Smart farming in pig production and greenhouse horticulture

An inventory in the Netherlands

Robert Hoste, Hyun Suh and Harry Kortstee

WAGENINGEN
UNIVERSITY & RESEARCH

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This study was carried out by Wageningen Research and was commissioned and financed by the Korean Rural Economics Institute in the Republic Korea (South Korea)

Wageningen University & Research
Wageningen, October 2017

REPORT
2017-097
ISBN 978-94-6343-218-4

WAGENINGEN
UNIVERSITY & RESEARCH

Hoste, Robert, Hyun Suh and Harry Kortstee, 2017. *Smart farming in pig production and greenhouse horticulture; An inventory in the Netherlands.* Wageningen, Wageningen University & Research, Report 2017-097. 38 pp.; 20 fig.; 1 tab.; 43 ref.

Het Korean Rural Economics Institute in Zuid-Korea wil inzicht hebben in de toepassing van zogenaamde smart farming in Nederland. Zij hebben Wageningen Research opdracht gegeven voor een inventarisatie van smart farming in de varkenssector en glastuinbouw. Smart technologie wordt breed toegepast in de varkensproductie en de glastuinbouw in Nederland. Verdere ontwikkeling hierin wordt verwacht in dataverzameling, data-analyse en visuele weergave van resultaten.

The Korean Rural Economics Institute in South-Korea wants to learn about the application of smart farming in the Netherlands. They committed Wageningen Research to make an inventory of smart farming in pig production and greenhouse horticulture. Smart technology is applied widely in pig production and greenhouse horticulture in the Netherlands. Further development is expected in data collection, data analysis and visual representation of outcomes.

Key words: Smart farming, ICT, Pig production, Greenhouse horticulture, Netherlands

This report can be downloaded for free at https://doi.org/10.18174/425037 or at www.wur.eu.

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Wageningen University & Research Report 2017-097 | Project code 2282100237

Cover photo: MS Schippers

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Preface

South Korea is famous for its high-tech industry, and the Korean government wants to implement so-called ‘smart farming’: high-tech applications in the agricultural sector in order to improve efficiency and profitability. The Korean Rural Economics Institute wants to learn about the application of smart farming in the Netherlands.

Smart farming is the application of modern information and communication technologies focused on a data-driven approach to deal with existing challenges and opportunities in agriculture. With this definition in mind an inventory was performed by Wageningen Research of the current use and the further developments of smart farming in two selected agricultural sectors: pig production and greenhouse horticulture. Also, the governmental strategy towards innovation, including smart farming was explored.

The project was led by Robert Hoste, pig production economist, who also performed the analysis on smart pig farming; Hyun Suh, researcher in Agro Food Robotics in Greenhouse Horticulture, performed the analysis on smart greenhouse horticulture and Harry Kortstee, researcher on farmers’ entrepreneurship, collected the information on the governmental strategy.

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Summary

Different management skills needed than in conventional farming

Smart technology is applied widely in pig production and greenhouse horticulture in the Netherlands. Application of smart technology in farm management requires different management skills than in conventional farming. Farmers must be able to make use of new technologies, but also to adapt their decision-making process. This requires updated curricula in farmers vocational education and training.

Data management essential

Further development is expected in data collection, data analysis and visual representation of outcomes. This requires attention to e.g. ownership of data, interoperability among vendors, and responsibility in case of inaccurate predictions.

Method

An inventory was made of currently existing smart techniques and applications in the pig sector and greenhouse horticulture, based on internet searches and interviews and enquiries of companies involved. The inventory focuses on the current status, but also gives some outlook towards further opportunities.

1 Introduction

1.1 Smart farming definition

Given the growing world population and increasing demand for high quality food without compromising the earth's ability to provide food for next generations, there is need for a smart way of food production (Gilpin, 2015). Farmhack.nl states that the 'Internet of Things, and the smart sensors that constitute it, will have a major impact on agriculture'. Also, Rabobank (2017) says that 'the demand for information throughout the supply and food chains will be a main driver in the evolution of digital agriculture and its widespread adoption'. FAO (2013) is focusing on smart options to ensure 'food security through increased productivity and income, adapting to climate change and contributing to climate change mitigation'. Wolfert et al. (2017) focus on improving a cyber–physical generic sense-model-act cycle (smart sensing & monitoring – smart analysis & planning – smart control) farm management cycle. It adheres to the definition of smart-akis.com:

> 'Smart Farming represents the application of modern Information and Communication Technologies (ICT) into agriculture, leading to what can be called a Third Green Revolution. Additionally to on-farm technology however, data exchange between parts of the supply chain is relevant, focusing on improving the management of the process throughout the supply chain, as well as providing consumers with information for trust building. Following the plant breeding and genetics revolutions, this Third Green Revolution is taking over the agricultural world based upon the combined application of ICT solutions such as precision equipment, the Internet of Things (IoT), sensors and actuators, geo-positioning systems, Big Data, Unmanned Aerial Vehicles (UAVs, drones), robotics, etc.'

Smart-akis.com says: 'Smart Farming has a real potential to deliver a more productive and sustainable agricultural production, based on a more precise and resource-efficient approach.' *The Economist* (2010) includes in its definition that data-driven predictive analytics can offer support to 'spot business trends, prevent diseases, combat crime and so on' in smart technologies. Combining these definitions, in this report we define smart farming as follows:

> *Smart farming is the application of modern information and communication technologies (ICT) focused on a data-driven approach to deal with existing challenges and opportunities in agriculture.*

1.2 General developments in smart farming

The Dutch agricultural production can be characterised as technology and innovation-driven, capital-intensive, partially footloose and highly efficient. The Netherlands has ample experience in highly intensive agricultural production. It has to deal with a high density of both people and farm animals in a small country. The country has a trade history as a gateway to the European continent for large volumes of agricultural products, resulting in being the second country worldwide in trade turnover of agricultural products.

Societal requirements have increased in the last decennia, including environmental, animal welfare, workers' and public health (see Hoste, 2017a), forcing farmers to invest in appropriate measures. This leads to an increased cost of production and a loss in competitive position (Hoste, 2017b; Horne and Bondt, 2014; Meulen, 2016), which in turn forces further intensification, efficiency and scale of production to survive. Smart farming could be a logic answer to cope with these demands. Indeed, Min (2016) expects that in the future differences in competitiveness between farmers and agricultural companies will no longer be based on traditional competitive advantages such as natural conditions (labour, land, capital), but on capital, technology and the management capability of people employed in agriculture.

A new, promising, development is the blockchain technology, a web-based transaction platform, which is still in an infant stage in agricultural applications. The Global opportunity report 2017 states that the 'blockchain technology market is estimated to grow from 210.2 million USD in 2016 to 2,312.5 million USD by 2021'. Due to its strong increase, it is expected that this technology will also play an important role in the agricultural sector, in payments, data exchange and digital identities, to name a few applications. Backus (2017) refers to the blockchain technology as a future development for the pig sector and he mentions some examples: for setting up a piglet passport, and guaranteeing the origin of feed ingredients in a specific market programme. In that sense we have to conclude that the current status of smart technology still has ample room to develop.

Markets and markets (2017) state that the total smart agriculture market worldwide is expected to grow from USD 5.18 billion in 2016 to USD 11.23 billion by 2022. Of this amount in 2022, USD 1.1 billion would be dedicated to the smart greenhouse market, almost doubling from USD 0.6 billion in 2016.

AgriDirect (2016) collected information on information sources of pig and poultry farmers in the Netherlands. They give the following information: 72.1% of the farmers use the web at least once per day. Of the pig and poultry farmers, 95.1% receive work-related newsletters by e-mail, and 67% of this group always or almost always read such newsletters. Social media are being used for their farm by 29.3% of the pig and poultry farmers. This is especially done to follow agricultural news (83.0%), and for contact with colleagues (49.4%), as well as for private purposes (33.8%). Agricultural apps are being used by 19.3% of the Dutch pig and poultry farmers, especially for following agricultural news (74.5%), ordering products (61.8%) and weather forecasts (36.4%). Whatsapp is used by 70% of Dutch farmers, especially for ordering (Prosu, 2017).

Kernecker et al. (2016) found that larger farms have a higher adoption rate of smart farming techniques than small farms. This is partly to be explained by differences between countries involved in the study and partly because some smaller farms apparently were too small for currently available smart farming technology and that these were too costly for them. Kernecker et al. conclude that the potential of smart farming technology should be clearly communicated to farmers to improve the application.

1.3 Method and material

Data about the current use of smart farming technologies in the pig supply chain and the greenhouse horticulture were gathered by a web search and by contacting in total about 10 companies active in the pig and greenhouse horticultural supply chain. Companies were asked about their current smart techniques and new developments. The inventory on smart pig farming is elaborated in more detail than the greenhouse horticulture; input from companies was limited here.

1.4 Reading guide

Section 2 starts with an overview of the Netherlands' governmental policy to stimulate innovation and smart farming. An overview of current developments in the application of smart farming in pig production is provided in Section 3 and in greenhouse horticulture in Section 4. Section 5 provides the discussion and conclusions.

2 Netherlands' governmental policy on innovation and smart farming

2.1 Golden Triangle

The Dutch government adheres to the philosophy of co-innovation, where government, industry and knowledge institutes, as a Golden Triangle, jointly work on innovation (Figure 2.1).

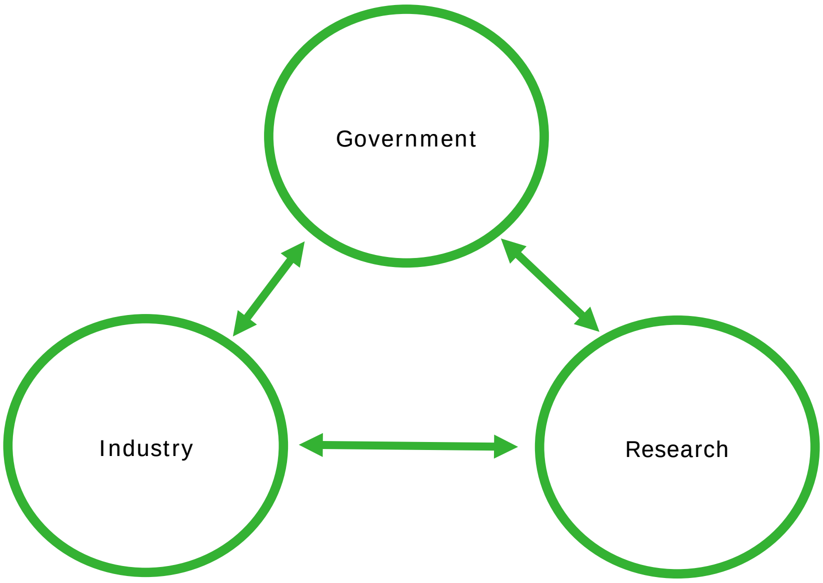

Figure 2.1 *Golden Triangle for co-innovation in the Netherlands*

The Ministry of Economic Affairs issued a strategic policy to focus on nine selected industries, so-called Topsectors, listed below:

- Horticulture and propagation materials
- Agri&food
- Water
- Life sciences and health
- Chemicals
- High tech
- Energy
- Logistics
- Creative industries.

The Dutch government has adopted the so-called Topsector policy. Nine economic top performing sectors have been indicated as most relevant for the Dutch economy. Governmental innovation funds are mainly focused on these economic sectors. Within this Topsector policy, companies, research institutes, and the Dutch government are working together to further improve the knowledge, innovation and economic position of the involved parties and the entire sectors. Within each Topsector, companies, research institutes and government are organised into so-called Topconsortia for Knowledge and Innovation (TKI), with their own knowledge and innovation agendas and objectives.

In the 2012-2015 period, the Dutch government invested about € 7 billion to further develop these Topsectors. Two of the nine Topsectors are related to the agricultural sector: Agri&Food (A&F) and Horticulture & Propagation materials.

Five priority areas per Topsector
The Knowledge and Innovation agenda 2018-2021 of Agri&Food, defined five key priority areas: Consumer & Society, Climate neutral, Healthy & Safe, Circular, and Smart Technology (TKI-agrifood). The Knowledge and Innovation agenda 2016-2019 of Topsector Horticulture and Propagation Materials also has five key priority areas: More and better with less, Collaborative value chains, Health and well-being, Food safety, and Food security (Topsector TU, 2015).

Financial support for innovative enterprises
Innovative businesses can help develop solutions to major social issues like global food security, ageing populations or life-threatening diseases. By developing new products they can also gain access to new markets. Innovation boosts economic growth and creates jobs. That is why the government provides financial support for innovative enterprise, enabling businesses to bring their innovative products and services onto the market more quickly. The government not only supports financially, but also by match-making, facilitating and by focusing on strategically important developments.

How does it work in practice to set up a co-innovative project?
Companies and research institutes are joint together in a public private partnership: a specific consortium of companies, research institutes and the government. Those partnerships can apply project plans to the Topsector. Originally companies were intended to initiate project proposals, but in practice this is often performed by research institutes. The Topsector selects appropriate projects, within the available strategy and budget and decides on granting a financial contribution to the project. Companies have to contribute their part both in effort and cash. Costs of involved research institutes are paid by the cash amounts both of involved companies and the government.

Stimulating smart farming
Smart farming is not emphasised as a top priority in itself, like in South Korea, but is integrated into the Topsectors innovation agendas in the different priority areas. The smart (high-tech) approach is found in other Topsectors as well.

Sources: Topsectoren; *Resource*.

2.2 Governmental support

The Dutch government supports innovation not only via contributions to co-innovation in the public-private partnerships, but also through tax benefits, innovation credit and grants and other initiatives. Also some EU grant schemes for innovation are available. Table 2.1 presents a selection of Netherlands and EU innovation funds related to smart agriculture.

Table 2.1 *Selection of Netherlands and EU innovation funds related to smart agriculture (amounts in million euros in 2017)*

Fund name	Budget	Explanation
SMART Industry field labs	14.5	Smart Industry field practice labs are environments in which companies and knowledge institutions Smart Industry Solutions can develop, test and deploy. The grant is 60% of the eligible costs and two-thirds from an interest-free loan.
Service Design vouchers	0.24	Research voucher of max € 3,000 for small/medium manufacturing enterprises to be deployed at knowledge institutions or a consulting firms.
SME Innovation incentive arrangement for regions + Topsectors	14.4	Knowledge vouchers Innovation consultancy projects and feasibility projects R&D cooperation Network activities and innovation real estate
Wet Bevordering Speur- en Ontwikkelingswerk (WBSO)	1.2	Fiscal instrument to reduce labour costs for Research & Development activities by companies
Innovation performance contracts	4.3	Subsidy for collaboration of about 10-20 SME's in the same region, supply chain or industry working together a long-term innovation path. € 2.9m is for rural projects and € 1.4m for regional projects
Innovation credit	40	The Innovation credit is funding the development of new products, processes or services with a strong business case. The credit is given as a loan. This fund is related to technical development projects
Public-private-partnerships research and innovation (PPS)	75	Financial participation in cooperative projects by companies and research organisations, performing fundamental research, industrial research, or experimental development
Eurostars (European Commission)	18	Programme for international market oriented R&D, for developing technology for new products, processes or services with foreign partners
EUREKA-cluster PENTA (Pan European partnership in micro and Nano-Technologies and Applications)	10	Supports research, development and innovation in the field of micro-and nano-electronics systems and applications. The projects should support the European strategy for micro-and nano-electronics. Funded by the European Commission.
EUREKA cluster-ITEA3 (Information Technology for European Advancement)	14.2 a)	ITEA3 is a European strategic research programme for the development of software intensive systems and services. Funded by the European Commission.
Horizon 2020 (European Commission)	1140	With Horizon 2020, the European Commission and the governments of Member States stimulate science and innovation in business and academia. So they can increase the competitiveness of Europe and work together on solutions to social issues that play across Europe. For example, for climate change, ageing, food safety and affordable sustainable energy

Sources: RVO; Topsectoren; Eureka

a) Year 2016

Some other initiatives of the Dutch government to encourage innovation are:

- *National Icons Competition*
  Every two years, the government organises the National Icons Competition for projects or products addressing societal issues. Participating projects / products show how Dutch innovations are among the world's best. Currently there are seven national icons of which two are agri-related: hybrid potato and the growboxx.
- *Innovation Expo*
  The Innovation Expo is a bi-annual event aiming to accelerate innovation. It is an innovation network comprising 3,000 representatives from the private sector, public bodies and knowledge institutions. They work together on innovations and technological breakthroughs.
- *'Volg Innovatie' database*
  The 'Volg Innovatie' ('Follow Innovation') database gives an overview of projects that are being (co-)funded by the Ministry of Economic Affairs. The Database is managed by the Netherlands Enterprise Agency.
- *National Science Agenda*
  The Ministry of Economic Affairs' National Science Agenda identifies focus topics for scientific research in the years ahead. It addresses questions like: What areas are promising for the Dutch science? How can science help to find solutions to societal issues? How can science create economic opportunities for innovation? Etc.
- *Innovation Attaché Network*
  Innovation attachés are employees at Dutch embassies and consulates. They assist Dutch companies doing business abroad. For instance, by introducing them to potential partners, like research institutions or other companies.
- *Smart Industry*
  The Smart Industry initiative of the Dutch government, research and industry representatives aims to strengthen Dutch industries by promoting the use of cutting-edge IT and technology, like 3D printing, nanotechnology and robots.

Source: Government; https://www.nationaleiconen.nl/.

Box 2.1 gives an example of a project within a public private partnership.

Box 2.1 Example project

July 2016 the Topsector Horticulture and Propagation Materials started with the Public Private Partnership Market Intelligence Voedingstuinbouw 2.0, related to market intelligence for Nutrition Horticulture. This project is being developed and implemented by Wageningen Economic Research, commissioned by and together with the GroentenFruit Huis. The GroentenFruit Huis represents companies active in the trade and marketing of fresh fruits and vegetables.

The purpose of this project is to enable companies, supply chains and production sectors to improve their decision making on market and marketing strategy in the short, medium and long term. The focus is on the development of tools for the food chain. Tools to be developed are: The FoodProfiler App, in which near time consumption behaviour is measured; the GlobalDetector, indicating optimal production and marketing areas in the world; and Forecasting tools, predicting the effect of market interventions.

The project runs from 2017 to 2020. The total budget amounts to € 1.76m, of which 50% is paid by the GroentenFruit Huis and the other 50% by the Government. Half of the total contribution of the GroentenFruit Huis consists of an in-kind contribution.

3 Smart pig production

3.1 Farm level smart solutions

3.1.1 Introduction

In terms of piglets weaned per sow and year, the Netherlands is the second country worldwide (29.5; Hoste, 2017b), only surpassed by Denmark. Cost of production amounts to about € 1.69 per kg of hot carcass weight, far lower than the € 2.63 per kg in South Korea (Hoste, 2016), typically reflecting the difference in production efficiency between both countries. The number of farms with pigs in the Netherlands is halved every 10 years, as a result of the strong competition. Availability of workers is limited and expensive (€ 25 per hour), resulting in pressure to improve labour performance and automation. Strong competition has led to high performance, low cost of production and shake-out of less-performing farms. Smart solutions have supported these developments.

The pig supply chain in the Netherlands is not vertically integrated but can be defined as a loosely coupled system, typically without written agreement, but based on common trade habits (Janssens et al., 2012). Product information is shared throughout the supply chain only to a limited extent: slaughter quality information is provided back to the farmer, but farm of origin information is kept with the product only to some extent. Still, in terms of food safety and product traceability, the supply chain is well organised, but data sharing throughout the supply chain would deliver improved opportunities to inform consumer about the origin and way of production of their meat. Pilot projects are being performed to improve information sharing up to the consumers. Part of the consumers are especially interested in products of their own region, or in products of animals that they have seen themselves. To this end, individual identification of animals and keeping this information is necessary and could support the trust of consumers in their products. Min (2016) describes a development of agriculture towards what he mentions 'eatertainment', in which consumers enjoy a combination of food and entertainment (like art, music etc.), as an opportunity for creating added value.

3.1.2 Smart solutions already applied in practice

Management information system

A high efficiency requires a high level of management capabilities. Dutch pig farmers all make use of a Management Information System (MIS), a software tool for recording all pig-related events, like giving birth or mortality. This tool supports the management of production processes, by drawing the farm workers' attention to necessary activities and interventions. Farmers also benchmark their data, not only over time (self-mirroring) but also with their colleagues, as to be able to mutually learn and improve results. Farmers typically are member of study groups of farmers, exchanging experiences and results in quite some detail and based on trust. Application of a MIS is a prerequisite for high performance in pig production. Farmers can use a hand-held device, reading the animal number (electronic identification is necessary), and showing performance information of the individual animals (Figure 3.1). This supports decision-making and instant interventions. Electronic identification (EID) of animals is necessary, which is done on a limited number of farms. Further development of EID is expected. A hand-held device also supports instant data entry, improving the data quality.

Figure 3.1 *Hand-held reader and electronic ear tag. Photo courtesy of MS Schippers*

A MIS typically produces performance information of individual animals, groups of animals, or on farm level. A current development is to implement user-friendly graphical reporting of results, including a dashboard-like presentation (Figure 3.2). This way of presentation gives quick insight into relevant parameters and draws attention to necessary interventions, rather than drowning the user in lots of data. This way an MIS is developing towards a decision-support system. Management information systems are increasingly linked to other modules, including financial administration.

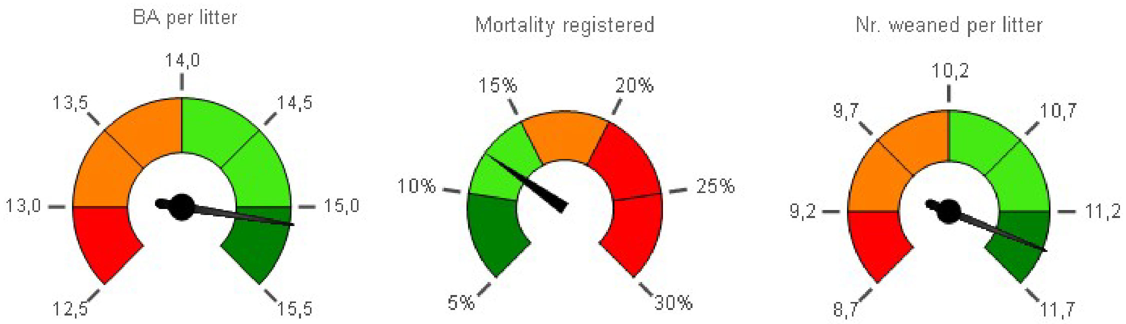

Figure 3.2 *Example of graphic dashboard presentation in a Management Information System for pig farms. Courtesy of Agrisyst*

(Electronic) individual identification of pigs

Sows are typically identified and managed individually. However, just part of the sows in the Netherlands have an electronic ear tag, mainly depending on the feeding equipment: for individual recognition at an automatic feeder station, sows need EID. EID is based on the Radio Frequency Identification technique (RFID). Measuring individually gives the opportunity for individual observation of growth, feed intake, and birth weight, behavioural patterns to signal diseases or activities to be performed (like insemination or separation), which is very supportive for operational management. Also if sows do not report to a feeding system this gives a signal of lack of appetite and maybe a disease.

Fattening pigs are typically being identified as a group (pen number, farm number), rather than as individuals. Electronic individual identification would give different advantages, but is assumed to be not economically feasible yet. This information supports improved operational management and labour saving in large groups, as well as in other stages of the supply chain, such as improved breeding (see Section 3.2) and improved traceability (see Section 3.3). Only a limited number of farmers are pioneering now with EID for fattening pigs.

Advantages of EID for fattening pigs
With EID, fattening pigs can be weighed individually, and actual feed intake can be measured individually. This gives the opportunity for continuous adaptation of the individual feeding regimes, both in terms of quantity and feed type. Such individual measuring of individual growth and feed intake is an important input for monitoring of the farm performance and gives an opportunity for immediate response in the case that individual pigs would not eat or grow. Individual performance data improve the forecast when animals are ready-to-market. Individual measuring gives the ability to benchmark within the farm: differences in results between pens or departments can be measured, which could be related to e.g. different climate circumstances. This measuring-analysis-control cycle leads to improved operational management and to reduced variability among pigs (precision livestock farming). In practice sometimes a simpler solution is already in use in which one pen has a weighing floor and weight development in the pen is assumed to represent the entire departments' performance.

Automatic sorting possible next step
On a few farms in the Netherlands fattening pigs are kept in large groups (like 300 pigs per pen). Pigs are being weighed either by a scale or by a vision system, in order to decide in which department the pig can get feed (feed composition differs according to their actual need) as well as to sort out pigs. In case of big groups of fattening pigs, sorting out can be not only difficult (for instance finding individuals in a big group and taking them out), but also dangerous (if a farmer faints, pigs might start attacking and even eating an unconscious person – although the probability that such an event might happen is very small, it prohibits some farmers from implementing such big groups). Automatic sorting out of sick animals (as long as they are able to walk and come to a monitor and passage way) and pigs ready for transport to the slaughterhouse can save labour as well as observation errors. Several commercial solutions are available, like Nedap Pig Sorting, Aco Funki Pig Sorting, or Optisort.

EID expected to be common use in 10 years
Electronic animal registration is found on a quarter of all pig farms in the Netherlands (Burgers, 2015a). Burgers does not make a distinction between sow and fattening pig farms, but most likely these are mainly large sow farms; in fattening, EID is only applied at a few farms. EID is likely to increase to common use within the next 10 years, as the price is decreasing and farmers are increasingly aware of advantages. Currently, RFID tags are not allowed as legal Identification & Registration means in the Netherlands, but this might change, as electronic identification has become a legal prerequisite for certain kinds of easier inspection of pigs for export.

Cough monitor as early warning system
A cough monitor, developed by the company Fancom, functions as early warning system to recognise potential (specific) diseases, by measuring coughing noises and comparing them to a pig farming noises' database. Microphones in the stable measure the sounds. This application is only used on a limited number of farms. A similar system has recently been developed by the pharmacy company Boehringer Ingelheim, with their Cough Index Calculator, which is an app on the smart phone.

Heat detection for easier insemination management
Non-pregnant sows can be housed in a way that they can see and smell boars. In combination with a reader and EID, sows with a peaking visiting frequency of the boar are likely to be or soon become in heat (Nedap). Other systems are being developed to have the boars walking in front of sows in heat, making it easier to inseminate, like the DateGate (Vereijken-Hooijer), or the Aco Funki system. In dynamic groups heat detection is applied on about 90% of the farms.

Pregnancy testing common on Dutch sow farms
Sow farmers use ultrasound testing devices to check for the pregnancy of sows. This is typically done 21 days after insemination. Sows proving to be non-pregnant are moved to the insemination department, in order to get her pregnant and thus reduce economic losses by non-productive sows. Pregnancy testing is common on Dutch sow farms.

Automatic feeding systems at 75% of the Dutch farms
Based on time-related feed supply patterns per pen, feed is automatically transported and released at a few specific times per day. Other systems make use of sensors in troughs to signal the need for refilling. Automatic feeding systems are found on three out of four pig farms in the Netherlands (Burgers, 2015a). Typically such systems are remote controlled.

Automatic balance farrowing pens to prevent crushing piglets
A balance floor in a farrowing pen is a moveable floor for either the sow or the piglets, in order to prevent crushing of the piglets when the sow is going to lay down (Figure 3.3). The floor is automatically lifted or left down if the sow (no longer) touches a sensor when she is going to stand or lay down.

Figure 3.3 *Balance floor in a farrowing pen. Photo Courtesy of Nooyen flooring*

New generation cleaning robots with monitoring needed
A cleaning robot is an automatic high-pressure device moving around in pig houses to clean and disinfect departments (Figure 3.4). As a robot, it follows an exact pattern in order to clean and disinfect. However, cleaning results are not monitored by the system, and farmers sometimes have to

do additional work to get it really clean. A future improvement could be to make the robot smarter by having it measure its work and then adapt the routine if necessary. Only then it saves tedious work at a reasonable cost.

Figure 3.4 *Cleaning robot. Photo courtesy of MS Schippers*

Climate control improves animals' living circumstances and performance
Pigs in the Netherlands are usually kept indoors. To control the indoor climate, climate control systems have been developed. The simplest climate control consists of a temperature-based air flow control. More advanced climate control systems also measure CO_2, NH_3, and relative humidity. Climate control is combined with specific information about the animals in the department, as the own heat production of animals depends on parameters like age, pregnancy and growth. The most advanced climate control systems measure outdoor weather conditions, such as temperature and rainfall, to consider the conditions for the optimal inside climate (for example, during a heavy shower the air inlet is reduced instantly to prevent a quick inside temperature decrease). Also, a day-night rhythm can be taken into account. Typically during hot days pigs grow less as they have less appetite. By continuous multifactorial monitoring and climate adaptation, the living circumstances for the animals improve, which in turn increases the animals' performance. The climate can be controlled by not only changing the ventilation volume, but also by adapting the position of inlet valves, the choice of air inlet (via e.g. soil pipes with reduced temperature fluctuations, and/or direct inlet), heating, or cool-spraying. Climate control is applied on virtually all farms, although they differ in the complexity of the control. Climate control devices are remote controlled.

Information of climate control devices is increasingly presented in a smart way. Rather than showing individual parameters' results, the outcome on whether the ambient climate in the departments would require attention by the farmer is shown (based on the so-called management by exception approach). Increasingly, visual presentation of outcomes is applied (Figure 3.5).

Figure 3.5 *Climate control devices. Photo courtesy of Fancom*

3.1.3 Smart solutions in development

Interviewees were asked about new developments there are involved in. Three directions of development are defined: data collection, analysis and use of data.

Improved *data collection* includes collecting more parameters, monitoring continuously, and collecting data of individual pigs rather than group averages. Data collection also refers to the way it is done: automatic data collection is expected to increase (including vision techniques) as it improves data quality (fewer entry mistakes, fully objective), real-time availability, and is not vulnerable to the farmers' mood to record.

Data analysis includes real time analysis and application in management decisions, better use of data in deriving relationship by linking data (big data).

As more information is available a *smart way to present* should be developed. An increasingly visually orientation can be made possible by proper visualisation, which makes data more valuable and the use is more user-friendly and attractive.

Biometric identification to avoid use of tags
An alternative to (electronic) ear tags for individual identification is a biometric identification for pigs based on imaging techniques (Iris scanning, and Retinal vascular imaging), to avoid the use of tags. Currently biometric identification is being developed based on vision system, recognising the shape and size of animals.

Monitoring the behaviour of animals
Behaviour of animals can be monitored by video. We are not aware of automatic video-based monitoring systems to warn for or predict aggressive behaviour. Given the increased attention to animal welfare, and especially the intact males' behaviour, this would be an interesting development.

Biosensors to trace fever or ovulation
Biosensors at not being used yet in commercial pig production. However, several applications are conceivable, like temperature and hormone measurements in order to trace fever or ovulations.

Beacons for biosecurity and labour control

A beacon is a small Bluetooth low energy radio transmitter and can be used as an indoor positioning system for farm staff inside the stables (Figure 3.6). Farm workers wear a beacon and signals are being received by standard smartphones placed at specific places in every barn (like at the entrance). This way the staff's movement can be measured continuously. Objective control of farm staff movements can support to control biosecurity, as is currently being tested in Segovia, Spain (Piñeiro, 2017). In a conventional system biosecurity (hygiene) is managed by protocols regarding the control of external pathogens entering the farm and the spread of the pathogens within the farm, as it requires strict rules regarding presence and working patterns for the staff (e.g. from young to older pigs, in order to reduce infection risks). In addition to biosecurity control, it can support time management of farm workers.

As far as known this technique is not yet implemented on pig farms in the Netherlands, but is being tested on two farms. The technology could be used to forecast working patterns of farm workers, to lock specific places in the stable that do not fit in the allowed working pattern, or to give a warning for unallowed or too long presence on specific locations.

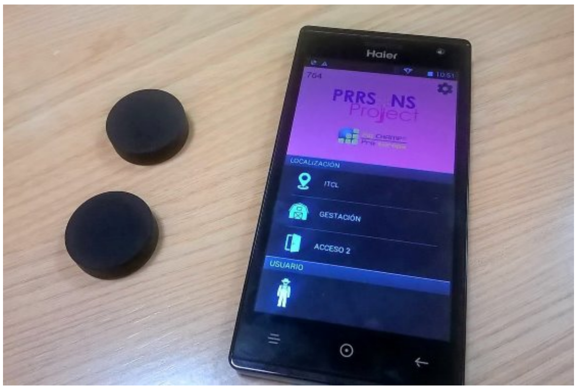

Figure 3.6 *Beacons for farm staff. Photo courtesy of Carlos Piñeiro*

3.2 Smart solutions in other stages of the pig supply chain

Pig breeding

Breeding organisations are improving their speed of genetics progress by new technologies like genomic selection, CT scans, and use of video and 3D camera images. Combining large amounts of data leads to far more insight in the animals' genetic potential and results in progress than in history. Breeding organisations typically improve animal performance (e.g. weaned piglets per sow and year, daily gain, feed efficiency), animal welfare and meat quality.

Feed production

Feed production is partly being automated, including sampling of incoming ingredients, grinding, mixing, and pelletising of the feed.

Slaughtering

Carcass classification

Slaughter pigs are being graded at the slaughter line in order to pay the providing farmer according to the delivered weight and quality, related to marketing opportunities per (main) part of slaughter pigs, as well as to make a preselection of market destinations. To this end different techniques are being developed and in use, like the so-called FOM (based on difference in reflectance of meat and fat), AutoFOM (based on ultrasounds) and 3D video classification system, in order to measure lean meat percentage, carcass composition and weight of individual primal parts of the carcass (like hams). Especially the AutoFOM system is popular as it gives more detailed information on the carcass composition than the FOM system.

Slaughter line automation
Slaughter lines are partially automated and robotised in order to save labour input, like automated driveway systems, electric or CO_2 stunning systems, carcass washing, scalding and dehairing, different saw systems to open the carcass and to cut specific bones like the backbone, etc. Some of those systems continuously monitor the size of the pigs/carcasses and adjusting their precise movements. Carcasses can be divided automatically based on a vision system that is makes a 3D carcass profile (Figure 3.7). This comprises automatic (robotised) cutting of the carcass to have the best yielding cuts (Vision-systems.com). Also automatic transport and storage identification is performed, based on hook identification and linked to the animals' ear number. (www.mps-group.nl)

Figure 3.7 *Laser-driven cutting positioning for dividing carcasses. Photo courtesy of Marel Red Meat Slaughtering*

Smart packaging
Retailers issue customer cards with specific offers and price deductions. Data on shopping behaviour is being used both to analyse shopping profile categories (in order to improve the retail concept), and to be able to offer specific products.

RFID tags are being used in shops both as an anti-theft system and for identification and automatic payment. Increasingly supermarkets are switching towards self-scanning and self-checkout by customers.

A new development and, as far as known, not used yet in the Netherlands, is a time and temperature indicator for fresh food products, developed by Keep-it Technologies. This smart shelf life indicator is put on food products by a small self-adhesive label. Based on time and temperature a reaction of non-toxic chemicals in the little device results in a changing colour of the indicator, which in the end shows the remaining shelf life of the product. This smart indicator replaces static indications like 'best before', and contributes to a reduction of food losses.

Checking nutritional content of food
Wageningen University & Research developed a device and app to check the nutritional content of food products. It can be used to see if the content is in accordance with the information on the label, like animal type (beef vs. horse meat) or fat content. It can enhance consumer trust.

3.3 Smart supply chain

Information exchange throughout supply chain

Abattoirs have information systems installed to inform farmers about the performed quality of supplied pigs on an individual basis (slaughter weight and some parameters on realised qualities), like Vion FarmingNet. The application has the ability to analyse seasonal patterns, differences between departments in the barn, or between e.g. origin or hybrid of the pigs. Farmers can use this software to inform the slaughterhouse about the number of pigs they plan to send for slaughter on a specific day, but also some specific quality parameters can be provided (e.g. either or not intact boars, market program etc.).

EDI Circle is a system in which invoices are being shared and digitally. Main users are feed suppliers, dairy and meat processors, accountants and farmers. Since invoices are digitalised, information can easily be processed in accounting software.

Individual identification tags are being used for pigs in the Netherlands, both electronic and non-electronic. Advantages of EID surpass the farm level, as this allows for easier traceability of the animals throughout the supply chain. Currently all pigs do receive an ear tag after birth (either electronic or non-electronic) with the farm ID number and a serial number, which is a legal obligation for identification and registration, for the purpose of managing contagious disease outbreaks. Piglets are typically being transported to another farm for the fattening stage. Once pigs are ready to be sent to a slaughterhouse, they receive an obligatory additional ear tag, on which the final farm's ID number must be represented. Application of an electronic identification might save this additional step. Also in terms of animal welfare the animal's integrity is improved when less tags are necessary. Once farmers have identified their pigs individually and electronically, guarantees can be given that certain pigs are being produced on farms that fulfil the requirements of certain market programs (like Varken van Morgen, Good Farming Star, Keten Duurzaam Varkensvlees etc.). Also per farm differentiations can be made between pigs that, for example, did or did not receive any antibiotics during their life, in order to guarantee the abattoir to only deliver pigs without antibiotics. Once pigs are individually identified throughout their life, this information can be used for optimising breeding programmes, as not only on-farm information is being used, but also slaughter performance information can be used in the breeding programme.

The Dutch government is willing to improve the transparency of the production process 'from farm to fork', aiming to improve trust of the consumers. When pigs are identified individually and information is kept until the ready meat product, places of origin can be communicated towards consumers, like farm numbers where the pigs were born and raised and the numbers of plants where they were slaughtered and processed. Therefore, the current supply chain quality system IKB should be improved to implement this information flow. Farmers' organisation POV is developing a generic Supply chain quality system, based on data sharing throughout the supply chain, and meant for general application. Details are not known yet.

Logistic optimisation

A lot of transport takes place for feed and animals. Companies have developed software to minimise transport distances, like Vion for getting pigs from lots of farmers to different slaughter plants, or Rendac to arrange transport of fallen stock. But also feed companies are using such logistics optimisation software to reduce feed transport.

Retailer apps

Some retailers in the Netherlands are launching apps that give information on the origin of products, including pig meat. The 'Boer @p' was launched at retailer Agrimarkt in the city of Goes, linking consumers with individual producers and farmers and their products in the shop. Using the TTAG technology, individual product items can be identified accurately worldwide, by automatic identification, recording and linking information of products throughout the agro and food supply chains. Consumers can find information with their smart phone on origin, way of production and quality of products (Connectingagriandfood.nl). Very recently major retailer Albert Heijn launched its Augmented Reality Product scanner (AH.nl). This app gives information on ingredients, origin and recipes.

3.4 Continuous developments in smart farming

3.4.1 Some smart pig farm related projects

A few current projects are being presented here as a selection to show that developments in smart pig farming are being supported.

FarmHack
FarmHack (http://www.farmhack.nl/agrivision-hack-smart-sharing-data/) is an initiative of some enthusiastic individuals to improve innovation in the pig sector by setting up a hackathon. The hackathon is a kind of marathon for developing smart ideas. In 2017 five groups of eager volunteers elaborated their ideas:

- SwineSmarts; hassle-free data flows controlled by the farmer. SwineSmarts closes feedback loops by linking slaughter data back to the farmer and to his suppliers of feed and genetics, thus bringing value to each.
- Piglantir, health monitor and predictor for pig rearing without antibiotics. Based on biometric identification (no tag, tattoo or chip), combining data from open and partner provided data sources to uncover relationships between environment, climate, nutrition, robustness and health status.
- PigAlert, eyes and ears in the barn. Series of visual images of individual pigs and the group inform a self-learning system about animal behaviour. After time, the system recognises anomalies. Sound recording and feed intake are fed into the system as well, to improve the analyses.
- FedBest, personalised diet for robust sows. Based on data on genetics, feed composition, feed intake patterns, optimal feed diet is determined.
- Porklane, DIY sales chain. An online marketplace was prototyped for the activities performed in the supply chain, where stakeholders in the supply chain can meet and join forces.

Internet of Food and Farm 2020
The Internet of Food and Farm 2020 (https://www.iof2020.eu/) is an EU-funded international project that creates an innovation ecosystem that accelerates the uptake of novel technologies in the farming and food sectors. In the framework partners can set up use cases. Two use cases are being set up so far in the pig production sector, one on pig farm management and the other on Meat transparency and traceability.

Pig farm management
This use-case focuses on linking data across the value chain in order to provide the pig farmers with the necessary information to effectively implement and carry out their management activities. It provides the five involved farmers with management information that enables continuous improvement of its sustainable production. Early warning systems are being developed on several group-level daily data streams, and boar taint presence is being reported to farmers. Expected results include a reduced boar taint in meat, increased feed efficiency and daily gain, improved animal welfare and a lowered carbon footprint.

Meat Transparency and traceability
This use-case aims to increase transparency in the meat value chain. A data system collects and shares data that is not yet covered by existing traceability data systems with supply chain partners. The majority of the data will be collected in the use-case on Pig Farm Management. Information will be shared among supply-chain partners to optimise business processes and reduce negative environmental aspects; quality issues will be identified, such as interruption of the cold chain; and transparency between producers and consumers will be increased. Expected results include an increased consumer trust in meat production, improved communication on the animals' welfare and health; optimised business processes; verification of pork quality; increased margins for high-quality products, and improved environmental performance (e.g. energy consumption, waste creation).

3.4.2 Some pig production related apps

Several apps are available for pig farmers (only in Dutch) (Sources: Burgers (2015b), AgroApps.nl):

- Apps with practical information on pig farming, like De Varkens App (commercial app as pocket book with practical information on pig farming); Hitte stress app (informing about ambient temperature and advice on activities for improved climate control in the barn); Abnormaal gedrag app (showing abnormal behaviour with augmented reality in 3D of animals like pigs); IJzercalculator (advising on actual iron need of a piglet).
- Commercial ordering apps, like from several feed companies, or MS Schippers equipment supplier.
- Farm management apps like BigFarmNet (commercial app of an equipment supplier, gives an overview of production and climate information; it is linked with the management information system, as well as with the climate control system).
- De Heus benchmarking app, in order to compare farm parameters with national averages and top 25% farms.
- Identification app Dieren en bedrijven of the Ministry of Economic Affairs, to check numbers of animals and farms in the national identification and registration system.
- Apps with market information, like Agrarische bedrijven: Boerderij Business (commercial app with market information of commodities).
- The Cough Index Calculator is an app of pharmacy company Boehringer Ingelheim, measuring coughing behaviour and suggesting to contact a veterinarian.

4 Smart greenhouse horticulture

4.1 Introduction

More than half of the land area in the Netherlands is used for agriculture and horticulture (CBS, 2017a). Among this usage, the greenhouse horticulture covers 4,400 ha of which the half the area is used for fruit/flower production, over 20% for vine tomato, 16% for paprika, and 13% for cucumber (CBS, 2017b) (Figure 4.1). Over the past several decades, the Dutch greenhouse sector has become the world leader in yield, continuously improving its efficiency. Vegetables and fruit yields in the greenhouse, for instance, are consistently increased over the period 1950-2015 (Figure 4.2).

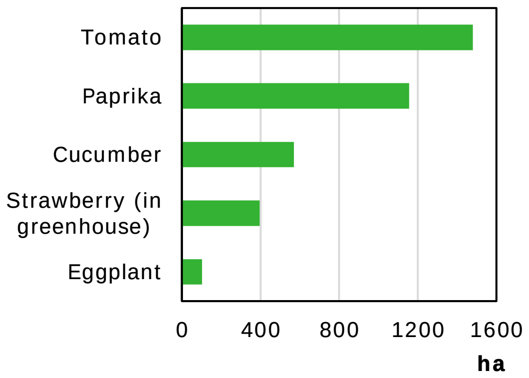

Figure 4.1 *Top five vegetables in greenhouse horticulture in the Netherlands (CBS, 2017b)*

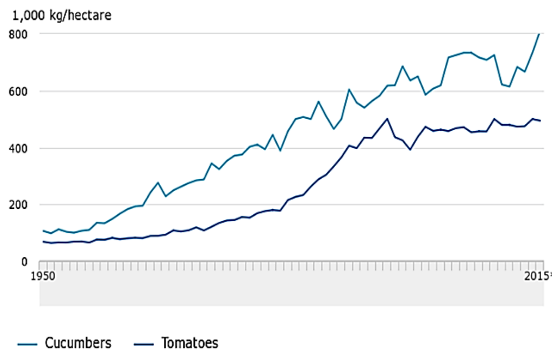

Figure 4.2 *Development of domestic yield of vegetables (cucumbers and tomatoes) under glass, 1950-2015 (CBS, 2017a)*

The Netherlands has the highest yield globally for tomato productivity, producing more tomatoes per hectare than anywhere else in the world (Figure 4.3). Compared to South Korea, the yield per hectare in the Netherlands is more than seven times higher than in Korea. This indicates a huge difference in production efficiency between two countries. For other greenhouse products, such as paprika, cucumber and strawberry, the Netherlands also has considerably higher yields than South Korea (MAFRA, 2014).

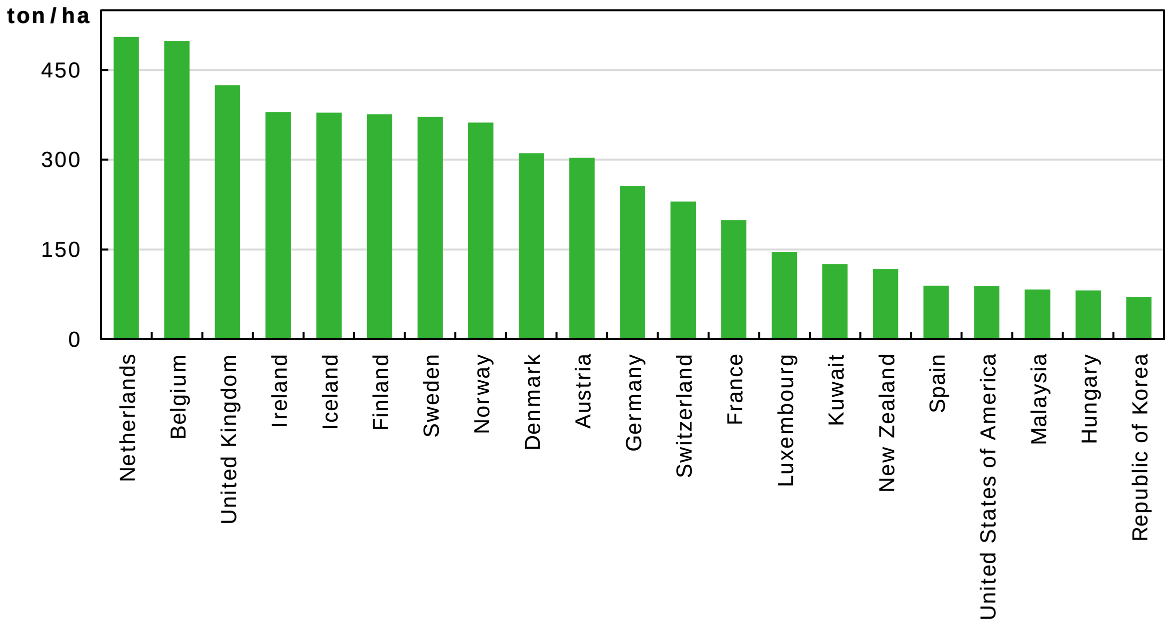

Figure 4.3 *Tomato yield of top 20 countries and South Korea (ranked by yield, ton/ha) (FAOSTAT, 2014)*

With the use of recent Information and Communication Technologies (ICT), the Dutch greenhouse industry aims to produce more with less resources. Climate control systems, machine and logistics process control systems, horticultural smartphone apps, labour registration and analysis systems and many other ICT solutions support Dutch growers operating their greenhouses as efficient as possible with minimal use of resources while gaining the maximum yield. Not only that, the Dutch greenhouse sector expects to implement a sustainable horticultural value chain with a crucial role of ICT, securing its position as a global leader in the greenhouse horticulture sector (Topsector TU, 2015).

This section gives a brief overview of the current status of ‘smart' activities in greenhouse horticulture in the Netherlands with a focus on recent research activities in automation and data exchange. Information availability and access to commercial applications in the greenhouse sector were limited.

4.2 Smart plant disease monitoring system

Monitoring pests and diseases in the greenhouse has gained much interest during the last few years and forms the basis of integrated pest management (IPM). Within the project, Healthy Greenhouse (Gezonde kas, 2015), a smart plant protection system was developed to timely alert the grower on the presence of pests and diseases, helping the grower in making decisions and in the application of measures (Figure 4.4). An automated plant stress detection system also provides an insight to the grower which included the use of DNA and sensor technologies, automated image processing software tools, biological control strategies and precision spray technology.

Figure 4.4 *Camera system with stereo vision and chlorophyll fluorescence, Side Crop View Platform. Photo courtesy of Gezonde Kas project*

Some pest species (e.g., white flies) are easy to monitor on yellow sticky traps. However, other pests like spider mite and aphids are a big challenge and require labour intensive plant observations. Thus, only easy-to-count pests and diseases visible to the human eye are monitored in practice. Several research projects including PeMaTo-EuroPep are currently running to develop an automated detection of challenging diseases caused by mites and aphids using multi- and hyper-spectral imaging and deep learning (Figure 4.5). 3D sensors (stereo cameras and laser scanners) and a chlorophyll fluorescence system are also used for disease detection based on image and reflectance analysis (Mahlein, 2016; Vukadinovic et al., 2016). Such an intelligent detection system enables a higher frequency and accuracy in scouting and denser monitoring in the greenhouse at an early stage of the disease.

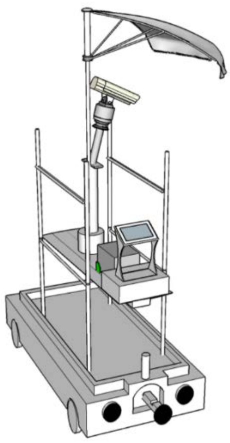

Figure 4.5 *Schematic 3D drawing of an automated disease detection system using the multispectral camera in the greenhouse. Photo courtesy of PeMaTo-EuroPep project*

The smart greenhouse drone using an intelligent sensor and vision system can monitor on a plant level, not on an area level, with data interpretation and forecasting in growing speed, insects and plant diseases and deficiency of fertiliser (Figure 4.6). Such a system can provide a truly extensive understanding of each plant's health and growth, focused on the plant's actual performance, not simply the environment around it. Using high-resolution and 3D imagery, monitoring system observes even the latest minute changes in the health of individual plants, giving growers the precise knowledge they need for proactive management.

Figure 4.6 *Example image of a smart drone in the greenhouse. Photo courtesy of APIS, the pollinator drone, Smart Farming Conference 2017*

Presently, more intensive monitoring of the crop with individual plant level but at the same time monitoring of large areas become feasible in practice which leads to better timed, local and better considerate actions. Furthermore, once infested plants are detected by an automated sensor system at an early stage, the infested plants can be removed by a robotic plant collection system.

4.3 Harvesting robot

Most of the procedures in Dutch greenhouse have already been automated except pruning and harvesting (Bontsema, personal communication). Removing the leaves from plants, pruning, in the greenhouse is a relatively simple procedure which up to now heavily depends on manual labour for cutting off the older leaves from the lower part of the stems. Priva recently introduced the Priva Kompano Deleaf-Line robot for pruning tomato plants in the greenhouse. The robot is in its pre-order stage at the moment, but is expected to be commercially available soon. Harvesting, in practice, still depends on the manual force which is a labour intensive and high-priced. Due to the limited performance of the automated systems, no commercial applications are currently available for such more selective and precise tasks in the greenhouse. To automate the selective harvesting process of high-value crops, for example, robots have been actively developed in recent research such as EU Crops, EU Sweeper projects and KasPR (Figure 4.7, Figure 4.8).

Figure 4.7 *Sweep pepper harvesting robot in the greenhouse. Photo courtesy of EU-Sweeper project*

Figure 4.8 *Cucumber harvesting robot for greenhouse application. Photo courtesy of the robot KasPR, Minor Robotics of the TU Delft*

Recent literature indicates that the robots are capable of harvesting fruit autonomously, under a certain range of environmental conditions (Bac, 2015). However, current harvesting robots are far from mature, and thus still in the research phase. Many challenges remain for the development of robotic systems for the sector, such as limited awareness of robotic systems among growers, insufficient robotic solutions, the difficulty of matching human-like dexterity with machines, fragmented technology development, weak administrative support, and infrastructure issues (Tractiva, 2016). However, rapid progress in the development of artificial intelligence, low-cost sensors and big data is opening up the opportunity for practical usage in the greenhouse. One of the major limiting factors in building autonomous systems that are capable of making the real-time reaction to various sensor inputs was the processing power. Thanks to the recent advent of GPUs (Graphics Processing Units), statistical inference techniques using the principles of machine learning, i.e. computing parameter values from training data, has become feasible for practical usage. The advanced level of processing power together with general purpose inference techniques like deep learning have enabled advanced reasoning capabilities in autonomous systems. Recently, two commercial prototypes of harvesting robots powered by deep learning and big data were announced (Figure 4.9, 4.10); however, the performance details are yet unknown.

Figure 4.9 *Strawberry harvesting robot in the greenhouse. Photo courtesy of Octinion*

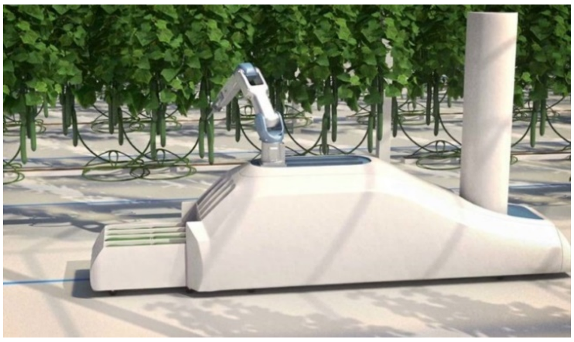

Figure 4.10 *Cucumber harvesting robot. Photo courtesy of CRUX Agribotics*

4.4 Smart inspection and sorting system

One of the most challenging processes of packaging greenhouse products is to uniformly grade and sort the products. The uniform grading and sorting lead to improving the quality of the merchandise as a final product, which is directly linked to the economic profit. Grading and sorting by human labours have often caused issues with uniformity because each labourer may perform differently depending on the working time and day as well as on a level of fatigue. However, smart inspection and sorting system can automatically measure the characteristics of each individual product such as size, colour, maturity, etc. Such a system can provide uniform inspection and sorting all year round, and thus improve the quality of the merchandise. In addition, the system can provide further insights to the grower by analysing product's specific information such as including planted/grown position within the greenhouse, harvesting worker, etc.

For example, the IRIS (Intelligent Rose Inspection & Sorting) system can uniformly sort and grade the rose using the multispectral camera and 3D imaging analysis. The system automatically measures bud height, bud width, colour, openness and the bud's angle of orientation with the sub-millimetre level of accuracy, and uniformly grades three roses in a second (Figure 4.11). According to Wouter Bac (Bac, personal communication), the high-quality roses can be further sorted with a premium quality grading which can serve high-end markets.

Figure 4.11 *Intelligent Rose Inspection & Sorting system PC interface (left), and camera inspection views (right). Photo courtesy of TechNature B.V.*

4.5 Data exchange platform

There is a great benefit to share data that are generated in the greenhouse (climate conditions, crop status, labour performance, energy usage, etc.) through the data-exchange platform. One of the most widely used data-exchange platforms for the greenhouse sector in the Netherlands is Letsgrow. Letsgrow was launched in 2002, where growers can be connected with the outside world and to share the data via online with specific permissions to whom his/her data is available for access. This platform, which is accessible from anywhere in the world, provides a real-time monitoring of the greenhouse environment as well as an analysis figure by comparing his/her performance with other growers (Pekkeriet et al., 2015). Thus, growers can gain a valuable insight and essential know-hows using flexible dashboards to manage greenhouse production (Figure 4.12). Not only that, growers can get an early warning of potential disease threats in real-time based on in-depth analysis of big data collected through the platform. Even before the diseases get to emerge, a necessary action can be made to prevent any crop damages.

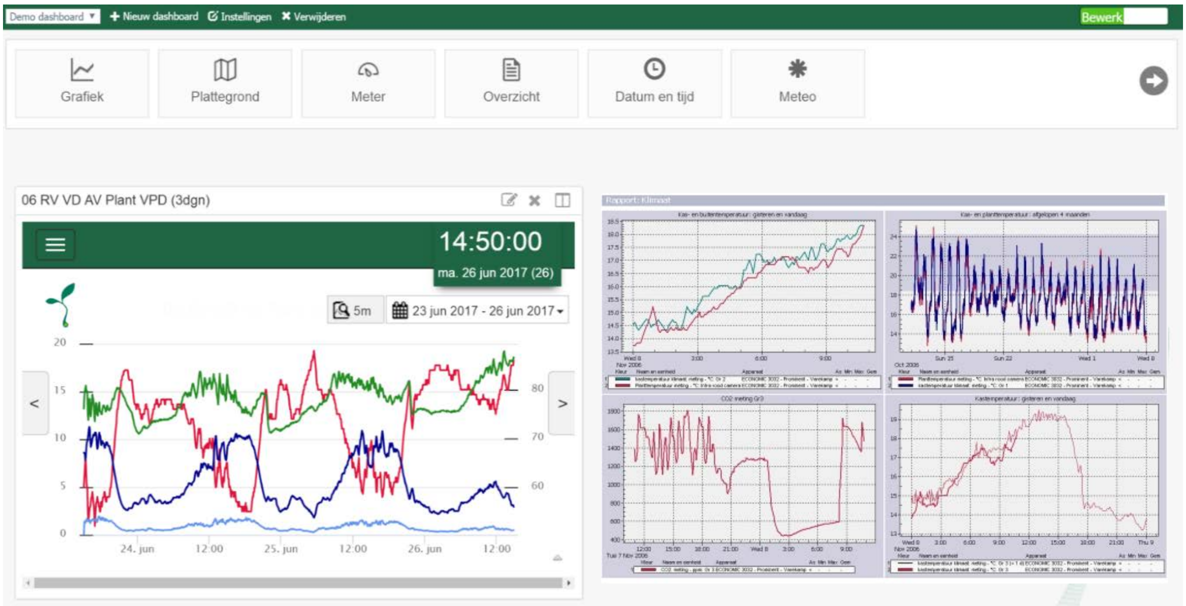

Figure 4.12 *Letsgrow online platform with flexible dashboard and analysis graph. Photo courtesy of Letsgrow.com*

Based on Letsgrow platform, for instance, B-Mex provides a model for complex greenhouse environments and crops. B-Mex provides an efficient energy management solution based on local data (provided and shared farms) combined with climate data. B-Mex is currently providing an online forecast called ‘BotrytisAlert’ which predicts the risk of Botrytis infection to the greenhouse crops. According to Peter van Beveren, the emergence of Botrytis has significantly reduced using BotrytisAlert in the greenhouse (Van Beveren, personal communication).

4.6 Future outlook

According to EU Scientific Foresight Study (2016), the future of smart farming will likely be dominated by data exchange through platforms. More greenhouses and equipment inside the greenhouse are expected to increase its connectivity. Based on Internet of Things (IoT), a wide variety of greenhouse data will be collected and exchanged in real-time, which will be accumulated as Big Data. Current production-oriented data exchange is expected to expand to the whole value chain of agriculture including logistics, distribution and consumption. The IoF2020 project is to link all the data generated from the entire value chain of agri-food and thus creating new values from them. Based on that, according to Sjaak Wolfert (personal communication), new business models which we have never thought before will be formed resulted by the IoF2020. It is also expected that Big Data, which could not be easily analysed in the past, will be further analysed by artificial intelligence to provide insight as well as prediction to a level that we never thought possible (Wolfert et al., 2017). Besides, automation and robotic systems will drive more labourers out of the greenhouse. At present, it is still an early stage to observe any visible changes in the greenhouse sector. However, smart farming is expected to make an accelerated transformation in the coming near future (Min and Suh, 2017).

5 Discussion and conclusion

5.1 Discussion

This report gives an inventory of smart farming in both pig production and greenhouse horticulture. The greenhouse horticulture is elaborated in less detail than the pig farming, which is also related to limited input from the companies. For insight into the current use of smart applications in greenhouse horticulture more work needs to be done.

Further developments of smart tech applications in agricultural production will be driven by the need for further increasing biological and economic performance, by reduced performance variability among biological entities (animals, plants), as well need for labour saving. Labour saving can be done by simplifying outcomes of data analysis, e.g. by visualisation, and is necessary as availability of farm workers is limited and labour is expensive. Developments, such as blockchain technology and big data analysis also allow for such developments in smart solutions.

Data ownership and security
Wolfert et al. (2017) and the Workshop report (2016) of the European Commission raised issues with data ownership as well as the data value and security. Wolfert et al. discussed two possible extreme scenarios of stakeholder networks based on the architecture of big data solutions: towards closed & proprietary systems vs towards open systems. In one system, farmers can become sub-contractors (or franchisers) in the supply chain; while in other system, farmers can actively involve in data sharing with the participation of short supply chains. Both of two scenarios are currently observed, but how they will evolve in the future is unknown.

A cooperative Datahub for dairy farmers has been set up in the Netherlands, as a platform for data flows and authorisation register in order to manage ownership and consent to use data by related companies like feed, processing, breeding or tech companies (smartdairyfarming.nl). This kind of initiatives is necessary to prevent an undesired shift of control towards companies.

Changing management approach
Application of smart farming serves different purposes, like reducing animal and plant diseases, improving biological performance, reduced environmental burden and labour fulfilment. However, these purposes are interlinked (e.g. reducing the number of sick animals also improves zootechnical performance) and smart farming application will support this integrative management approach. 'Smart farming … can enhance a very respected and transparent farming according to European consumer, society and market consciousness' (smart-akis.com).

The increase of smart farming requires different management skills than in the conventional approach. Farmers must be able to make use of new technologies, but also to adapt their decision-making process. This requires updated curricula in farmers vocational education and training. Min (2016) expects that competitiveness differs no longer based on traditional competitive advantages such as natural conditions (labour, land, capital), but on capital, technology and the management capability of people employed in agriculture. In this respect smart farming appears to be a logic answer to cope with the given demands. Still, the aspect of management capability should be elaborated, as capabilities appear to be very different between countries. However, adoption of smart farming might be decelerated if benefits for the farmers are not clear (Vangeyte, 2017) and if farmers conceive mistrust against supply chain partners on potential abuse of data (Bruinsma, 2017).

Risks related to smart solutions
Bos and Munnichs (2016) considered potential consequences of precision livestock farming (including smart technology), like further intensification, risk of alienation between animal and farmer as a consequence of animal husbandry without human intervention, risk of increasing power of processors and retailers at the cost of the farmer etc.

Big data may provide endless possibilities in agriculture with the record, monitor and predict real-life phenomena that can subsequently be used to guide decision making. Indeed, big data has already been applied in several areas such as weather forecasting, disease predictions and prevention, etc. However, to be empowered by big data and its analysis, interoperability among various vendors need to be standardised. Besides, extracting meaningful and actionable information out from the big data, thanks to the advance of artificial intelligence, also need to be emphasised. Still, there is always a risk of inaccurate predictions, especially because this may cause some irreversible disasters. In such a case, the responsibility of the inaccurate predictions may become a controversial issue: is it the farmer's responsibility who followed the solution provided by analysis which was developed by other commercial parties, or analytics that provided the solution based on inaccurate information?

5.2 Conclusion

Many smart solutions are being used in pig farming and greenhouse horticulture in the Netherlands. Not all Dutch farms use all available solutions already, but further implementation is expected. Further developments in smart farming are to be expected, aiming to reduce performance variability and to save labour input. Development may be expected in improved data collection (quality, number of parameters, continuously, as well as increasingly automatic monitoring), improved data analysis (real time, big data) and visualisation based on management by exception (convenient, time-saving). Application of smart technology in farm management requires different management skills than in conventional farming. Smart technology must be taken into account in the curriculum of farmers education.

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Appendix 1 Interviewees

Pig sector
Mrs. Anouk van Spronsen, Vereijken Hooijer
Mr. Mark Janssen, Fancom
Mr. Marc Cox, Agrisyst
Mr. Jan Brouwers, Agrovision
Mr. Arno van Brandenburg, Nedap
Mr. Paul Goethals, Wageningen University & Research
Mr. Sjaak Wolfert, Wageningen University & Research

Greenhouse horticulture sector
Mr. Jan Bontsema, Bontsema Consultancy
Mr. Wouter Bac, TechNature BV
Mr. James Lim, NH Trading
Mr. Harrij Schmeitz, Open InnovationCenter Feed Design Lab
Mr. Elias Kaiser, Wageningen University & Research
Mr. Peter van Beveren, B-Mex, Van Beveren Solutions
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REPORT
2017-097

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Report 2017-097
ISBN 978-94-6343-218-4

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