Objective sustainability assessment by Precision Livestock Farming

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Paper prepared for presentation for the 166th EAAE Seminar
Sustainability in the Agri-Food Sector

August 30-31, 2018
National University of Ireland, Galway
Galway, Ireland

Abstract
Sustainable livestock production is needed to feed the growing, wealthier and urbanizing world population. This results in a need for better genetics and a more precise way to monitor them. The challenge and the success of intensive farming will lie in how precisely we can steer the animals towards their genetic potential. Sustainability is however often a subjective phrasing that is hard to quantify by numbers. The continuous automated monitoring of varying needs of individual living farm animals at every moment and anywhere is called Precision Livestock Farming (PLF). Sensors have the potential to replace the eyes, ears and nose of the farmer by continuously assessing different key indicators throughout the production process, 24 hours a day and 7 days a week. The aim of this research is to demonstrate the value of a Business Intelligence product that gathers farm data from automated PLF sensors to score an objective set of measures that provide evidence on sustainability. This information can then be used, not only to improve the various processes that make up good production, but output can also be used in labelling, ‘a license to produce’. The roadmap towards a sustainable on-farm meat production is described hereafter in four categories: production efficiency (also regarded as the indicator for profitability), welfare, health and emissions. Production efficiency Key Production Indicators are generated from data created by Farm Controls that use PLF-sensor technology to monitor production. Typical basic production variables are feed provided, daily growth, water use… For the automated health and welfare assessment, production data will be scored against a predetermined standard, and the current production round will be compared against historical. Emerging PLF sensor technologies use the animal as a sensor to gather evidence on the animals’ bio response to its environment and management by the farmer. Typical examples of health and welfare variables are pig coughs, activity level of the flock, distribution of the flock… The final indicator of sustainable production is emissions, or more commonly accepted the carbon score. For this, a set of production KPI’s will be translated to their equivalent carbon measures. It is important that all stakeholders understand the environmental impact per individual animal and not the production unit as a whole. PLF-technology and continuous monitoring of animal bio responses will improve the understanding of the production process. This will allow the farmer to manage his process by exception. The fact information is created by machines means the system provides an inbuilt efficiency and frequency that cannot be equalled by humans. Current assessment by inspectors takes us so far, but to have sensible dialogue will require rethink, this is where technology will play a significant role. On-farm data collection and sharing will enhance the transparency throughout the production chain and help the consumer make educated decisions.

Keywords: Precision livestock farming; automation; key performance indicators; dashboard.

Introduction

The world population is expected to grow to 9.15 billion by 2050 according to the latest projections of the United Nations Population (FAO - Food and Agricultural Organization of the United Nations, 2017). With a current population of 7 billion inhabitants, this implies an increase of over 34% in the next decades. The increasing human population together with changes in consumption patterns caused by urbanization, increasing incomes and nutritional and environmental concerns will shape what we eat, who eats and how much (Herrero and Thornton, 2013). In lower income countries this growth is likely to have higher economic implications and subsequently a higher impact on the worldwide demand for animal products. Strikingly, the number of livestock farmers is decreasing as the demand for livestock increases. This leads to larger farms and more intensive production.

In future years, modern farmers will be under greater pressure to care for a large number of animals in order to remain economically viable. Whilst society believes animals are entitled to receive individual attention, due to scale, farmers will have less time to extensively observe each individual animal. It is therefore practically impossible for most European farmers to meet society's belief that they have a strong relationship with their animals. As a result of this contradiction there are social and economic consequences for all stakeholders involved, specifically the animals and farmers. Besides this, there is an increasing awareness and concern about animal welfare and health (Thornton, 2010). Today's consumers are more convinced that animals kept for food production should be raised, treated and slaughtered in a more humane way an should have a life worth living (Wathes et al., 2008). While Europe has invested in developing standardized methodologies for assessing and scoring animal welfare at farm level (Blokhuis et al., 2010) there is still a long way to go to actually improve animal welfare in intensive production systems. There is a growing global awareness of welfare conditions in animal production and a tendency towards more intensive production, resulting in a need for better genetics and a more precise way to monitor them. Intensification of livestock production and agriculture in general, has also had an impact on the environment through its emissions of greenhouse gasses (GHG), ammonia and odour (Lesschen et al., 2011). Licentious application of manure on the crop fields has led to an eutrophication of the surface water in some regions in the world (EEA, 2005). Manure action plans have been started up to counter the effects of eutrophication. Odour emissions are not wanted by the neighbouring community of the farms, and more and more protests occur when new plans for expansion are revealed. In this case, the consumer is applying the NIMBY-principle of 'Not In My Back Yard'. An assessment of White and Hall (2017) however showed that removing animals from US agriculture would reduce agricultural GHG emissions, but would also create a food supply incapable of supporting the population's nutritional requirements. Therefore, both manure and exhaust air treatment are essential for sustainable livestock production (Melse and Timmerman, 2009).

Another key factor in the solution to feed the world will be the development of the genetics of the animals. The study of Zuidhof et al. (2014) showed that broiler growth increased by over 400% with a concurrent 50% reduction in feed conversion rate in the past 50 years. But they also mention the presence of unintended effects such as immune function due to the past selection programs. Therefore, the challenge and the success of intensive farming will lie in how precisely we can steer the animals towards their genetic potential.

Agriculture has seen many revolutions: domestication of animals and plants, crop rotations, development of working tools, the "green revolution" with systematic breeding and man-made fertilizers and pesticides. Some suggest that now a fourth revolution is triggered by the exponentially increasing use of information and communication technology in agriculture (Walter et al., 2017; Wolfert et al., 2017). Nowadays, a range of technologies are available that potentially can help farmers in real time monitoring of each individual animal. Information and computer technologies offer a huge potential for this. Sensors have the potential to replace the eyes, ears and nose of the farmer by continuously assessing different key indicators throughout the production process, 24 hours a day and 7 days a week. The continuous automated monitoring of varying needs of individual living farm animals at every moment and anywhere is called Precision Livestock Farming (PLF) (Berckmans, 2004). This results in "early warning systems" that improve the management of individual animals needs at any time (Huybrechts et al., 2014; Kashiha et al., 2013; Van Hertem et al., 2018). The use of modern technology offers several advantages like ensuring more attention and care to the individual animals but also automated welfare monitoring methods based on imaging and sounds. PLF has the potential to improve animal welfare, increase the technical results, and minimize the carbon footprint and thus improve the sustainability index of the farm (Scholten et al., 2013). On top of that, the technology can monitor the animals 24 hours per day, and seven days a week, i.e. every minute of the animal's life whereas the farmer spends only a limited time to each individual bird.

Sound and image analysis are interesting non-invasive technologies to monitor a group of animals without interfering their natural behaviour. The significant potential to automate continuous measurements on farms using modern technologies has been demonstrated on eight European Conferences on PLF and by peer-reviewed conference proceedings: ECPLF 2003 in Berlin, Germany (Werner and Jarfe, 2003), ECPLF 2005 in Uppsala, Sweden (Cox, 2005), ECPLF 2007 in Skiathos, Greece (Cox, 2007), ECPLF 2009 in Wageningen, the Netherlands (Lokhorst and Groot Koerkamp, 2009), ECPLF 2011 in Prague, Czech republic (Lokhorst and Berckmans, 2011), ECPLF 2013 in Leuven, Belgium (Berckmans and Vandermeulen, 2013), ECPLF 2015 in Milano, Italy (Guarino and Berckmans, 2015) and ECPLF 2017 in Nantes, France (Berckmans and Keita, 2017). Despite the great potential of PLF, most farmers and other stakeholders (e.g. vets) do not currently have the skills to utilize these technologies that provide unprecedented decision-making capabilities effectively. It is time consuming to combine and analyse the data derived from different sensors in different formats and frequencies. Correct data aggregation and data presentation for the translation of farm data to information is key in the success of PLF technology (Van Hertem et al., 2017).

The aim of this paper is to describe how on-farm sensor techniques and PLF-systems can contribute to the automated assessment of sustainability on farm level, by continuous monitoring of animal behaviour.

The objective assessment of farm level sustainability

Farm level sustainability focuses on four pillars: production efficiency, health monitoring, welfare assessment and environmental impact through emissions control. For each of these pillars, sensor technology and PLF technology are available to objectively monitor and control key indicators in those fields. Bringing all key indicators together would allow the objective assessment of farm level sustainability.

Pillar I: production efficiency

The production efficiency of a livestock farm is directly related to the economic viability of the farm. The farmer is constantly balancing on a thread between minimal inputs such as feed use, water use, energy use, air use etc. and maximal outputs which is most of the animal growth and carcass quality. Therefore, for the farmer it is key to find the optimal balancing point in this operation.

Modern farms are equipped with automatic controls for feed and climate control in intensive livestock production sites. Each control unit uses sensors to measure key variables in the house for control purposes, for instance, a temperature sensor is a key input for a climate controller. Recent developments of new PLF sensor technologies allow the individual monitoring of animals in a group by a number of selected key indicators.

The continuous measurement of these key indicators by implemented PLF tools will result in a better understanding, but it will also give the farmer more grip on the livestock production process. The main inputs are feed and climate. Automation of the feed delivery will allow ad libitum feeding through an instant and automatic refilling of the feed bunker when feed is getting scarce in the house. Temperature based climate control is necessary for an optimal growth response of the animal to the delivered feed. Suboptimal temperatures will induce heat or cold stress on the animals, where energy will be spilled in maintaining a constant body temperature.

Automatic weight measurements allow the steering of the growth during the production process. Feed input (feed cost, feed type, feed amount) can be adjusted to the growth output of the animal when necessary. Influencing factors affecting this feed-growth relation are ambient indoor temperature, relative humidity and water intake of the animals. Continuous monitoring of these variables will help in fine-tuning the growth response of the animals. To steer the production efficiency towards a more efficient production of meat, key indicators have to be identified. A commonly used key indicator is the Feed Conversion Rate (FCR), which is the ratio between the amount of feed supplied to the animal and the growth. A better, i.e. lower FCR implies that less feed is supplied for the same production of meat. A more extended key indicator is the European Production Efficiency Factor (EPEF), which includes the FCR, mortality and the length of the production cycle. A higher EPEF implies that the cycle had a better FCR, a lower mortality and a shorter rearing period.

Pillar II: health monitoring

Animal health is of key important in the livestock industry as it impairs production efficiency through growth retardation or even mortality, animal welfare through pain and discomfort, and it can even impair human health through misuse of antibiotics or zoonosis. Prevention of diseases is always the first priority, but second will be the early detection of clinical signs of a disease. Most diseases are more easily treated when detected in an early phase.

It is important to create the best environment for the animals in order to prevent disease outbreaks. Correct climate control, sufficient and high quality feed and water provision, safe and clean pens etc. all contribute to maintaining your animals healthy.

PLF sensor technology is also developed to detect early signs of diseases in the pen so it can serve as a diagnosis tool for veterinarians. A simple example is the automatic monitoring of animal drinking behaviour because is many cases this will change first when a disease breaks out (Matthews et al., 2016; Williams, 1996).

A sound-based tool (Pig Cough Monitor™ (PCM), Soundtalks® and Fancom B.V.) for automated pig cough detection in a pig house was validated by Guarino et al. (2008), Hemeryck et al. (2015) and Berckmans et al. (2015). A mathematical algorithm processes all incoming sound, and identifies the number of coughs automatically. Pig coughing is a clinical sign of pleuritic or pneumonia.

Pillar III: welfare assessment

The welfare of an animal is related to its physical and the mental state. The Farm Animal Welfare Council (FAWC, 1979) defined in 1979 the five freedoms as a comprehensive framework to safeguard and improve animal welfare (http:/www.fawc.org.uk/). The definitions of these freedoms are:

1. Freedom from hunger and thirst;
2. Freedom from discomfort;
3. Freedom from pain, injury or disease;

4. Freedom to express normal behaviour;
5. Freedom from fear and distress.

Following this, the Welfare Quality consortium developed a protocol to assess the welfare status of the animals during the production cycle (Blokhuis et al., 2010). They have identified four principles with twelve criteria to objectively quantify the welfare level of the flock or herd. The assessments are done by a human observer, hence infrequently, expensive and time-consuming. Current assessment by human observers will take us this far, but the need for automated welfare (and health) assessments is growing. Sensor techniques such as cameras, microphones and electronic noses have the potential to replace the eyes, ears and nose of the farmer in the house. The FAWC states that stockmanship, plus training and supervision are necessary to achieve the required standards. PLF-technologies can assist the farmer in the supervision of his animals on a 24/7 basis.

Continuous feed and water registration in the farm makes it possible to assess the first freedom from hunger and thirst. Climate control sensors such as temperature sensors, relative humidity probes and CO_2 sensors will allow the automatic evaluation of thermal discomfort in the house.

Mortality recordings will give a general overview for the freedom from pain, injury and disease. In the PLF community, more and more automatic sensor techniques pop up to continuously monitor the health and welfare status of the animals in the house. A step further is to look at the animal as a sensor to gather evidence on the animals' bio response to its environment and management by the farmer.

A camera-based system (eYeNamic™, Fancom BV®, Panningen, the Netherlands) automatically translates the acquired images into indices of distribution and activity (Kashiha et al., 2013). These indices are a measure of the animals' position and movement, and can help in monitoring and studying basic animal behaviour. The eYeNamic activity levels show correlation with the level of foot pad lesions in the house (Pena Fernandez et al., 2018), lameness (Silvera et al., 2017) and gait scores (Van Hertem et al., 2018). The study of Colles et al. (2016) has shown the potential of animal activity monitoring in relation to Campylobacter infections in a poultry house, and the works of Dawkins et al. the relation between behaviour and welfare (2004), and between behaviour and leg disorders (Dawkins et al., 2017).

Pillar IV: environmental impact

Intensive livestock production is of major economical importance in many European countries, but it is also associated with a number of negative environmental impacts. Airborne emissions of ammonia, odour, greenhouse gasses and dust particles are unwanted by many civilians living close to intensive livestock production sites. Currently emission standards are becoming more stringent in European countries and the livestock industry is challenged to comply with them. Air scrubbing for end-of-pipe treatment of exhaust air is one of the available techniques for emission reduction. Because of economic, ecologic and technical reasons, this is however not considered as a Best Available Technique in EU (Melse et al., 2009).

Manure is often considered as an unwanted by-product of the livestock production process, but it can serve as an input in other agricultural processes in a circular agricultural economy. By reducing the emissions throughout the production process, resource usage can be optimized and the impact on the environment will be consequently reduced. Future meat production should evolve towards a system where resources are being reused and supplied according to the needs of the animal. Precision feeding of animals is a PLF concept to only feed the animal what it requires (Pomar et al., 2009). With this approach, feed conversion will be maximized because less feed will be required, nitrogen and phosphorus emissions will be reduced (Pomar et al., 2011).

With the implementation of air washers, litter burners and solar energy, … it is even possible to evolve towards a production cycle with a negative footprint.

Monitoring sustainability

The challenge is not only measuring key indicators in the farm, but also to bring them together into one index for each pillar, and into one overall sustainability index. How do these indicators add up? Does each indicator have an equal weight in the overall sustainability index? These are all questions that future research should reveal.

A first attempt was made in our study, and the data were presented in a sustainability dashboard that is being updated daily (Figure 1). This dashboard is now implemented in one pig farm. By seeing these values on a daily basis, it immediately raised the awareness of the farmer on the sustainability of his production.

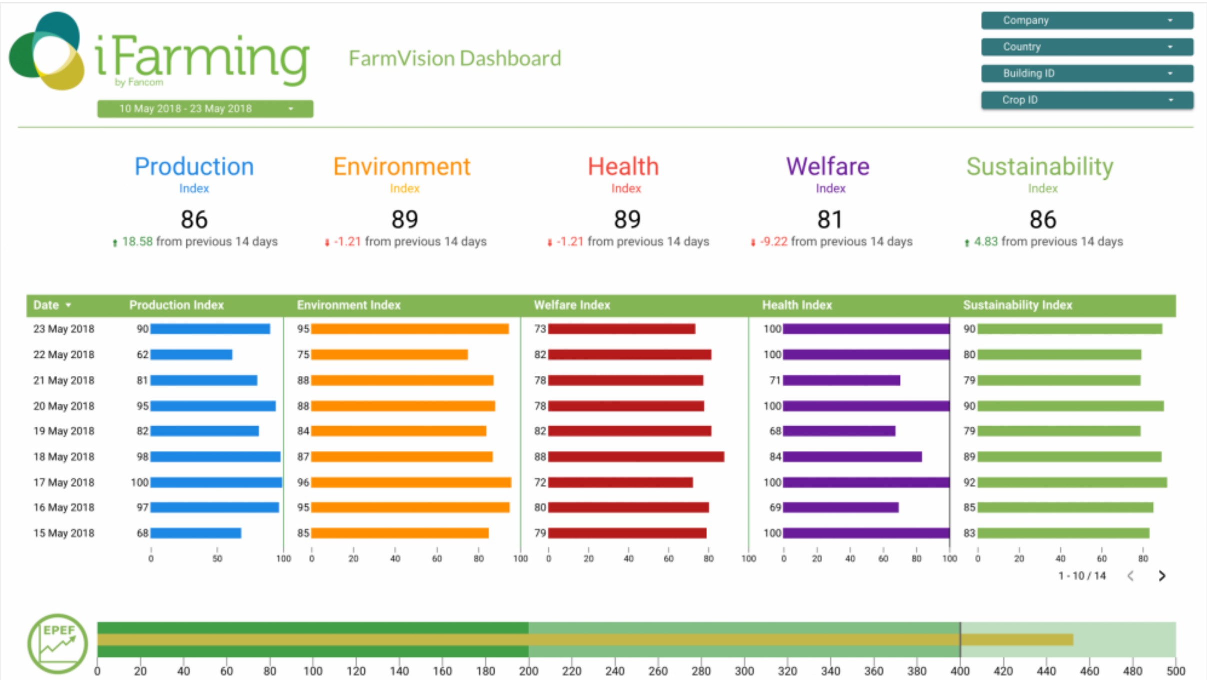

Figure 1. Sustainability dashboard for the daily monitoring of the sustainability level in a commercial intensive livestock farm.

Discussion

In this paper, we have presented four different pillars of sustainability. The implementation in practice happens often in several stages towards sustainable production. In the past, farming was very laborious, and the farmer was only interested in maximizing his "work output":"time effort"-ratio. The automation of certain processes allowed him to significantly improve this ratio, for example an automatic feeding line reduced the workload of the farmer to feed the animals. The next step was to add some intelligence to the automatic systems, e.g. start feed delivery when feeding pans are empty, or start the ventilation when temperature is too high. This can be considered as the first step in the sustainability process: making the production process more resource efficient.

The next steps involve more intelligence in process automation, and a better understanding of the production process. Maximum sustainability is however obtained at the final stage, when the complete production process is controlled. The need of the individual animal will play a bigger role as we move higher up the ladder of sustainability. So although adding more automation and technology to the production process looks like industrial farming, in fact the individual animal will get more attention and care. Some argue on the other hand that PLF methods raise a host of ethical issues (Werkheiser, 2018).

Technology developers develop PLF sensor techniques and automated controls for farmers so they maximize their profits. There is a wide range of tools in the market, but we see that in reality 80% of the farmers are still in the first stage of a very basic implementation with a feed and climate control. But we also know that there is the capability for all farmers to be at the fourth and final step towards sustainable meat production.

The technology is only a tool for the farmer to help him reach the genetic potential of his animals. PLF-technology and continuous monitoring of animal bio responses will improve the understanding of the production process. This will allow the farmer to manage his process by exception, i.e. only take action when the process deviates from the expected outcome instead of applying preventive measures such administering antibiotics at group level. Also in genetics there should come improvements towards more sustainable livestock production. In the past, the main focus in genetics was to improve the resource efficiency of the animals (Siegel, 2014; Zuidhof et al., 2014), which led to a divergence in specific animal breeds such as laying hens and broilers. Nowadays, more focus comes to welfare and health improvements in the breeds, resulting in higher weights for welfare indicators in selection indices. The technology can also serve a diagnostic tool for early disease detection, providing an objective assessment of clinical signs in the pen, whereas the assessment of human observers often is biased or subjective (Petersen et al., 2004; Schlageter-Tello et al., 2015). Not only genetics is important, but also nutrition. Farm level assessment of sustainability is only a small part of the puzzle on the improvement of the sustainability in the livestock production system. Other stakeholders such as feeding companies, animal geneticists, slaughterhouses, retail companies, etc. play an important role as well. Production data collection and sharing will enhance the transparency throughout the production chain and help the consumer make educated decisions.

The main hesitation for most of the farmers to invest into PLF-technology is high investment cost and the unawareness on the return on investment (Steeneveld et al., 2015). On the other hand, we also don’t know what is the cost of not investing in PLF-technology. The value that PLF will bring, cannot not be quantified in hard numbers alone. However, some of the farmers that started using PLF technology acknowledge the benefits of the technology. They state that it allows them to focus on the animals when near the animals, and on the management and operations when in the office. They stated that PLF changed their way of working due to a better organisation of their own time budget. A simple example of this is that with the pig cough monitor, the farmer could easily identify compartments at risk, and visit these compartments at the end of his inspection round to reduce the risk for transmission of the disease between compartments. PLF tools can positively impact farmers’ work, but the tools need to be adapted to the different farmer’s needs and skills (Hostiou et al., 2017).

Precision Livestock Farming is a hot topic in the research community. New technologies and sensor techniques are coming more and more into the commercial market. PLF-technology for health, welfare and emission monitoring is not in large numbers commercially available at this moment. There are however many application in the research pipeline that will evolve into commercial products in the near future. Therefore, we are growing closer and closer towards the automatic monitoring of a sustainable meat production.

Consumer organisations are raising more and more protests against modern intensive farming. A change in the way of how we currently produce our meat is inevitable. Some retail organisations and NGOs have developed their own brand or method for meat production (Mulder et al., 2014). Those are usually focused on the welfare of the animal, or on the environmental footprint of the production cycle to substitute for production efficiency. The adoption of alternative production methods or systems however only succeeded when the producer premiums are increased (Gocsik et al., 2015). Those types of farming are useful in the current world with various consumers, but they will not solve the problem on how to feed the world. Therefore, a more sustainable intensive farming is needed, and with the continuous monitoring of the animals with PLF technology, more and more people believe that this can be achieved (Banhazi et al., 2012; Scholten et al., 2013). Smart farming is key to developing a more sustainable agriculture (Walter et al., 2017).

Conclusion

The global demand for meat is growing, however increasingly stringent legislation challenge livestock producers to meet this demand. Intensification is a viable option to answer this demand, provided that the production becomes responsible and sustainable. Production efficiency should not be the exclusive factor to manage the meat production process. Instead, the animal should be at the centre of the equation. With the help of PLF technology, we can gather as much information as possible during the production process at farm level. The use of automated and intelligent PLF-technology and continuous monitoring of animal bio responses will improve the understanding of the production process. The translation of the data into a general sustainability index will allow the farmer to manage his process by exception, i.e. only take action when the process deviates from the expected outcome instead of applying preventive measures such administering antibiotics at group level. Production data collection and sharing will enhance the transparency and sustainability throughout the production chain and help the consumer make educated decisions.

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