is involved because of subsidies and permits that need to be provided to the farms who apply SMM or aim to do so (Gebrezgabher et al., 2013). Farmers are directly involved because the product is applied on their farm. Dairy processing companies are involved as these actors in the production chain have an increasing desire for sustainable production methods (Gebrezgabher et al., 2013). Lastly, academic groups are presumed to have a more objective look at SMM and are therefore also considered an important involved social group by Gebrezgabher et al. (2013). UNEP guidelines for S-LCA mention 5 stakeholder categories: Worker, consumer, local community, society, and value chain actors that are not consumers (UNEP, 2013). Jongeneel et al. (2009) applied his framework for social and economic analysis of environmental policies to manure regulations. In this application, the Dutch Agriculture and Horticulture Organization (LTO) and various other agricultural organizations were considered important stakeholders (Jongeneel et al., 2009). Additionally, the drinking water sector was seen as a stakeholder because nutrient leakage from animal manure would ultimately influence drinking water quality (Jongeneel et al., 2009).

For this research, four social groups were selected as relevant stakeholders: Farmers, workers on the farms, local community, and dairy processing companies. Farmers were selected as the implementation of SMM happens on their property and therefore directly affects them. Workers were selected as the implemented technology is expected to directly affect their work. Local community was selected as a stakeholder as it was mentioned by several similar studies and considered relevant especially for the social effects of SMM. Dairy processing companies are considered important stakeholders as they are closely related to dairy farms in the production chain and have a growing interest in sustainability of their supply chain (Gebrezgabher et al., 2013). Table 2 shows an overview of the stakeholders that will be considered for this research. The table also contains what part of the research (economic/social analysis) the stakeholder will be covered in. Lastly, the table shortly explains the relevance of the selected stakeholder for this research. Factors that were taken into account during stakeholder selection aside from relevance, were feasibility within this study and accessibility of the stakeholders for data collection.

Involved stakeholder	**Economic/social analysis**	**Relevance for this research**
Dutch dairy farmers	Economic	Considered the most important stakeholder as SMM is implemented on their property.
Workers	Social	Important stakeholder as implemented technology might replace, disturb or improve the labor performed by these workers.
Local community	Social	Important social stakeholder as the local community is often in social contact with the farms.
Dairy processing companies	Social	Important decision maker as they are closely related to farmers in the supply chain.

Table 2: Overview of selected stakeholders that will be considered in this research. The stakeholder groups are shown, the analysis they will be considered in and their relevance to this research.

As Dutch dairy farmers are central in this research, the economic analysis will be solely focused on this stakeholder category. For simplicity reasons as well as expected relevance, only a social analysis will be performed on the 'workers', 'local community' and 'dairy processing companies' stakeholder categories. Data on social effects on the workers and local community could largely be collected from the farmers themselves and its collection is therefore considered feasible for this study. The social analysis on the 'dairy processing companies' stakeholder category will be limited to the social relationship between the farmers and the dairy processing companies, for feasibility reasons. By performing a brief social analysis on 'dairy processing companies', involving this stakeholder category in this research was considered feasible and relevant.

4.4 Economic Impact Analysis

In the literature review, many frameworks were reviewed that have been developed to determine the economic impact of operations/policies. Input-output analysis (Oosterhaven, 2022), Computable General Equilibrium (CGE) models (Ghaith et al., 2021), Dynamic General Equilibrium Modeling (Schmidt & Wieland, 2013), Cost-benefit analysis (Mishan & Quah, 2020) and more. Specific frameworks have been developed for analysis of the sustainable impact of environmental policies, of which economic impact is one of the key components. An example of this is the Triple Bottom Line framework (Loviscek, 2021).

Jongeneel et al. (2009) addressed the need for a framework to evaluate the social and economic impact of environmental policies and subsequently developed one. Exemplary applications of their framework was applied to several environmental policies: The Fertilizer Act, the plant protection policy, the EU Water Framework Directive and the National Ecological Network. Its application to The Fertilizer Act makes it very relevant for this research.

Van Cauwenbergh et al. (2007) developed a Sustainability Assessment of Farming and the Environment (SAFE) framework which evaluates the economic well-being of farmers in the context of sustainable development. Because this framework is used to assess the economic aspects of sustainable development in agriculture, it was considered very relevant for this research. Van Cauwenbergh et al. (2007) created a hierarchical framework which consisted of 5 levels, shown in Figure 2. Each of the five levels will shortly be discussed in the context of this research.

4.4.1 Goal

The goal of SMM is to promote sustainable agriculture in which environmental, social and economic aspects are integrated (Zeng et al., 2023). Van Cauwenbergh et al. (2007) described the economic function of the agro-ecosystem as the ability to provide economic prosperity to the farming community.

4.4.2 Principle

Principles are general conditions for achieving sustainability (Van Cauwenbergh et al., 2007). The principle for the economic pillar of sustainability is defined as 'economic viability' (Van Cauwenbergh et al., 2007).

4.4.3 Criterion

A criterion is defined as the resulting state of the agro-ecosystem when a principle is respected (Van Cauwenbergh et al., 2007). A list of criteria for economic viability was presented in the SAFE framework of Van Cauwenbergh et al. (2007). Table 3 shows an overview of the criteria selected for this research, including an explanation of the criterion and their relevance to this research.

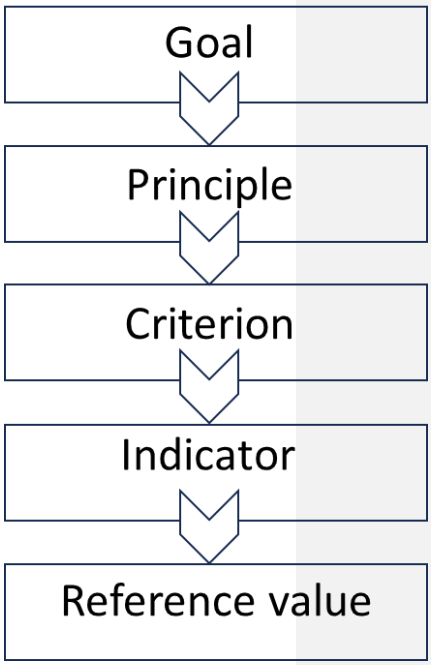

Figure 2: Structure of the SAFE framework (Van Cauwenbergh et al., 2007)

Criteria (As defined by Van Cauwenbergh et al., (2007))	**Explanation and relevance**
Dependency on direct and indirect subsidies is minimized	Provincial governments provide subsidies to encourage the application of SMM in the Netherlands (Gebrezgabher et al., 2013). These subsidies can have an impact on the economic well-being of farmers (Jongeneel et al., 2009) (Van Cauwenbergh et al., 2007). This criterion was considered relevant for this research as the implementation of SMM might have a significant effect on the dependency of the farmers on subsidies. Too much dependency on subsidies could hinder innovation (Van Cauwenbergh et al., 2007), and therefore negatively affect the farmers' economic well-being. Direct and indirect subsidies include direct income support and second pillar payments (Van Cauwenbergh et al., 2007).
Agricultural activities are economically efficient	Economic efficiency of agricultural activities was considered a relevant criterion for this research. Implementation of a SMM system comes with economic costs (Struhs et al., 2020) (Zeng et al., 2023). However, SMM systems are able to replace manual labor and thereby save the farmer money (Uvarov et al., 2020). Therefore, further investigation into this criterion for Dutch dairy farmers was deemed very relevant for this research. The payback period of the SMM system will be investigated to make an estimation of the economic efficiency of its implementation.

Table 3: Criteria used to measure the economic well-being of Dutch dairy farmers researched in this study, including explanation and relevance to the RQ.

These two criteria will be used to measure the economic well-being of Dutch dairy farmers who have adopted SMM.

4.4.4 Indicators

Indicators are quantitative or qualitative variables which can be assessed in relation to a criterion (Van Cauwenbergh et al., 2007). The following is a short explanation about the selected indicators per criterium. Table 4 gives an overview of the indicators, the source on which they are based, an explanation of their meaning and their relevance to the research questions of this study.

Dependency on direct and indirect subsidies is minimized

For this criterion the economic indicator '% of real net farm income from all subsidies' is selected based on similar choice by Sauvenier et al. (2005), who applied the SAFE framework in their study. To be able to determine this percentage, three indicators were subsequently selected based on similar procedures by Sauvenier et al. (2005) and Van Cauwenbergh et al. (2007): 1)Direct income support 2)Second pillar payments and 3) Total net farm income, all in € per month. The first two indicators will be added up and divided by the third indicator to get the percentage of real net farm income from all subsidies.

Agricultural activities are economically efficient

For this criterion the economic indicator 'Payback period of SMM system' is selected. If knowledge is present about this indicator, the value will be expressed in years. If no knowledge is present, a back-up approach is formulated. Four indicators will be used for this back-up approach. Two drivers: 1)Direct income support 2)Second pillar payments (both in € per month), and two barriers: 1)Cost of installment and 2)Cost of operating (installment in € and operating in € per month). With these four indicators, an estimation will be made of the payback period of the SMM system. A more detailed description of this approach can be found in the 'Research design and strategy' section.

Criterium	Economic indicator (based on source)	Description of indicator	Relevance
Dependency on direct and indirect subsidies is minimized	% of real net farm income from all subsidies (Sauvenier et al., 2005)	This indicator gives the percentage of total net farm income that comes from subsidies. If this value is too high, dependency on subsidies is too high.	The percentage of real net farm income from all subsidies gives an indication of how much of a farms' total income is derived from subsidies. This percentage is relevant as it gives an indication of a farms' dependence on subsidies.
	Direct income support (Van Cauwenbergh et al., 2007)	The first pillar of the Common Agricultural Policy (CAP) involves direct payments to farmers (Negre, 2022a). The CAP is a framework which the member states can apply on their own agricultural sector (Lugtenburg, 2021). To qualify for direct payments part of the first pillar of the CAP, Dutch farmers have to adhere to guidelines defined by the government. Under the 2021-2027 Cap reform, a significant part of these payments come through Basic Income Support for Sustainability (BISS) (European Commission, 2023).	When the new CAP of 2021 was approved by the European Commission, more focus was laid on biodiversity and sustainability (Lugtenburg, 2021). To qualify for direct income support, Dutch farmers now had to face new challenges because of the regional approach that was presented in the new CAP (Lugtenburg, 2021). Therefore, the implementation of SMM could be a forced decision by farmers just to qualify for direct income support. To research this, this indicator was selected.
	Second pillar payments (Van Cauwenbergh et al., 2007)	The aim of the second pillar is to promote biodiversity, sustainable agriculture and efficient use of resources (Negre, 2022b). Similar to the first pillar, farmers must adhere to certain guidelines to qualify for these payments (FarmEurope, 2022). Farmers can make extra efforts to qualify for payments through the eco-scheme of the second pillar of the new CAP (FarmEurope, 2022).	Similar to direct income support, second pillar payments require extra efforts by the farmer. These extra efforts could be a forced decision to qualify for additional payments, indicating a high degree of dependency on them. To research this, this indicator was selected.
	Total net farm income (Sauvenier et al., 2005)	Total net farm income in € per month. This value is revenues minus costs (Sauvenier et al., 2005). This value is used to calculate the '% of real net farm income from all subsidies'.	This indicator is relevant for calculating the '% of real net farm income from all subsidies'.
Agricultural activities are	Payback period of SMM system (Chen et al., 2020)	This indicator is used to define the time needed for the investment in SMM to generate enough income to recover the initial investment costs. This method has	Payback period has been used as an economic indicator in many recent studies (Dhiman & Sachdeva, 2021) (Barbosa et al., 2023)(Han et al., 2022)(Chen et al., 2020).

economically efficient		not previously been used to study the economic effect of SMM, but Chen et al. (2020) used it to conduct and economic analysis of biomass energy technology. As the method worked well in their research, it was chosen to be applied in this context. Payback period will be expressed in years.	Although no study was found on this method being applied on SMM, it was considered very relevant as economic analyses were successfully conducted on similar technologies.
	Cost of installment (Jongeneel et al., 2009)	Implementation of a SMM system comes with economic costs (Struhs et al., 2020) (Zeng et al., 2023). This indicator gives an insight into the actual costs of installment by asking the farmer for the installment costs in €.	Installment costs for a technology such as SMM at the stable can be high (Struhs et al., 2020). This indicator was considered relevant for this research, as it gives information about these installment costs.
	Cost of operating (Jongeneel et al., 2009)	Operational costs of SMM systems are amongst the major obstacles for adoption of an SMM system (M. Tan et al., 2021). This indicator will cover the operational costs of SMM by expressing the value in € per month.	Joshi & Wang (2018) found that for dairy farms in the US, operational costs are amongst the major obstacles for adoption of a SMM system. Research by Tan et al. (2021) supported this by mentioning operational costs and technical failures of SMM systems to be the main barriers to adoption. From these studies it can be concluded that operational costs of SMM systems seem to have a significant impact on the farmers who adopt them. Therefore, including this indicator in the economic analysis was considered vital.

Table 4: Economic indicators used to assess the selected criteria. Rows in which the criterion is mentioned contain the indicator, including description and relevance. Rows in which the criterion is not mentioned contain variables used to determine the indicators, also including explanation and relevance.

4.4.5 Reference Value

Reference values are used to describe the desired level of sustainability for each indicator (Van Cauwenbergh et al., 2007). The SAFE framework allows assessment based on either the comparison of an acquired indicator value with a previously defined absolute reference value or based on comparison of indicator values among each other (Sauvenier et al., 2005) (Van Cauwenbergh et al., 2007). For both indicators, PRP_min and PRP_max will be defined. For an explanation on how these will be used to normalize the obtained indicator value, see 5.5.1 Normalization of Indicators Economic Analysis. For the first indicator, '% of real net farm income from all subsidies' previously defined absolute reference values will be used. In the research by Sauvenier et al. (2005) PRP_min was defined at 0% of real net farm income from all subsidies. PRP_max was set at 100% of real net farm income from all subsidies. The same values will be used in this research.

For the indicator 'Payback period of SMM system', the reference value will be based on values obtained in other studies. Tan et al. (2021) determined the payback period of an anaerobic digestor (type of SMM system) on dairy farms to range from 4 years in the ideal situation, when subsidies are provided, to decades, when no subsidies are provided. Uvarov et al. (2020) compared three types of manure management systems and found the shortest payback period to be 2.4 years. As this was the lowest value found in literature PRP_min was determined to be 2.4 years. For the determination of PRP_max, values for payback period of a SMM system found in literature varied. Lazarus & Rudstrom (2007) found a payback period for certain SMM systems to be 10+years. The highest value found in literature was a projected simple payback period of an anaerobic digestor to be 35.99 years (Tan et al., 2022). This value was taken for PRP_max.

4.5 Social Impact Analysis

As described before, social effects are highly complex to investigate due to the levels that need to be examined. In this research, A research setup of a Social Life Cycle Assessment (S-LCA) is used following United Nations Environment Programme (UNEP) guidelines (UNEP, 2013). According to a review of S-LCA's by Hidalgo-Carvajal et al. (2023), S-LCA is a method that can be used to assess the social and sociological aspects of the products, both actual and potential impacts. These impacts can be positive and negative throughout the life cycle (Hidalgo-Carvajal et al., 2023). The UNEP guidelines propose stakeholders to consider, impact categories and sub-categories, but recognize that a set model for impact categories and impact categories which can be applied in every context does not exist (Hidalgo-Carvajal et al., 2023) (UNEP, 2013). However, the UNEP guidelines do provide stages that allow S-LCA to be performed (Hidalgo-Carvajal et al., 2023). UNEP guidelines provide four stages to perform S-LCA, which include 1) objective and scope definition 2) inventory analysis 3) impact assessment and 4) interpretation (UNEP, 2013). The following paragraphs will give an overview of the four stages of S-LCA as defined by UNEP guidelines.

4.5.1 Objective and Scope Definition

In this phase, a general overview is made of the broader ecosystem on which the researched object/technology, in this case SMM, has an effect. The aim of this section is to get an overview of why the research is being conducted, and what exactly will be involved.

Figure 3**Error! Reference source not found.** shows an overview of what such a studied ecosystem might include (UNEP, 2013).

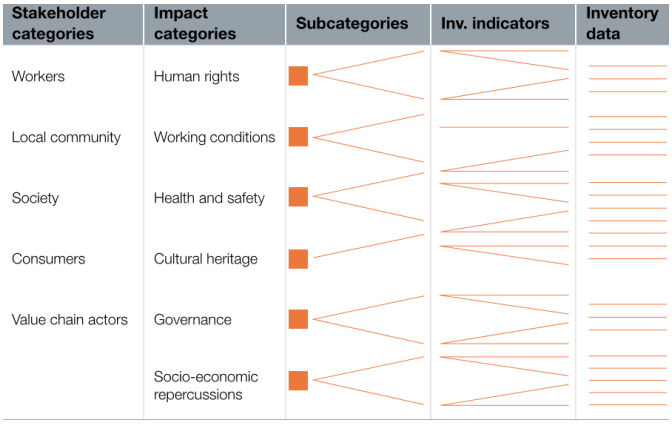

Figure 3: Possible ecosystem that can be studied with a S-LCA, including stakeholders, impact categories, sub-impact categories and indicators.

The stakeholders that will be explored in the social analysis of this research are the workers, the local community and dairy processing companies. An explanation and justification of this choice can be found in 4.3 Stakeholder Selection Review.

General concepts relevant to the research, involved stakeholders and key perspectives are mentioned in this part. In addition to this, the purpose of the research is stated as well as the scope, which defines what it is exactly that will be researched. The following information is vital in this section of a S-LCA (UNEP, 2013):

-Selection of impact categories, sub-impact categories and indicators.

-Determination of functional unit.

-Planning of data collection (elaborated on in Method of Data Collection).

For the stakeholder category 'workers' the impact category 'employment farm level' was chosen. This impact category represents the total number of employees that are present at a farm. This is a combination of the impact category 'working conditions' presented by UNEP guidelines (UNEP, 2013), and the social indicator 'employment opportunities' presented by Jongeneel et al. (2009). The impact category 'employment farm level' was considered relevant for this research. This consideration was based on the assumption that implementation of a technology that allows SMM might be a replacement for human labor.

For the stakeholder category 'local community' the impact category 'community engagement' was selected. Community engagement generally refers to how a product affects and interacts with involved communities (UNEP, 2013). For this stakeholder, the impact category 'community engagement' regards the involvement and acceptance of the local community with SMM on Dutch dairy farms. This impact category was taken from the UNEP S-LCA guidelines (UNEP, 2013). It was considered relevant for this research, as the effect of nitrogen regulations on farmer communities is often in the news, and the assumption was made that SMM plays a significant role in this.

For the stakeholder category 'dairy processing companies' the impact category 'governance/participation' was selected. This impact category represents the acceptance and the involvement of dairy processing companies in decision-making related to SMM at Dutch dairy farms.

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Dairy processing companies are closely related to Dutch dairy farms in the dairy value chain, and the assumption was therefore made that a certain degree of involvement in decision making related to SMM could be expected. This impact category was based on UNEP guidelines, which propose 'governance' as an impact category for value chain actors which are not consumers (UNEP, 2013).

Selection of sub-impact categories

Sub-impact categories aim to represent impacts within an impact category (UNEP, 2013). Sub-impact categories should be homogeneous and allow for scientifically valid aggregation (UNEP, 2013). For the impact category 'employment farm level' two sub-impact categories were considered: 'Working conditions' and 'employment quantity'. Working conditions were considered too complex to measure and were not expected to be heavily influenced by the introduction of SMM on the farm. Therefore only one sub-impact category was selected for this impact category: Employment quantity. For the impact category 'community engagement' the following two sub-impact categories were selected: 'acceptance of local community' and 'local employment'. These sub-impact categories will cover the entirety of the impact category and are homogeneous. For the impact category 'governance/participation', again two sub-impact categories were selected: 'company involvement' and 'supplier relationship' of SMM, based on . During selection of sub-impact categories, it was monitored that the whole impact category was covered by the sub-impact categories, whenever possible. Table 5 shows an overview of selected stakeholders, impact categories and corresponding sub-impact categories.

Stakeholder	**Impact category**	**Sub-impact category**
Worker	Employment farm level	▪ Employment quantity
Local community	Community engagement	▪ Acceptance of local community ▪ Local employment
Dairy processing companies	Governance/participation	▪ Company involvement ▪ Supplier relationship

Table 5: Overview of selected stakeholders, impact categories and sub-impact categories that will be considered in the social analysis of this study.

Selection of indicators

A selection of indicators was made to represent sub-impact categories in a way that makes them concrete and measurable. Table 6 shows an overview of the selected stakeholders, impact categories, sub-impact categories and corresponding indicators. For the sub-impact category 'employment quantity' the indicator 'loss/gain of employment at farm level due to adoption SMM' was selected. This decision was based on the indicator presented by Jongeneel et al. (2009), which stated 'number of employees lost'. For the sub-impact category 'acceptance of local community' the indicator 'Degree of acceptance of local community as experienced by farmer' was selected. This indicator was selected based on UNEP (2013), and chosen to gain an accurate indication of the situation while keeping feasibility in mind. For the sub-impact category 'local employment' the indicator 'local workers involuntarily relocated due to implementation SMM' was selected, based on similar indicator choice by (Bonilla-Alicea & Fu, 2022) This indicator gives an indication of the social situation regarding the local community, and data can be given by the farmer, making it feasible. For the sub-impact category 'company involvement' the indicator 'degree of involvement dairy processing companies in successful transition to SMM' and the indicator 'degree of involvement dairy processing companies in decision-making related to SMM' were selected, based on the indicator 'stakeholder involvement' presented by van Haaster et al. (2017). In the ideal situation, stakeholder involvement, in this case of dairy processing companies should improve the quality of the decisions (van Haaster et al., 2017). The

indicator 'degree of involvement dairy processing companies in successful transition to SMM' was selected to gain an understanding about the role of dairy processing companies in the transition to SMM. The indicator 'degree of involvement dairy processing companies in decision-making related to SMM' was selected to create an understanding about the further involvement of dairy processing companies once the SMM system is in place. For the sub-impact category 'supplier relationship' the indicator 'acceptance of dairy processing companies of SMM and related effects, as experienced by farmer'. This indicator was based on the indicator 'public acceptance', proposed in UNEP guidelines, and was applied to dairy processing companies. By gaining an understanding of the involvement as well as the acceptance of dairy processing companies, an overall understanding of the social relationship between the farmer and the dairy processing company is created. An explanation of how these indicators will be given meaning and how they will be quantified and normalized can be found in 5.4.2 Impact Assessment Social Analysis - Overview Indicators and5.5.2 Quantification and Normalization of Indicators Social Analysis.

Stakeholder	**Impact category**	**Sub-impact category**	**Indicators**	**Indicator based on reference**
Worker	Employment farm level	▪ Employment quantity	▪ Loss/gain of employment at farm level	(Jongeneel et al., 2009)
Local community	Community engagement	▪ Acceptance of local community	▪ Degree of acceptance of local community as experienced by farmer	(UNEP, 2013)
		▪ Local employment	▪ Local workers involuntarily relocated due to implementation SMM	(Bonilla-Alicea & Fu, 2022)
Dairy processing companies	Governance/ participation	▪ Company involvement	▪ Degree of involvement dairy processing companies in successful transition to SMM	(van Haaster et al., 2017)
			▪ Degree of involvement dairy processing companies in decision-making related to SMM	(van Haaster et al., 2017)
		▪ Supplier relationship	▪ Acceptance of dairy processing companies of SMM and related effects, as experienced by farmer	(UNEP, 2013)

Table 6: Overview of selected stakeholders, impact categories, sub-impact categories and indicators that will be considered in the social analysis of this study.

Functional unit social analysis

The functional unit will be farms which apply a SMM method that is registered and validated in the Dutch Rav (Regeling Ammoniak En Veehouderij, 2023). The functional unit of the social analysis performed in this research is purposefully different from the function unit of the economic analysis. The farm is the center of the social analysis and all social effects studied are in relationship to the farm. Interviews will be conducted with Dutch dairy farmers who apply SMM, to obtain information about the social impacts on selected stakeholders. Therefore, the functional unit of the social analysis is defined as: Farms which apply a SMM method as mentioned in Table 1.

4.5.2 Life Cycle Inventory Analysis

In this phase of the S-LCA, the collection of primary data takes place. The 'planning of data collection' as performed in the 'goal and scope' phase is executed and related to the functional unit wherever possible (UNEP, 2013). This phase is performed through structured interviews with Dutch dairy farmers and will be explained in Method of Data Collection.

4.5.3 Life Cycle Impact Assessment

In this phase of the S-LCA, the data that is collected is classified, categorized, and aggregated according to performance reference points (UNEP, 2013). Three steps are identified to be essential in this phase of a S-LCA:

1. Selection of impact categories and characterization methods and models.
2. Linkage of inventory data to particular S-LCA subcategories and impact categories (classification)
3. Determination and/or Calculation of subcategory indicator results (characterization).

Additionally, in the impact assessment, obtained indicator values are quantified and normalized (Bonilla-Alicea & Fu, 2022). This phase will be performed and elobarated on in section 5.4 Social Analysis Method and 6.2.1 Impact Assessment Social Analysis.

4.5.4 Life Cycle Interpretation

This phase explains what needs to be considered to draw conclusions from the study (UNEP, 2013). Including in this phase is reporting, concluding and recommending. The aim of the 'life cycle interpretation' stage is to identify the greatest contributors to social impacts and to propose changes to improve such impacts (Bonilla-Alicea & Fu, 2022). This phase will be performed in section 6.2.2 Life Cycle Interpretation.

4.6 Conceptual Framework

The key objective of this study is to gain a broader understanding of the economic impact of SMM on Dutch dairy farmers, and the social impact of SMM on Dutch dairy farmers, the local community and dairy processing companies. To obtain this, an economic analysis and a social analysis are performed. Figure 4 gives an overview of the main concepts used in this research. It starts with the researched technology: Sustainable manure management. SMM is a technology which influences multiple stakeholders, (farmers, provincial government, dairy processing companies, academic groups, consumer, local community, society, value chain actors, agricultural organizations and drinking water sector) as described in 4.3 Stakeholder Selection Review and shown in Figure 4. Relevant stakeholder

categories have been selected for both analyses, see 4.3 Stakeholder Selection Review. For the economic analysis, these are just the Dutch dairy farmers. For the social analysis, these are the workers, the local community, and the dairy processing companies. Frameworks explained in the literature review (S-LCA and SAFE framework) will be used to propose indicators and variables for the analyses, as shown in Figure 4. These indicators and variables will allow for measuring of the social and economic impact of SMM. A stepwise elaboration on the above-mentioned steps has been given in 4. Preliminary Literature Review and a short overview will be given in 5. Research Design and.

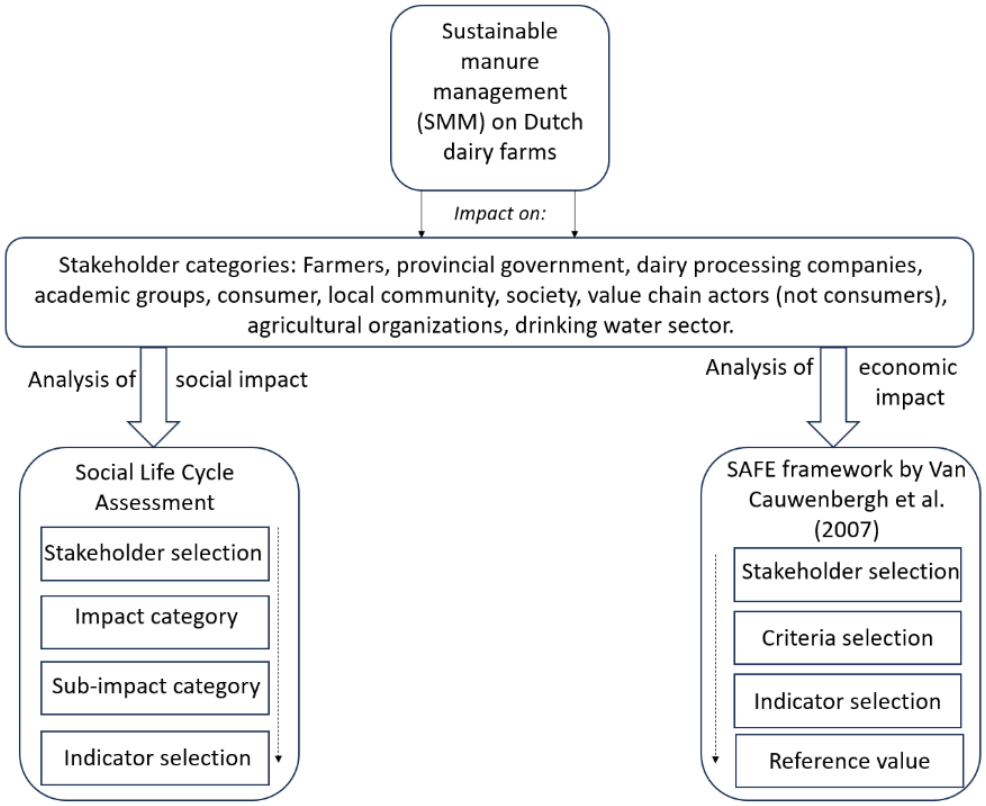

Figure 4: Conceptual framework of this study, including overview of all possible stakeholders and general overview of frameworks applied.

5. Research Design and Methods

5.1 Study Description

The study that was conducted in this research is mostly exploratory, with descriptive elements. This is because the social and economic effects of SMM were not previously studied in depth, as proved through the Literature Review. Therefore, an exploratory approach was considered most effective. In the literature review, the frameworks for the social and economic analyses have been discussed. The 'Research design and methods' section will give an overview of the frameworks that will be applied, and provide further explanation and justification.

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The data collection phase of this research was mostly exploratory with descriptive elements, consisting of structured interviews. A structured interview was chosen to make the process more time-efficient for the interviewees, considering the interviewees, Dutch dairy farmers, might have limited time. Interviews were possible because a significant understanding of the topic was acquired in the literature review performed before. Dutch dairy farmers that apply SMM as described in 4.1 Sustainable Manure Management' were asked for an interview. Indicators were defined for all social and economic analyses, aiming for concise determination of economic and social well-being of these farmers.

In this research, an abductive approach was taken. An abductive approach was considered most effective, as research in this field is limited. Frameworks were used that allow for observations from which conclusions will be drawn. A differentiation was made in the approach between the economic and social analysis (the economic analysis focuses on different SMM methods, while the social analysis focuses on different stakeholders) because enough data is present to hypothesize different outcomes, but not enough data is present to formulate clear hypotheses and take an inductive approach. Data was gathered from interviews, with the aim of deriving new conclusions that have not been drawn before. Table 7 shows an overview of the design of this study.

Descriptors	Design applied
Purpose of the study	Descriptive
Method of data collection	Interviews
Degree of crystallization	Exploratory
Power of researcher to influence variables	Ex-post-facto
Research environment	In field

Table 7: Overview of study design used in this research.

5.2 Method of Literature Review

Literature research was mainly conducted with the scientific database Scopus. In the beginning, broad terms were used for literature research to obtain as much information as possible. Later, more specific terms were used as the research narrowed down as described above. To start, inclusion and exclusion criteria were determined for the literature review. Table 8 gives an overview.

Criterium	Inclusion	Exclusion
Database used	Scopus, Google Scholar, Google	Web of Science, other databases
Publication type	Full-text available scientific articles, scientific reports, book sections, (online) newspaper article, news webpage	Full-text books, web pages (not from official news institution)

Language	English, Dutch	All other languages
Time period	Last 20 years (2003-2023)	Before 2003

Table 8: Inclusion and exclusion criteria used for the literature review.

The primary database that was used was Scopus. Scopus is known for its extensive database, valuable search- and analysis tools and more. Publication types that were excluded were full-text books and web pages that were not from official news institutions. For complementary information Google scholar was used. To find the latest news articles and facts Google was used. Full-text books were disregarded for time constraint purposes, and web pages were excluded because of their lack of validation. For certain information, web pages were needed, but it was chosen that these would have to come from official news institutions to prevent the use of misinformation. Publications could be either in Dutch or English, and had to be published in the last 20 years. The limit was set at 20 years to prevent the use of dated sources.

After determining the inclusion and exclusion criteria, core concepts and relevant keywords were determined. Table 9 shows an overview of core concepts and relevant keywords. Many of the terms were used in Dutch as well, as much of the research concerning Dutch dairy farms was published in Dutch language.

"Sustainable manure management"	"Nitrogen emission"	"Dutch dairy farm*"
"Social impact"	"Economic impact"	"Ammonia reduction"
"Dairy farm emission*"	"innovative technolog*"	"Social Life Cycle Assessment"
"Economic indicators"	"Emission reduc*"	"Payback period"
"Social and economic effects"	"Income and happiness"	"Sustainability analys*"

Table 9: Overview of core concepts and relevant keywords used to conduct the literature review.

Subsequently, a list of search strings was developed per RQ. For the RQ: What is the effect of the adoption of sustainable manure management on the economic well-being of Dutch dairy farmers and relevant stakeholders? The following search strings were developed and used in Scopus, in which keywords were searched within abstract, article title and keywords :

1) "Economic impact" AND "Sustainable manure management"
2) "Payback period" AND "Manure management technolog*"
3) "Sustainable manure management practices" AND income

For the RQ: What is the effect of the adoption of sustainable manure management on the social well-being of Dutch dairy farmers and relevant stakeholders?

1) "Social life cycle assessment" (Search within: Article title)
2) "Social life cycle assessment" AND "innovative technolog*")
3) "Social impact" AND "dairy cow manure management"

These search strings generally produced around 10-100 articles. These search strings were therefore considered broad enough to provide sufficient relevant data. First, the results were filtered for publication date and language as defined in Table 8. Articles were then checked for relevance by reading of titles. If they seemed relevant, the abstract and key concepts were read. If the study could be used in this research, they were saved in Mendeley reference manager for further consultation. Studies that were very applicable to this research were entirely read.

A general critical appraisal form, as well as critical appraisal forms both SRQ's were developed. This was done to help with systematically extracting useful data, information, and/or knowledge from the selected articles. Following are the general appraisal questions summed up.

General critical appraisal questions

1. Objective of the study:
    i. What is the primary objective of this study?
    ii. Is the research question stated clearly?
2. Scope of the study:
    i. What is the scope of the study? How well is it defined?
    ii. How relevant is the scope of this research?
3. Research methods
    i. What methods were used for data collection?
    ii. How relevant are they for addressing the RQ's?
4. Main findings
    i. What are the key findings/conclusions?
    ii. How relevant are the main findings to the RQ's?

Critical appraisal questions of SRQ: What is the effect of the adoption of sustainable manure management on the social well-being of Dutch dairy farmers and relevant stakeholders?

1. Indicators social well-being:
    i. How are indicators of social well-being defined in this research?
    ii. What measurements are used for determination of social well-being?
2. Data collection:
    i. How was data on social indicators collected?
3. Analysis:
    i. How was the collected data analyzed?
    ii. What analytical methods were used for normalization/quantification?
4. Stakeholder perspectives
    i. What stakeholder perspectives were included?
    ii. How well are different stakeholder perspectives incorporated in the study?

Critical appraisal questions of SRQ: What is the effect of the adoption of sustainable manure management on the economic well-being of Dutch dairy farmers and relevant stakeholders?

1. Sustainable manure management:
    i. What is the definition of SMM in this study?
    ii. Are specific details of SMM mentioned in this study?
2. Indicator selection
    i. How are indicators of economic well-being defined in this study?
    ii. What method is used to measure economic well-being?
3. Data collection:
    i. How was data on economic indicators collected?
4. Analysis:
    i. How was the collected data analyzed?

ii. Was the method of analysis appropriate for this study?

5. External factors
    i. Are external factors influencing economic well-being considered?

5.3 Economic Analysis Method

The aim of the economic analysis was to gain insight into the economic impact of the adoption of SMM on Dutch dairy farmers. In the economic analysis, a differentiation will be made between different types of SMM, and the outcome of the economic analysis will be correlated with the environmental impact of the adopted SMM method. In the literature review, the SAFE framework has been extensively discussed and a set of criteria, indicators and performance reference points (PRP) have been determined. This section will give an overview of the economic analysis that was performed on Dutch dairy farmers in this research. First of all, Table 10 gives an overview of the selected criteria, indicators and PRP's.

Criterion	**Indicator (unit)**	**PRP_min**	**PRP_max**
Dependency on direct and indirect subsidies is minimized	Percentage of real net farm income from all subsidies (%)	0	100
Agricultural activities are economically efficient	Payback period of SMM system (years)	2.4	35.99

Table 10: Overview of selected criteria and corresponding indicators and performance reference points, used in the economic analysis performed in this research.

To acquire accurate indicator values, information was needed from the interviewees. Therefore, per indicator, a set of variables, introduced in 4.4.4 Indicators' was used. With these variables, indicator values were calculated.

5.3.1 Percentage of Real Net Farm Income From All Subsidies

For this indicator, three variables were introduced in the Literature review: 1)Direct income support 2)Second pillar payments and 3) Total net farm income, all in € per month. For an explanation and justification of these variables, see 4.4.4 Indicators. To obtain an indicator value, Equation 1 was used.

Equation 1: Equation used to obtain indicator value for indicator: Percentage of real net farm income from all subsidies.

$$Percentage = \frac{Direct\ income\ support + Second\ pillar\ payments}{Total\ net\ farm\ income} \times 100\%$$

5.3.2 Payback Period of SMM System

For this indicator, two possible scenarios were proposed in the Literature review. If the Dutch dairy farmer has knowledge about the payback period of their SMM system, this value will be taken. If no knowledge of this value is present, which was assumed to be likely, a second approach was proposed. Four variables were used for this second approach. Two drivers of economic well-being of Dutch dairy farmers: 1)Direct income support 2)Second pillar payments and two barriers: 1)Cost of installment and 2)Cost of operating. Table 11 gives an overview of these variables, with an indication of whether they are a driver/barrier to economic well-being of Dutch dairy farmers and the unit in which they are expressed. The variables were assigned a number for clarity purposes.

Variable number	Variable	Driver/barrier of economic well-being Dutch dairy farmers	Unit
1	Direct income support	Driver	€ per month
2	Second pillar payments	Driver	€ per month
3	Cost of installment	Barrier	€
4	Cost of operating	Barrier	€ per month

Table 11: Overview of variables used to obtain indicator value for 'payback period of SMM system', including unit and indication of driver/barrier to economic well-being Dutch dairy farmer.

To obtain an indicator value (in years), Equation 2 was used. The numbers in the equation refer to the variable numbers assigned to the variables in Table 11.

Equation 2: Equation used to obtain indicator value for indicator: Payback period of SMM system.

$$Payback\ Period = \frac{3}{(1+2-4)\times 12}$$

5.4 Social Analysis Method

The stakeholders that were explored in the social analysis of this research were the workers, the local community and dairy processing companies. This section will present the inventory analysis phase and a beginning to the impact assessment phase of the S-LCA which has been performed in this research. Indicator selection is part of the inventory analysis phase. Table 12 gives an overview of the stakeholder, impact categories, sub-impact categories and indicators that were considered in this research. Explanation and justification of these selected choices can be found in the Literature review. It is important to note that in the social analysis, contrary to the economic analysis, the focus will not be on the different types of SMM. The implementation of SMM in general will be studied, with the focus on its effect on different stakeholders. This was done because the expectation was that the type of SMM would not make a big difference to the social impacts felt by the stakeholders. Further details on how the data collection, which is also part of the inventory analysis phase, was performed can be found in section 5.6 Method of Data Collection.

Stakeholder	**Impact category**	**Sub-impact category**	**Indicators**	**Indicator based on reference**
Worker	Employment farm level	▪ Employment quantity	▪ Loss/gain of employment at farm level	(Jongeneel et al., 2009)
Local community	Community engagement	▪ Acceptance of local community	▪ Degree of acceptance of local community as experienced by farmer	(UNEP, 2013)
		▪ Local employment	▪ Local workers involuntarily relocated due to	(Bonilla-Alicea & Fu, 2022)

			implementation SMM	
Dairy processing companies	Governance/ participation	▪ Company involvement	▪ Degree of involvement dairy processing companies in successful transition to SMM	(van Haaster et al., 2017)
			▪ Degree of involvement dairy processing companies in decision-making related to SMM	(van Haaster et al., 2017)
		▪ Supplier relationship	▪ Acceptance of dairy processing companies of SMM and related effects, as experienced by farmer	(UNEP, 2013)

Table 12: Overview of selected stakeholders, impact categories, sub-impact categories and indicators considered in the social analysis performed in this research.

5.4.1 Impact Assessment Social Analysis - Likert scale

The objective of the impact assessment is to give meaning to the indicators defined in Selection of indicators. Dutch Dairy farmers were interviewed for the data collection of this research. In this social analysis, two types of indicators were distinguished: Semiquantitative indicators that can be researched through yes/no questions and semi-quantitative Likert-type scale questions. A Likert-type scale, as shown in Table 13, was used for the interviewees to give an indication of the economic and social effects that SMM has on the defined stakeholders. A Likert-type scale was chosen as it was often used in similar research (Bonilla-Alicea & Fu, 2022)(Andrade et al., 2022). The Likert-type scale was based on the one presented by Franze & Ciroth (2011) and altered to fit the questions of this research. The interview guide (Appendix A: Interview guide) shows how the Likert scale was applied in different questions. In the case of yes/no questions interviewees were simply asked to answer the question with yes or no.

	Strong negative effect
	Negative effect
	Neutral effect
	Positive effect
	Strong positive effect

Table 13: Example of 5-point Likert scale that will be used to obtain values for semiquantitative indicators used in the social analysis.

5.4.2 Impact Assessment Social Analysis - Overview Indicators

Table 14 gives an overview of the indicators used in the social analysis of this research. The left column shows the indicator, the second column shows the relevant impact category. The relevant stakeholder is shown in the third column. Then, in the fourth column the table shows whether the questions were answered with yes/no or with a Likert scale as proposed

in 5.4.1 Impact Assessment Social Analysis - Likert scale. Lastly, the desired direction of outcome was defined in the fifth column. Desired outcome was based on what effects would promote sustainability of Dutch dairy farming and was based on desired outcomes of novel technologies promoting sustainability as defined by van Haaster et al. (2017). Defining the desired direction of outcome is vital as it is used to determine what is a positive and what is a negative effect (Bonilla-Alicea & Fu, 2022) and was taken into consideration in the interpretation of the results.

Indicator (unit)	**Impact category**	**Stakeholder**	**Likert/(yes/no)**	**Desired**
Loss/gain of employment at farm level (-)	Employment farm level	Worker	Semi-quantitative (Likert Scale)	Positive
Acceptance of local community as experienced by farmer (-)	Community engagement	Local community	Semi-quantitative (Yes/No)	Positive
Local workers involuntarily relocated due to implementation SMM (-)			Semi-quantitative (Yes/No)	Negative
Degree of involvement dairy processing companies in successful transition to SMM (-)	Governance/ participation	Dairy processing companies	Semi-quantitative (Likert scale)	Positive
Degree of involvement dairy processing companies in decision-making related to SMM (-)			Semi-quantitative (Likert scale)	Positive
Acceptance of dairy processing companies of SMM and related effects, as experienced by farmer (-)			Semi-quantitative (Yes/No)	Positive

Table 14: Overview of indicators that will be used per impact category per stakeholder. Indication of how the question will be answered by the interviewee, (yes/no) or Likert scale, and an indciation of the desired outcome for sustainability.

5.5 Operationalization

5.5.1 Normalization of Indicators Economic Analysis

Section 5.3 Economic Analysis Method gave an overview of how variables will be used to acquire indicator values used in the economic analysis. This section will show how the acquired indicator values were used together with the defined PRP's to give meaning to the values obtained in the interviews.

In 4.4.5 Reference Value, PRP_max and PRP_min were defined for both indicators. All obtained indicator values were normalized to a scale between 0 and 1, where 0 represents the worst economic performance and 1 represents the best economic performance. This approach was based on the approach taken for quantitative values in S-LCA (Bonilla-Alicea & Fu, 2022). Deviation from the SAFE

framework which was used for the economic analysis up until this point was purposefully done for feasibility reasons.

The equation, based on Bonilla-Alicea & Fu (2022), that was used to normalize the indicator values acquired in the economic analysis is the following (Equation 3):

Equation 3: Equation used to normalize indicator values of economic analysis.

$$Indicator, norm = 1 - \frac{Indicator, value - \text{PRP\_min}}{PRP\_\max - PRP\_\min}$$

In the case of both indicators, this equation was applicable because PRP_min represents optimal economic performance and PRP_max represents worst possible performance. Once again, for the normalized values, 0 represents the worst economic performance and 1 represents the best economic performance.

5.5.2 Quantification and Normalization of Indicators Social Analysis

Two types of semiquantitative indicators were used in the social analysis. The first one is a yes/no indicator, in which the value will be given a 0 or a 1. Similar to the economic analysis, 0 represents poor social performance. In case of the social analysis, this means a mismatch between the given answer and the desired value that promotes sustainability, as defined in Table 14. 1 represents agreement of the obtained value with the desired value, and thereby ideal social performance. If the desired answer is yes, and the given answer is also yes, the indicator value is 1. The second semiquantitative indicator is the type that was answered through the Likert-type scale. Answers could range from 1-5 as explained in 5.4.1 Impact Assessment Social Analysis - Likert scale. Depending on the desired direction of outcome, the values were normalized between 0 and 1, in which 0 again represents a mismatch with the desired effect, and 1 represents agreement. As the desired outcome of all indicators used in the social analysis is positive, only one equation was needed. An example of how normalization took place is given below.

For indicator “Degree of involvement dairy processing companies in successful transition to SMM” the desired value on the Likert scale is 5, which represents ‘strong and constructive involvement’. The normalized value was calculated with Equation 4, based on Bonilla-Alicea & Fu (2022).

Equation 4: Equation used to normalize indicator values obtained for Likert scale questions of the social analysis.

$$Indicator, norm = \frac{(Indicator, value - 1)}{4}$$

If the indicator value were 5, the normalized indicator value would be 1, indicating an ideal social performance of the examined stakeholder. If the indicator value were 1, the normalized value would be 0, indicating poor social performance.

5.6 Method of Data Collection

This section explains how data was collected that allowed for answering of the sub-research questions. Table 15 shows an overview of the objectives related to the sub-research questions presented in this research.

SRQ	Data to be collected	Source	Method
What is the effect of different sustainable manure management systems on the economic well-being of Dutch dairy farmers?	▪ Data on dependency of Dutch dairy farmers on external subsidies and data on payback period of SMM. ▪ Data on the different SMM systems and their environmental impact.	Dutch dairy farmers, scientific articles	Interview conducted with Dutch dairy farmer, literature review
What is the effect of the adoption of sustainable manure management by Dutch dairy farmers on the selected social indicators?	▪ Social effect of SMM on workers on Dutch dairy farms ▪ Social effect of SMM on local community of Dutch dairy farmers ▪ Social effect of SMM on dairy processing companies	Dutch dairy farmers	Interview conducted with Dutch dairy farmer, literature review

Table 15: Overview of data to be collected per SRQ, including the source where the data will be collected from and the method.

To obtain the data to be collected as shown in Table 15, structured interviews were conducted on Dutch dairy farmers. The Interview guide that was used can be found in Appendix A: Interview guide. At the start of the interview the Dutch dairy farmer was asked about their way of managing the cow manure produced at their farm, and whether they had a way of reducing ammonia emissions at their stable. If no SMM system as defined in Table 1 was present, many of the questions of the interview guide were still asked for background information. If there was a SMM system as defined in Table 1 installed, the interview guide was followed. Interviews were conducted via telephone calls and recorded for later transcribing.

5.7 Processing Data

Interviews amongst Dutch dairy farms were used for primary data collection. To come in contact with Dutch dairy farmers, multiple strategies were applied. First, farmers unions were contacted, such as NMV and LTO, which are Dutch dairy farmers' unions. In addition, dairy processing companies were contacted for their connections with Dutch dairy farmers. Lastly, personal network and online sources were used to come into contact with as many Dutch dairy farmers as possible. A structured interview was conducted, which can be found in Appendix A: Interview guide. Quantification and normalization of the data has been explained in 5.5.1 Normalization of Indicators Economic Analysis and 5.5.2 Quantification and Normalization of Indicators Social Analysis. An overview of the normalized values was made with Excel. Interviews were recorded, transcribed and translated to English. Recording was done with a 'voice recorder' application. Transcribing was done with the AI-software 'Turboscribe' to perform as time-efficiently as possible. Translating was done using the AI-software ChatGPT, again for optimal time-efficiency and quality of the translation. All translated transcriptions can be found in Appendix B: Transcribed Interviews. For privacy purposes, the names of the interviewees have not been published in this report, but for contact information the author can be consulted.

6. Results and Discussion

This section shows the results of the interviews conducted with Dutch dairy farmers. Interviews were conducted, of which 15 Dutch dairy farmers applied SMM as defined in this research and were therefore used for the results of this research. The aim of this section is to give a structured overview of the acquired data and discuss the results. The economic and the social analysis will be separately discussed, as different analyses were performed. First, an overview will be given of the SMM systems that were applied by the interviewees.

4.1 Sustainable Manure Management discussed the principles of SMM. Table 16 gives an overview of the goals of the SMM systems of the interviewed farmers and a short description of the SMM system itself. For clarity, the left column defines the goal of the SMM as defined in Table 1. The middle column gives the name of the equipment that was used the farms of the interviewees to achieve the goals shown in the left column. The right column shows the ammonia emissions reduction in percentage and the source on which this number is based.

Table 16: Overview of the SMM systems that were applied by interviewed Dutch dairy farmers. Included in the table are: The goal(s) of the SMM system, the name of the SMM system, a description of the SMM system and the ammonia emission reduction percentage of the system.

Goal(s) of SMM system	**Name SMM system applied by interviewed farmers**	**Description of SMM system**	**Reduction NH3 emission (source)**
-Lowering ammonia content in manure	Nitrogen cracker	A nitrogen cracker removes the nitrogen from the ammonia in the liquid fraction of cow manure and adds an acid to produce a chemical fertilizer (Hayton, 2023).	22% (Mosquera et al., 2017)
-Frequent and complete disposal of manure and urine into basement -Limit air transfer between stable and manure storage basement	Emission reducing floor	Emission reducing floor reduce ammonia emissions by ensuring clean, dry surfaces where feces and urine are separated as quickly as possible. This can be done through a sloped floor which allow the urine to drain quickly, a grooved floor, slatted floors and more (*Emissiearme Vloeren - Kenniscentrum InfoMil*, n.d.)	0% (Groenestein et al., 2023)
-Reducing the surface area covered with manure	Manure scraping robot	A manure scraping robot frequently removes the manure from the floor into the basement, reducing the ammonia emissions at the stable (Kenniscentrum InfoMil, n.d.).	46% (Van Dooren et al., 2023)
-Frequent and complete disposal of manure and urine into basement -Limit air transfer between stable and manure storage basement -Lowering ammonia content in manure	Mono digester combined with sealed basement and manure scraper	This combination uses the manure scraping robot to bring the manure into a closed basement. Furthermore, the mono digester ferments the manure to produce biogas (Melkveebedrijf, 2021).	72% (Van Dooren et al., 2023)

Figure 5 gives an overview of the different SMM systems and shows the relative number of interviewees that applied these systems. As visible, most Dutch dairy farmers that apply SMM have an emission reducing floor installed. After that, the most used method was nitrogen cracking. A basement with hay to separate manure and urine, a manure scraping robot and the combination of a mono digester with a sealed basement and a manure scraper were least often used.

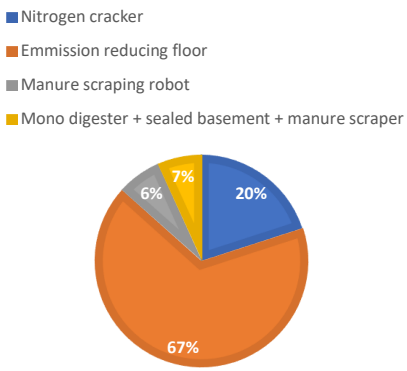

Figure 5: Overview of the different SMM systems and the percentage of the interviewees that applied the system.

An overview of all normalized indicator values obtained for both the economic and social analysis can be found in Appendix C: Normalized Indicator Values.

6.1 Economic Analysis

6.1.1 Normalized Indicator Values

Normalized values were obtained for each of the economic indicators according to the procedure explained in 5.5.1 Normalization of Indicators Economic Analysis.

Table 17 gives an overview of the average indicator values and the normalized values. It is observed that for the indicator 'Percentage of real net farm income from all subsidies', Dutch dairy farmers scored well since they are not very dependent on subsidies. For the payback period of the SMM system a less positive effect was observed. The indicator scored 0,54 on average, indicating a neutral economic effect. The average score was because some SMM systems scored very well on this indicator, while other SMM did not have any payback period at all. The average value was therefore not that positive or negative. More details on why this was observed are given below. Figure 6 shows the normalized values with the standard deviation included. The standard deviation of the indicator 'payback period of SMM system' was very high. This was because for different SMM systems, significantly different values were obtained for the payback period. A more detailed explanation is given below.

Table 17: Overview of indicator values and normalized indicator values obtained from interviews with Dutch dairy farmers.

Stakeholder	Indicator	Indicator type	Desired direction	Indicator value	Unit	Normalized value
Dutch dairy farmers	Percentage of real net farm income from all subsidies	Quantitative	Negative	5,11	%	0,95
Dutch dairy farmers	Payback period of SMM system	Quantitative	Negative	17,79	Years	0,54

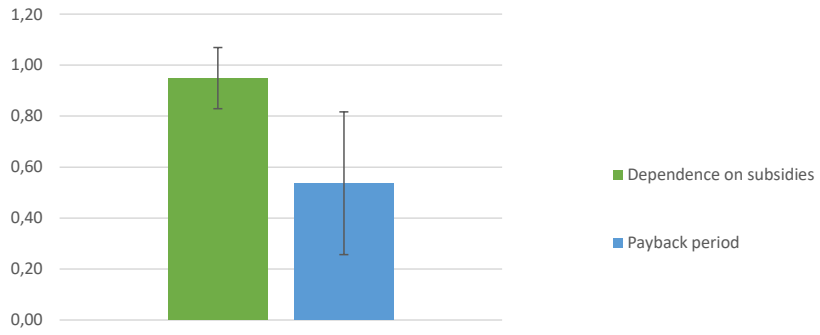

Figure 6: Normalized indicator values obtained from interviews with Dutch dairy farmers, including standard deviation.

In research by Sauvenier et al. (2005) the percentage of income of dairy farms coming from subsidies was 5.3%. This value is almost similar to the value obtained in this research. Therefore, the value obtained can be considered reliable. For the indicator 'payback period of SMM system', the indicator value is highly dependent on the type of SMM, in the results obtained in this research as well as in literature. However, Uvarov et al. (2020) researched three SMM options of which two had no payback period at all. Therefore, results with no payback period, which were often observed, can be considered normal. Lazarus & Rudstrom (2007) researched SMM systems with a payback period of 4, 8 and 10+ years. As the literature shows, results differ highly per SMM system, which was the case for the results of this research as well (which will be shown below). Overall, the obtained values for the payback periods were similar to the values found in literature and can therefore be considered reliable.

Table 18 gives an overview of the normalized values for both indicators. The average normalized value was 0,74, indicating a rather positive economic effect on the stakeholder, being Dutch dairy farmers.

Table 18: Normalized indicator value and average normalized indicator value for the stakeholder Dutch dairy farmers.

Stakeholder	Indicator	Normalized value	Average value
Dutch dairy farmers	Percentage of real net farm income from all subsidies	0,95	0,74
	Payback period of SMM system	0,54	

Variables were introduced to obtain indicator values as an alternative approach when the indicator value could not be provided by the interviewee (as explained in 5.3.1 Percentage of Real Net Farm Income From All Subsidies and 5.3.2 Payback Period of SMM Systems). For the interviewees that could not provide indicator values directly, an overview was made of the values provided for the variables. Table 19 gives an overview. The two variables 'direct income support' and 'second pillar payments' were taken together because interviewees were not able to differentiate between the two. It is important to note that these are only the values for the interviewees that gave data regarding these variables. If, for example, the interviewee knew what percentage of the farm's income came from subsidies, no more information was asked about the net farm income and the total subsidies.

Table 19: Overview of obtained values for the variables used in the equation to obtain indicator values. Values were not obtained from all interviewees, so these numbers are an estimation rather than an exact average value for all interviewees.

Variable	Average value	Unit
Installment costs	237300,-	€
Operational costs	339,25	€ per month
Net farm income	135000,00	€ per month
Total subsidies	327,78	€ per month

6.1.2 Results Per SMM Method

To gain a deeper understanding of how SMM affected the economic well-being of Dutch dairy farmers, a differentiation was made between the different types of SMM and their effect. Figure 7 shows the different SMM systems, and the normalized value scored for both economic indicators.

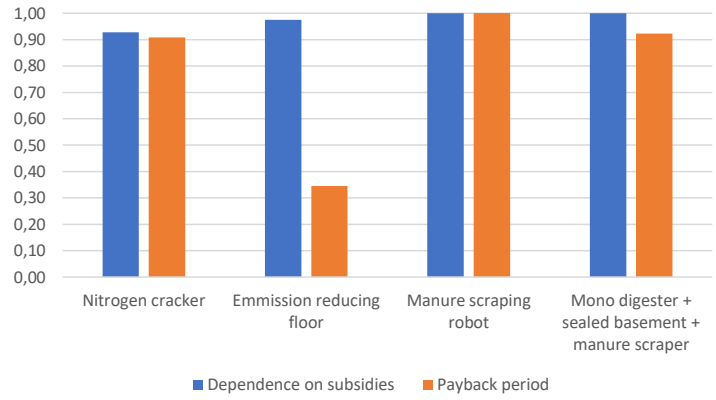

Figure 7: Normalized indicator values scored in the economic analysis, per SMM system.

A short narrative will be given to discuss the obtained indicator value per SMM method.

Nitrogen cracker

Nitrogen cracking revolves around removing the nitrogen from the ammonia in the liquid fraction of cow manure and adding an acid to produce a chemical fertilizer (Hayton, 2023). The fact that manure is converted into artificial fertilizer is the main reason for the short payback period of the nitrogen

cracker. With derogation being reduced in the Netherlands, farmers are forced to get rid of increasing amounts of surplus manure produced by their dairy cows, for which costs can range from €5 to €14 per m^3 (Hoes et al., 2022). For crops to grow optimally, nitrogen is needed for which artificial fertilizer has to be bought by farmers (Berkhout & de Wolf, 2021). The legislation and reasoning behind this will not be discussed in this research, but it results in the need for a double investment (paying to get rid of excess animal manure and paying for artificial fertilizer) for farmers who do not have a nitrogen cracker and produce too much manure to use on their land. The nitrogen cracker allows farmers to manage their surplus cow manure, and produce their own artificial fertilizer, thereby reducing costs on both fronts. This reduction in costs adds to the short payback period of the nitrogen cracker, as it's an economic benefit. In addition to this, farmers with a nitrogen cracker are eligible for 'Subsidiemodules brongerichte verduurzaming stal- en managementmaatregelen' (Sbv), which one of the interviewees with a nitrogen cracker received. This reduced the payback period of the nitrogen cracker even further. However, the dependency on subsidies has thereby increased a little bit. Overall, the nitrogen cracker had very positive economic effects on Dutch dairy farmers. However, with the focus on overall sustainability it should be noted that an ammonia emission reduction of only 22% is achieved with the SMM, as shown in Table 16. Therefore, this is a viable option regarding economic performance of Dutch dairy farmers but not ideal regarding environmental impact.

Emission reducing floor

As shown in figure X, this was by far the most used SMM method of the interviewed Dutch dairy farmers. An emission reducing floor has several principles which result in lower ammonia emissions. It quickly removes urine from the manure and brings it to the basement. Also, it prevents exchange of air between the basement and the stable. Lastly, it often removes manure from the floor, preventing accumulation on the floor (InfoMil, 2023).
When asked for the reason of Dutch dairy farmers for installing an emission reducing floor, almost all of them stated that it was mandatory to get a permit. Since 2015, dairy farmers in the Netherlands who want to build a new stable or install a new floor in their stable, are obliged to install an emission reducing floor to get a permit for building (KRO-NCRV, 2023). However, the actual effect of emission reducing floors on ammonia emissions has been subject of debate and resulted in a decision by judges in 2022 that certain emission reducing floors will not grant a permit (Botje, 2022). In a recent study by Wageningen University & Research, it was even concluded that no ammonia emission reduction was achieved trough the installment of an emission reducing floor (Groenestein et al., 2023). Interviewed farmers who had installed an emission reducing floor almost never had any subsidies. This resulted in a positive score for the indicator 'Percentage of real net farm income from all subsidies'. Maintenance of an emission reducing floor generally requires more work than for a traditional floor, because there are additional slatted floors and collection containers that need maintenance,as reported by interviewees. In addition to this, it was found in the interviews that the installation of an emission reducing floor often came with additional costs ranging from €35.000 to €100.000. Because there is no economic benefit to the floor, as well as no subsidies, higher operational costs and high installation costs, this SMM system scored very negatively on the economic indicator 'payback period of SMM system'. If no payback period could be calculated (because there was no way in which the floor generated any income) the indicator value was normalized to 0, indicating worst possible economic performance. The ongoing discussion about the actual validity of emission reducing floor for reducing ammonia emissions might explain the lack of subsidies and therefore often the lack of a payback period.

Manure scraping robot

This technology was often used in combination with other SMM practices, such as an emission reducing floor or a mono digestor. One farm applied it without other technologies. The manure

scraping robot is often heavily subsidized. 80% of the installation costs (which are often around €32.000,-) are often covered by subsidies. With the average yearly income (interviewed farmer could not give an estimation of yearly income) of a dairy farm being about €78.000 in 2023 (van der Meulen, 2023), this amounts to an estimated 32% of the total yearly income of the year in which the robot was purchased, which was 2023 for the interviewed farmer. However, because it is a one time deposit which does not cause any dependency, this SMM method scored very well on the indicator 'dependency on external subsidies'. The manure scraping robot also scored very well on the indicator 'payback period of SMM system'. This was because remaining installation costs were very low due to the high amount of subsidies, and the interviewee reported that the robot saved the farmer about 30 minutes of work per day. By taking the average hourly wage of a Dutch dairy farmer, €16,- per hour (Stevens, 2020), a payback period was estimated. The normalized value was exactly 1.0, indicating optimal economic performance for this indicator. If the farmer is able to get a subsidy on their manure scraping robot, this SMM method is an excellent option regarding the economic well-being of Dutch dairy farmers. With an ammonia emission reduction of 46%, this SMM method is a strong solution in terms of economic and environmental performance.

Mono digester combined with sealed basement and manure scraper

A mono digester breaks down manure and uses it to produce biogas. This combination used several technologies to obtain a very high reduction in ammonia emission (the interviewee claimed measurements showed about 80% reduction, Van Dooren et al. (2023) measured a reduction of 72%). In addition to this, very positive economic effects were observed. The initial investment was coupled with subsidies to get the process started, but over time the technology could finance itself and subsidies were no longer needed. The produced biogas is sold, and with high gas prices throughout most of 2023 the interviewee reported the SMM system to be profitable. The interviewee mentioned that it would not be healthy to continuously rely on subsidies, and that therefore the subsidy was ended. Now the technology financed itself and the payback period was very short. At the moment of the interview, the technology had already financed itself and was not creating profit for the owner. For a SMM system at the stable of Dutch dairy farms, this system showed optimal performance regarding economic and environmental factors.

6.1.3 Overall Learnings and Recommendations

Overall, it is observed that the emission reducing floor has the worst impact on economic performance due to the general lack of economic profit that it creates. As stated before, farmers generally install an emission reducing floor because it is mandatory to install one to get a permit if they want to build a new stable. With the addition of the ongoing debate about the environmental impact of the emission reducing floor (Botje, 2022) (Groenestein et al., 2023), the emission reducing floor can be considered far from effective in achieving sustainability. While the nitrogen cracker and the manure scraping robot both showed stronger results in terms of economic and environmental performance, the mono digester combined with sealed basement and a manure scraper is the best performing SMM system investigated in this research. It has a very strong environmental impact, with an ammonia emission reduction of 72%, and showed a strong positive impact on the economic well-being of the farmer who adopted the system.

SMM methods can generate economic profits for farmers in several ways. Subsidies, reducing the amount of daily manual labor and the production of artificial fertilizer and biogas are some of the economic benefits that SMM can provide the farmer with. If a SMM methods has one or more of these ways of generating profit, the two indicators that were selected for this research are an accurate way of describing the economic impact of the SMM method on the farmer. The payback period is a strong way of describing the economic viability of the installed technology, and by investigating the

percentage of income coming from subsidies, the farmers' economic independence is monitored. As has been mentioned by one of the interviewed farmers, it would not be good to continuously rely on subsidies for economic well-being. When a payback period was present, a strong inside into the economic well-being of Dutch dairy farmers who applied SMM could be created with the two indicators used in this research, being 'payback period of SMM system' and 'percentage of income coming from subsidies'. Difficulties arose when no payback period was present, because the SMM method had no way of generating income. In this case, additional indicators, which will be proposed below, would have been beneficial for the accuracy of the economic analysis performed in this research. With no subsidies and no payback period, normalized indicator values were 1 and 0 respectively, but no in-depth knowledge would be represented by these values about the economic effect of SMM on the investigated farmers. For follow-up research, an alternative indicator, solely representing the installment costs would be a recommendation. This is recommended because where a payback period is only present for most of the SMM systems, installment costs will always be present. Therefore, this indicator could give an insight into the economic impact if no payback period is present. Determination of Performance Reference Points for installment costs is considered feasible, so normalization of this indicator should be feasible. Installment costs were used as a variable in this research, but were not asked for when the payback period was known by the interviewee and because no Performance Reference Points were determined little analyzing could be done.

For the emission reducing floors, the economic impact can be described as very negative. Farmers were often very dissatisfied with the adoption of an emission reducing floor, and regularly mentioned that they only installed it because it was mandatory to get a permit for building a floor in their stable. The low dependency on subsidies is represented as a positive economic effect in this research, but it can only be considered positive if other sources of economic profit are there to replace it. Many interviewed farmers with an emission reducing floor reported that they had signed up for a subsidy, but that they didn't get selected and therefore never received any. With the two indicators used, the severity of the negative economic impact of emission reducing floors is not sufficiently reflected and an additional indicator regarding the installation costs would be recommended for follow-up research. For the investigation of the economic impact of other SMM methods, such as nitrogen crackers, mono-digestors or manure scraping robots, these two indicators are highly recommended as the economic impact that the normalized values reflected were often well in line with the attitude of the interviewed farmers towards the economic viability of the installed SMM technology.

6.2 Social Analysis

In this section, the last steps of the S-LCA performed in this research will be described. The results of the Life Cycle Impact Assessment (LCAI) and the Life Cycle Interpretation (LCI) will be given first. Following, recommendations will be given as foreseen by the LCIA and the LCI. Contrary to the economic analysis, the focus in the social analysis will not be on the different types of SMM, but rather the adoption of SMM in general will be researched, with the focus on the impact on different stakeholders.

6.2.1 Impact Assessment Social Analysis

The last steps of the LCAI include quantification and normalization of indicator values (UNEP, 2013). The values obtained through interviews were normalized according to the steps provided in 5.5.2 Quantification and Normalization of Indicators Social Analysis.

Error! Reference source not found. gives an overview of the indicators, the value obtained for each indicator and the normalized indicator values.

Table 20: Overview of the stakeholders, indicators, indicatory types and the desired direction used in the social analysis, including the indicator values and the normalized indicator values obtained from the interviews.

Stakeholder	Indicator	Indicator type	Desired direction	Indicator value	Unit	Normalized value
Workers	Loss/gain of employment at farm level	Semi-quantitative (Likert Scale)	Positive	3,8	Dimensionless	0,70
Local community	Degree of acceptance of local community as experienced by farmer	Semi-quantitative (Yes/No)	Positive	Yes	Dimensionless	1,00
Local community	Local workers involuntarily relocated due to implementation SMM	Semi-quantitative (Yes/No)	Negative	No	Dimensionless	1,00
Dairy processing companies	Degree of involvement dairy processing companies in successful transition to SMM	Semi-quantitative (Likert scale)	Positive	3,2	Dimensionless	0,55
Dairy processing companies	Degree of involvement dairy processing companies in decision-making related to SMM	Semi-quantitative (Likert scale)	Positive	3,3	Dimensionless	0,58
Dairy processing companies	Acceptance of dairy processing companies of SMM and related effects, as experienced by farmer	Semi-quantitative (Yes/No)	Positive	Yes	Dimensionless	1,00

6.2.2 Life Cycle Interpretation

The aim of the 'life cycle interpretation' phase is to identify the greatest contributors to social impacts and to propose recommendations to improve these impacts (Bonilla-Alicea & Fu, 2022). Table 20 gives an overview of the average indicator value per stakeholder group, to identify which stakeholder group is most affected.

Table 20: Overview of average normalized indicator values per stakeholder group, to give an overview of social impacts per stakeholder group.

Stakeholder	**Indicator**	**Normalized value**	**Average value**
Workers	Loss/gain of employment at farm level	0,70	0,70
Local community	Degree of acceptance of local community as experienced by farmer	1,00	1,00
	Local workers involuntarily relocated due to implementation SMM	1,00	
Dairy processing companies	Degree of involvement dairy processing companies in successful transition to SMM	0,55	0,71
	Degree of involvement dairy processing companies in decision-making related to SMM	0,58	
	Acceptance of dairy processing companies of SMM and related effects, as experienced by farmer	1,00	

First, it can be observed that for the stakeholder 'local community', an average value of 1,00 was reported. This represents optimal social performance . However, in reality almost no social impact was felt by this stakeholder group. A more detailed explanation will be given below. The stakeholder groups "workers" and "dairy processing companies" have reported average values of 0.70 and 0.71 respectively, indicating a positive social impact resulting from the adoption of SMM on Dutch dairy farms. However, to gain a more profound comprehension of the situation, an analysis will be conducted separately for each stakeholder group.

Workers

In general, the implementation of SMM resulted in an increase in labor at the farm. Interviewed farmers reported that the innovations often resulted in more maintenance, more broken machinery, and more complex processes to monitor. This was in line with outcomes of similar literature, in which anaerobic digestors of animal manure (a type of SMM) had a positive effect on job creation (Bijarchiyan et al., 2020). However, all farmers reported that the extra work was something that they did themselves, and not something that they hired extra employees for. Some mentioned that this was something they were content with, as this was the price they would have to pay for being future-proof. Others were not so satisfied, as they did not believe the SMM system really improved anything (but were forced to buy one to get a permit for building a new stable), and therefore did not see a justification for the extra labor. The indicator 'loss/gain of employment at farm level' gave an understanding of the social impact on workers at Dutch dairy farms, but fails to reflect some of the social discontent felt by Dutch dairy farmers who apply SMM. A complete lack of trust in the government, and a lack of trust in the SMM system are social impacts which bother many workers on Dutch dairy farms who apply SMM. Recommendations for alternative indicators are proposed in 6.2.3 Overall Learnings and Recommendations.

Local community

The implementation of SMM on Dutch dairy farms is accepted by local communities and local communities don't suffer any involuntary relocation of employment because of SMM. The expectation was that automatization could lead to unwanted social impacts for the local community. This could be a bad smell, the removal of local employment due to automatization or noise complaints of the local community due to SMM. However, these effects have not been observed in this study. Therefore, the outcome of the analysis on the stakeholder group local community seems very positive, but in reality no social impact is felt whatsoever by the local community (in the eyes of the interviewed farmers). Choice for the indicator 'involuntary replacement of local employment' was based on similar choice by Bonilla-Alicea & Fu (2022), who noticed a very negative social impact on this stakeholder because of the implementation of solar-panels (the indicator scored a normalized value of 0). It was expected that SMM could have a similar effect, but this effect was not observed via the method applied (interviews with Dutch dairy farmers). A follow-up study into this stakeholder group with the same approach would not necessarily be recommended, as interviewees often mentioned that they did not see a reason why SMM would significantly impact the local community. It is important to note that only interviews with Dutch dairy farmers have been conducted in this research, and that interviews with members of the local community could give different perspectives, and consequently different results. The only exception in which the interviewed farmers mentioned possible negative effects on the local community was the mono-digestor, which could give a bad smell and thereby negatively affect the local community. However, the interviewed farmer with a mono-digester claimed to have invited the neighboring people with doubts about the system, and reported them to be very positive about the mono-digestor after the visit. It could be beneficial to monitor the social impact of mono-digestors on the local community, but for other SMM systems follow-up studies with the same approach (interviewing Dutch dairy farmers) are not recommended. Interviews with members of the local community themselves will give another point of view which could be more relevant.

Dairy processing companies

The aim of the exploration into this stakeholder was to explore dairy processing companies as an important value chain actor, and to make an estimation of their involvement in decision-making related to SMM and acceptance of SMM on Dutch dairy farms. Through this, an estimation could be made of the social impact of the adoption of SMM on dairy processing companies. With an average normalized indicator value of 0,71, a slight positive social impact can be attributed to dairy processing companies in relation to SMM. This positive effect can generally be attributed to the fact that the indicator 'acceptance of dairy processing companies of SMM and related effects, as experienced by farmer' scored a normalized indicator value of 1.0. This value represents that Dutch dairy farmers reported dairy processing companies to fully accept the use of SMM and to support it. In research by Gebrezgabher et al. (2013), it was found that the most important criterion of dairy processing companies related to SMM is maximization of gross margin, or maximization of profit. This could explain the slight positive social impact on this stakeholder that is observed in this research. Many of the farmers reported that SMM did not result in extra money received per unit of delivered milk. However, Nam et al. (2020) reported that consumers' willingness to pay was higher for milk that was sustainably produced. This could therefore lead to improved maximization of gross margin of dairy processing companies, and explain their total acceptance of the use of SMM on Dutch dairy farms. For the first indicator 'Degree of involvement dairy processing companies in successful transition to SMM' a normalized indicator value of 0,55 was obtained. Interviewed farmers reported that although dairy processing companies have special departments that investigate the sustainability of the supplied dairy, it is the farmer who makes the decision related to the transition to SMM. This means that when a farmer is orienting into what types of SMM could benefit his/her farm the most, they have

full autonomy to decide which option fits them best. Related value chain actors, in this case dairy processing companies, give some guidance and are slightly involved, but in the end it is the farmer who makes the decision. For the second indicator 'Degree of involvement dairy processing companies in decision-making related to SMM', an average normalized indicator value of 0,58 was obtained. Again, it was reported that it is the farmer who makes the decision. The slightly higher score originated from a couple of farmers. They reported that dairy processing companies with a sustainability department would come to their dairy farm, and make demands about production sustainability. They would be rewarded with extra money per liter of milk if they would apply these changes. In this way, dairy processing companies would be able to influence decision-making related to SMM on the farms. Overall, dairy processing companies were involved, but generally constructive in their involvement. As stated before, in the end it was the farmer that made the decision. In case of the indicator 'Degree of involvement dairy processing companies in decision-making related to SMM', this means that interviewees reported that dairy processing companies come to the farm with ideas about SMM and how it should be applied, but that when a decision has to be made, it is the farmer who does it. All interviewed farmers reported that dairy processing companies fully accepted the use of SMM and its related effects, indicating a positive attitude of this stakeholder towards the technology. Overall, a slight positive social impact on dairy processing companies is observed. Further increasing the involvement of dairy processing companies might increase the social impact on dairy processing companies but this research assumes that it could bring the risk of leading to negative impact on Dutch dairy farmers by impeding with their independence.

6.2.3 Overall Learnings and Recommendations

The goal of the S-LCA performed in this research was to understand the social impacts of SMM applied at Dutch dairy farms. Indicators were selected and results were aggregated per stakeholder group to communicate the social impact of SMM. Because the goal of this study was to isolate the impact of SMM, the challenge in the methodology was to select indicators that would monitor social and economic impacts solely caused by SMM. This resulted in a low number of indicators. With more indicators, the concern was that social and economic impacts were not solely caused by the introduction of SMM but by other factors as well. With the indicators selected in this research the aim was that the social and economic impacts were solely caused by the introduction of SMM. For follow-up research, some recommendations will be given. To start, the stakeholder group local community can be disregarded in future studies that use the same approach of interviewing farmers only. Interviewed farmers generally reported that there was no reason for the local community to be influenced by the use of SMM on Dutch dairy farms and the results of this study confirmed this. It could be useful to investigate this stakeholder by gathering data from the local community directly, which could better highlight their viewpoint. Instead, the stakeholder 'government' could be researched. Many interviewed farmers reported that the installment of SMM and their doubts about it resulted in a more negative attitude towards the government. It could be very interesting to investigate the social impacts felt by the government due to the adoption of SMM on Dutch dairy farms.

For the stakeholder 'workers', only one indicator was selected for the social analysis. The scope of this research was narrow on purpose, but for extension of the scope recommendations will follow. For follow-up studies, a higher number and more specific indicators are recommended. Examples of possible indicators would be: 1) Feeling of satisfaction when doing work related to SMM system, as reported by the workers 2) Trust in the support and right intentions of government and other institutions involved in SMM relative to before the uptake of SMM and 3) Perceived contribution to

societal welfare and sustainability. Especially the trust that the government was concerned with the welfare of Dutch farmers is a very relevant social impact related to SMM on Dutch dairy farms and should be studied in more detail in follow-up studies. Many interviewees reported that they did not believe in the right intentions of the government, and they reported that they genuinely believed that the government was trying to get rid of farmers to obtain more space for building houses etc. This research considers this a social impact worth investigating.

For the stakeholder 'dairy processing companies' the selected indicators are considered suitable to gain a broad but superficial insight into the social impact felt by dairy processing companies due to SMM. For more concise information on the social impacts felt by this stakeholder group, follow-up studies are recommended to conduct interviews with people involved at dairy processing companies themselves. For feasibility reasons, the interviews were limited to Dutch dairy farmers only, but to gain a more precise image of the social impacts felt by this stakeholder, it is advised to obtain information from them directly.

7. Conclusions

The aim of this research was to investigate the social and economic impact of SMM technologies adopted on Dutch dairy farms. The SAFE framework and a S-LCA framework were applied to perform the social and economic analyses of this research and 15 structured interviews with Dutch dairy farmers were conducted for data collection. The selected indicators allowed for isolation of social and economic impacts solely caused by SMM and gave a significant understanding of the impact on the examined stakeholders.

It was found that economic impacts varied greatly depending on the type of SMM applied. Emission reducing floors had a significant negative impact on economic well-being of Dutch dairy farmers. On the other hand, a SMM system with a mono-digester combined with a manure scraping robot and a sealed basement showed very positive impact on economic well-being of Dutch dairy farmers. Combined with very positive environmental impact, this (the mono-digester + manure scraping robot + sealed basement) was the best performing SMM system investigated in this research. These results help answer the first research question, 'What is the effect of different sustainable manure management systems on the economic well-being of Dutch dairy farmers?', by informing that this effect is highly different for different systems and detailing the specific effects per SMM system. In the social analysis, the focus was not on the different types of SMM systems, but rather on the impact of SMM in general on selected stakeholders. It was found that SMM at Dutch dairy farms has a slight positive impact on workers, due to an increase in employment. There was no negative impact found on the social well-being of the local community in this research. The adoption of SMM on Dutch dairy farms causes a slight positive impact on dairy processing companies, as they reportedly tended towards constructive involvement regarding SMM, and showed full acceptance of the use of SMM. In general, positive social impacts can be attributed to the implementation of SMM on the stakeholders selected in this research (workers on Dutch dairy farms, local community and dairy processing companies), which help answering the second research question, 'What are the social impacts of the adoption of sustainable manure management on Dutch dairy farmers and relevant stakeholders?'.

From a theoretical perspective, this research has broadened the knowledge field about the impacts of SMM on Dutch dairy farmers and related stakeholders. The formulation of a clear methodology in which economic impacts as well as social impacts are included is a first step towards a full and thorough understanding of the effect of the adoption of SMM on Dutch dairy farms. With no indicators for social and economic analysis present for research in this field prior to this research, knowledge about the sustainability of SMM (from the social, economic and environmental perspective) was very limited. General indicators were tailored to this specific field of research, through which this study presents an approach for full investigation of the sustainability of SMM, whereas prior only the environmental aspect of sustainability was covered. With the nitrogen crisis being far from over and with the need for progress in this field remaining high, this research is an important step towards creating an effective way forward towards sustainable agriculture. Indicators and relevant stakeholders for follow-up research have been proposed, allowing for effective future research in this field as SMM further develops.

From a practical perspective, this research has shown which SMM methods are most effective regarding environmental and economic impact. This research has undermined the effectiveness of certain SMM methods, being emission reducing floors, while it has emphasized the effectiveness of other SMM methods. Also, it can be concluded that SMM does not cause a social impact on stakeholders selected in this research (workers on Dutch dairy farms, local community and dairy processing companies) that is so significant that immediate action (for example by the government) is

needed. Further research can be developed to explore the impact of SMM further, with indicators proposed in this research. Aspects that have not been covered in this research are impacts on the social relationship between farmers and the government, which is highly recommended for future research. Also not explored in enough depth was the profitability of the biogas produced with mono-digestors. One of the uses of this research is the exposure of these knowledge gaps, which can be tackled in further research. Other uses could be further development and research into the SMM methods that were found to be effective in this research, a deeper understanding of what SMM methods should receive more subsidies and which should not, and knowledge about what SMM methods should be disregarded in the future, as low sustainable performance was shown. Policy makers could use this research to make laws or aim subsidies at the SMM systems that have shown to be economically and environmentally viable, such as the mono-digestor with a manure scraper and a sealed basement. In this way, development of this SMM will happen faster and the transition to overall SMM will be more efficient.

Overall, the main objectives of this research were achieved. Knowledge is obtained about the social and economic impact of SMM on Dutch dairy farmers and selected stakeholders. With the use of the SAFE framework and the S-LCA framework, a solid foundation was built for the investigation of social and economic impact of SMM on farmers and related stakeholders. Upon this basis, further research could be conducted, with specific steps and focus points recommended in this research.

8. Limitations and Risks

The purpose of this research was to obtain knowledge about the social and economic impact of a technology that is designed for environmental purposes: SMM. The social analysis was performed on three stakeholders: workers on Dutch dairy farms, the local community and dairy processing companies. The economic analysis is performed on Dutch dairy farmers only. The scope of the research was narrowed down to these stakeholders only, to be able to focus on quality of data instead of quantity. While this improves the quality of the research, this narrow focus is the first limitation of this research. Despite attempts to design the research as effectively as possible, there are always limitations and risks. The following section will mention the primary limitations and risks of this research.

The main risk that this research faced was the drawing of unjustified cause-and-effect relations. Data on social and economic impact of SMM was gathered by interviewing Dutch dairy farmers about their personal experience. Social and economic changes since the uptake of SMM may be experienced but might not (exclusively) be caused by the uptake of SMM. Other changes or innovations at the farms might, partially or fully, be the cause of the social and economic changes experienced by Dutch dairy farmers. This risk was attempted to be mitigated through careful selection of indicators and variables that solely focus on SMM and aim to exclude other possible causes. However, a certain degree of unjustified drawing of cause-and-effect relations might still have taken place.

Another risk that this research is the high dependency on interviews. For primary data collection, interviews were conducted with Dutch dairy farmers who adopted SMM. The data collected in these interviews was the primary basis for the drawing of conclusions. Therefore, this type of research is highly dependent on this data, and therefore on the respondents. There is always the risk of not acquiring enough respondents. This risk was mitigated through several strategies. First of all, respondents were contacted through multiple channels, such as telephone calls, Emails, personal visits at farms etc. Also, it was emphasized that creating awareness about the social and economic effects of SMM on Dutch dairy farmers might well be beneficial for the farmers themselves. By reminding the interviewees of this fact, that chance of gaining response was increased.

Another limitation of this study was the narrow focus taken in the social analysis. Social analyses usually require investigation of multiple stakeholders who are all connected through social relationships (UNEP, 2013). As interviews with all stakeholders are not feasible in the time frame available for this study, prioritization was needed. The choice was made to focus on workers, the local community and dairy processing companies only, as it was estimated that the farmers would be able to give enough information about themselves and the local community. However, social impact goes far beyond just these stakeholders, and the narrow focus on just these three stakeholders is therefore a limitation of this study. Also, the fact that only the perspective of Dutch dairy farmers was investigated in this research is a limitation. It was concluded that no social impact was felt by the local community, but this was only according to the farmers. Interviews with members of the local community might give different results and would be worth conducting. However, due to time constraint this was not done in this research, making this a limitation.

In the economic analysis the interviewees were asked about the payback period of their SMM system. If this value was not known, an estimation was made through entering certain variables in Equation 2. This equation is an estimate of the payback period, but has limitations. The only economic benefits to Dutch dairy farmers considered in this equation are the sum of the subsidies received by the farmer, and operational costs. However, another economic driver to economic well-being of Dutch dairy farmers caused by SMM that could be considered for this equations is ‘reduced labor inputs due to

automatization' (Uvarov et al., 2020). The only economic barriers considered were installation and operational costs. However, increased electricity demands and time needed for registration for subsidies are also additional costs that are caused by SMM systems in general (van der Plicht, 2023). These were other economic barriers that could have been considered for this equation. These drivers and barriers to economic well-being were left out of Equation 2 because they were considered infeasible to measure through interviews alone. However, it is therefore important to note that the payback periods calculated in this research were an estimation.

Lastly, it is possible for farmers to experiment with novel SMM systems at the stable and still receive subsidies from the state (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). In this research, only systems considered in the Rav (Regeling Ammoniak En Veehouderij, 2023), were considered. However, these novel systems, with potentially different social and economic effects, were not considered in this research. Little is known about the ammonia emission reduction rate and therefore it would be hard to grant validity to these novel systems. In addition, the technologies considered in the term 'SMM' had to be limited at some point, and including all novel technologies which have not been officially approved yet would make this limiting process very complex. However, not including these novel SMM systems in this research is a limitation

9. References

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10. Appendix

Appendix A: Interview guide

Name of dairy farmer:
Date:

1. **<u>Questions about SMM/background information</u>**
    - Can you give a short description of the SMM used at this farm?
    - When was this SMM system adopted?
    - Why did this farm adopt a SMM system at the time?

2. **<u>Questions about economic impact of SMM</u>**
    - Can you give an estimation of the total amount of money that is given to you through subsidies each month?
        - Direct income support: _____ € per month
        - Second pillar payments: _____ € per month
        - (If known) Total subsidies per month: _____ € per month
    - What is your total net farm income per month?
        - Total net farm income: _____ € per month
    - Do you know the expected pay-back period of your SMM system?
        - If yes: _____ years
        - If no:
            - Can you give an indication of installment costs of your SMM system?
                - Installment costs: _____ €
            - Can you give an indication of monthly operation costs of your SMM system?
                - Operational costs: _____ € per month

3. **<u>Questions about social impact of SMM</u>**
   Give an explanation about the Likert scale.

- Has there been a **loss/gain of employment** at your farm due to the adoption of SMM? Choose between:
  1)Strong loss 2)Loss 3)No change in employment 4)Gain 5)Strong gain
  Answer: ___
- Is the use of SMM **accepted by** the **local community** in your experience? (Yes/no)
  Answer: ___
- Has there been an involuntary relocation of **local employment** due to the adoption of SMM? (Yes/no)
  Answer: ___
- How **involved** were **dairy processing companies** that your farm delivers to in the **successful transition** to SMM? Choose between
  1)Obstructive and unasked involvement 2)Unasked involvement 3)No involvement 4)Much involvement 5)Strong and constructive involvement
  Answer: ___
- How **involved** are **dairy processing companies** that your farm delivers to in **decision-making** related to SMM?
  1)Obstructive and unasked involvement 2)Unasked involvement 3)No involvement 4)Much involvement 5)Strong and constructive involvement
  Answer: ___
- Is the use of SMM and its related effects **accepted** by **dairy processing companies** that your farm delivers to, in your experience? (Yes/no)
  Answer: ___

4. <u>Closing question</u>

- Is there anything that we have not covered yet in this interview that you wish to address?

Appendix B: Transcribed Interviews

Questions and comments by interviewer are shown in italic.

Interview 1

Interviewee: Lennart Streng
Date: 18/01/2024

My first question is how your manure processing system looks. So, do you have something to limit your nitrogen emissions, like cracking or a specific floor? And how does that look on your dairy farm? We have a 'JOZ kraker' (nitrogen cracker gazoo from JOZ). *A 'JOZ kraker'?* Yes, that's right.

Okay, and when did you install that? We participated in the pilot. We were one of the first to have such an installation. And we've been running it since 2022.

Okay, interesting. And why did you choose to do that at the time? Well, we had multiple intentions. We are located on a narrow road and have to pass many people because we have little land. Little land in our possession. On a narrow road, a lot of freight traffic, that's also not ideal. Derogation was already in progress at that time about what we would do with it.

Yes. And yes, it's difficult to calculate. Okay.

And all the considerations together, we decided to invest in it. Okay. And there was SPV subsidy as well.

We received SPV subsidy. *You have SPV. Do you have an estimate of what percentage of your income comes from that subsidy?* Yes, the SPV subsidy is 50 percent.

Of? Of the installation. Of the installation costs. *Of the installation costs?* Yes, so of the installation, what it costs to get a system.

That is 50 percent. So that's obviously a nice bonus. However, the downside of the SPV subsidy is that you have to finance it mainly.

Yes. You only get your half when everything is correct. So that's a bit of the downside.

Is that a one-time amount of subsidy? Yes. In the meantime, you get some money back. Money, but that amount fits into the project.

How much do you get per year or per month? That's hard to say. But the installation has cost around 1.5 million. 350,000 euros of which is the subsidy.

You get half of that back in subsidies? Yes, that's correct. But it has to be pre-financed first. And that's a lengthy project because you also have to measure.

You have to name it, you also have to install it. And that still needs to be done, even at my place. Because we have some delays in the project.

And all that is written on the door, so you only get your half back then. Okay, so you only get the money back for that installation. *But do you also receive any other subsidies because you are participating in a pilot*? No.

No, not at all? No. *Okay. And when it was installed*? I have to say, with the knowledge we have now and the thoughts to be able to set it up in the current way, I would have dared to do it without that subsidy now as well.

Yes. What I've experienced now, and I know what it is. And then I can calculate it more easily. But at that time, it was just too high. Because, yes, we had one year, and we also didn't know what we were going to do. Yes, I understand, yes.

Do you have an estimate of the net income of your dairy farm on an annual basis, approximately? No, I wouldn't know that. *Okay, I understand. When that 'JOZ kraker' was installed, was there an estimate made of how many years it would take to fully recover the cost?* Yes.

How many years was that? Five years. Five years? Okay, I certainly have that.

I gave it within five years. I personally estimate it to be about three, three and a half years. But that's just because we had an expensive fair year.

So, that fair was expensive. Yes. And now the current master for cracking.

It runs on it tremendously. So yes, I can easily withdraw that. So, it was a good investment? Yes, basically.

But well, that is also influenced by the SBV subsidy. Otherwise, it would naturally take longer. And that's why we did it at the time.

Because it was five years. And five years, I think, that's manageable. But otherwise, if the SBV subsidy wasn't there, it would have been ten years already.

And I wouldn't have wanted that. Then I would have found it perfect. But well, with the knowledge we have now, I would have done it.

And soon you'll get that SBV subsidy. And then? Then you have 50% of your installation costs covered. But then it's also the end of subsidies? Yes, then it's over.

Okay. But in itself, that also has advantages. Because then you're not dependent on subsidies and other things.

That can determine what you have to do. *No, yes, that's right*. The installation, managing, so that's going well then.

Okay. *And is there more or less work? In terms of maintenance*? Or is there more or less work involved in your dairy farm? Because you now have such a 'JOZ kraker'? Yes, look. You have to separate all your manure.

And then a scraper goes into the manure separation. And then you also have to maintain the value of it. Because I know that you've always separated manure.

Yes. But it also means that you need maintenance. You have to keep an eye on the manure.

It's not nothing once in a while. So yes, you have to make sure that everything is in order. Yes.

The 'kraker' itself is much less work. In terms of maintenance, because we clean it once or twice a year. I think twice.

Yes. Internally. Yes, that's a day's work.

And things that break, that's all quite manageable. We run two pumps in the fan. Yes. And there are some electronic controls. But there aren't really any major issues. I have a manure separator, a scraper.

There are some wear parts in there. But yes, we've dealt with that a few times. Yes.

Okay. And is the use of such a 'kraker' accepted by other dairy farmers? S*peaking for the local community, do you feel that's the case?* Yes, in the beginning, it was quite skeptical. *Well, in the beginning, what is that?* But now everyone is okay with it.

Because the manure you get from it and the disposal costs are high. Everyone had to consider alternatives. Yes, that can get expensive.

Yes. And I already saw it starting to change a bit when the fertilizer price became very expensive. Because I made nitrogen fertilizer from manure, I naturally made more sustainable fertilizer.

And yes, I already saw a change happening then. Everyone wondered, how can you afford your fertilizer? Yes, that was a good choice, I think.

Because I talk to enough dairy farmers who now have to sell manure and buy fertilizer. *Yes. A pretty double investment*. Yes.

Seems to be. And do you supply dairy processing companies? Yes, Friesland and Capine. *And are they involved in your decision to get such a 'JOZ kraker'*? No.

No. Okay. They have their own project.

That's of course my jumpstart. The FrieslandCampina one. Yes.

But also FrieslandCampina. But that might still come here. But I haven't done that yet.

I don't know if I want to either. And considering the profit situation around here, it becomes a bit.

I don't know if that still fits in. Okay. *But they fully accept that you have such a 'JOZ kraker'*? Yes, because this is just a small installation.

Just a big container bin. And everything is in there, basically. So, I don't find it all that special.

There are even some bricks in it. That's all quite manageable. Okay.

Well, those were basically all my questions. Yes. But the installation is obviously a bit different.

It's a bit larger. Yes. No, but yours is basically a relatively small installation.

But if I understand it correctly, you are happy with the choice you made back then. Yes, because we have 200 cows. With electricity, we have a nice surplus of energy.

Because it's about 5 hectares in use. With 200 dairy cows. That's quite a lot.

So yes, you still have to get 3,000 to 3,500 cubic meters of manure per year. Yes. And that adds up, of course.

Because then you just have a surplus of manure with prices of at least 60,000 euros. And I think even a bit more. Yes.

Yes*, that's quite a lot*, yes. Yes, it adds up, yes. Let me see.

And that total net income of that dairy farm, you couldn't really give that, right? No, I find that difficult. We are a good business.

We don't do young stock here. We only buy dairy cows. So, we only do milk here and such. Yes.

We deliver well over 2 million liters of milk per year. Yes, that's going well. But we have to put a lot into it.

But to really figure it out. The costs are actually a bit less than the average farm. Yes, I understand, yes.

But, well, good to hear at least that you are happy with the 'kraker'. Yes. And those were all my questions.

What was your name for my own records? Lennart Streng. *Lennart Streng.* Yes.

Well, thank you very much for your time. It was very informative. And have a great day.

Yes, well, good luck with everything. Thank you. Goodbye.

Goodbye, goodbye.

Interview 2

Interviewee: Tom Groot Roessink
Date: 9/01/2024

Good morning, this is Bram speaking. I am a student at Wageningen University, and currently, I am conducting research on the social and economic impacts of sustainable manure processing on Dutch dairy farmers. I would like to ask you a few questions as part of this research, and I was wondering if you would be willing to answer them.

Yes, what kind of research is it, you mentioned? *It's about the social and economic impacts of sustainable manure processing on Dutch dairy farmers. The questions will take about 5 to 10 minutes. The research is aimed at raising awareness about the consequences of sustainable manure processing for Dutch dairy farmers.*

I do have about 5 minutes, sure. *Okay, the first question. Can you provide a brief description of the sustainable manure processing system used on this farm?* Yes, sustainable manure processing, what do you mean? *For example, do you have a method for handling the manure produced by your cows? Is there a system at the barn that you use to optimize manure utilization and minimize its impact on the environment?*

We actually use a combination of a stripper and a digester. The digester is used to produce biomass, and we use its heat as well. This produces both electricity and heat, and the surplus is supplied to the grid. In combination with that, we use a stripper.

The liquid fraction of the manure produced is processed with a stripper. This locks in the nitrogen from the animal manure, preventing it from escaping into the air when spread on the land. Or, if it is spread on the land, the nitrogen is captured and then added to fertilizer.

We use this combination to treat our manure. *Okay, that sounds good. Since when did you start using these two machines?* It must have been about 5 to 6 years ago*. And why did you choose to do so at that time?* Firstly, to reduce nitrogen and methane emissions. You need permits for everything, and there are all these new measures you have to comply with.

So, we chose to do this. We wanted to contribute something ourselves. And besides, with digestion, you don't use peak power, so it's also a bit cheaper for us.

Okay, that sounds good. Do you receive subsidies from the local or national government? Do they provide any subsidies because you are helping to reduce your nitrogen and methane emissions? No, not at all.

Okay, you don't receive any. Not even from the new CAP (Common Agricultural Policy)? No, we don't receive anything.

Okay, that's quite strange. What is the total net income of your dairy farm per month, if I may ask? Well, that's hard to say because we are a mixed farm. But for the dairy farm, it would be around 20,000 per month.

Okay, great. And when you installed that stripper back then, was there any discussion about the expected payback period? How long it takes, how long this device needs to be used before it pays for itself? Yes, that would be around 7 to 8 years. An estimate was made at that time.

A kind of agency did all the calculations, and it was expected to take 7 to 8 years. *Okay, great. Then I have another question about employment on your farm. Due to the implementation of this sustainable manure processing system, has there been any talk of loss or gain of employment? Is there more work? Looking at the daily operations related to this manure processing system? Or is there less work?* Yes, it does require more work. I am more involved in it now.

There is a separate bin, separate flows that you have to take into account, you are quite busy keeping things separate. Some valves, some bins that are new. You have to keep it all well separated and ensure that it stays pure. So that does cost me more work, yes*. Okay, is that a significant increase or just a bit more work?* Well, that is quite a bit more work, yes. It is quite a bit more work in a day.

Okay, and is the use of sustainable mesh farming accepted in the local community based on your experience? Yes, everyone is fine with that. Actually, not much is talked about it, to be honest. Yes, everyone is fine with it.

Okay, and has there been any forced displacement of local workers due to the implementation of sustainable mesh farming? No, no, in fact, there has only been more work added, so that was not the

case, no. *Okay, and how involved were dairy processing companies to which your farm supplies in the successful transition to sustainable mesh farming? I assume you supply dairy processing companies, is that correct?* Yes, that's correct. *And did they play a role in the successful transition to sustainable mesh farming*? Well, they are fine with it.

You see, they can then put labels on their milk again. But, ultimately, they don't make much profit from it, so it doesn't matter to them that much. They are aware of it, and to some extent, they have been involved, but not very intensively.

Okay, and if decisions need to be made regarding sustainable mesh farming on your dairy farm, are they involved in that? Well, they can say something about it, yes. Because they ultimately want to know exactly what kind of milk they are buying from us. Depending on that, they also determine a price per liter, of course. It has increased a bit, but not really significantly. So, they are somewhat involved in that aspect.

Okay, so they accept the use of sustainable manure processing on your dairy farm and the associated effects, and they fully agree with it? Yes, yes, absolutely.

Okay, well, those were all my questions, actually. Thank you very much for taking the time to share your insights. It helps me a lot.

Interview 3

Interviewee: Herman Pieter Prangsma
Date: 10/01/2022

My first question is whether you have a sustainable manure processing system. So, how do you process manure on your dairy farm, and do you take any measures to limit your nitrogen emissions? Yes, we have installed a low-emission barn floor. It is claimed to reduce ammonia emissions to some extent, although there is still some doubt about whether it truly achieves that. Recently, a court ruling was made on this matter, and there is not much consensus on it. However, it is said to limit ammonia emissions.

Okay, and when did you install it? That was in 2016, about eight years ago. *Okay, and why did you choose to install such a floor back then?* Well, we needed a new floor for a new barn, and for that, you need a permit, of course. We could only get that if we installed such a floor. Additionally, we wanted to address our nitrogen emissions. But mainly, it was for the permit.

Okay, do you receive any subsidies from the government because you have a floor that is supposed to reduce nitrogen emissions? Yes, we receive some. *And how much is that on a monthly or yearly basis, if I may ask?* Well, it's around 10 to 12k per year.

Okay, and what is approximately the percentage of your income that comes from these subsidies? It's about 20%. *Okay, 20%.* Yes.

And when the floor was installed, was there an estimation of the expected payback period? Like, how many years it would take for this floor to pay for itself? No, the floor just has to be there. So, there is no payback period, and no calculations were made about that.

Okay. What are the installation costs of such a floor? It's around 40,000. *Okay, around 40,000*. Yes.

Are there any operational costs associated with it? Is there something you need to do on a daily basis to maintain this floor? Yes, it takes about half an hour per day to maintain the floor and clean everything. Yes, about half an hour per day.

Okay, in any case, if I were to convert that into a monetary amount in euros, how much would that be approximately? Well, let's take an hourly wage of 50 euros. So, in that hour, you could, of course, do many other things. Let's assume an hourly wage of 60 euros.

We are busy for about half an hour a day. So, that would cost about 30 euros per day, I would say approximately. Operational costs are around 30 euros per day.

Yes, approximately, but that's a rough estimate. But I think that's about where it comes down to. *Okay, clear.*

Has there been an increase or decrease in work on your dairy farm as a result of implementing this sustainable floor? Yes, it's a bit more. As I explained earlier, about half an hour per day. Yes, a bit more.

Is the use of such a floor accepted by the local community in your area? Yes, it is accepted. Yes, certainly. Everyone understands that you need a permit for a barn.

I wouldn't see why that wouldn't be accepted. *Okay, has there been any forced relocation of local workers as a result of the implementation of sustainable manure processing?* No, no. There's just a bit more work.

Okay, and I assume you sell to dairy processing companies, is that correct? Yes, that's correct. *And are they aware that you have such a low-emission floor? Are they involved in the transition to such a floor*? Well, they are aware.

They have their own department that deals with sustainable milk production. But ultimately, they don't have much say in decisions. Because, in the end, it's just a dairy farm.

So, I am the one making the decisions. But yes, they have a kind of questionnaire. And based on that, you might qualify for a certification.

And then you could ask for extra money per liter. *Okay. So, decisions regarding your way of manure processing, they are not really involved in that*? Well, they are aware and involved to some extent, but not very much.

Okay, and do they accept the use of such a low-emission floor that you have installed? Yes, definitely. *Okay, those were actually all my questions.*

Where is your dairy farm located again, if I may ask? My dairy farm is in Ede. So, a dairy farm with about forty large cows. So, you need a decent-sized barn for that.

And that's why we chose this approach.

Okay, and do you produce too much manure? Do you have to sell or dispose of a part of the manure you produce? No, we are currently still land-based, so everything is fine for now. But now, with the quota being lifted, it might become a problem in the coming years. However, we hope that the government revisits this particular policy they have in place. And yes, theoretically, it should work out.

Okay, yes, I really hope so for you. Anyway, these were all the questions, so thank you very much for your time. It's truly appreciated.

Okay, yes, good luck with your research. Thank you, and have a nice day. Goodbye.

Interview 4

Interviewee: Nico Rietjens
Date: 12/01/2022

My first question is whether you have a manure processing system on your dairy farms and whether you are doing anything to reduce the nitrogen emissions from your manure, which your cows produce. Well, we had an emission-reducing floor installed, what is it? About 9 years ago. And it is said that the emissions should not be restricted.

Whether that's true, I strongly doubt it myself. But we have an emission-reducing floor. *Okay, and you had that installed 9 years ago.*

Yes, in 2015. And part of the stable has an emission-reducing floor, another part still has a traditional floor. But in 2015, we wanted to expand, and then we had to opt for an emission-reducing floor.

And why did you choose that at the time? Yes, we had to, otherwise, we wouldn't get a permit. Yes, we had to. We weren't really in favor of it ourselves because there is a potential investment involved.

Another cost to consider. *Okay. Do you receive any subsidies from the government for that floor?* Yes, well, we do get something.

I'm not sure if it's directly for that floor, but we also provide different feed. So, it's a combination of both. We receive about, yes, I think about, that's hard to say, I don't know exactly.

Do you have a rough estimate of what percentage of your income comes from those subsidies? So, what percentage of your income comes from the subsidies for reducing your nitrogen emissions? Yes, again, I find that hard to say, but let's say about 10%. *About 10%?* Yes, that's right. *Okay.*

And do you have a very rough estimate of your total net income from the farm per month? Yes, all in all, I think it's around 25,000. Yes, I think something like that. *Okay.*

Are there any installation costs associated with the installation of that Emission reducing floor? Yes, quite a bit, yes. Yes, it's 85,000 euros. O*kay, and are there any ongoing operational costs associated with it? Costs that you incur on a daily basis*. Yes, now that the manure quota is going away, we have to sell the manure we produce on the market.

And that's the thing, because we have an Emission reducing floor, we have to pay more for the manure we produce because it contains more nitrogen. So, that's a bit how it works. We install an Emission reducing floor and then we have to make an initial investment of 85,000 euros and then we have to pay extra to sell our manure.

That's quite strange. Is it true that you also have to purchase synthetic fertilizer separately? Yes, synthetic fertilizer must be purchased separately, yes. Yes, it's completely crazy.

We have to pay extra for the manure we produce with our Emission Reducing floor. And indeed, we also have to purchase synthetic fertilizer. And yes, the trust is just gone.

It doesn't make any sense. *Okay, and how much produced manure are we talking about, and how much do you have to pay for it?* Well, we have to pay for about 100 cubic meters per year. *Okay, and how much do you pay per cubic meter to sell that*? Just 20 euros per cubic meter.

20 euros per cubic meter? 20 euros per cubic meter. *Okay. Let me check, if I calculate that, 2000 divided by 12, is that 167 euros per month.*

Yes, and that's just for selling the manure? Yes. *Yes, it's quite ridiculous that you have to pay extra for that with your Emission reducing floor.* Yes.

Okay, and is there more or less work on your dairy farm as a result of that Emission Reducing floor? Is there a lot of maintenance, or does it save work? No, it's more work. There are scrapers for the cows.

But yes, it has to be cleaned more frequently, so it's more work. *Is that a lot more work or a little more work?* Well, it's just a bit more work. *Okay, and is the use of such an Emission Reducing floor accepted?* Yes, it is accepted.

Yes, we had no choice. Yes, it is accepted. I know half of the farmers.

Okay. *And do your dairy processing companies or organizations work with you in the business?* Yes, that's right, yes. *And have they been involved in the successful transition to such a floor? Or do they not have much to do with it?* No, they don't know anything about it at all.

Okay, so they're completely unaware of decisions about how you handle your affairs? No, they don't know anything about it at all. No, they are completely unaware. *Okay, but they do accept that you have such a floor?* Yes, yes, why not? Yes, it's eh... Again, they are completely... They are completely unaware, but yes... They accept it.

Okay, those were actually all my questions. And eh... Well, it's actually strange to hear that you install an emission-reducing floor, showing that you want to contribute to solving the nitrogen crisis. And then you incur additional costs in the form of installation costs.

And then, on a daily basis, you still have to pay extra for your manure surplus. So... Yes, it's just ridiculous. We, eh... Farmers just don't feel that the government is thinking along.

There can be two reasons, eh... That these measures are being taken. One, because they really want to address the nitrogen crisis, and it's a really big problem.

But nobody believes that anymore. And the only thing they actually want is just fewer farmers. Because it takes up a lot of space, and because other houses need to be built.

Yes, we're just being squeezed. I mean, I install such an emission-reducing floor. And I just pay 85,000 euros for it.

And then, I have to pay extra for the manure I sell. It's just too ridiculous for words. Y*es, I completely agree with you.*

And eh... That's also a bit what the research is for. To bring a bit more attention to it and... Yes, and maybe help with that. Yes, the problem is eh... The government knows.

And they can do any research they want. That's only good, of course. But they just stubbornly don't do anything with it.

And that's why we think there's just a hidden agenda. And that they actually want other things. *Yes, no, I understand.*

Yes, hopefully, we can still eh... Help a bit somewhere. Yes, well. Your answers certainly help with our research.

So, it's highly appreciated. Yes. And eh... Thank you very much.

And have a great day further. Yes, thank you. Bye-bye.

Interview 5

Interviewee: Jolanda Reuver
Date: 15/01/2024

Hello, this is Yolanda. *Hello, this is Bram*. *Good morning, I am a student at Wageningen University, and I am currently researching the social and economic consequences of sustainable manure processing on Dutch dairy farmers. I am looking for Dutch dairy farmers who are willing to answer a few questions. It takes about 5 to 10 minutes, and I was wondering if you might be open to that.* Yes, I do have some time. Where are you conducting your research? I *am at Wageningen University for my graduation thesis*. Oh, nice. Yes, I do have some time. *Great, that's wonderful*.

Now, my first question is, do you practice sustainable manure processing? Do you have a system installed for that? Do you have a barn that contributes to sustainable manure processing? Or, what do you do with the manure produced on your dairy farm? Well, that's a bit of a long story. We used to have a traditional dairy barn with straw, and the manure was piled up, and we would spread the produced manure on our own land. The excess manure had to be sold to farms in the area. Additionally, we had to purchase artificial fertilizer, resulting in double costs for us, which was not optimal.

Then, about ten years ago, in 2013, we decided to build a new barn. Naturally, you need a permit for that, and nowadays, you have to build sustainably to get that permit. It's not that straightforward; you have to construct sustainably. After lengthy discussions with various parties and the municipalities, we eventually obtained a permit. It was a combination of wanting to take care of the land.

So, we wanted to focus on biomass; we always say the most important biomass is beneath the ground. It's not the livestock in the barn; the crucial biomass is below the ground. So, the worms and all those small organisms that contribute to the health of the ecosystem are beneath the land. We wanted to take care of that, and, in combination, we needed a permit for our barn. Considering these two factors, we chose to build this barn. It includes a slatted floor. We buy slow manure, slow manure pellets, and our floor has a 3% slope, allowing the liquid manure and solid manure to be separated as quickly as possible.

This is an emission-reducing floor. You might have read about it; it's on the RAV list, which is often discussed. At that time, we built such a floor, and three other dairy farms in the Netherlands also built it, and it's all listed in the RAV, which you might be familiar with. Yes, I'm familiar with that indeed. Now, let me see, this is an emission-reducing floor made of asphalt. It's an asphalt floor with a slight slope, creating different streams. You get a liquid manure stream, a solid manure stream, a urine stream, and we have a manure drainage pipe.

So, we bring that liquid manure back to our land. Of course, we also have a solid fraction, which is a bit more challenging to handle, especially now with the frost and cold conditions outside. But you get various streams from this system, and it prevents them from coming into contact with each other. The contact of these substances with each other is what causes ammonia emissions, and this system reduces that. We are included in the RAV, and I believe it was Wageningen University that conducted research afterward. Yes, that's correct, it could very well be. Well, the average emission, I don't know exactly what the average emission is for a regular dairy barn, I think it's around 13%, and ours is 5.3%.

Well, that's good, yes, that's good. So, there's a significant difference that we achieve with that. It's just, I'm not exactly sure where it stands; that's what separating does, and it might be even more. You can wonder, is it really that precise? Yes, what is being measured there. But yes, the Wageningen

University conducted the research, and we have to assume that it's very accurate. So yes, that's quite a reduction in emissions that we achieve with our barn.

And when it comes to subsidies, were there any subsidies for that when you implemented it? That's also a reason why we did it. But, perhaps it should have stayed that way, with everyone using the same barn, and it would have been less complicated because there is, of course, quite a bit of dissatisfaction among the farmers.

Okay, and you mentioned subsidies. Could you give me an estimate of the amount of subsidies you receive? Do you receive subsidies, is it from the local government, or is it from the national government? Well, actually, it was promised with the new CAP back then that we would receive subsidies. But in the end, it's not that significant. Well, with the new CAP, that was also the case with our barn, since we do so many things to separate our streams and actually reduce ammonia, which according to that research has succeeded, you could enter a golden division in the new CAP, and then we would receive additional subsidies, which could amount to a considerable sum. But that didn't happen. We stayed in Bronze because there were very specific measures we had to meet. We had to include a lot of additional land, and we looked into that – is it worth it? Well, it's also the case that those subsidies, recently, I don't know what it was, I think it was halved, or they were reduced, but that means in the end, it doesn't add up at all. So, we're glad we made that decision at that time.

But we don't receive subsidies, and at that time, everything went very strangely. There is an engineering company, TAUW, that came to us, T-A-U-W, and it all went very strangely. They did all kinds of calculations, and at that time, we asked, "Can we see those, can we see what exactly we've incurred in costs and what additional income we should receive?" It all went very strangely, and then they said, "That's our research, and it's not for you," so we just don't have a very good idea of what we exactly get for our low-emission barn. But in the end, it's nothing; we don't get anything. So, you don't get anything for the low emissions and the contribution to the environment you make with that barn, no, nothing at all.

We just talked about a bronze division you were in, right? Yes. *Do you still receive anything from that, subsidies?*

Well, that's it. It was 40 euros per hectare, I believe; we have 130 hectares. Okay, so 40 times 130, yes, that should be about right on an annual basis. Do you have an estimate of what percentage of your overall income this, yes, these subsidies would be, yes, that would be less than 1%, less than 1%, yes. But whatever it is, the parties that provide these subsidies, ultimately, they just want a say in what happens. So, they say, one year they say, "Well, we need more corn, so we'll provide subsidies to farms that produce a lot of corn," and the next year, there's no need for corn, so they stop providing subsidies to farms that produce corn. So, it depends on what is needed at that moment, what subsidies suddenly become available. We just want to be in charge of our own farm, and we don't want constant influence from outside telling us what to produce and what is important at that moment. We don't want to become so dependent on subsidies that we can't decide for ourselves what happens. Okay, and you already mentioned that there are various costs involved, such an installation can cost 1.5 to 2 million euros, and you earn that back over generations. We just want to

earn that back on our own, and it's a family business, so we just have to work for it for a long time, but then it stays within the family, and ultimately, we want to do the same, and we don't want to be dependent on those subsidies and external influences.

Yes, I understand that very well, and yes, there are all these costs involved, such an installation, and you mentioned that TAUW engineering company came to do some calculations for your barn. Was there an estimate made at that time of the payback period for the barn you started?

Yes, initially, that would be 15 years, and, of course, you don't achieve that because that's if you just reinvest all your earnings back into that barn. But we also had to purchase additional land to accommodate the manure that we produce separately. So, we also have to earn money back on that. So, in the end, it becomes a very complicated picture because not all the money you earn keeps going back into that barn. Okay, and if you had to make an estimate of how long it would be with all those other costs, what would that be? Well, that would be around 20 years, so, as I said, it's really been a long-term investment, and we just wanted to see what the future looks like, what the short-term questions would be, and how we can remain a bit future-proof. And then this was the solution. Okay, so around 20 years, you say. Yes, that's about right, around 20 years.

Okay, then I have another question for you. Has there been any loss or gain in employment on the farm as a result of the introduction of sustainable manure processing or the introduction of your low-emission barn?

No, that's an increase in work; it costs a lot more work to manage that barn. All those extra streams, there are so many things that need to be treated extra. We have a large vat where we store urine, and it froze last week due to the frost. Because it's a bit of a new system that we have, and I don't know where the parts come from, but those parts are not readily available everywhere. So, we looked in the area if there was another farm that could maybe supply this part to us, and there wasn't. So, now we were dealing with that; we were trying to solve that problem earlier. And tomorrow, we'll probably have to go to Friesland to get a valve that fits exactly because there just aren't many of them because it's quite new. So, these are all problems that come with such an innovative experiment, and it makes it a lot more difficult for us but also a lot more labor-intensive. But this is what we wanted, and we want to be future-proof, so yes, that's why we chose it. More work, a lot more work. *okay.*

Does the use of such a sustainable barn, is that accepted by the local community, according to your experience? Yes, certainly, especially if you explain why it happens. Well, look, we live in Twente, our farm is in Twente, and you just notice that there's a lot less life in the area lately because everyone is damaging their land a bit with those intensive livestock farms and all that artificial fertilizer being thrown on it. Now that we've closed our own cycle a bit, a lot more starlings suddenly come to our land, and it's full of starlings. Many people with cameras come to our farm, and that's also a bit of why you do it. We use our own manure, and we have the idea that life understands that, and the animals come there again, and it's all a lot more lively again. Yes, that's a bit of a farm topic always, but if you explain why you're doing this, and people come to see how the farm is now, then they understand it very well. *Okay, and has there been any forced displacement of local workers as a result of the introduction of your new barn?* I don't think so, no, no, not that, no, okay.

I have one last question; you supply to processing companies, right? Is that correct? Yes, that's correct. How involved were they in decisions you make related to the installation of your new barn? Do they accept the consequences? Are they involved in the successful transition to such a new barn? Well, at the dairy company where we supply, there is a sustainability department, and I think they also have such a dairy company, and that sustainability department has to establish certain goals, certain conditions that a dairy farmer must meet, and then you are put in a certain class. Based on that, you can ask for extra money per liter, and we can ask for 50 cents more per liter because we have this sustainable barn. But in the end, yes, they are very involved in the transition, but in the end, I find that they set conditions where we don't really benefit, and they are more conditions that they themselves need. I would say, focus on other things because recently, there was a point where we needed more trees because they have different indicators that we must meet, and those are biodiversity, climate, energy neutrality, and much more, much more. And recently, we had to, we already have quite a few trees, we have many apple trees on our farm, and now we had to suddenly plant 40 extra trees to meet biodiversity requirements so that worms could live in them or something like that. And then I think, yes, do we now all have to plant extra apple trees to meet this requirement when it doesn't really add much, and there are already so many apple trees. So, now I'm specifically looking at what needs to be done on our farm to make it more sustainable instead of blindly setting guidelines that don't really fit our farm and don't add anything. It's just a way to stamp something without much substance. We can ask for extra money in the report, so that's good, but yes, it's difficult. *Okay, those were all my questions; thank you very much for your time. That helps me a lot; you provided very good answers.* Very nice, and good luck with your research. *Thank you very much, and I have one last question: do you happen to know other dairy farmers in the area who have a sustainable barn or are involved in sustainable waste processing?*

Interview 6

Interviewee: Jacob Nijhof
Date: 16/01/2024

The first question is whether you engage in sustainable manure processing on your dairy farm. For example, in the flooring, a specific stable design, by which you process your manure in a certain way.

Processing through primary floor slats. These slats simply all come back together.

Let me see, the manure ends up on the floor, and it ensures that it is separated. That's what the floor can do, yes.

Is it such a low-emission floor? Yes, that's correct. Okay, that's what the floor can do. Currently, we choose to mix everything back together. Processing in the simplest way. And if you want, I think you also need to do manure processing. But we haven't done that yet, so that's not the question.

Okay, and when was this floor installed? In 2016.

And why did you decide to do that at the time? Well, we were dealing with emission requirements back then. And what we had was not suitable because it's basically a floor that shines through. And you can't get anything in between. *Yes, that's correct*.

Do you receive subsidies from the government, the local government, the national government, for this low-emission floor? No, we don't receive subsidies for the low-emission floor. It goes towards sustainability. *Okay, and you receive subsidies for that?* So, if we don't have it, it's not damaging, right*?*

Okay, so do you receive a certain amount on a monthly basis? It's a benefit. *Okay, what does that mean?* Well, for example, you can depreciate half a million on those buildings. Yes. That's the lifespan. Yes. And you can choose in which year you depreciate the half-million. So, if you've made a lot of profit in a year, you say, I can depreciate it again. Okay, but you don't receive a specific amount from the local government. No subsidy. *No subsidy*? No, no subsidy. *Okay.*

When the floor was installed, was there an estimate made of how long it would take for the floor to pay for itself or something? No, it costs money. *It costs money? Do you have an estimate of the installation cost?* Yes, about double. *Double?* Yes, compared to traditional slats. O*kay, how much would that be approximately?* Well, for me, this feed lane costs 70 euros. A slat cost for me is 35 euros. *Okay, that's really not good. How much does it cover?* 10. Let me calculate. 3 plus 4... is 7. Look, 2... is 14. Okay. Then you're talking about... 1260 euros. 100,000 euros. 100,000 euros? But if that's times 14... No, times 14 is 1260, if I remember correctly. 1260 times 35 euros. Times 70 was it per meter, right? Yes, but the difference is quite large. Oh, yes. Okay, and there is... Sorry? At 1260 times 70, or 1260 times 35? Yes, both. First, 1260 times 35. The difference is 44,000 euros. 44,000 euros. 44,000 and 100 euros. Yes, that could be. Right. I don't think so. 40,000 euros. Yes, that's more expensive. You have about 44,000 euros.

Okay, and isn't there any economic benefit to that? Are you cheaper on a daily basis or something? No. *Only more expensive?* Yes. *Okay, what is more expensive about it?* Yes, in maintenance. Y*es, but I mean, to run it on a daily basis?* No, it's just a concrete floor. Yes, it looks modest. We also have additional variable costs. *Oh, additional variable costs?* Yes. Yes. *So, economically speaking, you're not so happy with your low-emission floor.* It's a prerequisite for the consequence. Yes, because you can't build it at all. No. Okay. *Economically, it's unfortunate*. Economically, it's unfortunate. *Okay.*

Is there more or less work on your dairy farm as a result of installing that low-emission floor? A bit more. *A bit more?* Yes. *Is the use of the low-emission floor accepted by the local community?* Yes, they know the other aspects. Okay, yes. I'm curious to see what the floor will hold. *Yes, I know.*

And I assume you are affiliated with dairy processing companies. That's Friesland Campina. *Friesland Campina*? *Does that know anything, does it know that you have some kind of floor?* Yes, that's a nutrient cycle change. *Nutrient cycle change*.
And are they involved in decisions related to your emission reducing floor? No. *Okay, but they do advertise that you have such a floo*r. Yes. *Okay, so basically, it's not really good for the cows, and economically it's not really feasible*. No. Okay. No, this doesn't cost anything more from the cows. I have …. Cows. I need more cows to replace the cows that die there. Okay. Yes, so basically, if I've given it correctly, you installed that combined floor because you needed the floor. Yes. But actual benefits from it? Benefits, no. Okay. That was also the expectation. *That was also the expectation?* Yes. *Then it's a bit of a strange arrangement that a permit actually requires a floor, and then it actually only has disadvantages*. But on paper, it emits less ammonia. Yes, but that... Yes. That it then gets thrown back into one pile, then I find that... No, that can't happen entirely. Okay. That goes

down, but... No, that... But eventually, we might just throw it all together. Yes. That's fine too. Okay. It could be an advantage in processing. Yes. But in itself, there is still emissions for the manure handling. Okay. On paper. No, that's also not... The conditional word is used. Okay. It does seal off the pit. Yes. Yes, exactly. Okay. And if it comes together under the pit, then that's the choice. Yes, exactly. It's not happening yet, of course. Right. Okay. Well, those were my questions then. Your name is Jacob. My name is Robert. Thank you very much for your time and your answers. Do you happen to know other dairy farmers who have such a low-emission floor? Yes, but I get more or less the same kind of answers from all of them. Yes. But I would still like to ask a few questions to... Um... Well, Geert Martens, for example. Geert? Martens. Do you happen to have his number for me? Yes, sure, okay. That would be great.

Interview 7

Interviewee: Geert Martens
Date: 16/01/2024

My first question is, do you engage in manure processing on your dairy farm? So, do you have a specific floor design or something in the stable? We have a low-emission floor. *And since when is that?* 2015. Yes, partially. We have a traditional part and a low-emission part.

Okay, and why did you choose a low-emission floor back then? We expanded, and to maintain the number of animals, we had to reduce ammonia. *Reduce ammonia?* Yes, normally it's 11 or 12 decation for a cow. And now we have a floor that is 6.5 meters thick, so you can double your number of cows.

6.5? Yes, I believe so. I think it was 6.5. *Okay, and do you receive any subsidies from the government because you reduce ammonia emissions?* No, we have been involved in fourth measure sustainable farming, and we are part of that.

Yes. And you can depreciate variably. *So, what does that mean, variable depreciation?* Variable depreciation is a very good idea.

Normally, you depreciate your stable over a certain period, and if you are involved in sustainable farming, you can depreciate variably. So, if you had a year with very high income, you can depreciate more than the normal stable rate. *Yes, clear*.

You can depreciate faster if you want. *But you don't receive any income support or other forms of payments from the European Union or the national or provincial government?* From the provincial government, no. Nothing at all.

Okay, and when you had that floor installed, was there an estimate made of how long it would take for the floor to pay for itself? No. *No, because there are no economic benefits?* No, I mean, it assumes that you can store less ammonia, so more ammonia stays in the manure. *That there is more ammonia in the manure?* Yes, that there is more nitrogen in the manure, but that's questionable, of course.

And the advantage of that would be that your crops will grow better or that there is less manure needed? Yes, indeed. One of the two. *Okay, but yeah, that's a bit difficult for*... Whether your crops will grow better or whether you need less manure.

But, there isn't really a clear economic benefit for you, apart from the fact that there is a chance that you... The only economic benefit is that we are allowed to keep more cows within the ammonia usage space that we have. *Yes, exactly. Clear.*

Is there more or less work on your dairy farm as a result of that low-emission floor? No. *Okay. Is the use of it more common in your area? Do you know more dairy farmers with such... Who have a low-emission floor*? Yes, but of course, there are different types.

Yes. And different types of floors. I mean, you have the key floor, you see them at all kinds of fairs.

But of course, many companies installed a low-emission floor after 2015 to meet the ammonia targets. *Yes. And how about your low-emission floor? What is its purpose*? It is to separate the manure and urine or to put it in a pit? To separate the manure and urine less.

It is a purifying floor, and that ends up in a pit. It is expected to reduce emissions. Exactly, so that it can escape less into the air.

Yes. Okay. And I assume that you supply dairy processing companies. Yes. *Are they involved in the transition to such a floor or decisions related to your ammonia target?* Only, I mean, through Focus Planet, that is the quality assurance system of Friesland Campina. *Yes.*

You can score in that through the nutrient cycle indicator, so to speak. It is also included in the nutrient cycle indicator for ammonia production and methane emission, and everything else. *Okay.*

And it counts in that. And I assume that we will receive compensation through that route. *Okay, so they are aware of it*... Yes, they are aware through the nutrient cycle indicator, yes.

Okay. And they also accept, completely, the additional effects of using that floor? Yes. Okay.

Well, those were my questions already. So, that went pretty quickly. Yes, we said that.

Thank you for your time. I have one last question. Do you happen to know other dairy farmers who also have such a...

Interview 8

Interviewee: Jappie Riedstra
Date: 17/01/2024

Okay, my first question is what you do with the manure on your dairy farm, whether you process it in the barn or have a sustainable way to handle it? Well, we just installed a small nitrogen cracker *You installed a small nitrogen cracker?* Yes. Can you briefly explain to me what its exact purpose is? *The goal is to produce electricity, you know.*

Okay, generating electricity. Bio-gas to electricity. *Okay, and what about the nitrogen in the manure? What happens to it?* I need to check that. It changes slightly in composition, but it becomes slightly less. *Okay, and when did you install this nitrogen cracker?* Two years ago.
Two years ago, and why did you decide to install it then? Because I see the challenge with CO2, and that's why we installed it.

Okay, do you receive subsidies from the government because you have such a machine? It falls under sustainable energy. *Okay, do you receive a monthly amount for that*? It is produced per kWh. *Do you have any idea what percentage of your income comes from it approximately?* If the electricity price is high, it's zero, and if the electricity price is high, it's about 5 percent maybe.

Alright, and was there an estimate made at the time of how many years it would take for this machine to pay for itself? 7 to 8 years. *Okay, let's see, is there more or less work on your dairy farm due to this nitrogen cracker? Do you have to maintain them a lot?* More work.

More work? Yes. *Much more work?* No, 20 minutes a day. *Okay, and is the use of it accepted in the local community? Or is it something that is not really talked about much?* I think it is accepted.

Okay. You are probably working towards it, I assume, right? It seems like a sustainable movement. *Yes, that is understandable.*

Let me see, I assume you supply dairy processing companies. Yes. Are they involved in decisions where you, for example, choose such a nitrogen cracker? Or do they not even know about it? Friesland Campina did it, yes.

Friesland Campina did what? They developed it more, so to speak. *Okay. And ultimately, are you the ones making the decision? Or is it a collaboration?* No, no, no, we make the decision.

Yes, exactly. And they completely accept that you chose it? Absolutely. Okay.

Great. These were already my questions, so we're... Oh, that was quick.

Yes, quite fast, huh? Yes, you are dealing with it quite extensively. *Sorry?* Are you doing some research? *Yes, well, this is for my graduation project. I'm participating in a larger study*.

I see. *And yes, we hope to…* Are we. Yes, thank you very much.

Let me see, your name was Jappie? Yes, J-A-P-P-I-E. *Well, thank you very much for your time.*

And have a great day. Good luck with the project, you know. *Thank you.*

Goodbye. Goodbye.

Interview 9

Interviewee: Geertje Enting
Date: 17/01/2024

Okay, my first question is what you do with manure on your dairy farm. Whether there is a way to process it or store it in a pit, for example. How does that work on your dairy farm? The solid manure goes to the manure place, and the liquid manure goes into the pits. And when the pits are full, it goes into the manure silo. You know, into the manure storage.

Yeah, and why do you separate these two in practice? Well, the solid manure comes from the deep-litter stall. And the deep-litter manure doesn't fit on the slats, and it also doesn't fit in the manure storage. So the solid manure is from the deep-litter system, and the liquid manure is different, it's from the slatted floor.

Yes. And that's why you separate them. And do you do anything to reduce your nitrogen emissions from that? Yes. In feed, you consider the amount of protein in your feed. And you also consider the amount of urea. So that the urea level in your milk doesn't exceed too much. If you want to manage protein more efficiently. Because if you manage protein more efficiently, you also address ammonia emissions. So you are dealing with nitrogen as a whole.

Yes. And is the floor designed so that the manure often goes into the pit, reducing ammonia emissions? A part of the barn has an emission-friendly floor with flaps. And another part of the barn still has a traditional slatted floor. But with a manure scraper. Okay.

And what is that, the manure scraper? Yeah, it scrapes the manure through the slatted floor. So it ensures that the manure doesn't stay on the slats but goes into the pit under those flaps. So that there is less ammonia emission at ground level.

Okay. And since when do you have this emission-friendly floor? I think it was in 2014, 2015. *And why did you choose it at that time?* Well, it's quite simple. I believe it's part of such a building decision. Yes.

And it was also listed as a requirement in our environmental permit. *Yes, to get a permit*. Yes.

Yes*. Okay. And do you receive any subsidies from the government? Because you have these flaps that help reduce your ammonia emissions and an emission-friendly floor.* Well, not for that. *You don't get that*? Those subsidy schemes are all more recent.

So now you can apply for various subsidies if you're quick enough. Yes. We already have it installed.

And you don't claim any subsidies for it? We did try. For example, for a new manure robot that can also spray water over the slats. Because that's an additional step we would like to take.

But yes, if the scheme is full, or fills up quickly, you can't apply*. Yes, then you miss it, right? No, I understand*. You've missed the boat, so to speak.

Yes. And do you have that manure robot already? Or were you considering buying one? No, we have one. But you can get a fancier one, so to speak.

The one that can spray water on the slats. And then you need the new one. And then, well, let me put it this way.

The earnings in the dairy fields are not that high. The money that splashes against the walls. So those are quite significant expenses for us.

And those could be easier to consider if you get a subsidy. And then you make such a purchase. But it was an unscheduled case.

If the scheme was full. So yes, no, then it stops. There's no fallback, so to speak.

We do want to do it, we want to purchase it. But for that, we need cooperation from the government. *Yes, and have you calculated what the payback period would be for the purchase? Suppose you get subsidies and reapply later.*

Well, because we haven't applied yet. Because the scheme was full. We haven't calculated that.

But we do calculate it. And we also calculate together with our accountants. We calculate this thoroughly.

Because you don't really calculate in terms of payback time. You just look at whether you can afford it. Or if you need to finance it? And what does it cost me? That's how we calculate it. L*et's see, for that emission-friendly floor or the manure robot you have now.*

Has a sort of payback period been calculated for it? Or is there no payback period? No, because it's just a machine that needs to be there. And we don't earn anything back from it. We won't deliver more milk with such a new manure robot.

So, we won't get more money for our milk. So, I don't see a payback time in that, it just costs to increase it. Everything, you know? Everything works to increase costs. Well, in that sense. And now that the derogation is off and maybe paying for manure in euros, nobody knows. If your milk processor wants to dispose of your manure on the field for 40 euros per cubic meter, you can quickly calculate. And suppose you, along with 2,000 or 5,000 colleagues of ours, have to dispose of such a volume, what that cost is like. Then you might consider a nitrogen separation or some other expensive installation. You can figure it all out. And even without subsidies, it can pay off.

Yes, I understand, yes. And isn't it the case that the manure robot might replace normal work? So, where you would normally have to pay someone to do that work, do you use the manure robot instead? No, but you are the one doing it. *It doesn't reduce your workload either?*

But yes, as a farmer, you already work 80 hours a week. So I can't... The only advantage of such a manure robot, besides doing its job and ensuring that the manure gets under the slats faster... You have clean slats, well, that's pleasant for the cows. But I can't attach a payback time to it.

I don't see it. No. *And isn't it that you say it's about 1 to 2 hours of work per week or something*? Yes, no.

And then you would do it manually, you know, by hand. But that's not... Then you would say to it... You would do it differently.

If your question is really focused on emission reduction and emission limitation. What it really does, I really can't... No, that's in my mind on a completely different scale. *Yes, I completely understand.*

Let's see... My next question was, is there more or less work on your farm as a result of that manure robot? And it's a little less than. Or just exactly what you said. No, when that thing runs, it does it itself.

So, you save some work there. *And what about other farmers you talk to or the local community? Do they generally accept the use of such a robot? Or how do you view it?* Yes. We have an outdated model.

So the neighbor's farm has a new type like we have. And this is just an accepted help in the barn. It simply does its job well.

Okay, great. And the last question. I assume that you sell your products to dairy processing companies.

Are they involved in decisions such as purchasing an emission-reducing floor or a manure robot? Or in general, decisions related to your nitrogen emissions? No, look. There is one of our measures that we do take, which they do get very involved in concerning nitrogen. And that is that we have sown all our grassland with a herb-rich mixture.

And that is also an emission reduction. And the people from our champion's club are very much involved in that because they encourage herb-rich grassland in the context of biodiversity. So that is a measure you didn't ask about, but we do implement it. And they do get involved in it.

And is that constructive involvement, so to speak? In our case, it's less constructive. Because we work with, if you have persistent herb-rich grass, you get a bonus on your milk.

And we miss that bonus. Because we see the added value of herb-rich grassland in other areas. In the sense that we are less prone to drought and more climate-adaptive. Because it gets drier, it dries up, and we irrigate. I'm not allowed to make this up.

Then we find that kind of measures, we see a lot in it. And the government also stimulates them. They could stimulate us even more and better.

Well, those were actually all my questions. I didn't find the manure robot very exciting. But I find that herb-rich grassland much more interesting.

Do you find it much more interesting, actually? Yes. Has that been an investment, to have that herb-rich... Yes, a lot invested in seed. And in machines to be able to sow and maintain it.

So, that was a considerable investment? Well, what is a considerable investment? Yes, it is an investment. And it comes back every three years because you have to sow it again.

Yes, you see the benefits of it. Since you mentioned that you are also resistant to drought. Yes, climate. Really anticipating climate and weather changes.

Yes, I understand. That is also. And maybe I haven't heard much about that yet.

The adjustment of herb-rich grass. Yes, well... So, that's a novelty. Yes.

A good idea from you. Well, we're not the only ones. *No.*

Others are doing it. Well, I find that interesting. And there should maybe be attention from the government, but there should be attention for it.

Yes. But well. Yes, interesting.

Oh, and that's from Wageningen. *Yes, all from Wageningen. I have one last question*.

May I also ask from which department this questionnaire is? *This is from the Business Management & Organization department. So, it looks a bit more at the economic and social impact of those sustainable dairy processing strategies. Because what the impact is on the environment is already a bit clearer.*

But what I often read, and what I now hear a lot from my colleagues, is that the regulations implemented by the government are not often very beneficial for the farmers themselves. No, that's right. There are many regulations, and they are really beneficial for various consulting firms.

Yes. They have very nice business models. Yes.

And then you can also conduct a survey. Yes. So, I find that really very, very sad.

That you can extract that money for advice. Yes. And for that money from the plan, so to speak, the farmer could have already done half of the investment.

Yes. Yes. So, I agree with my colleagues.

Yes. Well, what is especially a stumbling block for many is that indeed the derogation is decreasing, and many farmers then have to sell their self-produced manure, and then have to buy artificial fertilizer to spread on their land. Yes.

Which is a bit of a double investment, and some people also say that it's not really benefiting the land at all. No, it is, well, it has just come out of the discussion with our accountant, it's deeply sad that you have to pay 40 euros per cubic meter to dispose of your good manure. Yes.

And that you have to buy artificial fertilizer for that. Yes. Yes, those are costs.

Yes. And with artificial fertilizer, you damage your soil because it contains salt, and you don't nurture your soil as you would with your own manure. So, you have to dispose of it, which costs a lot of money.

A*nd then you have to buy artificial fertilizer, which costs money again*. Yes.

And it feels so wrong; we act as if manure is dirt, waste, while it is very necessary. Arable farmers really need it for their soil fertility. Yes. But it's a struggle for livestock farmers to contribute to arable farming.

Yes. Yes, well... That's how it goes. So, I totally agree with my colleagues.

Yes. And it just doesn't seem to end. No.

I don't understand that. No, but you are certainly not the only one who thinks that... That's also what the research is a bit about. Yes, no, I understand that.

Let me see, I have one last question for you. Can you tell if more dairy farmers have, for example, a manure robot or an emission-reducing system, or exactly as you said, herb-rich grassland? Yes. Everyone actually does it in their own way. Some have more opportunities, also financially, to do it.

And not everyone is in the same situation. But quite a few... There has been a lot of investment in those floors, robots, and spraying systems to reduce emissions from the grids, with government subsidies in recent years.

Interview 10

Interviewee: Geert Berenpas
Date: 18/01/2024

Oké, well, my first question is whether you would like to provide a description of how you handle manure on your dairy farm. Do you collect it in a pit, spread it on the land, or how does that work exactly? Yes, just a traditional method, that is, a cellar beneath the cow grids, so to speak, in the barn. And that's where all the manure gets collected. And when it can be spread again, depending on the season, we start with manure spreading.

So, you're land-based, right? Well, not entirely. *Not entirely, because you have an excess of manure that you produce, and you have to sell that, right?* Yes, yes, yes. *And I have to sell it to you?* Yes, the market needs it, yes. *And is it correct that you also have to purchase artificial fertilizers separately?* Yes, yes, yes. A part of your manure can be used on your own land. And in addition, you can supplement it with artificial fertilizers. Well, if you don't do that, then you end up with lower protein content in your feed. So, it's more efficient to grow protein on your land rather than buying protein through soy.

Ok, and do you do anything to limit nitrogen or ammonia emissions in the barn? To limit that? Well, there's an ammonia reducing floor in the barn. To what extent it works or doesn't work, I think the experts don't really agree on that. But the floor is there. In addition, we are currently feeding with top covers to reduce methane emissions. *Ok, and when did you have that floor installed?* That was in 2014. *And why did you choose to do that at the time? Was it to get a permit because it wouldn't be allowed otherwise?* No, we could have gotten the permit anyway. But that way, you had better depreciation options for your barn. It was a family restart barn, so you could voluntarily depreciate it. That was interesting enough for us to say we just need to meet those requirements.

Do you receive subsidies from the local government because you have such a floor installed? No, we didn't. We did try to apply for it. But the deadline for construction was discussing, so we had to leave

it to participate in subsidies. *Ok, and you missed that deadline, and you're just too late for that*? Yes, we were too late. It should have been there in 2012, and in 2014, so we were late.

Ok, and at that time when the floor was installed, was there an estimate made of how long it would take for that floor to pay for itself? Or was it just an investment that wasn't... Well, I've had some trouble with that floor, but the floor has been partly interesting because of the tax, but we still chose that floor. And from experiments, it turned out that there would be fewer flights of success, so the floor environment would be better. Technically, I had my doubts about that, but that's not the choice. You have to do something to push the financial incentives.

Yes, I understand that. And let's see, tax-wise, do you mean that you come back to repay it in installments that suit you, or is it really cheaper? No, we moved our company at that time, and then we had to say goodbye to our old barn and house. We continued at another location, and so many book profits came up that we could use that barn to write off those book profits, and that we didn't have to pay tax because if we wanted zero, we could save on tax, and the tax says that we actually need it to be able to make the investments in that barn. Otherwise, the horse wouldn't be able to round.

Do you have an estimate of what the installation costs of such a floor are? Oh, that was 70,000 euros, and otherwise, it would have been 35,000 euros. 35,000 euros more. *35,000 euros more*, yes, exactly. *And that difference in tax that you would have to pay wouldn't have been worth it on its own?* Yes, it wasn't worth it on its own. Much more, that was five times more. That was, *sorry, how much*? I say that was five times more, so that was 150,000 euros. What you had to pay more, if you didn't want to meet those conditions. *Oh, yes*. Ok. So, that's serious money. *Yes, so ultimately, that was a profitable investment for you?* Yes, yes, yes, it was. But that has to do with legislation because we've all been intertwined. It has nothing to do with the floor itself, but that was just because of the legislation.

Yes, yes, exactly. But that tax, so the 150,000 euros that you didn't have to pay, is that over a period of years that you gradually had to pay less? Or was it at that moment that you had to pay that 150,000 euros, but not in this case? That was over years. It still hasn't been 100% written off. So, when we go into the frenzy, when we stepped into it, we can, depending on our profit, determine how much we write off from that.

Ok, so you can just reduce your profit. *And that 150,000?* Yes, per year. *And then you decide for yourself how much you write off from that*. Yes, exactly. And that 150,000, is that what you've described over 10 years now? Yes, yes. *Ok, so that's about 150,000 per year?* Yes, yes. *Ok*.

And is there more or less work that you have with that floor? Is there more maintenance or less? Um, I was wondering. More? *A bit more?* Yes, more. Because there's an automatic manure robot going over it. And I think if there was just a traditional floor, then the manure robot, there's only one coming, and there are two waiting. So, one manure robot costs 15,000 euros. Only if you buy it, then you also have about 3000 maintenance per year. *Ok*.

And when you talk to other dairy farmers about such a floor, is it generally accepted to use it? Or are farmers very skeptical about it? They are skeptical. *Yes?* Yes. *But it is still accepted as*... Yes, because it is financially and technically interesting. And then the farmers get over it. Because if you do it in the barn, it's not fun. *Yes, completely understandable*.

Ok, last question. I assume that you supply dairy processing companies. Yes? Are they involved in decisions on the installation of such a floor? Not in the floor, but in the upper floors. *Ok, so they are*

aware of whether you take nitrogen measures and what has happened with manure occasionally? Yes, yes.

Is that constructive involvement or is it more in the way? No, active, active, active. Ok. *Ok, and they fully accept that you have such a floor and...* Yes, sure. Ok. *Well, those were actually all my questions.* Yes, fine. All good. *It was appreciated that you wanted to help with that. Odd actually that there are no subsidies at all, while you do your best to contribute to improving the environment*. Yes, well.

Okay, have a good day! Bye.

Interview 11

Interviewee: Jan van den Broek
Date: 18/01/2024

Okay, my first question is whether you do anything regarding manure processing on your dairy farm. Do you have a way to limit the nitrogen emissions from it? Or how does that work for you? Are you still there? Yes, I'm still here. Yes, we're working here, I have manure.

Okay, so you have a barn, I assume? Yes. And that manure, is it collected in a pit? Yes, but a part of it is with a low-emission floor. Yes, that's already underneath the slats, of course.

And you invested in that last year? Yes. *Great.*

And why did you choose to do that at the time? Because I added a section, and otherwise, I wouldn't get a permit. *Otherwise, you wouldn't get a permit*. Okay.

Do you receive any subsidy from the government because you have such a low-emission floor? No. *None at all?* No. *Okay, and is there any financial benefit to such a floor, or is it purely to get that permit?* It's purely to get a permit.

Otherwise, I wouldn't need it. Okay, because it's more expensive to install than a regular floor. Yes. *How much does the installation cost?* It costs €40,000.

Okay. It's an advantage, or yes, that is an additional advantage, I must say. Yes. The floor is soft on top. Rubber mats are on it, so that's fine for the cows. That was an additional benefit.

Okay, that's nice, at least. But tax-wise or in terms of repayments, there's no other financial benefit? No, nothing. *Okay.*

And on a daily basis, is it more expensive, do you have to do more maintenance on it? Is it more expensive, or is it the same maintenance as on a regular floor? Um, the maintenance of the manure fig is difficult. Or yes, a bit more challenging. *A bit more challenging*? You go over the manure fig, and that works less well on that floor than on a regular concrete floor.

Okay. And there's no payback period? You don't calculate when this floor will pay for itself over so many years? No. No, no, no.

Okay. And is there more or less work on your dairy farm as a result of that low-emission floor? I think slightly more. *Yes, slightly more, yes.*

Slightly more. Okay. And is the use of such a floor accepted when you talk about it with other dairy farms in your local community? Um, yes, yes.

We do get visits to farms here. And we do see that it looks environmentally friendly for the cows as well, compared to a concrete floor. *Yes.*

That has the advantage. *Yes, exactly*. Yes, when I compare it with other floors, this is the most favorable floor we have here, especially when it comes to other floors.

Yes, okay. And I assume that you supply dairy processing companies? Yes, Arla. *Arla?* Arla, yes.

Okay. And are they involved in decisions regarding, for example, the installation of such a floor? Or did they have any say when you were exploring? No, no. Nothing.

T*hey are not involved at all?* Um, well, they do ask questions, actually. Yes. It's called Arla Garten.

Yes. And there has been a question. You have to call here. Then you're still talking about nothing. But one of the questions is, do you have an initiative for the floor? Okay. *And if the answer is yes, do you get more per liter of milk or nothing?* No, no, no.

That doesn't work. Not yet. *Okay, but what is that for*? Uh, Arla Garten is actually a certification.

Yes, encouraging farmers to meet certain standards. And Arla Garten is like a nature-friendly certification. *Okay.*

E*xactly, so they do accept that you use such a floor?* Yes, definitely, yes. *Okay. Well, those were actually all my questions.*

Okay. It's very nice that you took the time. Yes. *But basically, if I understand correctly, the installation of such a low-emission floor is economically quite disadvantageous for you?* Yes, that's correct. *Okay.* I have no words for it.

Well, what was your name, if I may ask for my own records? Jan van den Broek. *Jan van den Broek. Thank you very much for your time, and have a great day.*

Yes, I'm going to work. Bye.

Interview 12

Interviewee: Judith van Dijk
Date: 19/01/2022

My first question is about your manure processing system. How do you collect the manure, and what measures do you take to limit nitrogen emissions? Our manure, we have a traditional barn. So when the cows defecate, it simply falls on the slatted floors. We have a manure robot that runs around all day. It ensures that the manure falls through the slats into the pit beneath the barn.

Okay, what is the purpose of the manure robot? Is it for your convenience, or is it to reduce nitrogen escaping into the environment? Well, it serves multiple purposes. Labor efficiency is a significant one. It runs once every hour, more frequently than I could manually do it. The slats remain clean, which is better for the cows – cleaner cows are healthier. And, of course, it helps with nitrogen emissions because the faster it gets into the pit, the lower the emissions.

Okay, since when have you had this robot? Since 2018.

Alright, do you receive any subsidies for this robot? None at all.

Okay, when you purchased the robot, was there an estimate of how many years it would take to pay for itself? No, there wasn't.

How much was the investment for this robot, if I may ask? It was 16,000 euros. We opted for a slightly more advanced version with a water tank, which moistens the slats, allowing for better cleaning.

Does it also have economic benefits, considering you handle it yourselves? Yes, it's all very indirect. You hope that the cow's health will improve indirectly. It's primarily about hygiene and labor relief.

Do you have an estimate of how many hours this takes on a weekly or daily basis for you? One hour per day.

Okay, moving on, is there more or less work on your dairy farm due to the adoption of this robot? And is it significantly less, like 90% less? Yes, definitely.

Is the use of such a robot accepted by the local community? Or is it not discussed much? It's never discussed; they have no idea. But you also don't see it; it's quite small. It's about 21 by 50 centimeters wide, and you can't see it from the outside.

I assume you supply to dairy processing companies. Yes, that's correct.

Are they aware that you are taking steps to limit nitrogen emissions in the barns? Are they informed, or do they have no clue? No, they have no idea.

Okay, assuming they knew, would they accept that you have such a robot? Yes, definitely. I think half of the farmers have something similar.

Well, that was quite quick, as those were all my questions. Oh, okay. So, I appreciate you taking the time. You're welcome. If there's anything else, feel free to call, and good luck. *Thank you very much.* Okay, bye!

Interview 13

Interviewee: Jan Roelof Jalvingh
Date: 19/01/2022

Okay, my first question is about your manure processing system on your dairy farm and whether you do anything to limit the nitrogen emissions from it. What does manure processing involve*? Well, how do you collect manure in your barn, and do you have any technology, such as a floor or a scraper, to reduce the nitrogen emissions?* No, we have a regular floor with a regular system.

Okay, and then the manure and urine, do they fall through the floor into the pit? Yes.

Okay, do you do anything to limit the nitrogen emissions? For example, removing it from the floor frequently and quickly putting it into the pit, or does it stay on the grate for a long time? Well, we have a manure scraper, which is coming soon. We have a part of the floor outside where the cows walk, which is closed. And soon, a manure robot or something like that is coming. *A manure robot?* Yes.

And that ensures that the manure is constantly pushed away on the floor? Yes, it collects the manure and then dumps it. *Okay, and you will be installing that soon?* Yes, preparations are underway.

Okay, are there any government subsidies or other agencies that can support you if you want to purchase such a robot? Yes, we have already received a subsidy for that. *How much is that approximately, if I may ask*? That was 80%. *80% of the robot is financed?* Yes, all at once. O*kay, and how much is the purchase value of such a robot?* 32,000. *32,000?* Yes, that was a scheme last year. Yes, that's good. Yes, there will be a new scheme, but whether it's 80%, I don't know.

No, and do you perhaps have a rough estimate of your net income from your dairy farm on a monthly or yearly basis? No. *No? Okay, I understand. At that time, or has an estimate been made for you of the expected payback period of such a robot*? *So, how many years it takes for it to pay for itself, which is essentially only that last 20%?* No, that's a difficult estimate. Look, because there are multiple things, of course. On the one hand, you have your reduced nitrogen emissions. Then, in principle, you get further not promised for, except that you have less manure loss, so you have more effective utilization of your nitrogen and manure. That is simply an economic advantage for the company. And you have a cleaner floor, so you also have fewer manure pit problems. So, you can also put a value on that, but that is not a calculated amount.

And it could potentially replace manual labor, right? Well, that mainly. We now clean the outdoor feeding area once or twice a day. And that is also still outdoors, so you have quite a bit of emissions. But also, those cows walk in the manure quite a long time. So, we finish that with the shovel, and that takes more time, yes. *And then that robot would take care of all that*? Yes.

And how many hours are you approximately spending on that per day, on what the robot would take over? Half an hour. *Half an hour?* Half an hour. Yes.

And let me see, my next question was, is there a loss or gain of employment on your dairy farm as a result of, for example, such a robot? But that would be a bit less, a bit less work, then you think? Yes. Yes, that's just how we see it. It saves labor, yes. It saves, yes. It saves a bit of labor, yes.

And when you talk to other dairy farmers or the local community, do they accept the use of such a robot? Do you not talk about that often? Yes, those robots are generally accepted systems. *Great.*

And my last question is, I assume that you supply dairy processing companies. Yes, yes. *Are they involved in decisions, or do you, for example, take such a manure robot*? *Or do they have nothing to do with it, are they completely separate? Or do they know about it?* No, yes, it is processed manure. Those regulations are generally well-known everywhere. They have no say in that. *They have no say in it?* No. Okay, clear. *But they fully accept it if you get such...* Absolutely, yes, no choice.

Okay, let me ask one last question. How many cows do you have approximately on your dairy farm? Around sixty. *Around sixty. Okay, well, those were all my questions.* Okay. So, well, that went quite quickly. *Your cooperation is highly appreciated*. All good. So, that's great. Already have a great weekend. *Okay, thanks.* Thank you, goodbye. *Thank you. Goodbye.*

Interview 14

Interviewee: Ynze Oenema
Date: 22/01/2022

Okay, my first question is about your manure processing system on your dairy farm and whether you do anything to limit your nitrogen emissions. I don't have a manure processing system. I just dispose of it. If I have too much, I give it to another farmer. The rest stays on our own farm. Nitrogen emissions, yes, as a farmer, you always address that. You try to feed as little protein as possible. It's excellent for nitrogen resilience and the pocket.

Additionally, I have low-emission slats. However, some doubt if it works, so you never really know what you're trying. I try to do it differently, experiment a bit. I've worked here for a while. I believe new low-emission technologies work. What I have are slats with flaps, and I'm not sure if they work. But, in general, they fit well.

Yes, it's a bit challenging to thoroughly check if everything really works as intended. Yes, it has been checked, and it's approved. I'm somewhat accustomed to this system. The new systems, for instance, from Lely and another company, suck the emissions away. Then you get a new product in the long run. So, you get a broader view of how it works because you're extracting something from the air, which becomes something new. We want it to stay in the pit through the flaps. So, you need to measure that the manure becomes more valuable through the flaps in terms of nutrient content. Otherwise, it would probably still evaporate. I don't believe our manure changes with or without flaps. So, I don't think it works. That's my down-to-earth take on it.

It did cost a lot of money, so that's my good deed for the world. *When did you install this floor?* In 2014*. Do you receive any subsidies from the government or any other institution for such a floor?* No, nothing at all.

You mentioned installation costs earlier. What are they approximately for this floor? Yes, it cost an additional 100,000 euros. An ordinary floor cost 40,000 at that time, and ours cost 140,000. Okay. *Is there an economic advantage for you? For instance, less work or maintenance?* No, a bit more work. *A bit more work?* Because, yes, this floor gets dirty a bit sooner. Yes. It doesn't really mean more work. It's not necessarily better for the cow because it's a bit tighter. Making it tighter makes it easier to need fewer flaps. Yes. However, it's not such a big difference. Maybe this floor is a bit dirtier. But, well, we regularly clean it with the manure robot. So, it works.

Let me see, do you also have a manure robot? Yes. *And does it push all the manure around on that floor?* Correct. Did you receive any subsidies for that? No, not for this one. We will get one for a new one. *You're getting a new manure robot?* Yes, we're buying one.

And then you receive subsidies? There's a subsidy for that, from the province of Deunten. *How does that work? Is it a monthly amount that you receive?* No, we just get a certain amount for the manure robot. It's a program where you can apply for subsidies.

*Do you have an idea of how much a manure robot would normally cost? And how much it will cost with the subsid*y? Well, you can get an 80% subsidy for a manure robot. Yes, exactly. However, we also invested in manure storage. If you have extra storage, you can better utilize the manure in the spring. You can get up to 60,000 euros in subsidies.

My investment is about 110,000 euros. So, you get an additional 50%. *And that 110,000 euros is for the robot and the storage?* That's correct.

And then there's an additional 100,000 euros? No, that doesn't come on top. No, that was already there. But that was nine years ago.

Yes, like that. This is already partially repaid. *And those manure robots won't save anywhere either?* Yes.

How much does it save in a day? How much when make an estimation? Yes, about fifteen minutes or so. However, it's not really about the work yet. It's mainly about hygiene.

For the cows? Yes. And it's also for the nitrogen. That's why we get the subsidy.

It's for nitrogen emissions. The more often you clean a floor, the less nitrogen emissions you have. With the cows, we scrape it only once a day by hand.

And now it's with a robot. And then it seems the more often you clean, the less emissions. Then it doesn't stay on the floor but goes under the floor.

And then you have less emission. Yes. *Is there any other economic advantage to that combination of the robot and storage for you*? Or is it really just for the hygiene of the cows and for nitrogen? Yes, okay.

That's the advantage, of course. High hygiene and better utilization of the manure. Better utilization of the manure.

Yes, because I have more storage, I can do it better in the spring. And the manure has a longer effect. So what I apply in the field in August, for example, works until September, until October.

And if, for example, I don't apply manure from July anymore, but apply more in the spring, then I have a longer utilization. *Yes, okay, clear. Let me see, is the use of a manure robot and its plow generally accepted in the local community or with other farmers*? Yes, everyone has come to think so.

At least, yes. *One last question. I assume you have a dairy processing company.*

Yes. *And are they still involved in your efforts to reduce nitrogen emissions?* Yes, we now have the Jumbo line, together with Jumbo. Yes.

And then we can, if we also, yes, who we really are is then a question, but also nitrogen emissions and such things. And if we all work well on that, then we get an extra fee per liter of milk. *Okay, so they are actively involved in that*.

Yes, in any case, Jumbo or the supermarket is, of course, trying to participate in the landscape, making it more sustainable. Yes. And they will pay for that.

And yes, collaboration with Jumbo, so to say. Okay. *So, I completely understand that you will take such a step.*

Yes, you can score points with that. You have to do something about nitrogen emissions, otherwise you can't participate in the program. *Yes, okay.*

Well, those were actually all my questions. Yes. So, it's really appreciated that you take the time to participate.

Great. What problem am I addressing again, you said? *Well, I specialize in food and technology, but I'm doing my thesis with the Business Management & Organization group. I'm participating in the larger group, looking into the consequences of sustainable milk processing.*

Oh yes. *For example, if you reduce nitrogen emissions on the milk farm, that's the economic benefit up to a certain number of reductions. It's a bit technically tricky.*

However, the easiest reduction in nitrogen emissions is by feeding less protein to the cows. Yes. But that's just a technical story.

It's attractive for every farmer to do that. Every farmer tries to do that. However, with all the management, how good is a farmer at managing these problems? Yes.

On one hand, it's just better than on the other. So, in general, all farmers are always positive if it's a bit understandable, if it's explained a bit clearly. However, young farmers may not be aware of it.

Some farmers do very well, for example, in terms of emissions. However, they may not be aware of it themselves. And they might get a bit upset when they hear the word that something needs to be done about nitrogen.

But they are actually doing well themselves. So, some don't really know that they are doing something to reduce nitrogen emissions. But they are doing it very well.

Yes, that's true. But there are also cases where, indeed, farmers have installed such low-emission floors. And then, well, they had to pay more to dispose of manure.

And anyway, many farmers then have to remove the manure they produce. And then they have to buy fertilizer for proper fertilization. Yes, I heard about that too.

Yes, and there is... Yes, but that's a bit of a given from the... And it also depends on the Netherlands itself. We haven't been able to make it clear in Europe in some weird way. For example, in the Netherlands, we have to remove manure.

I also have to dispose of 1500 cubic... 10 euros... I mean, I have to dispose of 15,000 euros to people this year. Yes, yes. And then I buy fertilizer again for 20 or 15,000 euros.

So, it will be even larger in a few years. The problems are heading towards 25,000 and 30,000 euros disposal. And then I also have to make more purchases.

So, on one side, I have to dispose of manure for a certain amount. It is transported by trucks to other companies. Yes.

And then I have to buy fertilizer made from grass. To... I can bring as much manure to the land. Yes.

Only in the form of fertilizer. And fertilizer is less environmentally friendly because it leaches more. And it's made from grass.

Yes. Somehow it's a very strange thing that costs more money. It's not good for the economy.

Not good for my wallet. Also bad for the environment. So, it's very strange that it got approved.

But maybe the only advantage is that there will be fewer nuts. Because that has a cost-following effect. So, that's the only advantage.

Maybe for the government. But it's really strange. Yes.

I have a neighbor who gets a bit angry about it. That... I can understand that. But there's not much you can do about it.

You can only adapt to a given project. But that takes years, of course. Yes.

Yes, no. Some are quite frustrated about it. Yes, I also know a neighbor who starts to shout a bit.

But yeah, well. I can get angry about it too. But it's not really useful against you.

No. But it's frustrating when you think about it. And especially, many citizens don't really understand it either.

It's never really explained clearly in the newspapers. For example, they sometimes talk about manure problems we have in the Netherlands. Yes.

Only if you just... You would actually be better off buying less fertilizer. And then applying more animal manure to the land. Then the manure problem is solved.

And you don't need as much fertilizer. Yes. *However, the lobby of gas producers is probably very good.*

Or maybe they just want fewer farmers. Because you do get fewer farmers, as it's cost-free for higher elevation. Yes.

But it's strange. *In both cases, I don't really like it. But yeah*.

No, it's not that it's very strange. And well, it is what it is. It will stay like this until 2026, anyway.

Then we have to bring less and less manure to the land. And import more fertilizer. And after 2026... Maybe there will be a new lobby from the government.

Maybe they'll start to understand it a bit. But we'll see. Did the jury manage to break in all at once? Yes.

Yes, I understand, yes. I often hear that. So, that's also a bit what the research is for.

To get more publicity for that. Yes, very good. *And hopefully, we'll make some progress*.

Yes, very good. Okay, yes. Thank you.

Thank you. And it's really nice that you took the time. It's highly appreciated.

Yes, very good. Okay, have a nice day. *Okay, bye.*

Bye, bye.

Interview 15

Interviewee: Erik Kuiper
Date: 24/01/2024

Okay, my first question is whether you have a manure processing system on your dairy farm, so how you collect manure in your stable, and whether you are doing anything to limit the nitrogen emissions from that manure. We engage in mono manure digestion. So, we built a stable with a completely sealed floor, equipped with a manure scraping system on the floor, so that every hour the manure is pulled to the collection pit. And during the scraping process, the manure is also pumped directly to the mono manure digester.

Okay, so you mentioned something about the floor. It's a sealed floor? Yes, it's a completely sealed floor. So, the stable is entirely below ground level, there is a manure basin underneath, a kind of manure reception point under there. But it is completely sealed. So, no emissions can escape from that point underneath; it is completely sealed.

Okay, and with that mono manure digestion, are you essentially producing your own synthetic fertilizer? No, not synthetic fertilizer. Yes, partially. There's a step afterward, so to speak. But in any case, the manure goes out of the stable, directly to the mono manure digestion. And the mono manure digestion is a sealed silo that is heated to 38 degrees Celsius. So, it's just a round insulated silo where the manure goes. And that manure is heated to 38 degrees, the same temperature as the cow. So, the cow's intestinal flora continues in that silo, keeping methane production stable. Thus, the methane still present in the manure, which causes nitrogen emissions, is artificially continued, and that methane is captured. And methane is a sustainable gas, green gas, which we sell to the industry.

Okay, and did you install the mono manure digestion and the sealed floor at the same time? Yes, they go together. *And when did you do that?* We built that in 2015. *And why did you do that at that time? Was it for a permit or because you emit nitrogen?* No, we are in a village called Noord-Döringen. And the village of Noord-Döringen has committed itself to being energy-neutral by 2020. Progressive for a village with 1200 inhabitants. Many farmers and a small church with people, so to speak. You're part of 160 houses, households. And we have committed ourselves, made agreements, isolated houses. And what needs to happen, needs to happen. We have voluntarily, together with the government and the province, secured subsidy money. What we could get. But it also turned out that for the farmers in our area, and we are an agricultural municipality, there was a lot to gain there. That had a lot of profit. Much more than insulating a house and double glazing and insulation. If you look closely, the profit is enormous there. And then it happened so nicely that the mono manure digestion had to be done. We have 17 farmers in our village. Six farmers are involved in digestion. And others too. We replaced over a million cubic meters of gas with our own manure. With our own

gas. *That goes pretty fast then. What a good initiative that is*. Yes, that's how it started. And if you look at that, you think, that can't be. You don't believe it. *What is that?* Every cubic meter of liquid manure contains 30 cubic meters of gas. That's bizarre. Every cubic meter of manure contains 30 cubic meters of gas. And if you calculate, I am the smallest in the whole system. I have 82 cows. I have 2600 cubic meters of manure. Well, 2600 cubic meters of manure times 30. Well, then we calculate how many cubic meters of gas it is. And I was shocked by that. I thought, Jesus. I just had to build a new stable. I had to tackle everything on my yard. I thought, then I'll include this now. I thought, this is an eye-opener for me. If I don't do more here, I'll regret it later.

Yes, I understand. I did that. In the first years, we caused ourselves a lot of headaches. And misery. You are dealing with something very sustainable. You are working on something very beautiful. But then you run into the wall of the government. That is very discouraging. That was very difficult. Eventually, we overcame that as well. And now we still supply gas. *That sounds good.*

And you just mentioned subsidies. Yes. Do you receive a certain amount per month from the provincial municipality or from the national government? Yes, from the RVO, from the government. We simply receive an SDE subsidy. Just like there is a subsidy on electricity, on solar panels. It's the same for green gas. Well, and we have that too. However, the SDE subsidy at the moment is purely for our financiers, for the investors, the banks, to ensure that the project is financially viable. But in the free market at the moment, we can earn much more than that SDE subsidy. So, the subsidy is nice, but we no longer ask for it. We just produce gas in the free market, whatever the market pays. And that is more than the SDE subsidy.

Okay, because what percentage of your income would be approximately from that SDE subsidy? Is it really only 1%? No, 0%. *0%?* We don't receive the subsidy anymore. Okay. We simply ask for the market price. Okay. And that's how it should be, right? The subsidy is very nice. It's something to get things started. But if something always has to rely on subsidy, forget it. It will never last. No, it's more to get it started and then, subsequently, if it can finance itself. Yes, that's how it should be. If something can't finance itself, it doesn't stand a chance. *No, I agree with you*.

When the mono manure digester and the sealed floor were installed, was there an estimate of how many years it would take for them to pay for themselves? Yes, when we started, it was before the war. That was really a critical turning point. The purchase price was 17 cents at that time. For the companies we sold to, and then we really needed that SDE. Our SDE was at 55 cents. You could earn 17 cents. Well, there was a nice gap there so that the SDE could finance the project and also be earned back. But then, with that 55 cents, where the SDE was capped, I had to run it for about 10 years to get it back in investment. But yes, the war has passed. Now, with certificates and everything, it fetches 1.70 euros. *So now it goes faster*? Yes, now I earn, because I'm also the smallest, it's difficult to earn it back quickly anyway. But now I earn it back in about 4 or 5 years. So, anyone who now joins our project with 80 cows, then you have to do it the way we do it. Then you can earn it back in 4 or 5 years. But if you're a farm with 150 cows, you earn it back in 2 years. That's not a problem at all. So, this is very interesting at the moment.

So, you earned it back in 5 years? I've earned it back anyway. We've been at it for a while. We've earned it back, but anyone who joins our project now, IJskoop. You can always look it up on the

internet, www.corporatieijskoop.eu. If you look that up, you'll see our project. That's what we do. Every farmer has their own mono manure digester. And collectively, in the region, we dig our own gas pipeline. This gas pipeline goes from farm to farm. And then, somewhere in the area, we could have a green gas upgrading station. So that you jointly upgrade the gas to natural gas quality. And that's just the key. Such a green gas station is very expensive. And it costs a lot of money to upgrade your gas. A lot of electricity and a lot of maintenance. And that's not feasible for an individual farm. Even if you have the fifty good ones, it's still a challenge.

But if you have a lot of gas together, millions of cubic meters, then such a green gas station can be earned back very quickly. The costs are much easier to spread out. The compressor runs very smoothly, and it runs continuously. The power consumption becomes much lower. Then it becomes interesting. So, you really have to work with a gas hub. Work with pipelines, from farm to farm. And collectively try to get as much gas as possible at one station. Then it becomes very interesting. *Yes, I think that's good.*

Let me see, I have a few more small questions. Has there been an increase or decrease in employment on your dairy farm now that you have the mono manure digesters and the sealed floor? So, more maintenance or less? You obviously have something with maintenance. You need more time. You have an extra machine. That machine needs daily attention. Coincidentally, I also have one. So, I also do daily rounds. That takes about fifteen minutes a day. You do everything with care. You do something, you check the manure pumps. Is it heated, etcetera, etcetera. Of course, you have some extra work. But if you consider... With a farm like ours, using around sixty to seventy thousand cubic meters of gas. For 1.50 euros, 1.70 euros at the moment. Then I find it quite pleasant. *Yes, I understand that.*

Is the use of such a sustainable manure processing system like what you have accepted by the local community? If I understand your story correctly, it should be... The way we approached it. If we understand the village to be energy-neutral by 2020. Yes, then everyone participates. It's a collective project. That's no problem. But we hear now... That some people want to build their manure processing system. And one person has a mono manure digester living nearby a few citizens. They are afraid of a reactor. It's a gas reactor. That's what they call it. Which is nonsense. It's just a silo that is round with a cover. And it does contain gas. But it's 100% gas. It's not explosive. People often think it's a bomb. And that it will stink. But none of that is true. It doesn't stink. You can't see it. You can't smell it. And it's not that dangerous either. Look, unless there's a major gas leak where a lot of oxygen comes in. Yes, then everything is dangerous. But that's not the system. But if you remove the cold air once. Then there's nothing to worry about. If people come once. Here to the warm barn. And they ask why there's a reactor. I say, it's against the door. That's it. It's very simple. A silo. And that's nothing special.

Okay. Last question. I assume you supply dairy processing companies. Is that correct? Are they aware that you, therefore, ferment your manure and have an acid-resistant floor? Are they involved in the transition to that? Or not at all? Not initially. Only a few knew about it. Mono manure digestion was in its infancy. It was all in its early stages. And they didn't know where to go. But in the city of Wageningen. A few students have already been here. And a few professors have also taken a look. And also started projects. And then you just see that the emission reduction is a huge gain. And then it was for everyone in the room. But yes, then you also get young people. And I always find that very strange. You're doing something very sustainable. And you're doing very well. And there are also people in politics. Who then become very skeptical. But that's fine. The innovation. I've said that before. And that's why it's not. But yes, there are also people who are afraid. That it was a great success. That the brakes on the celebration evening will be stopped. Because people like Thierry de

Groot. They don't come here. Everyone has been here. But people like Thierry de Groot. And the Party for the Animals. They just come. They don't want to see it. They don't want to believe it either. They just say no. The derogation must go on. And then it will be fine. But that's of course madness. In my opinion, really madness. But our barn has shown that you can achieve 75 to 80 percent. And that is huge. And I understand that if that is really embraced. That many people still think. Or a small group of people still think. Yeah, darn. That was not the intention. But that's how it is. Yes, that's not how it should be. No.

But by now, those dairy processing companies. They are involved now? Yes. I find them reluctant. But that's also typical of politics. And typical of the dairy farmers. And the manufacturer. It all goes very slowly. I think, if you do what we do. To make that a success. And really take a big step towards sustainability. Then you have to do this much faster. And embrace it much better. You also have to take that into account. In legislation. And government and stimulation. And that happens too slowly. That happens, in my opinion, much too slowly. We are now in 2024. We are trying to fill that in. And there is now a little rule about mono manure digestion. But, that's a rule. But that's nice. That's the beginning. But we've been working on it for years now. Because mono manure digestion should not be just a rule. No, mono manure digestion should be specified. What kind of mono manure digestion? Is it a mono manure digestion? Is it a mono manure digestion with a sealed floor? Is it with scraping? What system? If the system is such that it is 100% sealed. Yes, then you can achieve a reduction of 75 to 80%. Yes. And that should also be taken into account. In the entire legislation. What I find. That there should be a reward for that, yes, not be punished. But precisely be rewarded for that. That there should be a plus. Or whatever. If you don't do that. If a farmer doesn't get the plus. Or feels that he is doing it this way. Then it will never work. Then it will not unravel. Then you just have to put the financial incentive on it. And fortunately, we are doing that now. Since the war in Ukraine. The data wheel has been quite a bit punctuated. *Yes.*

And those dairy processing companies. They accept that you. Yes, definitely. They embrace us now. And they see it now. But you find it very difficult to impose all of that. Yes, that. They want to. But there are also many people. Who do not have the financial strength at the moment. Or who cannot do it yet. Or who are not helped. Or whatever reason. So, everyone is already a bit in the air at the moment.

How are we going to approach this without us... Without us not playing our part as educators. So, we have to impose it. And we have even more rules. And that's mainly what bothers us. And we do want it. But the encouragement must also come from the government. Yes, I understand. Yes, I get it. In any case, it sounds like a very good initiative. What you have in your village. And that it actually. Turns out well for you. So, that's good to hear. *That's nice.*

Those were actually all my questions. Let me see. You mentioned Operation Ijskout. Or Cooperative Ijskout. Yes, cooperative. Yes. If you just google Cooperative Ijskout. You'll find it easily. That is then the group with which you took that initiative. In our village. There are six farmers. Who are involved in development. That is now expanding. To 24 companies. There are now 16 companies. That are now building. And attacking without. So, my project was. Three times over. *Yes, that's really nice. That it's catching on so well. Okay*, *I'll Google that then*. Go ahead. *Thank you very much for your time. It's appreciated*. Have a nice day. *Goodbye.*

Appendix C: Normalized Indicator Values

	Farmer 1	Farmer 2	Farmer 3	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Farmer 11	Farmer 12	Farmer 13	Farmer 14	Farmer 15	Farmer 16	**Average results**	**Standard deviation**	**Avg indicator value**	**Unit**
Indicators																			
Economic analysis																			
Percentage of real net farm income from all subsidies (%)	0,85	1,00	0,80	0,96	0,99	1,00	1,00	0,95	1,00	1,00	1,00	1,00	0,68	1,00	1,00	0,95	0,09	5,11	%
Payback period of SMM system (years)	0,97	0,85	0,08	0,82	0,48	0,00	0,00	0,85	0,00	0,93	0,00	1,00	1,01	0,15	0,92	0,54	0,43	17,97	Years
Social analysis																			
Loss/gain of employment	0,75	0,75	0,75	0,75	1,00	0,75	0,50	0,75	0,25	0,75	0,75	0,25	0,25	0,75	0,75	0,65	0,22	3,60	-
Acceptance by the local community	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	Yes	-
Relocation of local employment	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	No	-
Involvement dairy processing companies in transition	1,00	0,50	0,75	0,00	1,00	0,00	0,50	1,00	0,75	1,00	0,50	0,00	0,25	1,00	0,00	0,55	0,40	3,20	-
Involvement dairy processing companies in decision-making	1,00	0,75	0,75	0,00	0,75	0,00	0,50	1,00	0,75	1,00	0,50	0,00	0,25	1,00	0,50	0,58	0,36	3,33	-
Acceptance by dairy processing companies	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	Yes	-