PRECISION LIVESTOCK FARMING: SCIENTIFIC CONCEPTS AND COMMERCIAL REALITY

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ABSTRACT

Precision Livestock Farming (PLF) is potentially one of the most powerful developments amongst a number of interesting new and upcoming technologies that have the potential to revolutionise the livestock farming industry. If properly implemented, PLF or Smart Farming could (1) improve or at least objectively document animal welfare on farms, (2) reduce GHG emission and improve environmental performance of farms, (3) facilitate product segmentation and better marketing of livestock products, (4) reduce illegal trading of livestock products and (5) improve the economic stability of rural areas. However, there are only a few examples of successful commercialisation of PLF technologies introduced by a small number of commercial companies which are actively involved in the PLF commercialisation process. To ensure that the potential of PLF is taken to the industry, we need to: (1) establish a new service industry, (2) verify, demonstrate and publicise the benefits of PLF, (3) better coordinate the efforts of different industry and academic organisations interested in the development and implementation of PLF technologies on farms, and (4) encourage commercial sector to assist with professionally managed product development.

1. INTRODUCTION

Efficient information management is very much part of profitable livestock production (Thysen, 2000; Lewis, 1998). The main purpose of precision livestock farming (PLF) is to improve the efficiency of production, while increasing animal and human welfare, via applying advanced IT, targeted resource use and precise control of the production process (Chamberlain-Ward, 1998; Cumby and Phillips, 2001). The main purpose of this article is to briefly review the current scientific state of art and, more importantly, the commercialisation aspects of PLF technologies with the view to facilitating more effective technology transfer between scientific and commercial organisations. By doing so, we hope that PLF will not remain simply “the engineers' daydream” but becomes the “animals' friend and the farmers' panacea” (Wathes *et al.*, 2008)

2. SCIENTIFIC ISSUES

1.1 Scientific concepts and principles of PLF

Precision farming through the adoption of electronic data collection, processing and application has the potential to improve production efficiency and reduce costs (Banhazi and Black, 2009; Banhazi *et al.*, 2009b; Banhazi and Lewis, 2009), as well as increase animal and human welfare. There is currently an abundance of information available to livestock managers, but it is not generally structured in a way that can be applied readily. For example, a survey of producers raising beef from pastures in southern Australia showed that over 400 pieces of information could be relevant for their farms. The information comes from many sources including academic organisations, government advisors, producer magazines, newspapers, radio, television and other media sources, company technical advisers and other producers. The information is frequently dispersed and sensationalised and not in a form that can be readily applied on farms. Consequently, farm managers tend to adopt procedures in areas where they have most interest or in which they believe they have most expertise and neglect many other areas that are also essential to drive productivity and profitability.

Furthermore, many producers perceive that adopting highly productive management systems involve increased risk. The perceived risks include the risk of financial failure because of unforseen environmental or market circumstances, damage to the farm infrastructure such as soils and pasture, compromises to animal health and welfare and the risk of increased stress on them from managing an intensified system. These risks are real. Thus, it is important 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. Such a system based on the Hazard Analysis Critical Control Point (HACCP) method has been developed for grazing beef enterprises in Australia (Black and Scott, 2002) and forms a model that can be applied to any other animal industry. The principles behind the system are as follows:

(a) Identify those processes which truly have a major effect on productivity, profitability and/or sustainability. These include the actions that if not carried out correctly will substantially reduce the viability of the enterprise.

These processes should cover every aspect of the enterprise from strategic planning of the business structure through all aspects of production to sale of the product. It is important to reduce the number of 'essential processes' to only those that will have a major impact on the enterprise if not carried out correctly. The number must be manageable because all are to be consistently applied over time. In the example with grazing beef enterprises in southern Australia, only 29 processes across the entire enterprise were considered to be essential for maximising profitability and sustainability.

(b) 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. Establish the frequency at which each measurement must be made and set maximum and minimum limits for each measured variable to ensure that the process will continually remain within the optimum range and will not get out of control.

(c) Apply the most profitable pre-determined corrective action whenever measurements are outside these limits. The process of having predetermined actions when the measurement limits are breached substantially reduces the stress level for the manager because the plan of action and when to apply it has already been established and the consequences are known. Partial or whole enterprise budgets are an important tool for selecting the most economically viable corrective action.

(d) 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. Such a process is important so the manager can 'go on leave' knowing that each critical process in the enterprise will be measured and carried out correctly by staff. Both high level (annual calendar and daily actions) and low level (how to do a specific task) procedures are essential.

(e) Provide the tools necessary for making the essential measurements, interpreting the measurements and deciding on the most profitable corrective action. These tools are an essential component of the 'package' and must be provided as part of any adoption package. There is a need also to train staff in these tools.

The fact that humans tend to become lax with the application of repetitive tasks is one of the main reasons for failure of systems like the one outlined above. Recording and checks of measurements and actions by other people is one way to help overcome the problem. The difficulty faced by many rural industries in industrialised countries is obtaining and retaining adequately trained and motivated staff. The lack of good staff frequently contributes to failure of well planned adoption programs.

The major role for Precision Livestock Farming is to simplify this process of collecting processing and analysing data so that the farm manager is presented with solutions, not problems (Berckmans, 2011). Advances in the application of the outlined procedure for adoption of essential enterprise processes will depend more and more on the automated measurement, interpretation and control of these processes. The procedure should include automation of all measurement systems, interpretation of the measurements, identifying when critical measurement limits are breached and built-in automatic control systems for each essential process to bring it back inside the acceptable limits. A useful example of the type of change needed within the animal industries comes from the world steel industry. In the 1950's, all tasks were undertaken by humans compared with today when the whole process is controlled electronically, almost all manual work tasks are automated and monitored centrally. This is a vision for Precision Livestock Farming, where animal welfare, environmental sustainability, productivity and profitability are all at an optimum using electronic measurement, interpretation and control.

1.2 Integration of traceability with PLF

Traceability within livestock management has largely been limited to movement and disease control applications such as the European passport system for cattle, the PigPass for pigs in Australia and the movement permit across state/provincial borders in Malaysia and Vietnam. Virtually no attempts have been made to unlock the economic benefit that traceability can have for livestock enterprises. There are a number of objective reasons why the integration of traceability and PLF has not progressed further, which include (1) availability of easy to implement and affordable automated identification systems, (2) overemphasised privacy concerns related to data captured on-farm, (3) inconsistent offering of traceability products to farmers and (4) too much focus on particular numbering technologies (simple numbering, barcode, RFID).

The most interesting example of the integration of traceability with PLF in our opinion is the exchange of information along the feed – animal – food chain. This information exchange (Figure 1) has a number of benefits.

- Feed and feed input providers can greatly improve the composition of their products if they have access to slaughterhouse statistics resulting from the feeding profiles applied on the farm.
- Farms can use such a system for the selection of the right feed (or right feed provider). They can also optimise their feed use/intake from the statistics of other farms on the network

- Abattoirs can use the system as a basis for cooperation with farms to produce and source more animals on weight and conformation specification.
- Industry statistics are a very important tool for both governments and the industry itself to steer the sector. Reliable statistics can be used for political decision making, benchmarking, lobbying and business decision making.

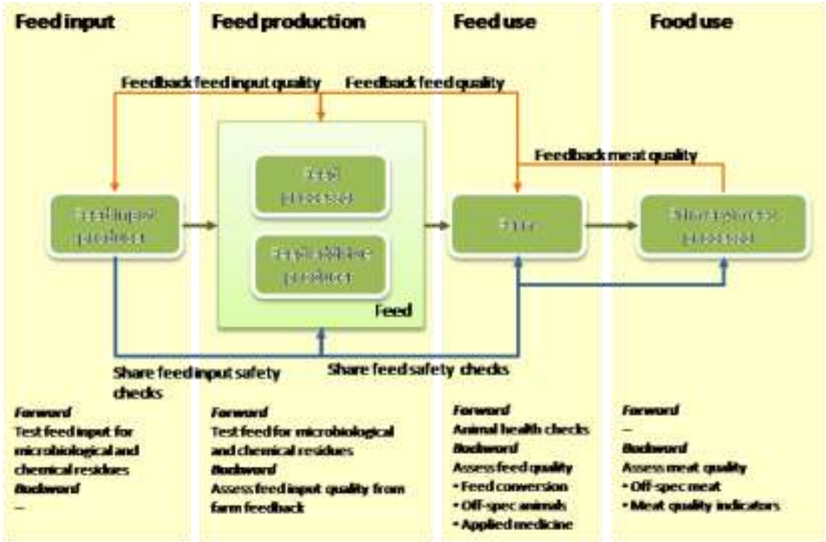

Figure 1: traceability systems and linkages with PLF (Lehr, 2011)

1.3 Scientific and technological developments

Many of the early PLF developments were predominantly instigated in Europe/UK. Early pioneers of the PLF concept were researchers at the Silsoe Research Institute, UK and Leuven University, Belgium. Additional developments took place in other EU countries, such as Germany, Denmark, the Netherlands, Finland and the Volcani Research Centre, Israel (Devir *et al.*, 1997; Halachmi *et al.*, 1998). In 2002 Australian PLF developments started with assistance provided by scientists based at the UK and Belgium (Banhazi *et al.*, 2003). Most pig industry related PLF developments were lead by scientists in South Australia (Banhazi *et al.*, 2007; Banhazi and Black, 2009) while researchers at USQ developed PLF applications for the beef industry. CSIRO researchers extensively investigated virtual fencing technologies (Bishop-Hurley *et al.*, 2007; Umstatter, 2011). In the table 1 a number of publications and resultant technologies are presented as an example of PLF tools developed over the years without aiming to accurately review of all developments over the years.

Table 1: examples of PLF technologies developed over the years

Reference	Technology/tools
(Exadaktylos *et al.*, 2011)	Improved egg incubators via synchronisation of hatching
(Gates *et al.*, 2001)	Intelligent ventilation control in livestock buildings
(Schofield, 1990; Brandl and Jorgensen, 1996; Wang *et al.*, 2008; Banhazi *et al.*, 2009b)	Weight estimation of pigs via machine vision tools
(Maltz *et al.*, 2003)	Dairy management to maximise profit
(Niemi *et al.*, 2010; Banhazi *et al.*, 2009a)	Improving profitability via precision feeding for pigs
(Frost *et al.*, 2000)	Sensor placement robot for pigs
(Mottram, 1997; Stewart *et al.*, 2007)	Cattle monitoring system
(Bull *et al.*, 1996)	Udder health and hygiene monitoring in dairy cattle
(Chao *et al.*, 2000; Park *et al.*, 1998; Park *et al.*, 2007)	Poultry carcass inspection
(Cronin *et al.*, 2008)	Automated egg counting and identification
(Doeschl-Wilson *et al.*, 2005)	Carcass composition prediction for pigs
(Hsieh *et al.*, 2011; Ruff *et al.*, 1995; Zion *et al.*, 2007)	Automated fish sizing and sorting
(Shao and Xin, 2008; Wouters *et al.*, 1990)	Improved thermal control for pigs via machine vision
(Guarino *et al.*, 2008; Chedad *et al.*, 2001; Moshou *et al.*, 2001)	Cough recognition in pigs

Recent developments in communication technology through mobile phone technology, telecoms and the internet offer a huge potential benefit to the design, application and value of PLF. Whilst independent applications on individual farms may be desirable to some customers, the advantages of centralised data collection, processing, management and reporting are significant. Data collected by sensors on the farm can be sent, by FTP for example, to a central site for processing, storage and reporting. The farm manager is saved this task and his time and expertise is instead available for farm and animal husbandry tasks. The centralised processing should supply him with only the data pertinent to his daily needs, with more detailed reports available as required, including through the centralised database the comparative performance of his unit, for example. In short, the benefits offered by a good PLF system should be obvious to the user and ideally should reduce his management workload, not increase it.

3. COMMERCIAL ISSUES

3.1 Examples and principles of commercialising PLF technologies

In livestock production there are already a few examples of commercialisation of PLF techniques. Good examples of commercial adoption of PLF techniques include the use of robotics in dairying, measurement of water usage, egg counting, bird weighing, better control of environment in poultry houses, computerised feed systems, climate control, automated disease detection, (Guarino *et al.*, 2008) growth measurement and real-time production site data capture in piggeries. The recent EU sponsored project BrightAnimal project (Lehr, 2011) has looked for evidence of PLF technologies in laying hens, pigs, diary and aquaculture fish used in a commercial environment in a number of countries, including Estonia, Denmark, Norway, United Kingdom, Australia, Malaysia, Vietnam and South Africa. In general, there was limited evidence of commercial PLF products used on farms. As expected, farmers in techno-friendly countries, like Estonia, are more inclined to use technology to reduce their dependency on hard-to-get (and expensive) workers and make their life a little more comfortable. However, even there the amount of technology deployed is very limited and key aspects of animal welfare or productivity are not monitored in an automated fashion routinely.

The commercialisation principles of PLF technologies need to include (1) a verification of the benefits of the PLF technique being proposed, (2) a clear communication of those verified benefits to customers, (3) identification of principle beneficiaries (i.e. operator vs. owner of the business), (4) provision of appropriate training and technical support, (5) correct specification, installation, commissioning and monitoring of the installed system. However, PLF developments have been largely spear-headed by academic organisations so far. In general, there is an inadequate engagement of commercial companies in the PLF technology development process. In order to increase the interest of suitable companies in providing services to farms, a collaboration between smaller specialist firms and larger generalist firms such as DeLaval, Fancom, Petersime etc is desirable. Transferring PLF technologies to companies that will supply and manage the systems is a significant step towards developing commercial PLF tools/products that customers want and that can be sold with confidence.

3.2 Limitation factors of commercialisation

The greatest problem of commercialisation is the lack of a consistent service offering for farmers. Farmers are biologist by nature and only technologists ocasionally. There is a need for a service sector that will be able to (1) take care of technology components, (2) interpret data captured by sensors, (3) formulate and send simple, relevant advice to farmers on a regular basis and (4) involve users in technology developments. This service sector would need to use suitable business models that avoid high initial investment costs for farmers. Affordable monthly or annual fees might well be compatible with farmers cash flow, especially is they are linked to performance improvements or animal sales. Although farmers usually invest part of their gains in technology, it is typically machinery that they would look forward to buying (as opposed to software or sensors).

The food industry in general is a very conservative industry and with good reason. Although it is one of the largest industries world-wide, its margins are very small and its products are usually very delicate. Agriculture is in addition a fragile industry, because it depends directly or indirectly on climatic factors and seasonal demand/supply circles. In addition, even for the more adventurous farmer it is very difficult to judge the applicability of a particular technology and 'guesstimate' its benefits. In other words, an important missing element is the absence of clear cost benefit data on PLF that takes into consideration the complexity of farmers' purchase decisions. Demonstrating and verifying the economical, welfare and environmental benefits of these technologies is an essential part of the commercialisation process.

The other key limiting factor of adoption rate of PLF technologies on farms is the lack of co-ordination between researchers, developers and technology suppliers. 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 would serve the farmers better. In addition, many of the PLF "products" have actually never been 'productised' (developed into a proper 'product'); but they went directly from the lab to the farm. Only some larger firms with enough development funds have taken up PLF as their guiding principle, such as Fancom, DeLaval, Petersime and a few others.

4. PLF AS A FACILITATOR OF PROGRESS: LIKELY BENEFITS AND MOTIVATORS OF IMPLEMENTATION

In the next 10 years it is very unlikely that PLF will revolutionise the livestock industries. However, in the next 5-10 years sensors will be deployed routinely around animals that might allow farmers to monitor effectively a range of useful parameters for all livestock species. This will enable a range of new services to be developed and implemented on farms, such as individual feeding, heat detection, health monitoring and animal localisation. Mobile robots will emerge for milking and other tasks both in the shed as well as in the open. Virtual fencing will contribute to better herd and meadow management and improved financial returns for grazing enterprises. Most farms in Europe will be computerised in 10 years time and will use software tools for their management.

PLF can greatly contribute to an objective discussion on animal welfare by providing real data to the otherwise very subjective discussion process. While PLF will not be able to necessarily resolve all welfare related questions, it will allow interested parties to detect and act upon time periods when animals were kept under sub-optimal conditions.

Green house gas emissions are going to be very important in the future and PLF can contribute to the reduction of such emissions by measuring emission and by potentially adjusting feeding, temperature and other parameters that influence the emission of gases. Farm enterprises in the supply chain are making a concentrated effort to keep animals under optimal conditions, to keep emissions down and to provide the best livestock product at the lowest possible price. PLF can assist in transporting this information to other parties within the supply chain, and ultimately to the consumer. It can facilitate more informed choices by consumers and can be the base for other business models, such as selling meat by protein contents, emitted GHG gases, food miles, or other concepts. The exchange of information on the feed-animal-food chain has a great potential for optimising livestock production. Feed producers could reap very important information from carcass composition data. Farmers could improve their feeding regime and chose the feed provider with the “best” feed for their animals. Traceability and PLF are the basis for such an information exchange. If there is a continued decline in the profitability of farms in Europe, perhaps retailers will start buying farms and require data exchange along the supply chain. Environmental control will be much improved within this time period and most farmers ten years from now will know how much GHG they emit. Driven by consumers and retailers they will be striving to reduce their emissions by capturing gases, adapting their feed and dealing better with waste. PLF will have its role in feeding strategies, perhaps linked to gas and waste production.

PLF can also contribute to the avoidance of illegal trading of livestock and livestock products. Smuggling animals is a major problem (health and financial) in countries like Malaysia. Illegal and unregistered (IUU) fishing is a billion dollar enterprise and cuts deeply into our fish banks. Misusing the available fish stock could be significantly reduced if the information chain was quicker to react.

5. THE WAY FORWARD: CONCLUSIONS AND RECOMMENDATIONS

1. The principles of PLF are well established and the routine utilisation of PLF technologies could be certainly contributing to improved livestock management on farms.
2. Integrating traceability with PLF would be a positive step forward and would improve the usefulness of PLF systems.
3. A number of interesting PLF developments have occurred over the past years that have great potential to revolutionise livestock management. PLF/smart farming technologies, (if properly implemented) could (1) improve or at least objectively document the level of animal welfare on farms (2) reduce GMG emission and improve environmental performance of farms (3) reduce illegal and facilitate product segmentation/better marketing of livestock products (4) improve rural economy and stabilise rural populations.
4. However, when it comes to commercialising these technologies (1) there are only a few good examples of successful PLF technology commercialisation exist and (2) only a small number of commercial companies are involved actively in the PLF commercialisation process.
5. Thus to facilitate the proper development and implementation of PLF products on farms (1) a new service industry needs to be established to be responsible for maintenance of hardware tools and management of collected data (2) benefits provided by PLF technologies need to be independently verified under commercial farm conditions (3) development and marketing efforts of different industrial and academic partners need to be better coordinated and (4) the involvement of commercial sector in the process of professional product development needs to be facilitated.

In addition, a “Federation of PLF focused companies” might be created with the aim of developing a "road map" document highlighting the critical steps that need to be taken to stimulate the commercial uptake of PLF/Smart Farming technologies. Such document should be based on the outcomes of a recently completed international PLF project and might be developed as part of a commercially focused PLF conference/meeting. PLF participants need to also engage their respective governments in order to secure public funds required for verification studies that would be unlikely to be financed by private companies.

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