Green Office Vrije Universiteit Amsterdam

Science for Sustainability Journal Green Office VU

Digitalisation of Dutch Agriculture: Implications of reducing Nitrogen pollution from livestock cultivation

Inder Kumar[1]
[1]Science, Business and Innovation (SBI), VU Amsterdam

*Corresponding author: Inder Kumar
E-mail: inderkumarpannu@yahoo.in
Orcid: https://orcid.org/0000-0001-9358-9616

ABSTRACT

For the last many decades, the EU's intensified agriculture model has shown a significant trend to reinforce the economy while feeding the world. The Netherlands is one of the EU's member follow neoliberalism in agriculture by importing cheap animal feed & fertilisers and exports meat & dairy products. The intensification of Dutch agriculture results from solid collaborations among the Agriculture Innovation System actors (AIS). Nitrogen (N), being one of the essential elements of building blocks of life, is a vital nutrient, an indicator for global food security, and supports agriculture's intensification. N in fertilisers and feedstock's intensive use comes with the consequences of wicked problems such as ammonia (NH_3) emissions in the air and nitrates (NOX) leaching in the soil. Around two-thirds of the Dutch farmlands and 80% of the crop, fertiliser is used for livestock cultivation. The Netherlands is famous for technological innovations worldwide (in terms of niche innovation); however, digitalisation is still an 'alien' term for Dutch farmers. A lack of landscapelevel technology implementation, weak policy infrastruture for monitoring pollution dynamics is one of the leading causes of the nitrogen crisis in the Netherlands. The N-crisis is causing distress in farmers, and the government is struggling for effective policy implementation. Therefore, there is a need for state-of-art initiatives which utilise maximum involvement of technology and the environment with minimum (government) efforts. This holistic and explorative cast-study research highlights the challenges and consequences of the Digitalisation of Agriculture Innovation System (DAIS) to resolve the Dutch N-crisis. Different aspects of research covered are 1) to address associates knowledge gaps, 2) analyse the cause of complex N-crisis in the Netherlands, 3) to analyse the current state of Dutch policy infrastructure & challenges and 4) to analyse present & future trend of DAIS transformations. This will ultimately lead to technology and policy recommendation supporting multi-stakeholders collaboration, creating a market of Nitrogen Trading System (NTS) at multiple levels and using digitalisation as a key for establishing Sustainable System Transformation (SST).

1. Introduction

The Netherlands is a small country (Dutch land area is 4,543 Km^2) and a member of the European Union (EU), which is comparatively 240 times smaller than the land area of the United States of America (USA). However, it is the second-largest food exporter of agricultural produce (94.5 billion euros in 2019) after the USA, and local livestock density (LU) is among the highest in the world (Noord Braband - 10LU/ ha) (Bos, Smit, & Schröder, 2013; CBS, 2020b; Wang et al., 2017). Import of cheap feed and fertilisers from abroad, intensive cultivation of produce and export of meat and dairy items is the consequence of international embedded industrial networking (De Vries, 2020a). Nitrogen (N), being one of the essential elements of building blocks of life, is a vital nutrient, an indicator for global food security and supports the intensification of agriculture(Groenestein et al., 2019). The intensive use of N in fertilisers and feedstock comes with the consequences of wicked problems such as ammonia (NH_3) emissions in the air and nitrates (NOX) leaching in the soil. Which ultimately reduces biodiversity in nature areas, promote eutrophication in water bodies, deteriorate soil health and food safety (Erisman et al., 2018). The two most important policies of the Dutch political agenda, manure and nitrate policy enforcement, are complex and generic, regardless of hotspots for emission areas. For the expansion of livestock cultivation, Dutch farmers require N-permit and the government provides permits only for low emission areas, and is slowing down the country's economy (Kleis, 2019). The lack of collaboration among landscape and regime actors creates tension among farmers and is one of the causes of farmers protest against the government. An Agricultural Innovation System (AIS) is a tool of collaboration and cooperation for research institutes, consultancy firms, IT firms, Agri-based firms, policy advisors, NGO's in the society. AIS enhances innovation patterns and knowledge exchange pathways to derive sustainable economic development (Lamprinopoulou, Renwick, Klerkx, Hermans, & Roep, 2014). Dutch AIS works on the principle of 'neoliberalism' to support the economy. The intensified agriculture industry struggles to develop state-of-art initiatives to deal with NH_3 emissions and NOX leaching from livestock cultivation (Candel, 2019; De Vries, 2020a). Introduction of Digitalisation in Precision Livestock Farming (PLF) by utilising tech-nologies such as Artificial Intelligence (AI), Cloud Computing (CC), Big-Data Analysis (BDA), Internet of Things (IoT) and block-chain has shown a massive potential to enhance sustainable development of economy and livestock cultivation (Wolfert, Goense, & Sorensen, 2014). However, though the Netherlands is famous for technological innovation worldwide (in terms of niche innovators), digitalisation is still an alien term for Dutch farmers. There is a lack of landscape-level technology implementation supported by weak policy infrastructure (Alreshidi, 2019; Government, NL, 2018). Therefore, there is a dire need for state-of-art initiatives to support the sustainable development of Dutch livestock cultivation. The Digitalisation of Agriculture Innovation System (DAIS) 's conceptualisation is one such initiative that can create ecosystem-level transformations and collaborations. DAIS has significant poten-tial to enhance Nitrogen Use Efficiency (NUE), reduce NH_3 emissions and NOX leaching to support sustainable economic development (Expósito & Velasco, 2020; Fielke et al., 2019). The DAIS transitions create an implication of yield or productivity enhancement and create wakes of innovation for farm management by streamlining the real-time data across multi-stakeholders involved in the supply chain (Figure 1).

1.1 Research objective and research questions

According to an article in the science magazine, headlines were stated as "Dutch economy is paralysed due to jam-packed livestock cultivation and nitrogen crisis". Around two-thirds of the Dutch farm-lands and 80% of the crop fertiliser is used for livestock cultivation. Nitrogen pollution from agriculture and lack of technological support to monitor pollution dynamics are causing distress in farmers, and the government struggles for effective policy implementation (Stokstad, 2019). This article pointed out the legacy of technological, societal, economic and institutional interactions in the Netherlands for Dutch agriculture (Fielke et al., 2019). The Netherlands and EU are facing challenges due to weak knowledge structure on conducting effective measurement of data on crop nutrient uptake and nutrient loss in the environment (Government, NL, 2018; European Commission, 2019). Therefore, this case-study research aims to address associates knowledge gaps and analyse the cause of complex N-crisis in the Netherlands, the current state of Dutch policy infrastructure & challenges and the present & future trend of DAIS transformations. The research question's broader lines underpin the DAIS transition that elevates above individual niche innovation consideration. The two main components of DAIS conceptualisation are; industry-specific (livestock cultivation), Nutrient Use Efficiency (NUE) & cost-effectiveness and regime & landscape-level technology and policy. So, the main research question and sub-questions are as follows:

> ***"To what extent, Digitalisation of Agricultural Innovation System (DAIS) can trans-form Nitrogen Use Efficiency (NUE) and cost-effective policy implementation at multiple levels for Dutch agriculture"? and sub-questions are:***

- How can digitalisation of the agricultural innovation system can enhance performance trajectory of nitrogen use efficiency and cost-effectiveness?
- How digitalisation of the agricultural innovation system interacts at the regime and landscape level to enhance policy and technology implementation?

2. The Literature Review

This empirical literature study represents the state-of-art literature reviewing process and is part of a single and holistic case-study that is explorative and qualitative. The DAIS transitions are considered a socio-technical process (Fielke et al., 2019). Therefore, firstly a theoretical framework will be established to understand different concepts and relationships. After that, the bibliographic analysis will be accompanied to enlighten the associated research gap in the literature and validate the research gap. And finally, desk research will be conducted on the related research gap.

2.1 Theoretical Framework

2.1.1 Agriculture Innovation System (AIS)

Wicked problems like climate change and resource scarcity coupled with ever-increasing energy costs are significant challenges in agriculture. This requires urgent attention in research & innovation to derive sustainable and innovative solutions (Lamprinopoulou et al., 2014). To understand the concept and the process which support; underlying innovation, knowledge exchange, and transformation of agricultural food sectors, researchers and policy advisors use a promising tool called AIS (Ortiz et al., 2013; Klerkx, Aarts, & Leeuwis, 2010; Spielman, Ekboir, Davis, & Ochieng, 2008). AIS encompasses an extensive network of stakeholders (research institutes, supply-chain actors and social interest groups such as charities and NGOs), including policy advisors. Two significant components of AIS are Agriculture Knowledge System (AKS) and Agriculture Information & Knowledge System (AIKS). AKS accounts for public-funded research, education and extension services and AIKS account for structural configurations of collaborations and innovations (Rivera, Qamar, & Mwandemere, 2005). This multi-level social and organisational

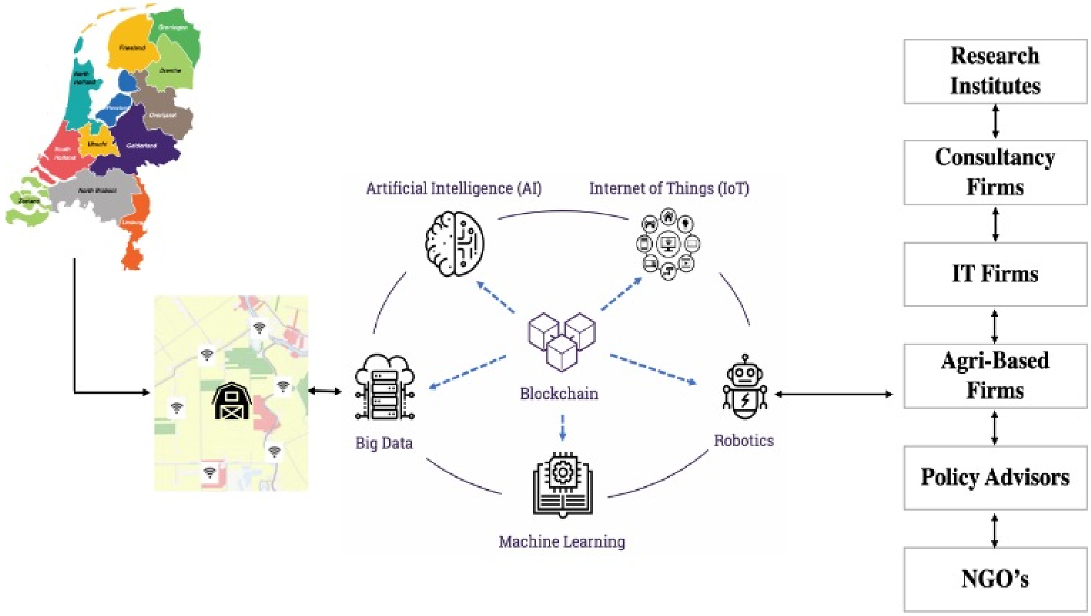

Figure 1: The conceptualisation of DAIS ecosystem level transformation and collaboration for the Netherlands. Source: (Fielke et. al., 2019; Ros et. al., 2018)

interaction among actors is influenced by laws, intellectual property rights, norms and values (Lamprinopoulou et al., 2014).

2.1.2 Multi-Level Perspective (MLP)

The neoliberal model of intensified Dutch agriculture results from its stability and lock-ins among niche-regime and landscape actors (Verbong & Geels, 2010). However, wicked problems such as Dutch N-crisis, climate change and biodiversity loss requires Sustainable System Transformation (SST) (Moors, Fischer, Boon, Schellen, & Negro, 2018). MLP is an analytical framework used by policy-makers to understand the complex socio-technical transitions and provides SST with long-term fixes (Grin, 2008). MLP has a nested hierarchy of; specialised niche, socio-technical regime and socio-technical landscape. Wherein Niche is imbedded in regime and regimes are embedded within the landscape. MLP is a socio-technical process, and particular challenges associated with SST are sunk investments, the opposition of regime actors to niche-innovators and high autonomy at the landscape level (Grin, 2008; Verbong & Geels, 2010). Therefore, to support SST, niche innovators must use the micro-perspective of market transformation from incremental gains to radical and thus create an external pressure to open up technological processes at regime level and loosen the landscape autonomy (Moors et al., 2018).

2.1.3 Digitalisation of Agriculture

The introduction of digital technologies in precision farming aims to enhance sustainable economic and environmental gains. Digital technologies based on real-time monitoring work with BDA, IoT, AI and CC principles can create significant changes in the agricultural system to enhance cost-effectivity, the productivity of produce, yield and fertiliser intake (Zwartkruis, Berg, Hof, & Kok, 2020). Considering smart farming, digital technologies go beyond increasing productivity and align the entire food supply chain for creating multiple advances (Wolfert, Ge, Verdouw, & Bogaardt, 2017). The digitalisation of agriculture can transform incremental productivity gains to radical and make it evident & implementable from a regional to a landscape level (Fielke et al., 2019).

2.1.4 DAIS transitions: a socio-technical process

Considering AIS, Digital technologies influence how different actors collaborate and establish solid and complex networks to enhance agricultural outcomes (Flach, Stappers, & Voorhorst, 2017). Digitalisation integration with AIS conceptualisation is to broaden-up the scope of data-driven decisions in agriculture while dealing with wicked problems (Tanwar et al., 2019). Data-driven innovations and knowledge exchange schemes in agriculture provide economically viable and sustainable solutions among niche-regime and landscape-level actors to collaborate and co-develop (McEldowney, 2019; Verbong &

Geels, 2010). Therefore, DAIS transitions support real-time based data-driven decisions to enhance NUE and cost-effectiveness.

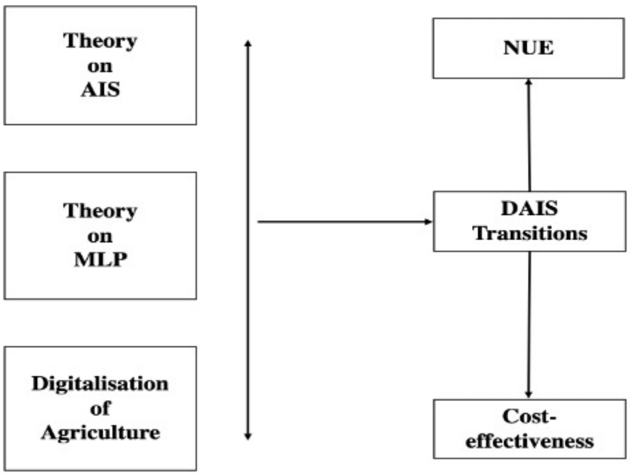

Figure 2: The foundation of the theoretical framework to conduct the case-study. Source: Verschuren & Doorewaard (2010)

2.2 Enlightenment of literature gap for DAIS & NUE

2.2.1 Bibliographic analysis

To study the empirical literature, around 80 topmost journal articles were exported from the 'Web of Science' website with keywords combination such as 'digitalisation & agriculture', 'AIS & MLP', 'AIS & NUE', 'digitalisation & AIS', 'digitalisation & AIS & NUE'. The record content of articles was a 'full record and cited references' and file format was 'tab-delimited (WIN)'. For bibliographies analysis exported journal articles were analysed by software 'VOSviewer'. Using the software, a map was created based on 'text data with chosen fields' and 'title and abstract fields' were examined. Figure 3 shows the overlay visualisation of the map created.

Considering this overlay visualisation, it is visible that publication of articles associ-ated with case-studies was initiated around the year 2017 (yellow colour). Various combination topics covered so far are based on terminologies such as; MLP, development, agriculture, system and knowledge etc. However, there are no direct relation in case-studies on digitalisation, NUE and policy implementation. Therefore, this justifies a research gap in the literature for case-studies on digitalisation and NUE at an MLP.

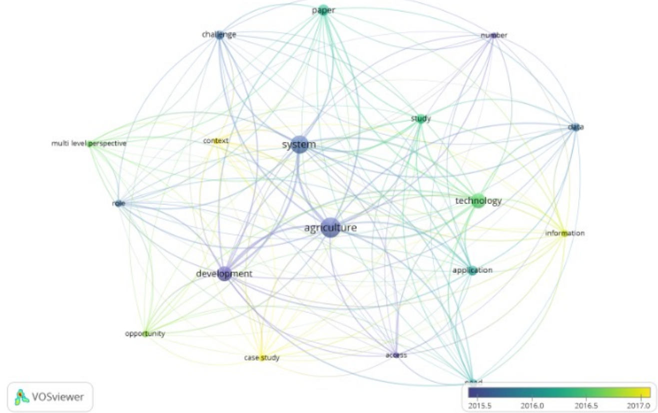

Figure 3: Overlay visualisation of DAIS for NUE at MLP in agriculture. Source: VOSviewer; Web of Science website

2.2.2 Validation of Research gap in literature Studies

According to a report of the European Commission (2019), research and innovation are the foundational stones of the society to fight against the environmental, economic and ethical challenges of the EU's farming and associated businesses. And to bridge the gap between research and farming practice, we require radicle innovations and multifunctional EU agriculture policies (McEldowney, 2019). The Netherlands follows the logic of liberalisation and thus privatisation of extension services. For example, agricultural consulting firms lead to propagating new information and services based on the clientele and protocols (Lamprinopoulou et al., 2014). For efficient information flow, robust transitional brokerage arrangements are required to associate demand and supply in the agricultural knowledge market while stimulating communication and co-operation between innovation stakeholders (European Commission, 2011). However, The government is experiencing a shortage of people with proper knowledge is the main reason for the slow development of precise agriculture (Government, NL, 2018). The policy is debatably one of the most significant factors in terms of the appropriateness of action (or non-action) within a societal context (Wilson, 2013). Considering niche to landscape-level implementation, there is an implementation gap of digital technologies in Farm Management System (FMS) such as IoT, BDA, CC, AL and block-chain (Alreshidi, 2019). According to Koch (2017) & Rissman, Owley, LRoe, Morris, and Wardropper (2017), there is an associated knowledge gap to address the social implications of digital agriculture future and the role of policy guiding it. However, there is also a lack of harmo-nisation between the multiple institutes involved at a national, regional, and sectoral level to expand lucrative processes in NH_3 & NOX action agendas without negotiating the agricultural sector's sustainability (Expósito & Velasco, 2020), small- and medium-sized farms face a technology gap. Thus, there is a significant gap in the awareness of pollutant dynamics and examination among farmers (Expósito & Velasco, 2020). The Dutch government is facing a challenge for innovative policy implementation to speed up the digitalisation of agriculture and support the transformation while keeping the labour market and society on board (Government, NL, 2018).

2.3 Desk research

2.3.1 DAIS for enhancing the performance trajectory for Nitrogen Use Efficiency (NUE) & cost-effectiveness

The concept of digital agriculture in smart farming provides the implication of yield or productivity enhancement. It creates wakes of innovation for farm management by streamlining the real-time data across the supply chain. And thus, the DAIS transition provides new avenues to reduce environment based cost externalities (Fielke et al., 2019). Precise agriculture and intelligent farming using the IoT, sensors, software, and devices go beyond basic management tasks of obtaining the primary data and enhancing the data quality by context and situation awareness in real-time (Figure 4) (Wolfert et al., 2014). Build-in intelligence and machine learning allow to conduct autonomous action remotely and help farmers derive data-driven decisions in FMS (Alreshidi, 2019). The utilisation of digital technologies in FMS will enable farmers to investigate and forecast their farm decisions. The cyber-physical progression with machine learning experiences provides self-sufficiency to FMS (Alreshidi, 2019; Wolfert et al., 2017). A significant amount of data can be generated using intelligent sensors and software on-farm. By using BDA, data-patterns can be drawn from the data collected. Using CC, drawn data patterns can be stored and accessed on multiple platforms. BDA & CC provide data sharing and management implication from a farm to a region and up until the landscape level (van den Broek, Hofwegen, Beekman, & Woittiez, 2007). AI-based machine learning principles can be combined with block-chain to protect IP rights, networking and data rights (Tanwar et al., 2019). Thus, digitalisation creates the enormous potential to develop chief modifications in functions and power associations for all multi actors involved in the value supply chain (Wolfert et al., 2017).

According to Tullo, Finzi, and Guarino (2019), Precision Livestock Farming (PLF) is described as process techniques and engineering principles for livestock farming to moderate environmental risks while scrutinising and modelling animal cultivation & management. There-fore, considering the DAIS transition, PLF is aligned with principles of NUE and cost-effectiveness. One of the primary aims of this study is to highlight the importance of knowledge creation and harmonised communication pathways of advanced farming practices. Practices such as optimisation of fertilisers, pesticides, irrigation water, the animal feels fall under precision farming principles, and introduction of digital technologies can create at par environmental opportunities and benefits. For example, GPS controlled devices coupled with sensors & AI (robots) used for pesticide spraying, fertiliser distribution and weeding, avoid excess chemical input in the soil and reduces the risk of water, air and soil pollution. Multi-gas detectors have specialised sensors to trace hazardous gasses such as NH_3 from manure storage areas (*Veiligheidstechniek, Nederlands (VTN) Products*, 2020). By collecting real-time data, data-driven decisions can be made to measure nutrient optimisation and cost-reduction (Walter, Finger, Huber, & Buchmann, 2017; Wolfert et al., 2017). According to a report by Delloite (2017), considering state-of-art technological innovations, software like 'fodjan smart feeding' for optimum feeding on farms provide implications of cost reduction and improves livestock health. Robots like 'swagbot' can flock cattle unconventionally, perform weeding, and pull heavy-weight. The robot also delivers livestock's health status by using sensors to examine body heat and drive, which ultimately enhances the NUE. These are the examples of niche-level innovations that require co-development and co-evolution at the regime and landscape-level for the digitalisation of the agricultural innovation system (Grin, 2008).

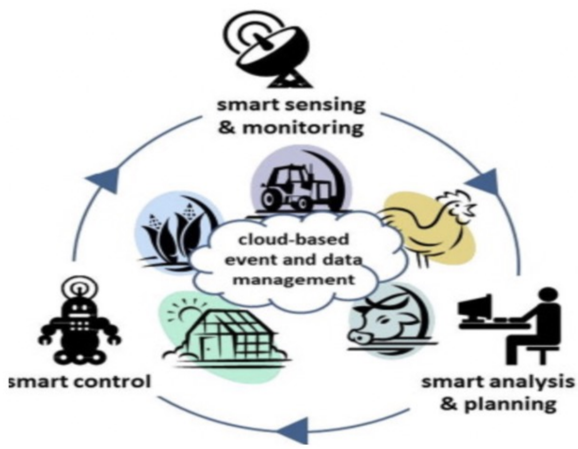

Figure 4: The cyber-physical managing sequence of Smart Farming enriched by digital technolo-gies and data management (Wolfert et al., 2014)

2.3.2 DAIS interaction at regime & landscape level to enhance technology and policy implementation

The digitalisation of agriculture results in the convergence of industries and increasing generalisability & homogenisation due to technological innovations. However, it also creates landscape questions regarding uncertainty and unclear consequences for the agricultural ecosystems (Digital Agriculture Convergence lab, 2017). A national AIS comprises the legacy of technological, societal, economic and institutional interactions with multi-stakeholders with a certain level of commitment (Fielke et al., 2018). As AIS is considered a socio-technic transition process, the disparity between niche innovators, regime and landscape actors is quite vigilant. Therefore, there is a need to develop a shared vision in innovation communities interacting at multiple levels. Prioritising digitalisation in AIS can align the DAIS transition's common goals (Paschen, Reichelt, King, Ayre, & Nettle, 2017; Pigford, Hickey, & Klerkx, 2018; Walrave, Talmar, Podoynitsyna, Romme, & Verbong, 2018). For EU's scenario monitoring, incentive schemes and cross-compliance requirements of the Common Agricultural Policy (CAP) have been the main policy tools applied to reduce environmental costs such as nitrogen pollution (Expósito & Velasco, 2020). The Dutch AIS is recognised for solid networking and strategic cooperation between policymakers, research institutes, agribusinesses and farmer unions. Wageningen University & Research Centre (WUR) is a role-model of the Public-Private Partnership (PPP) platform for innovation policy development and implementation (Lamprinopoulou et al., 2014). However, due to the commercialisation and privatisation of knowledge, Dutch AIS has become more competitive rather than collaborative and have been observed to deaccelerate the information and innovation diffusion in society to a greater extent. Consequently, the agricultural industry faces complications to develop a good market overview, measuring transformations in contributors' quality and well-defined communication that they are looking for (Lamprinopoulou et al., 2014).

3. The Conceptual Model

According to Verschuren and Doorewaard (2010), a researcher creates a conceptual model based on a theoretical framework. This precisely defines the relationship between the phenomenon and its occurrence within the project's research boundaries. It allows the researcher to develop a clear vision of the variables and concepts. Which ultimately guides the researcher to interpret and explain the collected data in the later stages of the research. Two co-descriptive elements of a conceptual model are:

- **A set of core concepts indicating phenomenon in the empirical reality**
  For this article, chosen core concepts are AIS, MLP, NUE and digital innovation for Dutch agriculture. These core concepts function are derived from the research objective and has been well illustrated in the research question. These core concepts refer to the phenomenon that can occur in different variations (Verschuren & Doorewaard, 2010). Such as cost-effective policy implementation to enhance the NUE results from the interaction of varying core concepts (Digitalisation, AIS & MLP) to a certain degree. And their occurrence defines the amelioration of Dutch agriculture for livestock cultivation with a commitment level. According to Verschuren and Doorewaard (2010), in this case, variables of core-concepts are 'ordinal' and has a form of 'graduation' as they show a 'level of commitment' and can be ranked in terms of 'a degree'.
- A set of assumed relationships between these concepts
- Direct Positive effect: AIS & MLP both involves multi-stakeholders and creates implications for policymakers. However, MLP directly affects AIS as the establishment of AIS is socio-technic transitions, considering niche-regime and regime-landscape interactions (Expósito & Velasco, 2020; Grin, 2008).
- Co-founding effect: Digital innovation has a spurious relationship between AIS & NUE. As per the research objective, the introduction of digital innovation such as BDA, IoT, AI and block-chain should streamline the knowledge pathways at a social, institutional, economic and environmental level. Multi-level collaborations among AIS actors with a commitment to enhancing NUE aim for DAIS transitions (Ros, Janssen, Bartelds, & Holster, 2018).
- Direct feedback effect: Due to Digital innovation's co-founding impact on AIS & NUE, there is a mutual influence between AIS & NUE. For Dutch AIS, policy guides and get guided by the digitalisation of agriculture in the Netherlands (Koch, 2017). The system requires to be cost-effective, efficient, and reduce environmental externalities. Data-driven decisions allow farmers to sustain their Farm Management System (FMS) and provide real-time based data sets to AIS actors for practical policy advice and implementation at a landscape level (Ros et al., 2018).

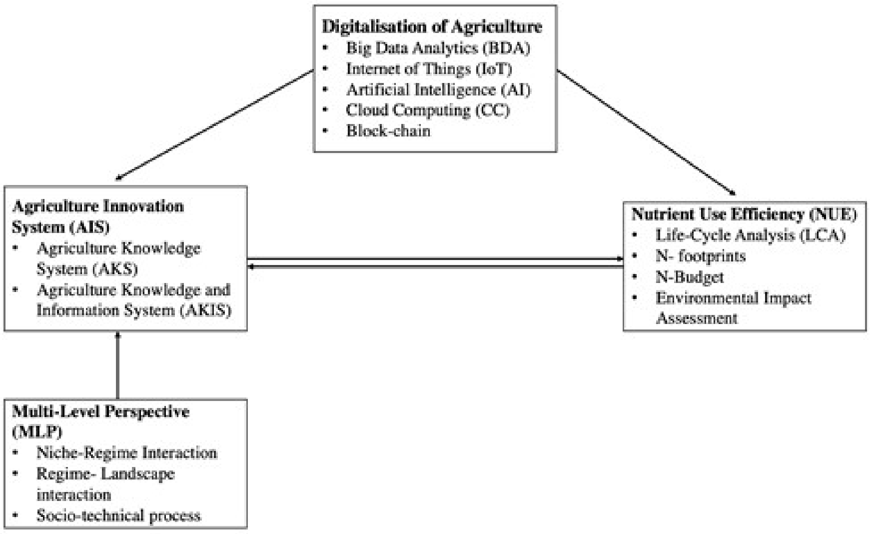

Figure 5: The cyber-physical managing sequence of Smart Farming enriched by digital technologies and data management (Wolfert et al., 2014)

Considering the core concepts, including their variables and the relationships between the concepts (Figure 5), this provides a visual and more profound level of understanding of the conceptual model for this article to conduct a single and holistic case-study explorative and qualitative.

4. The methodology

4.1 Data collection

As per the research strategy and framework used for this case-study research, data gathering was performed from multiple sources of evidence but covering the same set of findings for triangulation (Hancock & Algozzine, 2017) by the following:

- **Desk-research:** A literature review was performed to develop a deeper understanding of niche innovators and the innovation ecosystem. And thus, it presented the knowledge gap delaying institutional guidance for policy implementation for the DAIS transition.
- **Primary data:** Semi-structured intensive online interviews[1] were conducted with multi-stakeholders such as agricultural advisors, research institutions, regime and landscape players. The questionnaire was prepared with explicit links between the questions asked, data collected, and the conclusion drawn (Yazan, 2015). All interviews were recorded and transcribed. Communication with participants of the following organisations was established for the research:
- **Secondary data:** Annual reports, brochures, handbooks, reports and press releases from different organisations were studied. Such as; Scientific council of Government Policy (WRR in Dutch), National Inventory Reports (NIR), Pollution Release & Transfer Register (PRTR) and Information Inventory report (ITR), National Emission Model for Agriculture (NEMA) from the National Institute for Public Health and Environment (RIVM in Dutch), Central Bureau of Statistics (CBS) and Wageningen University & Research (WUR). Also, from companies such as Lely, Veiligheidstechniek, Nederlands (VTN in Dutch), Cultura Technologies and John Deere.
- **Participatory observation:** To provide transferability and confirmability to the research, co-relations were built while performing familiarisation with the textual and audio-visual data files for transcribing the Appendixes.

4.2 Data analysis

Gathered data was examined, categorised, tabulated for data analysis as a meaning-making process (Yin, 2002). According to Stake (1995), a solid aggregation strategy helps a researcher draw systematic analysis protocol to cut down misperceptions and misunderstandings. The research planning for DIAS transition was an 'iterative process', wherein execution of tasks was conducted 'parallel' or simultaneous (Creswell & Miller, 2000). Thus, concurrent data collection and data analysis were performed to validate the data. Pattern-matching, linking data to prepositions, explanation building and logical interpretations were also performed.

[1] As per the risk management strategy, the interviews conducted were semi-structured and online (via Skype and Zoom) due to the Covid-19 lockdown in the Netherlands from March-May 2020. However, questions were open-ended and recorded, not to hamper the data's quality for research purposes.

Name of organisation	Location	Name of Interviewee	Job role and area of expertise
Louis Bolk Institute (LBI)	Utrecht Area, The Netherlands.	Dr Willem Erisman	Director of LBI. He is a 'Nitrogen Expert' & 'Environment Policy Advisor'
Wageningen University & Research (WUR)	Wageningen, The Netherlands	Dr Wim de Vries	Professor, Dept Environmental Science. His expertise is o" "Integrated in Nitrogen impact analysis"
Nutrient Management Institute (NMI)	Wageningen, The Netherlands	Dr Gerard Ros.	Data Scientist/Senior researcher/Consultant at NMI. His area of expertise is in consultancy.
(RDA in Dutch), The council for Animal Affairs	The Hague, The Netherlands	Dr Jeroen Candel	Member of the council. His area of expertise is in policy advise.
FarmHack.NL	Wageningen, The Netherlands	Miss Anne Bruinsma	Chief Mobilisation Officer and Co-Founder. Her area of expertise is in innovativ processes on data and technology

4.3 Data validation and quality assurance

Validity can be described as the 'appropriateness' of the tools and data being used (Leung, 20165). Reliability and trustworthiness of the data are the cause and effect relationship in the research. The data validation method used was a postpositivist or systematic paradigm. Wherein triangulation of lenses converges data across sources, theories, concepts and methods used (Creswell & Miller, 2000). The first lens of validity was the researcher itself. For triangulation, literature review (desk-research), semi-structured online interviews (primary data) and practitioner's content exploration (secondary data) were performed. This provided internal validity to the research. The second lens used was the member check; during member checking, members were provided with the description, interpreta-tion & conclusion and were asked whether the recipients agree on the provided information or not. By contacting participants and 'measuring' the questions' interpretation, reliability was ensured. When finishing the research report, the interviews' conclusions were shared with the participants. In this way, the participant could validate whether the researcher's decision was interpreted correctly or not (Creswell & Miller, 2000). This provided external validity to the research.

5. Results

5.1 DAIS transformations to enhance the performance trajectory of NUE

For livestock cultivation, the Netherlands has a unique scenario of how this industry works at the national and the global level. On the one hand, Dutch farmland under cultivation has reduced up to 76% since 1960, and local livestock density (LU) is among the highest in the world (Noord Braband - 10LU/ ha) (CBS, 2020a; Wang et al., 2017; Bos et al., 2013). However, the country is struggling to cope with various challenges from last couple of decades such as; increase in emissions from livestock cultivation, manure surplus, deposition of nutrients in nature areas, reduction in biodiversity, increase in GHGs emission and effective policy implementation (Groenestein et al., 2019). Due to the proactive response of national policies and the EU's CAP policy, Dutch agriculture plays a significant role in its GDP and is not a closed or isolated system. The flow of import and export of goods makes it an interconnected and embedded system globally (Burger et al., 2012). Therefore, to enhance the sustainability aspect of precision agriculture, digitalisation of agriculture has to play a role at an ecosystem level by the following:

5.1.1 The need of a framework and indicators for Nitrogen Use Efficiency (NUE)

According to Erisman et al. (2018), for N management, decisions and actions at a national level require a robust database of 'N flow' and 'Key Performance Indicators (KPI). The KPIs are needed for policy development, monitoring, progress and information for the customers. They must also focus on NUE at the food industry level, including its production, processing and distribution (Ahlgren et al., 2012). NUE for whole Food Chain (NUEFC) (Figure 6) is the ratio of N available for human consumption and nitrogen input for the food system (+newely fixed and imported) (Erisman et al., 2018).

According to WUR, NL, ***"For the Netherlands, NUE for cropping is a bit above the global average, and it is around 60%, and NUE for livestock cultivation is only about 10%. NUE for the whole food chain includes crop and livestock***

and is surprisingly quite low in the Netherlands because our major agricultural produce comes from the livestock cultivation".

The KPIs developed by Erisman et al. (2018) to study N flow are; Life Cycle Analysis (LCA), nitrogen footprints, nitrogen budgeting and Environmental Impact Assessment (EIA). To explore the cause of the N-crisis in the Netherlands, there is a need to study N flow from a farm to a region & landscape level. According to practitioners, there is a prioritisation of one indicator over another.

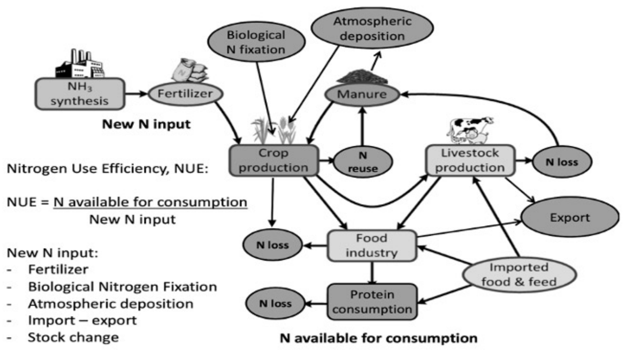

Figure 6: The components of NUE_{FC} in the national food system. Source: Erisman et al., (2018); Panel, (2016)

According to the LBI, NL, ***"I would prioritise N budgeting indicator because it makes more sense regarding how to deal with data available at the farm level. Data such as inputs and outputs on the farm, N harvested, N exported, and N brought back to the land in the form of manure and N losses through waste"***.

However, according to WUR, NL, ***"For Dutch NUE, the N profile is quite scattered, the feed for the animals not only has N footprints in the Netherlands but also from the point of origin as the Netherlands import a lot of feed from its neighbouring countries. And some farmers also export manure as a useful output. So, in my opinion, a Life-Cycle Analysis (LCA) indicator must be emphasised to study and to enhance NUE"***.

Erisman et al. (2018) developed the formula of NUEFC and is:

$$NUE_{FC} = \frac{N_{\ food\ availability}}{f + BNF + atm.\ dep + (i - e) + cs}$$

Where:
f=fertilizer;
i=import;
e=export;
cs=changes in stock.

Therefore, from a farm to a landscape level to study the N flow, the data required should be precisely based on indicators such as LCA & N-budgeting. Figure 7 displays the N flow in the Netherlands based on LCA & N-budgeting indicators for 2016.

According to WUR, NL, ***"For the year 2016, 900 M Kg N has imported out of which 300 M Kg came in the form of food & 340 M Kg as an imported feed. On the other hand, 435 M Kg N is exported in food (340 M Kg milk and meat) and manure. Therefore, the rest of surplus N was either consumed or lost in the system, causing N emissions in the form of ammonia in the air and nitrates via leaching in groundwater". So, it is clear the import of feed and has a significant impact on the N crisis of the Netherlands"***.

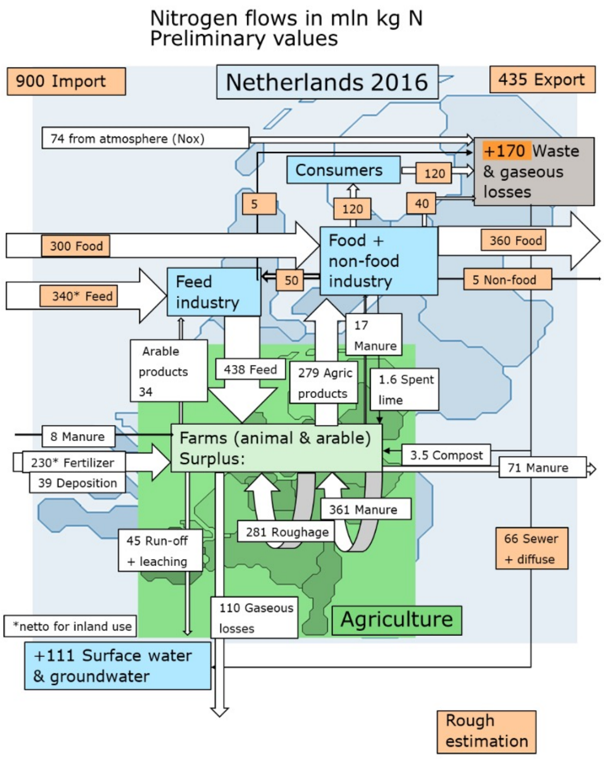

Figure 7: Preliminary flow chart for the Nitrogen (N) flow in the Netherlands (2016). Source: WUR (2019)

From figure 7, it is clear that the import and export of N plays a significant role in surplus N, contributing to N-crisis in the Netherlands. In the Netherlands, RIVM publishes annual reports for N emission data (Table 1). For the year 2017, the contribution (Kg N/ha/annum) value was calculated by dividing the terms in Kton/annum by 4.14 and was based on the Dutch land area of 4.543 Km^2 (De Vries, 2020b).

Provided figures in Table 1 are **'static figures'** based on per hectare land in the Netherlands. However, Nitrogen emissions are volatile and vary worldwide on a

Nitrogen flux	Contribution (Kg N/ha/annum)		
	NH_3	NOX	N
Emission in the Netherlands	25	19	44
Deposit in the Netherlands	11	2.5	13.5
Export abroad	14	16.5	30.5
Import abroad	4	3.5	7.5

Table 1: The emission-deposition balance for ammonia & nitrogen oxides for 2017. Source: De Vries, (2020); RIVM, (2020)

regional basis. Out of 12 provinces; Friesland, Overijssel, Gelderland & Noord-Brabant are the most contributors and hotspots of NH_3 emissions (above 15 Kton) as that of other provinces (below 8 Kton) (De Vries, 2020b).

According to LBI, NL, ***"Though we have enough data for N in the Netherlands, we do not have enough data about which part of the N came from the production in the Netherlands and which part came from the import. For the livestock sector, if we get the correct data about N input (from production and import) and meat export, then N budgeting can be useful to enhance NUE"***.

The Netherland's current N flow profile is based on complex LCA and N-budgeting indicators and is embedded nationally and internationally. NH_3 being volatile, travels through the farms. According to De Vries (2020b), 21% of NH_3 deposits within a 20 Km radius, and the rest, 79%, does not and is taken by the wind to other provinces or even abroad. This means, for example, NH_3 emissions caused by farms in Noord Brabant adds to the emission figures to the farms in Groningen and vice versa. The Netherlands also has 'cross-border' pollution, so one-third of NH_3 emissions are from neighbouring countries (Stokstad, 2019). Therefore, the government faces enormous challenges to obtain correct N flow data and surplus N.

5.1.2 The role of digitalisation enhancing NUE from farm-region to landscape level

According to Groenestein et al. (2019), the least NUE is for beef and milk production in livestock cultivation. The output of 1Kg Beef requires 5 Kg of feed and emits 1Kg of NH_3. The production of 1 L of milk requires 4 Kg of feed and emits 0.6 Kg of NH_3. And as per the current Dutch livestock census, there are 3 million Dairy cows and 0.2 million beef cattle (Statista, 2020). N volatilisation occurs in stables, manure storage and field application from cattle farming. NH_3 emissions in Dutch dairy farming were 21% higher in 2017 than in 2010, and total ammonia emissions were contributed by; 50% from manure, 48% from manure storage and 2% from manure processing & grazing (Leusink, 2019). Therefore, most opportunities to enhance NUE from livestock cultivation are cattle farming. PLF is accompanied by introducing various digital technologies in FMS, Such as; BDA, AI, IoT and CC. However, there is a gap in implementing these technological innovations from R&D to farmland and are supported by weak policy infrastructure (Alreshidi, 2019).

According to FarmHack, NL, ***"When I was working with the Dutch ministry, I witnessed and understood the huge impact of digitalisation in agriculture to scale up cost-price and efficiency of the system while making it sustainable. However, at the same time, I also observed how hard it is to introduce a new dialogue in policymaking. As a result, we at the sector level are underestimating the potential of precision farming, and for so many farmers, it is still an alien term"***.

To enhance Dutch NUE, there is a need for transformation in data by adding a real-time data profile and creating a unified N profile at the sector level.

According to the LBI, NL, ***"What I expect from digitalisation is to trace the N flow from production up until it ends in the form of manure. For example, Soybean, where and how it was produced, its transport, its processing & distribution, how much it is used by the cow, how much of it was lost as emissions and how much it ends up in manure"***.

Therefore, there is a need for state-of-art initiatives to create real-time data, data management & sharing, from farm to region and up until the landscape level (Alreshidi, 2019). The DAIS transformation is one such initiative wherein data sharing and management provide wakes of innovation for knowledge creation and harmonising communication pathways among different value supply chain actors and policymakers (Fielke et al., 2019).

5.2 DAIS transformation to enhance policy infrastructure for technology implementation

5.2.1 The current state of Dutch policy infrastructure for NUE

The food governance system of the Netherlands is split in between food policy and cl-mate change adaptation policy. Nitrogen is indirectly linked to both sub-systems as the amount of Protein (N) in the food-chain and Nitrogen emissions (NH_3 & NOX) in climate change adaptation policy (Candel, 2019). The two most essential derivates of Dutch nitrogen policies are the manure and nitrate policy. Farmers require licensing/permit to expand livestock cultivation. The permit criteria limit N depositions in Nature 2000 areas and the national ammonia emissions ceiling (RIVM, 2020). However, NH_3 being volatile in nature travel within the provinces and even abroad (De Vries, 2020a). Due to the generic nature of the policies, a permit can only be granted in the low emission provinces and cause an N crisis in the Netherlands. According to Kleis (2019), farmers and researchers' primary demand is a local deposition policy & local emission ceiling, sub categorised at regional level and nitrogen targets based on long terms (up to 20 years). According to policy advisors, the current N crisis is defined as 'a focusing event'. One of the government's short-treasures is buying up farms near nature areas and subsidising barns in low emissions (Candel, 2019; Kleis, 2019).

According to the LBI, NL, ***"The government is single-issue focused. My big frustration, I must say, is at this time, there is an opportunity to fix long term gains while reconsid-ering climate change from fossil fuels and agriculture"***.

The mechanism of 'short fixes' is defined as a mechanism of 'protecting turf' by the policy advisors, where the government creates regulations that do not put the economy at risk (Candel, 2019).

According to RDA, NL, ***"The Netherlands follow neoliberalism, and food is considered a financial product. Therefore, policies are derived to address the economy and pro-mote agriculture's intensification. Presently what matters more for the government is controlling the global food supply and food prices, which I call out-of-control neoliberalism"***.

5.2.2 Multi-policymakers collaboration to address data ownership and data collaboration in policy infrastructure

Real-time data generated needs to be collected and shared in multiple sectors to establish transparency in multi-stakeholder collaboration. On the one hand, digital technologies such as a combination of AI algorithms with block-chain technology management and data sets at multiple levels (Tanwar et al., 2019). On the other hand, there are data ownership issues at the farm level, as not every farmer agrees to share their FMS data sets at the industry level.

According to WUR, NL, ***"Farmers like to stay anonymous because in case nitrate leaching or ammonia emissions are found to be exceeding limits while collecting and sharing data, they will encounter penalties. And taking farmers' autonomy away from his land will cause distress among farmers, and we might lose people working on farmlands"***.

Multi stakeholders collaboration obtains data from farmlands and IT firms, research institutes, advisories, and private firms. To create an N life-cycle analysis effectively at the national level requires cross-sector partnerships and collaborating data in the cross-fit approach is defined as 'data collaborate' (Susha & Gil-Garcia, 2019).

According to FarmHack, NL, ***"Access to the real key data for many actors is still poor. Generating data, structuring and analysing data are aligned with special business interests and business models. It was observed that the connectivity and interoperability of data were missing"***.

Therefore, the current state of data collaboration is low. There is a need for expansion in policy infrastructure to define to what extent participants must engage, commit and collaborate. 'Collaborative governance' is accountable to create transparency in policy-making to justify the level of a multi-layer partnership (Scott & Carter, 2019). Therefore, there is a need for collaborations among policymakers to enhance policy and technology implementation in the DAIS transition.

For DAIS transformations, there is a need for long term N policies that are 'region oriented and customised. To support this policy infrastructure, we require a 'micro-perspective of market formation, where real-time data from the farm can be shared at multiple levels to support FMS and enhance NUE (Verbong & Geels, 2010).

According to WUR, NL, ***"I recommend Nitrogen Trading System (NTS), wherein with the help of digital technologies, progressive farmers can track their N targets and can trade their results with other farmers. Expansion in policy infrastructure can help promote NTS, and thus, long-term based N targets can be achieved"***.

There is a need for motivation and financial support among farmers to invest in digital technologies. Once they can make data-driven decisions, they can put extra efforts into reducing N-emissions with progressive behaviour, market formation such as NTS (Delgado et al., 2020).

6. Discussions

Two significant components of AIS are AKS and AIKS. AKS accounts for public-funded research, education and extension services and AIKS account for structural configurations of collaborations and innovations (Rivera et al., 2005). For the EU, AKS and AIKS have to sustain partnerships and innovation networks among 37 members, and thus members also have to oblige a certain level of commitment to EU's CAP. According to Hermans, Klerkx, and Roep (2015), the lack of funds, vertical & horizontal system fragmentations, lack of task-force supporting transformations, and lack of proper policy evaluation criteria are potential threats to the slow pace of multidisciplinary innovation network establishment. Intensification of agriculture to keep global food supply and market are at the core of EU's CAP policies. Therefore, there are broad-spectrum consequences such as an increase in GHGs emission, nutrient leaching and emissions affecting environmental health and biodiversity at the continent level. The roots of the current N-crisis in the Netherlands is more of international concern. Precision agriculture, through digitalisation, can confront these challenges and provide sustainable solutions at the ecosystem level. However, this is just the beginning of the era, and system-level transformation will take decades to make digitalisation an inherent property of agriculture. And these transformations must be supported by an overarching policy infrastructure.

The significant challenges and opportunities for DAIS transitions in the Netherlands for N crisis and to enhance NUE are as follows:

A. **NUE & N profiling:** Considering last one decade, domestic agriculture produces contributed 1.5-2.0% for Dutch GDP per annum (Plecher, 2020). The Netherlands being the world's one of the top food exporter, has shown a significant trend in an intensification of research and agriculture. Importing cheap feed from Latin-American countries and exporting dairy products, meat and manure around the world have promoted Dutch farmers to utilise utmost agriculture knowledge to escalate the production while consolidating land in use (Bos et al., 2013). However, internationally embedded industrial networking and the lack of vision in knowledge infrastructure to derive sustainable solutions create challenges such as N emissions and are deteriorating environmental health. The LCA and N-budgeting have to embedded in international industrial networking. Dutch N-crisis is not just a national issue as its roots are spread internationally. Therefore, we require collaborations at multiple-levels to create a unified N profile, including production, processing, transportation and distribution.

B. **Technology:** The Netherlands has a world-class knowledge infrastructure and cooperation among businesses to support digitalisation and transforming economies and society (Government, NL, 2018). However, the lack of financial and technological investments in the agriculture sector is slowing down the pace of this transformation as compared to other industries. Digitalisation has excellent potential to enhance NUE and reduce emissions by supporting the FMS. However, societal and economic problems such as lack of education among farmers for pollution dynamics and expensive technologies are also one of the root causes (De Vries, 2020a). Moreover, the consequence of neoliberalism promoting competition over cooperation in AIS prioritises the economy above the environment. Regardless of many companies working on digital infrastructure in agriculture, data collaborate rate is low. Economic-driven business models of companies and advisories are disoriented, and data sharing and management are working opposite to DAIS transitions. To create a unified N profile, there is a need for integrating real-time data generated from the farm in existing data infrastructure, and collaborations must be made to promote cross-sector data sharing and management. Wherein machine learning and block-chain technology must play a pivotal role to support transparency among different stakeholders while sustaining a certain level of commitment.

C. **Policy:** Current most important under discussion policies for N-crisis are manure and nitrate policy. Both policies enforcement are complex, input-driven and expensive (Candel, 2019). Ammonia emissions are volatile, and cross-border pollution makes the situation complex. The lack of region-oriented customisation of policies & policies based on short-term economic gains shows a lack of a vision among politicians to resolve the Netherlands' N-crisis (Ros et al., 2018). To support digitalisation, issues such as data ownership and data-sharing are still significant challenges for integrating a new dialogue in policy infrastructure. To support cross-sector collaborations conjoint with an overarching narrative, digitalisation, we require collaborative governance (Scott & Carter, 2019). However, due to a low level of; policy entrepreneurship, the pace of digitalisation & collaborative management slows down the speed of DAIS transitions. There is a dire need for policy (dis) integration to underpin overarching narrative (digitalisation) and cross-sector collaborations. There is also a need for a vision among politicians to derive region-oriented customisation of N policies with long term N targets and economic gains.

6.1 Technological and policy recommendations

- **Technology:** To support DAIS transitions, firstly, there is a need to disrupt the economy driven business model of the industry. Digitalisation can disrupt the industry. However, intelligent collaborations are the key to tackle wicked problems in society, such as N-crisis. Landscape-level technological implementation to streamline real-time data from FMS with a cross-sector approach is the ultimate foundation of brilliant collaborations among multi-stakeholders of

AIS. There is also a need for data rights innovations to make farmers data ownership explicit. AI algorithms, coupled with block-chain technology, is the key to maintain a level of commitment and transparency among different actors of collaborations. To create a unified N profile and enhance NUE at the sector level, technology implementation and collaborations must be embedded at the international level. There is also a need to educate farmers and society on technology use and creating awareness regarding pollution dynamics.
- **Policy:** Current policy evaluation and monitoring infrastructure has an input-driven approach and must be transformed into a result-driven process to support DAIS transitions. There is a need for a government vision to develop policies based on long-term economic gain and N targets. Policy evaluation must be transformed from a generic to a local approach, where policies are region-oriented and customised. There is a need to introduce new dialogue in policy (dis) integration to support data ownership rights explicit. There is a need to support policy entrepreneurship to support the brilliant collaboration of PPP. Associations which has a maximum environmental impact with minimum (government) efforts. There is a need for expansion in policy infrastructure to support real-time data in FMS with NTS. This is one of the potential ways to help DAIS transitions while creating a Nitrogen trading market among farmers and other value-supply chain actors (micro-prospective approach) with a Multi-Level Perspective (MLP).

6.2 Scope for further research

The Netherlands is one of the EU's member. It has to oblige to the EU's CAP policy wherein different members have unique challenges for their national AIS infrastructure (Rivera et al., 2005). Due to its embedded roots in international networking, the nitrogen crisis makes the situation more complex. There is a need for enormous state-of-art case-study research supporting maximum environmental impacts with minimum (government) efforts (Ros et al., 2018). To enhance NUE and N-profile for a country like the Netherlands, there is a dire need for collaboration involving national and international actors involved in livestock and crop cultivation in production, distribution, processing and transportation (Erisman et al., 2018). We require research on different aspects of the industry collaborations such as finance, investments, policy (dis) integration by involving actors from various industries in education, research, advisory, IT firms, farming associations, companies and NGO's. There is a need for research on nitrogen dynamics with an ecosystem approach while considering biodiversity losses, nature areas, food safety, soil and water health etc.

7. Conclusion

This holistic case-study research enlightened the challenges and consequence of the DAIS transition in the Netherlands to enhance the NUE and ecosystem-level sustainable economic development. This research's explorative nature touched upon technological, societal, economic, and institutional interactions in the Netherlands for Dutch agriculture (Fielke et al., 2019). EU's intensified model of agriculture has shown significant trends for the economy while feeding the world. The Netherlands is one of the pioneer countries in the EU and globally has played as a role model in R & D for the rest of the world. However, Dutch agriculture's neoliberal model is internationally embedded, and the Dutch food-chain is struggling to sustain the system. Thus, NUE is of global concern (Candel, 2019). Dutch AIS is facing particular challenges to creating system-level transformations such as (De Vries, 2020a; Ros et al., 2018);

- **Political challenge:** Lack of policy evaluation criteria, lack of a vision for policy (dis) integration.
- **Societal:** lack of awareness among farmers for pollution dynamics, lack of funds and expensive clientele based advisory services.
- **Technological:** Economic driven and polarised business models, low level of data collaboration, expensive technologies to support FMS, low level of education among farmers and low level of policy infrastructure for landscape-level implementation.

The primary agricultural produce of Dutch agriculture is from the livestock sector, precisely cattle farming. Nutrient losses and NUE is a bigger problem for the system and has shaken the economy. Issues like the volatile nature of NH_3, cross-border pollution, and inefficient policy infrastructure are in dire need and seek help from agriculture's digitalisation. PLF supports FMS by using digital technologies such as IoT, CC, BDA and AI. Though the Netherlands has enough data on nutrient losses and NUE, most of the numbers are 'static figures' with a high uncertainty level. However, as Dutch AIS is more competitive than collaborative, and there are separate data sets available with advisories, research institutes, companies, and IT firms, they are neither known to the public nor visible in national reports (Ros et al., 2018). The key to resolving the Netherlands N-crisis is by creating real-time data from the farm and integrating all data-sets to develop a

Aspects of Lens	Results	Matches aspects,	Does not match aspect of lens –	Relates back to conceptual model
Agriculture Innovation System (AIS)	AIS is more competitive than collaborative.	Strong network establishment for AKS & AIKS promoting intensification of agriculture.	Intensification is being prioritized over sustainability. Vertical and horizontal system fragmentations. Lack of funds and versatility of EU's CAP is slowing pace of transformations.	There is a need to re-design the entire approach. Smart collaborations are required among knowledge institutes, policy-makers, farmers and market chain.
Multi-Level Perspec-tive (MLP)	Technological innovations are being flourished at Niche level. However, lack of policy infrastructure is slowing implementation at landscape level.	Close relationship among research institutes, Start-ups, Scientific associations, companies and advisory.	Business models are economic driven and are polarised. Finance, investments and market opportunities are the biggest challenges for landscape level implementation of technologies. Lack of workforce to bridge 'lab to land' in value-supply chain.	There is a need of new collaborative and cost-efficient business model innovations to support a market which is farmer-oriented, works for everyone while profiting the customer and environment. Nitrogen Trading System (NTS) is one such micro-perspective approach of market formation which has potential to support Sustainable System Transformations (SST)
Nitrogen Use Efficiency (NUE)	Varies within the sectors. Highest NUE is observed in crop production sector and is 60%. Least NUE is ob-served in cattle-livestock farming and is 10%. Dutch agriculture produce is most-ly from livestock cultivation.	Most emissions (NH_3) are from feed, stable & manure (50%) and manure storage (48%). Ammonia being volatile in nature creates cross-border pollution.	Import of feed and export of produce is a big issue to profile NUE for whole supply chain in different sectors. Lack of awareness among farmers regarding pollution dynamics of surplus N (NH_3 & NOX). Lack of data on effective nutrient uptake data and environmental losses.	There is a need to create a unified N profile. Smart collaborations are required to enhance NUE and create N profile form production, processing, distribution and processing. There is a need of better education system to create awareness.
Digitalisation Of Agriculture and NUE	Digitalisation has a great potential to enhance NUE. By using technologies such as sensors, robots, software, big-data and cloud computing, great trend has been observed in N emission reduction.	Strong collaboration of companies working for precise farming, research institutes	Digital technologies are expensive and not many farmers are currently using them at the farm and in stables. Data-sharing and data ownership are still issues need to be addressed at multiple level. Lack of data on surplus N profiling (NH_3 & NOX). Business models are economic driven and are polarised. Lack of data collaborate among different actors of the industry.	There is a need of data right innovations to make farmers data ownership explicit. Multilevel and cross-sector collaborations are required to effectively utilise Big-data and cloud computing data from Farm Management System (FMS). AI algorithms combined with block-chain technology has great potential to create transparency in whole supply chain and sustain collaborations at a certain level of commitment.
Current state of Policy Implementation	Current most important polices contributing N-crisis are Manure policy and Nitrate policy.	Policy enforcement are complex and generic in nature. Livestock cultivation expansion require N permit and is only available for low emission areas.	Politicians uses the mechanism of 'protecting turf' for policy implementation while not risking the economy. Government is providing short-term economic and N targets.	Region-oriented customized polices are required with long term economic fixes and N targets. There is a need of vision among politicians to resolve N crisis.
Policy (dis) Integration considering digitalisation	Require introduction of new dialogue in policy (dis) integration.	Government is aware about need of smart collaborations and lack of people working in task-force.	Low level of policy entrepreneurship is slowing collaborative governance. Current political state is fragmented and there is a lack of leadership. Challenges such as data-sharing and data-ownership are still unresolved issues.	Smart collaborations are required with public and private partnerships. Need of new initiatives with maximum environmental impact with minimum (government) in-volvement.

Table 2: Structuring results and discussion section

unified N profile. Therefore, DIAS's expected transformations are to promote system-level collaborations to create a suitable N-profile and share the data at multiple levels with a commitment level (Alreshidi, 2019). Blockchain, coupled with machine learning experiences, can sustain the networking while protecting data-sharing rights, data-ownership, and IP rights (Tanwar et al., 2019). Moreover, though the Netherlands has a significant level of technological niche innovators, the landscape level implementation of technologies is low and requires expansion in policy infrastructure. To resolve Dutch N-crisis, we need region-oriented, customisable, long-term N targets and economic gains (Kleis, 2019). DAIS transitions are state-of-art initiative where technology is guided by policy and drives policy development (Fielke et al., 2019). Technological developments always lack policy development for landscape-level implementation due to high investments and economic risks (Ros et al., 2018). Therefore, DIAS transformations have to create such collaborations which support business innovations, create market opportunities and support the education system. The utilisation of digital technologies in FMS keeping NTS is one such collaborative initiative for market creation, where farmers, by utilising real-time data, can trade their surplus N results with other farmers &

sectors and can enhance sustainability with maximum environment performance and minimum (government) efforts (Ros et al., 2018; Delgado et, al., 2020).

References

Ahlgren, S., Baky, A., Bernesson, S., Nordberg, Å., Norén, O., & Hansson, P.-A. (2012). Consequential life cycle assessment of nitrogen fertilisers based on biomass – a swedish perspective. *Insciences Journal*, 80–101. doi: 10.5640/insc.020480

Alreshidi, E. (2019). Smart sustainable agriculture (SSA) solution underpinned by internet of things (IoT) and artificial intelligence (AI). *International Journal of Advanced Computer Science and Applications*, *10*(5). doi: 10.14569/ijacsa.2019.0100513

Bos, J. F., Smit, A. B. L., & Schröder, J. J. (2013). Is agricultural intensification in the netherlands running up to its limits? *NJAS – Wageningen Journal of Life Sciences*, *66*, 65–73. doi: 10.1016/j.njas.2013.06.001

Burger, J. R., Allen, C. D., Brown, J. H., Burnside, W. R., Davidson, A. D., Fristoe, T. S., … Zuo, W. (2012). The macroecology of sustainability. *PLoS Biology*, *10*(6). doi: 10.1371/journal.pbio.1001345

Candel, J. J. L. (2019). The expediency of policy integration. *Policy Studies*, 1–16. doi: 10.1080/01442872.2019.1634191

CBS. (2020a). *Agricultural exports hit record level.* Retrieved on 13 May 2020 from https://www.cbs.nl/en-gb/news/2020/03/agricultural-exports-hit-record-level.

CBS. (2020b). *Greenhouse gas emissions 3 per cent down in 2019.* Retrieved on 14 May 2020 from https://www.cbs.nl/en-gb/news/2020/19/greenhouse-gas-emissions-3-percent-down-in-2019.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory Into Practice*, *39*(3), 124–130. doi: 10.1207/s15430421tip3903_2

De Vries. (2020a). *Bouwstenen voor nieuw stikstofbeleid.* Retrieved on 13 May 2020 from https://www.wur.nl/upload_mm/8/8/7/6c616079-61b6-4a8b-91fd-b5544e1babe7_De%20Vries%202020%20Milieu%20%282%29%20Dossier%2037-43.pdf.

De Vries. (2020b). *The nitrogen-debate: Need for a new nitrogen policy.* Retrieved on 14 May 2020 from https://koerstue.nl/koersief/online/current-affairs/need-for-a-new-nitrogen-policy.

Deloitte. (2017). *Smart livestock farming potential of digitalization for global meat supply.* Retrieved on 09 March 2020 from https://www2.deloitte.com/content/dam/Deloitte/de/Documents/operations/Smart-livestock-farming_Deloitte.pdf.

Digital Agriculture Convergence lab. (2017). *#DigitAg Digital Agriculture Convergence Lab.* Retrieved on 06 March 2020 from https://www.hdigitag.fr/en/.

Erisman, J., Leach, A., Bleeker, A., Atwell, B., Cattaneo, L., & Galloway, J. (2018). An integrated approach to a nitrogen use efficiency (NUE) indicator for the food production–consumption chain. *Sustainability*, *10*(4), 925. doi: 10.3390/su10040925

European Commission. (2011). *Innovation union competiveness report, 2011, Brussels.* Retrived on 03 March.

Expósito, A., & Velasco, F. (2020). Exploring environmental efficiency of the european agricultural sector in the use of mineral fertilizers. *Journal of Cleaner Production*, *253*, 119971 (11 p.). doi: 10.1016/j.jclepro.2020.119971

Fielke, S. J., Garrard, R., Jakku, E., Fleming, A., Wiseman, L., & Taylor, B. M. (2019). Conceptualising the DAIS: Implications of the 'digitalisation of agricultural innovation systems' on technology and policy at multiple levels. *NJAS – Wageningen Journal of Life Sciences*, *90-91*, 100296. doi: 10.1016/j.njas.2019.04.002

Flach, J. M., Stappers, P. J., & Voorhorst, F. A. (2017). Beyond affordances: Closing the generalization gap between design and cognitive science. *Design Issues*, *33*(1), 76–89. doi: 10.1162/desi_a_00427

Government, NL. (2018). *Dutch digitalisation strategy.* Retrieved on 19 February 2020 from https://www.government.nl/binaries/government/documents/reports/2018/06/01/dutch-digitalisation-strategy/Dutch+Digitalisation+strategy+def.pdf.

Grin, J. (2008). The multilevel perspective and design of system innovations. *Managing the transition to renewable energy: theory and practice from local, regional and macro perspectives, 47–80.*

Groenestein, C., Hutchings, N., Haenel, H., Amon, B., Menzi, H., Mikkelsen, M., … Webb, J. (2019). Comparison of ammonia emissions related to nitrogen use efficiency of livestock production in europe. *Journal of Cleaner Production*, *211*, 1162–1170. doi: 10.1016/j.jclepro.2018.11.143

Hancock, D. R., & Algozzine, B. (2017). *Doing case study research: A practical guide for beginning researchers.* Teachers College Press.

Hermans, F., Klerkx, L., & Roep, D. (2015). Structural conditions for collaboration and learning in innovation networks: Using an innovation system performance lens to analyse agricultural knowledge systems. *The Journal of Agricultural Education and Extension*, *21*(1), 35–54. doi: 10.1080/1389224x.2014.991113

Kleis. (2019). *Where is the vision for agriculture? – public policy expert candel: 'stop the quick fixes'.* Retrieved on 14 May 2020 from https://resource.wur.nl/en/show/Where-is-the-vision-for-agriculture-Public-policy-expert-Candel-Stop-the-quick-fixes-.htm.

Klerkx, L., Aarts, N., & Leeuwis, C. (2010). Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. *Agricultural Systems*, *103*(6), 390–400. doi: 10.1016/j.agsy.2010.03.012

Koch, A. (2017). Iot in agriculture-how is it evolving and which policy areas need ad-dressing to facilitate its uptake. *Farm Institute Insights*, *14*(1), 1–5.

Lamprinopoulou, C., Renwick, A., Klerkx, L., Hermans, F., & Roep, D. (2014). Application of an integrated systemic framework for analysing agricultural innovation systems and informing innovation policies: Comparing the dutch and scottish agrifood sectors. *Agricultural Systems*, *129*, 40–54. doi: 10.1016/j.agsy.2014.05.001

Leung, L. (20165). Validity, reliability, and generalizability in qualitative research. *Journal of Family Medicine and Primary Care*, *4*(3), 324.

Leusink. (2019). *Ammonia emissions in dairy farming continue to rise.* Retrieved on 13 May 2020 from https://www.agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2245&themaID=2282.

McEldowney. (2019). *Eprs | european parliamentary research service.* Retrieved on 03 March 2020 from https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/630358/EPRS_BRI(2019)630358_EN.pdf.

Moors, E. H., Fischer, P. K., Boon, W. P., Schellen, F., & Negro, S. O. (2018). Institutionalisation of markets: The case of personalised cancer medicine in the netherlands. *Technological Forecasting and Social Change*, *128*, 133–143. doi: 10.1016/j.techfore.2017.11.011

Ortiz, O., Orrego, R., Pradel, W., Gildemacher, P., Castillo, R., Otiniano, R., … Kahiu, I. (2013). Insights into potato innovation systems in bolivia, ethiopia, peru and uganda. *Agricultural Systems*, *114*, 73–83. doi: 10.1016/j.agsy.2012.08.007

Paschen, J.-A., Reichelt, N., King, B., Ayre, M., & Nettle, R. (2017). Enrolling advisers in governing privatised agricultural extension in australia: challenges and opportunities for the research, development and extension system. *The Journal of Agricultural Education and Extension*, *23*(3), 265–282. doi: 10.1080/1389224x.2017.1320642

Pigford, A.-A. E., Hickey, G. M., & Klerkx, L. (2018). Beyond agricultural innovation systems? exploring an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. *Agricultural Systems*, *164*, 116–121. doi: 10.1016/j.agsy.2018.04.007

Plecher. (2020). *Distribution of gross domestic product (gdp) across economic sectors in the netherlands.* Retrieved on 16 May 2020 from https://www.statista.com/statistics/276713/distribution-of-gross-domestic-product-gdp-across-economic-sectors-in-the-netherlands.

Rissman, A. R., Owley, J., LRoe, A. W., Morris, A. W., & Wardropper, C. B. (2017). Public access to spatial data on private-land conservation. *Ecology and Society*, *22*(2). doi: 10.5751/es-09330-220224

Rivera, W. M., Qamar, M. K., & Mwandemere, H. K. (2005). *Enhancing coordination among AKIS/RD actors: An analytical and comparative review of country studies on ag-ricultural knowledge and information systems for rural development (AKIS/RD).*

RIVM. (2020). *Greenhouse gas emissions in the Netherlands 1990–2018 National Inventory Report 2020.* Retrieved on 13 May 2020 from https://www.rivm.nl/bibliotheek/rapporten/2020-0031.pdf.

Ros, G. H., Janssen, H., Bartelds, N., & Holster, H. (2018). *Uitwerking concept MaxiMi: op weg naar resultaatgestuurd mestbeleid? (No. 2908)* (Tech. Rep.). doi: 10.18174/461897

Scott, T. A., & Carter, D. P. (2019). Collaborative governance or private policy making? when consultants matter more than participation in collaborative environmental planning. *Journal of Environmental Policy & Planning*, *21*(2), 153–173. doi: 10.1080/1523908x.2019.1566061

Spielman, D. J., Ekboir, J., Davis, K., & Ochieng, C. M. (2008). An innovation systems perspective on strengthening agricultural education and training in sub-saharan africa. *Agricultural Systems*, *98*(1), 1–9. doi: 10.1016/j.agsy.2008.03.004

Statista. (2020). *Number of animals in livestock farming in the netherlands in 2016.* Retrieved on 13 May 2020 from https://www.statista.com/statistics/617676/number-of-animals-in-livestock-farming-in-the-netherlands/.

Stokstad. (2019). *Nitrogen crisis from jam-packed livestock operations has 'paralyzed' Dutch economy.* Retrieved on 13 February 2020 from https://www.sciencemag.org/news/2019/12/nitrogen-crisis-jam-packed-livestock-operations-has-paralyzed-dutch-economy.

Susha, I., & Gil-Garcia, J. R. (2019). A collaborative governance approach to partnerships addressing public problems with private data. In *Proceedings of the 52nd hawaii international conference on system sciences.* Hawaii International Conference on System Sciences. doi: 10.24251/hicss.2019.350

Tanwar, S., Bhatia, Q., Patel, P., Kumari, A., Singh, P. K., & Hong, W.-C. (2019). Machine learning adoption in blockchain-based smart applications: The challenges, and a way forward. *IEEE Access*, *8*, 474–488. doi: 10.1109/access.2019.2961372

Tullo, E., Finzi, A., & Guarino, M. (2019). Review: Environmental impact of livestock farming and precision livestock farming as a mitigation strategy. *Science of The Total Environment*, *650*, 2751–2760. doi: 10.1016/j.scitotenv.2018.10.018

van den Broek, Hofwegen, G., Beekman, M., & Woittiez, M. (2007). Options for increasing nutrient use efficiency in dutch dairy and arable farming towards 2030: an exploration of cost-effective measures at farm and regional levels (No. 55). *Legal Research Tasks Nature & Environment*.

Veiligheidstechniek, Nederlands (VTN) Products. (2020). Retrieved on 14 May 2020.

Verbong, G., & Geels, F. (2010). Exploring sustainability transitions in the electricity sector with socio-technical pathways. *Technological Forecasting and Social Change*, *77*(8), 1214–1221. doi: 10.1016/j.techfore.2010.04.008

Verschuren, P., & Doorewaard, H. (2010). Designing a research project. In *Designing a research project: Project design* (pp. 1–25). Nijmegen: Eleven International Publishing.

Walrave, B., Talmar, M., Podoynitsyna, K. S., Romme, A. G. L., & Verbong, G. P. (2018). A multi-level perspective on innovation ecosystems for path-breaking innovation. *Technological Forecasting and Social Change*, *136*, 103–113. doi: 10.1016/j.techfore.2017.04.011

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences*, *114*(24), 6148–6150. doi: 10.1073/pnas.1707462114

Wang, J., Liu, Q., Hou, Y., Qin, W., Lesschen, J. P., Zhang, F., & Oenema, O. (2017). International trade of animal feed: its relationships with livestock density and n and p balances at country level. *Nutrient Cycling in Agroecosystems*, *110*(1), 197–211. doi: 10.1007/s10705-017-9885-3

Wilson, G. A. (2013). Community resilience, policy corridors and the policy challenge. *Land Use Policy*, *31*, 298–310. doi: 10.1016/j.landusepol.2012.07.011

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big data in smart farming – a review. *Agricultural Systems*, *153*, 69–80. doi: 10.1016/j.agsy.2017.01.023

Wolfert, S., Goense, D., & Sorensen, C. A. G. (2014, April). A future internet collaboration platform for safe and healthy food from farm to fork. In *2014 annual SRII global conference.* IEEE. doi: 10.1109/srii.2014.47

Yazan, B. (2015). Three approaches to case study methods in education: Yin, merriam, and stake. *The Qualitative Report*. doi: 10.46743/2160-3715/2015.2102

Yin, R. K. (2002). *Case study research: Design and methods.* Thousand Oaks, CA: SAGE Publications.

Zwartkruis, J. V., Berg, H., Hof, A. F., & Kok, M. T. (2020). Agricultural nature conservation in the netherlands: Three lenses on transition pathways. *Technological Forecasting and Social Change*, *151*, 119235 (12 p.). doi: 10.1016/j.techfore.2018.03.006