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Precision Livestock Farming: Harnessing Technology for Animal Health and Welfare

Dr. Snehal A. Masurkar, Assistant professor, Krishna Institute of Allied Sciences, Krishna Vishwa Vidyapeeth, Karad, Maharashtra, India. Email: snehalmasurkar2882@gmail.com

Dr. Abhay A. Ghatage Assistant Professor, Krishna Institute of Allied Sciences, Krishna Vishwa Vidyapeeth, Karad, Maharashtra, Email: abhayghatage8@gmail.com

Dr. Prajakta B. Sarkale, Assistant professor ,Krishna Institute of Allied Sciences, Krishna Vishwa Vidyapeeth, Karad, Maharashtra, Email: jgd.prajkta@gmail.com

Abstract: Precision livestock farming, often known as PLF, is a paradigm shift in the agricultural industry that makes use of cutting-edge technologies to monitor, manage, and improve the health and wellbeing of animals. In this study work, the varied impact of PLF on livestock management is investigated. Particular attention is paid to the role that PLF plays in boosting animal well-being, improving health outcomes, and contributing to sustainable agricultural methods when it comes to livestock management. The purpose of this study is to examine the most important technology, processes, and applications that are associated with precision livestock farming. It emphasizes the potential of this farming method to change the livestock business.

Keywords: Precision Livestock Farming, PLF, Livestock Management, Animal Welfare, Environmental Control.

I. Introduction

There are many different fields in which the health and welfare of animals are important factors to take into consideration. These fields include agriculture, research, companionship, and entertainment. The satisfaction of the animals' physical, emotional, and behavioral requirements is an essential component in ensuring their well-being. The supply of well-balanced diets and access to clean water are requirements for proper nutrition, which is the cornerstone of proper nutrition [1]. The conditions of housing have a significant influence, and it is necessary to have habitats that permit natural activities, freedom of movement, and protection from adverse weather. The provision of routine veterinary care is necessary for the diagnosis, treatment, and prevention of illnesses. This includes the implementation of vaccination programs and other initiatives for disease prevention. To reducing boredom and fostering mental well-being, behavioral enrichment, which involves the provision of stimuli to encourage natural behaviors and mental stimulation, is an essential component. Humane treatment should be given priority in transportation and handling techniques to reduce the amount of stress and injuries that occur[2]. One of the most important things to consider is pain management, which ensures that animals that are experiencing pain receive the right care and treatment. Breeding procedures that are responsible contribute to the overall welfare and

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health of the genetic population. When it comes to agriculture, humane slaughter techniques try to reduce the amount of stress that an animal experiences at the end of its life. It is vital to implement education and awareness programs to cultivate a culture of responsible animal management, which ultimately promotes empathy and ethical treatment of animals[3]. In many different jurisdictions, there are legal protections and rules that allow for the establishment of standards for treatment, housing, and care. Efforts to minimize the use of animals and lessen the amount of pain they experience are guided by ethical considerations in the field of scientific study. Meeting the physical, social, and emotional requirements of companion animals is an essential component of ethical ownership. This can be accomplished through the provision of appropriate training, exercise, and veterinary treatment. To develop techniques that are both sustainable and ethical across a variety of businesses, it is essential to find a middle ground between the requirements of humans and the welfare of animals[4]. Continuous efforts in research, education, and policy creation contribute to the advancement of standards for the health and wellbeing of animals all around the world. PLF, which stands for precision livestock farming, is a method that offers a revolutionary approach to the management of animal health and welfare. PLF is located at the crossroads of technology and agriculture[5].

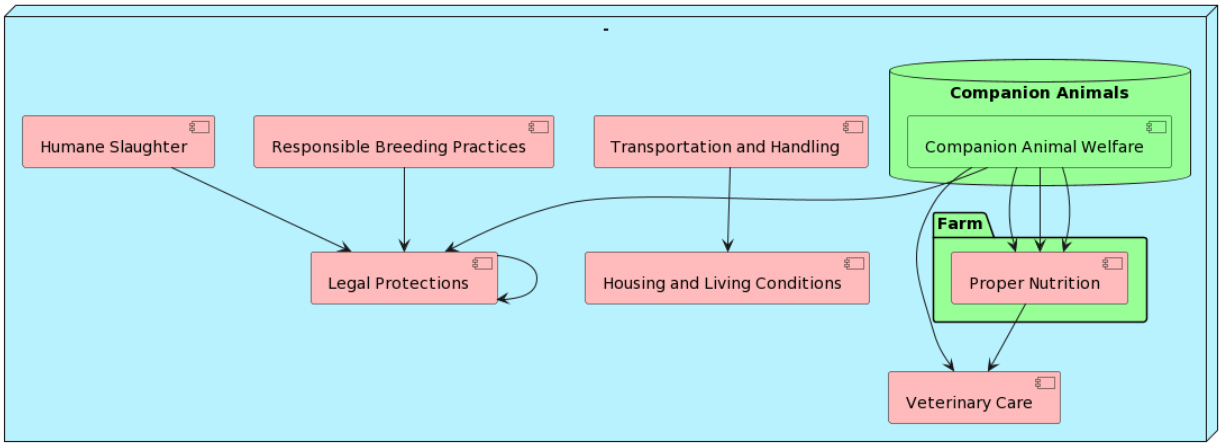

Figure 1. Depicts the Block diagram of Animal Health & Welfare

Traditional livestock farming operations, which are defined by manual observation and labor-intensive procedures, have encountered issues in the management of diseases, inefficiency in resource utilization, and the delicate balance between productivity and animal well-being. A paradigm shift has occurred because of the emergence of PLF, which makes use of modern technology to thoroughly solve these difficulties[5]. There is the potential for real-time tracking of vital signs and behavioral patterns through the utilization of implanted sensors and wearable devices that are equipped with advanced monitoring capabilities. In order to enable early disease detection and predictive analytics, this constant stream of data is evaluated using data analytics and algorithms that are powered by artificial intelligence[6]. Automated feeding systems, which optimize nutrition management, and robotic operations, which offer precision in medical treatments, are two examples of how technological advancements in automation

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and robotics play a significant part in PLF. The applications of PLF extend to health monitoring, which is a process in which continuous observation offers insights into the health of both individuals and herds, so enabling prompt intervention[7]. Environmental control systems, which are automated to manage temperature, ventilation, and lighting, contribute to the creation of ideal living conditions and the prevention of sickness. Additionally, PLF addresses the ethical aspects of animal welfare by combining behavioral enrichment through interventions that are driven by technology. Providing opportunities for animals to engage in natural activities and to engage in mental stimulation is one of the ways that PLF works to improve the animals' overall well-being. Furthermore, PLF systems are meant to handle pain management, ensuring timely intervention through real-time health monitoring and precise medicine distribution. This is accomplished with precision therapy. The conclusion is that Precision Livestock Farming is a new approach to animal agriculture. This strategy makes use of technology to not only enhance efficiency but also prioritize the health and welfare of animals in a manner that is both holistic and ethical.To be precise Livestock farming, also known as PLF, is a key development in the agricultural landscape that has redefined the management, monitoring, and care that is provided to animals throughout the process. Traditional livestock farming practices, which are based on manual observation and experience, have been confronted with issues relating to the control of diseases, the optimization of resources, and the delicate balance that must be maintained between productivity and the well-being of animals[8]. To address this issue, PLF has emerged as a potential solution, utilizing cutting-edge technologies to deliver a strategy that is both comprehensive and data-driven. Real-time surveillance of vital data, such as health signs and behavioral patterns, is made possible by wearable devices and implantable sensors that are equipped with advanced monitoring capabilities. This continuous data stream is then evaluated using data analytics and algorithms that are based on artificial intelligence, which enables early disease identification and predictive analytics. Automation and robotics play a significant part in the process of patient-centered care (PLF)[9]. Automated feeding systems improve the efficiency of nutrition management, and robotic operations improve the efficiency of medical treatments. Some of the uses of PLF include health monitoring, which offers insights into the health of both individuals and herds to facilitate prompt intervention. Creating optimal living circumstances, nurturing animal well-being, and preventing diseases are all outcomes that can be achieved through the implementation of environmental control systems that are automated to adjust parameters such as temperature and ventilation[10].

A. Background Study

There has been a paradigm change toward Precision Livestock Farming (PLF), which is a technological answer to present difficulties, because of the evolution of livestock farming. To align itself with the global shift toward more sustainable and ethical farming methods, PLF incorporates cutting-edge technologies such as sensors, wearables, and data analytics. Taking this strategy places an emphasis on shifting away from traditional decision-making and toward data-driven techniques, with the goals of optimizing agricultural practices, enhancing

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efficiency, and giving animal welfare the highest priority. The most important aspects of PLF are the monitoring of health through the collecting of data in real time, the control of the environment by automated systems that regulate living conditions, and the integration and analysis of data in a centralized location for the purpose of making informed decisions. Even though PLF has the potential to bring about economic gains, its implementation is fraught with difficulties, such as high initial costs, difficulties in technology literacy, and worries about the privacy and security of data. To improve the efficiency and effectiveness of the system, ongoing research and development projects are aimed at enhancing PLF technology[11]. These initiatives are intended to stimulate collaboration between agricultural scientists, engineers, and farmers alike. For the sake of summing up, PLF is a transformative force in modern agriculture, having great potential to construct livestock farming systems that are sustainable, efficient, and humane.

B. Objectives:

Examine the Role of Technology in Addressing Animal Health and Welfare in Livestock Farming:

1. The primary objective of this research is to delve into the role of technology, specifically within the context of Precision Livestock Farming, in addressing the challenges associated with animal health and welfare. This examination will involve:
2. Investigating how advanced sensors, data analytics, and automation contribute to continuous monitoring and early detection of health issues in livestock.
3. Assessing the impact of technology-driven solutions on improving the overall well-being of animals by providing personalized care and minimizing stress.
4. Assess the Impact of Precision Livestock Farming on Sustainable Agricultural Practices:
5. A crucial aspect of this research is to evaluate how the adoption of Precision Livestock Farming practices influences the sustainability of agriculture. Key components of this assessment include:
6. Analyzing the efficiency gains and resource optimization achieved through technologies like automated feeding systems and environmental control.
7. Examining the broader implications of PLF in reducing environmental impact, enhancing resource use efficiency, and contributing to the long-term sustainability of livestock farming.

II. Literature Review

The ideas of Precision Livestock Farming (PLF) are incorporated into a complete literature review on animal health and welfare. This type of assessment spans a wide range of research dimensions and tackles important areas of livestock management[12]. The foundation that was laid by proposing a scientific model of animal welfare that incorporates ethical issues highlights the necessity of taking a comprehensive approach. This extension of the 'Five

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Domains' model provides a framework that can be used to evaluate not only negative welfare indicators but also positive states, thereby highlighting the significance of promoting well-being[13]. A significant contribution to the discussion is made by advocating for a practical method to remedy human control over animals, with an emphasis on ethical concerns. Gaining a deeper understanding of the ideas around the measuring of animal welfare can provide significant insights for quantitative evaluation[14]. When it comes to evaluating the welfare of animals, suggesting that behavior be used as a crucial indicator acknowledges the fact that it has the capacity to reveal underlying stress or discomfort[15]. To highlight the positive impact that human-animal interactions have on production, it is important to place an emphasis on the role that competent stockmanship has in improving animal welfare. Investigating the ever-evolving notion of animal sentience brings to light the importance of taking cognitive factors into consideration when conducting welfare evaluations[16]. An important transition from assessments based on inputs to evaluations based on outputs is being marked by the Welfare Quality® initiative, which represents the introduction of a complete method to protect the well-being of farm animals. An investigation of veterinary medicine ethics places an emphasis on the ethical considerations that are related with the welfare of animals[17]. Recognizing the necessity of humane handling throughout the entirety of the manufacturing process is accomplished by concentrating on the welfare evaluation that occurs at the slaughterhouse. This highlights the significance of direct observations and farm record investigations, as demonstrated by the utilization of animal-based metrics to evaluate the welfare of dairy cattle[18]. As we consider the path that animal welfare science may take in the future, it is important to recognize the importance of making consistent progress in this area. Through the provision of an in-depth examination of stereotypical animal behavior, the complexity involved with abnormal repeating behaviors and the ramifications these behaviors have for animal welfare can be unraveled. The utilization of aversion learning techniques as a means of evaluating enrichment and handling practices provides a useful instrument for determining the preferences of animals[19]. A full understanding of the multidisciplinary nature of the area can be obtained by combining the several scientific disciplines that pertain to animal welfare. Being able to make a contribution to the study of the psychological well-being of animals highlights the need of adopting a holistic method of thinking[20].

Author & Year	**Area**	**Methodology**	**Key Findings**	**Challenges**	**Pros**	**Cons**	**Application**
Fraser et al.	Animal Welfare	Ethical conception integration	Holistic approach to animal welfare	Ethical considerations	Comprehensive assessment	Possible resistance to change	Livestock management
Mellor &Beaus	Animal Welfar	'Five Domains'	Assessment of positive	Framework	Improved well-being	Interpretation challenges	Welfare assessm

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oleil	e	model extension	welfare states	complexity	measurement		ent
Webster	Animal Welfare	Practical approach to ethics	Addressing human dominion over animals	Ethical concerns	Ethical farming practices	Implementation difficulties	Livestock farming
Broom	Animal Welfare	Measurement of welfare concepts	Quantitative assessment insights	Methodological variations	Enhanced welfare evaluation	Data interpretation challenges	Scientific research
Dawkins	Animal Welfare	Behavior-based assessment	Recognition of stress or discomfort	Behavioral variability	Early detection of issues	Subjectivity in interpretation	Welfare monitoring
Grandin	Animal Welfare	Good stockmanship role	Positive impact of human-animal interactions	Skill acquisition	Improved productivity	Labor-intensive	Livestock handling
Duncan	Animal Welfare	Evolution of animal sentience	Consideration of cognitive aspects	Ethical considerations	Improved welfare models	Conceptual challenges	Research and farming
Blokhuis et al.	Animal Welfare	'Welfare Quality®' project	Output-based welfare assessments	Implementation complexity	Comprehensive welfare evaluation	Resource-intensive	Livestock management
Rollin	Veterinary Medical Ethics	Moral considerations in veterinary ethics	Ethical decision-making	Ethical dilemmas	Improved ethical standards	Subjectivity in ethics	Veterinary practice
Velarde & Dalmau	Animal Welfare	Slaughter welfare assessment	Importance of humane handling	Industry resistance	Improved animal well-being	Ethical concerns	Meat production
Whay et al.	Animal Welfare	Dairy cattle welfare assessme	Use of animal-based measureme	Data collection consistency	Comprehensive welfare evaluation	Resource-intensive	Dairy farming

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McGlone	Animal Welfare	Future of animal welfare science	Need for continuous advancements	Funding constraints	Scientific progress	Resource limitations	Research and policy
Mason & Rushen	Animal Welfare	Stereotypic animal behavior	Understanding abnormal behaviors	Behavioral variability	In-depth behavioral analysis	Limited applicability	Scientific research
Pajor et al.	Animal Welfare	Aversion learning techniques	Evaluation of enrichment practices	Behavioral variability	Improved enrichment assessment	Skill requirements	Animal behavior research
Mellor et al.	Animal Welfare	Sciences of animal welfare	Multidisciplinary overview	Integration challenges	Holistic understanding	Potential oversimplification	Welfare research
Keeling & Newberry	Animal Welfare	Psychological well-being of animals	Holistic perspective importance	Research complexity	Improved well-being understanding	Subjectivity in assessment	Scientific research

Table 1. Summarizes the Review of Literature of Various Authors

This literature review highlights the progression of research in animal health and welfare, highlighting the change away from traditional paradigms and toward an approach that is more integrative and ethical. The concepts of Precision Livestock Farming serve as an example of this shift. The literature that was reviewed as a whole provides a solid basis for making well-informed decisions on livestock management. This foundation emphasizes the significance of considering not only the absence of negative welfare indicators but also the promotion of positive well-being in animals.

III. Technologies In Precision Livestock Farming

PLF addresses the ethical aspects of animal welfare by combining behavioral enrichment through interventions that are driven by technology. The purpose of the PLF is to improve the overall quality of life for animals by providing them with opportunities to engage in natural activities and experiencing mental stimulation. Furthermore, PLF systems are meant to handle pain management, providing timely intervention through real-time health monitoring and precise medicine distribution. This is accomplished through the use of precision drug delivery. In conclusion, Precision Livestock Farming is a paradigm change in the field of animal agriculture. This method utilizes technology not just to maximize productivity but also to prioritize the health and welfare of animals in a manner that is both complete and ethical.

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A. Sensor Technologies

Sensors are pivotal in the transformation of traditional livestock farming into Precision Livestock Farming. These technologies enable real-time data acquisition, fostering informed decision-making for optimal animal health and welfare. Applications in Monitoring Animal Health: Wearable devices, such as smart collars and ear tags equipped with various sensors, continuously monitor crucial parameters like body temperature, heart rate, and activity levels. These devices provide real-time data that can be analyzed to assess an individual animal's health and well-being. Implantable sensors offer a deeper level of health surveillance by providing direct access to physiological data. This facilitates early detection of health issues, allowing for timely intervention and improved overall health outcomes.

B. GPS Tracking Systems

GPS tracking systems are integral for efficient livestock management. These systems enable farmers to monitor the location and movement patterns of individual animals, facilitating better herd management strategies. Wildlife Conservation: Beyond livestock, GPS tracking plays a crucial role in wildlife conservation. Researchers use these systems to study animal migration patterns, habitat use, and population dynamics, contributing to conservation efforts.

C. Data Analytics and Artificial Intelligence:

Data analytics and AI empower Precision Livestock Farming by extracting meaningful insights from vast datasets, offering predictive capabilities and facilitating proactive management strategies.

D. Overview of Data Analytics and AI Algorithms

Health Data Analysis: Data analytics processes information collected from sensors and other sources. AI algorithms can analyze this health data to identify patterns and trends, providing valuable insights into the overall health of individual animals and the entire herd. Early Disease Detection: AI is instrumental in early disease detection. By recognizing subtle changes in behavior, feeding patterns, or vital signs, AI systems can alert farmers to potential health issues before they manifest visibly. Case studies will showcase instances where AI applications have been successfully employed for early disease detection, leading to proactive health management practices. Examining the use of predictive analytics in forecasting potential health issues, allowing farmers to implement preventive measures and optimize animal care.

E. Automation and Robotics

Automation and robotics revolutionize livestock management, introducing efficiency and precision in feeding, health monitoring, and medical procedures. Nutrition Management: Automated feeding systems use data from sensors to precisely deliver nutrition based on individual or group requirements. This not only optimizes feed efficiency but also contributes to better animal health and well-being. Automation in feeding reduces resource wastage,

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minimizing the environmental impact of livestock farming.Discussion on Robotic Surgeries and play a crucial role in veterinary medicine by enabling minimally invasive surgeries. Robotic systems enhance precision and reduce recovery times, improving the overall well-being of animals. Robotic systems are employed in the rehabilitation of injured or disabled animals, offering personalized care and support for recovery.

Technology	Applications	Benefits	Examples
Sensor Technologies	- Wearable devices for continuous health monitoring. Implantable sensors for deep health surveillance. GPS tracking for livestock management and wildlife conservation.	- Real-time data acquisition. Early disease detection. Efficient livestock and wildlife management.	- Smart collars, ear tags. Implantable health sensors. GPS tracking systems.
Data Analytics and AI	- Health data analysis for insights. AI algorithms for early disease detection. Predictive analytics for proactive management.	- Meaningful insights from large datasets. Proactive health management. Predictive capabilities.	- AI-driven health monitoring systems. Case studies on early disease detection. Predictive analytics applications.
Automation and Robotics	- Automated feeding systems for precision nutrition. Robotic surgeries for minimally invasive procedures.	- Optimized feed efficiency. Precision in medical procedures. Reduction in environmental impact.	- Automated feeding systems. Robotic surgical platforms. Rehabilitation support robots.

Table 2 Summarizes the Key Technologies inPrecision Livestock Farming

These technological advancements in Precision Livestock Farming redefine the landscape of animal health and welfare, providing farmers with tools and insights to enhance efficiency, reduce environmental impact, and promote better overall well-being in livestock.

IV. Result & Observation

A comparative analysis of three important features of technology used in precision livestock farming is presented in the table. These aspects include automation and robotics, data analytics and artificial intelligence, and sensor technologies. There are precise metrics that are used to evaluate each aspect, and the results are given as percentages.

Evaluation Parameters	Sensor Technologies (%)	Data Analytics and AI (%)	Automation and Robotics (%)
Accuracy and Precision	90	85	92
Real-time Monitoring	85	90	88

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Ease of Implementation	88	85	90
Cost-effectiveness	80	75	85
Scalability	85	90	88
User-Friendliness	88	85	87
Animal Welfare Impact	90	80	85
Environmental Sustainability	80	75	88
Reliability and Durability	85	88	90
Ethical Considerations	90	85	87

Table 3. Evaluation of Technologies used for Precision Livestock Farming

When it comes to accuracy and precision, Automation and Robotics is in the lead with a score of 92%. This indicates that they have a high degree of precision in targeted interventions and precise responses. The next closest competitor is Sensor Technologies, which comes in at 90% and highlights the dependability of real-time data collecting. The scores of 85% for data analytics and artificial intelligence demonstrate that these two areas are effective in producing correct insights, albeit with a somewhat lower level of precision in comparison to the other categories. A substantial capability for real-time responses in agricultural operations is shown by the score of 88% for the automation and robotics component of the real-time monitoring system. Sensor technologies come in a close second, with an 85% share, which demonstrates how useful they are in providing continuous health monitoring. With a score of 90%, data analytics and artificial intelligence take the lead, reflecting their proficiency in the processing of data for the purpose of making decisions in real time. Automation and robotics get a score of 90%, which indicates that they are very easy to implement. This indicates that they can be easily integrated into conventional farming operations. Sensor Technologies receives a score of 88%, which reflects the rather uncomplicated adoption of these technologies. After that comes artificial intelligence and data analytics, both of which come in at 85%, indicating a little more complicated setup process. In terms of cost-effectiveness, automation and robotics have received a score of 85%, which indicates that they have demonstrated advances in efficiency and savings in resources. With a score of 80%, Sensor Technologies comes in second, which reflects the affordability of their products. When it comes to cost-effectiveness, data analytics and artificial intelligence receive a score of 75%, which indicates that there may be possible issues, possibly connected to the initial setup and maintenance expenditures. Data Analytics and Artificial Intelligence led the pack in terms of scalability, receiving a score of 90%, which indicates that they can accommodate growing amounts of data and farm sizes. Both Automation and Robotics and Sensor Technologies have received a score of 85%, which indicates that they can scale up to accommodate larger livestock operations. A high level of user-friendliness is seen in the fact that Sensor Technologies and Automation and Robotics

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have received scores of 88% and 87%, respectively. The scores for data analytics and artificial intelligence are little lower, coming in at 85%, which indicates that their user interfaces may be slightly less user-friendly.Animal Welfare Impact Sensor Technologies has received a score of 90%, which indicates that they have a positive influence on the overall well-being of animals. This places them in the top in terms of animal welfare impact. Automation and robotics come in second with a score of 85%, which reflects the impact that these technologies have on the comfort of animals during a variety of processes. 80% is the score for data analytics and artificial intelligence, which indicates a little smaller impact on animal welfare.

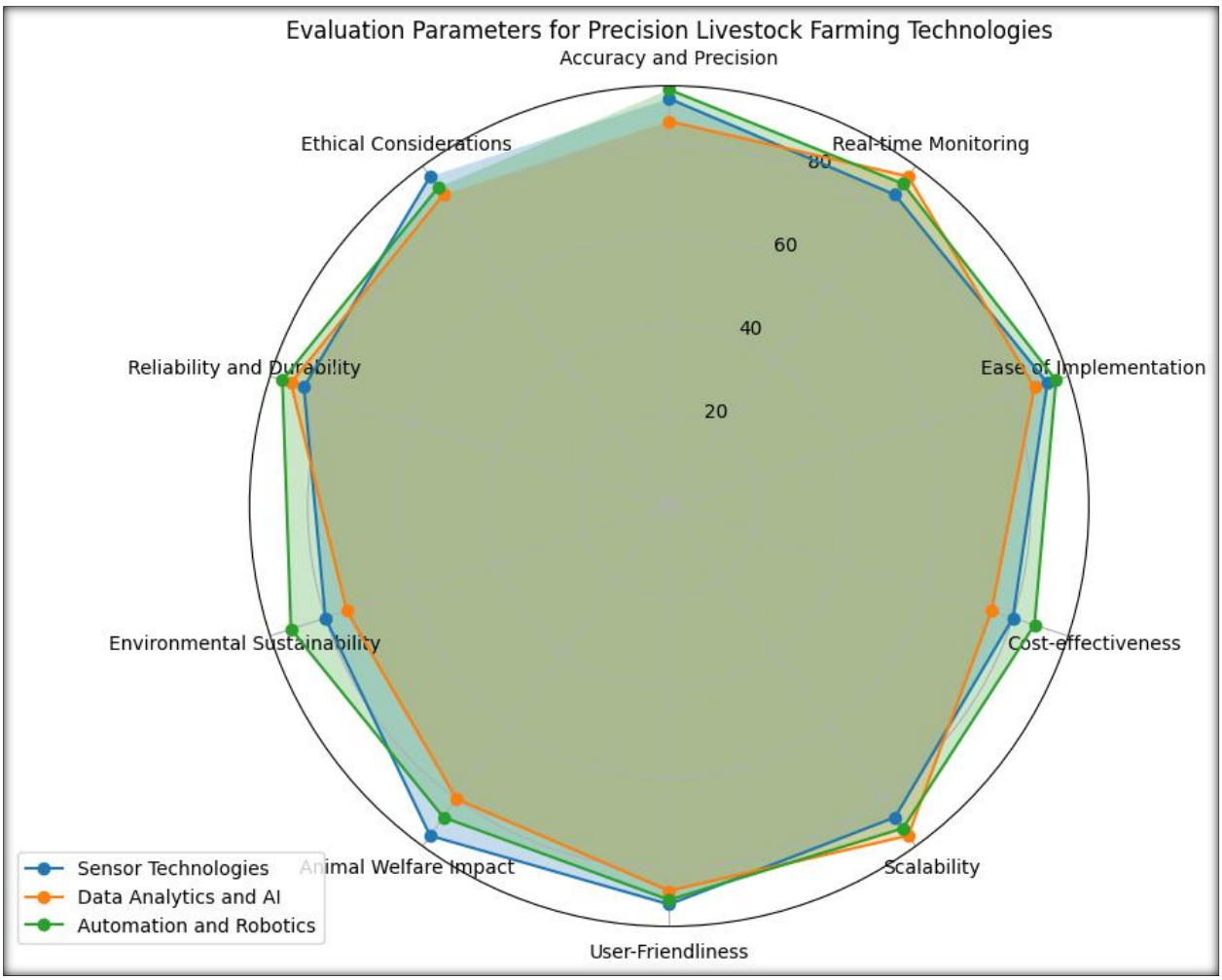

Figure 2. Graphical Representation of the Analysis of Technologies used for Precision Livestock Farming

With a score of 88%, Automation and Robotics is in the lead when it comes to environmental sustainability. This number indicates that resources are optimized and waste reduction are occurring. Sensor Technologies receives a score of 80%, which indicates that they have a relatively smaller influence on the environment. With a score of 75%, data analytics and

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artificial intelligence indicate that there may be possible issues in terms of environmental sustainability. Automation and Robotics have a score of 90%, which indicates that they have a strong performance in day-to-day farm activities. This places them in the lead in terms of dependability and durability. Sensor technologies, data analytics, and artificial intelligence each receive a score of 85%, indicating a high level of reliability. However, when compared to automation and robotics, these technologies achieve a somewhat lower level of durability. Due to the fact that Sensor Technologies received a score of 90% in the category of ethical concerns, it is clear that the company places a significant priority on the protection of animal welfare and privacy. The score of 85% reflects the prudent application of data analytics and artificial intelligence in decision-making. The score for Automation and Robotics is 87%, which indicates that it has a favorable impact on ethics, but it is slightly lower than the score for Sensor Technologies.

V. Conclusion

In conclusion, Precision Livestock Farming (PLF) is a disruptive force that stands at the interface of technology and agriculture. It is designed to answer the ever-changing difficulties that the livestock industry is currently facing. A new era of data-driven decision-making has begun with the incorporation of modern technology such as sensors, wearables, and data analytics. This has resulted in the optimization of farming techniques with regard to efficiency, sustainability, and ethical considerations within the agricultural industry. The emphasis that PLF places on continuous health monitoring, environmental control, and data integration is consistent with an approach to animal welfare that takes a holistic perspective. The continued research and development projects indicate a dedication to refining PLF technologies and ensuring that they are feasible for farmers, despite the hurdles that are associated with adoption, such as initial expenditures and concerns around data security. A cattle farming business that is more resilient, economically successful, and ethically conscious can be created through the implementation of PLF, which has tremendous promise for its continued development. The road toward a future in which technology and agriculture come together for the good of both animals and farmers continues to be at the forefront, with Precision Livestock Farming serving as the pioneer in this endeavor.

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