Methods and approaches for risk assessment in livestock farm management

KRISTINA PAVLOVA
Institute of Information and Communication Technologies - BAS
BULGARIA

Abstract: - To promote sustainable agricultural development, this article explores basic techniques and strategies for risk assessment, analysis, and management in livestock farms. A methodical, multidisciplinary strategy is required for effective risk management in order to solve the intricate problems associated with livestock production. We offer a workable framework for implementing a model risk management strategy tailored to the specific traits and weaknesses of the livestock industry. Risk management in livestock operations covers a wide range of uncertainties, including changes in revenue and production costs, the constant threat of disease, fluctuations in input and output market prices, and the risks associated with capital investments. The work uses a number of important mathematical ideas and indicators to handle these concerns. These quantitative tools assist farmers in making well-informed decisions by allowing an objective comparison of various tactics and a study of their possible effects.

Key-Words: - livestock farms, risk, management, risk assessment, analysis.

Received: June 25, 2025. Revised: October 17, 2025. Accepted: November 13, 2025. Published: May 15, 2026.

1 Introduction

Livestock production is one of the most vulnerable agricultural industries because it is subject to a number of risks, including social, economic, biological, and climatic threats. Two advantages of good risk management include lowering losses and boosting agriculture's resilience. Risk management is crucial to preserving economic stability, sustainable output, and farmers' competitiveness. As a component of the agricultural industry, livestock farming is subject to a variety of risks, including biological (diseases, epidemics), economic (market volatility, shifts in feed and product prices), managerial and institutional (changes in subsidies, the regulatory framework), and climatic (extreme weather conditions).[1]. Modern farm management requires integrated approaches to identify, assess, and minimize these risks. The application of quantitative methods, such as sensitivity analysis, expected value, variance, and probabilistic modelling, contributes to an objective assessment of possible losses and gains under different scenarios [2]. On the other hand, qualitative approaches such as SWOT analysis, expert assessments, and scenario planning help strategic thinking and long-term planning under uncertainty [3]. One of the most crucial tools for agricultural management is an agricultural management information system (AMIS). The framework for farm life, resource allocation, and activity execution is established by the AMIS. They encompass a broad range of tactics and methods for maintaining a sustainable, resilient, profitable, and productive farm. [4]

Risk assessment methods are increasingly used in livestock production - especially in the development of investment projects, insurance schemes, biosecurity programmes, and decision-making in resource-constrained environments. Integrated early warning and monitoring systems that combine economic and biological data to better predict risk are also becoming particularly important [5].

Risk management in agriculture, and in particular in livestock farming, is becoming increasingly important in a context of increased market uncertainty, climate change, and increased biological risk. Increasing market share and maximizing profit are the goals of the farmers' market activity. There is a desire to avoid or lessen the possibility of failure. [6] Livestock farms in Bulgaria are often exposed to various threats, from animal diseases and fluctuations in commodity prices to unpredictable changes in the regulatory environment [7].

In response to these challenges, the international and Bulgarian scientific literature increasingly focuses on the need to use quantitative approaches to identify, measure, and minimize risk [1], [8]. Among these approaches, mathematical models play a key role, including concepts such as expected value, standard deviation, sensitivity analysis, probabilistic estimates, and Monte Carlo simulations [9], [10].

In (1), develop a multivariate probability model that shows how the probability distribution of crop yield changes in response to droughts.

These models allow farmers not only to assess the likelihood and impact of different risk events, but also to plan appropriate adaptation strategies - such as insurance, diversification, or the creation of buffer reserves [11]. Their application in livestock production in Bulgaria is still limited, but available research and pilot practices show the potential of this approach [12].

In modern agroeconomic science, mathematical models and quantitative approaches are increasingly important for risk assessment and decision support. By using expected value formulas, variance, sensitivity analysis, probabilistic risk, and simulations, farmers can analyse different scenarios and take preventive or adaptive measures.

2 Problem Formulation

2.1 Risk analysis and assessment methodology.

A crucial component of risk management in cattle ranching is risk analysis and evaluation. By assisting in the identification of possible hazards, their severity, and their importance, they promote improved decision-making. The analytical procedure includes the following steps (Figure 1):

- Risk identification is the process of recognizing and characterizing potential hazards.
- Determining the probability and possible impact is known as risk assessment.
- Classification by risk matrix: low, medium, high risk.
- Finding the most vulnerable components is known as sensitivity analysis.
- Monte Carlo simulations are used to forecast outcomes under different scenarios. [13].

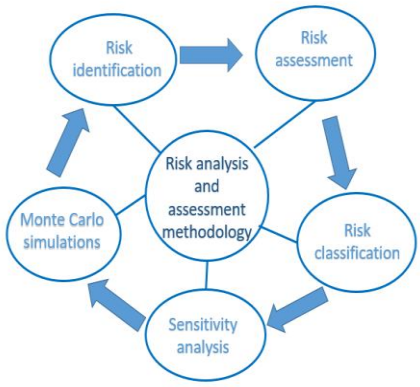

Fig. 1. Stages for risk analysis in agriculture. (Source: created by the authors)

2.2 Plan for Risk Management

Livestock farms need to put in place systematic risk management procedures if they want to be sustainable and competitive in the long run. To systematically detect, evaluate, prioritize, and reduce potential risks, these plans combine financial tools (including insurance and diversification), technical safeguards, crisis response protocols, and preventative health measures. A strong risk management strategy not only safeguards the health and welfare of animals but also increases farm stability and lowers financial losses in unforeseen situations. The goal of the strategic plan, known as the Livestock Risk Management Plan, is to lessen the detrimental effects of different risks on livestock, production, and farmers' earnings. A plan like this is crucial to the long-term viability of any livestock farm. The possible actions are listed in Table 1.

Table 1. Measures to reduce a particular risk. (Source: created by the authors)

Risk	Proba-bility	Impact	Measures
Animal diseases	Medium	High	Vaccination, biosecurity, veterinary control
Price fluctuations	High	Medium	Buyer contracts, reserve funds
Equipment breakdowns	Medium	Medium	Maintenance, back-up systems
Staff shortages	High	Medium	Training, mechanisation

3 Reducing risk in livestock farm management in Bulgaria.

A key component of Bulgarian agriculture, livestock raising boosts the nation's gross agricultural product, maintains food security, and generates employment in rural areas. Despite its significance, Bulgaria's cattle farming industry is susceptible to a number of threats that could jeopardize its sustainability, economic viability, and productivity. Regional problems including market volatility, climate change, and demographic changes in rural areas frequently make these risks worse. These risks are a result of the intricate interactions between biological, environmental, economic, and management elements.

Disease outbreaks (such as brucellosis, mastitis, and parasitic infections), feed price volatility, severe weather, antiquated infrastructure, and restricted

access to contemporary veterinary and technology services are the biggest threats to Bulgarian livestock farms. Due to structural and financial limitations, many small and medium-sized farms also struggle to invest in preventive measures or adjust to external shocks. Effective risk management in livestock farming is essential for lowering production losses, preserving farms' long-term viability, and adhering to national and European regulations on environmental protection, animal welfare, and health. The creation and execution of structured risk management plans that include biosecurity precautions, disease prevention procedures, financial risk management tools (like insurance or subsidies), and action plans for natural or technological disasters are typical components of risk reduction strategies. Promoting and putting into practice comprehensive risk management frameworks that are suited to regional agricultural conditions is becoming more and more crucial in Bulgaria. The purpose of this study is to investigate the methods, challenges, and prospects for reducing risk in Bulgarian cattle farm management. The study aims to provide useful suggestions for enhancing resilience and decision-making in Bulgarian cattle operations by examining qualitative and quantitative data from selected case studies. [14]

The main risks in the sector, the mechanisms for their management, and the challenges for Bulgarian farmers are presented.**3.1. Patterns in the quantity of farms (2005-2020)**

According to the Ministry of Agriculture data, the number of farms decreased by 75% over 15 years, from 500,000 in 2005 to 132,742 in 2020. (Figure 1). [15]

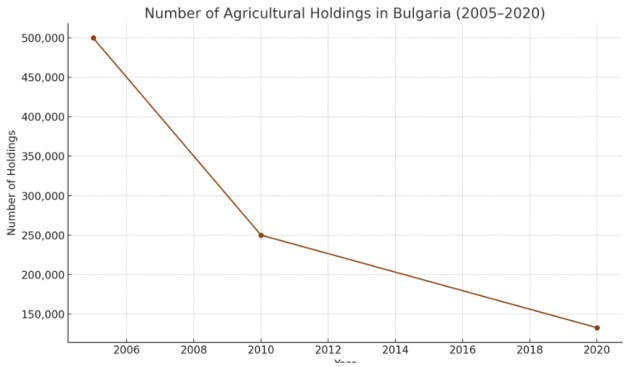

Fig. 2. Bulgaria's Agricultural Holdings Count (2005–2020).
(Source: created by the authors)

3.2. Number of farms affected and animals destroyed due to diseases (2018-2025)

According to data from the Ministry of Agriculture and Food [15], livestock facilities have been affected by dangerous diseases since 2018, destroying over 5.1 million animals. Figure 2 shows the dynamics of final output and net entrepreneurial income in agriculture for the period 2021-2024. There has been a decline in economic performance, particularly in terms of net income.

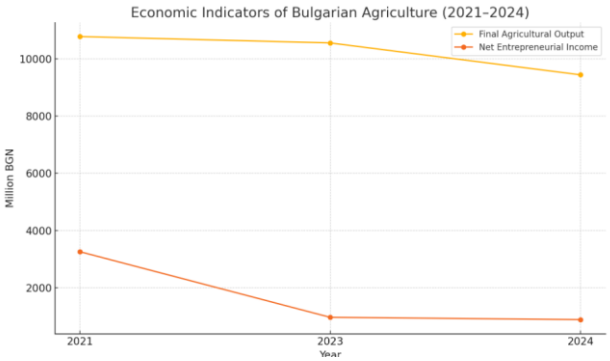

Fig. 3. Economic Indicators of Bulgarian Agriculture (2021–2024)". (Source: created by the authors)

4 Basic mathematical formulas and concepts used in agricultural risk management

Agricultural risk management uses a variety of statistical and mathematical techniques to help identify, quantify, and reduce hazards. The following basic mathematical ideas and formulas are applied in this field:

4. 1. Expected Value

The ability to predict potential events and assess their likelihood is essential for making well-informed decisions in risk analysis and management in cattle production. The expected value (EV), a statistical metric that represents the long-run average of a random variable, weighted by the probabilities of each possible outcome, is one of the most basic ideas in probability theory and decision analysis.

Simply put, given the inherent uncertainty of the different elements affecting livestock operations, the anticipated value provides a single numerical estimate of what a farmer or decision-maker can expect "on average" over time. Disease outbreaks, changes in milk or meat prices, feed costs, reproductive outcomes, or death rates are a few examples of these variables. The idea is also pertinent when weighing other risk-reduction tactics, such as investing in preventative health initiatives, diversifying production, or buying insurance.[16]

This formula (1) estimates the average value of a possible outcome, accounting for the probability of each alternative.

$$E(X) = \sum_{i=1}^{n} P_i X_i \quad (1)$$

- E(X)– expected value
- Pi– scenario probability i
- Xi – scenario outcome value i

4. 2. Variance and Standard Deviation

Effective risk management in livestock farming requires the capacity to measure and investigate variability in key performance indicators, such as production outcomes, resource costs, and income levels. Among the main statistical methods used to assess this variability are variance and standard deviation, two closely related measures that indicate the degree of uncertainty and diversity within a given data set.

Variance provides a measure of how dispersed the values are within a given distribution by quantifying the average squared deviation of observations from their mean. Because it reflects this variability in the same units as the original data, the standard deviation—the square root of variance—is more generally applicable and intuitive in comparison analysis. Increased risk exposure is frequently indicated by high variability or standard deviation in livestock production, such as milk yield, animal weight gain, or market pricing. These elements could be economic, environmental, or biological. [17]

They measure risk by the fluctuations (2) around the expected value:

$$\boldsymbol{\sigma^2 = \sum_{i=1}^{n} P_i \cdot (X_i - E(X))^2} \quad (2)$$

- σ^2 – variance
- σ – standard deviation

4. 3. Value at Risk (VaR)

In the context of contemporary risk management, making well-informed decisions necessitates a precise evaluation of possible financial losses.. Value at Risk (VaR), a statistical method that calculates the maximum expected loss of a portfolio or business over a specified time horizon, at a particular confidence level, is one of the most popular metrics for this purpose. VaR was initially developed for use in the financial industry (3). However, in agricultural and livestock production, where market uncertainties, disease risks, and climate unpredictability can have a significant financial impact, this is becoming increasingly important. Calculates the expected loss with a certain degree of confidence:

$$VaR = \mu - z\sigma \quad (3)$$

- μ– expected value
- *z*- value for the selected confidence level
- σ– standard deviation

4.4. Insurance expectation formula (Actuarially Fair Premium)

The actuarially fair price (AFP), a theoretical premium representing the insured party's projected loss, is a fundamental concept in risk-based insurance pricing. It is determined by multiplying the likelihood of an unfavourable event by the size of the corresponding loss. The AFP excludes risk-loading elements, profit margins, and administrative expenses, in contrast to market premiums. It is a standard for measuring the efficiency and equity of insurance programs, especially in public-private models, where governments frequently subsidize a percentage of the cost to promote farmer involvement.

The great specificity and variety of risk profiles across locations and production systems make the application of AFP in the context of livestock insurance particularly pertinent. Reliable actuarial models and access to trustworthy historical data on livestock illnesses, mortality, and economic losses are necessary for accurate AFP estimate (4). Adoption of risk management technologies, transparency, and farmers' confidence can all be boosted by matching insurance rates with actuarially true values. [18]

$$Premium = PL \quad (4)$$

- P – probability of an event (e.g., drought)
- L – loss when this event occurs

4.5. NPV (Net Present Value)

By discounting future money back to today's worth at a particular rate, Net Present worth (NPV), a fundamental financial metric, determines the profitability of an investment by calculating the difference between the present value of cash inflows and outflows (5).

$$\text{NPV} \approx \sum_{t=1}^{n} \frac{CFt}{(1+r)^{\text{t}}} - I \quad (5)$$

- CFt - Cash flow (profit, savings, income) in year t,
- r - Discount rate (interest, alternative rate of return, e.g., 0.08 = 8%);
- n - Number of years (project period)
- I - Initial investment (initial cost)

5 Examples of livestock management

Mathematical formulas and concepts for risk management in Bulgarian agriculture are presented. Specific examples from livestock farming are given, such as risk management in dairy, pig, or poultry farms. Examples are provided of how each formula is used to assess a real-life situation. The examples used (for the price of milk, losses due to illness, feed costs, etc.) are illustrative and calculated based on hypothetical scenarios to demonstrate how mathematical formulas are applied to assess risk. They are not taken directly from an official database, but are based on realistic values observed in Bulgarian practice. In other words, they demonstrate the calculation method rather than presenting actual empirical data.

- Expected value of milk income

On a small dairy farm, the following prices per litre of milk are expected depending on the market (Table 2)(6):

Table 2. Price per litre of milk.
(Source: created by the authors) Scenario

	Price (BGN/l)	Probability
Good market	1.30	0.3
Medium market	1.10	0.5
Bad market	0.90	0.2

$$\mathrm{E(P)} = 0.3 \text{ x } 1.30 + 0.5 \text{ x } 1.10 + 0.2 \text{ x } 0.90 = 1.10 \text{ BGN} \quad (6)$$

This is the expected market price you can use to plan your budget.

- Disease risk on a pig farm (using variance)- There are three disease loss scenarios (Table 3), (7), (8):

Table 3. Disease loss scenarios.
(Source: created by the authors)

Loss (BGN)	Probability
0	0.7
10,000	0.2
30,000	0.1

- Expected loss:

$$\mathrm{E(L)} = 0.7 \text{ x } 0 + 0.2 \text{ x } 10000 + 0.1 \text{ x } 30000 = 5000 \text{ BGN} \quad (7)$$

- Dispersion:

$$\sigma^2 = 0.7 \text{ x } (0\text{-}5000)^2 + 0.2 \text{ x } (1000\text{-}5000)^2 + 0.1 \text{ x } (30\,000 - 5000)^2 = 0.7 \text{ x } 25 \text{ x } 10^6$$

$$\sigma^2 = 17.5 \text{ x } 10^6 + 5 \text{ x } 10^6 + 62.5 \text{ x } 10^6 = 85 \text{ x } 10^6 \sigma \approx 9220 \text{ BGN} \quad (8)$$

This indicates significant uncertainty around the average loss, requiring management through prevention, biosecurity, and insurance.

- Value at Risk (VaR) of feed costs at a poultry farm (9).

Assume that the standard deviation is σ = 800 BGN, and the average monthly feed costs are μ = 5000 BGN. 95% confidence interval (z ≈ 1.65):

$$\mathrm{VaR} = \mu + \mathrm{z} \text{ x } \sigma = 5000 + 1.65 \text{ x } 800 = 6320 \text{ BGN} \quad (9)$$

- The price of cow mastitis insurance (The figures used in the instances are merely illustrative and do not reflect genuine statistical data.) (10).)
  - Annual incidence of mastitis in cows: P = 0.15 (this value is taken based on historical data for each farm or through expert assessment)
  - Average mastitis loss: L = 400 BGN

$$Premium = \mathrm{P} \text{ x } \mathrm{L} = 0.15 \text{ x } 400 = 60\ BGN/\text{cow} \quad (10)$$

With this premium, a fair insurance for farmers can be offered.

- Investment in new sheep farm equipment (NPV), (11)

Let's say the project requires a 20,000 BGN initial investment, brings in 6,000 BGN/year for 5 years, at a discount rate of 8% („The probabilities used in the examples are illustrative and do not reflect actual statistical data.")

$$\mathrm{NPV} \approx \sum_{t=1}^{5} \frac{6000}{(1+0.08)^{\mathrm{t}}} - 20000$$

$$\mathrm{NPV} \approx 23962.53 - 20000 = 3962.53$$

The project is profitable - a good investment.

4 Conclusion

Risk analysis and management in cattle ranching must be continuous and strategic. A methodical approach to evaluating and adjusting to environmental changes is necessary to achieve sustainable and competitive production. By using best practices and preventive measures, farm efficiency is increased and the probability of losses is greatly decreased.Risk management in livestock production is an essential element for the sustainable development of the agricultural sector in Bulgaria. Using mathematical models and quantitative methods like expected value, variance analysis, sensitivity analysis, probability estimates, and Monte Carlo simulations, farmers can methodically and objectively evaluate such risks and their economic impact.Case studies from dairy, swine, and poultry farms show that these methods are helpful in practical situations. They make it easier to make decisions that lower losses, boost output, and encourage proactive risk management related to biology, the economy, and climate change. Given the increasing unpredictability of agriculture, which includes price swings, animal illnesses, and shifts in the market and regulatory landscape, it is especially critical to include these strategies into management procedures.This study emphasizes the necessity of continuing education and technical support to help farmers implement science-based risk management strategies more broadly.Long-term, this might help make Bulgarian cattle production more sustainable and competitive.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed to the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or the Scientific Article Itself

The research is funded by Project КП-06-Н82/3 /06.12.2024: “Modelling and optimisation of risk at agricultural sites” with the Bulgarian National Science Fund.

Conflict of Interest

The authors have no conflicts of interest to declare.