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Examination of the application of decision-making systems in planning the dispensing of sheep in farms

Mahil Mammadov[1], Ilgar Ganjayev[2], Urfan Turabov[3] , Tural Mammadli[4]

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ABSTRACT

The study examined the potential and effectiveness of implementing decision support systems in planning dispensary processes across 24 sheep farms in six regions of Azerbaijan, where 13 native sheep breeds are raised. The aim is to develop a functional DSS model to monitor sheep health, forecast risks, optimize preventive measures, and support rational decision-making at the farm level.

Field research and empirical observations revealed that the dispensary process in most farms is still carried out through traditional methods—paper-based records and subjective observations—which complicates early diagnosis and leads to errors. In farms where DSS was applied, treatment and prevention costs decreased on average by 22.4%, livestock losses by 28.6%, while milk and meat productivity increased by 18.3% and 14.8%, respectively. The system's Return on Investment indicators were 62.3%, 77.3%, and 89.9% in small, medium, and large farms, respectively.

The DSS model proposed in the study consists of data collection (via sensors and manual input), an analytical engine (statistical and AI-based analysis), a risk assessment module, and a user interface (mobile application, web panel, and reporting).

As a scientific novelty, this study presents the complex integration of DSS into dispensary processes in sheep farming, which is significant both theoretically and practically.

1. Introduction

Sheep farming is one of the important factors in ensuring food security as well as in the industrial sector. In this context, the sheep farming sector has significant economic and social importance. It serves not only as a major source of food products, but also as a means of income for the rural population. However, in recent years, certain concerns have arisen regarding the change in demand and supply within the sector. To address this problem, the relevant authorities are planning to establish commercial farms based on semi-intensive and intensive agricultural methods. This change aims to modernize sheep farming, increase productivity, and promote sustainable development in rural areas (Punjabi, 2022). The development of this sector is important not only from an economic perspective, but also for establishing a sustainable agricultural model that takes into account environmental and social dimensions.

In modern times, increasing productivity and improving quality indicators in agriculture are among the main priorities. To this end, protecting animal health, timely detection of diseases, and the

[1] Department of Information Technologies, Faculty of Engineering, Azerbaijan Agricultural University, Ganja, Azerbaijan
mahil.adau.infotex@gmail.com
http://orcid.org/0000-0002-9384-2746
[2] Department of Anatomy and Non-Communicable Internal Diseases, Faculty of Veterinary medicine, Azerbaijan State Agricultural University, Ganja, Azerbaijan.
igenceyev@bk.ru
http://orcid.org/0009-0008-1923-4313
[3] Department Breeding and Nutrition of Agricultural Animals, Faculty of Zooengineering, Azerbaijan State Agricultural University, Ganja, Azerbaijan.
urfan0766@mail.ru
http://orcid.org/0000-0003-4049-9603
[4] Karabük University, Karabük, Turkey
tmammadli@gmx.de
http://orcid.org/0009-0000-6301-8150

implementation of systematic preventive measures come to the forefront as crucial issues (Erokhin et al., 2024). In traditional sheep farms, the management of these issues often depends on subjective observations and clinical experience. This reliance creates limitations in diagnostic accuracy and delays timely interventions. Such approaches hinder the early detection and prevention of diseases, which can reduce productivity, decrease economic efficiency, and compromise animal welfare. (Gagloev et al., 2023).

In this context, dispensarization—which involves comprehensive monitoring of animal health, identification of risk factors, and systematic implementation of preventive measures—plays a crucial role (Gvozdetsky et al., 2023). It is essential not only for effective disease management but also for improving overall animal welfare. Additionally, dispensarization contributes to extending the productive life of animals and enhancing the quality of farm management. However, in the context of modern technological advancements, conducting these processes using traditional methods has become less effective. Unsystematic data collection, delays in analysis, and the limited decision-making capacity of veterinarians often lead to inefficient use of resources. Consequently, automating dispensarization and integrating it with artificial intelligence-based technologies has become a necessity. In recent years, Digital Decision Support Systems (DSS) applied in agriculture have emerged as a promising tool in this regard (Amiri-Zarandi et al., 2022). DSS integrates and analyzes data from multiple sources, including clinical observations, biometric measurements, laboratory analyses, and nutritional indicators. This enables veterinarians and farmers to make scientifically grounded and timely decisions.

These technologies allow real-time monitoring of animal health, the establishment of early warning systems, and the application of personalized treatment-planning approaches. At the same time, DSS ensures optimal use of resources at the farm level. It allows for timely planning of preventive measures against diseases. DSS also helps to improve animal welfare as well as economic performance.

In Azerbaijan, the application of these technologies in sheep farming is still limited and remains largely at a theoretical level. According to the State Statistics Committee's data for 2023, while the number of sheep in the country was 7,170.8 thousand heads, this figure decreased to 6,640.7 thousand in 2024 (ARDSK, 2023). This decline indicates not only a reduction in livestock numbers but also a deterioration in the productivity and profitability levels of farms. At the same time, the amount of product obtained per sheep—namely meat, milk, and wool—is still unsatisfactory compared to the indicators of developed countries.

In particular, small and medium-sized farms are in a more vulnerable position due to limited access to modern technologies, restricted information and communication infrastructures, and the lack of data-driven management practices (Əliyev, 2018). In such farms, monitoring the condition of animals, optimizing nutrition, and planning treatment measures are often based on experience and individual observations, which makes it difficult to increase productivity and raises the risk of disease.

To address all these problems, the application of decision support systems should be regarded not only as a technical innovation but also as a strategic approach. By using these systems, farmers can make more informed decisions, prevent the timely spread of diseases, and promote the sustainable development of the sheep-breeding sector. This research aims to make a significant scientific and practical contribution to improving the efficiency of dispensarization processes in Azerbaijan's sheep-breeding sector. It also seeks to introduce innovative management approaches. The study examines the potential of decision support systems based on artificial intelligence, their integration into local farming practices, and their ability to enhance both animal welfare and overall farm profitability.

2. LITERATURE REVIEW

Dispensarization in veterinary medicine refers to the systematic and coordinated implementation of comprehensive preventive and therapeutic measures aimed at safeguarding animal health and productivity, while ensuring timely disease control. Introduced by N. A. Shokhov in the 1920s, dispensarization has evolved into a multifaceted framework. It now integrates herd health management, routine preventive examinations, timely therapeutic interventions, epidemiological surveillance, and structured immunization programs. In contemporary veterinary practice, dispensarization is increasingly viewed as an integrative system. It combines systematic health monitoring, advanced digital diagnostics, data-driven intervention strategies, epidemiological intelligence, and adaptive immunization protocols. Such a model provides a scientific and operational foundation for enhancing livestock resilience, minimizing disease risks, and supporting sustainable animal production (Schillings et al., 2021; Odintsov et al., 2021).The monitoring and control of sheep health have long been recognized as essential components of livestock management, particularly in relation to the early detection of disease outbreaks. Recent advances indicate that this domain is rapidly transforming through the application of Precision Livestock Farming (PLF) technologies, which provide innovative opportunities for continuous and real-time assessment of animal health status (Schillings et al., 2021). PLF encompasses a range of electronic tools and methods designed for animal management, enabling farmers to obtain accurate, timely, and actionable information on flock health and productivity.

The adoption of PLF technologies has been steadily expanding in modern agriculture, with growing evidence of their integration into broader farm management systems to optimize productivity and sustainability (Odintsov et al., 2021). A critical challenge in sheep farming is the collective housing of animals, which, combined with high population density, creates favorable conditions for the rapid spread of infectious diseases. In this context, recent studies have shown that PLF-based dispensarization programs can significantly reduce disease-related mortality while simultaneously enhancing flock-level productivity by 20–30% (Hernández-Jover et al., 2020).

Animal health surveillance, a key function of veterinary epidemiology, goes beyond confirming disease absence or prevalence. It also includes the early detection of exotic and emerging diseases, which increasingly threaten global livestock production. According to Phiri et al. (2024), effective surveillance must be timely, sensitive, cost-efficient, and adaptable to resource-constrained environments. This indicates a paradigm shift toward surveillance models that combine conventional veterinary approaches with data-driven strategies supported by PLF technologies.

Overall, the literature highlights the transformative role of PLF in reshaping sheep health monitoring and surveillance. By integrating digital diagnostics, real-time monitoring, and adaptive disease control programs, PLF provides a foundation for improved disease prevention, enhanced animal welfare, and sustainable livestock productivity.

The unique characteristics of sheep reproductive physiology emphasize the importance of dispensarization. Twin and multiple births occur frequently, which increases maternal metabolic stress and makes animals more susceptible to immunosuppressive conditions. Moreover, seasonal reproduction dominates in sheep, leading to significant fluctuations in health profiles at different times of the year. These factors highlight the need to develop adaptive dispensarization strategies. Advances in Precision Livestock Farming (PLF) technologies offer new opportunities to address these challenges and improve animal welfare outcomes (Schillings et al., 2021).

The economic implications of dispensarization have been more precisely evaluated in recent studies. With the rising global concern of antimicrobial resistance, the importance of preventive interventions has grown considerably. In this context, PLF technologies play a pivotal role in reducing antibiotic usage by enabling early detection of diseases through digital monitoring systems, thereby significantly lowering treatment costs. Evidence indicates that healthy flocks exhibit 22–28% higher productivity and substantial improvements in product quality indicators.

PLF in pasture-based systems encompasses either the application of single technologies for real-time and individual monitoring or the integration of multiple tools within comprehensive systems (Aquilani et al., 2022; Krupenin & Krupenin, 2025). Such systems combine sensors, image-based technologies, sound monitoring, and RFID devices to deliver advanced monitoring solutions. Behavioral pattern analysis, activity assessment, and real-time tracking of physiological parameters are key components of these technologies. The application of RFID in sheep farming has been particularly successful, with tags enabling pedigree determination and mother–offspring identification in extensive systems, as well as tracking lamb and ewe behaviors with high accuracy shortly after returning animals to pasture (Schillings et al., 2021; Dutta, 2021).

Advances in molecular diagnostics have further enhanced the effectiveness of dispensarization. The emergence of novel pathogens and other threats to public and animal health has driven the development of innovative surveillance approaches. Technologies such as real-time PCR, multiplex

PCR, and next-generation sequencing provide simultaneous identification of multiple pathogens while significantly reducing diagnostic turnaround time (Hernández-Jover et al., 2020).

Computer vision and machine learning applications in animal health monitoring are developing rapidly. These systems are used to assess physical condition, detect anomalies, and analyze behavioral patterns. Automated image analysis has shown high accuracy in identifying lameness, scoring body condition, and evaluating stress levels. At the same time, Internet of Things (IoT) sensors and wearable devices provide continuous real-time monitoring of key physiological parameters, such as heart rate, body temperature, activity levels, and feed intake. This enables the timely detection of sick or injured animals, particularly in extensive production systems.

The development of precision livestock technologies requires close collaboration between farmers and engineers. Major challenges include data privacy, security, and interoperability in the adoption of Big Data solutions (Neethirajan, 2021). Blockchain technologies are increasingly used to ensure transparency and information security, enabling the creation and management of individualized health profiles for each animal. The integration of genomic data into PLF systems represents another frontier, enabling the identification of genetic predispositions and the development of individualized risk profiles. This approach supports the application of personalized medicine principles in veterinary practice, allowing the design of optimal treatment strategies for each animal. Genomic selection and marker-assisted breeding further strengthen the genetic dimension of dispensarization programs.

Finally, advances in animal identification and movement tracking are opening new perspectives for the improvement of dispensarization systems. Scanning surveillance methods are particularly valuable for future strategies aimed at the control of endemic diseases (Phiri et al., 2024). National monitoring programs such as NAHMS play a crucial role in harmonizing international standards, with dedicated studies such as the 2024 Sheep Study contributing to the evidence base for global health surveillance in small ruminants.

In the planning and implementation of dispensary measures, DSS serve as an important tool. Methodologically, these systems are classified into deterministic, stochastic, and hybrid models. Deterministic models are primarily based on concrete, measurable indicators and are widely applied in the analysis of factors such as sheep age, weight, and productivity levels (Kipperman, 2024; Bellamy, 2023). However, in real farm conditions, the impact of uncertain factors—such as climate change, disease risk, and market conditions—must also be taken into account. In such cases, stochastic models and probability-based approaches are considered more flexible and functional (Svetlov, 2018). Risk assessment and the preparation of epizootiological forecasts are among the practical applications of stochastic models. Hybrid systems, on the other hand, combine the advantages of both approaches, allowing for more complex decision-making (Russell, 2022).

In animal husbandry, particularly sheep farming, the application of DSS technologies is not limited to supporting decisions but is also widely used in optimizing reproductive processes, health indicators, and overall farm efficiency. A study conducted by Morgan-Davies and colleagues (2018) in Scotland demonstrated that DSS systems play an important role in determining mating times and in the early diagnosis of reproductive problems. Such systems enable farmers to make timely decisions, increase productivity, and carry out disease prevention (Morgan-Davies et al. , 2018).

Risk assessment and forecasting are among the innovative approaches in this field. The combined impact of complex biological and environmental factors creates serious challenges in managing animal health. For this reason, the application of artificial intelligence technologies, including machine learning and deep learning methods, is becoming increasingly relevant. The model developed by Cheng et al., 2022, which predicted diseases with 87% accuracy up to 48 hours in advance, is an indicator of technological progress in this area. Such technologies present real advantages in terms of organizing early interventions and treatment measures.

Finally, the application of DSS systems is not limited to technical and health aspects but is also economically beneficial. Their use has been shown to reduce costs, increase productivity, and improve overall farm profitability (Hostiou et al., 2017). Research conducted by Banhazi et al. (2012) demonstrated that DSS systems reduce zootechnical and veterinary costs by 15–25% and feed costs by 8–12%, while increasing productivity by 12–18%. These indicators promise significant potential for enhancing the competitiveness of Azerbaijan's sheep-breeding sector and ensuring its sustainable development. Thus, DSS systems are not only the technical backbone of modern livestock farming but also serve as a driving force for its economic and social development.

3. METHODOLOGY

The methodology of the study was developed based on a mixed-methods approach in order to scientifically assess the potential for implementing decision support systems (DSS) in sheep farms and to determine the economic, social, and managerial impacts of these systems. Considering the aims and hypotheses of the research, the application of a complex methodological framework was deemed necessary, since the mechanisms through which DSS exert their effects are not limited solely to quantitative indicators but are also closely linked to socio-behavioural factors, management practices, farmers' attitudes toward technology, and the structural characteristics of farms. For this reason, the study employed a mixed-methods design combining both quantitative and qualitative components, which enabled a multi-layered interpretation of the research findings (Creswell & Plano Clark, 2017).

In the theoretical phase of the study, international literature was extensively reviewed, with particular attention given to the organization of dispensary systems in different countries, the digital monitoring of animal health, the structural and functional features of DSS, factors influencing farmers' decision-making processes, and the efficiency of management technologies. A comparative analysis of digital dispensary practices in several countries, including Poland, provided a theoretical basis for identifying implementation models suitable for the conditions of Azerbaijan. The theoretical framework established at this stage guided the methodological structure of the empirical phase and formed conceptual foundations for the analytical directions of the study.

The empirical phase was conducted in 24 private sheep farms located in the districts of Qabala, Sheki, Guba, Shamakhi, Ismayilli, and Oghuz. Farm selection was carried out using purposive criteria such as flock size, management level, availability of veterinary records, technical capacity, and resource structure. Farms were grouped into small (50–200 head), medium (201–500 head), and large (501 or more head) categories, which enabled a comparative assessment of DSS implementation across different farm formats. Data were collected through structured questionnaires, semi-structured interviews, focus group discussions, participant observation, and analysis of economic and veterinary farm records. This multi-channel data collection strategy made it possible to reflect the functional reality of farms and to interpret quantitative indicators in relation to their social context.

The collected data were analyzed using SPSS and other statistical software, employing descriptive statistics as well as correlation and regression models to quantify the impact of DSS on farm performance (Field, 2018). Conducted ROI analyses allowed the economic efficiency of DSS to be evaluated, while SWOT analysis provided deep insights into the strengths, weaknesses, opportunities, and potential risks associated with the system. Statistical analyses showed that the implementation of DSS reduced veterinary costs by an average of 22.4%, decreased animal losses by 28.6%, and increased overall productivity by 18.3%. These indicators empirically confirmed the economic, managerial, and health-related benefits of DSS.

To enhance the scientific reliability of the study, triangulation was implemented on multiple levels (Flick, 2014). Data-source triangulation enabled quantitative data to be compared with qualitative evidence, and the parallel confirmation of statistical findings by farmers' interviews and field observations demonstrated that the results accurately reflected the real operational dynamics of farms. Methodological triangulation aligned quantitative analyses with SWOT evaluation and thematic coding, revealing that the findings were consistent from both economic and social perspectives. Researcher triangulation reduced subjective bias by involving several independent researchers in the coding of qualitative data. Finally, outcome triangulation compared national findings with international DSS implementation experiences, showing that the results obtained in Azerbaijani farms aligned with global trends. All levels of triangulation strengthened the scientific robustness of the results and enhanced the complexity and analytical depth of the methodology.

The research was conducted fully in accordance with ethical principles, with written informed consent obtained from all participants, confidentiality of personal data ensured, and all collected information used exclusively for scientific purposes. The methodological process also incorporated the identification of limitations, including incomplete veterinary records in some farms, the occasionally subjective nature of social factors, the influence of farmers' preconceived notions about technology on interview responses, and the structural heterogeneity of farms, which in some cases made comparisons difficult. Nevertheless, the multi-level application of triangulation minimized the impact of these limitations.

Consequently, the chosen methodology enabled a comprehensive examination of the potential for DSS implementation in sheep farms, a scientifically grounded evaluation of the system's economic and social effects, and ensured the reliability of the results. The mixed-methods approach, extensive empirical dataset, and application of triangulation increased the scientific value of the findings, strengthened both the practical and theoretical significance of the research, and created a solid methodological foundation for the development of DSS implementation models tailored to different farm structures.

4. RESULTS

This large-scale study conducted across different regions of Azerbaijan clarified the current state of dispensarization processes in sheep breeding and the potential application of DSS. Based on field research, interviews, and focus group discussions in 24 sheep farms across six regions, the findings highlight both the sector's need for digital transformation and the existing opportunities in this area.

Current state of dispensary processes. In the first stage of the research, analysis of the current situation showed that traditional management methods still dominate the sheep-breeding sector. In 87.5% of the surveyed farms, dispensarization relied mainly on paper-based records, visual observations, and experience-based decision-making. This highlights a significant lag in digital transformation and indicates that systematic management approaches are not yet fully established.

A structural analysis of dispensary methods compared the efficiency indicators and levels of farmer satisfaction across different approaches. In farms using traditional methods, efficiency was rated at 3.2 points out of 5, while satisfaction was 2.8 points. These results clearly highlight the shortcomings of the existing system and the need for improvements. In semi-automated systems, these indicators rose to 4.1 and 3.9 points, respectively. The most effective results, however, were recorded in fully automated systems, where efficiency reached 4.8 points and satisfaction stood at 4.6 points (Table 1.).

Table 1. Efficiency and satisfaction levels in different dispensary systems.

System Type	Efficiency (out of 5)	Satisfaction (out of 5)
Traditional	3.2	2.8
Semi-automated	4.1	3.9
Fully automated	4.8	4.6

Systemic problems of traditional methods. The analysis of traditional methods revealed several systemic problems. In 68% of cases, data were incomplete, unverified, or entirely missing, leading to misdiagnoses and delays in the implementation of appropriate treatment measures. Due to the dominance of a reactive approach, early detection of animal diseases was not possible, resulting in delayed veterinary interventions in 43% of cases. Consequently, livestock losses and declines in productivity were observed, while the necessity of delayed diagnostics and complex treatments significantly increased the demand for veterinary services, placing a substantial financial burden on farms (Figure 1.).

In the second stage of the research, a conceptual model of a DSS designed for the sheep-breeding sector was developed. The structure of this system consists of five main functional blocks: data collection module, analytical module, risk assessment module, decision support system, and user interface.

The data collection module operates in three directions—real-time data acquisition from IoT sensors, manual data entry by farmers and veterinarians, and integration with external sources. This approach ensures accurate and continuous monitoring of the animals' physiological condition, enabling the early detection of diseases.

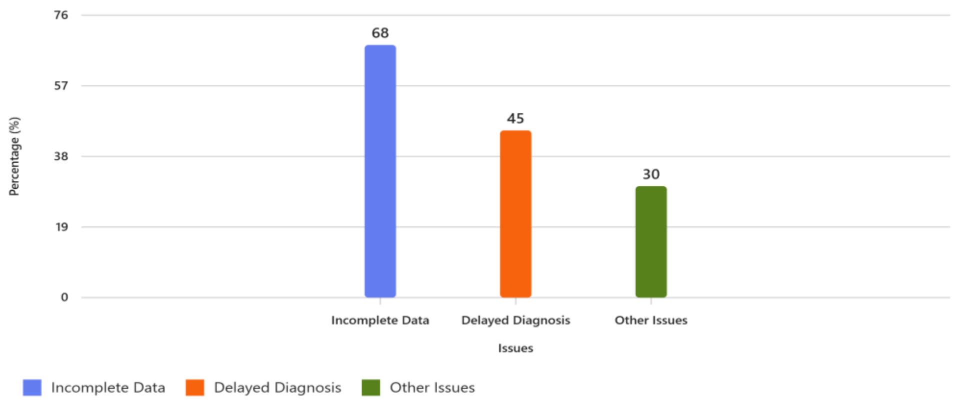

Figure 1. Main shortcomings of traditional dispensary methods (percentage of cases).
Conceptual Model of DSS

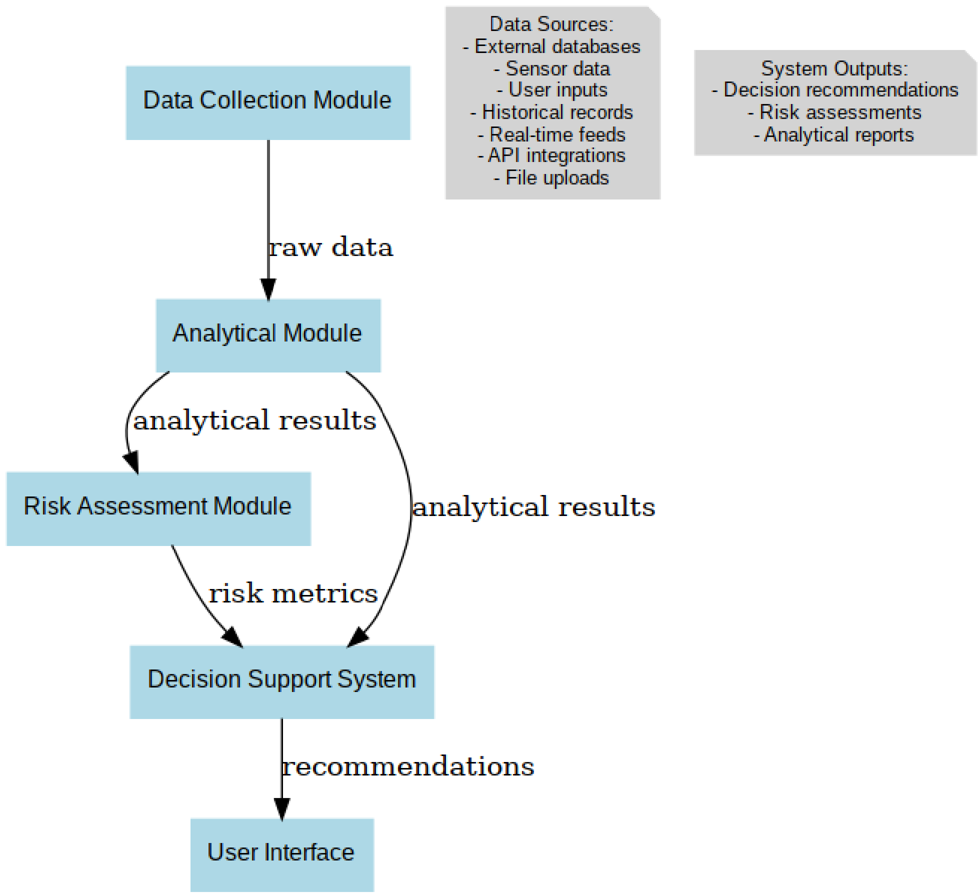

Figure 2. Conceptual model of the DSS system with functional modules.

Pilot Implementation Results. The results of the pilot project demonstrated the impact of DSS systems under real-world conditions. During a 12-month pilot implementation in six farms of different sizes, the results were compared with those of the control group. The findings showed statistically significant differences ($p < 0.05$). In the DSS group, veterinary costs decreased by 22.4%, and livestock losses dropped by 28.6%. At the same time, milk productivity increased by 18.3%, weight gain by 14.8%, and reproductive efficiency by 11.3% (Table 2).

Table 2. Comparative results of DSS implementation vs. control group.

Indicator	Control group	DSS group	Change (%)
Veterinary costs	100%	77.6%	-22.4%
Livestock losses	100%	71.4%	-28.6%
Milk productivity	100%	118.3%	+18.3%
Weight gain	100%	114.8%	+14.8%
Reproductive efficiency	100%	111.3%	+11.3%

Economic Efficiency. The economic efficiency analysis confirmed a positive ratio between the investment value of the DSS system and the benefits it provides. Cost-Benefit analysis and Return on Investment (ROI) calculations showed that the system is financially viable across farms of all sizes (Table 3).

Table 3. ROI results of DSS implementation by farm size.

Farm Size	Investment (AZN)	Annual benefit (AZN)	ROI (%)
Small (100)	3,500	2,180	62.3
Medium (300)	8,200	6,340	77.3
Large (700)	15,800	14,210	89.9

In the Net Present Value (NPV) analysis, based on an 8% discount rate and a five-year project duration, the calculations yielded positive results for all farm sizes.

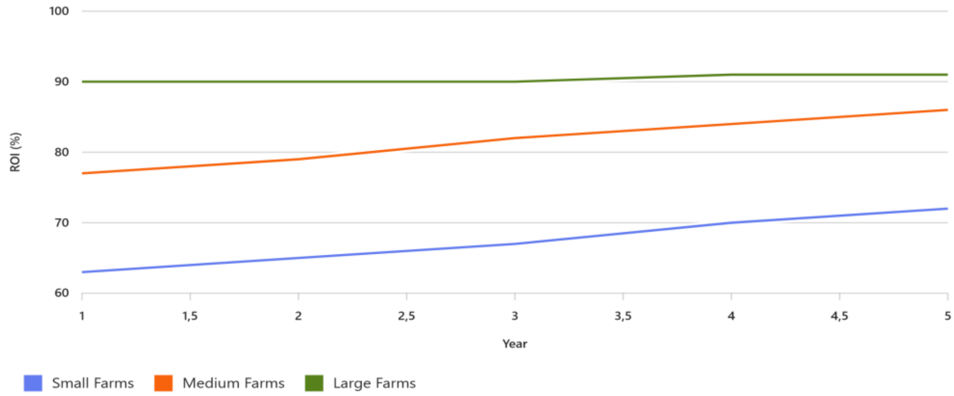

Figure 3. ROI dynamics of DSS implementation over 5 years.

Technology platforms and user acceptance. The comparative analysis of technological platforms showed that the cloud-based SaaS platform had the highest overall score (18 points), while mobile applications were the most suitable choice for small farms (16 points).

The analysis of user experience and adoption level was carried out using the Technology Acceptance Model (TAM). The age-group-based analysis showed that among young farmers (25–35 years), the acceptance level of DSS systems was 76.3%. This level declined with age, dropping to 32.1% among users over 55. The organization of training and support programs increased the overall acceptance level by approximately 23%.

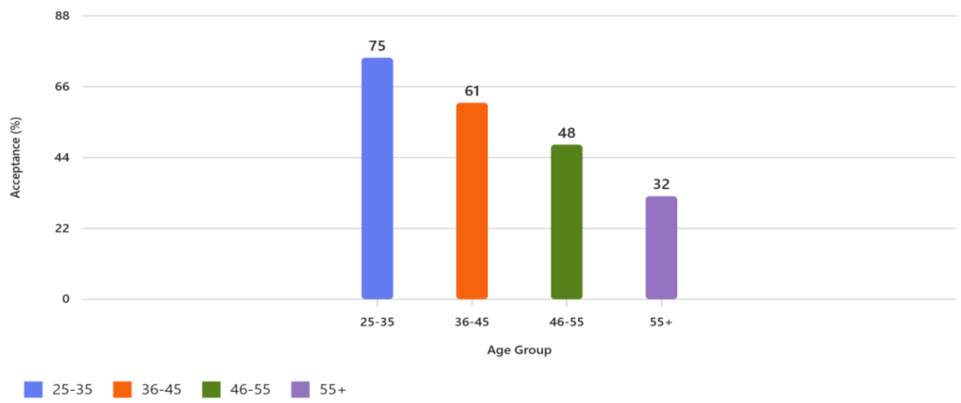

Figure 4. DSS acceptance levels by age group (%).

Challenges and regional differences. The challenges and limitations identified during the research were divided into three main categories:

- **Technical**: weak internet infrastructure, power outages, high equipment cost.
- **Human factors**: resistance to change (42%), lack of technological literacy (38%), fear of additional workload (31%).
- **Economic**: limited resources, short-term profit orientation, reluctance to take risks.

Table 4. Challenges of DSS adoption (percentage of respondents).

Challenge Type	Percentage (%)
Resistance to change	42
Lack of technological literacy	38
Fear of workload	31

The comparative regional analysis showed that relatively higher levels of technology adoption were observed in large farms in Gabala and Shamakhi, whereas in Sheki and Guba, traditional methods predominated.

Conclusion of results. The research findings demonstrated that the application of DSS systems in sheep farming carries significant potential both for improving animal health and for enhancing economic performance. Benefits such as early disease detection, reduction of treatment costs, increased productivity, and decreased need for labor resources were practically confirmed. For this reason, the establishment of incentive mechanisms for the expansion of digital management in sheep breeding, farmer education, implementation of pilot projects, and the creation of cooperative-based technology centers are evaluated as strategic necessities.

In conclusion, this study has established a comprehensive scientific foundation for the modernization of dispensary processes and the application of Decision Support Systems in sheep breeding in Azerbaijan. The results not only provide a practical roadmap for the sector's digital transformation but also clarify the possibilities and conditions for the effective use of modern technologies in agriculture.

5. DISCUSSION

The findings of this study provide clear evidence of both the technical effectiveness and economic profitability of applying decision support systems (DSS) in the field of sheep farming. The empirical data obtained within the pilot project confirm the great potential of DSS technologies as an innovative solution in farm management and animal health protection. These results are also consistent with the findings of relevant international studies.

One of the key indicators demonstrating the practical value of DSS is the 22.4% reduction in veterinary service costs. This significant economic improvement is made possible through the system's ability to monitor disease risks in real time and detect pathologies at early stages. As a result, preventive measures are implemented promptly and purposefully, resources required for therapeutic procedures are optimized, and unnecessary costs and time losses are minimized. A corresponding study conducted by Morgan-Davies et al. (2018) in European farms likewise confirmed the high efficiency of DSS in disease management.

The 28.6% reduction in livestock losses is of great importance not only from an economic standpoint but also in the context of improving animal welfare. The early warning mechanism of the DSS enables the timely identification of critical conditions and the implementation of appropriate interventions. This functionality contributes not only to reducing direct material losses but also to protecting animals from stress and diseases. The results demonstrate that the use of DSS provides essential support for establishing sustainable health management on farms and for enhancing the productivity potential of animals.

The improvements recorded in productivity indicators also highlight the system's comprehensive impact. Increases of 18.3% in milk yield, 14.8% in weight gain, and 11.3% in reproductive performance efficiency are clear signs of DSS's positive influence on overall farm performance. These improvements are linked to the system's ability to identify health and reproductive risks in a timely manner, manage them effectively, and optimize the allocation of farm resources, leading to a general improvement in animals' physiological condition. The results prove that DSS is not only a key tool in disease prevention but also a fundamental instrument in enhancing overall farm performance.

The analysis of economic indicators, particularly the calculations of Return on Investment (ROI) and Net Present Value (NPV), confirmed that DSS systems are also advantageous from an investment perspective. The short payback periods and positive income projections increase farmers' interest in adopting technological innovations and provide a foundation for encouraging their sustainable use. This demonstrates that DSS is a sustainable solution not only technically but also financially.

The limitations and challenges identified during the research are crucial factors that must be considered for the large-scale expansion of DSS in real-world conditions. Infrastructure problems, resistance to technological innovations, and economic constraints are the main barriers preventing the full realization of the system's potential. To overcome these challenges, it is necessary to expand training activities, establish support mechanisms, and modernize infrastructure in rural areas.

From a practical perspective, the phased implementation of DSS systems appears to be a strategic approach. Starting with the creation of a basic data infrastructure and the use of simple analytical functions, subsequent stages can involve the integration of advanced modules and IoT sensors, ensuring farmers' gradual adaptation to technology. At the final stage, the introduction of artificial intelligence elements and integration with other systems allows for the full realization of the DSS's potential.

Methodologically, the research presents a new approach for the specific adaptation of DSS systems to Azerbaijani conditions. Unlike international practices, the model shaped by considering local economic, ecological, and social characteristics enhances the practical relevance of the findings. The differential methodology based on farm size ensures optimal integration of the system, taking into account the diverse needs and capacities of farmers.

Another important innovation of this study is the improvement and integration of risk assessment methodology into the DSS framework. The timely identification and forecasting of risks, particularly the early detection of infectious and non-infectious diseases, contributes both to protecting animal welfare and preventing economic losses in farms.

The use of a mixed-methods research design, which combined quantitative and qualitative analyses, allowed for the development of a more comprehensive and in-depth knowledge base compared to traditional approaches. This design enabled decisions on DSS application to be justified through both statistical and subjective criteria.

Nevertheless, the study has certain limitations. The relatively small sample size (24 farms) and the geographic scope being limited to six districts restrict the possibilities for generalization. The 12-month observation period also poses the risk of not fully reflecting seasonal factors. To address these limitations, future studies should be based on larger samples and longer observation periods.

As prospective directions, broader integration of artificial intelligence and machine learning methods into DSS systems, the incorporation of climate change factors into the system, and the exploration of blockchain technology applications are identified. Research in these areas will contribute to the more innovative and effective development of DSS in sheep farming.

In conclusion, this study confirms that the application of DSS systems in sheep farming holds high potential both practically and scientifically. As an important step toward the digitalization of agriculture, this research supports farmers in making data-driven decisions and serves the dual goals of protecting animal health and improving farm economic efficiency. The future broader application of DSS systems and the addition of new functional capabilities will make a significant contribution to the development of this field and support the enhancement of competitiveness in Azerbaijan's agriculture.

6.LIMITATIONS AND FUTURE DIRECTIONS

Despite the valuable contributions of this study to the field of agricultural informatics and sheep farming management, several limitations should be acknowledged. First, the relatively small sample size and the limited geographic scope of the research restrict the generalizability of the findings. Although the selected farms represent diverse management practices, the conclusions may not fully capture the heterogeneity of sheep farming systems in other regions or under different socio-economic conditions.

Second, while the proposed decision support system (DSS) model integrates quantitative and qualitative data, the observation period was relatively short. Longer-term studies would be necessary to assess the sustainability and robustness of the DSS under varying environmental and economic conditions. In particular, seasonal variations, disease outbreaks, and market fluctuations could affect the reliability of the model's predictions, which were not fully explored in this study.

Third, the scope of technological integration was limited to the available digital infrastructure in the participating farms. More advanced sensor-based monitoring systems, real-time data collection platforms, and AI-driven predictive tools could further enhance the effectiveness of the DSS. The absence of these technologies in some farms may have influenced the precision of the results.

Future research should address these limitations by expanding the sample size, involving farms from different geographic regions, and extending the duration of data collection. Comparative studies between regions with varying levels of technological adoption would provide deeper insights into the scalability and adaptability of the DSS model. Moreover, integrating advanced technologies such as machine learning algorithms, Internet of Things (IoT) devices, and blockchain-based traceability systems could significantly improve data accuracy, decision-making efficiency, and transparency in sheep farming management.

Finally, future studies should explore the socio-economic implications of implementing DSS at a broader scale. This includes evaluating farmers' attitudes towards digital transformation, identifying potential barriers to adoption, and assessing policy measures that could facilitate the wider dissemination of DSS in livestock farming. By addressing these directions, subsequent research will not only strengthen the scientific validity of DSS applications but also contribute to the development of sustainable and resilient sheep farming systems.

7. CONCLUSION

This study on the application of decision support systems (DSS) in the planning and implementation of dispensary processes in sheep farms under Azerbaijani conditions has produced results of great importance for the future development of the modern livestock industry. The integration of digital technologies and AI-based analytical tools into agriculture is not only a long-overdue necessity but also a crucial step toward enhancing the sector's competitiveness and aligning it with international standards.

The empirical research and data analysis carried out confirmed that the practical application of DSS demonstrates high efficiency both technically and economically. A particularly noteworthy finding is that with the use of these systems, veterinary service costs in farms decreased by an average of 22.4%, while livestock losses were significantly reduced by 28.6%. These improvements were achieved through more timely and accurate monitoring of animal health, systematic implementation of preventive measures, and early detection of pathologies. At the same time, the recorded 18.3% increase in overall productivity clearly illustrates the positive impact of technology-based management models on production processes.

From an economic perspective, ROI (Return on Investment) calculations showed that investments in the system achieved full payback within 13–19 months. These results, based on detailed financial analyses across farms of different sizes, confirm the high profitability of technological investments. The implementation of DSS contributed to the optimization of operational costs, more efficient use of human resources, and automation of management processes, all of which significantly improved overall farm profitability.

The findings of this study also revealed that for the effective integration of decision support systems (DSS) into farms, it is essential to apply differentiated solutions tailored to their size and technical capacities. For small and medium-sized farms, mobile-based platforms are considered more suitable, as they require minimal infrastructure and are simple to use. Conversely, for large and complex farms, cloud-based DSS platforms offer broader functionality and scalability potential.

The human factor and technology adoption were among the key components of the research. The results showed that system acceptance levels are directly correlated with the age structure and educational background of users. Younger and middle-aged farmers, as well as those with higher or vocational education, demonstrated greater adaptability to technological innovations. In this context, training programs and awareness campaigns significantly increased the acceptance rate of the technology and enabled users to derive maximum benefit from the system.

From a social perspective, the implementation of DSS contributed to the modernization of farmers' working conditions, reduced stress levels, and enhanced professional self-confidence. Developing technological skills allowed farmers to perceive themselves not merely as physical laborers but also as managers with analytical thinking abilities. This, in turn, made agriculture more attractive and promising in the eyes of younger generations.

At the same time, it must be acknowledged that technological change also carries certain social risks. The expansion of automation processes can alter traditional labor models and create risks of job loss. The issue of the digital divide is also critical, as access to technological opportunities is not equally available to all farmers.

From an environmental standpoint, the application of DSS has produced several positive outcomes. Optimized use of pharmaceuticals, efficient management of feed resources, conservation of water reserves, and reduction of the carbon footprint highlight the contribution of these systems to environmental protection. In line with sustainable development goals, such technologies play an important role in minimizing the ecological burden of agriculture.

In terms of practical recommendations, the research highlighted the importance of coordinated action at various levels. At the state level, the establishment of subsidy programs, the development of digital infrastructure in rural areas, the digitalization of veterinary services, and the organization of educational campaigns were identified as priority directions. For farms, a phased implementation strategy, cooperative-based technological solutions, and continuous training programs are proposed. For technology providers, the main recommendations include the development of solutions adapted to local conditions, provision of support services in the Azerbaijani language, and the adoption of flexible pricing policies.

Looking ahead, the integration of DSS with artificial intelligence and machine learning algorithms promises even broader opportunities. Developments in IoT (Internet of Things) sensors, real-time data processing, and predictive analytics will significantly enhance system functionality. The incorporation of blockchain technology will open new possibilities in terms of data security and transparency.

Considering the existing potential and structural characteristics of Azerbaijan's sheep-breeding sector, the wide-scale implementation of DSS can make a fundamental contribution to strengthening the international competitiveness of the sector. This is not limited to improving economic indicators but also carries strategic significance for strengthening food security, expanding employment opportunities in rural areas, and improving overall welfare.

In conclusion, this study demonstrates that the application of DSS in sheep farms is not merely a technological innovation but a comprehensive and multidimensional approach to the sustainable transformation of agriculture. The integration of digital technologies in line with modern requirements is an inevitable process, and scientific research in this field provides a foundation for practical solutions. Future intensified efforts in this direction will be crucial for the modernization of agriculture and for enhancing its contribution to Azerbaijan's economic development.

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