Needs and barriers for Data Driven Climate Smart Agriculture for arable farming

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Management Summary

Agriculture offers food, feed, bio based non-food, livelihood and ecosystem services to the population, but it is also widely viewed as one of the reasons (and solutions to) of today's problems such as climate change loss of biodiversity and lack of food security.
We define data driven climate smart agriculture for arable crop production as consisting of a) in the short to medium term, the use of precision farming methods to reduce inputs such as fertilizers and pesticides which result in greenhouse gas emissions, and b) in the medium to long term the development of data driven methods to model and support complex multiple cropping thereby increasing the productivity, the biodiversity and reducing the environmental impact of agricultural practices. On top of this, a data driven supply chain management can support efficiency for climate smart agriculture and hence provide a quicker uptake of complex agricultural produce systems.

The use of fertilizers and pesticides in farm products is a complex phenomenon, not entirely explained by business priorities. A better understanding of environmental variables including the weather can lead to more informed decisions with less inputs. However, giving up the certainty on controlled outcome of fertilizers and pesticides is often mentioned as preventing the network of suppliers and processors/distributors with farmers as producers from practicing more climate smart farming, as is the operational ease of current practice. Hurdles that are often mentioned include: a lack of knowledge about climate smart agricultural practice; a subsequent lack of knowledge regarding the impact of climate smart agricultural measures on production and enterprise performance notably regarding reduced tillage; a lack of right parameters and visualisation of progress on targets of soil quality; a lack of knowledge about soil needs for manure; a lack of knowledge about diversification strategies in relation to the economic performance and resistance to change rooted in ingrained personal habits often explained by family tradition and supported by regional social pressure.

Needs were related to the expressed lack of knowledge. Both in literature as expressed in the workshop farmers expressed a need to learn about climate smart agriculture practice. Underlying is a need to make decreasing soil quality and nutrient loss visible, so that they can take measures. ICT tools can make these slow changes of soil quality and nutrient loss visible.

Although conventional farmers rely on and believe in technology there are concerns about technology automating farmer’s decisions. Farmers are looking for independent advice, and ICT solutions supporting or replacing such advice are under careful scrutiny. It is recommendable that any ICT solution should support the farmer’s decision rather than taking decision away from the farmer and automating the entrepreneur so to speak. Also, approaches, data management and algorithms should be transparent, well explained and open.

As far as pilot set-ups, for scale up it is advisable to open up access to innovations by using peer to peer support groups of farmers around innovative farmers to tackle the resistance to change existing practice (often based in tradition) and the unease, which goes with change. ICT based social tools can support peer-to-peer advice, the most trusted source of advice, and farmer’s expressed a need to talk about soil quality.

1 Introduction

Agriculture offers food, feed, bio based non-food, livelihood and ecosystem services to the population, but it is also widely viewed as one of the reasons (and solutions to) of today's problems such as climate change loss of biodiversity and lack of food security. Farming contributes to about 25% of human-based greenhouse gas emissions (Smith et al, 2014) through deforestation, livestock husbandry and insufficient soil nutrient management. Farming also affects groundwater levels and quality, soil quality, biodiversity and food security, and it is therefore very important to take action to reduce its environmental footprint.

Increasing resilience and biodiversity while preserving the necessary produce to feed the world is a task that requires interventions from various stakeholders in society, including interventions such as research, regulations and governmental support. Innovations are needed at both in production (such as agricultural practices, land management, logistics and processing), in the market (such as market demand, attitudes and consumption) and in the governance of value chains (f.i. profitability of production) for mitigating emissions from agriculture and achieving the change to a both a healthy and sustainable agricultural system (Smith et al, 2014).

We define data driven climate smart agriculture for arable crop production as consisting of a) in the short to medium term, the use of precision farming methods to reduce inputs such as fertilisers and pesticides which result in greenhouse gas emissions, and b) in the medium to long term the development of data driven methods to model and support complex multiple cropping thereby increasing the productivity, the biodiversity and reducing the environmental impact of agricultural practices. On top of this, a data driven supply chain management can support efficiency for climate smart agriculture and hence provide a quicker uptake of complex agricultural produce systems.

Key to realizing this ambition is a transition to *data driven agriculture*, where in the end individual plants and animals get precisely what they need, and nothing additional is discharged to the environment. Furthermore data driven agriculture is now on the cusp of handling multiple cross thus enabling greater crop biodiversity and supporting far more natural biodiversity.

Developments in Data Science, including the integration of multiple data sources with complex crop models mean that a revolution is about to occur in agricultural practice. Real time crop monitoring and decision support in combination with climate smart and nature inclusive agriculture practices will offer a sustainable solution, providing tools for the stakeholders (farmers, farmer associations and food processors) to make agriculture climate smart by using less inputs such as fertilizer and pesticides in a controlled way. Data Driven farming also is a major precondition to realizing the uptake of multiple cropping approaches within the Precision Agriculture paradigm, and it is this which will lead to greater biodiversity. Furthermore, innovative precision farming will manage the complexity of multiple crops and many parcels in a profitable way. The use of connected crop insurance to enable greater environmental risks to be taken is a further dimension for which experimentation is needed. Farmer associations such as ZLTO need insights and opportunity to develop climate smart agri using both Information technologies and other modalities such as insurance to de-risk investments.

The use of fertilizers and pesticides in farm products is a complex phenomenon not entirely explained by business priorities. A better understanding of environmental variables including the weather can lead to more informed decisions with less inputs. However, giving up the certainty on controlled outcome of fertilizers and pesticides is often mentioned as preventing the network of suppliers and processors/distributors with farmers as producers from practicing more climate smart farming, as are other barriers.

The following document outlines the needs and barriers assessment for data driven climate smart agriculture based on literature research, interviews and a stakeholder workshops.

2 METHODOLOGY

The stakeholder analysis was done based on the AUSI method, which was developed and tested in the FP7 project GreenElec[1]. (van Dort, 2013). The AUSI method is state of the art value network analysis, based on work of Verna Allee (Allee, 2011) and Raphael Kaplinsky and Mike Morris (Kaplinsky, 2002).

Interviews and literature studies were used to assess the needs. We used the following studies:

<u>On general barriers to switching to more climate friendly farming</u>

Studies used: Carolan (Carolan, 2006) : an analysis based on 29 interviews of 3 farm managers, 8 consultants, 5 governmental experts, and 13 farmers, followed by focus groups of farmers, and experts. On barriers to adopting legumes I used a study by Ostberg (Ostberg, 2019), based on unstructured interviews with 2 farmers, a trader, a consultant and a breeder of plants.

<u>On barriers to crop diversification</u>

Meynard e.a. (Meynard et al, 2018): an analysis of 63 papers, interviews with 30 experts of public and private organisations, 53 semi-directive interviews with stakeholders including 39 farmers, value network analysis of three value chains in France. I also used a study by Stilmant e.a. (Stilmant et al, 2019), based on a survey of 128 crop system experiments in 15 European countries.

<u>On barriers to the adoption of manure</u>

On barriers to the adoption of manure in arable farming, I used the proceedings of the manure workshops, which I conducted myself together with Theun Vellinga, WUR. The conclusions were based on stakeholder workshops with 42 experts from the whole value chain from The Netherlands, Northern Germany and Belgium.

<u>On the barriers to adoption of precision farming</u>

On the barriers to adoption of precision farming of fertilizer I used a survey of the Belgium Ministry of agriculture and fishing (2017), which was the output of a survey among 527 farmers and contractors in Belgium.

Additionally I did semi-structured interviews to check findings for the North-western European region with

- A farmer consultant from the Landeskammer in Lower Saxony, Germany.
- Two arable farmers in West Brabant, The Netherlands.
- An adviser from the farmer's organization ZLTO.

[1] https://cordis.europa.eu/project/rcn/201957/factsheet/en

3 STAKEHOLDER ANALYSIS

In figure 1 the value map of the value network for the food value chain (arable) is shown. The graph is based on analysis of roles, critical success factors, value and assessment of governance ability, which are described in table 1 and 2. The arrows in the map depict the value flow, both of tangible and intangible values, whereas the nodes depict the stakeholders.

In the graph, the following important things can be noted. First of all, this whole value network is driven by the actions and spending of the consumer. The regular channel through (discount) supermarkets will see the most flow of value (52% of the revenue share[2]). The food processing industry has the highest EBITDA margin in the value chain (7,3%[3]) and is the product innovator. A high EBITDA margin allows companies to invest in innovation.

Secondly, the supermarkets are governing the value chain with their buying power and market concentration: trough contracts with farmers; through high standards related to safety of the consumers and to meet some of the environmental and labour concerns such as EUREPGAP. This governing role of supermarkets makes them capable of organizing innovations with involve collaboration around data in the value chain, and although their EBITDA margin is limited they have a significant cash flow, resulting from the many products they sell.

The degree of concentration and hence buying power of the supermarkets in The Netherlands is a serious cause of concern. As about 80% of the food is sold through supermarket chains[4], from which only five chains hold 85% of the total market share, these chains together with the buying companies have enormous buying power. The large scale production of food in The Netherlands has caused a supply surplus and as supermarkets have difficulty differentiating they are instead competing on price, causing price reductions throughout the chain with the lowest profit margins for primary producers[5]. Fresh fruits and vegetables are increasingly being sourced through arrangements of direct and (semi-)permanent relationships with farmers ("preferred suppliers"), which are predominantly SME's with low negotiation power. Although providing security of income on one hand, on the other hand the contracts have a significant impact on farmers' income and possibilities to produce when levels of produce and standards are difficult to meet. White label brands, in addition to supermarket dominance, have even caused large food processors such as Unilever to lose profits.[6] Due to these developments farming has become more uncertain and unattractive for next generations, causing 21% of the farmers to be 65 years or older (versus 9% in 1990) and an increasing number of agricultural farms to go out of business due to a lack of successors[7].

Thirdly, in general SME's, such as farmers, have a low capacity to both organize themselves and to innovate, lacking both funds, knowledge and time for innovation.

Compared to other value chains and especially noticeable in the Netherlands, there are a lot of advisors around the farmers. Sales people, from chemical producers and equipment manufacturers, call themselves advisors. Independent advisers also advise farmers, but through a fee. The Netherlands lacks an independent government funded advise service to farmers, and farmers lack the funds, and both the knowledge and the time to distinguish between advisors. Hence independent advise and advise from knowledge institutes in inaccessible, although ZLTO as a farmer's association tries to make innovative knowledge from knowledge institutes available to farmers. Because of lacking funds, advise from chemical producers and equipment producers are most frequent heard on the farm. In interviews and the workshop farmers expressed a large distrust in advise from sales people.

Because of the frequency of visits of suppliers to the farm and the free nature of their advice, advise for farmers has devaluated. This is worrisome, given the need for knowledge about climate smart agriculture. Moreover, since chemical companies de risk farmer operations with fertilizer and crop protection and thus deliver value, advise, although scrutinized because from sales people, does carry weight. All the more reason for an affordable, independent governmental advise organisation in The Netherlands.

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[2] Source: Foodstep o.b.v. CBS and data Wageningen Economic Research, Snapshot 2019, The Dutch AgriFoodTech Sector, Agrifoodtech platform

[3] The competitive position of the European food and drink industry, ECSIP consortium, 2016

[4] Circle Scan: Current state and future vision Agri & Food sector,July 2014, Circle economy

[5] Circle Scan: Current state and future vision Agri & Food sector,July 2014, Circle economy

[6] The challenge of the role of supermarkets for sustainable agriculture and trade related issues, Somo 2005

[7] Circle Scan: Current state and future vision Agri & Food sector,July 2014, Circle economy

Furthermore, since ICT often automates processes and methods a working, and thus contains advise engrained in the software, this might lead to distrust of ICT solutions. The impact of this on requirements of solutions will be researched further in the workshop, see chapter 8.

There is an extra take away in this network, which is specifically valid about the flow of information in the food value chain to consumers, which is dominated by info from both the processor and the supermarket. Although supermarkets claim to act in the interest of consumers, they are also together with the processors the dominant, if not only, source of communication (in the form of advertising) to the consumer about food, as can be seen in the graph. It is debatable whether the needs of the consumers are completely in line with the needs of consumers as expressed by the (concentrated) supermarkets. For instance, recent market research amongst more than 50% of the consumers in The Netherlands indicates a willingness to pay more when this results in fair prices for climate smart farming[8]. Consumer expenditure on certified sustainable food in supermarkets increased by 22% between 2016 and 2017[9]. Also, they express an inclination to eat less meat[10], In contrast with this supermarket advertising contains disproportionate meat advertising (40% of advertising budget)[11] and focuses on low prices. Because the consumer advocacy in this value chain is rather limited, food being a commodity product, consumer power is relatively low and spending power of the consumer is limited because of the concentration of supermarkets.

Although not in scope of the project, the analysis results give input to two recommendations to Dutch government: 1) to implement the EU guideline for a governmental truly independent farmer advice organization 2) to increase the balance in the governance of the value chain by educating consumers more on food, thus counterbalancing the dominance of supermarkets in communication and increasing their empowerment in their role in the value chain to express their need for climate smart food.

[8]https://www.trouw.nl/duurzaamheid-natuur/duurzaam-mag-best-meer-kosten-als-het-geld-maar-goed-terechtkomt~bd3563a0/

[9] Source: MDV (2017), Snapshot 2019, The Dutch AgriFoodTech Sector, Agrifoodtech platform

[10] https://www.trouw.nl/duurzaamheid-natuur/consument-kiest-steeds-vaker-voor-vleesvervanger~b711da92/

[11]https://www.trouw.nl/duurzaamheid-natuur/supers-bepalen-keuzes-van-de-consument-nu-nog-vooral-vlees~bda8bb12/

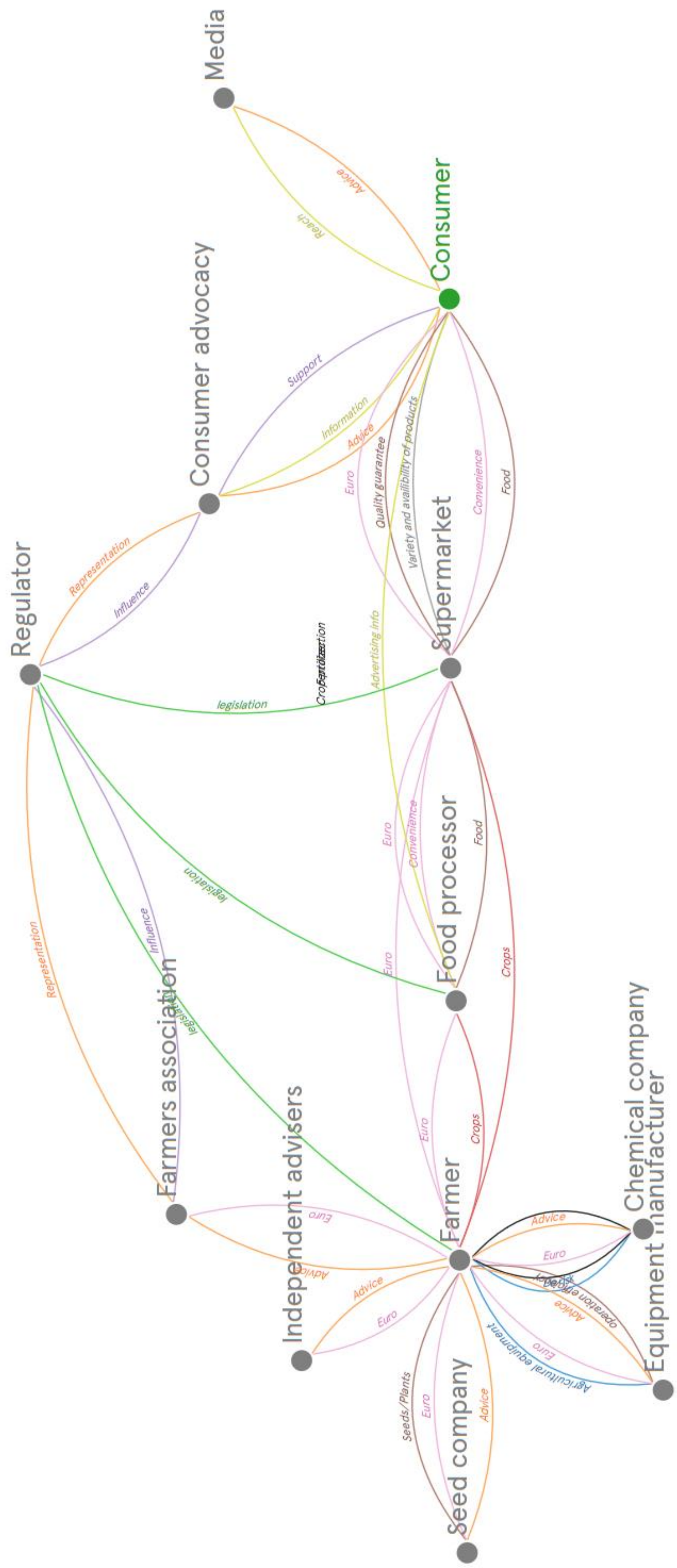

FIGURE 1, VALUE MAP OF THE AGRIFOOD VALUE NETWORK

The food and agriculture value chain contains some of the world's largest corporations, from Bayer Monsanto and DowDuPont in agrichemicals and seed, to Nestle and Kraft Heinz as food processors, and Walmart and Tesco in supermarket retail. These players continue to increase in scale and influence, with f.i. Bayer acquiring Monsanto in 2018. The dynamics of this concentrated value chain is important when introducing and scaling up innovations. It is important to take into account existing networks, distribution channels and strategies of the incumbent corporates who dominate it, and more often than not collaborate with them to upscale[12].

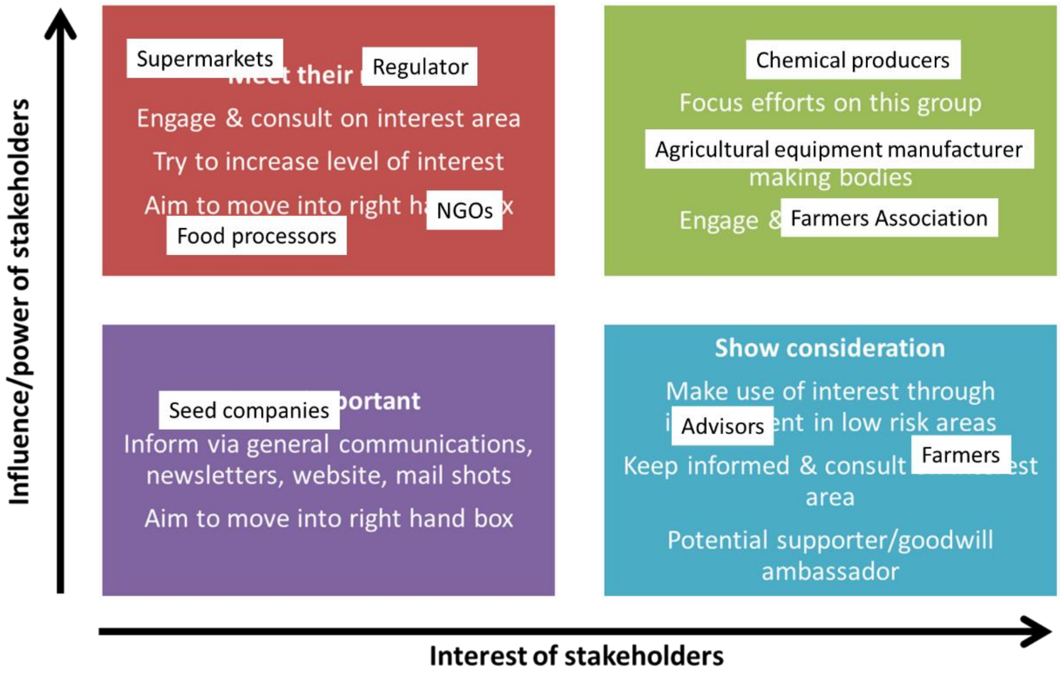

FIGURE 2, ASSESMENT OF NEEDED STAKEHOLDER MANAGEMENT

Figure 2 gives the assesment of stakeholder reaction and necessary action for data driven climate smart agriculture according to the Mendelow matrix (Mendelow, 1991).

[12] http://www.anterracapital.com/news-article-i038

TABLE 1 AND 2, STAKEHOLDER ROLE, INTEREST, VALUE DELIVERED AND GOVERNANCE

Stakeholder	Role	Interests (CSF)	Value and EBITDA margin	Governance
Consumer	Consuming food	Nutritious, tasty and healthy food for an affordable price.		Low
Supermarket	Outlets of agricultural products, from fresh vegetables produced by farmers to foods processed by food processors xi	A: vailability of products and variety Solid Inventory Control and volume supply); product quality;conveience: opening hours and low travel distance for customers; right price level, understanding of customer; viii	Variety and availability of favorite products; quality guarantee; convenience iii Net profit European supermarkets 4.2% in 2016iv EBITDA Margin Annual (TTM) 3.29 % v	High governors of the food chain/buying power: major market 84% share in the hands of 5 supermarkets[i] (NL 2016)weakening the bargaining power of farmers and food producers; arrangements of direct relationships with producers; high standards related to safety of the consumers and to meet some of the environmental and labour concerns
Agrochemical companies	Producers of feritlizer, pesticides, herbicides and fungicides	Develop novel agrochemicals and bundled products, organize resourcing continuity; assess effectiveness and determine safety profiles; comply to government regulations;	Crop protection, fertilizer; de risk of operation;; BayerMonsanto projected EBITDA margin 2019 26,5%[vi]	High because of concentration, BayerMonsanto and DowDuPont belong to world largests coorporations
Equipment manufacturers	Producers of agricultural machinery	Develop new machinery and integrated solutions; collaborate in the value chain around innovations (such as data); [ix] inventory management[x]	Machinery; efficient operation; EBITDA margin 10.8% in 2017[vii]	Medium, investment in machinery depending on volatile and low margin farmers market with medium concentration
Adviisors	Advice to farmers about business and farm practice	Trustworthy advice; ability to build relationships, good network	Advice	**Low**

Stakeholder	Role	Interests (CSF)	Value and EBITDA margin	Governance
Food processor	Manufacturing that starts with raw animal, vegetable, or marine materials, and which transforms them into intermediate foodstuffs or edible products through the application of labour, machinery, energy, and	Focus on production efficiency; secure quality sourcing and supply chain management; understanding and connection with customers; added value through innovation; flexibility to incorporate new regulation[xvii] [xviii]	Food products; convenience and time savings; advertising info Profit margin 7,3% in 2012 (EU)[xii], EBITA margin expansion from 5.5 percent in 200207 to 10.2 percent in 2011-16 (8 big companies world wide)[xiii] EBITDA Margin Annual (TTM)	Low, because of supermarket concentration
Arable farmer	Prepare land, plant and take care of crops, harvest crops for consumption; take care of animals to provide meat, dairy and eggs, as well as	Manage production; control costs[xix]	EBITDA Margin Annual (TTM) 4.65 % 2019 [xv], Estimated income in The Netherlands ca. 39.000 per unpaid annual work unit in 2018[xvi]	Low, SMEs
Regulator	Manage societal needs,; provide regulation to ensure food safety[xxi], ensure innovation	Ensure societal support for legislation; legislate; enforcement; intervene on market short comings with subsidy or legislation	Admission of food, research subsidy, policy guidelines	FSA, GDPR, CE
NGO	Lobby for societal cause,	Ability to formulate a position; provide credible information, raise societal support	Societal representation, information	Low

4 Climate Smart Agriculture definition and approach

4.1 Definition of Climate Smart Agriculture

FAO defines Climate-smart agriculture (CSA) is a "method to guide actions and strategies necessary to transform agriculture to effectively support development and ensure food security in a changing climate". It has three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible (FAO, 2015).

In recent communication FAO also includes biodiversity in CSA; defining CSA as "sustainable agriculture and strategies which promote resource-use efficiency, conserve and restore biodiversity and natural resources, and combat the impacts of climate change" (FAO 2017).

Agroecology adds another aspect on top of CSA: it also questions the structure of the entire food production system and the value chain and its suppliers (business value network). Core element of agroecology is the notion that agroecosystems should mimic the biodiversity levels and functioning of natural ecosystems (Pimbert, 2017). In this document we will focus on FAO's original, narrow definition for practicality sake, but we will take into account the value chain.

Table 3, project scope and mapping

	Mitigation	Adaptation	Extreme events
Climate-smart agriculture	reducing and/or removing greenhouse gas emissions, where possible	adapting and building resilience to climate change	building resilience to climate change
Project scope	We define data driven climate smart agriculture for arable crop production as consisting of a) in the short to medium term, the use of precision farming methods to reduce inputs such as fertilisers and pesticides which result in greenhouse gas emissions, and b) in the medium to long term the development of data driven methods to model and support complex multiple cropping thereby increasing the productivity, the biodiversity and reducing the environmental impact of agricultural practices		

Since we define data driven climate smart agriculture for arable crop production in the project proposal as consisting of a) in the short to medium term, the use of precision farming methods to reduce inputs such as fertilizers and pesticides which result in greenhouse gas emissions, and b) in the medium to long term the development of data driven methods to model and support complex multiple cropping thereby increasing the productivity, the biodiversity and reducing the environmental impact of agricultural practices, we will focus on mitigation. On top of this, a data driven supply chain management can support efficiency for climate smart agriculture and hence provide a quicker uptake of complex agricultural produce systems.

4.2 Solutions for reducing and/or removing greenhouse gas emissions (Mitigation)

Emissions from artificial fertilizers are one of the main sources of elevated emissions of greenhouse gasses in arable agriculture (Smith et al, 2014). Artificial fertilizers improve the output of most crops, but have a negative impact on the performance of the natural nitrogen cycle in the environment (Raven et al, 2005). Increasing the use of farming methods and cultivation of crops which depend less on synthetic fertilizers, such as the cultivation of leguminous crops, using manure and using precision farming technique to apply fertilizer, would reduce emissions while increasing soil fertility. Erosion is another source of soil degradation and emission of greenhouse gasses (Liang, 2018). Preventing erosion with farming techniques such as the growth of cover crops, mulching and minimal or reduced tilling would further contribute to reduction of emissions of greenhouse gasses while retaining soil quality.

Paustian (Paustian, 2016) therefore defines the possible mitigation practices as follows:

i. Convert to perennial vegetation
ii. Restore to wetland
iii. Add nutrients; add lime; grow N-fixing species
iv. Grow cover crops; reduce or vegetate fallow fields
v. Reduce fertilizer to economic-optimal rates
vi. Reduce or halt tilling; implement residue retention
vii. Improve timing and placement; use enhanced-efficiency fertilizer
viii. Rotate perennials; use agroforestry; use high c-input species; grow cover crops
ix. Add amendments such as compost and bio-char

Paustian’s scheme is in line with practices currently used for soil quality. In the H.2020 iSQAPER project an inventory of innovative soil management practices assessment in Europe and China was done (Barão e.a., 2017). The three most common practices identified in Europe were manuring & composting (14%), minimum tillage (14%) and crop rotation (12%).

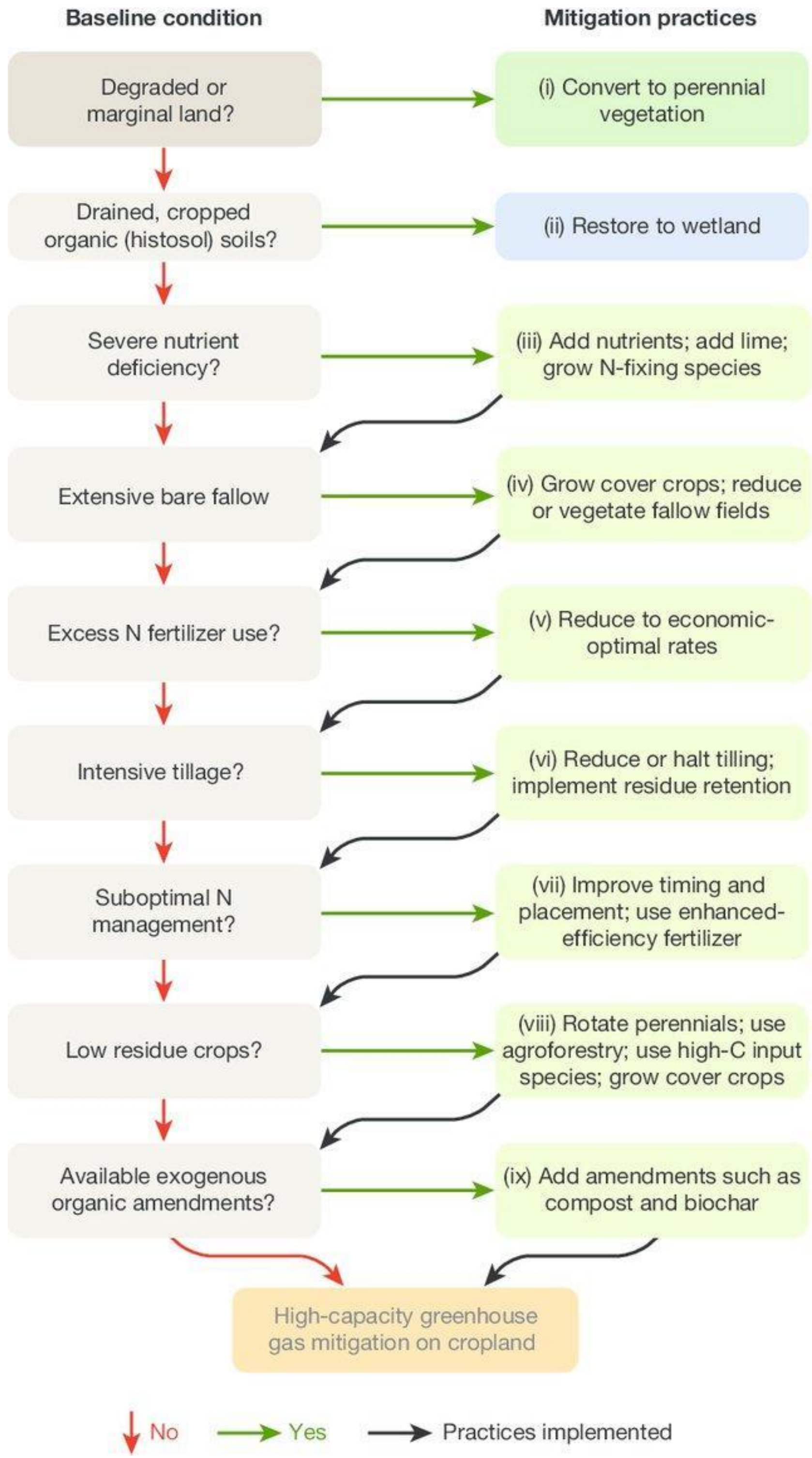

FIGURE 3, MITIGATION SCHEME FOR ARABLE FARMING (PAUSTIAN, 2016)

In this report we translate the possible mitigation practices as follows:

TABLE 4, OVERVIEW OF CSA MEASURES AND PARAGRAPHS

Mitigation for arable agriculture		Paragraph
i.	Convert to perennial vegetation	Omitted
ii.	Restore to wetland	Omitted
iii.	Add nutrients; add lime; grow N-fixing species	5.1 Cultivation of leguminous crops 5.7 Manuring
iv.	Grow cover crops; reduce or vegetate fallow fields	5.2 Permanent soil cover by cover crops
v.	Reduce fertilizer to economic-optimal rates	5.3 Precision fertilizer
vi.	Reduce or halt tilling; implement residue retention	5.4 Minimum/Reduced tillage 5.5 Residue maintenance / mulching
vii.	Improve timing and placement; use enhanced-efficiency fertilizer	5.3 Precision fertilizer
viii.	Rotate perennials; use agroforestry; use high c-input species; grow cover crops	5.2 Permanent soil cover by cover crops 5.6 Crop diversification and crop rotation / multi cropping / strip cropping
ix.	Add amendments such as compost and bio-char	5.7 Manuring & Composting

5 MITIGATION PRACTICES FOR ARABLE FARMING

5.1 Cultivation of Leguminous crops

Legumes are plants that can fix nitrogen from the atmosphere and lower the need for synthetic fertilizers. They form a symbiosis with rhizobia-bacteria which transforms nitrogen from the atmosphere into nutrients available for plants (Raven et al, 2005).
The amount of nitrogen, which will be converted, varies with species, soil type, pH, available nitrogen and other nutrients in the soil, temperature, rate of photosynthesis, amount of water, and mechanical practice (Jordbruksverket, 1999).

Grain legumes, legumes cultivated for their edible seeds, also have a high nutritional value. They provide relatively cheap protein with slow-releasing carbohydrates, minerals and vitamins (Tharanathan, 2003).

They also contribute to an agricultural system that is more diverse. The break crop effect is another advantage of adding legumes to the crop rotation. Because legumes belong to different plant families than cereals, they are susceptible to different pests and diseases and compete against other weeds. Therefore including a legume in the crop rotation can reduce pathogens and weed, improve pest control, and improve soil structure with extra nitrogen (Kirkegaard et al, 2007). In this way legumes positively affect the yield of subsequent or intercropping crops, compared to monocultures.

It should be noted that in the interview with the Handelskammer it was mentioned that in North Western Europe (The Netherlands, Belgium and Lower Saxony), the use of legumes as a cover crop in order to bind nitrogen was a less obvious choice, because of the large abundance of other sustainable nitrogen alternatives such as manure in this part of Europe.

5.2 Permanent soil cover by cover crops

Soil temperature is one of the variables influencing CO2 emissions. High soil temperatures speed up the respiration of the soil and thus boost CO2 emissions (Brito et al., 2005). This shows that it is essential to safeguard the soil with vegetation, not only for soil and water conservation (reduction in soil temperature), but also to reduce greenhouse gas emissions. (Bot, 2005).

Soil cover can be either with intermediate crops or with mulches from crop residues of prior harvests accumulated on the soil surface.

Retaining mulch between crop rotation offers protection against erosion and can also retain higher humidity in dry areas, enrich the soil with organic matter, increase C concentration, and stop the re-growth of weeds if the mulch is dense enough (Kahlon 2012).

Cover crops will provide C inputs to the soil throughout the year during fallow periods. A good soil cover, including a well-developed rooting system, decreases the soil's wind and rain eroding impacts. Cover crops therefore decrease nutrient losses, and diminish the loss of nitrate, otherwise converted to N2O in riparian zones and waterways. (Paustian, 2016). The positive effect of cover crops on water quality is currently under study in the Driver Impacts project by the Handelskammer in Northern Germany.

5.3 Precision fertilizer

Another way of reducing greenhouse gas emissions in arable agriculture is to manage N more accurately in order to minimize surplus N that the crop does not use while retaining high yields. Fertilized crops typically

use far less than 100% of the applied N; the remainder is available for loss. According to a recent study (Basso e.a. 2019), maize farmers in the US could reduce N by up to 31% with little impact on crop yields.
Better nitrogen management can be accomplished by: (1) better matching rates of application of N to crop requirements using advanced data modelling; (2) applying fertilizer at variable rates across fields depending on natural soil fertility patterns or within the root zone rather than soil surface; and (3) applying fertilizer when the crop can use it, such as several weeks after planting, or earlier, but using slow-release coatings to delay dissolution. (Paustian 2016).
Although some form of precision farming is already adopted by 41% of Belgian farmers in 2017, and precision fertilizer has an intended use by 58% within 5 years, it is seldom applied to use less inputs (16%). Most respondents use precision farming for higher yields (48%) or to save time (48%) (Belgium Ministry of agriculture and fishing, 2017).
Precision fertilizer is one of the applications which is most often mentioned when precision farming is considered. 58% of farmers considering precision farming within 5 years mentioned precision fertilizer, after plot mapping (67%), precision pest and disease management (66%) and GPS plot measurements. For contractors this was 56%, after differential gps (93%), plot measuring (93%), plot mapping (86%) and variable sowing (83%). Interesting enough precision fertilizer was considered more by contractors than precision pest and disease management (52%).

5.4 Minimum/ Reduced tillage

There are three aspects impacting climate change involved when comparing tillage systems: sequestration of CO2, direct emissions of N2O and potential fuel savings. Reducing or eliminating tillage is a recommended farming methods for improving soil carbon sequestration confirmed by numerous studies, mostly American studies (recommended by the Intergovernmental Panel on Climate Change (IPCC1)).
There are different strategies to reduce tilling, see figure 4 (Krauss e.a., 2019)

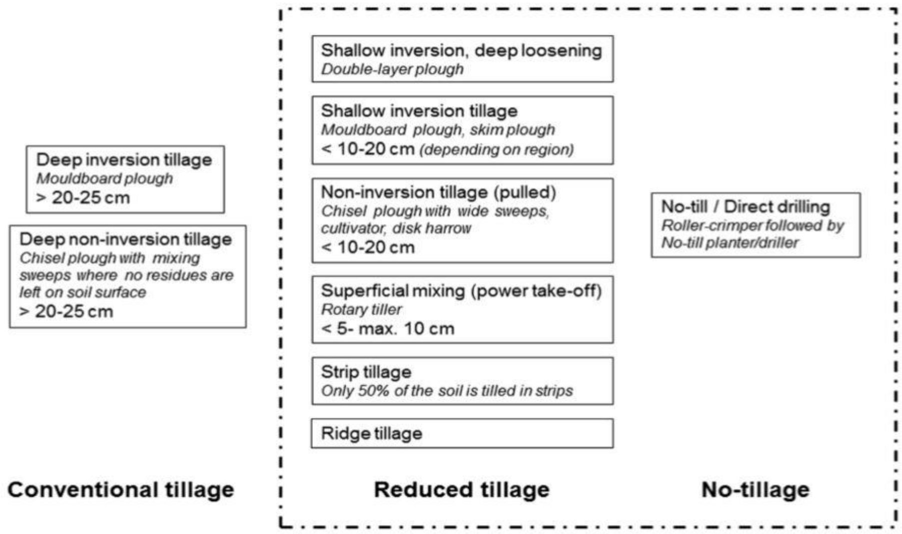

FIGURE 4, STRATEGIES FOR TILLING (SOURCE: KRAUSS E.A., 2019)

Among the main benefits, which are mentioned, are soil physical properties, soil fauna, energy and labour efficiency; and impact on climate change.

Several experiments demonstrated however that three techniques of tillage including conventional tilling resulted in comparable results in carbon sequestration (Krauss et al, 2017c, Dimassi 2014). Variations were noted over time based on climate conditions and also the depth. Minimum tillage actually increased the sequestration of carbon at the surface (0–10 cm), but lowered it to higher depths (10–30 cm) (Dimassi 2014). Dry years ensure sequestration of carbon with a minimal tillage method, while years with heavy rainfall result in carbon being released when compared to tilled soil.

Arable agriculture is the main factor of N2O emissions worldwide (Syakila and Kroeze, 2011). Although reduced tillage is considered a method for mitigation of N2O emissions, long term studies indicated only few differences between tillage systems in humid climates and lower emissions in dry climates (van Kessel et al, 2013).

Consequently, the effectiveness of tillage methods depends on climate conditions, especially on rainfall. Reduced tillage can improve mitigation, but in humid temperate climates it does not appear to be efficient for carbon sequestration nor N2O emissions. Although Paustian recommends reduced tillage, he also argues that applicability in cold climates is limited. (Paustian, 2016).

5.5 Residue maintenance / mulching

Soil cover is a key components of climate smart agriculture. Soil cover can either be plants, such as intermediate crops, or mulches composed of crop residues, accumulated on the soil surface and remaining after previous harvests. Keeping mulch between crop rotations provides better protection against erosion and will provide higher soil humidity in dry regions, feed the soil with organic matter, and, provided that the mulch is thick enough, prevent the re-growth of weeds.

Mulch improves soil physical conditions, hydrological properties and C concentration. (Kahlon 2012). Residues from crops improve water and nutrient cycling, and influence crop production. For example nutrient efficiency increases and pest problems decreases have been observed (Hansen et al., 2013). Residue maintenance can also positively impact crop growth, yield, and quality (Clay 2019).

5.6 Crop diversification and crop rotation / multi cropping / strip cropping

Crop diversification is one of the potential levers for creating more environmentally friendly and sustainable input systems (fertilizers, plant protection products, etc.). In reality, the specialization of rotations and regions has adverse implications for more than one reason: I increased use of natural resources (fertilizers and therefore fossil fuels and GHG emissions) since legumes have disappeared in rotations ; (ii) increased use of pesticides in simplified systems due to increased pressure from weeds, pests and diseases; (iii) reduction of biodiversity connected to homogeneous habitats and growing pesticide use; (iv) contribution to stagnant yields ; (v) reducing the availability of ecosystem services and public goods.

Despite its benefits, diversification is limited by a number of brakes, as demonstrated by research in France by Meynard et al. (2018). In this context, a higher variety of species within annual crop systems has advantages and potentialities. This diversification, which is reflected over time (multiple crops over one year, including service or cover crops, lengthening rotations) and in space (associated crops, strip crops), appears to be a main answer for the development of multifunctional agroecosystems less greedy in inputs.

TABLE 5, OPPORTUNITIES FOR CROP DIVERSIFICATION

Crop rotation	Diversification over time	multiple crops over one year
		including service or cover crops
		lengthening rotations
Multi cropping or strip cropping	Diversification in space	associated crops
		strip crops

In the H.2020 DriverImpacts project an analysis of a large set of data on crop diversification showed that crop diversification has the following benefits (Beillouin et al 2019): i. a higher resource use efficiency, ii. a higher

Land Equivalent Ratio, iii. a lower pest and disease pressure, iv more biodiversity, v higher C sequestration, vi better soil quality, vii better weed suppression and viii less erosion.

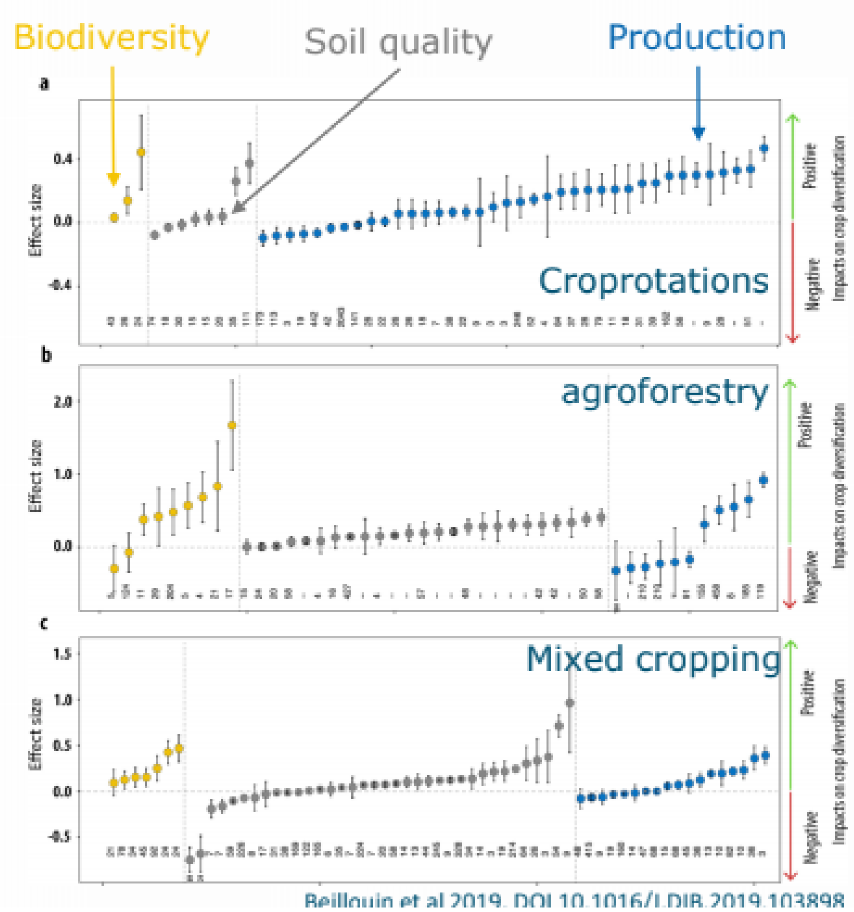

FIGURE 5, CROP DIVERSIFICATION BENEFITS (SOURCE BEILLOUIN ET AL 2019)

5.7 Manure & composting

Livestock manure in agriculture offers significant organic matter. The addition of organic matter increases soil physical features, in particular aggregation and porosity, which in turn increases water infiltration and water retention ability, tilts soil and decreases soil erosion (Teernstra, 2016).

As nutrients released as organic residues decompose in plant-available mineral forms, it also enhances soil fertility (Daniels et al., 2019). Synthetic fertilizers are 100% inorganic and when applied, they do not contribute to the soil organic matter content. (2016, Teernstra).

6 Barriers

6.1 General barriers to shifting from conventional farming to climate smart farming methods

Sustainable agriculture can be a hard sell due to the long-term view required, according to Carolan, 2006. Consequently, unlike the promised instant advantages in conventional agriculture, sustainable agriculture requires farmers to form a long-term vision on their operation (Bird et al. 1995; Carolan et al. 2004; Scott and Walter 1993).

But it takes more than just a vision. The increasingly widespread one-year lease agreement also includes challenges (Duffy et al. 2003; Edwards and Smith 2004) and lenders seeking reimbursement of loans by requiring farmers to focus on short-term financial profits [Carolan 2005a]).

For example, lower soil and nutrient loss rates are not easily noticeable to farmers without precision tools or soil tests to assess concentrations of nitrogen and phosphor. Similarly invisible are rises in concentrations of useful microorganisms in the soil, or reductions in the quantity of leaching chemicals in the water table, and the elimination of residues of pesticides. These seemingly invisible distant qualities can often lead to tension among stakeholders as they consider adopting certain farm management practices.

Conversely, stakeholders characterized the expenses of sustainable agriculture as significantly more noticeable. One of the noticeable costs of sustainable agriculture mentioned, for example, was its inability to generate the high yields resulting from more conventional agriculture. As researched, after a reduction in the use of fertilizers and pesticides, yields often decline during the period that the soil fertility, structure and useful microorganisms are rebuilt. (Gliessman 1998).

Besides yield loss, the weeds were frequently quoted as noticeable expense of sustainable farming. While weeds ' impact on returns relies on various variables (e.g. soil structure and fertility, crops, climate, etc. (Forbes and Watson, 1992) ; weeds' cultural significance in agriculture is less variable. Weeds have long been a symbolic no-go in agriculture, usually conceived as a sign of poor farm management (Bell 2004; Burton 2004; Carolan 2005a; Wilson 2001).

Another major issue in farming practice has to do with the farmers communication and attitude towards technology. On the one side, conventional farmers mainly communicated in terms of ' technological rationality, ' relying on empirical evidence, science, technology, and experts (Fischer 2000 ; Plough and Krimsky 1987). On the other hand, proponents of sustainable agriculture spoke more about personal and familiar experiences and integrated information, making it hard to distinguish between between experts and non-experts (Fischer 2000; Plough and Krimsky 1987).

This attitude and way of communication, combined with a production oriented, commodity-driven orientation of conventional agriculture (Burton 2004 ; Lyson and Guptill 2004 ; Lyson, Torres, and Welsh 2001 ; McHenry 1997 ; Wilson 2001), helps to explain why its proponents could 'see' some things (e.g. yields and weeds) and not others (e.g. biodiversity benefits and soil texture improvements).

The transition to environmentally sustainable agriculture is not comparable to the implementation of a gradual incremental innovation, but rather a complicated learning process which can take a few years (Röling and Jiggins, 1998). Most farmers, consultants, and scientists adopted the farm or crop as the key unit around which shared knowledge can be created. Scaling up this understanding to include the water system, landscape or eco-system presents unique learning challenges, and hence for agricultural education, and "making things visible''. (Röling and Jiggins, 1998)

Barriers
Short term system lock in (leases, contracts)
Decreasing soil quality and nutrient loss are not easily visible
Drop of yield following a decrease in the use of fertilizer and pesticides
Presence of weeds is not acceptable
Conventional farmers place faith in empirical evidence, the scientific method, technology, and experts

6.2 Barriers to cultivation of Leguminous crops

Most of the problems according to (Ostberg, 2019) were absence of customer demand, weather conditions, absence of suitable varieties because of underinvestment in legume innovation as a minor species, and small and variable yields for lentils and difficult harvesting.

Maynard, (2018) identified the following barriers:

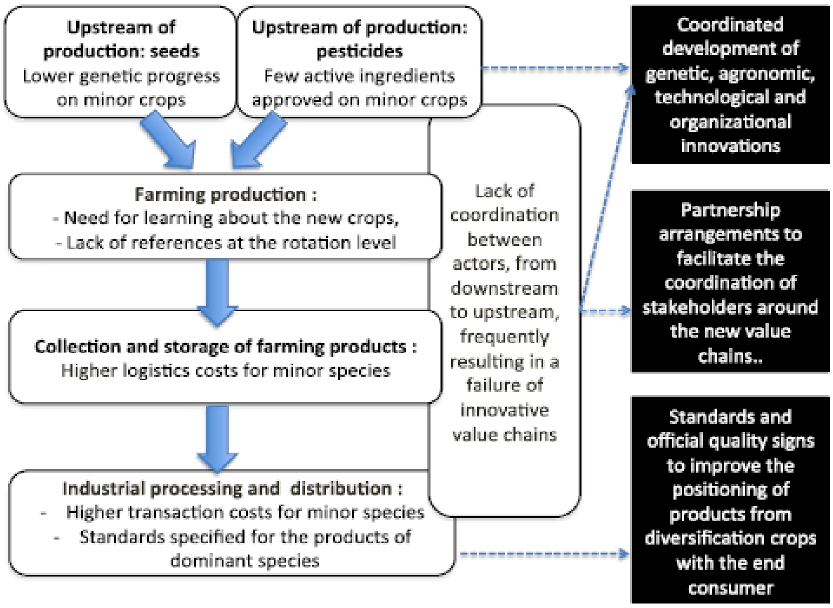

Figure 6, Barriers to the introduction of minor crops (Source Maynard, (2018)

Barriers
Low consumer demands yet
Weather conditions
Lack of suitable varieties due to underinvestment in innovation of legumes as minor species
Lower genetic progress on minor crops
Fewer pesticides approved
Need for learning about new crops
Lack of references in rotation
Higher logistics costs for minor species

Higher transaction costs for minor species
Lack of standards
Lack of coordination in new to establish value chains

6.3 Barriers to permanent soil cover by cover crops

See 5.4, since cover crops are an extra crop to crop rotation.

6.4 Barriers to precision fertilizer

From the study in Belgium it appeared that farmers did not have a clear vision what precision agriculture entailed (Belgium Ministry of agriculture and fishing, 2017). A lot of them thought that it was just using gps in planning; and that it was not about using data collection or decision support.

However 57% indicated to use precision techniques already today or at least within 5 years. For those farmers the economic size of the company was a determining factor in the decision to invest. More than half of farmers (62%) with a yearly revenue of at least 250 000 euro were already using precision farming or will be within the next 5 years. Only 40% of companies with a yearly revenue below 150 000 euro indicated to do so. About half of farmers (53%) were reluctant to invest in precision farming because of the size of their farm.

Another challenge mentioned by interviewed farmers was the investment in and possibilities of their machinery (30%); doubts about the business case or intentions to wait till the technology becomes cheaper (22%); lack of knowledge (14%) or not understanding the benefits of the technology yet (10%).

When asked what would help to convince the non users 37% indicated research into costs and benefits; lowering costs with at least 10% (36% of non users); and another 31% mentioned successful practical experience from an exchange with colleague farmers. The remaining 10% needed technological support to use the technology.

Barriers
Current machines
Farm too small for investment
Lack of insights into benefits
Lack of insights business case
Lower costs

6.5 Barriers to Residue maintenance / mulching

A challenge mentioned for residue management on farm land, is the strategy to increase revenue by harvesting crop residues for animal feed or as feedstock for biofuel production (Maw et al., 2019).

Barriers
Crop residue harvested and sold

6.6 Barriers in crop diversification and crop rotation / multi cropping / strip cropping

Nearly 66% of participants highlight the commitment and expertise of the individuals engaged in the collective among the main variables that enable effective crop diversification (Stilmant, 2019). Then (40 percent) mentions the reality that there should be technical solutions, adapted tools, and an operational organisation between the actors. Failures are ascribed primarily to bad market conditions or absence of appropriate inputs (seeds, etc.). Therefore, it is logical for the interviewees to identify first the development of interactions among stakeholders as a catalyst for success, then the development of adapted agronomic solutions and lastly a favourable economic context.

After that, regulation appears as the most restrictive factor for the development of diversification strategies. Meynard et al. (2018) already recognized a lack of technical references, competition with large species on the market and the multiple modes of coordination between the actors as challenges. At the agronomic level, they highlighted above all the need to improve genetic advancement for small species as well as the absence of solutions for plant protection. Stakeholders stress the need to create resilient alternatives to water stress and solutions for weed management and crop protection in particular (Stilmant, 2019).

6.6.1 At the farm level

There is no easily accessible knowledge (1) needed to implement diversification strategies, (2) related to the financial performance and impacts of crop diversification strategies. The availability, the cost of the initial plant material (seed) or the required agricultural machinery for both crop management and harvest are also a brake in about 50 percent of the studies (Stilmant, 2019). More than 40% of surveyed show that a barrier is represented by the system's profitability in the current economic and legislative context. For more than 50 percent of participants, the poor agronomic performance of innovative crops and the uncertainties about the stability of their performance are a problem. Finally, the complexity of managing diverse crop systems is highlighted by more than 30 percent of innovative groups. This complexity limits its adoption, particularly as it is accompanied by cultural and traditional obstacles to change ("my father did not grow lentils, why would I do it?").

Farmers identified two more general reasons which complicated crop diversification, namely the need to learn about new crops and the lack of technical and economic crop rotation models (Maynard, 2018).

Whenever farmers introduce a new crop, they first have to get acquainted with its management and its harvest. This takes time, often several growing seasons (Chantre and Cardona 2014), during which the abandon of the new crop is a high risk (Conley and Udry 2010). Because farm consultants are not experts on minor crops, an unexpected low performance often remains unexplained. Several farmers have verified that if one or two unexplained failures occur, the new crop will be abandoned.

The farmers in the study stressed that there were no accurate references to the agronomic consequences of the introduction of a particular crop into a particular rotation in a particular region (Duc et al. 2010; Zimmer et al. 2016). Farmers pointed out that the advice about minor crops by chambers of agriculture or cooperatives often concerns only their management, and rarely the management of the consecutive crop. They added that farm accounting organisations calculate financial margins per crop, not by subsequent crops or rotation. Effects were not always quantified: although the decrease in nitrogen fertilization allowed by a prior legume was generally indicated, the decrease in herbicide use allowed by lengthening the rotation was seldom quantified. This absence of techno-economic crop rotation model for all minor crops in various climate zones is an obstacle to diversification.

Barriers
knowledge needed to implement diversification strategies in relation to the economic performance
The availability, the cost of the initial plant material (seed)

The availability of necessary agricultural machinery, both for the management of the crop and for the management of the harvested product
profitability of the system in the current economic and legislative context
The complexity of managing diverse crop systems
Lack of info about new crops
Lack of technical economic crop rotation models

6.6.2 Collection and storage of farming products

More than 66 percent of the studies raise the issue of volumes of minor crops, which must be adequate to allow the development of profitable transport and storage chains (Stilmant, 2019). Product sorting is performed specifically by organizations mobilizing association cultures.

At the collection stage, logistical cost reduction approaches combined with strategies for economies of scale, appeared to be detrimental to minor crops. The frequent geographical spread of minor crops, resulting in lengthy distances between fields, involves high logistical costs relative to the volume.

The harvesting period of minor crops is sometimes at the same time as major crop harvest, which consequently has a lower priority in transport and storage allocation.

Lastly, specialists noted the availability of silos as a significant challenge to the adoption of minor crops. In fact, the scaling up of farming systems has led to investments in big silos which are less suitable for small quantities. The collection organisations are rapidly selling their small batches of minor crops to make space in the silos for the major crops; as a consequence these are not sold at the best price. Logistic issues also lead in the storing different quality batches mixed together in the same silo for convenience.

Barriers
long distances between fields of minor crops within the collecting areas, resulting in high logistical costs compared to the volume
harvest period of minor crops sometimes overlaps the major crops harvest
Lack of availability of large silos for minor crops

6.6.3 Industrial processing and distribution

Other barriers include competition on the global market for diversification crops with cheaper products and sanitary standards or minimum quality standards, particularly for human consumption outlets (25% and 20%).

More than half of the 11 crops studied are used to produce animal feed. Those crops are in direct competition with substitute feed resources. Pea, lupin, faba bean or alfalfa pellets face are under very heavy competition from soybean meal, and from co-products of the biofuel industry, such as rapeseed meal and wheat draff.

According to stakeholders from the animal feed sector, it is often more sensible from a business perspective for processors to source on the global market, with ready accessible raw materials with reliable compositions and cost efficient high volumes, than to set up a local supply chain for pulses. A restricted volume, geographically distributed or far from customers, increases transaction costs and limits the adoption of minor crops. In these extremely competitive markets, quality guarantees through labels and brands, could support segmentation favourable to minor species. However experts indicated that the customer specifications are sometimes contradicting.

Barriers
competition for diversification crops with cheaper products on the international market
sanitary standards or standards of minimum quality, especially for outlets for human consumption
Not yet existing new value chains

6.6.4 Governance and collaboration of the value chain

Nearly 40% of the research indicate the difficulty of implementing collective actions between farmers and the absence of communication between stakeholders in the sector. As many obstacles to the development of collaboration that could lead to the supply of significant volumes for the sectors a real contractualization between the links is involved. The lack of a guaranteed price with a clear distribution of value added is pointed out as a significant barrier (66%). 40% believe that multi-year contracts to predict the duration of supply could be an major lever for promoting investments and lowering risks for innovative farmers.

An analysis of the linseed value chain, highlighted the importance of stakeholder coordination in value chains with diversified minor crops. The linseed value chain is defined by a strong governance of the processors and chain collaboration, through production contracts and quality specifications of the raw material, to support traceable production. To secure a constant supply, the processors contract the farmers and collecting firms (either cooperatives or brokers), and provide incentives to integrate minor crops in their rotations. As the farmers interviewed have indicated, (see also Hart and Holmstrom, 1987 and Fares, 2006), contracts for innovative crops need to be multiannual to support investments in machinery and training and knowledge. It is essential to de-risk farmers with a profitable buyer and technical support over the long term to encourage farmers to make such investments.

The stakeholders stressed that this governance promotes the sharing of information between the different stakeholders, but also between stakeholders and research and development institutes.

Barriers
difficulty of implementing collective actions between farmers and the lack of communication between the actors throughout the sector
Difficulty of implementing innovation at stakeholder level, when coordination in the value chain is lacking

6.7 Barriers in manure & composting

From the expert workshops conducted in 2018 by Theun Vellinga, Ferry Leenstra (WUR) and Mascha van Dort (TNO) with various stakeholders in the value chain it appeared that in both The Netherlands, Germany, Belgium and Chechia manure quality seems to be problematic.

Workshop participants, including manure processors, stated that the requirements of arable farmers (other than transaction amounts) are currently unknown. Given the market circumstances in which manure is currently dumped at low prices and live stock farmers subsidize transport of manure (and hence pay a larger share than the arable farmers), needs and requirements of arable farmers did not get a lot of attention in the past decades. Consequently there are no end -user specifications (f.i. contents, desired nutrients, undesired contamination, consistency). This is even more of a challenge given that arable farmers in Czech Republic reported that they were unsure of the soil needs for manure. Because artificial fertilizer is cheap and abundant, arable farmers report to have lost the knowledge how to use manure.

Moreover, there appears to be a large variation in the quality of manure and manure analysis is considered unreliable. Large variations in quality assessment before and after transport was reported and also within one badge of manure. This is of a particular challenge to precision fertilizing.

An extra challenge is the need to secure that the manure does not contain undesirable materials such as heavy metals, residue of animal medicine or other contaminations.

Moreover, manure is associated with problems, risks because of strict laws and even fraudulent practices such as illegal transport, illegal dumping of manure etc. This prevents reliable actors willing to invest and be associated with manure and limits innovation, particularly in stakeholder collaborations both nationally and internationally. Stakeholders are passive to organize themselves and waiting for government to take the lead, but at the same time not trusting the government in its capacity as a lawmaker because of changing regulations.

Internationally there is but few cooperation between arable farmers and manure producers because of long value chains. And although society is pressing for change on one hand, stakeholders report that local community stakeholders are also pressing because manure stinks.

Barriers
The requirements of arable farmers are unknown
Lack of knowledge of the soil needs for manure
large variation in the quality of manure
Manure analysis is considered unreliable
Quality
Lack of investment into innovation of manure
fraudulent practices
Stakeholders are passive to organise themselves; lack of trust
few cooperation between arable farmers and manure producers
Manure stinks

7 From barriers to needs and actions

Challenges mentioned in the previous chapter for the adaptation of all climate smart practices all can be grouped into

1 Adoption challenges on the farm
2 Adoption challenges off the farm (logistics, storage, market)
3 Adoption challenges in organizing the value chain
4 Adoption challenges related to attitudes
5 Innovation challenges related to the value network constellation (imbalance in value network / governance) or economic challenges (policy)

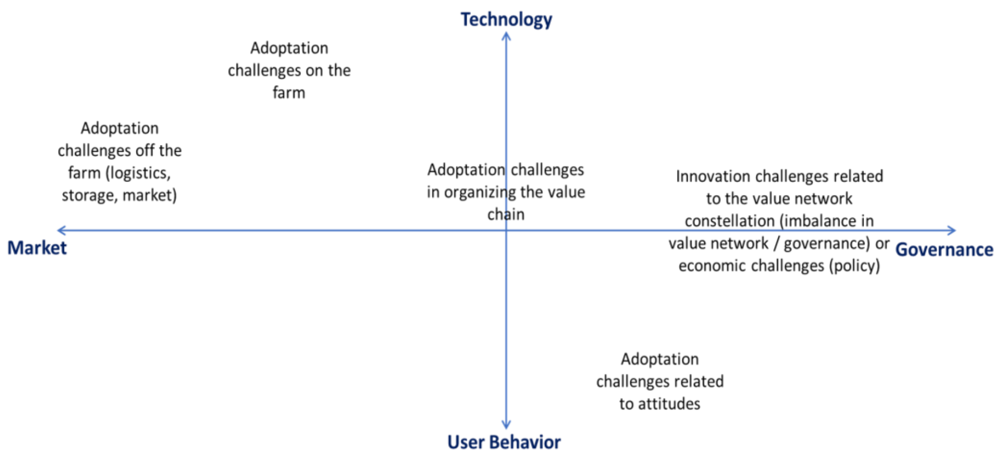

Figure 7, Possible interventions for barriers to innovation

In the following tables the project team identified data driven services which could help solve the challenges:

Table 6 Adoption challenges on the farm

Adoption challenges on the farm	Opportunities for data driven CSA
Decreasing soil quality and nutrient loss are not readily visible	Facilitating a New Way of ''Seeing'' with cheap soil quality trackers (f.i. AgroCares Scanner)
Drop of yield following a decrease in the use of fertilizers, pesticides and herbicides	Transition models Crop insurance approach as a back up based on crop models
knowledge needed to implement diversification strategies in relation to the economic performance	Crop rotation models, both technical and economical with stress on the combination of crop models with economic model
The complexity of managing diverse crop systems	Real time decision support (crop models, appropriate data feed), useful and with good acceptable business model
Current machines unsuitable for précision fertilizers	Light weight new machinery (robots?) for precision fertilizers , moving away from large tractors
The availability of necessary agricultural machinery for crop	Light weight, heavy duty new machinery (robots) for inter or multi

rotation/strip cropping, both for the management of the crop and for the management of the harvested product	cropping including business models; sharing/renting platforms (data managed?) for costs and rent outs of machinery (is this possible when everyone harvests at the same time?)
Lack of info about new crops (other than own crops)	Need for learning about new, old and other crops
Lack of knowledge of the soil needs for manure	Need for learning about manure, could be supported by quality sensors both of manure and soil
Lack of insights into benefits of precision farming	Successful practical experience from other farmers, stories/testimonials. Could be across platforms (EIP-Agri)
profitability of the multi cropping system in the current economic and legislative context	Business case - and policy influencing, organising market places
Lack of insights business case of precision farming	Insights in business case, stories/testimonials. Could be across platforms (EIP-Agri)

TABLE 7 ADOPTION CHALLENGES OF THE FARM (LOGISTICS, STORAGE, MARKET)

Adoption challenges of the farm (logistics, storage, market)	**Opportunities for data driven CSA**
Minor crops have long distances between fields, resulting in high logistical costs compared to the volume	More efficient profitable collection and logistics; smart collections and logistics
harvest period of minor crops overlaps with major crops harvest leading to competition in silos	Profitable storage chains; use smaller silos
(Large) silos availability for minor crops	Profitable storage chains; smart collections and storage
Higher transaction costs for minor crops	Organising the market place with platforms
The requirements for manure of arable farmers are unknown	Organising the market place, opportunity platform
The availability, the cost of the initial plant material (seed) of legumes	Organising the market place, opportunity platform
Low consumer demands of legumes	Organising the market place, opportunity platform

TABLE 8 ADOPTION CHALLENGES IN ORGANIZING THE VALUE CHAIN

Adoption challenges in organizing the value chain	**Opportunities**

Sanitary standards or standards of minimum quality of legumes, especially for outlets for human consumption	Definition and adaptation of standards and official quality signs, to improve the image of minor crops with the end consumer
Large variation in the quality of manure	Reliable, easy and quick to do measurements; certification of quality; platform for sharing data about quality
need to secure that the manure does not contain undesirable materials	Certification of quality
Manure analysis is considered unreliable	Reliable, easy and quick to do measurements; certification of quality; platform for sharing data about quality
Not yet existing new value chains	Developed value chains with good coordination between the stakeholders, including a fair distribution of added value, balanced business models and a good share of information, transparent systems
difficulty of implementing collective actions between farmers and the lack of communication between the actors throughout the sector	Coordination in the value chain; contracts; platforms
Difficulty of implementing innovation at stakeholder level, when coordination in the value chain is lacking	Coordination in the value chain; contracts; platforms
Stakeholders in the manure chain are passive to organise themselves; lack of trust in manure chain	Coordination in the value chain; contracts; platforms; certification and transparency
few cooperation between arable farmers and manure producers	Coordination in the value chain; contracts; platforms

TABLE 9 ADOPTION CHALLENGES RELATING TO ATTITUDES

Innovation challenges related to attitudes	**Communication actions**
Presence of weeds is not acceptable in conventional farming	Communication by farmers organisations; advisors; knowledge institutes
Conventional farmers place faith in empirical evidence, the scientific method, technology, and experts	Take into account when developing new services

Manure stinks	Communication by government, schools to the public; manure deposition solutions
Low consumer demands of legumes	Communication and market development

TABLE 10 INNOVATION CHALLENGES RELATED TO THE VALUE NETWORK CONSTELLATION OR ECONOMIC CHALLENGES

Innovation challenges related to the value network constellation (imbalance in value network) or economic challenges	**Legislative or policy action**
Short term system lock in (leases, contracts)	Provide investment incentives; regulation
Farm too small for investment in precision farming	Provide investment incentives; crate cooperatives and/or networks; provide platforms
Lower costs of precision farming	Provide investment incentives - check
Lack of suitable 'commercial' varieties due to underinvestment in innovation of legumes as minor species	Invest in research; market development
Lower genetic progress on minor crops	Invest in research; market development
Fewer pesticides approved in legumes	Invest in research
Competition of diversification crops with cheaper products on the international market	Subsidies and regulation
Crop residue harvested for energy production and sold	Regulation
Fraudulent practices in manure	International certification system; Maintain law; change policies requiring export
Lack of investment into innovation of manure	Invest in research; change policies requiring export

8 Workshop results

In the workshops with stakeholders in the value chain, and in 2 separate interviews, the needs were checked and discussed. The workshop was attended by 6 arable farmers from the region of Zevenbergschen Hoek, two advisers from ZLTO and 1 independent adviser. In the workshop practical insights into climart smart arable farming were presented by a climate smart arable farming advisor, working with one of the farmers. Over the last years, this collaboration and subsequent measures resulted in an great increase in soil quality and earth worms, necessary in this area to mitigate heavy rain falls in clay areas. During the presentation extra needs were identified, and all literature needs and brainstormed needs were voted upon in 3 rounds of dot voting (included in Annex 1). The extra needs identified in the workshop were in line with literature findings; and most were already identified but worded differently, except the need for independent advice.

Most expressed needs were on the arable farm, few were off the farm in the logistics chain or in collaboration in the value chain. Some farmers expressed needs in the cooperation between arable farming and husbandry. Those needs were mostly about lack of quality guarantees for manure, unknown requirements from arable farmers and lack of cooperation between arable farms and animal husbandry. In general the logistics and market place in the Netherlands are considered well organized, even for minor crops. There are few needs for improvements regarding the legumes value chain.

Expressed needs on farm were mostly about a need to learn about climate smart agriculture in practice, tailored to own arable farm; a loss of knowledge about soil quality, and relation between farm method and soil quality. As a hurdle to finding this knowledge, farmers expressed an inability to distinguish between good and bad advice, due to loss of knowledge, limited time available, limited budget and limited education level (SME).

From value network analysis of the agri-food chain, conducted parallel to this project in a project for the EU EASME, and also from interviews in the needs analysis, it appeared that compared to other European countries, farmers in the Netherlands are surrounded by a lot of stakeholders (farm suppliers) offering advice and also other farm advise organizations (independent advisers, farmer's organization). The Netherlands does not have a single, government owned, affordable independent advise organization for farmers. Because of the nature of farmer's small business (limited budget, education level and time available) independent innovation advise from knowledge institutes is difficult to access.

Farmers expressed a need for independent advise, other than from sales people from fertilizer, pesticide and seed providers. Although the arable farmers in the workshop were conventional and trusting technology, they expressed a lack of trust in ICT based decision support tools which acted as a sort of advice (taking the decision from farmers). This became noticeable when a ICT powered technological driven soil quality tool was presented; an climate smart innovative farmer was wondering about the closed hence unclear calculations used, whether they were applicable for the methods used by arable farmer.
The workshop also showed that personal farmer experience with innovative climate smart agriculture measures and the results in count of earth worms, triggered a complete peer group to be also interested in innovations. Peer experience therefore seems essential to support scale up of innovations, apart from economic or soil quality benefits.

There were few needs expressed regarding strip cropping or light equipment. This was considered as too early in development.

9 Conclusions and recommendations

Both in literature as expressed in the workshop farmers expressed a great need to learn about climate smart agriculture practice. Underlying is a need to make decreasing soil quality and nutrient loss visible, so that they can take measures. ICT tools can make slowly make changing soil quality over time and nutrient loss visible.

Although conventional farmers rely on and believe in technology there are concerns about technology automating farmer's decisions. Farmers are looking for independent advice, and ICT solutions supporting or replacing such advice are under careful scrutiny. It is recommendable that any ICT solution should support the farmer's decision rather than taking decision away from the farmer and automating the entrepreneur so to speak. Also, approaches, data management and algorithms should be transparent, well explained and open.

As far as pilot set-ups, for scale up it is advisable to open up access to innovations by using peer to peer support groups of farmers around innovative farmers to tackle the resistance to change existing practice (often based in tradition) and the unease, which goes with change. ICT based social tools can support peer-to-peer advice, the most trusted source of advice, and farmer's expressed a need to talk about soil quality.

Top opportunities picks were:

Table 11, Top needs for data driven Climate Smart Agriculture

Adoptation challenges	**Opportunities for data driven CSA**
Minerals in balance C/N	Addition to Cool Farm Tool BO-app
Lack of knowledge of the soil needs for manure	Need for learning about manure, could be supported by quality sensors both of manure and soil
Need for independent advise (other than advise by pesticide, seeds etc. sales people)	Benchmark advisers, open data tools, f.i. advise Farmers association Flanders
Need of pure, unmixed compost from regional waste streams	Regional inventory and ict market place for waste streams including costs, GPS and quality from food industry etc.
Need for insights into value versus risks for reduced tillage	Calculator of value versus risks and rotation plan
Need to feel and touch soil quality and talk about it, also addressing a need to learn from each other about soil quality	App to encourage sharing video's of the soil crumb tests and talk about soil quality
Manure analysis is considered unreliable	Reliable, easy and quick to do measurements; certification of quality; platform for sharing data about quality
Decreasing soil quality and nutrient loss are not readily visible	Facilitating a New Way of ''Seeing'' with cheap soil quality trackers (f.i. AgroCares Scanner)

few cooperation between arable farmers and manure producers	Coordination in the value chain; contracts; platforms

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Annex 1. Result of workshop needs assessment

Adoptation challenges	Opportunities for data driven CSA	
Minerals in balance C/N	Addition to Cool Farm Tool BO-akk	8/4/3
Lack of knowledge of the soil needs for manure	Need for learning about manure, could be supported by quality sensors both of manure and soil	8/1
Need for independent advise (other than advise by (pesticide, seeds etc. sales people)	Benchmark advisers, open data tools, f.i. advise Farmers association Flanders	7/4/7
Need of pure, unmixed compost from regional waste streams	Regional inventory and ict market place for waste streams including costs, GPS and quality from food industry etc.	7/4/2
Need for insights into value versus risks for reduced tillage	Calculator of value versus risks and rotation plan	7/1
Need to feel and touch soil quality and talk about it, also addressing a need to learn from each other about soil quality	App to encourage sharing video's of the soil crumb tests and talk about soil quality	6/4/5
Manure analysis is considered unreliable	Reliable, easy and quick to do measurements; certification of quality; platform for sharing data about quality	6/1
Decreasing soil quality and nutrient loss are not readily visible	Facilitating a New Way of ''Seeing'' with cheap soil quality trackers (f.i. AgroCares Scanner)	6
few cooperation between arable farmers and manure producers	Coordination in the value chain; contracts; platforms	6/1
The requirements for manure of arable farmers are unknown	Organising the market place, opportunity platform	5
Lack of info about new crops (other than own crops)	Need for learning about new, old and other crops	5
Large variation in the quality of manure	Reliable, easy and quick to do measurements; certification of quality; platform for sharing data about quality	5
The availability of necessary agricultural machinery for crop rotation/strip cropping, both for the management of the crop and for the management of the harvested product	Light weight, heavy duty new machinery (robots) for inter or multi cropping including business models; sharing/renting platforms (data managed?) for costs and rent outs of machinery (is this possible when everyone harvests at the same time?)	4
knowledge needed to implement diversification strategies in relation to the economic performance	Crop rotation models, both technical and economical with stress on the combination of crop models with economic model	4
Independent benchmark including health for feed for animal husbandry	Feed calculator	3/3
Stakeholders in the manure chain are passive to organise themselves; lack of trust in manure chain	Coordination in the value chain; contracts; platforms; certification and transparency	3
profitability of the multi cropping system in the current economic and legislative context	Business case - and policy influencing, organising market places	3
Lack of insights business case of precision farming	Insights in business case, stories/testimonials. Could be across platforms (EIP-Agri)	3
Drop of yield following a decrease in the use of fertilizers, pesticides and herbicides	Transition models Crop insurance approach as a back up based on crop models	3

Identify fake solutions	Quick scan solutions	2
Lack of insights into benefits of precision farming	Successful practical experience from other farmers, stories/testimonials. Could be across platforms (EIP-Agri)	2
Not yet existing new value chains	Developed value chains with good coordination between the stakeholders, including a fair distribution of added value, balanced business models and a good share of information, transparent systems	2
harvest period of minor crops overlaps with major crops harvest leading to competition in silos	Profitable storage chains; use smaller silos	2
The availability, the cost of the initial plant material (seed) of legumes	Organising the market place, opportunity platform	1/1
Weeds/CO2/soil feed/roots/protection earthworms	Sun light calculator	1
Higher transaction costs for minor crops	Organising the market place with platforms	1
Sanitary standards or standards of minimum quality of legumes, especially for outlets for human consumption	Definition and adaptation of standards and official quality signs, to improve the image of minor crops with the end consumer	1
need to secure that the manure does not contain undesirable materials	Certification of quality	1
difficulty of implementing collective actions between farmers and the lack of communication between the actors throughout the sector	Coordination in the value chain; contracts; platforms	1
Rendement calculation head land, input for leaving corners	EAOS	1
Insights into calculation of soil quality: what is measured, how does it relate to my method, locallity	Open bodemindex	1
Current machines unsuitable for précision fertilizers	Light weight new machinery (robots?) for precision fertilizers , moving away from large tractors	
(Large) silos availability for minor crops	Profitable storage chains; smart collections and storage	
Low consumer demands of legumes	Organising the market place, opportunity platform	
Minor crops have long distances between fields, resulting in high logistical costs compared to the volume	More efficient profitable collection and logistics; smart collections and logistics	
Difficulty of implementing innovation at stakeholder level, when coordination in the value chain is lacking	Coordination in the value chain; contracts; platforms	

Annex 2, Sources for Value Network Analysis (tables 1 and 2)

[i] Snapshot 2019, The Dutch AgriFoodTech Sector, Agrifoodtech platform
[ii] The challenge of the role of supermarkets for sustainable agriculture and trade related issues, Myriam Vander Stichele, Somo, 2005
[iii] Critical success factors for the supermarket Albert Heijn: A mixed methods study, Jing Xu, University of Amsterdam, August 2012
[iv] Global Powers of Retailing 2018 Transformative change, reinvigorated commerce, Deloitte
[v] https://csimarket.com/Industry/industry_Profitability_Ratios.php?ind=1305
[vi] http://www.xinhuanet.com/english/2019-04/26/c_138010013.htm
[vii] Mercer Capital Value focus Agribusiness industry 2017
[viii] Critical success factors for the supermarket Albert Heijn: A mixed methods study, Jing Xu, University of Amsterdam, August 2012
[ix] Agricultural machinery ahead of the field, Rabobank industry note 340, 2012
[x] Mercer Capital Value focus Agribusiness industry 2017
[xi] The challenge of the role of supermarkets for sustainable agriculture and trade related issues, Myriam Vander Stichele, Somo, 2005
[xii] The competitive position of the European food and drink industry, ECSIP consortium, 2016
[xiii] Food Processing & Handling Ripe for disruption?, McKinsey, Match 2018
[xiv] https://csimarket.com/Industry/industry_Profitability_Ratios.php?ind=505
[xv] https://csimarket.com/Industry/industry_Profitability_Ratios.php?ind=503
[xvi] Snapshot 2019, The Dutch AgriFoodTech Sector, Agrifoodtech platform

[xvii] Indian Processed Food Industry Analysis, Anirudhh 2014
[xviii] https://www.theanswerco.com/3-key-success-factors-for-the-food-manufacturer-of-the-future/
[xix] Jacqueline K. Holland e.a (2014), Understanding Producer Strategies: Identifying Key Success Factors of Commercial Farms in 2013, Southern Agricultural Economics Association’s 2013 Annual Meeting, Dallas.
[xx] Connor J.M. & Schick W.A. (1997), Food Processing An Industrial Powerhouse in Transition, second edition, Wiley-Interscience.