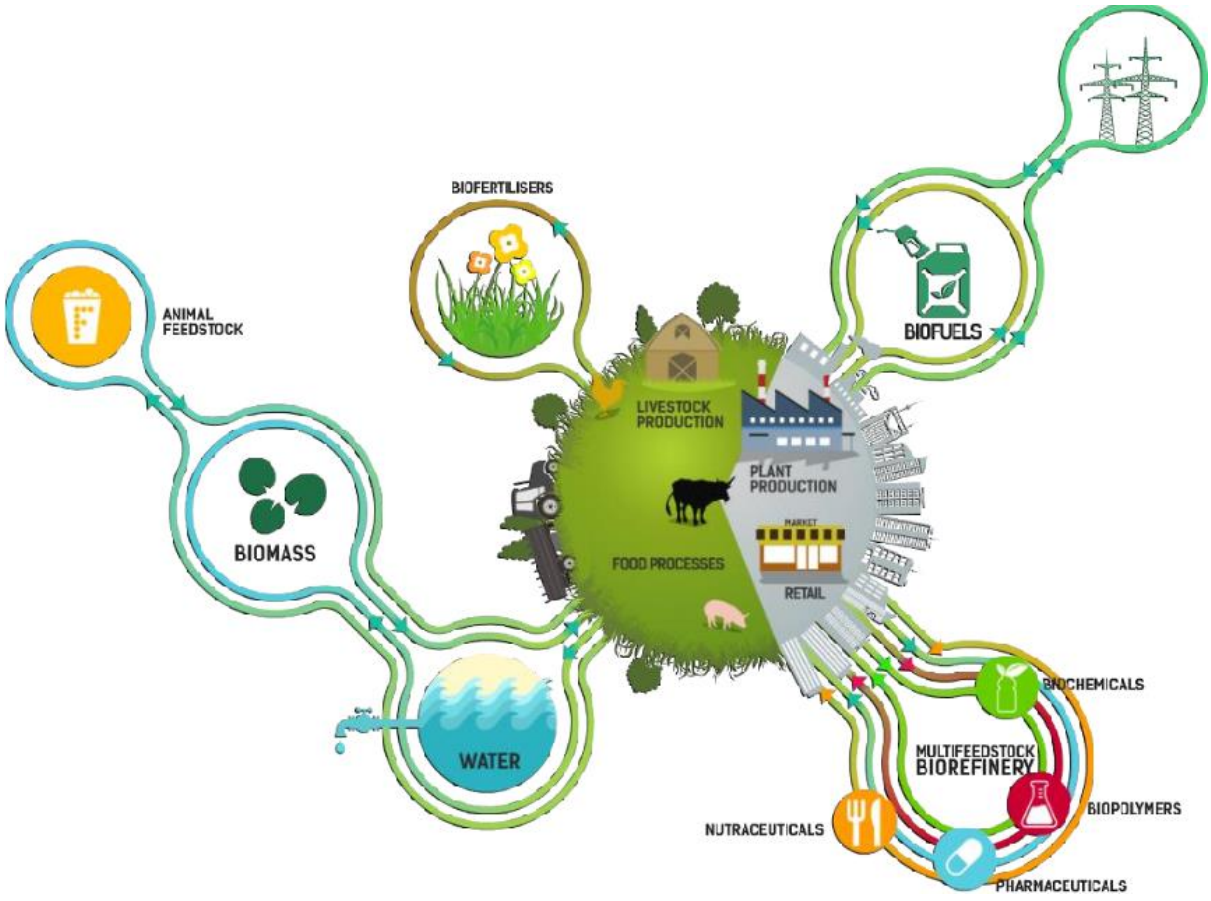
ACT project Group 2461

Building circular agri-food chains: Stimulating regional collaboration between arable and pig farmers

A consultancy report about a feed-manure exchange between Vallei Varken and arable farmers



Date: 26-06-2020
Coach: Gonja Hikspoors
Commissioner: Francien de Jonge
Team:
Tomas van der Heijden
Lisa Ligtermoet
Arjan Uijterlinde
Ferneau Ploumen
Sijin Chen
Zhao Zhao

Contact Information

Contact Details

Commissioner:
WUR Science Shop
Francien de Jonge
T: +31(0) 317-484577
E: Francien.deJonge@wur.nl

Team secretary:
Arjan Uijterlinde
T: +31(0) 623259047
E: Arjan.Uijterlinde@wur.nl

Source cover page illustration: (Toop et al., 2017)

Disclaimer:

"This report is produced by students of Wageningen University as part of their MSc-programme. It is not an official publication of Wageningen University or Wageningen UR and the content herein does not represent any formal position or representation by Wageningen University. "

Summary

This consultancy report explores the reconcilability of a feed-manure exchange between pig farmers of Vallei Varken and arable farmers in the region. Based on this research, recommendations will be provided to the Science Shop of the WUR (who commissioned this consultancy project) on consecutive steps in order to develop and foster such an exchange.

Vallei Varken is a cooperation between 3 livestock farmers, 2 pig farmers and 1 pig breeder, that aims to increase the sustainability, profitability and financial stability of their business through the establishment of a feed-manure exchange. Such a proposed feed-manure exchange, which includes arable farmers, fits well into the new but prevalent circular agriculture paradigm and should further develop the initiative of Vallei Varken. Namely, the exchange of by-production materials - crop residues and manure - between farmers has the potential to reduce the participation of intermediary parties and shorten the supply chain.

The corresponding research has been based on a literature review and on semi-structured interviews with 7 farmers (6 arable farmers), in which the latter method mainly focused on grasping the current state of Vallei Varken's feed and manure system, the terms and conditions and stimulating or hampering factors perceived by both pig farmers and arable farmers. The current feed and manure system of Vallei Varken is not optimal in terms of circular principles; feed is mostly sourced from feed company Agrifirm, and mainly imported from all over the world, and manure is – due to regulations - exported to unidentified arable farmers.

In light of the terms and conditions for a feed-manure exchange, both Vallei Varken's pig farmer as well as the majority of the interviewed farmer stressed the requirement of trust and loyalty. Next to a required foundation of trust & loyalty, arable farmers mention mutual financial benefits as a prerequisite. Since the quality and composition of pig manure varies and is by multiple farmers considered a hampering factor, clear numbers are mentioned as a term and condition. Due to the heterogeneous characteristics of the interviewed farmers, the meaning of the condition 'good' manure quality highly differs.

Furthermore, this variety of interviewed farmers leads to farmer dependent perceptions on several stimulating or hampering factors. For instance, pig manure quality and the proposed continuity & financial stability are both considered to have hampering and stimulating effects on farmers' willingness to participate. The notion that 4 out of 6 arable farmers already have a collaboration with a livestock farmer, is as well considered one of the hampering and stimulating factors. Moreover, attention will be paid to issues of acreage availability, lack of crop residues and underlying assumptions.

As a conclusion, most of the interviewed arable farmers have a positive attitude towards the establishment of a feed-manure exchange that fosters a local and circular system. However, expressed concerns by arable farmers about the quality and amount of manure may hinder their willingness to participate and should therefore be further explored.

Acknowledgements

Throughout the writing of this report, we have received great guidance from several people who have made this process more enjoyable and educational. We want to thank our coach Gonja Hikspoors for her great investment of time in this project and her helpful remarks. She enabled our team to work together smoothly and ensured that this process was engaging and pleasant for the whole collective. Francien de Jonge, our commissioner, who has been positive and supportive from the beginning onwards, we want to thank for her uncurbed enthusiasm about this topic. She was always available for comments and not once have we caught her without a contagious smile on her face. As such, she kept our spirits high. Evelien de Olde, our academic advisor, proofread several chapters and was a pivotal factor in the success of this work. Her critical but fair view improved our writing and thinking.

We also want to thank Jelle Beeren, process and project manager of De Kroes, and Koen Kelderman, sales manager at Agrifirm's pig department, who both forwarded us many contacts of farmers and as such drastically sped up the process of finding farmers that were willing to be interviewed. These farmers we want to thank for sparing their valuable time to us. Without them, this project would have been far less impactful.

Finally, we want to thank Gerald Deetman, head of Vallei Varken, and Gerard van Eijden, Vallei Varken's veterinarian, for their commitment to sustainability and their time spent informing us about their ambitions.

ACT-2461

Tomas van der Heijden; Sijin Chen; Ferneau Ploumen; Lisa Ligtermoet; Arjan Uijterlinde; Zhao Zhao (see appendix 11.1)

Content

List of abbreviations

NPK ratio	- Nitrogen, Phosphorus and Potassium ratio
LNV	- Dutch Ministry of Agriculture, Nature & Food Quality
GHG emissions	- greenhouse gas emissions
SOM	- Soil Organic Matter
NWC	- Nitrogen Working Coefficient

1 Introduction

The objective of this consultancy report is to provide the WUR Science Shop and Vallei Varken, a pig farm in Putten, Gelderland, with recommendations on how to effectively continue with the development of a collaboration between Vallei Varken and arable farmers to establish a feed-manure exchange. The recommendations consist of desirable consecutive research steps, which are based on the literature review and semi-structured interviews that were performed to write this report.

Vallei Varken is a cooperation between 3 livestock farmers, 2 pig farmers and 1 pig breeder, that aims to increase the sustainability, profitability and financial stability of their business through the establishment of a feed-manure exchange. Vallei Varken has already established a short supply chain with key market partners and sells fixed quantities of pork to supermarket chain Boni, catering company de Kroes and several regional butchers. The rest of the supply chain also consists of fixed partners that perform other key activities, such as transportation and pig slaughtering.

In order to further develop the initiative, Gerald Deetman, head of Vallei Varken and one of the 3 pig farmers involved, wants to establish a level of circularity within the supply chain. Manure is the main waste output of his farm and is currently transported to other unidentified farms. The manure supply chain is currently unexplored and does not consist of fixed partners that collaborate on a basis of trust. To valorise the manure and use it as a foundation of collaboration, Vallei Varken wants to cooperate with arable farmers that want to offtake the manure and apply it to their land to maintain soil fertility and ensure crop growth. In turn, Deetman wants to receive crops that do not enter the regular consumer market and crop residues that can serve as a feed input. With this exchange, Vallei Varken aims to develop a stable relationship with several arable farmers, which establishes an input-based interdependency between 2 farming systems. It is required that such a system generates more profit and stability for all involved stakeholders.

The proposed collaboration is based on principles that are strongly in line with the 2030 vision that was devised by the Ministry of Agriculture, Nature and Food Quality in 2019 (Rijksoverheid, 2019). To counter the environmental problems that are propelled by the currently unsustainable agricultural practices in the Netherlands, this vision calls for circular agriculture principles to be adopted by all actors within the Dutch food system. To attain circularity, it reports that a high level of collaboration between farmers and other agricultural stakeholders is required. Such a collaboration ideally happens within short agri-food supply chains, based on the valorisation of biomass waste streams. This requires a high level of integration between livestock farmers and arable farmers that can use each other's 'waste' as the main input to their farming systems.

1.1 Project aim & research questions

To fulfill the purpose and to close the knowledge gap, the following research questions are formulated:

To what extent are the terms and conditions for feed-manure exchange between arable farmers and Vallei Varken's pig farmers reconcilable?

To answer this main research question, the following sub questions will be answered:

a) Why is feed-manure exchange between livestock farmers and arable farmers important to stimulate agricultural circularity?
b) What is the current state of the feed-manure system of Vallei Varken's pig farmers?
c) What are the terms and conditions of pig farmers and arable farmers concerning feed-manure exchange?
d) Which factors do Vallei Varken's farmers and arable farmers deem as hampering or stimulating in fulfilling the terms and conditions?

Based on the current status of a potential feed-manure exchange with Vallei Varken, the purpose of the underlying research that has been carried out is to explore the reconcilability of terms and conditions expressed by arable farmers and pig farmers to engage in a feed-manure exchange. In order to analyse a potential collaboration in light of developments on circularity, chapter 2 serves as the theoretical background of the report. A definition that captures the emerging paradigm of the

circular economy is provided and the importance of circular agriculture is described, along with its defining principles. To map the current state of Vallei Varken in terms of supply chain flows and farm characteristics in chapter 3, a semi-structured interview was conducted with Gerald Deetman and his farm veterinarian Gerard van Eijden. Chapter 4 discusses the required integration of specialized arable farming systems with Vallei Varken and the possible effects this may pose on important farm variables, such as feed composition and soil fertility. Chapter 5 offers an analysis of the semi-structured interviews that were conducted with Vallei Varken and 6 arable farmers and particularly focuses on the terms and conditions they identify as important within a feed-manure exchange. The stimulating and hampering factors that respectively encourage or obscure the willingness of arable farmers to participate in an exchange are determined in chapter 6. After a conclusion and discussion of the results, the final chapter provides recommendations on consecutive steps to take by the Science Shop & Vallei Varken, which includes suggestions on future research possibilities.

2 Circular Economy and Circular Agriculture: Importance, Principles and Policy Landscape

This chapter aims to establish a theoretical groundwork for the Vallei Varken feed-manure exchange initiative. First, an operational definition of circularity is presented that has been adopted throughout the whole report. For this purpose, the defining differences between the principles and properties of the foundations of a linear economy and the emerging circular economy are briefly explained. Even though the theoretical core of circular agriculture is based on the defining characteristics of the circular economy, it has various distinctive principles that are solely geared towards the processing of waste streams that are typical of agri-food chains. These principles are elucidated in 2.2, after which 2.3 focuses on the national and EU level policy landscape that aims to stimulate the transformation of linear agri-food chains into less wasteful circular chains.

2.1 Emergence of the Circular Economy

Since the birth of the Industrial Revolution, the concept of linear economy has served as a foundation for dominant economic systems across many European countries (Rizos, Tuokko, & Behrens, 2017). Central to a linear economy framework are its intrinsic characteristics, which rely upon a take-make-dispose trajectory (MacArthur, 2013). This implies that raw materials are collected, transformed into products, and ultimately discarded as waste (Sariatli, 2017). Despite the substantial material wealth linear economic systems have generated for western European countries up until the 20th century, this consumption trajectory has not been without consequences (MacArthur, 2013; Sariatli, 2017). These practices have caused a myriad of environmental and socio-economic issues and cannot supply the growing global populace with essential services (Giampietro, 2019).

In response to these widespread issues, a circular economy framework has been developed to tackle problems caused by the linear economy. Although the application of circular economy in an economic model was first coined by Pearce and Turner (1990), the concept finds it origins in the 1960s (Geissdoerfer et al., 2017; Rizos, Tuokko, & Behrens, 2017; Sariatli, 2017). Boulding (1966), one of the founding fathers of a circular economy framework, analysed a shift to an enhanced cyclical, closed system. In consideration of the growing attention for alternative economic systems during the following years, the framework of circular economy orchestrated numerous theories and models that challenge predominating economic structures "based on the overconsumption of natural resources" (Rizos, Tuokko, & Behrens, 2017, p. 1), such as natural capitalism by Lovins, Lovins, and Hawken (1999), biomimicry by Benyus (1997) and industrial ecology by Lifset and Graedel (2002) (Foundation, 2017). The latter one, which consolidates energy and material flows of industrial systems, minimizes waste and takes into account both localized and global natural and social environments, has propelled the establishment of a new circular economy paradigm through stressing the immanent relationship between economy and environment (Foundation, 2017; Rizos, Tuokko, & Behrens, 2017).

Nevertheless, despite the large body of research dedicated to circular economy, consensus on how a circular economy exactly looks like, including specifications for all relevant domains, has not been reached yet (Korhonen et al., 2018). Moreover, due to the diverse backgrounds of the concept, definitions of circular economy vary across different disciplines (Kirchherr, Reike, & Hekkert, 2017; Rizos, Tuokko, & Behrens, 2017). In general, circular economy captures socio-economic models that go beyond a production-consumption-disposal trajectory (de Jesus et al., 2019). Accordingly, a circular economy is based on a reduce-reuse-recycle trajectory (Kirchherr, Reike, & Hekkert, 2017). Drawn upon the definition of Geissdoerfer et al. (2017, p. 759), within a circular economy "resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops". As argued by Ward et al. (2016), in a circular economy the concepts of waste and pollution do not exist as such, since all waste streams will be recycled and used as input for new products. In other words, "everything is an input to everything else" (Rizos, Tuokko, & Behrens, 2017, p. 1). In compliance with the three principles of "design out waste and pollution, keep products and materials in use, and regenerate natural systems", circular economic systems aim to minimize the ecological impact of production, while they generate positive impacts on economy, society and environment (Ghisellini, Cialani, & Ulgiati, 2016; Kjaer et al., 2019; MacArthur, 2013). Both creativity and innovative technologies, as well as cultural evolution and social inclusivity are required to drive and foster real transformative change towards a truly sustainable economy (Graedel and Allenby, 1995; Korhonen et al., 2018).

2.2 Importance of Circular Agriculture

In order to reach a circular economy all components of the economy have to adapt, which includes the agricultural sector. The emergence of the circular economy as a paradigm and the notion of circularity has become more prevalent in agricultural policies to reduce the negative consequences of the current food production system. Indeed, agriculture globally faces large and diverse challenges, which surround the limitations of the dependency on the input of finite resources and the negative environmental impacts of food production systems. Food production for the global populace degrades terrestrial and aquatic ecosystems, depletes water sources, and drives climate change (Godfray et al., 2010). This ultimately threatens the food supply for a growing global populace, which is estimated to reach 9 billion people in 2050.

Today's food supply chain is responsible for 26% of total anthropogenic greenhouse gas emissions. An additional 5% is caused by non-food agriculture, such as feed production (Poore and Nemecek, 2018). Additionally, the agricultural sector suffers from large nitrogen losses, which ultimately contaminate groundwater and surface water systems. As such, food production causes 32% of global terrestrial acidification and 78% of eutrophication, which results in the loss of ecological balance in natural systems (Poore and Nemecek, 2018). This can substantially impact biodiversity and ecological resilience (Röös et al., 2013). The farm stage is the most dominant in terms of pollution and waste and represents 61% of food's greenhouse gas (GHG) emissions, 29% of acidification and 95% of eutrophication (Poore and Nemecek, 2018).

The negative impacts of animal products considerably exceed those of vegetable substitutes (Poore and Nemecek, 2018). 83% of the world's farmland is used for meat, aquaculture, eggs, and dairy production. They contribute approximately 58% of food's different emissions and only supply 37% of protein and 18% of calories globally (Poore and Nemecek, 2018). Emissions from feed production often exceed emissions of vegetable protein farming. This is caused by the feed-to-edible protein conversion ratios that are greater than 2 for most animals, which reduces the energetic efficiency and increases environmental pollution (Tilman and Clark, 2014).

To reduce the issues that are caused by conventional agriculture, a large body of research is dedicated to identification of food production and consumption systems that are less environmentally polluting and reliant on intensive use of finite resources (Duque-Acevedo et al., 2020; Kremen, Iles, & Bacon, 2012). Circular agriculture tries to provide solutions for the issues that the current agri-food chain propels. It focuses on the decoupling of environmental pollution and agricultural food production, through maximization of resource use efficiency and waste stream valorisation (de Boer and van Ittersum, 2018; Jurgilevich et al., 2016). It is based on the principle of optimal use of biomass, which enables that waste streams of one supply chain can be used as raw materials for another. This eradicates the idea of waste at the end of the food chain. Due to the reduce-reuse-recycle trajectory it follows, the adoption of circularity principles within the agri-food chain has widespread implications for food production. The change towards circular agriculture involves a radical shift in the use of agricultural products and food processing residues (Thigssen, 2018). As such, circular agriculture aims to provide sufficient agricultural products to the growing world populace within the boundaries set by our planet.

Circular agricultural systems are based upon four main principles, as defined by de Boer and van Ittersum (2018):

The foundational principle is to safeguard natural resources, including soil, air, water, and biodiversity. Within agricultural systems, which can be achieved through the following 3 sub-principles:

1. Plant biomass should be consumed by humans first
2. By-products of the food chain should be recycled back into the food system
3. The use of animals in the food system should be optimized

In a system based on these principles, plants are the basic building blocks and arable land is primarily used to produce nutritious foods from crop biomass that fulfil human nutritional requirements (Van Zanten, Van Ittersum, & De Boer, 2019). The production and consumption of food from plant sources, a range of by-products are produced, such as crop residues and food waste. Unavoidable human edible by-products should be reused as human food, and not used for other purposes that are less energetically efficient. They should only be used for other purposes if options to use them

for human food are exhausted. Human food and human inedible food contain carbon and valuable nutrients that can be used to feed livestock or maintain soil fertility. This would reduce food-feed competition, which is induced by the production of feed crops on arable land that instead could be utilized for food production. 40% of the total available crop land globally and 1/3 of all cultivated grains are dedicated to feed production (Mottet et al., 2017).

Principle 2 and 3 necessitate that animals play a pivotal role in the construction of circular agri-food chains to recycle plant biomass that is not suitable for direct human consumption. This requires large integration between livestock farming systems and arable farming systems. The choice of future crops and the rotations in which they are cultivated should be based on the potential they have to feed humans and the non-food value that they possess for farm animals or soil enrichment. The precise value of each by-product that is generated in the agri-food chain for either feed or the soil is a new and evolving area of research (van Hal, Weijenberg, et al., 2019; Van Zanten, Van Ittersum, & De Boer, 2019).

2.3 Policy Landscape of Circular Agriculture

Since the 1990s, the concept of circular economy has experienced a tremendous increase in popularity (Ghisellini, Cialani, & Ulgiati, 2016; Vanner et al., 2014). The representation of the concept in the European Circular Economy package, the European Commission's Work Programme 2017 and the Horizon 2020 research and innovation programme shows the widespread importance on the agenda of many policymakers, especially within in the EU (Commision, 2016; Commission, 2015). In conjunction with efforts of the European Union towards a circular economy, the Dutch government has committed itself to the ambitious objective of a fully circular economy by 2050.

Both within the EU's and the Dutch circular economy policy programmes, agriculture is an important sector. The Netherlands want to become a leader in circular agriculture by 2030 (Rijksoverheid, 2016). In order to realize this vision, the Ministry of Agriculture, Nature and Food Quality (LNV) published a report with the main objectives and policies it wants to introduce (Rijksoverheid, 2019). It highlights that it wants to construct a food system that produces in an economically and ecologically viable way, which promotes biodiversity and farm profitability. The report emphasizes the importance of local fertilizer supply chains for arable farmers, composed of crop residues, organic manure, compost, and industrial by-products. Regarding feed, human-inedible by-products and crops (grass) should be used to the greatest degree and are preferably derived from local agri-food chain waste streams. Moreover, it prioritizes collaboration within regions and agri-food chains, supports the shortening of agri-food chains, and aims to valorise waste streams.

Hence, these developments show the increasing scientific and political interest in a circular economy paradigm and in a circular agricultural system. However, the operationalization of these concepts and principles within the daily reality of arable farmers and livestock farmers requires the adjustment of a range of farming practices. Moreover, the current organization of the supply chain of Vallei Varken is required to change in order to adopt arable farmers as key partners.

3 Description of Current State of Feed-Manure System Vallei Varken

In order to map the current state of Vallei Varken's feed-manure system, this chapter starts with a detailed introduction on the structure of Vallei Varken as an initiative. After an outline of all partners involved, the specific feed and manure flows are discussed. Additional representative visuals of the current system and the desired situation offer a quick and comprehensible overview of the present and desired future supply chain.

3.1 Introduction Vallei Varken

Vallei Varken is a partnership between three different pig farms in the region of Gelderland, the Netherlands. One farm provides the other two farms with piglets, which in turn fatten the pigs. Vallei Varken has 6.000 fattening pigs in total: 4.000 on one farm and 2.000 on the other farm. The breeding farmer has an additional number of 600 sows. One of these fattening farms is operated by Gerald Deetman, the founder of Vallei Varken. Until ten years ago, Deetman owned a conventional pig farm with a closed system in Putten, which he took over from his parents. Since his pigs were suffering from various health-related problems, he realized that a different mode of farming was required. Gerard van Eijden, his farm veterinarian, assisted Deetman to tackle these problems. As part of the new plan, keeping offspring of one pig together throughout their lifetime led to a reduction of antibiotics use in the next year. Since Vallei Varken's pigs have both more space to perform natural behaviour and more access to play with materials compared to conventional pig farms, as well as the non-castration of piglets, this pork meat acquired a 'Beter Leven 1-star label'. Efforts to improve the health of pigs became the core of the new farming style and are still of great importance for the entire Vallei Varken chain (Deetman, 2020b).

The establishment of Vallei Varken stems from the desire to improve the entire pork supply chain. A close collaboration between different actors, which ranges from transport companies to retailers, enables to disclose and solve underlying issues in the entire value chain. For example, price fluctuations are a common but often problematic phenomenon experienced by many actors within the agricultural sector. In order to offer a form of continuity and stability, Vallei Varken employs fixed costs prices (which include labour costs) that are revised every 3 months. This financial model stimulates all actors involved to actively work on the quality of the products instead of increasing margins. Secondly, the low level of maximized carcass utilization is a serious problem within the pig husbandry. Maximized carcass utilization refers to the optimal sale and consumption of all components of the animal, which is of major importance for the concept of circularity. In comparison to a maximized carcass utilization of 50% percent with conventional sales channels, Deetman increased this number to 78% as a result of a different pig breed and Vallei Varken's short supply chain sales (see Figure 1) (Deetman, 2020b).

Vallei Varken consists of many different actors, which are depicted below. The majority of pork meat is sold to Boni, a large supermarket in the Netherlands, de Kroes, a butchery and catering company, and Boerenhart, a cooperation in local food products. These actors form together with the pig farms, slaughterhouse and consumers, the core of the collaboration (see Figure 2 – in Dutch). The outer ring represents the participation of, among others, a transport company, veterinarian and feed company. Ultimately, Vallei Varken aims to incorporate all stakeholders within the partnership in order to develop and propagate one shared vision on a short supply chain regarding quality and circularity (Deetman, 2020b).

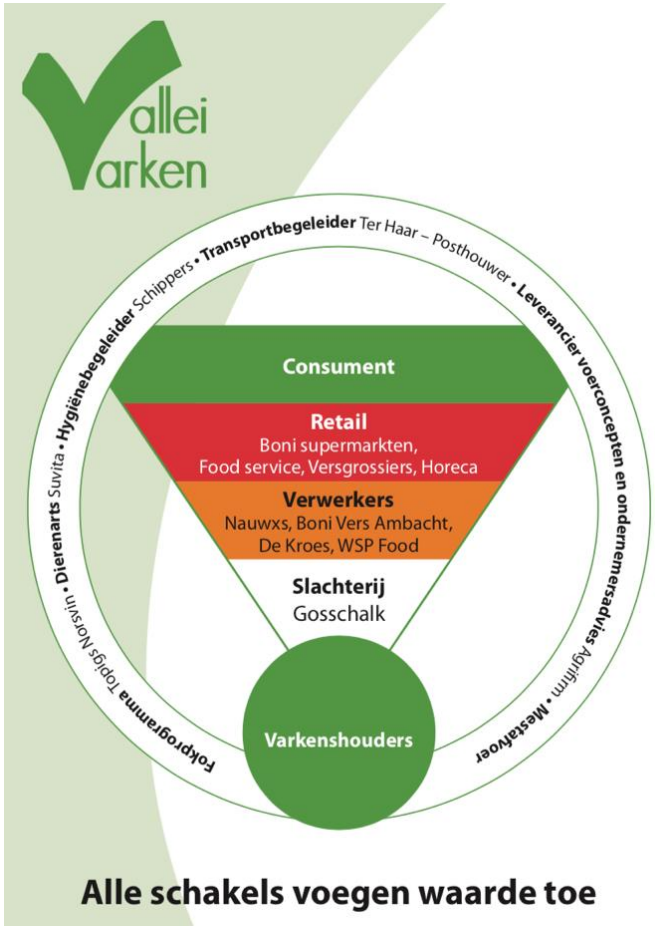


Figure 1: The current supply chain of Vallei Varken

Figure 2: poster by Vallei Varken

3.2 Vallei Varken's current feed and manure system

The feed for Vallei Varken's pigs is currently sourced from major feed company Agrifirm, which tries to meet the requirements of the farmers in such a way that the pigs grow most efficiently. Agrifirm is a Dutch cooperative enterprise in the agricultural and livestock sector, spread across the world. The feed for Vallei Varken is currently produced in factories located in Zwolle and Veghel (Deetman, 2020a). Next to the provision of pig feed, Agrifirm offers entrepreneurial advice to agricultural companies, including Vallei Varken.

Vallei Varken approximately uses about 100 tons of feed per week (all 3 farms). The pigs are mainly fed with a mixture of concentrates and waste streams, which approximately accounts for 40-50% of the feed (Deetman, 2020b). An energy rich waste stream from human food production is used in the concentrates which originates from the Netherlands. Furthermore, the concentrates consist of barley, wheat, corn, soybean meal, turnip meal, sunflower meal, palm oil, and soybean oil. These raw materials come from the ports in Amsterdam and Rotterdam, which in turn are imported from all around the world. Where the materials are bought is dependent on the current price (Deetman, 2020a)

The concentrate feed is adjusted to the specific needs of the pigs. Different breeds and the age of the pig are of influence on the specific desired composition of the concentrates, which is also the case for Vallei Varken. In order to ensure that the concentrates are plentiful, they are bought 3 months in advance (Kelderman, 2020).

In Figure 3 the current system has been visualised as a flowchart. As will be further elaborated upon in chapter 4, manure of Vallei Varken's pig farmers has to be removed from their farms in order to comply with the Dutch regulations for farmers. Deetman produces, combined with the other 2 pig farmers, a total amount of 7.000 cubic meters of manure per year. Since one of the pig farmers utilizes 1.000 cubic meters of manure on his own fields, annually 6.000 cubic meters of manure is transported by Schoonhoven Mesttransport. In addition, Deetman has a manure storage capacity of 1.200 cubic meters on his own farm (Personal communication, Deetman & van Eijden, 8 June 2020). The manure distributor, Schoonhoven Mesttransport, stores its manure in Kraggenburg, Flevoland (Deetman, 2020a).

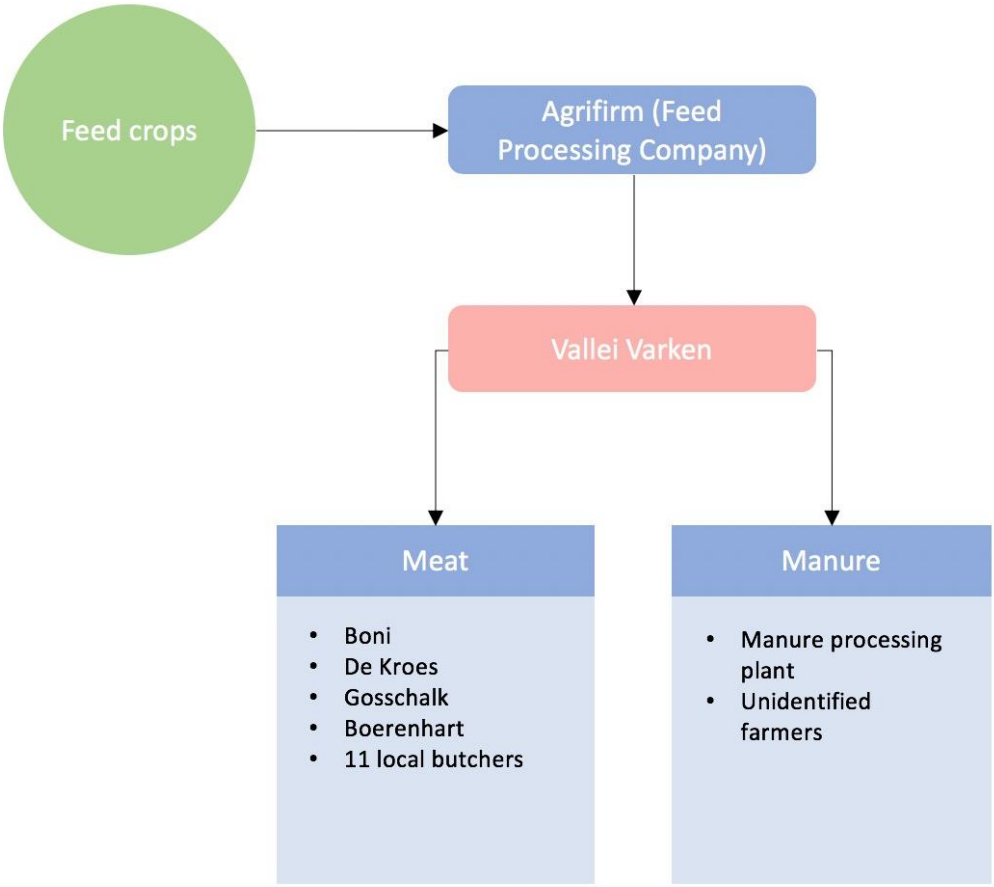


Figure 3: The current feed and manure supply chain of Vallei Varken, in which the main feed input are feed crops from unidentified farmers and the manure is bought by unidentified arable farmers.

3.3 Ideal Supply Chain of Vallei Varken

Based on Vallei Varken's existing feed and manure system, the next step towards reaching a more circular system is to establish a third ring that includes the integration of arable farmers for a feed-manure exchange.

The desired supply chain of Vallei Varken will foster the connection between different stakeholders, while reducing the involvement of external actors. Compared to the existing situation, the main difference is the flow of manure and the composition of feed. The new supply chain aims to boost the reuse of resources and the exchange of manure for feed. Arable farms are thus an essential actor and should be involved in the Vallei Varken initiative. Through their involvement, both manure streams and food production residues are efficiently utilized, which are all conducive to the establishment of a circular supply chain. The production of arable farms will be divided into two streams: feed and residues will be partly sold to the feed company, and grains and vegetables will be partly sold to the food production sector for processing only. The waste generated in this process can also be provided to the feed company as input for pig feed for Vallei Varken.

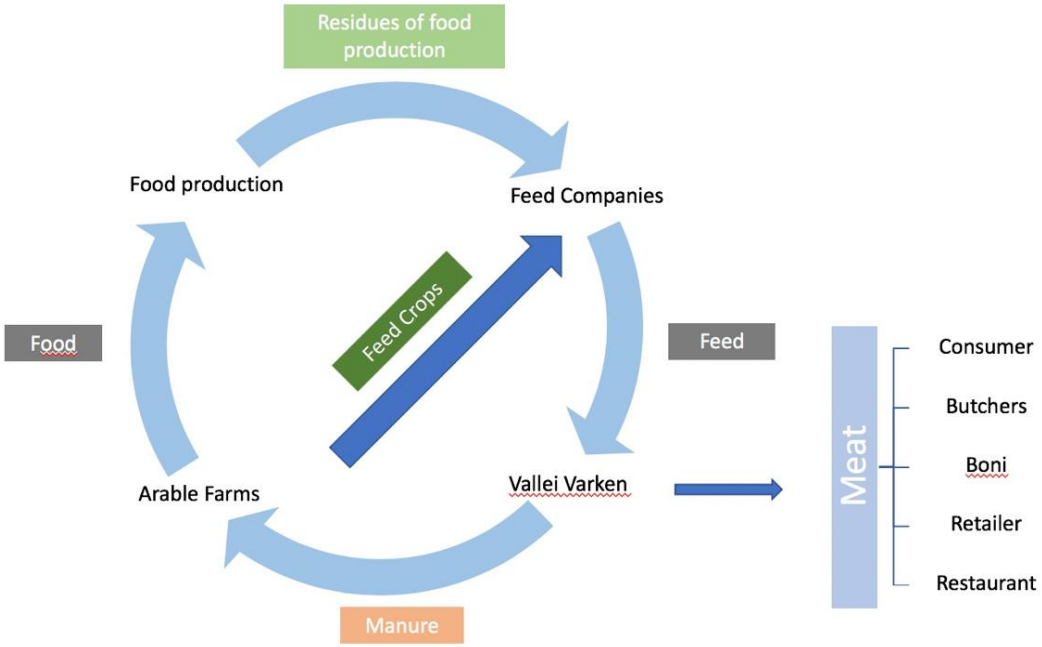


Figure 4:The desirable future supply chain of Vallei Varken, in which arable farms are included that produce a considerable part the feed. Their feed crops are transported to Agrifarm (indicated by dark blue arrow), which processes it into feed that is suitable

Thus, a proposed feed-manure exchange that benefits both Vallei Varken and regional arable farmers requires a sound understanding of what both parties require from each other in terms of collaboration ethics, feed quality and quantity, and manure quality and quantity. Such reconciliation requires a beyond farm level integration of 2 specialized farming systems in terms of their most important energetic inputs to maintain soil fertility and crop performance and pig health and pork quality.

4 Feed-Manure Exchange Between Arable Farming Systems and Vallei Varken: Farm Integration and Variables

Within this chapter, a brief description of farm specialization and the newly arisen need for farm integration to increase sustainability is provided. Consecutively, in order to address the insecurities that exist regarding the integration of pig farming and arable farming, this chapter describes the different variables that are possibly affected by it. The relationship between pig feed and manure quality is elaborated upon and the effects of manure quality on soil fertility and crop performance are illuminated. Differences in the state of these variables should be accounted for, because they can affect several partners within the Vallei Varken supply chain.

4.1 Specialized agricultural systems

Vallei Varken mainly wants to incorporate by-products, such as potato peels, crops of non-marketable quality, such as low-quality grains, and crop residues into the feed. Vallei Varken does not yet want to focus on the utilization of waste streams, such as brewery spent grain or bakery waste grain. As such, the proposed feed-manure exchange does not fully fulfil the circular agricultural principles as defined by de Boer and van Ittersum (2018).

Vallei Varken's initiative intends to valorise waste streams and shorten input and output value chains, which increases local collaboration and knowledge-sharing and reduces transport movements and associated GHG emissions. Such an exchange necessitates extensive integration between livestock farming systems and arable farming systems in order to calibrate the needs and desires of both parties in terms of required feed composition and manure quality. Moreover, the other stakeholders are also closely involved, because the final quality of pork and crops affects all actors along Vallei Varken's supply chain that are dependent on the agricultural products

The circular agriculture report published by LNV stresses that regional collaboration, shortening of supply chains, and the integration of arable farming systems and livestock farming systems are pivotal components of circular agriculture (Rijksoverheid, 2019). Due to such integration, specialized farming systems are inclined to become more interdependent, as feed and manure in a circular agricultural system form the energetic backbone of the integration of livestock farming systems and arable farming systems. These connections can enable the reuse and recycling of by-products derived from different stages of food production, processing and consumption.

Farming systems in the Netherlands have also become increasingly specialized. Already in the 16th century, agricultural districts came into existence in the Netherlands, based on their production potential of products such as cheese, milk and crops. Especially after the 1950s, most holding specialized in either arable farming or milk production. The mixed farms in the sandy regions of the Netherlands, where arable production serve the diet of on-farm livestock, became dairy farms, pig fatteners or poultry keepers. Since the 1960s, traditional mixed farming systems that provided their own feed and manure, made way for specialized farming systems (Bieleman, 2010).

Agriculture advisory officers started to propagate the idea of specialisation among farmers on mixed farms. Pigs and poultry could be kept without any farming land at all, as fodder could be imported and purchased. Simultaneously, a process of scaling up and supply chain reorganization occurred. Within the pig farming supply chain, many economic sub-sectors came into existence that specialized on a particular part of the process, such as breeding and fattening and dealers and transporters who took care of the export of pigs (Bieleman, 2010). When creameries started to focus more on the production of cheese the volume of skimmed milk diminished, and less high protein feed became available to the pig farming sector. 60-80% of national pork production was dependent on imported feed stuff, often from tropical origin. At the same time, arable farmers increased their artificial fertilizer use and manure surpluses were created due to the increasing intensity of livestock farming in the Netherlands. Manure was transported to parts of the country that had less livestock farming activity, resulting in more transport movement and associated GHG emissions.

The decoupling of global crop and livestock systems and the increased adoption of specialized, intensive cropping and livestock operations causes many undesirable social and ecological outcomes (Naylor et al., 2005). On the cropping side, specialized systems are characterized by synthetic inputs to reduce pests, decrease weed pressure and manage nutrient availability, and frequent tillage. This leads to pollution, rising costs of production, waste accumulation, and increased GHG emissions (Kleinman, Pimentel, & Bryant, 1995).

Paradoxically, despite the potential of integrated farms to improve the sustainability of farming operations, the number of crop-livestock farms is declining throughout Europe (Martin et al., 2016). Crop-livestock integration beyond the farm level may solve this issue. For instance, groups of local farmers can exchange materials such as grain, straw and manure. The development of collective agricultural systems raises questions about how to shape crop-livestock integration among different farms, impacts, consequences and conditions that are created by such integration (Martin et al., 2016).

Integrated agricultural systems promote ecological interactions over space and time between system components (e.g., crops, grasslands, and animals). Moreover, they create opportunities for synergistic resource transfers between them (Kremen, Iles, & Bacon, 2012). They offer opportunities to substitute technologies, such as synthetic inputs. However, inputs that are adjusted due to beyond farm level integration and collaboration affect individual farm functioning. A change in fertilizer quality, for instance due to the adoption of higher manure use, influence soil fertility and nutrient mineralization rates, which ultimately affects crop performance.

4.2 Manure

4.2.1 Emission reduction

In the Netherlands, pig production farms are required to limit their ammonia emissions by using an air scrubber (Starmans and Hoek, 2007). These air scrubbers make use of water in combination with a packing material with a large porosity. The water is trickled upon the packing material and the air is sucked through this packing material. In turn, the air has to pass through a curtain of water that is either around a pH of 7 or altered to a pH of 4. The water reacts with the ammonia that is in the contaminated air and the ammonia (NH3) will be dissolved in the water and becomes ammonium (NH4). The water that contains a high amount of ammonium, 2.1 moles per litre washing water, will be stored and is allowed as an inorganic fertilizer for the agricultural sector (Veerman, 2005; Vonk et al., 2012).

4.2.2 Policy

Currently, manure is removed from livestock farms in order to comply with the Dutch regulations for livestock farmers (Rijksoverheid, 2020). These regulations state that every farm has a mineral balance and cannot exceed the limitations on the several elements contained by the manure. The amount of manure that has to be removed from the pig farms is determined by the amount of land the farmer owns. The manure surpluses are transported to other farmers, usually arable farms, who are allowed to take in more manure than they currently produce or have in storage (Rijksoverheid, 2020). Under the current regulations, a maximum of 170 kg nitrogen of animal manure is allowed to apply on 1 hectare (Rijksoverheid, 2020).

The current system uses manure distributors, which link arable farms to animal husbandry farms in order to balance the mineral equation of both farms. The scope of these distributors is nationwide, which implies that manure from the south of the Netherlands can be transported to the north in order to balance it. This causes major transport movements without a large focus on local needs and possibilities for cooperation (Leenstra et al., 2019; Rijksoverheid, 2020).

4.2.3 Manure types

A problematic characteristic of pig manure is the uncertainty and variability of its NPK ratios. The NPK ratios in the manure are dependent among others on the growing stage and feed intake of pigs (van Bruggen et al., 2010). This causes some deviations in NPK ratio’s between farms and even between barns on the same farm. As indicated in Table 1, the type of pig farm – fattening or breeding – has impact on the specific composition of manure. For instance, liquid manure of fattening pigs

contains more kg nitrogen per ton compared to liquid manure of piglets. As Vallei Varken wants to make use of both the manure of fattening and pig farms, these differences need to be taken into account.

Furthermore, the manure settles over time in the slurry pit. This leads to different layers in the manure with different ratios, which is problematic for arable farmers (Timmerman and Smolders, 2002). The manure is sampled before the transport movement; five samples are taken from the whole truck, which serves as the basis for the determination of the NPK ratios (Timmerman and Smolders, 2003). However, it takes some time before these samples are tested on NPK ratios. Furthermore, these ratios can highly differ between truckloads as well (Hoeksma and Boer, 2005). Since the manure probably has already been applied on the field when these ratios in the manure are known, the farmer cannot correct for these values anymore. This gives a lot of uncertainty to the importer. Techniques like Near-InfraRed (NIR) which can determine the nutrients real-time are being developed, but have not been approved yet (Zedde, Kekem, & Boer, 2014).

Table 1: summarized from https://www.rvo.nl/sites/default/files/2019/04/Tabel-5-Forfaitaire-stikstof-en-fosfaatgehalten-in-dierlijke-mest-2018.pdf

Animal	Description	Manure code	Kg nitrogen per ton	Kg phosphate per ton
Pigs	Straw manure	40	8,1	8,0
	Filtrate after manure separation	41	6,8	1,6
	Slurry	42	2,0	0,9
	Solid fraction	43	25,7	21,4
	Liquid manure piglets	46	3,8	2,4
	Liquid manure fattening pigs	50	6,4	3,8

4.2.4 Manure Processing

A number of manure processing technologies have been developed and are outlined by (Foged et al. (2012). These technologies can roughly be categorized into two main streams; the primary separation and the secondary separation. When making use of primary separation, the faeces and the urine are separated at the source. The secondary separation uses the slurry of the animals to separate it mechanically. When this is done, two products are produced: effluent and solid fraction (Dijk and Galama (2019).

4.3 Feed

4.3.1 Pig Feed

Animal feed is an integral part of a circular agricultural system. As mentioned before, livestock can use by-products that humans are unable or unwilling to consume as food, thereby converting them into valuable products. The selection of feed ingredients affects the overall pig health and performance. A high-quality diet enables pigs to endure stressors associated with disease. A safe and nutritionally balanced feed composition is a preventative measure to help animals cope with pathogens. The overall animal health & welfare status is enhanced through specific feeding strategies, feed composition, feed formulations or feed processing (van der Werf, Petit, & Sanders, 2005).

As feed usually contributes to more than 60% of the total costs in pig farming systems, practices to limit these expenses have received more attention during the last years (Sauvant et al., 2011). Pigs are omnivorous animals that are able to digest almost all plant-based components, various residues or leftover foods, such as bread, other grains, vegetables and fruits. Traditionally, pigs were mainly fed with food or leftovers produced by households to increase the value of by-products ("Feeding by-products to pigs," 2018).

However, due to the low dry content matter of food waste, it cannot be solely used to satisfy pigs' mostly high nutritional requirements, or it can be fed to low productivity animals (van Hal, de Boer, et al., 2019). Feeding these animals special pig feed would be best to maintain and foster their growth rate (van Hal, de Boer, et al., 2019). As the quality of pig feed affects the quality of the final product, adding high-quality food waste to pig feed, which necessitates an increase in the share of

cereal by-products, is essential to meet the higher nutritional requirements (van Hal, de Boer, et al., 2019). Grain cereals serve as a good source of pig feed, and if they are cracked, rolled or soaked, pigs can digest and absorb them optimally (Hawton, Bache, & McKenzie, 2019). The main ingredients of pig feed are wheat, barley and lupine, but sometimes other grains such as peas and triticale are also used (Mekbungwan, 2007).

4.3.2 Alternative Feed Products

Livestock production is essentially the process of converting biomass into livestock. In this process, it is crucial to reduce waste and environmental pollution. Nowadays, feed production takes up a high number of land resources and generates a serious amount of waste and pollution, which runs counter to sustainable development (Poore and Nemecek, 2018; van der Werf, Petit, & Sanders, 2005). There are many benefits to using by-products and high-yielding crops as pig feed. First, by-products with high nutritional value can provide pigs with sufficient nutrition, while those with low nutritional value can be returned directly to the soil (van Hal, de Boer, et al., 2019). In this way, by-products can be fully utilized to transform into useful resources. Secondly, using by-products as feed can save land resources and put more land into the production of human edible crops. Finally, making full use of by-products can promote the establishment of circular agricultural systems (van Hal, de Boer, et al., 2019). Overall, feed plays an important role in establishing the circular integration of crop and livestock farms.

4.3.3 Feed-Manure Relationship

From the perspective of circular agriculture and integration between arable and livestock farming system, crop farms can provide grain, residues and food waste to pig farms as animal feed. In exchange, arable farmers can get pig manure as fertilizer. In addition, there is mutual influence between the exchange of feed-manure. High-quality feed determines the quality of animal products and manure to a certain extent. Conversely, manure with high nutrient content facilitates the growth of crops and improves food and feed quality (Asai et al., 2018). In a circular system, the exchange of feed and manure can be a win-win method for crops and livestock farms, while also improving circularity and promoting sustainable development.

The impact of feed on the environment is mainly affected by its composition. Compared with feed composed of unprocessed crop ingredients, feed that mainly contains by-products consumes more energy but has lower terrestrial ecotoxicity (van der Werf, Petit, & Sanders, 2005). The choice of raw material does not only affect the feed characteristics of pigs, it also affects the impact of animal feed on the environment (Strid Eriksson et al., 2005).

4.4 Soil

This section provides some background information about the soil on which the arable farmer grows its crops. Subsequently, the role of the soil in combination with the livestock manure is briefly mentioned.

4.4.1 Soil Types

The Netherlands consists of around 280 different soil types. These soils are classified based on the soil set-up, organic matter content, texture, and particle size (Silvis and Voskuilen, 2016). Every soil is set up from a basis of sand, silt and clay. As a result, soils can be classified as seen in the figure below (Nemes and Rawls, 2004).

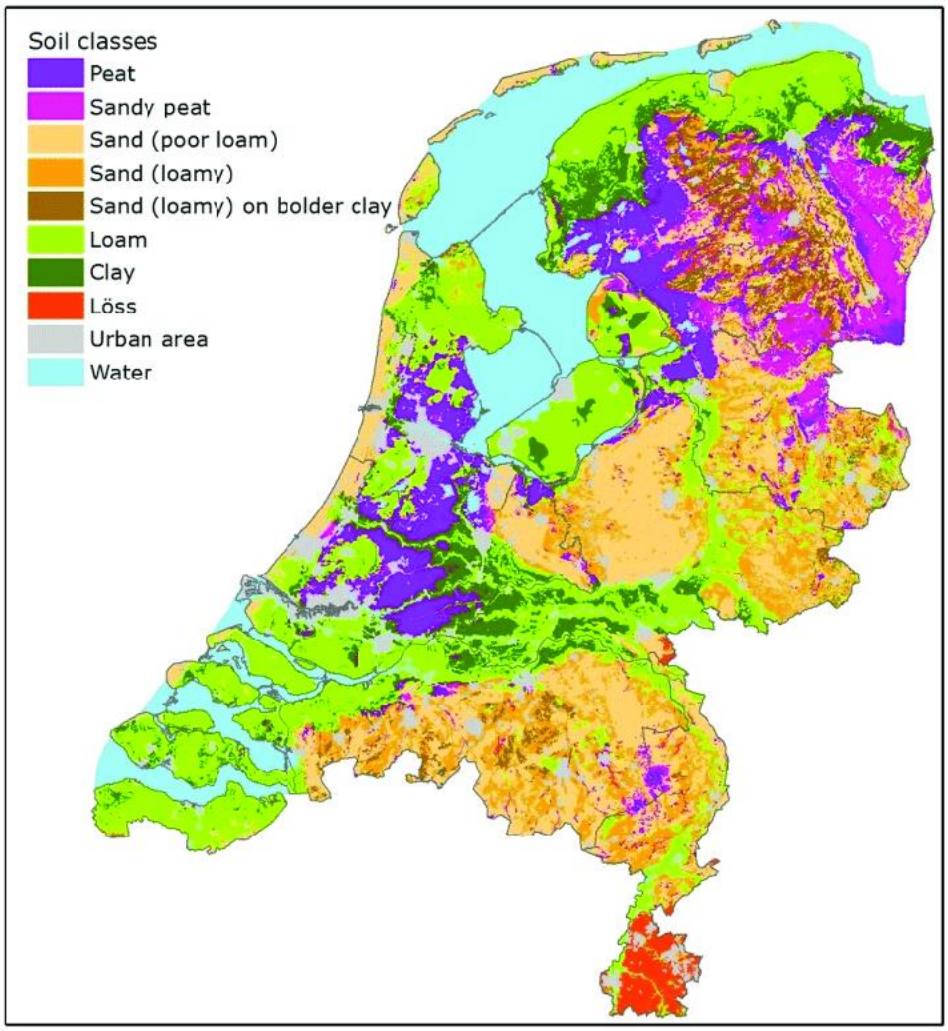


Figure 5 Soil map of the Netherlands (Van den Berg et al., 2017).

4.4.2 Soil Quality

The quality of the soil is besides water and air quality, one of the main components of environmental quality (Andrews, Karlen, & Mitchell, 2002). Unlike water and air quality, soil quality is not solely defined in terms of pollution. However, it plays a key role in the decision-making process on the treatment of the soil (Doran and Parkin, 1994). The figure of Bünemann et al. (2018), as depicted below, illustrates the different indicators used to determine soil quality. The total organic matter content is the most frequently used indicator, followed by soil structure and water storage capacity. These indicators are, like organic matter content, connected to the service of biomass production. However, the soil structure and water storage capacity are also both linked to the threat of soil compaction.

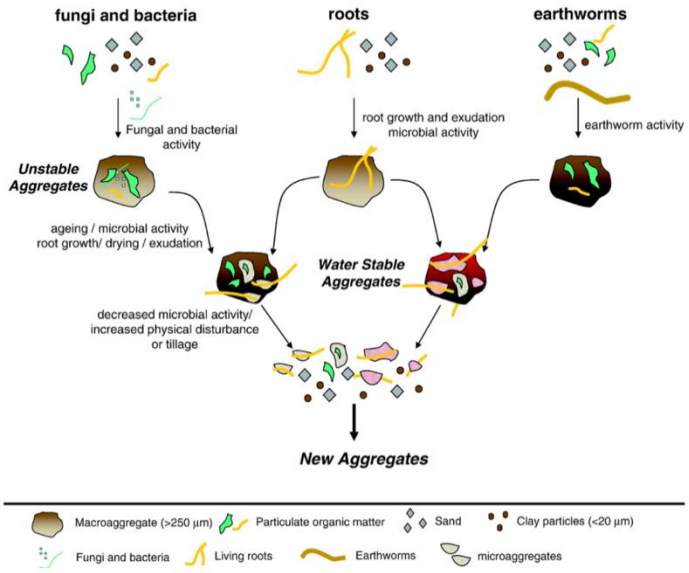


Figure 6: Mechanism of soil aggregate formation. Showing the influence of the three groups present in the soil (Six et al., 2002).

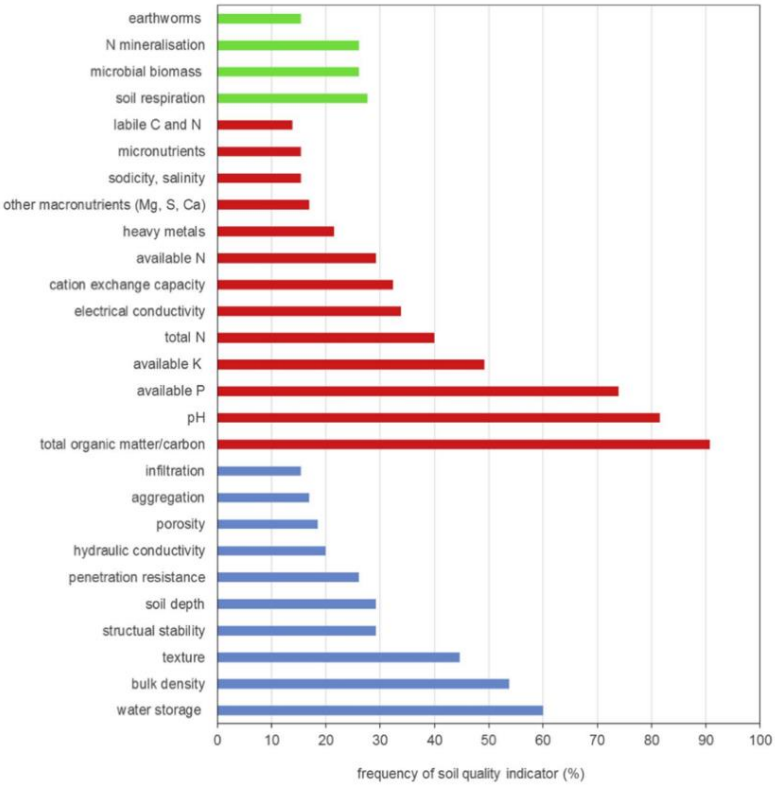


Figure 7: Frequency of review appearance of different soil quality indicators (Bünemann et al., 2018).

4.4.3 Soil-Manure Relationship

When the essential nutrients for plants, such as nitrogen, phosphorus and potassium are not sufficiently available in the soil, the plant will show deficiency symptoms (Uchida, 2000). In order to maintain a certain nutritional value of the soil, these nutrients have to be added. This is done by adding products which contain these nutrients and can be taken up by the plant. These nutrient requirements have to be met in order for the plant to reach up to its full potential (Barber, Walker, & Vasey, 1963).

Artificial fertilizer and manure are two products which contain high quantities of these nutrients. In many countries a combination of artificial fertilizer and manure is used in order to boost the production of plants and grow crops. The nutrients in manure have to be mineralized and made available for the plant to take it up (Eghball et al., 2002). Artificial fertilizer already contains the mineral version of the nutrient and can be taken up by the plant immediately. This is an advantage for artificial fertilizer over the use of regular manure. The plant immediately has the right nutrients at the right time (Van Zanten, Van Ittersum, & De Boer, 2019). This can potentially increase yield and decrease the nutrient runoff at the same time. This is due to the Nitrogen Working Coefficient (NWC) of 100% (Dijk et al., 2004). The NWC of manure is lower as the nitrogen comes in two forms: N-mineral and N-organic. N-mineral has the same NWC as artificial fertilizer. However, the N-organic has a lower NWC. This is due to the mineralization process mentioned before.The plant immediately has the right nutrients at the right time(Van Zanten, Van Ittersum, & De Boer, 2019). This can potentially increase yield and decrease the nutrient runoff at the same time. This is due to the Nitrogen Working Coefficient (NWC) of 100% (Dijk et al., 2004). The NWC of manure is lower as the nitrogen comes in two forms: N-mineral and N-organic. N-mineral has the same NWC as artificial fertilizer. However, the N-organic has a lower NWC. This is due to the mineralization process mentioned before.

5 Terms and Conditions of Pig and Arable Farmers

In this chapter the terms and conditions of the different interviewed farmers regarding a potential feed-manure exchange with Vallei Varken will be discussed. In order to clearly present these individual terms and conditions, they will be categorized into main themes.

5.1 Trust and Loyalty

The initiator of Vallei Varken, pig farmer 1, points out that trust and loyalty are the building blocks of a potential feed-manure exchange. A collaboration build on trust and loyalty should prevent that participating arable farmers immediately withdraw from Vallei Varken's initiative when the circumstances are changing. In particular, a manure price increase on the conventional market could threaten the involvement and loyalty of arable farmers.

Nevertheless, farmer 2 acknowledges that a foundation of trust is crucial. In the past, farmer 2 tried to establish a manure trade with a livestock farmer in the area. Up to now, these attempts have not been successful, with a lack of trust and loyalty as one of the determining factors. The arable farmer created agreements multiple times, but when the livestock farmer could get more money for his manure anywhere else, the farmer broke the agreement and prioritized financial benefits over loyalty and cooperation. Therefore farmer 2 considers a collaboration with Vallei Varken attractive under the condition of mutual trust. Similarly, due to negative experiences regarding a previous manure exchange, farmer 7 considers trust a prerequisite condition for a potential collaboration with Vallei Varken.

More specifically, farmer 4 stressed how trust and loyalty play a vital role on product quality in a proposed feed-manure exchange. Since the quality of pig manure is an issue for multiple arable farmers (see chapter 6), farmer 4 mentioned that trust could function as assurance for the delivery of high-quality – constant - specialized manure.

Although many farmers value a condition of trust & loyalty, farmer 3 points out that for him a loyalty relationship, solely built on trust, is unfavourable. *"In the end I am just an entrepreneur"*. He highlights that farming is not a hobby, *"I need to make money"* (Personal communication farmer 3, June 11th 2020). Indeed, these quotes show how terms and conditions of trust & loyalty may clash with financial benefits for arable farmers; the latter discussed in the next section.

5.2 Financial Benefits

Since a feed-manure exchange around Vallei Varken is still under development, not all financial specifications have been examined or determined. The initiators of Vallei Varken plan to cover quality adjustment costs, transportation costs and spreading costs (Personal communication Deetman & van Eijden, June 8th 2020). However, since Vallei Varken considers manure a valuable input, the pig farmer does not provide extra financial contributions to arable farmer.

In consideration of the current financial contribution for arable farmers who import and spread manure on their farms (Dijk and Galama, 2019), interviewed arable farmers expressed their requirement of a financial added value in a potential feed-manure exchange with Vallei Varken. A statement of farmer 3, *"there should be a financial benefit for arable farmers",* indicates the importance of mutual benefits (Personal communication farmer 3, June 11th 2020). These benefits are not limited to manure grants in financial terms, however. For farmer 3, who already collaborates with a livestock farmer, an exchange of field area would be financially beneficial.

Up to now, Vallei Varken does not sell any other product than pork on the market. If there are possibilities to sell other arable crops to one organisation, farmer 6 considers a cooperation more beneficial for arable farmers. Farmer 4 expressed that the assurance of market demands for Vallei Varken products serves as an economic benefit from a potential collaboration. Similarly, farmer 2 is willing to close deals with the supermarket chain Boni and catering service de Kroes (already participating in Vallei Varken, see chapter 3) in order to optimally benefit from a potential collaboration. Farmer 7 agreed with farmer 3, and emphasized the importance and thus requirement of an economic advantage for participating arable farmers. In other words, the arable farmer should not be considered as a facile manure disposal spot, but as an equal partner (Personal communication farmer 7, June 16th 2020).

In relation to financial benefits for both pig and arable farmers, farmer 2 expressed his concerns about the inclusion and interruption of external parties, such as advisors. This farmer is reluctant towards the participation of stakeholders who just want to do business when prices and margins are high but quit when the margins are not interesting anymore.

5.3 Clear Numbers and Specifications

However, farmer 7 points out he needs to be made sure that the market demand of Vallei Varken is present and will be apparent for the upcoming years in order to be convinced of the financial benefits of such a collaboration. This issue requires, besides the condition of trust, an overview with clear numbers on sales & profits. In addition, farmer 6 would like to know in more detail how consumers are going to be targeted. At the moment, Vallei Varken does not market its products by using advertisements or promotions. If in the future other non-meat products are sold under the flag of Vallei Varken, farmer 6 prefers requires getting more insights into this process.

These two farmers are not the only interviewed farmers who expressed the condition of clear numbers and more transparency, other farmers require specifications in particular on manure quality. Farmer 3 states *"it is extremely important that you know what is in your manure" (*Personal communication farmer 3, June 11th 2020). Hence, a potential collaboration requires specifications on the composition of the pig manure. Therefore, test samples – which indicate the specific content of certain minerals - have to be accurate, *"the mineral levels you indicate in the manure must be correct"* (Personal communication farmer 3, June 11th 2020). Accordingly, farmer 6 requires knowing the specific quality of pig manure, which should fit the soil or crop demands.

5.4 Manure Quality

Besides the required knowledge in terms of clear numbers on manure composition, farmer 3 and 4 mention the condition of a constant manure quality. Similarly, farmer 7 stressed that the pig manure of Vallei Varken should not be characterized by fluctuations of high and low percentages of nutrient components. A constant quality is important to achieve an equally fertilized soil and is necessary to calculate what amount of extra artificial fertilizer use is allowed regarding a farms' nitrogen maximum. Farmer 4 considers the quality of pig manure more fluctuating compared to cow manure. Overall, pig manure is indeed known as manure with a fluctuating composition of nutrients (Geelen, 2001). Therefore, farmer 4 and 5 indicate that manure quality and composition should be known beforehand.

In relation to the requirement of clear numbers on the quality and constancy of manure, the underlying condition of this requirements is a 'good' manure quality. Farmer 2 highlighted the requirement of a good manure quality, as well as farmer 6. In consideration of the manure quality in general, farmer 5 mentions that it is "*ridiculous that we get money to spread manure on our fields. It actually means that you get very bad manure. Because if the manure would be of good quality, why don't arable farmers have to pay for it?"* (Personal communication farmer 5, June 15th 2020).

However, since the interviewed farmers are scattered over the Veluwe and Flevopolder.and are thus farming on different soil types, the meaning of what a good manure quality entails highly differ. Therefore, the next chapter will elaborate on this topic and discusses both the hampering and stimulating effects of the quality of pig manure.

6 Hampering & Stimulating Factors

As the outline of the terms and conditions already brought to light some impediments for a potential collaboration, this chapter examines the hampering and stimulating factors expressed by both arable farmers and Vallei Varken's pig farmer for such a feed-manure exchange. Since the requirements of interviewed arable farmers differ, some factors are considered to have both a limiting and stimulating effect.

6.1 Pig Manure Quality

Due to the heterogeneous characteristics of the interviewed farmers, the quality of pig manure regarding a collaboration with Vallei Varken is both considered a hampering and stimulating factor.

Phosphate & Nitrogen in Manure:

Vallei Varken's pig farmer expressed his concerns about the high phosphate content of pig manure (Personal communication Deetman & van Eijden, 8 June 2020). As explained in chapter 4, due to phosphate regulations arable farmers are limited in the amount of manure they are allowed to use on their fields. Indeed, arable farmers 4 and 7 acknowledge the hampering effect of phosphate regulations on manure use, *"phosphate is the limiting factor"* (Personal communication farmer 7, June 16th 2020). Although farmer 4 prefers organic manure over artificial fertilizer, the current phosphate content in pig manure - especially within the solid fraction - is too high for his sandy soils, which are located in the Veluwe area. On these soils, the solid fraction of pig manure could be solely used when this component is exempted from phosphate regulations (Personal communication farmer 4, June 12th 2020). However, farmer 4 indicates that this is not likely to happen in the short term (check, literature research. In order to meet the nitrogen demand as much as possible with animal manure, the phosphate content in the liquid fraction needs to be minimized. Accordingly, the chairman of LTO Akkerbouw confirmed that pig manure is often not suitable for the sandy soils of the Veluwe region, in which Vallei Varken's pig farm is located as well (Personal communication, June 12th 2020). For this reason, a collaboration with arable farmers in the Flevopolder could prove to be more productive, as they are located on rich clay soils with a lower phosphate content.

Accordingly, farmer 2 – who is located in the Flevopolder – stressed "*phosphate is not a problem for us"* (Personal communication farmer 2, 11 June 2020). Since soil tests on his farm indicate that his soils are poor, he is allowed to use 80 kg per ha. In addition, both farmer 3 and farmer 5 point out that a high phosphate content in pig manure is not a hampering factor; pig manure works well on Flevopolder soils (Personal communication farmer 3, June 11th 2020). One farmer highlight that the high phosphorus solid fraction is beneficial, *"I use sow manure for really good fertilization"* (Personal communication farmer 2, June 11th 2020). Moreover, farmer 5 stressed the importance of phosphates and its use regarding a worldwide shortage. He is allowed to import 120 kg phosphate per year (the same amount for farmer 6), but remarks that "*the plant does not need that much".*

Nevertheless, farmer 5 experienced difficulties with increasing the phosphate content of his soils, as he rapidly reached his nitrogen limit. "*Phosphate is no problem for me, nitrogen is the biggest problem" (*Personal communication farmer 5, June 15th 2020). Similarly, farmer 6 states that nitrogen is the limiting factor on his farm in terms of manure import. Farmer 2 agrees on this point, as he mentions that with *"animal manure you quickly reach the limits (of 170 kg)".* According to this farmer, a separation of the solid fraction, where the nitrogen is drawn out, is therefore a possible solution (Personal communication farmer 2, June 11th 2020). In consideration of the specific soil properties of each farmer, phosphate and nitrogen contents in pig manure function both as stimulating and hampering factor.

Form of Manure:

Furthermore, multiple farmers identify the physical characteristics of pig manure as a barrier. Farmer 2, 3, 6 and 7 promote the use of straw manure – with a high organic matter content - for an optimal soil structure. Farmer 6 suggest transporting straw to Vallei Varken's pig farm in exchange for manure which includes straw (Personal communication farmer 6, June 16th 2020). Similarly, farmer 5 and 7 emphasize that straw manure is better for soil life compared to slurry, i.e. pig manure. Hence, he is reluctant to use pig manure. *"I don't want that liquid stuff"*, *"you throw so much water on the land that you suffocate it"* (Personal communication farmer 5, June 15th 2020). Farmer 6 agrees that pig manure contains much water and highlights that in general the quality of pig manure

is not beneficial. The addition of components that contribute to a better quality of pig manure and improves soil life is a prerequisite for farmer 5. On a side note, farmer 2 mentioned that his knowledge on pig manure quality is limited, *"for now the price is especially important"* (Personal communication farmer 2, June 11th 2020). However, farmer 2, 3 and 4 expressed their preference for solid manure. Specifically, granular manure, as being made by Gycom through drying and pressing of chicken manure, would be, except for farmer 2, desirable for precise application. Farmer 5 states: *"if it does not contain antibiotics, you can easily squeeze a granule of it"* (Personal communication farmer 5, June 15th 2020). In turn, *"the most liquid fraction can (when it does not contain straw residues) be used as organic foliar fertilizer"* (Personal communication farmer 5, June 15th 2020). In view of phosphate regulations, farmer 4 mentions he is probably only able to use this liquid fraction of pig manure. Nevertheless, farmer 7 – for which phosphate is the limiting factor – states that even the liquid fraction is unfavourable, since the application is not as precise as a field sprayer with liquid artificial fertilizer. Farmer 6 suggests that the liquid fraction could potentially be only used to fertilize his wheat, probably not to fertilize his potato fields. However, farmer 6 has still many questions about the exact quality of pig manure and the specific effect on soil structure and soil life.

Vallei Varken's willingness to adjust manure quality:

In regard to the pig manure and phosphate problems faced by some arable farmers, Vallei Varken's pig farmer is willing to adjust the manure quality (Personal communication Deetman & van Eijden, June 8th 2020). Vallei Varken's pig farmer aims to eliminate uncertainty in terms of manure composition through joint storage, mixing and sampling (Personal communication Deetman & van Eijden, June 8th 2020). Through the homogenization of large quantities of manure, Vallei Varken expects to be able to deliver constant and high-quality manure.

Furthermore, two possible methods have been brought up that could stimulate the quality and applicability of pig manure. Firstly, Deetman acknowledged the possibility to change the feed intake of pigs through a reduction of its phosphate content – and thus the content of pig manure – in order to mitigate phosphate issues for arable farmers on sandy soils. Farmer 5 stressed the importance to critically scrutinize the feed intake of pigs in order to improve the manure quality. Secondly, another method to decrease the phosphate content of pig manure is to mix it with washing water from the air scrubbers, which would at the same time reduce the phosphate content and increase the nitrogen content. Farmer 4 (who is located on sandy soils) is interested in this idea and suggest to *"perhaps spreading it with a field sprayer"* (Personal communication farmer 4, June 12th 2020). However, according farmer 4 mixing washing water from the air scrubbers with manure is currently in all probability impossible due to current legal regulations.

Experiences Using Pig Manure:

The use of pig manure is not new to all farmers; farmer 2 used pig manure on his conventional fields in the past and still uses sow manure on his organic fields. He is satisfied with the quality of the sow manure and its effect on his soils. However, negative experiences in the past regarding pig manure affect opinions and thoughts about future collaborations. As an illustration, farmer 4 shared his bad experiences with pig manure – and especially with the pig farmer from 15 years ago. *"His samples were way too high for what it could be"* (Personal communication farmer 4, June 12th 2020). About 6 or 7 years ago, farmer 5 has used the solid fraction of pig manure, characterized by a high phosphate content, and mixed it with compost. However, the high copper content and presence of other heavy metals had a negative effect on the underwater weight of his potatoes. Since his potatoes require a high underwater weight, he switched from pig manure to straw manure (Personal communication farmer 5, June 15th 2020).

Besides the nitrogen and phosphates content and the physical properties of pig manure, concerns have been raised about the quality of pig manure in terms of fluctuations and lack of actual numbers (see chapter 5). In addition, farmer 2 shared his thoughts about using manure from non-organic pig farms on organic fields. As he prefers – and currently does – to spread pig manure on organic fields, the non-organic character of Vallei Varken's pig manure is therefore a hampering factor.

6.2 Continuity and Financial Stability

The core working mechanisms of Vallei Varken's initiative – i.e. long-term agreements and fixed costs price - have been proposed by Deetman and van Eijden as stimulating factors for participating arable farmers. However, the interviews show ambiguous opinions and thoughts on this topic, which makes continuity & stability both a hampering and stimulating factor.

Offtake Reliability:

The issue of 'offtake reliability' has been raised by farmer 2; a farmer who appreciates the added value of financial stability that Vallei Varken aims to offer. Since he has had negative experiences - where certain parties last-minute refused to buy his yield – currently he closes annual deals or sells his yield after the harvest. Therefore, the idea of long-term agreements build on trust appeals to him. On a side note, farmer 7 mentions that this building trust will take a while. Although these long-term agreements and 'offtake reliability' offers a certain degree of trust, farmer 6 is concerned about the validity of these agreements when the yield is of different quality.

Nevertheless, farmer 4 is more hesitant towards contracts that offer stability and trust. He highlights that *"young farmers or entrepreneurs who aim for more security are more likely to farm based on contracts"* (Personal communication farmer 4, June 12th 2020). Due to high funding, stability is desired by either the entrepreneur or the bank. Therefore, this farmer only works partly with contracts.

Fixed Cost Price:

An important component of Vallei Varken's structure is the employment of fixed costs prices (as explained in chapter 3). The main reason behind these fixed costs prices are price fluctuations in the agricultural sector. As farmer 7 states: *"The market for farmers has been ruined. Very low prices are offered, but prices in supermarkets never change"* (Personal communication farmer 7, June 16th 2020).

However, the interviews indicated that not all farmers experience these price fluctuations to the same extent or consider them as unfavourable. For example, farmer 2 experiences little to no negative price fluctuations, *"due to my varied cropping plan"* (Personal communication farmer 2, June 11th 2020). In addition, since farmer 5 produces for a stable niche market – *"I grow something special"* – he does not experience serious price fluctuations. For his client's quality is more important than price. However, he does experience price fluctuations for his potatoes and onions (Personal communication farmer 5, June 15th 2020). Similarly, farmer 3 has to deal with serious price fluctuations in the onion market. However, he states, *"I'll go for the market".* A fixed costs price should be higher than the average price on the conventional market calculated over X years (Personal communication farmer 3, June 11th 2020). It is *"just maths, manure ditto".* Similar to farmer 4, farmer 3 understands the preference for a fixed costs price and stability when *"you have just started as farmer and you are in over your head",* which is not the case for him. Farmer 7 understands the ideas behind a fixed cost price but marks good communication and realistic prices as crucial factors.

6.3 Existing Collaborations

Central to a feed-manure exchange is the cooperation with a livestock farmer. However, multiple interviewed farmers (3, 4, 5, 6) are already involved in collaboration schemes, which has both hampering and stimulating effects on a potential collaboration with Vallei Varken.

Farmer 3 is one of these farmers who already collaborates with a livestock farmer in the neighbourhood. As part of this collaboration, the exchange of fields to farm on enables farmer 3 to grow potatoes on the livestock farm and to get access to manure, while the livestock farmer grows maize on the fields of the arable farmer. Besides the low transportation costs, farmer 3 stressed the mutual benefits for both parties involved. Based upon this collaboration, he considered himself determined to circular agriculture, *"we are already doing a bit of circular agriculture'"* (Personal communication farmer 3, June 11th 2020). Accordingly, farmer 5 highlights he is already involved in circular agriculture for 10 years. *"I get solid manure from goat farmers, and straw goes back to them"* (Personal communication farmer 5, June 15th 2020). Similarly, farmer 4 joins a land swap project with livestock farmers in the area. He gets his manure from four different livestock farmers,

with who he cooperates for 15 years. Both farmer 4 and 5 mentioned the importance of trust and loyalty in the maintenance of relationships. Since their collaboration with these livestock farmers date back to many years ago, farmer 5 explains *"if it goes well, you are not going to change or mess with it"* (Personal communication farmer 5, June 15th 2020). These statements indicate that a potential switch in terms of collaboration is less desirable.

On the other hand, the fact that these farmers already have close and productive collaborations with livestock farmers could stimulate to enlarge the scope of exchange and cooperation. Indeed, farmer 3, 5 and 6 did not immediately reject the idea of a feed-manure exchange with Vallei Varken.

6.4 Acreage Availability

Although the topic of acreage availability has been brought up by only one farmer, it has widespread implications and limitations for a potential collaboration with Vallei Varken's pig farmers. Farmer 2 stressed how his variation in acreage impedes to arrange long term agreements, including strict deals on amounts of deliverables and on a specific cropping plan. However, he states: *"I am able to make a 3-year agreement for an acreage, I can meet these demands"*. Due to increased competition with other farmers in the area it is essential for farmer 2 to explore and tap into new markets (Personal communication farmer 2, June 11th 2020).

6.5 Lack of Crop Residues

In consideration of feed-food competition the use of waste streams and crops residues as input for Vallei Varken's feed is the basis towards a more circular system. However, since multiple farmers (2,3,4) highlight that their crop residues are left on the field in order to contribute to the build-up of soil organic matter, this lack of crop residues for Vallei Varken's pig farmer is a limiting factor. Farmer 2 explains that the reuse of these crop residues is of major importance for the soil quality of organic fields (Personal communication farmer 2, June 11th 2020). Farmer 5 uses leaf material to improve his soils but brings straw to livestock farmers where he gets money from in return. In regard to the use of straw, farmer 6 chops it to feed the soil.

Besides the notion that the production of crops for direct feed production contradicts the core principles of circular agriculture, it also provokes resistance among farmers. Famer 4 expresses his preference of farming for human consumption purposes, as he explained that it gives him *"a better feeling than when it goes to the feed sector"* (Personal communication farmer 5, June 15th 2020). Only when Agrifirm cannot use these grains as baking flour, for example due to a too low protein content, the yield will often be used as feed input (Personal communication farmer 5, June 15th 2020).

6.6 Underlying Assumptions

The underlying assumptions of a collaboration in terms of feed-manure exchange highly differ among the interviewed farmers, and thus functions both as stimulating and hampering factor. Farmer 3 is sceptic towards a potential collaboration as he states: "*When I hear the story, I think that the pig farmer has a manure problem and we need to solve it*" (Personal communication farmer 3, June 11th 2020). According to this farmer, there needs to be some financial reward/incentive for arable farmers. "*He (the pig farmer) must have some useful land for me, otherwise it is difficult"* (Personal communication farmer 3, June 11th 2020).

On the other hand, farmer 2 highlights how a potential collaboration connects to his feeling of doing good. It gives this farmer a "*feeling of socially responsible entrepreneurship and societal contribution."* Being part of a circular and local agricultural chain is important to him. *"If I can sell my products locally, I do that first, but if the market is saturated you have to find other options"* (Personal communication farmer 2, June 11th 2020). A collaboration with Vallei Varken, which is focused on fulfilling local market demands, aligns well with his perspective. Farmer 7 agrees with farmer 2 and stressed that he considers a local food production system as favourable.

6.7 Summary

Table 2: overview of stimulating and hampering factors

	Hampering factor	**Stimulating factor**
Manure	Phosphate in pig manure | Nitrogen in pig manure	Phosphate in pig manure
	Liquid form of pig manure	Pig manure as granular manure
		Vallei Varken's willingness to adjust manure quality
	Negative experiences regarding pig manure	
Continuity & financial stability		Offtake reliability
	Fixed cost price	Fixed cost price
	Long-term agreements	Long-term agreements
Collaboration with livestock farmer	Already collaborating with livestock farmer	Already collaborating with livestock farmer
Acreage availability	Acreage availability	
Crop residues	Lack of crop residues	
Underlying assumptions	Fixing problem of pig farmer	Doing good

7 Discussion

This section of the report reflects on the sub-questions of the research and discusses decisions involved in examining these sub-questions. An outline of the value of the presented results and its limitations complement this chapter.

7.1 Sub-questions

The following sub-questions were to be answered:

a) Why is feed-manure exchange between livestock farmers and arable farmers important to stimulate agricultural circularity?

A feed-manure exchange is an important first step towards a more circular agricultural system. The idea of circularity is to recycle all waste streams and use everything to its full potential. The largest waste stream of an animal husbandry farm is the manure stream. This manure can be used on an arable farm in order to supply the crops with minerals and organic matter, instead of using artificial fertilizer. Furthermore, crop residues or waste streams of the food industry can be used in the feed for the pigs, as pigs are able to upcycle non-edible products into edible animal protein.

On the other side, arable farmers usually leave the crop residues on the field to contribute to the build-up of soil organic matter. These products could perhaps be used in the feed of the pigs, but it depends on the residue whether it is suitable for a pig to eat.

b) What is the current state of the feed-manure system of Vallei Varken's pig farmers?

In the current state, Vallei Varken's manure is transported to a storage owned by Gerald Deetman in Kraggenburg, Flevoland. This manure is in turn used by arable farmers in the neighbourhood of the storage which is distributed by Schoonhoven Mesttransport. The feed that is required for the pigs, approximately 100 tons, is delivered by Agrifirm every week.

c) What are the terms and conditions of pig farmers and arable farmers concerning feed-manure exchange?

Arable farmers have specific demands for the manure they will receive and therefore require clear numbers on the pig manure quality. The manure has to be of constant quality with appropriate NPK ratios. However, fluctuations of NPK ratios causes problems for the use of pig slurry. Vallei Varken wants to do as much as possible to make sure that the quality of the manure stays constant. In addition, both pig and the majority of arable farmers require a foundation of trust & loyalty, which is strongly intertwined with the condition of mutual financial benefits. Although trust has been mentioned as important requirement, trust of arable farmers has often been scorched by unwilling or fraudulent farmers.

d) Which factors do Vallei Varken's farmers and arable farmers deem as hampering or stimulating in fulfilling the terms and conditions?

Due to the heterogeneous characteristics of the interviewed farmers, pig manure quality and the proposed continuity & financial stability are both considered to have hampering and stimulating effects on farmers' willingness to participate. The notion that 4 out of 6 arable farmers already have a collaboration with a livestock farmer, is as well considered one of the hampering and stimulating factors.

7.2 Value of Results

7.2.1 Research

The results of this research form the basis of exploring and developing the proposed feed-manure exchange by Vallei Varken. This research has been carried out according the described methods in the methodology section (see appendix 11.2). The literature study on circular economy and circular agriculture provided useful insights into the new paradigm of circular farm systems. Furthermore, the information about circularity has been of important use to understand the concept and the ambitions of Vallei Varken.

7.2.2 Interviews

Conducting the interviews after writing the major part of the literature review worked out well. However, contacting arable farmers therefore needed to be done according a very tight time schedule in order to meet the deadline of the report.

Although the interviews gave a good representation of the view of the different interviewed stakeholders, attention needs to be paid to the following points:

Firstly, the interviews conducted with the pig farmer that initiated the concept of Vallei Varken were focused on the points of their interest. Secondly, when arable farmers were contacted, some of them were hesitant towards a collaboration with Vallei Varken. However, this is a normal reaction to a new and unproved project. During the interviews the hesitation vanished and made place for discussion. The farmers were open about the project and shared their concerns and opportunities.

7.3 Limitations

For the interviews with the arable farmers it was chosen to contact farmers that were already connected to the feed producer Agrifirm, since Agrifirm is also involved in the project of Vallei Varken. Besides that, another reason to do this was the time limitation of the ACT project. Asking Agrifirm for their existing relation (in combination with the list provided by Jelle Beeren) was the fastest way of receiving contact persons. However, for a more broad and general survey on arable farmers interest it would be interesting to interview arable farmers that are not yet directly related to Agrifirm.

For this consultancy project, 7 farmers have been interviewed of which 6 were arable farmers. This number of interviewees has not been enough to reach a so-called data saturation point or to execute statistical analysis. In order to be able to make quantitative conclusions based on the interest of the arable farmer, it would be an option to interview non-Agrifirm related arable farmers as well. By doing this, the research would give a better view on the overall opinion and stimulating/hampering factors from arable farmers on the ideas of Vallei Varken. Next to that, asking non-Agrifirm related arable farmers would give a higher chance of reaching a larger amount of local farm enterprises. Thirdly, this gives the opportunity to make choices for farmers based on for example soil type or size of the farm enterprise.

Most of the interviews are conducted in real life, only 1 farmer has been interviewed online via Zoom. Through meeting the farmers in person the interviews were considered to be less formal, but more of an informal conversation. This way of conversation makes room for discussions and gives the interviewee the opportunity to react or answer to the proposed questions about the subject.

For the analysis, due to time restrictions the interviews have been summarized and not transcribed (as explained in appendix 11.2). Namely, summarizing the conducted interviews entails less processing time compared to transcribing. However, most importantly the summary gives a good overview of the information gathered from the interviews.

8 Conclusion

During this ACT project it was researched what the needs and desires are for arable farmers and Vallei Varken's pig farmers to cooperate within the concept of Vallei Varken. The semi-structured interviews with 6 arable farmers and the subsequent analysis of their answers determine that the terms and conditions of pig and arable farmers are largely reconcilable. Generally, the farmers exhibited a positive attitude toward Vallei Varken's concept. Half of the farmers have substantial interest in the project and have indicated that they want to further examine the implications of collaboration (see appendix 11.5).

Cooperation on the basis of trust was regarded moderately positively. Mainly manure quality and quantity are considered as variables that require more research. Arable farmers desire to be aware of the substances they apply to their land to determine the effects it will pose on soil fertility and crop performance. The current lack of numbers about the manure quality that can be offered and the unknown potential to further increase this quality in alignment with the temporally variable and spatially dependent required quality, is regarded as a strong hampering factor.

Low quality manure could affect soil quality and crop performance, which ultimately hampers farm profitability. Farm revenue is a factor that poses a large influence on reconcilability of the 2 parties and was frequently mentioned during interviews. A financial analysis on the effects of a potential collaboration on farm profitability of potential arable farmers is therefore necessitated to further develop Vallei Varken's initiative.

9 Recommendations

In this chapter, recommendations for future research or adaptations to Vallei Varken's ideas about a feed-manure exchange are provided. These have arisen from the interviews conducted with Vallei Varken, 6 arable farmers, and sector experts. The stimulating and hampering factors that determine the reconcilability of the needs and desires of both parties are translated into the main input of the recommendations. These are ordered among 3 themes: manure treatment, future collaboration analysis, and economic analysis. Consecutive research should focus on these topics to provide more clarity about the quality and quantity of the products that both parties can offer each other, the possible economic effects of collaboration, and the exploration of farming systems of interested farmers to conduct improved identification of needs.

9.1 Manure treatments

9.1.1 Processing

This research has brought to light that manure quality is an important factor for most arable farmers as it is one of the first things mentioned by arable farmers when asked about the terms and conditions or hampering factors. Arable farmers prefer a specific kind of manure with guaranteed ratios of NPK. The uncertainty in unprocessed pig manure is a reason for the arable farmers to use different kinds of manure instead, as well as the ratio of organic matter that is present in the manure. A way to achieve more certainty and a higher organic matter content would be to process the manure. Looking into the several processing techniques that are already on the market gives an insight into the possibilities. The processing technologies mentioned in this report such as acidification, separation, and pressing manure into pellets should be explored in order to gain an adequate view of what is possible. A mixture of these processing technologies is a possibility as well in order to reach the optimum quality of a manure mixture for the arable farmers. Further research is required on mixing washing water and by-products of the air scrubbers with pig manure in terms of legal options and the effects on manure quality.

9.1.2 Application

Since the arable farmer has preferences in terms of minerals and nutrients for his crops, future research should be executed to investigate which manure components are relevant and important for the crops of the arable farmers willing to cooperate with Vallei Varken. The research could be carried out as a combined literature and field research. This could provide insights into the pig manure quantities required by different crops and can lead to the production of farm and crop specific manure.

Another recommendation for the future of the Vallei Varken concept in what form the manure can be applied to the crops in the most efficient and effective way. This is important information for arable farmers, since they have to know the possibilities of fertilization in order to make decisions about a fertilization scheme.

9.1.3 Marketing

A different idea of manure valorisation could be to market treated manure as fertilizer for garden usage. The fertilizer is in that case sold under the brand of Vallei Varken. This makes it possible to take a bit of pressure of the arable farmers as the about manure disposal partner. This topic could also be an interesting project future research. It could then be explored what possibilities exist for such an idea.

9.2 Future collaborations

9.2.1 Size of Collaboration

There are different options for Vallei Varken in terms of cooperation with arable farms. In consideration of a cooperation with several different arable farmers, there would be no lack of raw materials for animal feed production in the first place. Secondly, the deposition of the pig manure can be done more easily, due to the higher amount of available arable fields to fertilize. However, the cooperation with many different arable farmers will be more difficult. This is related to the fact that there are more different demands and wishes which have to be met. Also, the supply chain will be longer because more farmers contribute to a larger circle in which the cooperation takes place.

On the other hand, Vallei Varken can cooperation with the minimum amount of local arable farmers. It is more convenient to establish communication with only these farmers, but it is also easier to strengthen mutual cooperation and trust. However, the storage and surplus of manure depends on the demands of those arable farmers. This has great influence on whether the two parties can obtain enough feed and fertilizer from each other.

Discussing these two opportunities, it could be interesting to research all possibilities in terms of collaboration between Vallei Varken and arable farmers. This allows for analysing to determine in which formation the concept will work most optimal for all collaborating parties.

9.2.2 Case study with one interested farmer

During the research a lot of farmers asked for numbers, such as financial benefits. To gain a better understanding of how pig manure affects farm variables, a case study with one farmer would be helpful. On-farm measurements can be performed to acquire a sound overview of the farm variables. If possible, an experiment between 2 fields could be initiated, which aids in the identification of the effects of pig manure on soil fertility and crop performance. Such an experiment would offer new insights into which adjustments have to be made to manure to create a product that is highly suitable for arable farmers.

9.3 Economic analysis

The chain of Vallei Varken has to make a profit over the whole line. The arable farmers said that making a little more money over several years in the collaboration of Vallei Varken instead of on the free market is important. The farmers want to see that they earn more when they actively participate in such a collaboration. It would be wise to analyze the whole chain and what is earnt over the whole chain. It is valuable to arable farmers to know how participation affects their financial situation and how this could show temporal fluctuations.

9.4 Animal feed

This research was to gather more knowledge on the collaboration between pig and arable farmers. For future research it would be interesting to investigate how the crop-feed exchange can be actuated. Within this research it would be interesting to look what the feed producer wants to have in terms of crops and concentrates. After that, also look to the wants and needs for the arable farmer in terms of growing possibilities. Finally, comparing and combining these two situations to reach the most efficient supply of the feed producer. This all to make it possible that the specific feed can be produced for the circular concept in which the arable farmer and the feed producer are working. Next to that it would also be interesting to investigate how animal feed could be made from crop residues by making adjustments with the use of mineral and nutrient concentrates.

10 Literature

Asai, M., Moraine, M., Ryschawy, J., de Wit, J., Hoshide, A. K., & Martin, G. (2018). Critical factors for crop-livestock integration beyond the farm level: A cross-analysis of worldwide case studies. *Land Use Policy, 73*, 184-194. doi:https://doi.org/10.1016/j.landusepol.2017.12.010

Barber, S. A., Walker, J. M., & Vasey, E. H. (1963). Mechanisms for Movement of Plant Nutrients from Soil and Fertilizer to Plant Root. *Journal of Agricultural and Food Chemistry, 11*(3), 204-207. doi:10.1021/jf60127a017

Benyus, J. M. (1997). Biomimicry: Innovation inspired by nature: Morrow New York.

Bieleman, J. (2010). *Five centuries of farming: a short history of Dutch agriculture 1500-2000* (Vol. 8): Wageningen Academic Publishers.

Boulding, K. (1966). E., 1966, the economics of the coming spaceship earth. *New York*.

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., Fleskens, L., Geissen, V., Kuyper, T. W., Mäder, P., Pulleman, M., Sukkel, W., van Groenigen, J. W., & Brussaard, L. (2018). Soil quality – A critical review. *Soil Biology and Biochemistry, 120*, 105-125. doi:https://doi.org/10.1016/j.soilbio.2018.01.030

Commision, E. (2016). Commission Work Programme 2017 - Delivering a Europe that protects, empowers and defends. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2016) 710 final*.

Commission, E. (2015). Closing the loop-An EU action plan for the Circular Economy. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM, 614*(2), 2015.

de Boer, I. J., & van Ittersum, M. K. (2018). Circularity in agricultural production. *Animal production systems and Plant production systems. Wageningen University and Research*.

de Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2019). Eco-innovation pathways to a circular economy: Envisioning priorities through a Delphi approach. *Journal of Cleaner Production, 228*, 1494-1513.

Deetman, G. (2020a, 12 june). [Phone call].

Deetman, G. v. E., Gerard (2020b, 8 june). [Personal communication].

Dijk, W. v., Conijn, J. G., Huijsmans, J. F. M., Middelkoop, J. C. v., & Zwart, K. B. (2004). *Onderbouwing N-werkingscoëfficiënt organische mest. Studie ten behoeve van onderbouwing gebruiksnormen*. Retrieved from Lelystad: https://edepot.wur.nl/42870

Dijk, W. v., & Galama, P. (2019). *De maat van mest : Perspectief van mestbewerking op de boerderij voor akkerbouwers en melkveehouders*. Retrieved from Wageningen: https://edepot.wur.nl/472431

Duque-Acevedo, M., Belmonte-Ureña, L. J., Plaza-Úbeda, J. A., & Camacho-Ferre, F. (2020). The Management of Agricultural Waste Biomass in the Framework of Circular Economy and Bioeconomy: An Opportunity for Greenhouse Agriculture in Southeast Spain. *Agronomy, 10*(4), 489.

Eghball, B., Wienhold, B. J., Gilley, J. E., & Eigenberg, R. A. (2002). Mineralization of manure nutrients. *Journal of Soil and Water Conservation, 57*, 470-473.

Feeding by-products to pigs. (2018).

Foged, H., Flotats Ripoll, X., Bonmatí Blasi, A., Palatsi Civit, J., Magrí Aloy, A., & Schelde, K. M. (2012). Inventory of manure processing activities in Europe.

Foundation, E. M. (2017). What is a circular economy? *Ellen Macarthur Foundation*.

Geelen, P. (2001). Perspectieven voor bewerkte varkensmest. *PPO-bulletin akkerbouw, 5*(2), 18-21.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm? *Journal of Cleaner Production, 143*, 757-768.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production, 114*, 11-32.

Giampietro, M. (2019). On the Circular Bioeconomy and Decoupling: Implications for Sustainable Growth. *Ecological Economics, 162*, 143-156. doi:https://doi.org/10.1016/j.ecolecon.2019.05.001

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (2010). Food Security: The Challenge of Feeding 9 Billion People. *Science, 327*(5967), 812. doi:10.1126/science.1185383

Graedel, T., & Allenby, B. (1995). Industrial Ecology Prentice Hall. *Englewood Cliffs, NJ*.

Hawton, J., Bache, D., & McKenzie, B. (2019). High-Moisture Grains for Swine. *eXtension*.

Hoeksma, P., & Boer, E. (2005). *Vaststellen van de bemonsteringsnauwkeurigheid van drijfmest*: Agrotechnology & Food Innovations.

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards Circular Economy in the Food System. *Sustainability, 8*(1), 69.
Kelderman, K. (2020, 16 june). [Phone call].
Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221-232. doi:https://doi.org/10.1016/j.resconrec.2017.09.005
Kjaer, L. L., Pigosso, D. C., Niero, M., Bech, N. M., & McAloone, T. C. (2019). Product/service-systems for a circular economy: The route to decoupling economic growth from resource consumption? *Journal of Industrial Ecology, 23*(1), 22-35.
Kleinman, P. J. A., Pimentel, D., & Bryant, R. B. (1995). The ecological sustainability of slash-and-burn agriculture. *Agriculture, Ecosystems & Environment, 52*(2), 235-249. doi:https://doi.org/10.1016/0167-8809(94)00531-I
Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production, 175*, 544-552.
Kremen, C., Iles, A., & Bacon, C. (2012). Diversified Farming Systems

An Agroecological, Systems-based Alternative to Modern Industrial Agriculture. *Ecology and Society, 17*(4).
Leenstra, F., Vellinga, T., Neijenhuis, F., Buisonjé, F. d., Gollenbeek, L., & Wageningen Ur, C. S. (2019). *Manure : a valuable resource* Retrieved from http://edepot.wur.nl/498084
Lifset, R., & Graedel, T. E. (2002). Industrial ecology: goals and definitions. *A handbook of industrial ecology*, 3-15.
Lovins, A. B., Lovins, L. H., & Hawken, P. (1999). A road map for natural capitalism.
MacArthur, E. (2013). Towards the circular economy, economic and business rationale for an accelerated transition. *Ellen MacArthur Foundation: Cowes, UK*, 21-34.
Martin, G., Moraine, M., Ryschawy, J., Magne, M.-A., Asai, M., Sarthou, J.-P., Duru, M., & Therond, O. (2016). Crop–livestock integration beyond the farm level: a review. *Agronomy for Sustainable Development, 36*(3), 53. doi:10.1007/s13593-016-0390-x
Mekbungwan, A. (2007). Application of tropical legumes for pig feed. *Animal science journal, 78*(4), 342-350.
Mottet, A., de Haan, C., Falcucci, A., Tempio, G., Opio, C., & Gerber, P. (2017). Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security, 14*, 1-8. doi:https://doi.org/10.1016/j.gfs.2017.01.001
Naylor, R., Steinfeld, H., Falcon, W., Galloway, J., Smil, V., Bradford, E., Alder, J., & Mooney, H. (2005). Losing the Links Between Livestock and Land. *Science, 310*(5754), 1621. doi:10.1126/science.1117856
Nemes, A., & Rawls, W. J. (2004). Soil texture and particle-size distribution as input to estimate soil hydraulic properties *Developments in Soil Science* (Vol. 30, pp. 47-70): Elsevier.
Pearce, D., & Turner, R. (1990). Economics of natural resources and the environment, Hemel Hempstead: Harvester Wheatsheaf. *Perman, R., Ma, Y., McGilvray, J. and Common, M.(2003) Natural Resource and Environmental Economics. 3rd edition, Longman*.
Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987. doi:10.1126/science.aaq0216
Rijksoverheid. (2016). *Nederland circulair in 2050: Rijksbreed programma Circulaire Economie*. Den Haag.
Rijksoverheid. (2019). *Realisatieplan Visie LNV: Op weg met nieuw perspectief*. Den Haag.
Meststoffenwet, (2020).
Rizos, V., Tuokko, K., & Behrens, A. (2017). *The Circular Economy: A review of definitions, processes and impacts*. Retrieved from
Röös, E., Sundberg, C., Tidåker, P., Strid, I., & Hansson, P.-A. (2013). Can carbon footprint serve as an indicator of the environmental impact of meat production? *Ecological Indicators, 24*, 573-581. doi:https://doi.org/10.1016/j.ecolind.2012.08.004
Sariatli, F. (2017). Linear Economy versus Circular Economy: A comparative and analyzer study for Optimization of Economy for Sustainability. *Visegrad Journal on Bioeconomy and Sustainable Development, 6*(1), 31-34.
Sauvant, D., Van Milgen, J., Faverdin, P., & Friggens, N. (2011). *Modelling nutrient digestion and utilisation in farm animals*: Springer Science & Business Media.
Silvis, H., & Voskuilen, M. (2016). Grondsoort en grondprijs.
Six, J., Feller, C., Denef, K., Ogle, S., de Moraes Sa, J. C., & Albrecht, A. (2002). Soil organic matter, biota and aggregation in temperate and tropical soils-Effects of no-tillage.
Starmans, D. A. J., & Hoek, K. W. v. d. (2007). *Ammonia, the case of the Netherlands* Retrieved from http://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=3572066

http://site.ebrary.com/id/10686814

http://dx.doi.org/10.3920/978-90-8686-597-0 doi:10.3920/978-90-8686-597-0

Strid Eriksson, I., Elmquist, H., Stern, S., & Nybrant, T. (2005). Environmental Systems Analysis of Pig Production - The Impact of Feed Choice (12 pp). *The International Journal of Life Cycle Assessment, 10*(2), 143-154. doi:10.1065/lca2004.06.160

Thigssen, A. (2018). Circular agriculture: a new perspective for Dutch agriculture. *Wageningen University & Research, 13*.

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *nature, 515*(7528), 518-522. doi:10.1038/nature13959

Timmerman, M., & Smolders, M. M. A. H. H. (2002). Bezinklagen: een bron van mineralen. *Praktijkkompas. Varkens, 16*(4), 10-11.

Timmerman, M., & Smolders, M. M. A. H. H. (2003). *Bezinklagen en bemonstering van varkensmest*. Retrieved from Lelystad: https://edepot.wur.nl/34309

Toop, T. A., Ward, S. M., Oldfield, T. J., Hull, M., Kirby, M. E., & Theodorou, M. K. (2017). AgroCycle@ developing a circular economy in agriculture. *Energy Procedia, 123*, 76-80.

Uchida, R. (2000). Essential nutrients for plant growth: nutrient functions and deficiency symptoms. *Plant nutrient management in Hawaii's soils*, 31-55.

van Bruggen, C., de Bode, M. J. C., Evers, A. G., van der Hoek, K. W., Luesink, H. H., & van Schijndel, M. W. (2010). *Gestandaardiseerde berekeningsmethode voor dierlijke mest en mineralen : standaardcijfers 1990-2008*. Den Haag: Centraal Bureau voor de Statistiek.

Van den Berg, F., Tiktak, A., Hoogland, T., Poot, A., Boesten, J., van der Linden, A., & Pol, J. (2017). *An improved soil organic matter map for GeoPEARL_NL: Model description of version 4.4. 4 and consequence for the Dutch decision tree on leaching to groundwater* (1566-7197). Retrieved from

van der Werf, H. M. G., Petit, J., & Sanders, J. (2005). The environmental impacts of the production of concentrated feed: the case of pig feed in Bretagne. *Agricultural Systems, 83*(2), 153-177. doi:https://doi.org/10.1016/j.agsy.2004.03.005

van Hal, O., de Boer, I. J. M., Muller, A., de Vries, S., Erb, K. H., Schader, C., Gerrits, W. J. J., & van Zanten, H. H. E. (2019). Upcycling food leftovers and grass resources through livestock: Impact of livestock system and productivity. *Journal of Cleaner Production, 219*, 485-496. doi:https://doi.org/10.1016/j.jclepro.2019.01.329

van Hal, O., Weijenberg, A. A. A., de Boer, I. J. M., & van Zanten, H. H. E. (2019). Accounting for feed-food competition in environmental impact assessment: Towards a resource efficient food-system. *Journal of Cleaner Production, 240*, 118241. doi:https://doi.org/10.1016/j.jclepro.2019.118241

Van Zanten, H. H. E., Van Ittersum, M. K., & De Boer, I. J. M. (2019). The role of farm animals in a circular food system. *Global Food Security, 21*, 18-22. doi:https://doi.org/10.1016/j.gfs.2019.06.003

Vanner, R., Bicket, M., Withana, S., Ten Brink, P., Razzini, P., Van Dijl, E., Watkins, E., Hestin, M., Tan, A., & Guilcher, S. (2014). Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains. *Study prepared for the European Commission, DG Environment*.

Uitvoeringsregeling Meststoffenwet, (2005).

Vonk, J., Pul, W. v., Schols, E., & Groot, G. d. (2012). *Naleeftekorten bij luchtwassers in de intensieve veehouderij : Effect op emissie(-reductie) van ammoniak*: Rijksinstituut voor Volksgezondheid en Milieu RIVM.

Ward, S. M., Holden, N. M., White, E. P., & Oldfield, T. L. (2016). *The "circular economy" applied to the agriculture (livestock production) sector—discussion paper.* Paper presented at the workshop on the sustainability of the EU's livestock production systems.

Zedde, H. J. v. d., Kekem, C. v., & Boer, E. P. J. (2014). *Rapport : bemonsteren en analyseren van dierlijke mest op een vrachtauto* (9789461737014). Retrieved from Wageningen: https://edepot.wur.nl/304191

11 Appendices

11.1 Appendix 1 ACT Group Composition

Group ACT-2461 is a diverse team that is composed of six Master's students from Wageningen University and Research. In the following section, each team member will introduce themselves by highlighting their specific role and contribution to this project.

Arjan Uijterlinde – Secretary
MSc Biosystems engineering, specialization Farm Technology

My current specialization in Farm Technology aligns well this project. This specialization focuses on innovation and technology that can be introduced to improve or remodel an agricultural system to decrease environmental impact, improve production or decrease labour hours necessary to complete the task. In this project specifically I will make use of my expertise on manure distribution, agricultural systems and innovations to properly map the way the desired system could work. Furthermore, I will make use of my communication skills in order to reach out to third parties and update them on this project.

Ferneau Ploumen – Team member
MSc Biosystems engineering, specialization Information Technology

Within the study Biosystems Engineering, I chose to specialize on Information Technology. I mainly focus on production processes and the connected informatics. Improving processes and biosystems by making them more efficient, more productive, but also decrease labour. For my BSc thesis I did research on automation of the animal feed production process. This combined with my technical and practical knowledge on arable and livestock farming, I can contribute to a good research and result on the topic of this project.

Lisa Ligtermoet – Controller
MSc Organic Agriculture, specialization Sustainable Food Systems

My current specialization in Sustainable Food Systems combines well with my bachelors in Rural Sociology & Development in which I have learnt to focus on 'the social' and to discover underlying assumptions. I will contribute to this research by exploring the support base for a collaboration between pig and arable farmers, considering stakeholders' reflections on current constraints, limitations and possibilities. Furthermore, I will make use of my planning and organisational strengths – as a controller - to track financial bookkeeping activities and ensure that deadlines are properly met.

Sijin Chen – Team member
MSc Organic Agriculture, specialization Agroecology

My undergraduate major is agronomy, which mainly involves planting measures of different crops and growth characteristics. At present, my major is agroecology. I have learned a lot about organic agriculture, circular agriculture and sustainable agriculture. I have a certain degree of understanding about short food chain supply and local food systems. In this project, I can play a role in exploring circular agriculture models and shortening supply chain. My role is a member of the group, which means that in the group, I will actively cooperate with the coordination arrangements of the manager, propose diversified ideas, and complete the task on time.

Tomas van der Heijden – Manager
MSc Plant Sciences / MSc Organic Agriculture, specialization Agroecology

In my undergraduate studies I majored in journalism, which has enabled me to be a pro-active worker who enjoys getting to the bottom of things and to reveal the human side of every story. Currently I pursue a master's degree in plant sciences, focusing on natural resource management. This allows me to take a holistic view on systems functioning and to draw relationships between different variables and parameters. I enjoy researching both the social and natural aspects of systems. My experience in journalism has taught me to be an adept reader, writer and speaker. These skills help me to be a manager that properly maintains an overview of what needs to be done.

Zhao Zhao – Team member
MSc Organic Agriculture, specialization Agroecology

Complementary to the knowledge on crop cultivation and crop breeding I have gained during my BSc Agronomy. I am currently learning about organic agriculture and crop ecology. I have background knowledge about the circular agriculture system and the food supply chain. I am a member of the team and can provide a framework for the project on how a circular agriculture system can operate sustainably and I will do my best on all the tasks, actively participate in discussions, actively communicate with group members, follow the manager's task arrangements and complete tasks on time.

11.2 Appendix 2 Methods

This appendix serves as methodological basis and explanation of the research carried out for this consultancy report.

Literature research

Both chapter 2, 4 and partly 3 are based on literature research, which allowed this team to shape a framework for many issues of the project. As part of this project's research strategy, literature databases provided by the WUR have been used to collect all relevant data sources. The focus has been – as much as possible - on recent literature (0-10 years old), as circular economy is still a rather novel concept. The literature review allowed us to perform the following activities:

- Understand the driving factors behind the growing popularity of circular economic principles
- Acquisition of a deeper understanding of the possibilities (legal, technical and socio-economic) of resource exchange between 2 different farming systems
- Identification of the current level of circularity between arable farmers and pig farmers
- Determination of the factors that cause the current lack of local integration between arable farming systems and animal husbandry systems in the Netherlands
- Analysis of stakeholders' influence and interest in regard to the outcome of this project

Interviews

Semi-structured interviews with Vallei Varken's pig farmers and arable farmers have served as the foundation for chapter 3, 5 and 6. An additional expert interview with Koen Kelderman from Agrifirm offered valuable insights into feed practices. A list with questions for the semi-structured interviews with both the pig farmer and arable farmers can be found in appendix 3.

Preparation & selection:

Semi-structured interviews are chosen because they are more free-flowing and informal than structured interviews (Zhang & Wildemuth, 2009). Semi-structured interviews rely on social interaction between the researcher and interviewee; they have provided us with the opportunity to adjust the interview to the atmosphere in which it was conducted. Moreover, this method allowed the interviewer to ask deeper questions than those that were thought of in advance and gives space for getting a more elaborate understanding on certain topics (Boeije et al., 2009). The interview question aimed to reveal main themes (e.g. 'requirement' 'policy', 'profit', and 'nitrogen'), instead of quantitative data. Although we planned to reach a data saturation point, which indicates that interviews with new interviewees will most probably not provide new insights, due to limited time available for this research we have been able to interview 6 arable farmers. These farmers are scattered over the region of Veluwe and Flevoland and are approached through a snowball method. The process- and project manager of de Kroes, Jelle Beeren, shared a list with arable farmers who we could contact. As the minimum interviewed farmers has been indicated on 3, we are satisfied with the gathered information. However, this data has not been sufficient to execute statistical analysis or to make general claims.

Interview conditions:

The interviewee has been asked for permission to record the interview. Due to time limitations, the interviews – in Dutch – are not completely transcribed but have been summarized. However, these summaries have been sent to the interviewees to confirm whether the summary accurately reflects their arguments. As we aimed to minimize the effect of different communication methods on the content of the interview, we have tried to use the same communication method as much as possible. In the end, 6 out of 7 of all interview farmers have been interviewed in person, 1 farmer has been interviewed online via Zoom.

Interview analysis:

In order to protect the privacy and anonymity of interviewed farmers their names have not been mentioned in the report and summaries of the interviews are not included as appendix. If, for any reason, you are not satisfied with this latter decision, please contact our team secretary. References (Personal communication farmer X, date) are added to quotes or strong claims. As chapter 5 and 6 are based on these interviews with arable farmers, general statements will be referred to according a "farmer X" notation. Since the interviewed pig farmer is the head of Vallei Varken and initiator of a potential feed-manure exchange, his name (Gerald Deetman) and the name of his farm veterinarian (Gerard van Eijden) are mentioned in this report.

11.3 Appendix 2 Interview lists

11.3.1 Pig farmer Vallei Varken

Introduction and thank Gerard van Eijden & Gerald Deetman for their contribution and time;
Explaining scope and aim of this interview and duration of this interview;
Asking for permission to record the interview.

---

1. Vallei Varken

PQ: (Gerald) When did you start your farm?

PQ: Can you tell us a bit about your farm, the size & how many pigs etc.?

PQ: With which goals did you start working? *(Ideals: economic, social, environmental)*

PQ: How did this change over time?

MQ: You decided to initiate Vallei Varken. Why did you do this?

PQ: You already have fixed contracts with the supermarket chain Boni and some butchers and restaurants. Why did you decide to set up such contracts?

MQ: What does Valleivarken look like in terms of main inputs and outputs? (e.g. feed, meat, etc.)

MQ: What do you do with your manure?

MQ: Considering the current structure of Valleivarken and the sale of pig meat to supermarkets/restaurants, do you also aim to increase direct sales (business to consumer)?

2. Circular Agrifood Chain

MQ: Your next goal is to build a circular agrifood chain. What would such a chain look like? *(Sketch a vision)*

MQ: What do you understand under circular agri-food chains?

Theoretical reminder: According to the definitions of circularity made by the WUR, a system can only be called circular if the feed is a by-product of food production that has not entered the human market yet.

MQ: Why did you decide that this is something you want?

MQ: Which terms and conditions are important to you? *(e.g. Profit increase, geographical limitations, environmental benefits, social benefits, etc.)*

MQ: Are you/Vallei Varken open to collaborate with arable farmers outside the province of Gelderland, e.g. Flevoland? (stress soil conditions in Gelderland)

MQ: Why do you think arable farmers want to cooperate in a feed-manure exchange with Vallei Varken?

PQ: Have you already reached out to some arable farmers to gauge their interests in an exchange?

MQ: Will arable farmers be financially compensated? *(Background: Currently you need to pay as a livestock farmer to get your manure removed**.** In an exchange, you would receive pig feed for manure. Feed production is less lucrative than crop production for human consumption for arable farmers.)*

MQ: What would you like to receive from arable farmers? *(Residues, whole crops, etc.)*

MQ: How will you be able to obtain manure that is suitable for the different desires of different arable farmers? *(Pellets?) (Suggestion: take samples of manure to assess quality, before manure is taken for transport)*

MQ: Have you ever considered to grow crops for feed on your own farm?

MQ: Which factors do you perceive as stimulating for this collaboration? *(Policy, trust, resources, etc.)*

MQ: Which factors do you perceive as hampering for this collaboration? *(Policy, trust, resources, etc.)*

Thank them again + explaining that we will send a summary of this interview to them

11.3.2 Arable farmers

Introduction and thank them for their contribution and time;
Explaining scope and aim of this interview and duration of this interview;
Asking for permission to record the interview.

---

1. **Explanation of Vallei Varken**

2. **Introduction farm**

PQ: When did you start your farm?

PQ: With which goals did you start working? (*Ideals: economic, social, environmental)*

PQ: How did this change over time?

PQ: Can you tell us a bit about your farm, the size & what type of crops you grow?

MQ: Where do you sell your products? (afzetmarkt)

MQ: Do you have any idea/ can you make an estimation of how many kg crop residues you dispose per year? (for example: maize stover)

MQ: What do you currently do with your crop residues?

MQ: What type of fertilizer do you use? Where do you get your fertilizer from?

MQ: If animal manure, what type of manure do you use and how much of it per hectare?

MQ: Have you ever considered to collaborate with a livestock farmer for the exchange/import of manure as fertilizer?

3. **Circular Agrifood Chain**

PQ: Are you familiar with the concept of circularity?

If not, explain what the concept entails

MQ: What do you understand under circular agri-food chains?

MQ: What would such a chain look like? *(Sketch a vision)*

Theoretical reminder: According to the definitions of circularity made by the WUR, a system can only be called circular if the feed is a by-product of food production that has not entered the human market yet (food-feed competition).

Vallei Varken works with fixed costs prices (revised every 3 months), and thus offers a form of stability (less price fluctuations)

MQ: Are you struggling with serious price fluctuations? To what extent would a fixed cost price diminish the burden of strong price fluctuations?

MQ: Is this a system (feed-manure exchange) you would, eventually, want to join?

MQ: Which terms and conditions are, in the case of joining the system, important to you? *(e.g. Profit increase, geographical limitations, environmental benefits, social benefits, etc.)*

MQ: Which factors do you perceive as stimulating for this collaboration? *(Policy, trust, resources,* etc.)

MQ: Which factors do you perceive as hampering for this collaboration? *(Policy, trust, resources, etc.)*

If they mention the quality of pig manure as a problem, which is not suitable for their soils, please ask:

MQ: What other options do you suppose for using animal (especially pig) manure in arable farming, to process the manure to make it more efficient for application? *(Pellets?) (Suggestion: take samples of manure to assess quality, before manure is taken for transport)*

PQ: Do you feel the need to adjust your farm practices, considering the new agricultural policies? *(e.g Carola Schouten vision on kringlooplandbouw)*

Thank them again + explaining that we will send a summary of this interview to them

11.4 Appendix 4 Long list of stakeholders

This is a long list of parties who are engaged in this project or have effects on the stakeholders' action.

- *Francien de Jonge* - Commissioner of this ACT project, who works on the WUE science shop, is the main contact person and in charge of this ACT project.
- *Valleivarken (pig farmers)* – Consists of three pig farmers and have demands for this project. They have fixed contracts with Boni, about the amount and quality of the pigs. And they are willing to create a more circular agriculture system and shorter food supply chain by cooperate with other stakeholders.
- *WUR ACT project team* - Executive project team.
- *WUR ACT coach* – Provide supports for ACT team, check the project process and team members' personal development.
- *Wageningen University & Research (WUR)* – Science shop of the ACT project. Provide platform for initiators and ACT team to contact.
- *Pig farmers* – Keep the pigs for their meat. When fed and growing the pigs produce manure. This manure has to be removed from the farm in order to comply with government regulations. Ideally this manure will be exchanged for feed which is grown by neighboring arable farmers in order to establish a short supply chain.
- *Arable farmers (crops/vegetables)* – Provide straw or crops to feed producers. They sell crop products to the market. In a circular short food chain, arable farmers are the consumers of pig manure, which will be the main input into their farming systems for nutrient provisioning.
- *Fertilizer companies* – These companies produce artificial fertilizer with specific N/P/K content for the arable farmers. These fertilizers possibly can be replaced by pig manure and these companies might have the knowledge on how to guarantee certain N/P/K ratios in the manure.
- *Agrifirm* – These feed producers try to mix and match feed for each specific farmer. They buy several high-quality products and combine them in order to create feed that suits best for the situation on the farm. Wherever possible these factories use waste streams which can be valorized by livestock.
- *Butchers* – Butchers help pig farmers slaughter pigs. It depends on the agreement between the butcher and the farmer who sells the product. The butcher can slaughter the pig for the farmer and give the meat back, or the butcher can sell it for them.
- *Consumers* – Farmer's decision largely depends on consumer behavior. It is important that the circularly produced feed and manure ensure high product quality for both arable farmers and pig farmers to maintain consumer interest in the meat and crop products. If they consume pork and crop products that is provided on local markets from producers directly, will make the food supply chain shorter.
- *Supermarket chain Boni*– Valleivarken's farmers maintain fixed meat supply contracts with this supermarket chain. This arrangement ensures a stable income and reliable availability of high-quality pork.
- *Retailers* – Traditional retailers, like shops, supermarkets and food companies, buy raw materials from producers and sell the pork, vegetables and food, etc. in the markets. In a shorter food supply chain, they mainly offer these products in the non-local markets. Or they are only responsible for the sale of products which are difficult to directly find the buyers, such as pig trotters and ears.
- *Restaurants* – Local restaurants can purchase pork and vegetables from farmers directly rather than retailers. These restaurants have a higher quality standard than most customers.
- *Large buyers in foreign markets* – Have an interest in large amounts of high-quality feed, manure pellets and pork, etc.
- *Farmers committee* – A bridge for farmers to communicate and cooperate, better collaboration to make the agriculture system more circular and get a stable income.

- *Transport company* - Transport companies are needed in several stages of the supply chain to ship the materials and products between producers, middlemen and consumers. These companies are now intermediating between arable farmers and pig farmers for manure.
- *EU / Local government / Ministry of Agriculture, Nature and Food quality* - The Dutch government has an interest in more circular agriculture, might be interested in this project and might have funding available.
- *Steering committee* – Committee advising the project "Building circular agri-food chains: Stimulating regional collaboration between arable and pig farmers", which consist of Gerard Straver, Francien de Jonge, Gerard van Eijden, Gerald Deetman, Jelle Beeren, Koen Kelderman, dr. Evelien de Olde and ir. Pieter de Wolf.

11.5 Appendix 5 List of interested arable farmers

Table 3 List of interested arable farmers.

Farmer	Location	Interested	Willing to be approached for further steps
X	X	Yes, maybe	Yes
X	X	No	Yes
X	X	Yes	Yes
X	X	No, not really	Yes
X	X	No, not really	Yes
X	X	Yes, maybe	Yes