# EIP-AGRI Focus Group
# Reducing livestock emissions from Cattle farming

# Mini-paper – Precision Livestock Farming

## Authors

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## Introduction

While livestock production forms one of the pillars of the EU food industry it faces many societal challenges, not least from the rising demand for meat protein, increasingly stringent environmental regulations, coupled with the falling numbers of young farmers entering the industry. Environmental degradation as a result of the releases of harmful substances in the atmosphere can ultimately lead to regional tensions and violence, affecting economic policies and farmers' income.

It is estimated that 7.1 Gigatonnes of $CO_2$-equiv are emitted yearly in the livestock sector, representing 14.5 percent of all anthropogenic GHG emissions. Cattle (raised for both beef and milk) are the animal species responsible for the most emissions, representing about 65% of the livestock sector's emissions (FAO, 2013). In terms of activities, feed production and processing (including land use change) and enteric fermentation from ruminants are the two main sources of emissions, representing 45 and 39 percent of total emissions, respectively. Manure storage and processing represent 10 percent of total GHG emissions (Gerber, 2013). The remainder is attributable to the processing and transportation of animal products. Emission intensities currently vary widely within and across geographic regions and production systems, by a factor of between two and four, especially for products from ruminant animals (meat and milk) but also for pork and poultry. Intensive animal production systems tend to have higher overall GHG emissions, but their emissions intensity is lower than in low-yield extensive systems.

For all livestock production systems, opportunities exist and are being developed to improve the efficiency of production and decrease emissions per unit of animal product. Some of these options require novel technological interventions whereas others are 'simple' principles that can be applied already in most production systems. As farms continue to increase in size, taking advantage of economies of scale, farmers continuously seek new tools and technologies to reduce their operational cost and for increasing their sustainability. Livestock operations today are characterized by narrower profit margins than in the past, whereas the competition in the market has gradually increased. Consequently, small changes in production efficiency can have a major impact on profitability. In addition, given that today's livestock production is influenced by the consumers demands for high quality and safer products, there is pressure for a more environmental friendly production, zero zoonotic disease transmission, and improved animal welfare. All these reflect a continuing change in the way in which livestock operations are managed and lead to new production model which has to be based around technology and innovation, exploiting the principles of Precision Livestock Farming (PLF) (Berckmans, 2004). In general terms,

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precision farming has been previously considered in a specific EIP Agri focus group with the following aim: to organise data capture and processing to mainstream the application of Precision Farming for input and yield optimisation, while trying to identify the main reasons behind the current lack of adoption, and identifying the key barriers to the implementation of Precision Farming on European farms (EIP-Agri, 2015).

PLF technologies enable continuous, automatic monitoring of animal welfare, health, production and environmental impact in real-time (Berckmans, 2007). PLF technologies can help farmers to increase livestock production and quality of production in a sustainable manner. Although nowadays, there is an abundance of information and technologies available to livestock farmers and managers, it is not generally structured in a way that can be readily applied. One reason could be that PLF research has been primarily carried out using traditional scientific approach of dividing on-farm processes into discrete and manageable pieces to determine solutions and provide important process improvements. Furthermore, many producers perceive that adopting high productive management systems involves increased financial risk. Currently, PLF techniques are predominantly applied in monitoring the health and welfare of pigs, poultry and dairy cows. Even though these technologies have shown great promise in the areas of health, reproduction and quality control, it is the precision feeding seems to be the most promising for reducing emissions of GHG and ammonia (Gerber et al. 2013).

## Precision livestock technologies

Precision Farming (PF) in Europe uses new technologies in the handling and management of farm information, and in managing of spatial and temporal variability found on all crop producing farms. The premise of PF is that this better use of this information improves economic returns and reduces environmental impact. More information for the precision farming with focus on data management, use of precision farming technologies for input and yield optimisation and the main barriers for the implementation of Precision Farming on European farms can be found in the recent final report of the EIP-Agri focus group for precision farming which published in November 2015.  Similar to Precision Farming, Precision Livestock Farming research and development has, over many years, adapted and developed information and communication technologies for livestock farming systems. Sensors, cameras, microphones, satellite positioning systems, automated equipment control and robots, wireless communication tools, Internet connections and cloud storage are at the technical core of an information-driven or 'information intensive' livestock production.

Precision Livestock Farming is defined as "the use of information and communication technologies for improved control of fine-scale animal and physical resource variability to optimize economic, social, and environmental dairy farm performance" (Eastwood et al., 2012). Another more or less similar definition coming for the most recent EU funded project for precision livestock farming, the EU-PLF project. According to this, Precision Livestock Farming (PLF) can be defined as "intelligent management and care of (individual) animals in livestock farming by continuous automated monitoring/controlling of the production/reproduction, health and welfare of (individual) animals, thereby allowing quick corrections when deviations from normal are monitored" (**http://www.eu-plf.eu/**) .Precision livestock farming can offer a management tool that enables a farmer to monitor animals automatically and to create added value by helping to secure improved health, welfare, yields and environmental impact. Precision livestock farming is an approach that seeks to cater for the individual animal's needs in bigger herds, by integrating health, genetics, feed, social behaviour and resource use and availability, through the support of sensor-based monitoring systems. Precision livestock farming thus can readily be extended to individual animal level approaches towards optimising feed quality and digestibility, and animal health and husbandry (Wathes et al., 2008).
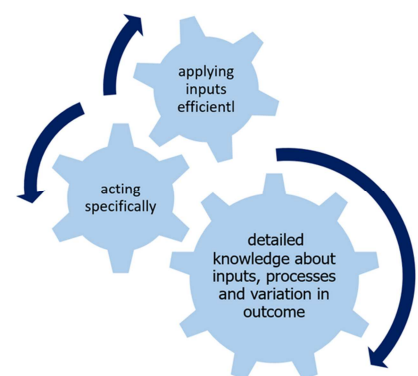
Fig. 1 presents the basis of PLF. Although the concept is for biological process (animal physiology, welfare, behaviour) the same concept is also applied to physical process (Aerts et al. 1998, 2003)
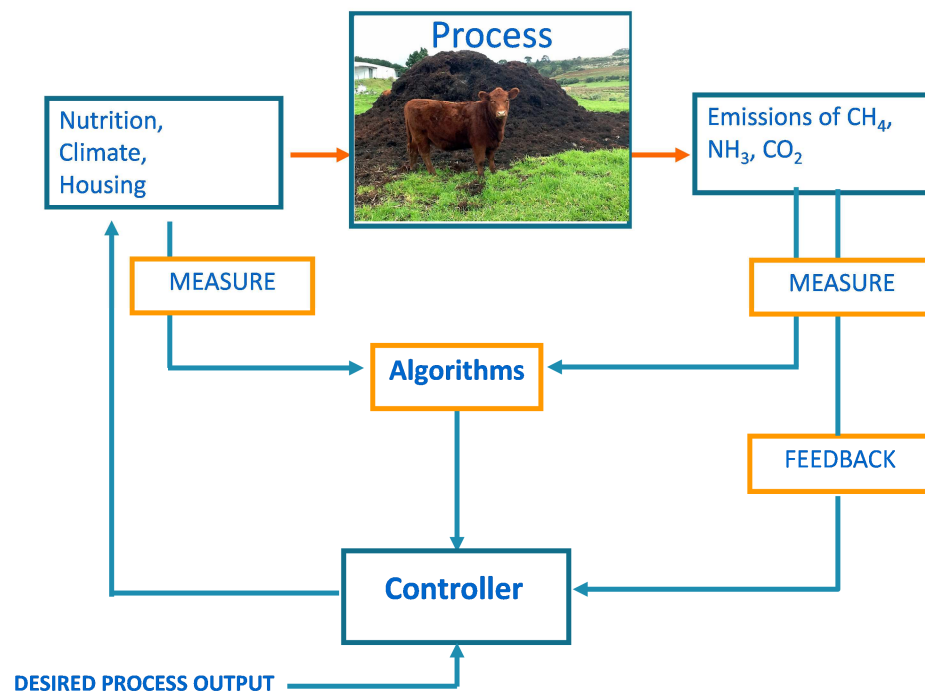
Fig. 1. Schematic overview of the key components of PLF to control biological processes (after Aerts et al. 1998, 2003)

There are several PLF technologies but still, very few of them used in practise. Although there are not developed for emission control or reduction, their use can also lead to a better emission control.

| Reference | Application |
|---|---|
| Frost et al. 2000 | Sensor placement robot for pigs |
| Gates et al. 2001 | Intelligent ventilation control in livestock buildings |
| Matlz et al. 2003 | Dairy management to maximise profit |
| Stewart et al. 2007 | Cattle monitoring system |
| Shao et al. 2008 | Improved thermal control for pigs via machine vision |
| Banhazi et al. 2009 | Improving profitability via precision feeding for pigs |
| Maertens et al. 2011 | GaitWise: real time cow gait tracking |
| Van Hertem et al., 2016 | Automated lameness detection in cows |

| | |
|---|---|
| [http://agrifarm.dk/en/technologies/air-cleaning-in-the-dairy-barn](http://agrifarm.dk/en/technologies/air-cleaning-in-the-dairy-barn) | Indoor climate control |
| [http://agrifarm.dk/en/the-first-hybridventilated-farm](http://agrifarm.dk/en/the-first-hybridventilated-farm) | Indoor climate control |

Although there are several PLF technologies aimed at increasing the sustainability of livestock farms, only the precision feeding is indicated by the Global Research Alliance (2013) as the most promising PLF technology for reducing ammonia and GHG emissions from livestock farms. However, taking into account the rapid development of monitoring and climate control technologies we should probably see in the near future the use of intelligent PLF systems for emissions reduction through optimised barn climate control and better air flow through smart ventilation systems.

## Precision feeding

Precision feeding is about getting the right nutrient to the right animal at the right time. Although direct mitigation effects are uncertain and hard to predict, precision feeding will increase feed efficiency and productivity and consequently can improve farm profitability. This can be done by controlling:

- individual feed intake
- the amount and composition of manure produced and the associated emissions from manure
- the enteric CH4 production.

Customised balanced feeding programmes in grazing dairy cattle systems have shown to increase productivity and reduce enteric methane emissions intensity (15-20%) and also N excretion (20-30%), which results in reduced emissions from manure.

According to Knapp et al. (2014), in dairy cattle the mitigation of methane emission by controlling nutrition approach may be obtained i) altering the rumen VFA production pattern; ii) altering rumen microbe populations and increasing the rumen passage rate of digesta; iii) optimising feeding in order to increase milk yield (dilution effect).

Feed efficiency explains large part of the variability in GHG emission intensity (Thoma et al., 2010). Moreover, feed efficiency was identified as one of the most important parameters controlling GHG-emissions intensity, acidification and eutrophication potential in both beef and dairy cattle (Cederberg et al., 2009; Guerci et al., 2013).

Monitoring feed intake is one of the main constraints both for precision feeding and for estimate methane emission. Dry matter intake, in fact, is the main factors affecting methane emission (Hristov et al., 2013). Some technologies are available for monitoring feed intake on free-stall cattle (Chizzotti et al., 2015; Bikker et al., 2014; Mendes et al., 2011), whereas more efforts should be devoted for obtaining similar results also on grazing cattle. Moreover, feeding cows according to individual needs improves production and nutrient utilization compared with feeding a single diet to all cows (Maltz et al., 2013). However, in order to accomplish this aim, individual data about milk yield and composition and body weight are needed. On-line milk composition analyser that measures milk fat, protein, and lactose in real time at each milking with concurrent measurements of BW are now available and might generate useful data to refine the feeding program of dairy cows (Maltz et al., 2009). A very recent study demonstrated that when both energy and protein efficiency were improved, land use, water use, and GHG emission reductions ranged from 23.4 to 35.5% (White, 2016).

Diet manipulation is proposed as one of the techniques for reducing ammonia from agriculture in the UNECE Guidance Documents (UNECE, 2014) but also in a recent review from FAO dealing with techniques for reducing non-CO2 GHG emission from livestock facilities (Hristov et al. 2013)

Precision feeding, which combines genetics of the animal with feeding and grazing management, requires advanced technological facilities to precisely monitor the animal's needs and manage pastures and forage production appropriately, and can be rolled out in high-value farm systems that use highly technological farming systems. In pig production, the inclusion of dietary fibre reduces $NH_3$ emission by shifting the nitrogen from urine to faeces due to promotion of bacterial growth in the large intestine (Jarret et al., 2012). A significant reduction in $NH_3$ emission can also be achieved by lowering the dietary electrolyte balance or supplementing with acidifying salts such as benzoic acid or $CaSO_4$ (Philippe et al., 2011). For dairy cattle, decreasing N excretion can be achieved by an improvement of rumen protein metabolism leading to lower $NH_3$ and $N_2O$ production. Two methods are recommended: firstly, decreasing crude protein content in the diet to 14% (from 17-18%) which is often practiced, so that less N is excreted whilst both maintaining milk production, and secondly, limiting the digestion of ingested food meal in the rumen. According to Lee et al. (2012), feeding cows to amino acid requirements may be a promising way decreasing N excretion. However, more efforts must be devoted to obtain optimal prediction of amino-acid requirements in lactating dairy cows. As a consequence, improved understanding of amino-acid utilization in dairy cattle needs more research effort (Arriola Apelo et al., 2014).

Feeding strategies aimed to reduce methane emission include: i) increasing dry matter intake; ii) adoption of grain processing techniques; iii) increasing concentrate/forage ratio; iv) increasing forage quality; v) lipid supplementation; vi) lowering rumen pH below 5.5.

The effects of these strategies have been recently reviewed by Knapp et al (2014). In terms of methane reduction, lowering rumen pH and increasing concentrate amount in the diet resulted in the highest reduction (up to 15-20%). However, these strategies may lead also to milk yield reduction, negative effects on animal welfare and adverse consequences on GHG emission at global level (increasing demand of grains for concentrates). The other strategies allow to obtain lower percentages of methane mitigation (from 2 to 6%), without worsening animal performances.

According to Pomar et al (2013) the essential elements for precision feeding in livestock production systems are

- the proper evaluation of the nutritional potential of feed ingredients,
- the precise determination of nutrient requirements,
- the formulation of balanced diets that limit the amount of excess nutrients, and
- the concomitant adjustment of the dietary supply and concentration of nutrients to match the evaluated requirements of each pig in the herd.

A recent report from Global Research Alliance on agricultural greenhouse gases (2013) indicates that precision feeding can have a direct effect on resource efficiency and emissions reduction only if it is supporter well by training, education and knowledge transfer. The same report is also highlight the need for creating customised feeding programmes and feed supply chains, which main in turn rely on stable market conditions and commodity prices.

The Fig. 2 below summarises the main drivers for success, barriers for implementation and mitigation potential of precision feeding systems (Global Research Alliance, 2013; Pomar et al. 2013)
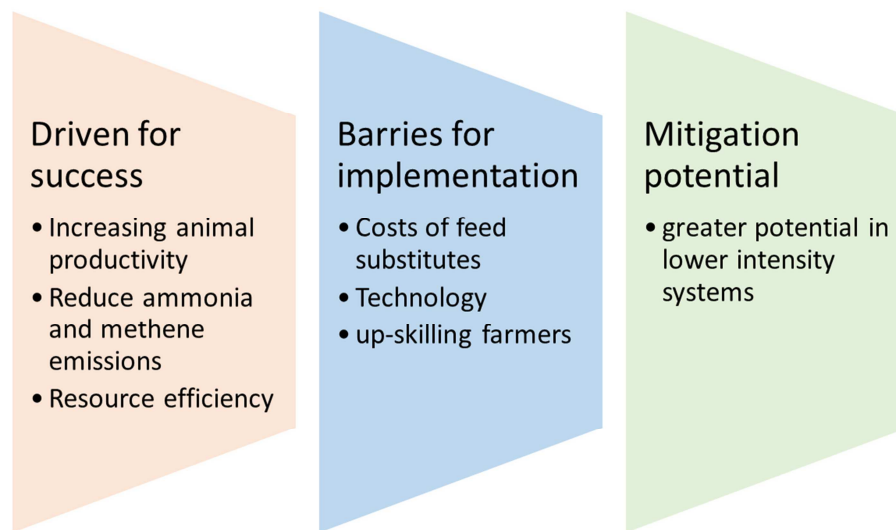
Fig. 2. Barriers for implementation and mitigation potential of precision feeding systems (Global Research Alliance, 2013; Pomar et al. 2013)

## Farmers adoption

Although most farmers can see the benefits of using a more precise approach to manage their livestock production with additional information, the tools provided by precision farming and other information technologies have not yet moved into mainstream livestock management. The increased complexity of the systems inhibits easy adoption and makes calculations as to the financial benefits uncertain.

As indicated by many PLF experts, the main problem of commercialisation and fast implementation of PLF systems in livestock production chain is the lack of support mechanisms, knowledge transfer and a consistent service offering for farmers. Experts highlight the need for a service sector that will be able to (Banhazi et al. 2012).

- take care of technology components,
- interpret data captured by sensors,
- formulate and send simple, relevant advice to farmers on a regular basis,
- involve users in technology developments.

This service sector would need to use suitable business models that avoid high initial investment costs for farmers.
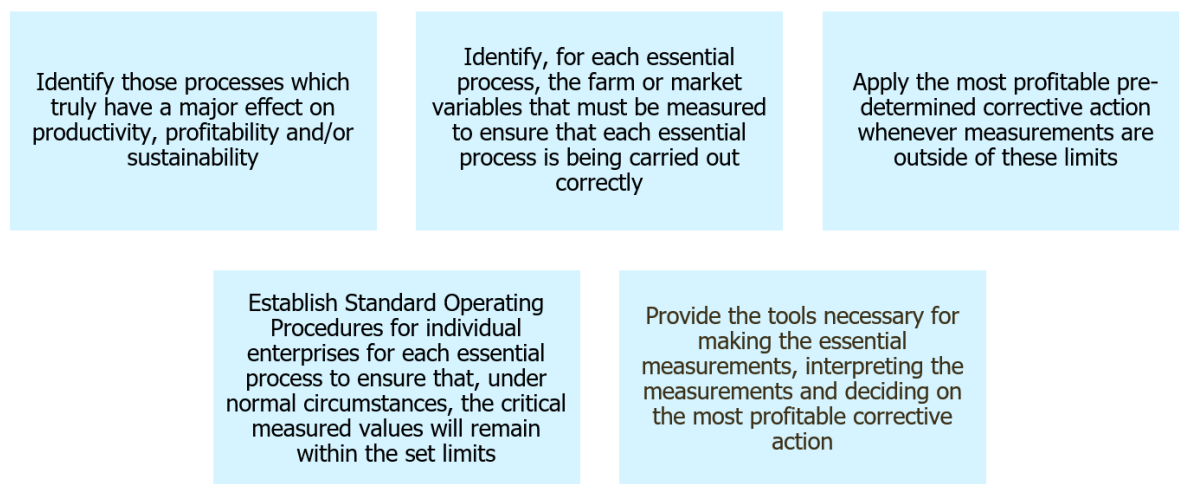
The lack of co-ordination between researchers, developers, market and farmers is the other important limiting factor of adoption rate of PLF technologies Achieving better co-ordination between the developers and suppliers of PLF tools is very difficult, but would result in the development of better integrated systems. That in turn would results in greater commercialisation of PLF systems as integrated systems to serve the farmers better (Banhazi et al. 2012).

The decision to purchase and implement a precision dairy technology represents a significant investment for a producer, who often faces the challenge of choosing a technology that will serve their needs for several years. In a recent study among other aspects trying to identify the parameters currently measured on farms, find the considerations a farmer takes when selecting precision dairy farming technologies, and determine the parameters perceived by producers as most useful (Borchers, 2015). Producers were able to select multiple parameters because several technologies can monitor multiple parameters. Additionally, the potential exists for producers to have more than one technology. Producer responses indicated that the most commonly measured parameters by already adopted technologies were: daily milk yield (52.3%), cow activity (41.3%), not applicable (31.2%), and

mastitis (25.7%). The least used technologies were rumen pH (0.9%), respiration rate (1.8%), methane emissions (1.8%), body condition score (2.8%), and heart rate (3.7%) (Borchers, 2015).

In the same study (Borchers, 2015) an attempt was made to quantify the criteria that the farmers considering more important for acquiring a PLF technology. The farmers indicated benefit-to-cost ratio as most important, followed by total investment cost, simplicity and ease of use, proven performance through independent research, and availability of local support.

According to Banhazi et al (2012), in order to increase the adoption level of these new PLF technologies in livestock sector it is essential to develop a management system that ensures only the most essential procedures are carried out, they are all carried out correctly and consistently, and in a way that controls risk. The main principles of such system are (Banhazi et al. 2012):

| | | |
|---|---|---|
| Identify those processes which truly have a major effect on productivity, profitability and/or sustainability | Identify, for each essential process, the farm or market variables that must be measured to ensure that each essential process is being carried out correctly | Apply the most profitable pre-determined corrective action whenever measurements are outside of these limits |

| | |
|---|---|
| Establish Standard Operating Procedures for individual enterprises for each essential process to ensure that, under normal circumstances, the critical measured values will remain within the set limits | Provide the tools necessary for making the essential measurements, interpreting the measurements and deciding on the most profitable corrective action |

## Contribution of PLF to resource efficiency

A better use of resources contributes to lower the emission intensity. In this sense, Precision Livestock Farming has demonstrated to contribute to farm efficiency, particularly in dairy cattle. For beef cattle, however, PLF has experimented less development. The use of technology now focuses on the management of grazing. As reviewed by Ali et al. (2016), satellite remote sensing is a promising tool to properly manage grasslands in terms of animal production and ecosystem protection. For animal management, attention is now on telemetry technologies, particularly the use of GPS. This allows an automatic record of behaviour (particularly foraging), which combined with pasture characteristics may allow more accurate determination of animal intake and provide tools for decision making (Orr et al., 2012; Thompson et al., 2015). Finally, GPS location has been also used to estimate emissions from grazing animals by means of inverse modelling (McGinn et al., 2015).

Concerning emissions reduction precision feeding seems to have a direct impact on emission reduction. However, it is expected soon that emission reduction could be achieved also through smart ventilation systems and optimised barn climate.

## Proposal for potential operational groups

- Precision Livestock Farming Technologies
- Integration of PLF with breeding and nutrition initiatives

- Demonstrating the viability of PLF in small and medium livestock farms
- Integrating PLF, the Internet of Things and Big Data

## Proposals for (research) needs from practice

- A reliable and low cost system for measuring ventilation rate in livestock buildings
- Low cost sensors for detection of emission and concentration of ammonia and GHG
- Establish a common protocol for measuring ammonia and GHG in livestock operations
- Develop self-learning systems that optimise barn climate in naturally ventilated barns by e.g. altering barn openings => avoid high temperatures in the barn
- Hybrid ventilation system
- Targeted ventilation in animal occupied zones
- Sensors for in vivo detecting rumen environmental parameters (methane; H2; CO2; VFA)
- Sensors for monitoring animal behaviour at pasture (position, feeding activity, rumination)

☞ To be put in the **web form**

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