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Precision livestock farming: potential use in water buffalo (*Bubalus bubalis*) operations

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Thanks to advanced technology, physiological, behavioral and production indicators of animals can be reliably measured. Advanced technology also allows facility owners to focus on the health and performance of each animal by diagnosing diseases and problems that cannot be directly detected by the farm owner or technical staff using sensors, cameras, activity meters, technological tools and equipment. Precision livestock farming (PLF) aims at managing animals individually with real-time continuous monitoring of their health, welfare and production/reproduction as well as any environmental factors that may affect them. PLF technologies provide highly detailed data to users to help them measure and manage the performance of individual animals or herds of animals based on various criteria. In addition to providing a very large database for users, PLF technologies provide an instant assessment of the data and use figures and charts to clearly present the results. PLF technologies are mainly used in dairy operations rather than in water buffalo farming; however, this type of production accounts for approximately 200 million animals worldwide. Thus, the aim of this study was to assess the potential use of PLF technologies in operations conducted with these animals. Also, this study aims to provide insight into the sector and to researchers by addressing the opportunities for and potentials of using PLF technologies in water buffalo farming.

KEYWORDS: animal welfare / precision livestock farming / real-time data / water buffalo

Precision farming/precision agriculture technologies have progressed rapidly in recent years, especially in developed countries, with advances in information

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technology. In agriculture, state-of-the-art technologies are used in both livestock operations and vegetable production. Several tools and new equipment have been developed for sustainable agriculture. Precision livestock farming (PLF) is a system that is used to manage livestock based on process engineering principles and technologies [Morgan-Davies *et al*. 2018].

The objectives of PLF are to continuously monitor and manage individual animals or herds of animals using real-time data on animal health, welfare, production/reproduction as well as any environmental factors that affect them. Animal behavior and ambient conditions are continuously monitored and recorded using cameras and real-time video analysis systems, microphones and real-time audio analysis systems or sensors positioned around or above the animals [Berckmans 2017]. The primary objective of using this technology is to ensure that the health and welfare of animals is conducive to reliable reproductive performance and to reduce any environmental impacts on animal yield and performance. PLF technologies provide those involved in animal production with a tool facilitating continuous automatic monitoring and control of environmental, physiological and behavioral variables to help ensure animal health, performance and welfare. Gebresenbet *et al*. [2003] reported that information systems could be applied to monitor animal welfare during animal transport. Umstatter *et al*. [2009] reported that nonelectrical shock systems (voice alerts) instead of electric fences should be used for animals under extensive management conditions.

The benefits of using PLF technologies in livestock operations include increased yields, reduced labor and maintenance costs, improved product quality, minimized negative environmental effects, improved animal health and welfare, and improved risk analysis and management [Bewley 2010].

New technologies are being made available to the livestock sector. These include electronic animal recognition and monitoring systems, automated milk assessment systems (milk quantity, milking time, milk flow rate, electrical conductivity of milk, and milk temperature), mastitis-detection devices, automatic animal-weighing systems, activity meters, devices to measure ambient temperature and relative humidity, devices to monitor and measure intensive feed consumption, manger systems that measure roughage consumption, water holder systems that measure water consumption, electronic scale roughage-intense feed mixers and distributors, image analysis systems, audio analysis systems, ultrasonographic imaging devices (pregnancy diagnosis), herd management software, and Internet links to various organizations and associations of interest (e.g. breeders' associations, milk yield and quality control organizations, and genetic evaluation centers) [Uzmay *et al*. 2010]. Information technologies play a large role in these automated systems, while genetic studies improve productivity [Abacı 2015]; however, the expected benefits from the application of these systems are only possible if the operators have sufficient knowledge on their functions and can efficiently use these systems [Göncü and Gökce 2017]. Previous studies have indicated that cooperation between different branches of science is required to develop PLF systems [Carpentier *et al*. 2019, Norton *et al*. 2019].

To achieve adequate monitoring and management levels in a PLF system, the following three conditions must be met [Berckmans 2006]: (1) the parameters for the behavioral or physiological condition of an animal must be continuously measured using an accurate and cost-effective sensor technology; (2) there must be a reliable prediction (expectation) of how these parameters may change or how the animal will react at any time and (3) the predictions and online measurements must be integrated into an analytical algorithm for automatic monitoring and/or management.

PLF technologies enable the user to collect data on such issues as individual nutrition, regular milk records (yields and components), pedometer and pressure plate data, electrical conductivity of milk, automatic rutting detection, body weight, temperature, resting behavior, ruminal pH, heart rate, nutritional behavior, blood tests, respiratory rate, rumination time and scoring, as well movement ability using image analysis at an individual level. Using these data, the system directly focuses on animal health and performance and thus minimizes care and maintenance costs [Coffey and Bewley 2014, Yıldız and Özgüven 2018].

PLF comprises the following four basic system principles with regard to the species and purpose of its production: (1) use of scientific data from the system; (2) measuring, monitoring, and managing the system; (3) proper use of technology; and (4) identifying and targeting variation sensitivity in the system [Wishart 2019].

Scientific data

To appropriately apply the PLF system the relevant animal species and their biological and morphological characteristics must be accurately determined. Although some applications are common for all animal species, some may vary based on species characteristics [Wathes *et al*. 2008, Mertens *et al*. 2011, Guarino *et al*. 2017]. An accurate livestock management system must rely on accurate scientific data. The data collected through these systems pass through various stages, such as raw data; processed data; data analysis and evaluation; and, finally, data use for specific purposes [Marchesi 2013].

Measuring, monitoring, and managing

A PLF system uses basic measurements such as ambient temperature, relative humidity, density and weight. Necessary measures are taken and interventions made according to accurate measurements using sensors and cameras to maintain the desired features within specified parameters [Banhazi and Black 2009, Van Hertem *et al*. 2016, Fournel *et al*. 2017].

Technology

Using technology in agriculture and livestock operations decreases the workforce and ensures that accurate and easy measures for the health and welfare of animals are automatically taken. Sensors and measuring devices may be used to collect data, which are analyzed using software developed for specific purposes, with reports produced accordingly. Technological advancements allow more detailed and accurate measurements and automations [Voulodimos *et al*. 2010, Defra 2013], while also allowing users to measure and evaluate some previously unattainable factors, such as thermal biometric changes. The development of individual identification and computer-assisted technologies has made it easier to collect and process large amounts of data within agricultural systems without the need for extensive workforce or intensive workload [McManus *et al*. 2016].

Variation in sensitivity

One of the main benefits of the PLF systems is that they can identify variations of an individual animal's characteristics within the herd and allow operators to take specific measures on that animal to ensure its health and welfare. PLF systems may be used to identify the characteristics of individual animals or herds and facilitate herd management by providing accurate measurements and helping identify monitoring and management protocols according to individual needs. Dealing with animals individually and not within a herd by controlling housing and environmental conditions will increase that animal's welfare and yield [Coates and Penning 2000, Wathes *et al*. 2008, Bramley 2009, Montossi *et al*. 2013, Black 2014].

Precision livestock farming applications

Healthy animals and products may be ensured with the aid of PLF technologies through checkups during each stage of production. Such technologies also increase and sustain efficiency and quality, easily maintain records of various parameters orderly and instantly, generate animal breeding models, and allow timely interventions on animal health and welfare.

To consider the ideal technology that will be used in an PLF farming operation, the following characteristics must be identified:

(1) the system must explain the underlying biological process;
(2) the system must be able to convert collected data into meaningful actions;
(3) the system must be cost-effective;
(4) the system must be flexible, strong and reliable;
(5) the data must be easily accessible by the user;
(6) the user must be included as both a developer of the technology throughout all stages and a tester of the system;
(7) the system must be commercially demonstrated; and
(8) the system must have a uninterrupted development and feedback cycle.

With the help of radiofrequency identification devices (RFID), which are used extensively in the dairy industry, individual animals are automatically recognized and quickly distinguished in environments comprising many animals. With the help of the RFID labels attached to the animals (e.g. on their necks or feet, subcutaneously, or in the rumen), the receiver identifies the animal and transfers the data to a specific program. Thus, it is possible to monitor animal behaviors and operational efficiency and to direct the animals toward automatic doors [Özcanhan 2006]. The basic principle of the RFID technology is provided in Figure 1.

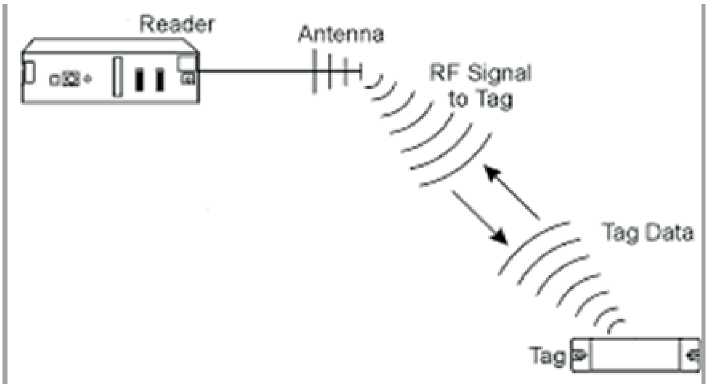

Fig. 1. Basic Principle of Radiofrequency Identification Systems. Source: AIM [2000] and Uzmay *et al*. [2010].

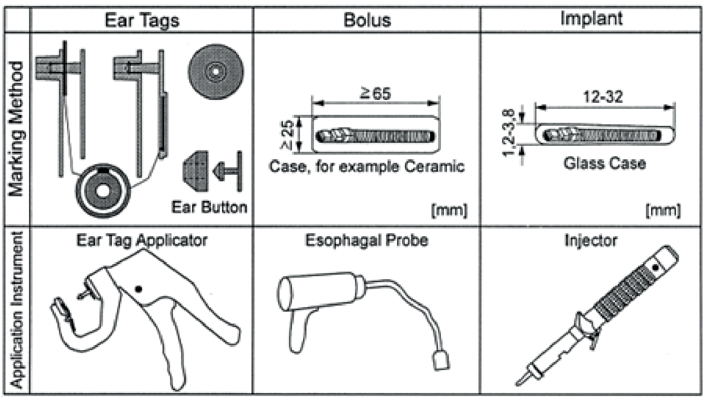

Fig. 2. Electronic identification tags and equipment. Source: Artmann [1999].

Some new technologies have recently been introduced in information technology to ensure protection of animal health and welfare. These new technologies provide more effective animal monitoring and traceability. Among these, the most efficient comprise RFID and the electronic rumen bolus [Caja *et al*. 1999, 2004, Conill *et al*. 2000, McAllister *et al*. 2000, Erdem 2007]. Operations are beginning to transition from traditional animal identification systems to biometric and electronic identification systems, with several businesses recently making this transition available [Shukla *et al*. 2014, Carné *et al*. 2009, Štoković *et al*. 2009, Erdem 2007, Evans *et al*. 2005, Caja *et al*. 1999, Jansen and Eradus 1999, Çelikyürek and Karakuş 2017]. Various electronic identification tags and equipment are presented in Figure 2.

Major advanced technologies included in PLF applications include: [Kaya *et al*. 1994, Frost *et al*. 1997, Doluschitz 2003, Uzmay *et al*. 2010]:

(1) electronic animal recognition systems;

(2) automatic milk measurement systems integrated into milking systems (milk quantity, milking time, milk flow rate, electrical conductivity of milk, milk temperature);

(3) automatic animal weighing systems;

(4) activity meters;

(5) automatic intensive feed units (monitoring and measurement of intense feed consumption);

(6) manger systems that measure roughage consumption;

(7) water holder systems that measure water consumption;

(8) electronic scale roughage-intense feed mixers and distributors;

(9) image analysis systems;

(10) audio analysis systems;

(11) ultrasonographic imaging devices (early pregnancy diagnosis in water buffalo);

(12) herd management software and Internet links to various helpful organizations (e.g. breeders' associations, milk yield and quality control organization, genetic evaluation centers).

Breeders and consumers have expectations and demands for livestock enterprises, such as food safety, cost-effective and sustainable production and marketing, environmental protection, occupational health, as well as animal health and welfare [Hartung *et al*. 2017]. PLF technologies ensure that breeders are able to detect and control the health and welfare of animals at any time with the aid of continuous direct monitoring. From this, it is evident that there will be an increase in product efficiency and quality, because the animals will be healthy and well taken care of in the long term [Berckmans 2014]. Relevant analyses in livestock farming can be conducted more effectively and accurately using the latest technology and, at the same time, production stages and progress will be under control with the help of the system's traceability features [Mancino 2016]. Furthermore, more decisive and accurate steps will be taken in livestock businesses that will play active roles in national breeding programs and strategies, while also providing access to necessary reliable data in international markets [Werkheiser 2018]. Individual animal recognition systems were created and appropriate software developed for PLF applications from specific needs in the industry. The targets of PLF applications in animal breeding are to keep the production process under continuous control using automated animal recognition, detection, measuring and computing systems and technologies to optimize profitability, health, product quality and safety, and environmental protections [Tomaszewski 1993]. With the help of PLF technologies, breeders can take immediate action to resolve problems in one animal or within a herd instead of merely identifying those problems. As PLF technologies become widespread, the cost will decrease and this technology will be made available to and become affordable for small family farms in developing countries [Berckmans and Guarino 2017]. One of the PLF targets is to make livestock activities not only more economical, but also socially and environmentally sustainable [Vranken and Berckmans 2017, Fournel *et al*. 2017, Tullo *et al*. 2019]. All the equipment that collects data on animals through computerized herd management systems (i.e. electronic animal recognition, mobility measurement, milk meters, animal weighing, intensive feed systems) transfer that data into specific software; these data are then recorded in the animal's individual record [Tömek 2007]. Herd management software also stores both the measured data and data entered by the user for each animal in a database. Some of the collected data include ear number, information from herd books, insemination, calving and drying, results of pregnancy and health controls, and information on diagnosed diseases and treatments. The parameters of the data can be determined and recorded by the breeder and exchanged through the Internet network of organizations and associations [Bergfeld 2006, Tömek 2007].

Approximately 200 million water buffalo are bred throughout the world, with 97% of them in Asia, 2.04% in Africa, and ~1% in South America, Australia and Europe [FAOSTAT, 2017]; however, studies are limited on the use of PLF technologies for the health and welfare of these animals. De Rosa *et al*. [2009] conducted a study on the development of a farm-level water buffalo welfare monitoring program and discussed indicators used to monitor welfare of these animals based on those recommended for dairy cattle. Researchers have investigated the effects of stress on reproductive performance and welfare of water buffalo and reported that changes in field shortage and some behavioral and physiological responses cause stress in weaned females. Some welfare indicators used for dairy cattle can easily be applied to water buffalo without any modifications (e.g. injuries and avoidance distance); however, some criteria such as body condition score, contamination and shelter must be adapted specifically to

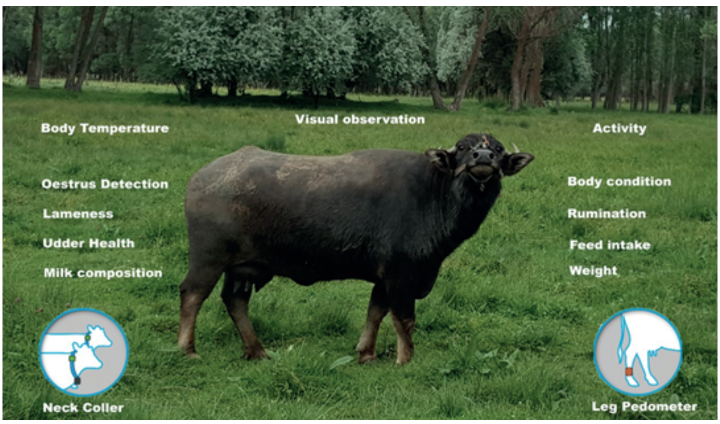

Fig. 3. Buffalo monitoring points.

water buffalo. The criteria that are suitable for PLF technology applications must then be determined. The probable monitoring points that can be used for water buffalo are presented in Figure 3.

Water buffalo breeding is usually a small business [Tadavi *et al*. 2017]. Siddiky and Faruque [2017] recommended that breeding studies be conducted using imported sperm and high-yielding breeds, such as Murrah, Nili-Ravi or the Mediterranean Race, to determine the effects of various factors on milk yield. Roustemis *et al*. [2016] examined water buffalo farms in Greece and reported that breeding farms in that country consist of large and moderate-size farms, with large farms focusing only on meat production and moderate-size farms involved both in meat and milk production. Those researchers indicated that breeders deliberately do not prefer extremely large operations because of the construction and feeding costs [Roustemis *et al*. 2016]. The trend in Italy for higher meat and milk yields using genetics and technology has resulted in an increase in milk yields in water buffalo bred under intense conditions; however, a simultaneous deterioration in animal welfare has been observed [Borghese 2013, Napolitano *et al*. 2017]. Although water buffalo breeders have only three to four animals on their farms that are used mainly for their meat for the family in rural Turkey, modern farms have also been established near major cities and keep approximately 100 animals based on the consumer demand for water buffalo dairy products [Soysal 2013, Ermetin 2017].

Conclusion

Water buffalo are bred mainly under extensive conditions using traditional methods; however, the production system must be changed and advanced technology needs to be used in breeding techniques because of the growing demand for buffalo meat and dairy products. Water buffalo breeding is not an alternative to cattle breeding, rather it must be adapted and developed given its unique qualities and characteristics. In turn, the developing technology and livestock opportunities throughout the world must also be adapted to water buffalo breeding. Studies on the protection and development of water buffalo breeding should focus not merely on improving the level of breeding and efficiency, but also on complying with intensive conditions and breeding using technological facilities. In this context, it is essential that the level of production and product quality be increased in buffalo production facilities with the use and dissemination of PLF technologies so that breeders can increase their revenues and consumers can be ensured healthier and better quality products.

Many genetic, feeding and breeding studies have been conducted on water buffalo; however, studies on water buffalo breeding and compliance with PLF technologies under intensive conditions are relatively limited. PLF technologies must be used more to identify reproductive problems (e.g. hidden rutting, non-fertilization), heat stress and milking issues. When adopting PLF technologies, it is natural to go through a certain transition period in breeding. The most important issues in this respect include recognizing the temperament of buffalo; adapting PLF technologies, especially those used in dairy cattle, to water buffalo breeding; and training breeders.

The software used with PLF systems for buffalo breeding may not be complex and needs to comply with very specific standards. User-friendly computer software and systems have to be designed in a format that business owners and technical staff can easily understand, predict risks over the short term and increase productivity and profitability in livestock over the long term.

PLF technologies are constantly evolving, while new parameters and animal monitoring methods are being created with these evolving improvements. Although some systems collect animal yield records, plan breeding and monitor many other events with respect to animal welfare, water buffalo breeders do not have adequate information which technologies they should use and how they should evaluate the results. It is essential that breeders be trained in this regard and adopt technological innovations. Further research is recommended in this field, involving various stakeholders and leading to support policies for intensive water buffalo breeding.

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