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An Evaluation of Sensor Technologies Suitable for Domestic Livestock Business Production and Health Management

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Abstract: The globe is actively pursuing the digitalization of social, economic, and political activities. With the advancement of technology in several fields, including agriculture, livestock production is also an area that necessitates the utilization of developing technologies. However, knowledge and competence are quite limited, especially in underdeveloped nations. Therefore, it is crucial to address this knowledge deficit by gathering information and disseminating it to a wide audience to facilitate continued study in the field. With the emergence of sensors designed for various domains, it is crucial to explore the potential utilization of these technologies in evaluating the status of rangelands and enhancing animal output. Technologies play a crucial role in implementing precision farming practices for livestock, specifically in monitoring individual animal behavior, grazing conditions, health status, and fodder consumption. Assessing both the grazing behavior of cattle and the characteristics of the rangeland is crucial for managing grazing stock. Rangeland resources play a crucial role in global cattle production. The abundance, species composition, and chemical composition of forages and pasture undergo changes due to environmental and management factors, resulting in dynamic fluctuations. Assessment and monitoring of rangeland resources are necessary for improved management and utilization. Traditional evaluations that include human or mechanical tallying, recognition, and analysis of chemical makeup are arduous and time-consuming. Sensors can be used to monitor the state of grazing areas and understand the grazing behavior of animals in field circumstances. This information can help improve the management of grazing stock. In order to enhance or substitute traditional methods, it is crucial to comprehend the existing technology, such as sensors or biosensors. The purpose of this review study is to enhance knowledge about the existing technologies and their significance in relation to rangeland resources, specifically in tropical rangelands. Typically, in tropical regions, GPS systems are frequently employed to evaluate the condition of rangelands, but they do not take into account the grazing stock. The analysis further clarifies that sensor technologies play a crucial role in swiftly and effortlessly detecting cattle health problems and movements at the field level. Nevertheless, similar to other technological advancements, sensors (specifically biosensors) has certain limitations, such as the precision of measurements and the occurrence of repeating data allegations. However, the assessment clarifies that the implementation of sensor technologies in animal production can effectively reduce the amount of time and energy required.

Keywords: Sensor Technology; Precision Farming for Animal; Environmental Effect on Forages; Animal Production.

1. Introduction

In the realm of livestock production, the most significant factors contributing to production inputs are animal health, the presence of high-quality feed, and sufficient feed supply. Rangelands are the primary source of forages for herbivore animals in numerous regions across the globe [1]. Grazing land resources provide sustenance for herbivores and play a crucial role in supporting the livelihoods of numerous individuals worldwide who rely on livestock, either directly or indirectly [2]. Nevertheless, the current rangelands necessitate effective management to achieve optimal and sustainable utilization. Effective management of rangelands necessitates thorough surveillance with suitable technologies. Sustainable rangeland management has garnered attention in the past two decades [3]. Efficient management and evaluation of the cultivated forages should be prioritized, utilizing cost-effective methods. In agriculture, several sensor technologies are used to gather accurate agricultural data, such as optimizing crop production, managing livestock, and adapting to climate change in farming activities [4]. Sensors or biosensors are analytical instruments that convert a biological reaction into an electrical signal. In essence, biosensors must exhibit high precision, regardless of physical conditions such as pH and temperature, and should be capable of being reused [5]. Biosensors have been employed since the 1960s by Clark and Lyons to detect and interpret various reactions, including those based on enzymes, tissues, immune sensors, DNA, and thermal and piezoelectric mechanisms. Furthermore, a study conducted by [6] demonstrated that the progress of technology, specifically the ongoing development in sensor technology, has opened up possibilities for the surveillance of animal behavior. Knob and Basis [7] defined a biosensor as a device that converts biological information into a detectable signal when an analytic is present.

2. Literature Review

Acidity, gravity, temperature, asset tracking, and accelerometer sensors are the most common types of sensors used in farming. As tools for resolving issues, sensors are vital in agricultural productivity. Soil analysis, crop production estimation, weed and beneficial crop classification, and pest and disease control are some of their many uses [8]. Farmers rely heavily on sensors in their animal production activities. However, there is a lack of understanding among academics and farmers in underdeveloped nations regarding the various kinds of sensors and the applications they could serve. In the context of cattle production, this study seeks to fill the knowledge gap on the many kinds of sensors, their applications, and the limitations of these sensors. The use of real-time sensors has been extensively studied and has found use in various fields, including animal production. Through the use of real-time sensors, many parameters such as physical condition, disease detection, feed intake, feeding habit, and welfare conditions may be tracked for individual animals. Domestic animals, especially dairy cattle, can have their health and condition monitored and evaluated using sensors, as shown in references [9-10].

3. Proposed Methodology

3.1. Materials and Methods

This information is based on a literature review that examined numerous studies that discussed biosensors and how they may be used to assess the quality of feed. Fifty studies were retrieved for the publication using a search using the following keywords: bio (sensors), forages, quality (chemical composition), and bio (sensor) applications. Only 42 of the retrieved studies were considered suitable for the review because of how pertinent they were to the topic at hand. Bio (sensors) as a concept, commonly utilized biosensors in pasture settings, forage quality assessment, application restrictions, and final thoughts make up the study's framework.

3.1.1. Discussion

Thirdly, sensors for detecting livestock pathogens. One time-honored way to check for common diseases in livestock is with an enzyme-linked immunosorbent assay (ELISA) plate. Although this approach is important, it usually requires a lot of time and a lot of different elements. New developments have made it possible to diagnose illnesses with very few reagents. Table 1 makes reference to biosensors and sensors as examples of technological advances. A comprehensive evaluation has been carried out by [11], highlighting the rise of new technology in the sector. These biosensors also allow for the rapid assessment of animals' health and wellbeing in the field, as demonstrated by the aforementioned studies. According to research [13], the best ways to lessen the impact of environmental dangers on a worldwide scale are to use remote sensing and GIS. It is possible that these technologies will make it easier, faster, and cheaper to discover germs that cause disease.

3.2. Methods for Measuring Grazing Land Quality

When looking at feed for cattle, grasslands are the most economical option from an agricultural perspective. But they contribute to global warming in two ways: first, by burning fossil fuels, and second, by releasing greenhouse gases indirectly [14]. The world's grasslands are undergoing quick transformations, although they remain important and affordable feed supplies for ruminant cattle. For the sake of future use, it is important to assess these grasslands to see how much they can hold and how they are doing generally. Also, to avoid overgrazing grasslands, it’s important to set reasonable limits on the number of animals that can live there [15]. A study that was carried out at the field level examined the state of rangeland grassland and herds using ground-based sensor technologies and global positioning system (GPS) [16]. Based on the results of the study, the data can be used to generate time series and address cloud contamination concerns more effectively. In order to achieve a balanced supply and demand for feed and animals, it is essential to optimize forage and pasture production and apply appropriate resource management, as shown in the comprehensive research of [16]. Making better decisions with the use of extrapolative tools and forecasting models is possible with the use of data that is either real-time or nearly real-time on the physical and/or chemical properties of the vegetation in the target area. Prior studies have shown that high-resolution, spectral-and spatially-capable remote sensing devices can accurately assess pasture quality [17]. By utilizing these systems, more precise data can be derived. The presence of no photosynthetic plants or dead vegetation in pastures competes with photosynthetic plants for space. All of these things affect the pasture quality, which in turn affects the total output of the animals that graze there. The feasibility of getting accurate and reliable data by mapping the precise fraction of perished vegetation using Aisa FENIX imaging spectroscopy was proved in a study conducted in New Zealand, as reported by [18]. The use of hyperspectral sensing allowed for the accurate and precise identification of feed species, according to a study by [19]. Conventional methods can provide more precise results when trying to ascertain a pasture’s botanical makeup. While these procedures do the job, they are labor-intensive and take a long time. In order to cover more ground, it is helpful to use modern ways of assessing the rangelands’ flora and other features, as stated in [20]. Figure 1 [21] shows how real-world image analysis is used to identify forages. Several studies have shown that it is possible to understand that when using sensor technologies, the use of advance in agriculture. Adapted from [43].

Table 1. Application of the sensor on grazing and behavior of livestock

Biosensor	Application	Reference
Grazing/ Feeding behavior	Pressure sensing	Braun et al. 2013; Nydegger et al. 2010; Pahl et al. 2016; Rutter et al. 1997
	Acoustic sensing	Benvenutti et al. 2016; Navo et al. 2013
	Acceleration sensors	Giovanetti et al. 2017; Herinaina et al. 2016; Mattachini et al. 2016; Oudshoom et al. 2013.

Information about rangeland conditions, grazing animal distribution, and the chemical composition of pasture forages can be more accurately gathered through the integration of systems and methodologies. A cost-effective alternative to on-site evaluation that can identify different types of rangeland deterioration was shown by the research of [22] to be the use of numerous approaches.

3.3. Thirdly, Forage Quality Evaluation Sensors

It is common practice to ascertain the chemical make-up of high-quality fodder using conventional procedures. Some examples of these methods include “wet” chemistry and near-infrared spectroscopy (NIRS) analyses performed in a lab. However, variables like analysis time, sample size and collection method, cost, and accessibility to sample locations impact these methodologies. Alternative methods, such as the use of sensors, for assessing pasture quality have emerged as a result of recent technical developments. Thanks to advancements in computing power and more complex statistical approaches, near-infrared spectroscopy (NIRS) may now be used to efficiently evaluate the chemical composition of different forage samples. Quick analysis and lower costs are two benefits of this methodology [23, 24]. Better monitoring of warm-season legumes can be achieved by integrating NIRS with machine learning calibration approaches, as explained by the authors. Using this method, conventional forage analytical techniques are superfluous. In order to evaluate the quality of fodder, the NIRS method was created and first used in the mid-1970s [25]. Since its introduction, NIRS methods have been used more and more to assess different aspects of fodder quality [26]. As an alternative to the time-consuming and expensive laboratory procedure, the NIRS analysis provides information about the composition of fodder quickly and reasonably priced [27]. According to the studies cited in [28], it is possible to measure the output of pasture biomass and the crude protein content using sensor technology.

Thanks to developments in sensor technology, compact multispectral cameras with remote sensors are now available, making them ideal for installation on UAVs. In plant monitoring, these cameras have multiple uses [29]. The use of UAVs (unmanned aerial vehicles) has several advantages, such as improving data accuracy and cutting down on evaluation time for plant monitoring. Many areas of agriculture have flourished thanks to the use of these technologies, including the following: seed sowing, weed identification, fertility evaluation, mapping, crop prediction, and pesticide and fertilizer exploration and application [29]. The unmanned aerial vehicle allows scientists to use spectral data with a high resolution (<1 m) collected from large areas to calculate a vegetation index. This index may then be understood in relation to dry matter (DM) biomass, sward height, or nutrient content. Table 2 shows the results of a comparison study on the use of unmanned aerial vehicle (UAV) methods for evaluating forage pastures under cow grazing settings.

3.4. Devices for Monitoring Livestock Movement and Forage Consumption

Sensors like global positioning systems (GPS) and accelerometers have proven to be useful in tracking the movement of grazing animals in open areas [30, 31]. The grazing habits of cattle elk were the subject of a study by [32] that aimed to track their status and environmental factors. The authors came to the conclusion that they had witnessed important rangeland phenomena that are relevant to the management of local resources. Despite some difficulties, a study [33] found that grazing in the modern age of high technology does provide new opportunities for improving grazing methods. According to reports, digital technologies have the potential to lower resource consumption, promote the use of production methods that are kind to animals and the environment, and speed up the process of making these products. This calls for the investigation of novel approaches, one of which is the integration of digital technology into all stages of cattle production.

For commercial grazing operations with a big number of cattle, sensors provide a vital alternative for quickly evaluating feed consumption. Predicting pasture consumption is possible with the help of several emerging technologies that assess sensor data and identify specific behaviors [34, 35]. Research by [36] showed that tracking the jaw movement of grazing cattle can reach varied degrees of precision. The use of electromechanical sensors, which can identify particular animal habits like bite detection and exact pasture position, was lauded by the authors. Grazing management procedures could be improved with this technology. Measurements for Assessing Grazing Animal Welfare 3.5. It can take a lot of time to check on the health of grazing animals in pasture or range. On the other hand, cutting-edge tools can make animal welfare evaluations go more quickly and with less effort. To improve the efficiency of grazing-based livestock production and to guarantee that grazing cattle's basic health and welfare needs are met, monitoring their foraging behavior is essential [37].

According to data compiled by Food and Farming Technology, among Australia' smost important industries (https://www.foodandfarmingtechnology.com/news/livestockmonitoring/), it was possible to monitor grazing cattle feed.

(a) (b)

Figure 1. Example of the image analysis on a real image. Each pixel in the image is automatically analyzed and classified as either grass (blue), clover (red), weeds (yellow), or unidentified (black overlay). (a) Example input image. (b) Automatically analyzed image [21].

Table 2. Comparison of the UAV-based method for estimation of estimation of herbage mass for tall fescue and dry ryegrass-based pastures rotational grazed by lactating cows.

Biomass estimation (Kg DM/ ha)				Comparison vs. UAV					
	Mean	**SD**	**N**	**Bias**	**T-Test**	**RMSE**	**RE**	**R2**	**r**
UAV	2017	530	52	—	—	—	—	—	—
C-Dax	1971	350	52	−46	0.37	363	18	0.53	0.73
Ruler	2073	636	52	56	0.30	386	19	0.63	0.80
Mean	2022	472	52	5	0.90	313	15	0.65	0.81

(a)

(b)

Figure 2. Sensor (a) and sensor applied to grazing stock (b)

Sensors that are compatible with ear tags are used to conduct the intake (Figure 2). Livestock grazing is a characteristic behavior of pasture-based cattle. Thus, keeping a careful eye on these traits is essential for gauging the health of the animals and the pasture's state for future management decisions. In addition, by analyzing data acquired from sensors that track the cows' movements, algorithms may potentially predict how much grass each cow will eat.

The use of integrated sensor technologies to control the movement of grazing animals was also demonstrated in a study by [38]. The schematic depiction in Figure 3 of the same source shows how to easily monitor grazing livestock in the field. They went on to say that more study is needed to enhance the technology system in real-world settings so that animal productivity may be better managed.

On vast rangelands, accelerometers can be used to remotely monitor the health of animals, which would normally necessitate a lot of human intervention [39]. Using a variety of digital technologies might improve sheep welfare, according to research by [40]. Keep in mind that technology variations and field conditions can affect how successful these tools are. Additional research in this field is required. Numerous studies offer in-depth analyses of grazing habit, and technological developments have made it feasible to track every step in real time. However, as indicated earlier, there are a number of reasons why these technologies may not be widely used in all areas.

Inadequate technical knowledge and appropriate tools constitute a major obstacle to the use of sensors in the management of cattle health and production [41]. For example, collecting, drying, and grinding vegetative samples is a time-consuming process, even if the NIRS application yields data quickly and at a low cost. Unmanned Aerial Vehicles (UAVs) are vital for determining the health, yield, and diversity of a pasture's crops and forages, as indicated before. But they can only be used for grazing purposes [42], thus future R&D efforts may have to deal with the difficulties of implementation. Many sensor systems were effectively deployed in temperate zones to aid farmers in making educated decisions, according to the research carried out by [20]. Current technology, however, is inadequate for usage in the majority of tropical regions; this may be an area where the cattle production sector should concentrate its future efforts.

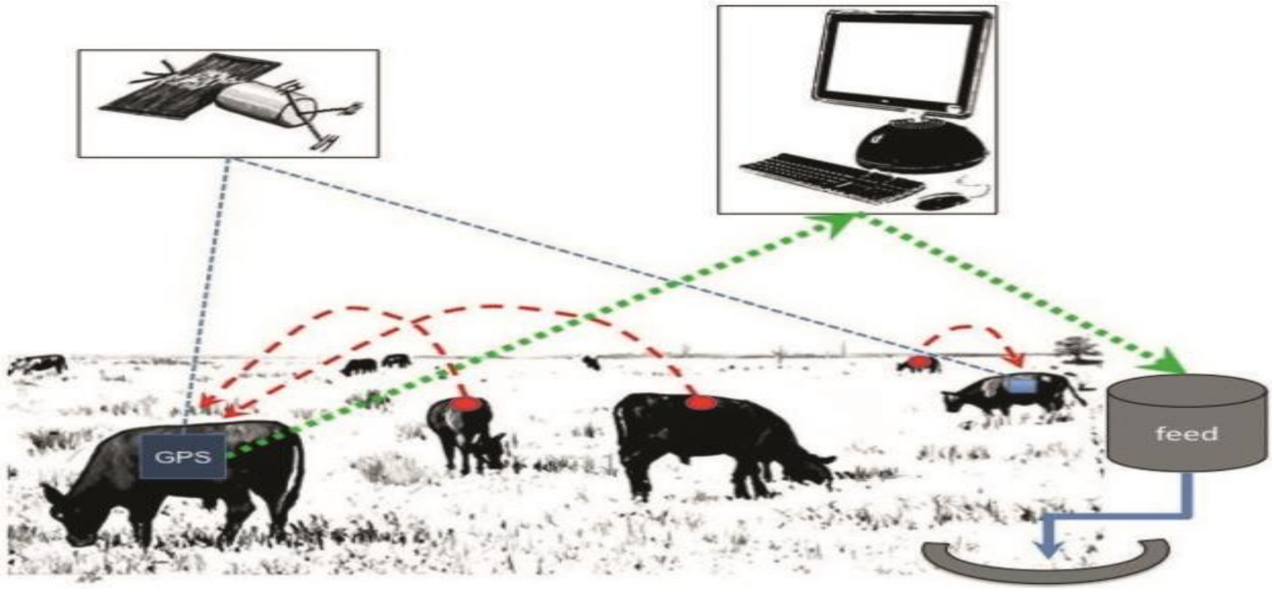

Figure 3. Schematic of a precision grazing system [38]

4. Conclusion and Future Research

It is essential to examine and improve upon current knowledge as well as investigate researchable subjects in order to promote progress in this era of digital technology. At present, digital technology, such as sensors, are used in agriculture, especially in the production of animals, by developed nations. The future of cattle production in developing nations might be substantially improved with the deployment of sensor technology, even though there is still a lack of understanding and execution of this technology in these areas. Hence, prior research on the topic was used to produce this brief analysis. Utilizing sensor technology under grazing settings allows for the easy and accurate collection of data about the health, production, and welfare of cattle. Additionally, state-of-the-art technology makes it possible to monitor and evaluate the grazing behavior of cattle and the forage quality in pasture areas. Particularly for evaluating large samples, these technologies, when used properly, can drastically reduce costs and turnaround times.

However, general knowledge in this area is lacking among professionals in the sector. As a result, efforts should be made to educate the public, undertake additional studies, and launch development programmers, particularly in developing countries. No data were used to support this study.

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