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# *Factors Influencing the Implementation of Digitalization in the Livestock Industry 4.0*

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***Abstract.*** **The current era is characterized by a digital revolution, and businesses and industries are undergoing accelerated transformation. Now, terms like "Industry 4.0," "digitalization," and "smart" are frequently employed to describe these adjustments. To thrive in the current era, even Livestock Farms must adapt to this transition and employ digitalization. However, Livestock Farmers may delay associating their industry with digitalization and AI. To aid them in this transition, a scientific study was conducted to determine which livestock processes are useful for digitalization and their industry-wide advantages. In addition, it examines the viability of emerging technologies such as blockchain, IoT, Big Data, and AI in animal husbandry. By understanding each process and its digital solution, the various periods of digitalization can be defined.**

***Keywords: Digitalization, Livestock Farms, Industry 4.0, AI, digital transition, efficiency.***

## I. INTRODUCTION

The food sector today is interfacing with two main changes: the implementation of industry 4.0 technologies and the need for sustainability [1].

Mohd Javaid et al. (2022) recognized and explored important uses of Agriculture 4.0 technologies, suggesting concepts like "smart farming," "several critical technologies," and the "Exploring Agriculture 4.0 Domain" in depth [2]. A variety of artificial intelligence technologies can be incorporated into the process of livestock production and management, such as machine vision, voice recognition, virtual reality, and wearable devices, to transform traditional feed management, increase production efficiency, and reduce labour costs [3]. The convergence of blockchain-based IoT infrastructure is anticipated to provide another foundation for the livestock sector dependent on the devices used, the services provided, and the overall architecture of the integrated system. It would allow integrated systems to function ecologically and sustainably without compromising animal welfare standards, resource management, or livestock output. In the livestock domain, technologies are developed to raise animal production sustainably [4].

Production has evolved into smart farms with numerous sensors and actuators that generate vast amounts of data, requiring processing and reasoning to avoid unfortunate situations. All these requirements and technologies have made the agriculture environments highly dynamic and complex [4]. In this context, Artificial Neural Networks (ANNs) excel at learning from experience [5] and sophisticated self-adaptive scientific software ecosystems - SSECO [6], [7].

Livestock farming is one of the 21st century's less digitalized domains, but it can benefit from adopting digital tools. Improvements in animal welfare and long-term sustainability in livestock farming may be achieved using cutting-edge technology like big data analytics, machine learning, the Internet of Things, sensors, etc [8]. Farmers will be able to take better care of their animals sooner if IoT can assess the probability of sickness based on general information, such as a rise in temperature and a reduction in movement, and then alert them. Doing so increases manufacturing efficiency while manual labour and associated costs are decreased [9]. Livestock based on the Internet of Things can have their health monitored and controlled, and their surroundings and field supervised for the best feeding practices [10].

However, this process is hampered by various factors such as the remoteness of pastures from farms and settlements; difficult access to high mountain pastures; insufficient internet and network connectivity in these areas; the need for continuous monitoring of large hard-to-reach areas; the need to process and analyse dynamically

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incoming information related to the status of animals as well as that of pastures and many others. A topical issue in research is the use of different approaches to monitoring the state of cattle and pasture breeding [11]. On the other hand, not many studies until now have reported an evaluation of the social and environmental impact of solutions that substantially reduce the workforce [12]. Also the requirements of smart livestock husbandry for practice are very high [13].

There have been bottlenecks in developing smart livestock husbandry, and the problems are mostly related to the immaturity of related technologies, imperfection of related equipment, and a lack of product supply chains [14]. Designers of large Agriculture 4.0 research and development programs need to ensure that the focus goes beyond the development of the latest sensor or device. Such programs need to take a more holistic perspective to include consideration of supporting regulatory, business model, advisory, and capability development to enable uptake and ensure the benefits of Agriculture 4.0 are shared [15]. We also are willing to underline the challenges and opportunities of Agriculture 4.0 in cattle husbandry.

## II. Methods and Research Design

This research aims to provide Livestock Farmers with a guide to understanding the concepts of digitization, digitalizing, and digital transformation in their context. This research question seeks to determine which digital tools and platforms are most successful for enhancing farm management and decision-making and how they may be integrated with current systems and processes.

This study examined the factors that influence the digitalization of livestock operations. Using a Google Forms-created online survey, data for this study were gathered for this investigation among five countries—Argentina, Bolivia, Brazil, Germany, and Paraguay. The questionnaire comprised ten closed-ended questions designed to collect data on the attitudes and experiences of livestock producers regarding the use of digital technology in livestock operations. The chi-square test was utilized in this study as a statistical method for further data analysis.

Limitation of the study - the study does not examine the attitudes of other actors in the cattle business and is limited to a specific locale, which may impact the generalizability of the results. Finally, self-reporting through a survey also introduces the possibility of response bias, in which participants may provide socially desirable answers or do not accurately reflect their actual experiences or opinions. The study's findings will be analysed while considering these limitations, and future research can address these limits by employing different sampling methodologies, open-ended questions, and increasing geographic coverage.

By evaluating these aspects, the research may provide light on the obstacles and possibilities related to using digital technology in livestock operations. Also, the study may aid in identifying best practices and strategies for increasing the use and utilization of digital technologies in the cattle business.

### A. Methods

Using descriptive and inferential statistics, one hundred livestock producers from Argentina, Bolivia, Brazil, Germany, and Paraguay participated in an online questionnaire. The questionnaire was made available in four languages: English, Spanish, Portuguese, and German, to assure accessibility and inclusivity. This multilingual approach was intended to increase the diversity of perspectives captured by the survey by facilitating participation among farmers who spoke these languages. These countries were chosen to provide a variegated representation of livestock producers from various regions, each with distinctive characteristics and contexts about digitization in livestock operations. By including participants from multiple countries, the study sought to capture a variety of perspectives and experiences, thereby enhancing knowledge of the factors that influence the adoption of digital technology in cattle husbandry. This study will use the chi-square test as a statistical method for further data analysis.

### B. Research design

This quantitative study employed a survey-based methodology and a quantitative research design. The authors were using the following research design “Fig.1”.

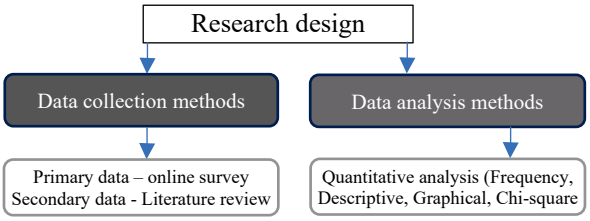


Fig. 1. Research design.

The sampling technique utilized in this investigation was convenience sampling. Given the practical constraints and limited resources, convenience sampling was an appropriate method for efficiently recruiting participants. Livestock producers were solicited through various livestock-related groups and organizations, such as industry associations, agricultural cooperatives, and online forums. This strategy enabled access to a large pool of willing and easily accessible potential participants.

## III. Data Analysis

65 percent of the sample's 100 livestock producers reported using digital technology. These participants were categorized as "technology adopters" and provided insightful information regarding their experiences, obstacles, and benefits of digitization in livestock agriculture. The "non-adopters" comprised 35 participants who did not use digital technology. Their perspectives and reasons for not implementing digital technology were crucial to comprehending the obstacles and limitations associated with digitization in the livestock industry.

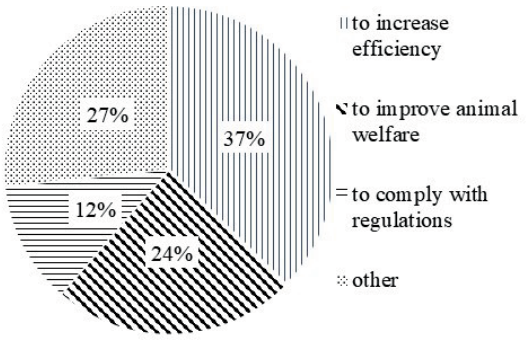


Fig. 2. Q2.What is the primary reason why you have implemented digital technologies in your livestock enterprise?

"Fig.2" indicates that the key motivations for deploying digital technology in livestock operations are to boost efficiency and improve animal welfare. Regulatory compliance was a lesser priority but was nonetheless mentioned by several respondents. It also implies that cattle industry owners may have other, non-question-specific motivations to embrace digital technology. Efficiency and animal welfare are the most often mentioned reasons for deploying digital technology in the cattle business.

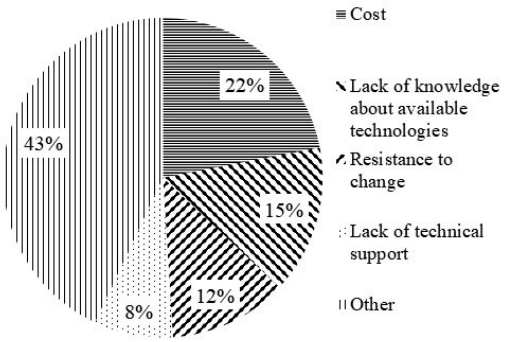


Fig. 3. Q3.What are your biggest challenges when implementing digital technologies in your livestock enterprise?

The survey also inquired about the most significant obstacles to utilizing digital technology in livestock agriculture "Fig. 3". The cost was the most often cited obstacle (22%), followed by lack of awareness about current technologies (15%), unwillingness to change (12%), and lack of technical assistance (8%). In addition, 43% of respondents also noted other obstacles.

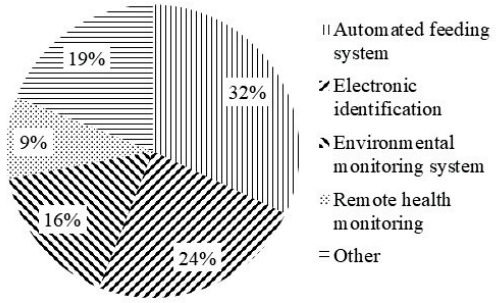


Fig. 4. Q4.Which digital technologies you have implemented in your livestock enterprise?

In addition, respondents were questioned on the digital technology they had deployed in their cattle operation. Automated feeding systems were the most generally installed technology (32%), followed by electronic identification (e.g., ear tags) (24%), environmental monitoring systems (16%), and remote health monitoring (9%). 19% of respondents also cited other technology "Fig. 4".

The survey also inquired about the implications of digital technology implementation on livestock farming. The most often reported positive benefits were better animal health (28%), greater output (26%), and decreased labour expenses (18%). Some responders (12%) also noted a rise in profitability, while others (16%) highlighted additional impacts "Fig.5".

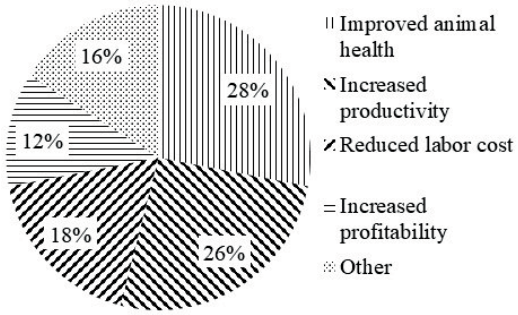


Fig. 5. Q5.How has the implementation of digital technologies affected your livestock enterprise?

According to the data, a substantial proportion of respondents acknowledged the positive effects of digital technology on animal health and production. This indicates that digital solutions have enhanced animal welfare and productivity in livestock operations. In addition, the results validate digital technology's potential as a valuable instrument for optimizing livestock husbandry practices. Diverse perspectives were expressed by respondents regarding the future of digital technology in livestock agriculture. Forty percent of those surveyed believed digital technologies would become even more important. This demonstrates a positive outlook and highlights the perceived value and potential innovations that digital solutions may bring to the livestock industry. In contrast, 28% of respondents indicated that digital technologies would continue to be significant, but not to the same degree as today. This perspective implies a degree of stability and acknowledges that digital technology has already had a significant impact on livestock operations, with the expectation that its significance will likely plateau or reach a saturation point.

Intriguingly, 12% of respondents predicted that the significance of digital technology would diminish in the future. This viewpoint may reflect concerns or doubts regarding digital solutions' long-term viability or efficacy in livestock agriculture. In addition, 20% of respondents were doubtful about the significance of digital technology in the future, highlighting the need for additional research and analysis to completely comprehend the potential trajectory of technological advancements in the livestock industry "Fig.6".

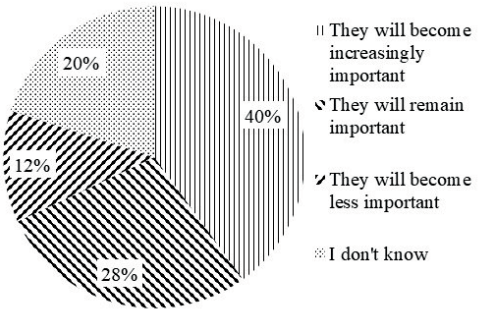


Fig. 6. Q6.How do you see the role of digital technologies evolving in livestock farming in the future?

In order to determine which elements would increase the likelihood that farmers would adopt digital technology, the study queried respondents about the aspects that would affect their choice. The most often reported reason was lower cost (24%), followed by improved technical assistance (18%), a greater understanding of existing technologies (15%), and proof of their usefulness (11%). In addition, 32% of respondents also noted other issues "Fig.7".

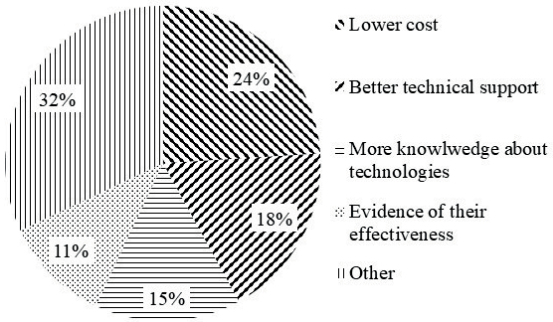


Fig. 7. Q7.What factors would make you more likely to implement digital technologies in your livestock enterprise?

Cost and technical assistance are significant variables in influencing the possibility of integrating digital technology in a livestock operation, according to "Fig. 7". In order to stimulate deployment, the findings also underscore the need for a better understanding of current technologies and proof of their efficacy. This information sheds light on the elements that may impact the adoption of digital technology in the livestock business. Finally, it implies that cost and technical assistance are important factors and that there is a need for further information and data to support technology adoption decision-making.

Respondents were asked how they maintain their knowledge of digital technology in livestock agriculture (Q8). Trade periodicals (29%) and internet resources (27%) were the most prevalent information sources, followed by conferences or workshops (18%). 26% of respondents additionally indicated other sources of information.

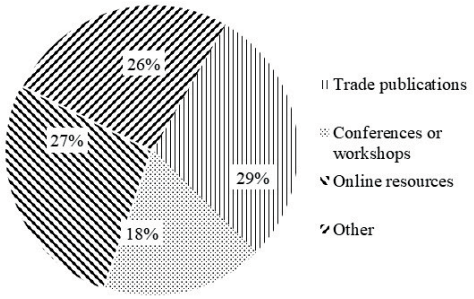


Fig. 8. Q8. How do you stay informed about digital technologies in livestock farming?

The survey also gathered information about farmers' familiarity with digital technology in livestock operations. For example, 36% of respondents reported being very comfortable, 28% reported being comfortable, 14% were indifferent, 12% reported being unpleasant, and 10% reported being uncomfortable. It indicates that most respondents are comfortable using digital technology in livestock operations, with just a tiny fraction indicating discomfort (Q9).

There may be some ambiguity or lack of expertise with digital technology in the business, judging by the relatively high percentage of respondents who reported feeling indifferent. This information sheds light on how familiar cattle firm owners are with digital technology. Most respondents seem comfortable utilizing these technologies, although there may be some confusion or lack of expertise that must be addressed to promote wider uptake and use. "Fig.9" reveals that the majority of the respondents feel that the future of cattle farming will become more technology-driven, reflecting a belief in the expanding use of digital technologies within the business. Twenty-two respondents feel that the future of livestock farming will stay mostly unchanged, indicating a more conservative or cautious view of technology's role in the business. In addition, 18 respondents feel that animal farming will become more environmentally and socially sustainable in the future, focusing on environmental and social sustainability in the business. For example, 15 respondents specified "other" opinions on the future of cattle farming, but we have no information regarding their opinions.

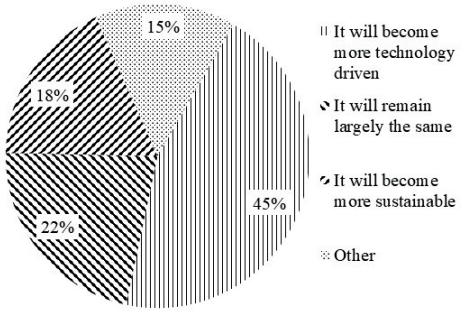


Fig. 9. Q10.How do you see the future of livestock farming in general?

In conclusion, most respondents have incorporated digital technology in their livestock operations to enhance efficiency and animal welfare. The technologies most often utilized were automated feeding systems and electronic identification. Cost and a lack of information on accessible technology were the primary obstacles to deploying digital technologies. Respondents reported several beneficial

outcomes, including enhanced animal health and enhanced output. Others were dubious as to whether digital technology would become more significant. Cheaper costs and improved technical assistance would influence the choice of farmers to use digital technology. The most prevalent knowledge sources on digital technology were trade periodicals and internet sites. In general, farmers' familiarity with digital technology varied.

*A. Chi-Square test*

According to the study findings, the key motivations for employing digital technology in livestock farming were to boost efficiency (28%) and improve animal welfare (18%). Cost (22%) and lack of information about available technology (15%) were the greatest barriers to using digital technologies. Automated feeding systems (32%) and electronic identification (such as ear tags) (24%) were the most typically installed digital technology.

TABLE 1 SURVEY SUMMARY

| Survey Question | Category 1 | Category 2 | Category 3 | Category 4 | Category 5 |
|---|---|---|---|---|---|
| 1 | 65 | 35 | - | - | - |
| 2 | 28 | 18 | 9 | 20 | - |
| 3 | 22 | 15 | 12 | 8 | 43 |
| 4 | 32 | 24 | 16 | 9 | 19 |
| 5 | 28 | 26 | 18 | 12 | 16 |
| 6 | 40 | 28 | 12 | 20 | - |
| 7 | 24 | 18 | 15 | 11 | 32 |
| 8 | 29 | 18 | 27 | 26 | - |
| 9 | 36 | 28 | 14 | 12 | 10 |
| 10 | 45 | 22 | 18 | 15 | - |

28% of respondents noted that digital technologies improve animal health, 26% of respondents said that they increase output and 18% of respondents noted that digital technologies reduce labour costs - “Table 1”.

Respondents that have adopted digital technology in their cattle operation claim various advantages, as shown in “Table 2”. Most respondents claimed that the deployment of digital technology had enhanced animal health (32%) and production (25%). These findings are consistent with the principal motivations for deploying digital technology: to enhance efficiency and animal welfare. The data also shows that respondents who have used digital technology have reported lower labour expenses (23%) and higher profitability (11%). Although they are not the most often cited advantages, they are important and show that digital technology may improve the financial viability of cattle operations. 9% of respondents who have used digital technology claimed "Other" advantages, which is interesting. However, it is impossible to establish these benefits without more information, but it shows that integrating digital technology in cattle farming may provide various benefits beyond those identified in the survey.

TABLE 2 CHI-SQUARE TABLE

| | Animal Health | Increased productiv. | Reduced labour costs | Increased profitabil. | Other | Total |
|---|---|---|---|---|---|---|
| Implement. digital technologies | 21 (32%) | 16 (25%) | 15 (23%) | 7 (11%) | 6 (9%) | 65 100% |
| Not implement. | 7 (20%) | 10 (29%) | 3 (9%) | 5 (14%) | 10 (29%) | 35 100% |
| Total | 28 | 26 | 18 | 12 | 16 | 100 |

The chi-square test assessed the association between digital technology installation and the stated efficiency levels, animal welfare, and profitability. There was a substantial relationship between the use of digital technology and reported levels of efficiency ($\chi 2$ = 9.58 (9,48 minimum for p=0,05), p= 0.05, degree of freedom = 4).

Therefore, it can be concluded that there is a significant relationship between the implementation of digital technologies and the reported effects on livestock enterprises, supporting the hypothesis that livestock farmers who have implemented digital technologies report higher levels of efficiency, animal welfare, and profitability than those who have not.

The data also reveals that respondents who have yet to incorporate digital technology did not report any improvements in animal health, productivity, labour expenses, or profitability. This shows that digital technology may be crucial for reaching these gains and that cattle producers who have to adopt them may be losing out on possible advantages. However, it is crucial to highlight that the reasons for not integrating digital technology may be diverse and complicated, and one chart can only capture some of them.

TABLE 3 CHI-SQUARE FOR GREATEST OBSTACLES

| | Cost | Lack of knowledge | Resistance to change | Lack of technical support | Other | Total |
|---|---|---|---|---|---|---|
| Implemented digital technologies | 20 31% | 14 22% | 8 12% | 7 11% | 16 25% | 65 **100%** |
| Not implemented | 2 3% | 1 2% | 4 6% | 1 2% | 27 42% | 35 **100%** |
| Total | 22 | 15 | 12 | 8 | 43 | 100 |

A chi-square test may also be used to evaluate the hypothesis that livestock producers' greatest obstacles for digital technology integration are different for those who already adopted digital technologies and for others who are planning to implement it in the future. To do this, a contingency table will be produced, including the frequencies of the two variables: "Largest obstacles livestock producers face when applying digital technology" and expectation of none-implementers "Not implemented".

“Table 3” shows that 20 out of 65 respondents who implemented reported cost as their biggest challenge, while 14 out of 65 reported lack of knowledge as their biggest challenge.

“Table 3” displays the worst problems respondents encountered while using digital technology in their cattle operation, divided by implementation category.

As seen in the “Table 3”, 43% of respondents cited "Other" as their major issue. This shows that cattle producers may encounter additional obstacles when deploying digital technology beyond those stated in the study. The particular category of "Cost" was the most often reported problem, with 22% of respondents citing it as their

greatest obstacle. This is not unexpected, given that integrating new technology may be costly, and smaller livestock operations may have limited funds for such expenditures. This is further confirmed by the fact that when respondents were asked to name their greatest issue, implementation costs and a lack of knowledge and technical help/support were the most often reported obstacles. 15% of respondents reported a "Lack of understanding about accessible technology" as their key issue, making it the second most often stated obstacle. This emphasizes the significance of education and training for livestock producers to stay up with the continuously expanding technological environment. 12 % and 8% of respondents named "Resistance to Change" and "Lack of Technical Support" reasons for their organizations' failure to adapt to new technologies. These obstacles imply that more assistance and resources may be required to assist livestock producers in understanding and using digital technology. Cost and lack of understanding are two major obstacles cattle producers face when utilizing digital technology. This underscores the necessity of providing livestock farmers with inexpensive and accessible technological solutions and education and training programs to keep them aware of the advantages of various technologies.

For this study (“Table 3"), the chi-square statistic is computed as follows: $\chi 2 = 28.17$. A chi-square distribution table with 4 degrees of freedom and a probability p of 0.001 can be consulted to find the critical value of chi-square, which is 18.47. Given that the calculated chi-square statistic (28.17) is higher than the critical value (18.47).

## IV. Conclusions

The findings of this study provide compelling evidence that incorporating digital technology in livestock husbandry positively affects productivity, animal welfare, and profitability. According to the study's findings, automated feeding systems and electronic identification, such as ear tags, were the most widely used digital technologies on the surveyed livestock ranches. Compared to those who did not adopt digital technology, livestock producers who did so reported greater efficiency, enhanced animal care, and increased profitability. This finding suggests that integrating digital technologies can substantially improve livestock farming's key performance indicators. Statistical analyses, such as the chi-square test, were administered to examine the correlation between digital technology adoption and outcomes. The chi-square test results supported the hypothesis that there is a significant correlation between the use of digital technology and levels of productivity, animal care, and profitability. This finding supports the notion that adopting digital technology is associated with favourable outcomes in livestock husbandry which is not new. In addition, it was conducted to evaluate the possibility that livestock producers' greatest obstacles are emerging when integrating digital technology, so real situation experience with technology adoption is arises during implementation. Respondents cited cost as the primary impediment to adoption, and there was a significant correlation between the obstacles cited and the implementation cost and lack of technical support. This finding emphasizes the significance of resolving cost-related obstacles and providing sufficient support to facilitate the adoption of digital technology in the livestock industry. The research findings indicate that livestock producers can improve their operations by adopting digital technologies through technology transfer. The results indicate that adopting digital technology is associated with productivity, animal welfare, and profitability gains. Nonetheless, it is essential to recognize and resolve the obstacles that impede the widespread adoption of digital technology, specifically the implementation cost and the availability of expert assistance. To encourage the widespread adoption of digital technology in livestock husbandry, efforts should focus on reducing implementation costs, providing financial incentives, and enhancing access to knowledge and technical support. By addressing these obstacles, the livestock industry can maximize the benefits of digital technology, resulting in more efficient and sustainable agricultural practices.

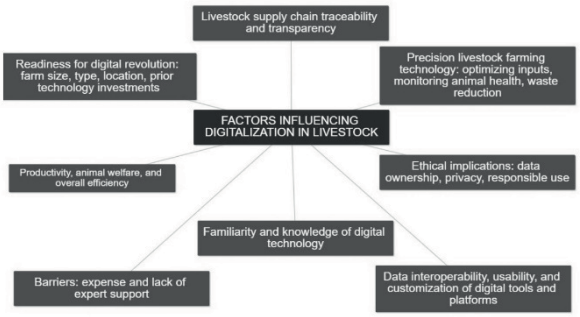


Fig. 10. Factors influencing digitalization in livestock

Also, the findings of this study highlight the need for sustained research and collaboration among stakeholders to surmount obstacles and facilitate the widespread adoption of digital technology in livestock husbandry. As a result, the industry can realize its maximum potential and attain enhanced productivity, animal welfare, and financial outcomes. We present a small model based on the survey which could help to visualize our findings “Fig.10”.

The livestock farming industry's readiness for the digital revolution varies depending on factors such as the farm's size, type, location, and investment in technology. While some farms have made significant investments in digital technology and are reaping its benefits, others may require thorough preparation to catch up. The cost is a major barrier to adopting digital technology, which affects small-scale producers with limited resources the most. Furthermore, data ownership, privacy, and ethical use of digital technology in livestock farming need addressing. Despite these challenges, more livestock farms recognize digital technology's potential benefits and are preparing for the digital revolution. Precision livestock farming technology has received substantial investment in recent years, and it aims to use data and analytics to optimize inputs like feed and water, monitor animal health, and reduce waste. There is also a growing awareness of traceability and transparency in the livestock supply chain, which can be facilitated by digital technologies such as blockchain. Three of the most widely accepted forms of digital technology amongst farmers were automated feeding systems, electronic identification, and environmental monitoring. These tools may improve feeding precision, animal tracking, and herd management while reducing the need for human labour. The survey

found that many farmers have seen an uptick in animal health and output after adopting digital technologies for use in livestock care. As a result, there may be more room for cost savings and optimization of digital technology since just a minority of respondents indicated increased profitability. Additionally, the research highlights the ethical considerations associated with using digital technology in livestock husbandry especially in respect to new standards of Industry 5.0.

## REFERENCES

[1] R. Stefanini and G. Vignali, "The Environmental, Economic and Social Impact of Industry 4.0 in the Food Sector: a Descriptive Literature Review," *IFAC-PapersOnLine*, vol. 55, no. 10, pp. 1497–1502, 2022, doi: 10.1016/j.ifacol.2022.09.602.

[2] M. Javaid, A. Haleem, R. P. Singh, and R. Suman, "Enhancing smart farming through the applications of Agriculture 4.0 technologies," *Int. J. Intell. Networks*, vol. 3, pp. 150–164, 2022, doi: 10.1016/j.ijin.2022.09.004.

[3] A. Amato *et al.*, "Artificial Intelligence-Based Early Prediction Techniques in Agri-Tech Domain," *Lect. Notes Networks Syst.*, vol. 312, pp. 42–48, 2022, doi: 10.1007/978-3-030-84910-8_5.

[4] J. Gomes *et al.*, "A scientific software ecosystem architecture for the livestock domain," *Inf. Softw. Technol.*, vol. 160, 2023, doi: 10.1016/j.infsof.2023.107240.

[5] K. Manikas, "Revisiting software ecosystems Research: A longitudinal literature study," *J. Syst. Softw.*, vol. 117, pp. 84–103, 2016, doi: 10.1016/j.jss.2016.02.003.

[6] L. Ambrósio *et al.*, "Enhancing the Reuse of Scientific Experiments for Agricultural Software Ecosystems," *J. Grid Comput.*, vol. 19, no. 4, 2021, doi: 10.1007/s10723-021-09583-x.

[7] F. Gualdi and A. Cordella, "Artificial intelligence and decision-making: The question of accountability," *Proc. Annu. Hawaii Int. Conf. Syst. Sci.*, vol. 2020-Janua, pp. 2297–2306, 2021, doi: 10.24251/hicss.2021.281.

[8] R. S. Alonso, I. Sittón-Candanedo, Ó. García, J. Prieto, and S. Rodríguez-González, "An intelligent Edge-IoT platform for monitoring livestock and crops in a dairy farming scenario," *Ad Hoc Networks*, vol. 98, 2020, doi: 10.1016/j.adhoc.2019.102047.

[9] D. Lovarelli, J. Bacenetti, and M. Guarino, "A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production?," *J. Clean. Prod.*, vol. 262, 2020, doi: 10.1016/j.jclepro.2020.121409.

[10] L. O. Tedeschi, P. L. Greenwood, and I. Halachmi, "Advancements in sensor technology and decision support intelligent tools to assist smart livestock farming," *J. Anim. Sci.*, vol. 99, no. 2, 2021, doi: 10.1093/jas/skab038.

[11] E. Valchev, P. Malinov, T. Glushkova, and S. Stoyanov, "Approach for modeling and implementation of an intelligent system for livestock cattle on pastures," *IFAC-PapersOnLine*, vol. 55, no. 32, pp. 211–216, 2022, doi: 10.1016/j.ifacol.2022.11.141.

[12] S. Lertpiromsuk, P. Ueasangkomsate, and Y. Sudharatna, "Skills and Human Resource Management for Industry 4.0 of Small and Medium Enterprises," *Lect. Notes Networks Syst.*, vol. 236, pp. 613–621, 2022, doi: 10.1007/978-981-16-2380-6_54.

[13] Y. Zhou, W. Tiemuer, and L. Zhou, "Bibliometric analysis of smart livestock from 1998-2022," *Procedia Comput. Sci.*, vol. 214, no. C, pp. 1428–1435, 2022, doi: 10.1016/j.procs.2022.11.327.

[14] E. Totin *et al.*, "Institutional perspectives of climate-smart agriculture: A systematic literature review," *Sustain.*, vol. 10, no. 6, 2018, doi: 10.3390/su10061990.

[15] C. R. Eastwood, J. P. Edwards, and J. A. Turner, "Review: Anticipating alternative trajectories for responsible Agriculture 4.0 innovation in livestock systems," *Animal*, vol. 15, 2021, doi: 10.1016/j.animal.2021.100296.