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The impact of Precision Livestock Farming on work, skills and human-animal interactions

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Abstract: Automation and digitalisation in livestock farms have become more and more important in recent years in many countries, giving rise to what is called Precision Livestock Farming (PLF). The large deployment of sensors and advanced technologies, originated from industry, meets the current economic, structural and social constraints of farms. PLF is developing in different animal sectors to facilitate the monitoring of herds due to the increase of herd size and the decrease of workforce availability. Reducing the hardness of repetitive tasks seems also to be a factor of adoption of these new technologies. This review focuses on the impact of PLF on the farmers' profession and organisation of their work. Time savings are observed due to the introduction of robots and sensors in farms because they replace recurrent physical tasks (milking, feeding) while simplifying the monitoring of animals. Other dimensions of work are impacted by PLF such as work flexibility and new schedules. The information provided may reduce the mental workload informing the interventions required (optimal moment for insemination, detection of health problems to anticipate curative action). However, PLF also creates new tasks such as maintenance and monitoring of equipment, interpretation of data provided by these tools. Thus, the mental workload can sometimes be increased due to the complexity of the information to manage the multiple alarms or alerts. The relationship between the farmer and his animals is also modified. The impact of PLF on farmers' work leads to positive aspects and can be attractive for young people. But work consequences can also be sources of failure if they are not adapted to the needs and skills of farmers. It is therefore essential to take into account farmers' work, and its different dimensions, to facilitate the adoption of these new technologies.

Keywords: precision livestock farming, monitoring, technologies, labour, work

Introduction

The emergence of new technologies and their use in animal husbandry, giving rise to precision livestock farming, appears as one of the possible levers for responding to the need for development of sustainable livestock farming (Eastwood *et al.*, 2004). Economic benefits are not the only reason for producers to equip their farms. Although economic models have been developed for analysing the value of investing in precision livestock farming technology (Bewley 2010, for example), Dolechek et Bewley (2013) explain that even if certain technologies are not economically viable, they provide opportunities for significant improvements in farmers' quality of life. For example, several scenarios developed by Jago (2011) show that the purchase of automatic oestrous cycle detectors can be unprofitable if the detection performance of the equipment is inferior to that of the farmer, while saving two hours of worktime per day. Indeed, economic considerations aside, time-saving is often cited as one of the arguments for equipping farms given the increase in herd sizes or the reduction in labour force (Eastwood *et al.*, 2012 ; Jago *et al.*, 2013). However, while a reduction in workload is promoted as one of the arguments for adopting precision technologies on livestock farms, still little is known about the impact on the farmer's work and profession. Farmers resort to precision livestock farming because they aspire to less arduous and repetitive work and more free time. Some are notably

attracted by these new technologies and find therein a certain pride in relation to their close contacts and neighbours (Billon and Pomiès, 2006). Such technologies are often cited as an advantage, but the impact on duration and other dimensions of work such as changes in tasks, the new skills to be acquired, or the effect on the human-animal relationship, remain little known. The objective of this article is to present the impact which these new technologies have on the work and profession of livestock farmers, based on a review of the scientific and professional literature.

Definition and general principles of precision livestock farming

Different definitions of precision livestock farming are given in the literature. Bewley (2010) defines precision dairy farming as the use of technologies which enable the measurement of physiological, behavioural, and production indicators on animals with the aim of improving herd management strategies and farm performances. These performances can be economic, social or environmental (Eastwood *et al.*, 2004). According to Berckmans (2012), it is a question of farm management by means of surveillance and recording of automated, real time measurements of animal production, breeding, health and well-being. A relatively consensual definition applying to the range of animal sectors can be proposed: precision livestock farming is defined by the coordinated use of sensors to measure behavioural, physiological or production parameters on animals, or the characteristics of the farm environment (temperature, hygrometry, ventilation), and Information & Communication Technologies (ICT) for exchanging, storing, transforming and restoring this information to the farmer to help decision-making in conjunction with his own observations. Robots which relieve farmers of certain daily tasks (milking, feeding, building atmosphere adjustment) are sometimes coupled to data transfer technologies, and are generally started, adjusted or driven by the sensors which they contain.

According to Aerts (2003), Berckmans (2004) and Whates (2007), several conditions need to be assembled to enable continuous monitoring and management of the farm. First, animal-related variables must be measured and analysed continuously at an appropriate level and frequency with the help of sensors. These variables include the live weight, ingested food quantity, feeding behaviour (ingestion, mastication, rumination, frequency of mouthfuls), and social behaviour. Physiological parameters (body temperature and pH, milk composition and physical-chemical characteristics) can also be measured. As a second step, a reliable predictive model of animals' reactions to environmental conditions (diet, climate, farming practice) must be developed. A comparison between what is expected (as calculated by this mathematical model) and the data provided by the sensors would identify animals which have a problem and require particular attention from the farmer. Finally, the predictive model and measurements taken are integrated into an algorithm so as to automate farm monitoring and management, and even real time environmental control via alerts sent to farmers (by smartphone, computer), or to robots, for example for fodder distribution or animal sorting. Rutten *et al.* (2013) described these principles and added an information integration stage taking into account other data (economic, strategic, historical) as well as a decision-making step by the farmer. The exactitude expected in "precision livestock farming" therefore depends on the quality and reliability of the monitoring of each herd or flock member (cattle, sheep) or batch of animals (pigs, poultry), in terms of their physiological and behavioural reactions over time to farm conditions (Meuret *et al.*, 2013).

Precision livestock farming: how to build another relationship with space and time

Saving time

One of the reasons why farmers opt for precision livestock farming, at times even before economic considerations, is the desire to improve their productivity and quality of life (de Koning, 2010). Even if this aspect is relatively little documented in the bibliography, some references are appearing in the fields of milking robots, feedstock distribution and, to a far lesser extent, radio frequency identification (RFID). Most authors agree in highlighting the time saved by new technologies. In a study carried out in the Netherlands, Rodenburg (2012) reported a 29% time saving in the case of farms equipped with robots. Billon and Pomiès (2006) consider the time saving to be lower, of the order of 20%, for a herd of 60 cows. Fleuret and Marlet (2014) report a saving of 3.8 minutes per cow per day (box 2). Time savings are also significant in terms of feed distribution. According to Rodenburg (2007), if 7.7 minutes

per day per calf are needed for individual and manual feeding, only 3.8 minutes are required when milk distribution is automated and the calves are managed in a group. Time saving can be up to 38 minutes per day and 230 hours per year for a group of 10 calves fed on milk. In farms in Quebec (Pellerin, 2000), the aid an automatic feed dispenser, compared to manual distribution, would allow a saving of 300 to 800 hours per year. Finally, on sheep farms (Ait-Saidi *et al.*, 2014) data collection (for example, animal weight) via automated information gathering based on electronic identification, gives an advantage in terms of time saving and process accuracy compared to manual data collection requiring information to be recorded in a notebook and transcribed on a computer.

The time saved can be reinvested in production-related tasks, farm management, or personal activities. 28% of farmers using robots for milking confirm that they take more weekends (Fleuret and Marlet, 2014). 83.7% of farmers acknowledge that the time saved makes them more available for their families and 68.9% have noticed a better quality of life (Billon and Pomiès, 2006).

At first sight it appears logical that the assistance given by precision livestock farming contributes to a reduction in daily working time especially when associated with robots which replace the farmer in certain tasks (milking, feedstock distribution, animal surveillance, building atmosphere adjustment...). However, new tasks emerge as a result of the introduction of robots and the digitalisation of farms: maintenance of the new tools and analysis of the data generated by these machines. Such operations can, in certain cases, reduce the observed time savings.

Changing the nature of the work

The introduction of precision tools brings changes to the farmers' work content regardless of the sector (milk, pork, poultry) (Désire and Hostiou, 2015). Certain tasks emerge related to data consultation, tool management (identification tags, collars, installation of scales) or the maintenance and repair of equipment. Part of the physical work is replaced by management tasks comprised essentially of checking, often several times a day, the information generated by pre-set alerts. The latter indicate equipment malfunction or problematic animals requiring farmer intervention or an increase in surveillance. On farms equipped with one or more milking robots (Fleuret and Marlet, 2014), 40 minutes a day on average are spent in front of the computer (box 2). Farmers handle increasingly large herds with more precise management of individual animals (exception management) rather than batches of animals (Rodenburg, 2007). This operating mode leads to targeted actions and efficiency. Certain daily or regular work tasks can disappear : milking, animal feeding, or the weighing of poultry.

The measured parameters provided by new technologies help increase the objectivity of farmers' observations. Equally signs can be detected earlier than by humans (oestrous cycles, health issues...). However, such new technologies are unable to substitute completely for the farmer. The data provided by the tools and that derived from their own observations have led some farmers to different combination strategies (Table 1) (Désire and Hostiou, 2015). The level of confidence accorded to equipment could depend on experience as G1 and G2 group farmers have been in place longer, though it seems to depend more on the type of tool: the simpler the tools, the greater the confidence farmers show in them.

Table 1: Different verification and confidence levels according to type of device

4 farmers make / no longer make verifications	They trust the data	4 poultry farmers	G1
14 farmers make verifications	5 trust the data but still run checks	3 cattle farmers (2 oestous cycle detectors, 1 robot), 2 pig farmers (selffeeders)	G2
	5 trust certain data and verify all or part of it	2 cattle farmers (robot), 3 pig farmers (concentrate feeder)	G3
	4 do not really trust the data and make verifications	1 cattle farmer (robot), 3 poultry farmers	G4

Finally, some farmers establish new daily tasks (Billon and Pomiès, 2006; Rodenburg, 2012) such as "pushing" toward the robot cows which have a too prolonged gap between milking. It would appear that "managed" movements (a cow must go to the robot to pass from the sleeping to the feeding area) limit the number of cows to "push", while "free" movements increase it. According to certain specialists, given that the gain in milk production through an increase in milking frequency is low, such practices are not always desirable.

Box 2: Time savings with the milking robot

(Source : Etude Chambres d'agricultures de Bretagne - Marion Fleuret - de la salle de traite au robot, quels impacts pour l'exploitation laitière? 8 pages – 2014)

Example of a routine day for a farm with 47 dairy cows managed by the farm manager

Time of the day	Task	Time spent
07.20-08.00	Robot software	5'
	Pushing late cows	5'
	Cleaning the robot area	10'
	Stall cleaning and excrement clearing	20'
08.00-09.00	Preparing food	20'
	Taking care of the heifers	30'
	Removing excrement	10'
09.30-09.50	Robot software	10'
	Stall cleaning	10'
13.00-13.15	Robot software	5'
	Excrement clearing	10'
17.00-18.00	Robot software	5'
	Pushing late cows	5'
	Cleaning the robot area	10'
	Stall cleaning and excrement clearing	10'
	Interventions on the cows	Variable

In green: the new tasks generated by the installation of the robot

The 3.8 minutes saved per cow per day relate to milking time and observation of the animals. This result has been calculated by comparing a routine day (without particular problems) with the old milking system and with the robot. This represents a 3 hour per day saving for a herd of 50 dairy cows. The time saved depends on the pre-robot equipment. In fact the 43 farmers investigated spent on average more than 5 hours per day milking with under-dimensioned and ageing equipment. In the case of a milking barn calibrated to milk in 1.0-1.5 hours, the time savings with the robot are lower.

Creating new time-space relations

In addition to the time savings, farmers particularly appreciate (Tech PORC, 2014) the additional flexibility for organising their work since they are able to personalise the schedule of tasks throughout the day, and adapt it to their family life. Out of 43 Breton farmers equipped with a milking robot, 15 believe they have gained in flexibility but not in working time (Fleuret and Marlet, 2014). Nevertheless the introduction of new technologies on a farm sometimes necessitates reorganisation of the work since the points of reference evolve. "Nobody knew who was doing what any more" said a Breton farmer having just installed a milking robot (Fleuret and Marlet, 2014). With milking no longer punctuating each day, the setting of times and tasks becomes more difficult and more dependent on farmers' choice.

Digital technologies can transform the relationship with space. For example, this is the case in "precision grazing" (Laca 2009) where a satellite replaces the herdsman in controlling the group via geo-localisation of individual animals. As the farmer's continuous presence is thus no longer required, he can partially free himself from caretaking the herd or flock. Such tools however are very recent, and lead to questions about their effectiveness in the field, and possible errors arising from "fully computerised" control without the intervention of ground personnel.

Farmers' physical and mental health: is precision livestock farming a plus?

Physical health

Robots, occasionally coupled with sensors, replace the farmer in physically demanding tasks. In dairy farming the most illustrative case is the milking robot, where the physical work of milking is replaced by animal surveillance tasks and management of the information provided by the computer (de Koning, 2010). The use of sensors on pig farms to measure feedstock levels removes the need for farmers to climb onto silos to take physical readings (TechPorc, 2014). A communication network allowing the robots to be piloted by remote control (feed, sewage treatment plant, ventilation) reduces trips between dispersed sites. However, good communication between workers is essential for their security since an operation made on a dangerous robot (for example, a grinder) must be brought to the attention of others so that the machine is not started by remote control (TechPorc, 2014).

Mental workload

Precision technologies have a positive effect on the reduction in farmers' mental workload as they help anticipate physiological or sanitary events which are sometimes hardly visible to the human eye (temperature change, heart rate, etc.). For example, dairy farmers are under less pressure to detect animals that are on heat, or for taking the decision to inseminate, due to the use of automated oestrous cycle detection equipment (Courties, 2014).

However, the mental workload associated with the use of precision technologies can be increased. Indeed a considerable amount of information is generated regularly by certain sensors, making it difficult to select the key information for decision making. The management of alarm warnings is highlighted by farmers as being a source of stress, making it essential to establish priorities in order to decide at which moment to intervene. A study (Hogeveen *et al.*, 2013) has thus shown that dairy farmers would react to only 3% of mastitis warnings generated by milking robots. The management of alerts received by farmers on their phones has been identified as a further stress source. Yet, a study conducted in France showed that 12 farmers out of 18 receive alerts on their phones, but only of a technical nature concerning equipment and not their animals (for example, breakdown of a milking robot) (Désire and Hostiou, 2015). Only 4 of the farmers experienced stress as a result of these alerts. Although all the farmers felt stress during the time taken to familiarise themselves with the tool, they learned how to sort the alerts and decide which were the most important. The presence of technological devices on a farm can complicate the replacement of the farmer (for holiday or illness) as it is not always straightforward to find workers to manage these tools. While these new technologies provide help for a diagnosis, they are unable to replace farmers' know-how and experience in identifying animals needing attention (Bewley, 2010).

What relationships between human, animal and machine?

New technology on farms changes the ways of working with the animals, either directly by modifying interaction situations (visual, sound and tactile) and monitoring practices, or indirectly by providing the farmer with new information on the animals. This is likely to affect farmers' daily experience with, and perception of, their animals, the animals' behaviour, and lastly the human-animal relationship, as well as their performances (Hemsworth 2003).

On the one hand, certain technologies run the risk of damaging human-animal relationships. Automation can thus reduce the number and length of farmer-animal interactions (transition from twice-daily manual to robot milking, automatic straw-mulching). The physical distance between farmers and animals is likely to increase. The opportunities for directly observing the animals, their behaviour, their health and well-being, could be reduced. However, it is such occasions which help familiarisation with the animals and allow farmer and animals to know one another better. Fear among animals when faced by man could then more easily set in, especially in the case of animals with a nervous disposition (Boivin *et al.*, 2012), which would tend to reduce their well-being. The proportion of positive to negative interactions could equally find itself modified. Regular positive interactions such as at feeding time, and the closeness these produce, diminish with the effect that relationships are essentially made via adverse interactions such as vaccinations, castration, trimming, where the farmer is directly in contact with the animals (Cornou, 2009). This risk is however less prevalent for certain species, or in certain livestock systems. For example in sow breeding, displacements of animals from barn to barn during their life cycle, or for insemination, puts the farmer and his animals regularly in contact, even if feeding is automated. On poultry farms, the daily collection of dead birds is an occasion for coming in contact with the batch.

On the other hand, new technology lightens certain constraints, lowering the hardship and obligation for the farmer and reducing manhandling of the animals, for example when the farmer "pushes" his cows into the milking parlour. New situations favouring positive interactions and human-animal contact can occur such as when farmers with a milking robot need to move frequently and calmly among the herd to check the equipment, or to bring forward cows which have not come to be milked spontaneously. Some farmers use the time saved by precision livestock farming to observe and be present with their animals. These new practices can have a beneficial effect on the animals and be a source of satisfaction for farmers themselves (Fleuret and Marlet, 2014).

Data supplied by the new technology contributes further to change the view the farmer has of his animals, and provides an individualised, rather than herd-scale, vision of the animals. The data also takes up time at the expense of other tasks, and having to sort through the mass of data available can prove to be complicated for the farmer. This transformation in the nature of the job carries with it the acquisition of new skills but equally the loss of "traditional" skills, and for some farmers can result in demotivation for their profession and relations with animals (Cornou, 2009).

The change for the animals is equally substantial. Experience shows that animals adapt relatively quickly. In the case of milking robots, authors such as Driessen (2015) describe this technology as giving relative freedom to the animal, allowing it to express its own subjectivity in its choices and even to collaborate directly in the work (Porcher and Schmitt, 2010) in what is nevertheless a constrained system where movement circuits are imposed since the animal has to go first via the robot if it wants to rest or feed.

In the end, animals as well as farmers confronted with the new technology find themselves actively involved, and acquire skills and new routines. The technology does not necessarily create more distance between human and animal, but new relationships are formed (Lagneaux and Servais, 2014). To help construct these, training could be provided to farmers to reduce negative interactions, for example by encouraging positive daily contacts (visits, movements amongst the animals, voice contacts...), at appropriate periods (young age, weaning...), or by encouraging the selection of animals for breeding which have good relationships with man.

A need to acquire new skills?

A work reorganised with new skills

As seen previously, the introduction of precision livestock farming frequently reduces the time dedicated to certain tasks, even eliminating them, and at the same time creates new activities. The farmer is led to manage the collected data - organising data bases, characterising, sorting and selecting the pertinent information from the mass available to analyse and cross check it in order to set sensible alert and intervention thresholds. All or part of this data management work is frequently delegated to consultancy firms or manufacturers which allows the collected information to be pooled and the analysis refined. However, this leads to the issue of decision-making autonomy in the case of farmers who may show total confidence in the responses given by the algorithms, and who no longer have a critical view over the data. Furthermore the maintenance of these diverse technological devices (robots, sensors, computers, connectors) requires skills which until recently did not feature in a livestock farmer's job.

The creation of places and methods of learning

As a result of the new tasks which have to be done, further skills need to be acquired by farmers and other categories of farm workers (partners, associates, salaried staff). Should farmers look for their "technology partner" within a limited geographical area so that they can be replaced? Training of specialists in the replacement services or groupings of employers will also be necessary. This will result in a little less suppleness in the human resource management of such structures, but will be essential for their flexibility and relevance in order to be continually consulted. Finally, there is the question of training unpaid workers. In agriculture, and notably in herbivore farming, there is a long tradition of work carried out by volunteers. In the case of new technology being essential for the running of farms, numerous untrained volunteers will be excluded from collective workforce. Will this technological revolution thus create a sociological rupture in the composition of collective workforce?

The training requirements of other farm stakeholders (advisors, vets...) also need attention to ensure that farmers are properly accompanied in the running of their businesses. Given the various audiences there will be a need to adapt training to take account of individuals' differing learning capacities. Given the complexity and possibilities provided by the actual technology in place, the length of apprenticeship will vary. As with all training, individual factors must be taken into account such as the "learners'" professional backgrounds, their taste for new technology and available time, the capacity and methods of apprenticeship developed, etc. Deployment of the new technology to an audience at ease with such innovations can also be done by an innovative and Internet-connected form of apprenticeship (online training of the Mooc (massive open online course) type, web conferences, remote support via new content-exchange platforms (videos, photos taken and transferred by smartphone).

The extent to which "technical support" for a given technology is available locally will also affect the level of expertise that farmers can reach. In areas where a technological application is widely used, support services are likely to be more numerous, competent and reactive than in places where such usage is less prevalent. In the latter case the level of independence which farmers have in relation to the given technology will be crucial for validating its use in the field.

The instantaneous nature of data exchange on the farm demands a higher degree of reactivity on the part of support bodies. There is also a need to develop new organisations in farmers' partner structures to respond to this need (new services, data exchange compatibility to facilitate analysis). Given that this thematic is promising and relatively recent in livestock farming, it can be expected to help renew the work themes of innovation groups (surveys by advisory structures to help farmers with these themes?). It has already allowed renewal of events such as technical theme days, and open days bringing together agricultural organisations and manufacturers.

Discussion

Impact on aspects of work which need to be made more tangible

Although precision livestock farming is presented in numerous studies as a lever for reducing farmers' working time, these time savings remain somewhat theoretical, especially as they are only achievable if the farmer spends an equal or even greater time putting the technologies in place. There are few studies and little feedback on farmers' experiences with the new technologies, or on the changes these have brought to farmers' views on their profession and the relationship with their animals. Indeed much of the technology is still very new (for example, equipment for detecting calving or going on heat, which has only been commercialised since the 2000s). It is even more difficult to estimate time savings on tasks which have not necessarily been benchmarked, or which are not always clearly quantified (surveillance during birth-giving or for oestrous detection). Indeed some of these tasks can be done while animals are engaged in other activities (for example, during milking or feeding, surveillance for going on heat). Additionally, time spent on new technology will probably differ between start up and the ensuing years as farmers learn to master the innovations (Eastwood *et al.*, 2012). De Koning (2010) states that time savings from using milking robots as opposed to traditional milking practice represent 20 to 30% of the total time devoted to milking, depending on the farm. Yet lack of time, particularly for their apprenticeship, is highlighted by farmers as the reason for not adopting precision technologies (Fountas *et al.*, 2004 quoted par Lawson *et al.*, 2011). This factor is cited irrespective of the size of the farm (Reichardt and Jurgens 2009).

The adoption of technology on a farm leads to a change in the content and nature of tasks, and has, therefore, an impact on different aspects of the work whether organisational (who does what and when), or sociological (relationship to work, to animals, to the profession), etc. Yet if so few references exist for characterising working time, there are even fewer for making other aspects of the work (physical or psychological hardship, well-being at work, human-animal relationship).

The cost/benefit relationship of introducing precision livestock farming

The issue of cost/benefit relationship is one of the principal reasons for whether or not farmers adopt new technologies (Bewley and Russell 2010). However, calculation of this ratio is not easy since, beyond the technical and economic facts to consider, work changes are rarely taken into account. Indeed it is extremely difficult to quantify the economic value of the well-being brought to the farmer by new technologies (Otte and Chilonda 2000). For example, it is hard to measure the satisfaction derived from having healthy animals, or working in safe conditions, or from improving the farm's environmental impact (Huirne *et al.*, 2003). It is therefore the balance between economic performance and improvement of life quality which has to be evaluated to decide whether or not an investment is appropriate. Other factors need considering since the choice of technologies to be adopted can depend on the farm workforce's expectations, or the financial capacity and life cycle of the operation (for example, the farm's acquisition, or not, in the short term).

A farmer's role which remains essential for decision-making

The objective data measured by sensors enables anticipation of, and even reassurance for, the farmer's decision when this is associated with *in situ* observation. To think that a farm can run itself alone thanks to the technologies is too simplistic. These help decision making but the farmer's know-how remains essential in order to manage and react. It is therefore necessary to be attentive that these skills do not disappear (Jago *et al.*, 2012). The more that farmers master the different aspects of their job, the greater the benefits will be (responsiveness, independence, relevance...). This expertise can apply at the collective level, rather than to an individual. Currently these technologies are installed in farms which have operated without. The farmers therefore analyse the contributions made by this new information through the lens of their prior knowledge and skills. What then will be the perspective of farmers and staff who start directly in such operations?

Conclusion

The development of precision technologies on livestock farms modifies the content and nature of the tasks carried out by farmers and other workers, and has consequences for a range of work aspects, whether these be organisational (who does what and when), or sociological (relationship to work, to animals, to the profession). Less physical work and more office-based activity has given a new meaning to the livestock farmer profession. With the deployment of such technologies in the agricultural sector, as in many others, some leaders hope for an improvement in image to render their profession more attractive. Although the new technologies provide help with identifying problems and their causes, they will not be able to replace completely the farmer's know-how and experience in detecting those animals needing attention.

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