

International Journal of Agriculture Extension and Social Development

Volume 9; SP-Issue 9; September 2026; Page No. 21-36

Received: 20-06-2026
Accepted: 26-07-2026

Indexed Journal
Peer Reviewed Journal

Application of AI in veterinary diagnostics and livestock management in Bagalkot, Karnataka, India

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DOI: <https://doi.org/10.33545/26180723.2026.v9.i9Sa.4244>

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Abstract

Livestock rearing plays a vital role in the rural livelihoods, income, and nutritional security of smallholder and landless farmers in Bagalkot district, Karnataka. The region supports diverse livestock, including indigenous Khillari cattle, buffaloes, sheep, goats, and backyard poultry such as Giriraja birds. However, the sector faces challenges such as disease outbreaks, high poultry mortality, fodder shortages, water contamination, and climate-related risks, including floods from the Krishna and Ghataprabha rivers and recurring droughts. In this context, Artificial Intelligence (AI) and Machine Learning (ML) offer promising tools for improving livestock management and veterinary services. This study aims to examine the role of AI and ML in livestock management and veterinary diagnostics in selected areas of Bagalkot district, particularly Bagalkot, Ilkal, Mudhol, and Jamkhandi taluks. A descriptive research approach was adopted using secondary data from government reports, veterinary department records, and digital agriculture platforms, covering AI-enabled mobile applications, disease surveillance systems, predictive analytics, telemedicine, remote advisory services, and image-based diagnostic tools. The findings indicate that AI and ML can support early disease detection, animal health monitoring, timely local-language advisories, climate-risk adaptation, fodder management, water monitoring, and improved access to veterinary care. These technologies can help farmers make timely decisions, improve resource use, and strengthen livestock health management. However, low digital literacy, limited infrastructure, and lack of awareness remain major barriers to wider adoption. Strengthening digital connectivity, farmer training, and institutional support is therefore essential for effective implementation. Overall, AI and ML have strong potential to improve veterinary services, disease control, and climate resilience in livestock systems across Bagalkot district.

Keywords: Bagalkot, livestock, Artificial Intelligence (AI), Machine Learning (ML), veterinary diagnostics, disease surveillance, telemedicine

1. Introduction

1.1 Background and Context

Livestock rearing is vital to rural livelihoods in Bagalkot district, Karnataka. In 2024, the district recorded 177,989 cattle, 206,749 buffaloes, 632,968 sheep, 397,632 goats, and 2,040,128 poultry birds ^[1]. However, livestock farmers face challenges related to animal diseases, access to veterinary services, fodder availability, and climate-related risks, highlighting the need for improved livestock health monitoring and management systems ^[7, 9, 22].

1.2 Importance of Livestock in Rural Livelihoods

Livestock provides milk, meat, eggs, income, employment, manure, and nutrition, particularly for small and marginal farmers. In Bagalkot district, sheep and goats represent important livelihood resources, given their substantial populations ^[1]. Improving animal health, productivity, and access to effective livestock-management services can contribute to increased household income and strengthened

livelihood security ^[7, 22].

1.3 Livestock Production Systems in Bagalkot District

Bagalkot's livestock sector includes cattle, buffaloes, sheep, goats, and poultry ^[1]. Livestock production is influenced by factors such as landholding, fodder and water availability, and access to veterinary services ^[7, 22]. Dairy animals contribute to integrated crop-livestock farming, while sheep, goats, and poultry provide additional sources of household income ^[1, 3]. Therefore, timely access to animal-health and veterinary services is essential for maintaining livestock health, productivity, and livelihood security ^[7, 10, 11].

1.4 Major Challenges in Livestock Management

Bagalkot farmers face challenges related to animal diseases, delayed diagnosis, limited access to veterinary services, fodder and water availability, rising production and treatment costs, and animal mortality. These constraints can

reduce livestock productivity and increase the economic burden on farming households, highlighting the need for early disease detection, continuous health monitoring, timely veterinary support, and efficient management of livestock resources [7, 9, 11, 14, 22].

1.5 Climate and Environmental Risks to Livestock

Climate variability, extreme weather events, floods, and water shortages can adversely affect livestock health, productivity, feed and water availability, and household livelihoods [9, 17]. These risks highlight the need for early-warning mechanisms, weather information, continuous animal-health monitoring, and climate-resilient livestock management practices [8, 9, 22]. In Bagalkot district, strengthening access to timely weather and veterinary information could help farmers respond more effectively to climate-related livestock risks.

1.6 Need for Digital Transformation in Veterinary Services

Timely veterinary care is essential for reducing disease progression, livestock losses, and associated economic impacts. Digital technologies can improve access to veterinary services through mobile advisories, remote consultations, digital health records, disease reporting, and early-warning systems [3, 10, 11]. National digital livestock initiatives can further support the collection and exchange of animal-health information and improve service delivery [12]. Platforms such as the National Animal Disease Referral Expert System (NADRES-V2) can support animal-disease surveillance and provide information for veterinary decision-making [2].

1.7 Artificial Intelligence and Machine Learning in Livestock Sector

Artificial intelligence (AI) and machine learning (ML) are increasingly being applied to livestock disease surveillance, disease-risk prediction, image-based diagnosis, health monitoring, and veterinary decision support [4, 5, 7, 13]–[15, 19]. In India, the National Animal Disease Referral Expert System Version 2 (NADRES-V2), developed by ICAR–National Institute of Veterinary Epidemiology and Disease Informatics (ICAR–NIVEDI), supports animal-disease surveillance and risk forecasting using epidemiological and environmental information [2]. These developments demonstrate the potential of AI and digital technologies to strengthen livestock-health management, disease preparedness, and veterinary service delivery.

1.8 Research Problem

Despite the importance of livestock to rural livelihoods in Bagalkot district, farmers continue to face challenges related to disease detection, access to veterinary services, fodder and water management, and climate-related risks [1, 7, 9, 11]. Although artificial intelligence (AI) and machine learning (ML) offer potential solutions for livestock health monitoring, disease prediction, diagnosis, and decision support [4, 5, 7, 13]–[15], their local applicability and practical usefulness in Bagalkot remain insufficiently understood [26]. Therefore, this study examines the potential of AI and ML to address livestock-management challenges in selected taluks of Bagalkot district.

1.9 Research Gap

Although India is increasingly adopting digital, artificial intelligence (AI), and machine learning (ML) technologies for livestock health and management [3, 6, 7, 10, 12], district-specific evidence on their applicability in Bagalkot remains limited [26]. Their potential to support disease surveillance, veterinary service access, climate-risk adaptation, fodder planning, and water-resource management in local livestock systems is not yet well understood [9, 11, 14, 22]. Therefore, this study examines the local applicability of AI and ML for livestock management and veterinary diagnostics in selected taluks of Bagalkot district.

1.10 Objectives of the Study

General Objective: To examine the potential role of Artificial Intelligence and Machine Learning in livestock management and veterinary diagnostics in selected taluks of Bagalkot district [4, 5, 7, 26]. **Specific Objectives:** (1) To identify livestock-management, animal-health, and veterinary-service challenges in the study area [7, 9, 22]; (2) to examine AI- and ML-based applications relevant to livestock disease surveillance and veterinary diagnostics [4, 5, 13]–[15, 19]; (3) to assess the potential of AI-enabled tools for climate-risk management, fodder planning, and water-resource monitoring [8, 9, 17, 22]; (4) to identify barriers to the adoption of AI- and ML-based livestock services [6, 10, 22, 25]; and (5) to suggest strategies for improving the adoption of digital livestock technologies in Bagalkot district [3, 10, 12, 22].

1.11 Research Questions

The study addresses the following research questions: (1) What are the major livestock-management and veterinary-service challenges in the selected taluks of Bagalkot district? [7, 9, 22] (2) What AI- and ML-based applications are relevant to disease surveillance, veterinary diagnostics, and animal-health monitoring? [4, 5, 7, 13]–[15, 19] (3) How can digital technologies support climate-risk adaptation, fodder planning, and water-resource management? [8, 9, 17, 22] (4) What technological, social, institutional, and infrastructural barriers affect the adoption of AI-enabled livestock services? [3, 6, 10, 22, 25].

1.12 Scope of the Study

The study examines the potential use of AI and ML in livestock management and veterinary diagnostics in selected taluks of Bagalkot district—Bagalkot, Ilkal, Mudhol, and Jamkhandi. It covers animal health, disease surveillance, veterinary services, climate risks, fodder and water management, telemedicine, and digital advisory systems [2]–[15, 17]–[22]. The study relies on secondary data and does not involve developing or clinically validating a new AI model.

1.13 Significance of the Study

The study links AI and ML with the practical livestock needs of rural Bagalkot. It highlights their potential for disease surveillance, veterinary access, climate-risk management, fodder, and water management [7, 9, 11]–[14, 22]. The findings may support farmers, veterinarians, researchers, and government agencies in adopting suitable digital livestock services and improving timely, accessible, and resilient animal-health management [3, 10, 12, 19].

2. Review of Literature

2.1 Concept of Artificial Intelligence

Artificial Intelligence (AI) refers to computational systems that perform tasks such as learning, pattern recognition, prediction, reasoning, and decision support [4, 5]. In livestock, AI can analyse sensor data, images, farm records, and environmental information to support animal-health and management decisions [4, 6, 8, 18]. Its effectiveness depends on data quality, infrastructure, technical skills, and human oversight [22, 24, 25].

2.2 Concept of Machine Learning

Machine Learning (ML) is a branch of AI that learns patterns from data for prediction, classification, and decision support [5, 24]. Major approaches include supervised learning, unsupervised learning, and deep learning, which is useful for complex data such as images, video, and sound [5, 13]. In livestock, ML is used for disease-risk prediction, behaviour analysis, animal identification, health monitoring, and diagnostic support [5, 7, 13, 15]. Its performance depends on the quality, size, and representativeness of training data [24, 25].

2.3 AI in Agriculture and Rural Development

AI in agriculture mainly supports monitoring, prediction, and decision-making by combining weather, sensor, remote-sensing, and farm data [4, 5, 8, 9]. However, adoption among smallholders can be limited by connectivity, cost, digital literacy, extension support, and institutional factors [3, 6, 10, 22, 25]. Thus, AI adoption should be viewed as a socio-technical process, not only a technological intervention [22, 25].

2.4 AI Applications in Livestock Management

AI applications in livestock operate at three levels: animal, farm, and system. At the animal level, AI supports identification, health, behaviour, reproduction, and feeding [5, 6, 8, 18]. At the farm level, it assists production forecasting, record management, and resource planning [4, 5, 6, 8]. At the system level, AI supports disease surveillance, climate-risk assessment, veterinary planning, and digital advisory services [2, 9, 11, 12, 19]. However, most evidence comes from data-rich systems, so its suitability for smallholder livestock farming remains uncertain [3, 22, 25].

2.5 Machine Learning in Animal Health Monitoring

ML can monitor changes in animal movement, feeding, posture, vocalization, and temperature to identify possible health problems [5, 7, 18, 19]. A 2024 review of 44 studies highlighted deep-learning methods such as CNNs and Faster R-CNN for livestock behaviour recognition [13]. However, such changes may have causes other than disease [7, 19]. Therefore, ML alerts should be treated as early indicators requiring veterinary interpretation, not as final diagnoses [7, 13, 19].

2.6 AI-Based Veterinary Disease Surveillance

AI-based disease surveillance helps identify disease patterns, predict outbreak risks, and support preparedness rather than replace veterinary diagnosis [2, 7, 9, 14]. In India, NADRES-V2, developed by ICAR-NIVEDI, uses GIS, AI, and ML to forecast major livestock diseases at the district level and provide risk alerts and advisories [2]. However, risk forecasts indicate potential outbreaks and do not confirm

infection in individual animals [2, 7, 14].

2.7 Image-Based Animal Disease Detection

Image-based AI can analyse photographs and medical images to support animal-health screening and diagnosis [13, 14, 15, 19]. Its performance depends on image quality, training data, validation, and clinical conditions [13, 15, 24]. Smartphone images may help identify visible conditions, but differences in breed, age, lighting, and image quality can cause errors [13, 15]. Therefore, AI-based image screening should support, not replace, veterinary examination and diagnosis [7, 13, 19].

2.8 Telemedicine and Remote Veterinary Advisory Services

Veterinary telemedicine connects animal owners with veterinarians through teleconsultation, triage, monitoring, and remote diagnostic support [11, 19]. It can improve veterinary access, especially in underserved areas [10, 11]. However, it cannot replace physical examination, laboratory tests, surgery, vaccination, or emergency care [11, 19]. Effective use also requires professional judgement, data protection, reliable connectivity, and appropriate veterinary oversight [11, 19, 22].

2.9 AI for Fodder, Feed, and Water Management

AI and data-driven technologies can support livestock resource management through fodder forecasting, feed planning, water monitoring, and climate-based advisories [8, 9, 17, 18]. However, sensor-based systems may be costly and technically difficult for smallholders [3, 6, 22, 25]. In Bagalkot, practical applications could include fodder-shortage alerts, feed-cost information, water-availability advisories, and climate-based resource planning [9, 26].

2.10 AI for Climate Risk and Disaster Management

Climate variability can affect livestock health, water, fodder, productivity, and disease patterns [8, 9, 17]. AI and ML can combine weather, environmental, livestock, and disease data to provide early warnings and risk assessments [2, 8, 9]. Such information can support fodder storage, water planning, shelter preparation, and vaccination decisions [8, 9, 22]. However, AI depends on reliable data and timely action by farmers and institutions [9, 22, 25].

2.11 Digital Literacy and Technology Adoption among Farmers

AI adoption in livestock depends on digital literacy, affordability, perceived usefulness, trust, language, connectivity, training, and institutional support [3, 6, 10, 22, 25]. For rural farmers, simple applications, local-language interfaces, affordable services, farmer training, and reliable veterinary support may be as important as the AI technology itself [3, 10, 11, 12].

2.12 Research Gaps Identified from Literature

The literature shows growing use of AI and ML in livestock monitoring, disease surveillance, diagnosis, telemedicine, feeding, and climate-risk assessment [4, 5, 7, 9, 11, 13, 19]. However, evidence on their local applicability and adoption among smallholder farmers in rural India remains limited [3, 6, 22, 25]. Bagalkot also lacks sufficient district-specific

research linking AI with animal health, veterinary access, fodder, water, climate risks, and digital infrastructure [26]. Therefore, this study examines the potential role, practical relevance, and adoption barriers of AI and ML in livestock management and veterinary diagnostics using secondary data from government, institutional, veterinary, and digital agriculture sources.

3. Study Area Profile

3.1 Location and Administrative Profile of Bagalkot District

Bagalkot district is located in northern Karnataka and covers about 6,583 km². It has 2 revenue divisions, 9 taluks, 198 Gram Panchayats, and 638 villages [1]. Its predominantly dry climate and dependence on agriculture and livestock make it suitable for studying rural livestock management and veterinary challenges [1, 26].

3.2 Physical Geography and Major River Systems

Bagalkot lies in the northern Deccan Plateau at about 533 metres elevation. The Krishna, Ghataprabha, and Malaprabha rivers influence agriculture, irrigation, and water availability [1]. The district includes both dryland and irrigated areas, creating variations in fodder resources, water availability, and drought and flood risks [1, 9].

3.3 Climate and Agro-Ecological Conditions

Bagalkot lies in Karnataka's Northern Dry Agro-Climatic Zone (Zone III), with a warm, dry climate. Temperatures may reach about 42 °C, with winter minimums around 15 °C and annual rainfall of about 570 mm. Rainfall variability,

dry spells, high temperatures, and localized floods affect water availability, fodder, heat stress, livestock productivity, and animal health [9, 17, 22].

3.4 Agriculture, Land Use, and Rural Livelihoods

Agriculture and livestock are closely linked in Bagalkot through crop residues, manure, and household labour [3, 26]. Major crops include sorghum, pulses, groundnut, maize, sugarcane, grapes, and pomegranate. Crop residues support livestock feeding, while animals provide milk, meat, eggs, manure, and supplementary income [1, 3], making fodder, water, animal health, and climate resilience important for rural livelihoods [8, 9, 17, 22].

3.5 Livestock Economy and Production Systems

Livestock production is an important part of Bagalkot's mixed-farming economy. Cattle and buffaloes support dairy activities, while sheep, goats, and poultry provide meat, breeding, eggs, and additional income [1, 3]. Integration with crop farming enables the use of crop residues as feed and manure as fertilizer [3, 26], supporting livelihood diversification despite risks from disease, fodder costs, water scarcity, and climate variability [7, 9, 22].

3.6 Livestock Population and Species Composition

According to Karnataka Department of Animal Husbandry and Veterinary Services (2024), Bagalkot recorded 177,989 cattle, 206,749 buffaloes, 632,968 sheep, 397,632 goats, 18,391 pigs, and 2,040,128 poultry birds [1]. Sheep are the largest major livestock group, while poultry represents the largest animal-resource category [1].

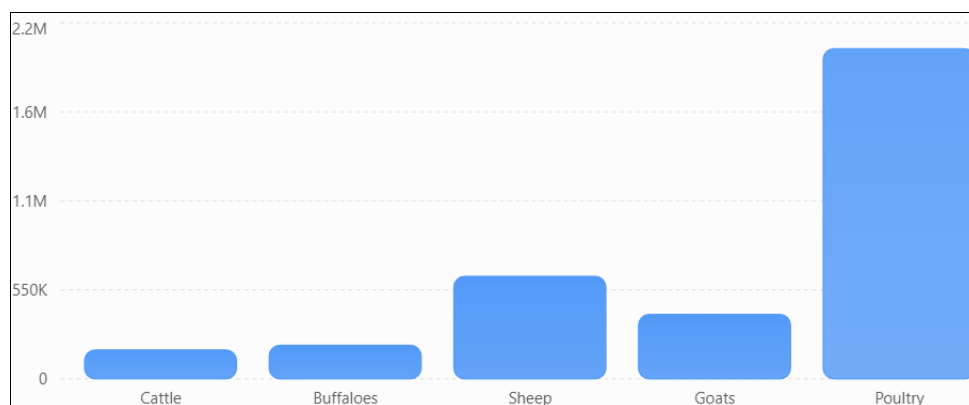


Fig 1: Livestock and poultry population in Bagalkot district, Karnataka, 2024

3.7 Major Livestock Breeds and Local Animal Resources

Bagalkot has indigenous, crossbred, and locally adapted livestock. Khillari and Krishna Valley cattle are important indigenous breeds, while sheep, goats, buffaloes, and poultry are major livestock resources [1, 3, 6]. The Mudhol Hound is also associated with the district.

3.8 Veterinary Infrastructure and Animal Health Services

Veterinary services in Bagalkot include hospitals, treatment, vaccination, disease surveillance, breeding, and livestock extension [2, 7, 12]. The district has 15 veterinary hospitals and 52 veterinary doctors. Its Integrated Livestock Information

System supports digital records on treatment, disease outbreaks, vaccination, breeding, fodder, insurance, and veterinary institutions [12].

3.9 Selection of Study Taluks

The study focuses on four selected taluks—Bagalkot, Ilkal, Mudhol, and Jamkhandi. They were selected based on livestock importance, species diversity, climate risks, veterinary-service access, digital connectivity, and availability of secondary data. These taluks provide varied contexts for examining AI and ML applications in livestock health, veterinary services, disease surveillance, and climate-risk management [1, 2, 9, 12, 26].

Table 1: Livestock Population of Selected Study Taluks, 2024 ^[1]

Taluk	Cattle	Buffaloes	Sheep	Goats	Poultry
Bagalkot	16,883	17,402	75,750	58,825	110,759
Ilkal	8,918	5,952	94,703	44,949	549,037
Mudhol	34,680	47,182	65,115	53,920	59,668
Jamkhandi	30,349	49,713	29,240	39,776	253,083

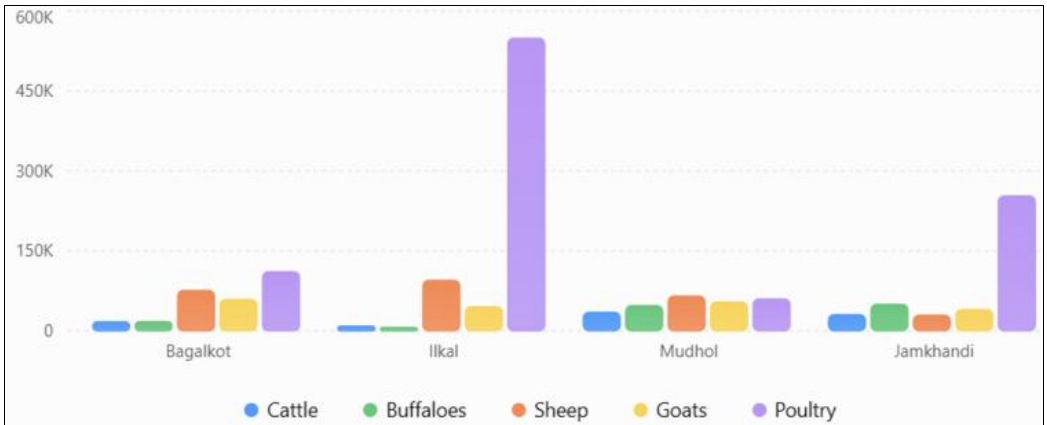


Fig 2: Livestock and poultry population of selected study taluks, 2024.

3.10 Climate, Environmental, and Livestock Risks

The study area faces three major livestock risks: animal-health risks such as diseases and delayed treatment [7, 11, 14]; resource risks including fodder shortages and water scarcity [8, 9, 17]; and climate risks such as heat, drought, rainfall variability, and floods [9, 17, 22]. These risks can interact and affect livestock health, productivity, and access to veterinary services [7, 9, 11, 22].

3.11 Relevance of the Study Area to AI-Enabled Livestock Management

The study area is suitable for examining AI and ML due to its substantial livestock population and challenges related to animal health, resources, veterinary access, and climate [1, 7, 9, 22]. Existing digital systems and NADRES-V2 demonstrate the potential of AI-based livestock management [2, 12]. However, effective adoption depends on data availability, connectivity, affordability, digital literacy, local-language support, veterinary validation, and institutional support [3, 6, 10, 11, 22, 25].

4. Materials and Methods

4.1 Study Design and Research Approach

This study employed a descriptive-exploratory documentary research design based on secondary quantitative and qualitative data. The study combines district-level livestock and veterinary information with a structured review of government records, institutional reports, digital livestock initiatives, and peer-reviewed literature to assess the relevance, potential applications, implementation requirements, and constraints of Artificial Intelligence (AI) and Machine Learning (ML) in livestock management and veterinary diagnostics. The study does not develop, train, or experimentally validate an AI or ML model. Instead, it examines existing evidence and technologies in relation to the livestock, veterinary, environmental, and socioeconomic context of selected areas of Bagalkot district.

4.2 Study Area and Unit of Analysis

The study was conducted at the district and selected-taluka levels, with Bagalkot district serving as the primary geographical unit and Bagalkot, Ilkal, Mudhol, and Jamkhandi considered as the selected administrative units. The unit of analysis was not an individual farmer or animal; rather, it comprised documented livestock statistics, veterinary-service information, disease-surveillance information, AI/ML applications, institutional initiatives, and published evidence relevant to livestock management and veterinary services. This approach is appropriate for assessing the contextual relevance of emerging technologies without making farmer-level adoption or impact claims.

4.3 Selection of Study Taluks

Four selected administrative areas—Bagalkot, Ilkal, Mudhol, and Jamkhandi—were included purposively to provide contextual variation in livestock production, agricultural livelihoods, environmental conditions, veterinary-service access, and climate-related risks. Selection also considered the availability of reliable secondary information relevant to livestock health, disease surveillance, veterinary services, digital advisory systems, and climate-related livestock risks. The selected areas were not intended to constitute a statistically representative sample of all livestock households or administrative units in Bagalkot district. Rather, they were selected to support a context-sensitive assessment of the opportunities and constraints associated with AI- and ML-enabled livestock services.

4.4 Data Sources

The study relied exclusively on secondary sources. Data and documentary evidence were obtained from government departments, district administration records, national research institutions, official livestock databases, digital agricultural and veterinary platforms, peer-reviewed

scientific publications, and relevant institutional reports. Major institutional sources included the Karnataka Department of Animal Husbandry and Veterinary Services (AHVS), Government of Karnataka; Bagalkot District Administration; Government of India; Indian Council of Agricultural Research (ICAR); and ICAR-National Institute of Veterinary Epidemiology and Disease Informatics (ICAR-NIVEDI). Scientific literature was used primarily to examine the technical applications, potential benefits, limitations, and adoption conditions associated with AI, ML, digital agriculture, veterinary diagnostics, telemedicine, and livestock management.

4.5 Document Search Strategy and Source Selection

Relevant documents were identified through structured searches of official government and institutional websites and scholarly literature sources. Search terms were developed from the study objectives and included combinations of “Artificial Intelligence,” “Machine Learning,” “livestock management,” “veterinary diagnostics,” “animal disease surveillance,” “disease forecasting,” “telemedicine,” “digital agriculture,” “precision livestock farming,” “fodder management,” “water management,” “climate risk,” “technology adoption,” “Karnataka,” and “Bagalkot.” The search focused primarily on recent literature and current institutional information while retaining earlier foundational studies where they were directly relevant to the development of the field.

Priority was given to official government publications, recognized national institutions, peer-reviewed scientific studies, and established digital livestock or agricultural platforms. District-specific information was preferentially obtained from official Karnataka and Bagalkot government sources, while scientific evidence concerning AI/ML applications and their limitations was obtained from peer-reviewed literature and recognized research institutions.

4.6 Inclusion and Exclusion Criteria

Documents were included when they met one or more of the following criteria: (i) addressed livestock management, animal health, veterinary services, AI, ML, digital agriculture, disease surveillance, telemedicine, climate risk,

fodder/feed management, water management, or technology adoption; (ii) provided information relevant to India, Karnataka, Bagalkot, smallholder livestock systems, or comparable rural contexts; (iii) were published by a government agency, recognized research institution, or peer-reviewed journal; and (iv) contained sufficient information to identify the source, geographical or thematic context, and principal findings.

Documents were excluded when they contained unverifiable claims, lacked identifiable authorship or institutional ownership, duplicated information available from a more authoritative source, or had no meaningful relevance to livestock management, veterinary services, AI/ML, or the study objectives. Where multiple sources reported the same information, preference was given to the most authoritative and directly applicable source.

4.7 Data Extraction and Data Management

A standardized data-extraction framework was used to organize information obtained from the selected documents. The extraction fields included source or institution, publication year, geographical coverage, data period, source type, livestock category, animal-health issue, veterinary-service issue, AI/ML application, reported or potential benefit, implementation requirement, limitation, and relevance to Bagalkot district. Quantitative data were recorded using their original units and reporting years, while qualitative evidence was classified according to predefined analytical themes.

Data from livestock censuses, departmental administrative records, research studies, and institutional programmes were maintained separately during analysis to avoid inappropriate aggregation of datasets with different definitions, geographical coverage, reporting periods, and collection methods. Where differences were identified between sources, the reporting year and source characteristics were retained rather than combining incompatible figures.

4.8 Analytical Themes and Indicators

The documentary evidence was organized into three major analytical domains: livestock-system context, AI and ML application areas, and adoption and implementation conditions.

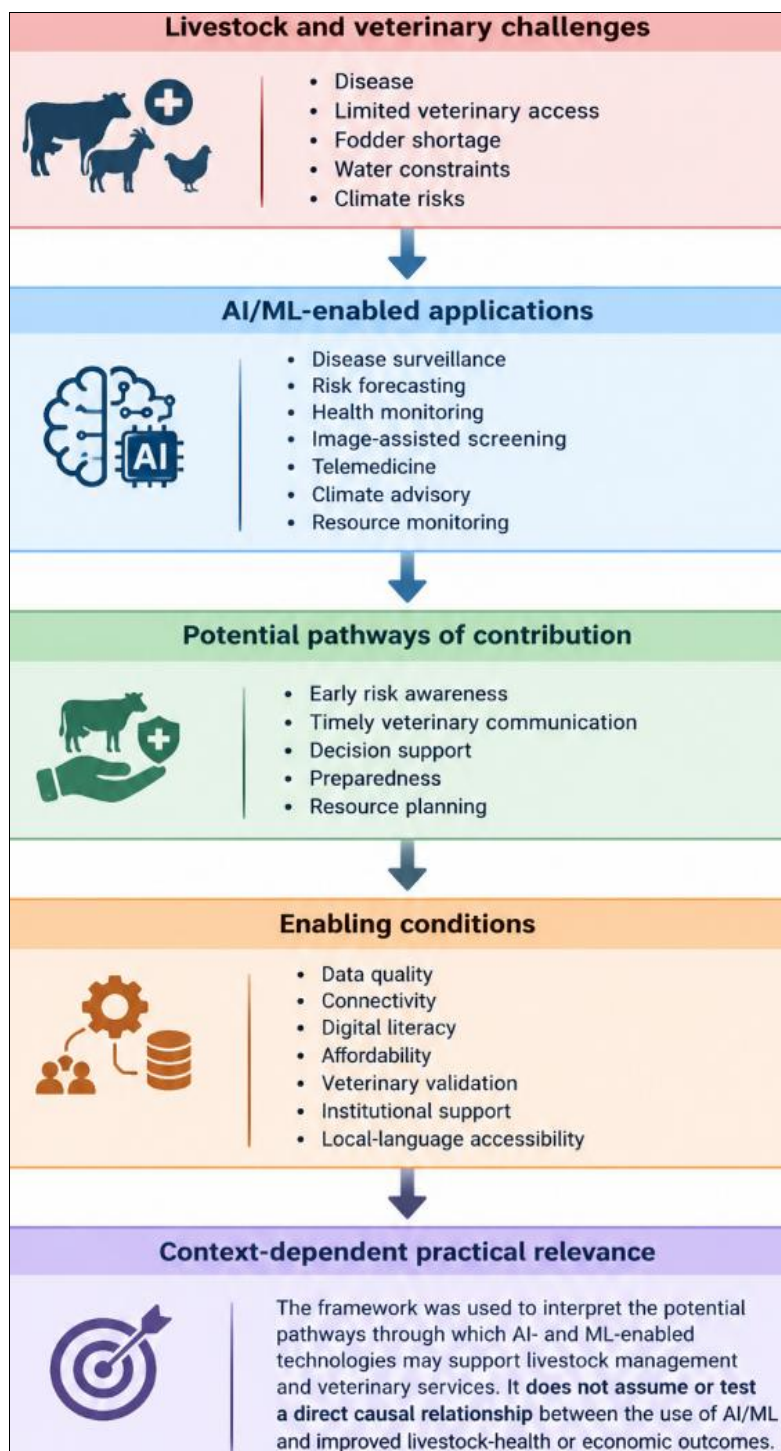
Table 2: Analytical Themes and Indicators

Analytical Domain	Key Indicators
Livestock-System Context	Livestock and poultry population; species composition; crop–livestock production systems; veterinary infrastructure and service availability; animal-health and disease risks; fodder and water availability; climate and environmental risks
AI and ML Application Areas	Disease surveillance and outbreak-risk forecasting; animal-health and behaviour monitoring; image-assisted screening and diagnostic decision support; telemedicine and remote veterinary advisory; fodder and feed-management support; water-resource and environmental monitoring; climate-risk assessment and early-warning systems
Adoption and Implementation Conditions	Data availability and quality; mobile and internet connectivity; digital literacy; local-language accessibility; cost and affordability; veterinary involvement and professional validation; institutional capacity; interdepartmental coordination; farmer awareness and trust; data privacy and governance

This classification enabled the study to examine both the technological opportunities and the conditions required for their practical application in Bagalkot livestock systems.

4.9 Analytical Framework

The study adopted a contextual analytical framework linking livestock-management challenges with potential technology-based responses and their implementation requirements



4.10 Data Analysis

Quantitative secondary data were analysed using descriptive statistics, including totals, percentages, proportions, and category-wise comparisons where comparable data were available. Livestock population data were examined according to species, geographical unit, and reporting year. Comparative interpretation was undertaken only when the datasets had sufficiently similar definitions, geographical coverage, and reporting periods.

Qualitative documentary evidence was analysed using deductive thematic analysis. Initial analytical codes were developed from the study objectives and conceptual framework. These included animal-health challenges, veterinary access, disease surveillance, diagnostic support,

telemedicine, climate risk, fodder and water management, digital literacy, connectivity, affordability, institutional support, and technology-adoption barriers. Relevant information from the selected documents was classified under these themes and compared across sources to identify common findings, contextual differences, potential applications, and implementation gaps.

No inferential statistical analysis was performed because the study did not use farmer-level survey data, experimental observations, or a probability-based sample. Similarly, no AI/ML model was trained or evaluated; therefore, the study does not independently estimate model accuracy, sensitivity, specificity, precision, recall, or predictive performance.

4.11 Data Quality Assurance and Source Triangulation

The credibility of the findings was strengthened through source triangulation, involving comparison of evidence from official government records, national research institutions, peer-reviewed literature, and established digital livestock platforms. A source hierarchy was applied according to the type of information being examined.

Official district and state government records were prioritized for livestock population, administrative information, and veterinary-service statistics. ICAR and ICAR-NIVEDI sources were prioritized for information concerning national livestock disease surveillance, forecasting, and institutional AI-enabled initiatives. Peer-reviewed research was prioritized for evidence concerning AI/ML applications, diagnostic technologies, telemedicine, technology adoption, implementation challenges, and reported technical performance.

Differences in reporting year, geographical coverage, livestock-category definitions, and data-collection methods were documented before comparison. Where conflicting figures were identified, the study did not average or combine them; instead, the most appropriate authoritative source was retained and its reporting period or methodological context was stated.

4.12 Ethical Considerations

The study used publicly available or institutionally reported secondary information and did not involve direct recruitment, interviews, experiments, or collection of personally identifiable information from farmers, veterinarians, or livestock owners. Accordingly, no primary participant-level dataset was generated. Academic integrity was maintained by identifying and appropriately acknowledging the original sources of all secondary information.

The study also recognizes that digital livestock systems may involve farm locations, animal-health records, disease information, and other potentially sensitive operational data. Therefore, AI-enabled livestock technologies are discussed as decision-support tools requiring appropriate professional oversight, rather than as autonomous replacements for veterinary professionals. No identifiable individual or farm-level information is presented.

4.13 Study Limitations

Several limitations should be considered when interpreting the findings. First, the study relies entirely on secondary data, and its conclusions are therefore influenced by the availability, quality, completeness, and reporting practices of existing sources. Second, government and institutional datasets may differ in reporting year, geographical unit, livestock definitions, and data-collection methodology, which can limit direct comparisons between datasets.

Third, the study does not collect primary information from farmers, livestock owners, veterinarians, or veterinary institutions and therefore cannot directly measure farmer-level awareness, adoption, satisfaction, willingness to use, or actual use of AI-enabled technologies. Fourth, the selected taluks were purposively considered and are not statistically representative of all livestock households in Bagalkot district.

Fifth, the study does not develop, train, or experimentally

validate an AI or ML model and therefore does not provide original evidence of diagnostic or predictive performance. Sixth, the study does not evaluate the cost-effectiveness, financial feasibility, interoperability, algorithmic bias, or real-world implementation performance of individual AI systems in Bagalkot. Finally, much of the available AI evidence comes from commercial, experimental, or data-rich livestock environments. Consequently, the applicability of such technologies to smallholder livestock systems in Bagalkot should be interpreted as potential and context-dependent rather than as demonstrated impact.

4.14 Methodological Scope of the Study

The methodological scope of this study is therefore limited to a district-level documentary and thematic assessment of the relevance, opportunities, and constraints of AI- and ML-enabled livestock technologies. The study evaluates how existing evidence and institutional initiatives relate to the livestock and veterinary challenges of Bagalkot district. It does not claim to establish causal effects, farmer adoption rates, clinical diagnostic accuracy, or economic benefits of AI/ML technologies in the study area. This defined scope allows the findings to remain consistent with the secondary-data design and prevents technological potential from being presented as empirically demonstrated impact.

5. Potential AI and ML Applications for Livestock Management in Bagalkot District

5.1 Framework for Assessing Application Relevance

The relevance of AI- and ML-enabled livestock applications was assessed using a context-based framework rather than technical capability alone. Each application was considered in relation to the major livestock and veterinary challenges identified in Bagalkot, its suitability for cattle, buffaloes, sheep, goats, and poultry, affordability for smallholder households, data requirements, connectivity needs, dependence on sensors or specialized equipment, need for veterinary supervision, local-language accessibility, and potential for delivery through existing government veterinary and extension systems. The framework also considers scalability, climate suitability, and the availability of institutional support. This approach recognizes that a technically advanced AI application may not necessarily be practically useful if farmers cannot afford it, reliable data are unavailable, connectivity is poor, or veterinary professionals cannot validate and act on its outputs.

5.2 AI-Enabled Livestock Data, Identification, and Record Management

Reliable livestock information is a basic requirement for many AI- and ML-enabled services. Digital identification and record-management systems can organize information on animal identity, vaccination, treatment, breeding, production, mortality, and disease history. AI may subsequently be used for pattern recognition, anomaly detection, automated classification, and decision support based on these records. For Bagalkot, improved digital livestock records could strengthen the continuity of veterinary information and support disease surveillance, vaccination planning, reproductive management, and follow-up care. However, successful implementation requires consistent animal identification, regular data

updating, interoperable information systems, farmer participation, and institutional coordination. Therefore, digital record management should be viewed as a foundational component of AI-enabled livestock services, rather than as an independent technological solution.

5.3 Animal-Health Monitoring and Early Risk Detection

AI and ML can support animal-health monitoring by analysing behavioural, physiological, environmental, and production-related information. Changes in movement, feeding, rumination, body temperature, posture, activity, or vocalization may indicate possible health or welfare problems. Sensor-generated or farmer-reported information can be analysed to identify deviations from normal patterns and generate early alerts. For Bagalkot, such systems may be relevant for identifying possible disease, heat stress, nutritional problems, or abnormal behaviour before conditions become more serious.

However, an AI-generated alert should not be treated as a confirmed diagnosis. Similar changes can result from disease, heat stress, nutritional deficiencies, reproductive status, housing conditions, transportation, or other management factors. Consequently, veterinary examination remains essential for clinical confirmation and treatment. Lower-cost mobile reporting and institution-supported monitoring may be more appropriate for smallholder systems than expensive individual sensor installations.

5.4 Disease Surveillance and Disease-Risk Forecasting

Disease surveillance and disease-risk forecasting represent among the most relevant AI/ML applications for Bagalkot because livestock disease can affect animal health, household income, and the availability of veterinary services. AI and ML can integrate historical disease records with livestock population information, weather conditions, environmental indicators, and geographical information to identify patterns associated with increased disease risk. Such systems can support early warning, prioritization of surveillance activities, and preparedness by veterinary authorities.

An important Indian example is NADRES v2, developed by ICAR-NIVEDI, which uses multiple livestock, disease, weather, and environmental variables to generate district-level disease-risk information. Its relevance to Bagalkot lies primarily in the potential for data-supported disease preparedness and early communication.

The terms surveillance, forecasting, screening, and diagnosis should not be treated as interchangeable. Surveillance refers to systematic monitoring of disease events; forecasting estimates future disease risk; screening identifies possible health problems; and diagnosis involves clinical confirmation, often supported by laboratory investigation. Thus, an AI-based disease-risk forecast should be interpreted as an early-warning and decision-support mechanism rather than proof that an animal or area has a particular disease.

5.5 AI-Assisted Veterinary Screening and Diagnostic Decision Support

Computer vision and machine-learning techniques can assist veterinary professionals by analysing photographs, videos, radiographic images, ultrasound images, and other visual information. In rural settings, smartphone-based image

sharing may allow farmers or field workers to transmit photographs of visible abnormalities to veterinary personnel for preliminary assessment. Potential applications include screening of skin abnormalities, wounds, visible lesions, body-condition changes, lameness indicators, and other externally observable conditions.

For Bagalkot, this approach could potentially reduce delays in obtaining preliminary veterinary guidance where physical access to veterinary services is difficult. However, image quality, lighting, camera characteristics, animal breed, age, species, disease stage, and similarities between different conditions can affect AI performance. Therefore, AI-assisted image screening should be considered diagnostic decision support rather than autonomous veterinary diagnosis. Veterinary examination and laboratory testing remain necessary when clinical confirmation is required.

5.6 Tele-Veterinary Services and Digital Farmer Advisory

Tele-veterinary services can provide remote communication between livestock owners, veterinary professionals, extension personnel, and animal-health institutions. Digital platforms may support teleconsultation, preliminary triage, sharing of photographs and videos, vaccination and deworming reminders, disease reporting, referral to veterinary hospitals, and follow-up communication. Kannada-language text, voice, or video services could be particularly relevant for improving accessibility in rural communities.

For Bagalkot, tele-veterinary services may be among the more feasible digital interventions because they can extend information and communication without requiring every livestock owner to possess sophisticated equipment. However, remote services cannot replace physical examination, emergency treatment, vaccination procedures, surgery, sample collection, laboratory diagnosis, or other interventions requiring direct veterinary involvement. Their effectiveness therefore depends on reliable connectivity, veterinarian availability, appropriate referral mechanisms, data protection, and professional oversight.

5.7 AI for Feed, Fodder, and Water-Resource Planning

AI and ML can support livestock resource management by analysing livestock numbers, seasonal fodder availability, crop residues, weather conditions, feed prices, water availability, and environmental information. Predictive systems may help identify periods of likely fodder shortage and support decisions regarding fodder conservation, storage, alternative feed resources, and seasonal planning. Similarly, digital water-monitoring systems can combine sensor measurements, weather information, and historical observations to identify potential changes in water availability or quality.

These applications are particularly relevant to Bagalkot because livestock systems are affected by seasonal resource availability and climate variability. Potential applications include fodder-shortage forecasting, crop-residue mapping, drought-related fodder advisories, feed-cost monitoring, water-availability alerts, and livestock drinking-water risk assessment.

However, AI cannot determine water safety without appropriate measurements, and individualized precision-feeding systems may be difficult to implement among

smallholder farmers because of equipment costs, data requirements, and technical-support needs. Low-cost advisory systems and shared-service models may therefore be more practical.

5.8 AI for Climate-Risk Alerts and Livestock Protection

Climate variability and extreme weather conditions can affect livestock through heat stress, water scarcity, fodder shortages, disease-risk changes, and flood-related losses. AI and ML can analyse weather forecasts, historical climate data, livestock information, vegetation indicators, and environmental variables to generate early-warning information. For Bagalkot, such systems could support advance preparation for heat waves, drought, heavy rainfall, and flooding.

Potential applications include heat-stress alerts, water-planning advisories, fodder-storage recommendations, livestock-shelter preparation, disease-risk warnings, vaccination planning, and emergency livestock movement information. The value of such systems depends not only on prediction quality but also on whether warnings reach farmers and veterinary personnel in sufficient time and whether they have the resources to act. AI therefore supports risk awareness and preparedness rather than directly preventing climate-related losses.

5.9 AI Applications for Dairy, Small Ruminants, and Backyard Poultry

The relevance of AI/ML varies according to livestock species and production systems in Bagalkot.

Dairy cattle and buffaloes

Potential applications include digital health and production

records, heat-stress alerts, reproductive monitoring, milk-yield trend analysis, mastitis-risk screening, feed planning, and vaccination or treatment reminders. Such applications may be useful where sufficient production and health records are available.

Sheep and goats

For small-ruminant systems, practical applications may include disease and mortality reporting, vaccination and deworming reminders, fodder-shortage alerts, heat-stress advisories, and digital livestock records. Advanced location-monitoring technologies may be useful in selected systems but could face affordability and connectivity constraints.

Backyard poultry

AI-enabled applications may support mortality reporting, disease-risk alerts, vaccination reminders, heat and ventilation advisories, biosecurity guidance, and preliminary image-assisted screening of visible health problems. Because backyard poultry systems generally have limited digital records and smaller production scales, low-cost mobile and local-language advisory services may be more practical than expensive automated systems.

Overall, species-specific applications should be designed according to the scale, resources, management practices, and digital capacity of the livestock system rather than applying a single technology model across all species.

5.10 Feasibility of AI/ML Applications in Bagalkot

Based on the documentary evidence and the contextual conditions identified in the study area, AI/ML applications can be grouped according to their potential practical relevance.

Application	Contextual feasibility	Main requirements
Disease surveillance and risk forecasting	High	Reliable disease and weather data; veterinary-department integration
Mobile veterinary advisory and tele-triage	High	Mobile connectivity; Kannada support; veterinarian availability
Digital livestock records and vaccination reminders	High	Reliable animal identification and regular data updating
Climate and fodder advisories	High	Localized weather/resource data and extension communication
AI-assisted image screening	Moderate	Good-quality images and veterinary validation
Wearable health and reproductive sensors	Moderate to Low	Equipment affordability, maintenance, connectivity
Precision feeding and individualized productivity prediction	Low to Moderate	High-quality farm data, equipment, technical support
Fully automated livestock-management systems	Low	High investment, reliable infrastructure, advanced technical capacity

These categories represent a contextual feasibility assessment, not experimentally measured technology-performance results. An application was considered relatively high in practical relevance when it could potentially be delivered through existing government, veterinary, mobile, or extension systems with comparatively limited additional equipment. Applications requiring specialized equipment, continuous sensor data, advanced connectivity, or substantial private investment were considered less immediately feasible for resource-constrained smallholder systems.

5.11 Comparative Assessment of AI and Digital Livestock Tools

Existing AI and digital livestock technologies differ in their functions, accessibility, and potential relevance to livestock management. Therefore, a comparative assessment was conducted to examine their applications in disease surveillance, image-based diagnosis, tele-veterinary support, digital health records, climate and fodder management, and Kannada-language accessibility. Since the present study is based on secondary data, this comparison evaluates functional relevance and potential applicability rather than actual farmer-level adoption or usage in Bagalkot.

Table 3: Comparative Assessment of AI and Digital Livestock Tools

Tool	Main Function	Livestock Application	AI/Digital Component	Kannada/Local-Language Relevance	Relevance to Bagalkot
NADRES-V2	Disease-risk forecasting	Disease surveillance and early warning	AI/ML predictive analytics	SMS/alert ecosystem	High
Dairy Kannada	Dairy advisory and management	Breeding, feeding, disease, vaccination and records	Digital advisory	Kannada	High
PashuCare	AI disease diagnosis and veterinary support	Image-based disease screening and tele-veterinary support	AI image diagnosis	Kannada and other Indian languages	High potential
E-Pashudhan	Digital livestock management	Health records, disease detection and animal identification	AI/image-based functions and digital records	Multilingual	High potential
Pashu Sathi	Livestock healthcare	Disease scanning and veterinary consultation	AI disease scanning	Indian-language support	Moderate–High potential
CattlePal	Cattle image screening	Visual screening of diseases	Computer vision/ML	Limited/unclear	Moderate potential
AHVS Karnataka	Veterinary-service management	Veterinary and animal-husbandry service information	Digital/GIS service mapping	Karnataka-focused	High institutional relevance

The comparison indicates that the selected technologies have different functional roles. NADRES-V2 is mainly associated with disease surveillance and risk forecasting, while Dairy Kannada provides Kannada-language dairy advisory services. PashuCare and E-Pashudhan provide broader AI-enabled functions, including image-based disease screening and digital livestock management. CattlePal has a more focused image-screening function, whereas AHVS Karnataka is primarily relevant for veterinary-service and institutional support. For Bagalkot, disease surveillance, Kannada-language advisory, mobile-based diagnosis, digital health records, and tele-veterinary services appear particularly relevant. These findings indicate potential applicability rather than confirmed farmer adoption.

6. Potential AI-Enabled Veterinary Diagnostics and Service Delivery in Bagalkot District

6.1 Veterinary Service Context and Diagnostic Constraints

Veterinary services in rural Bagalkot may be constrained by distance, transport, connectivity, veterinary personnel, and diagnostic facilities, affecting timely reporting, diagnosis, treatment, and follow-up. Digital technologies can improve case reporting, communication, information management, and referral, but should complement veterinary examination and laboratory diagnosis. Existing Karnataka livestock information systems support records on treatment, disease, mortality, vaccination, breeding, fodder, insurance, and veterinary services, but do not indicate district-wide AI deployment.

6.2 AI-Assisted Disease-Risk Identification and Surveillance

AI and ML can analyse disease, livestock, weather, environmental, and historical data to identify disease-risk patterns and support surveillance, preparedness, risk communication, and resource allocation. In India, NADRES v2, developed by ICAR-NIVEDI, provides district-level disease-risk forecasting using such data. For Bagalkot, similar systems could support early warnings and targeted veterinary preparedness. However, risk identification, surveillance, forecasting, screening, and diagnosis are distinct functions; AI alerts indicate potential risk and do not confirm disease, which requires veterinary and/or laboratory

assessment.

6.3 Digital Case Reporting and Symptom-Based Screening

Digital case-reporting systems can enable farmers, field workers, and veterinarians to record symptoms, unusual mortality, behavioural changes, reduced production, and other health observations. AI-supported screening can analyse these reports and identify cases requiring veterinary attention, potentially reducing communication delays in remote villages. However, symptom-based AI should not independently prescribe treatment because similar signs may have different causes. Urgent cases—including sudden mortality, severe respiratory or neurological signs, inability to stand, suspected zoonotic disease, abortion clusters, or rapidly increasing disease events—should be immediately escalated to qualified veterinary personnel.

6.4 Image-Assisted Screening and Diagnostic Decision Support

Computer vision and deep learning can analyse photographs, videos, radiographs, and ultrasound images to identify patterns associated with possible health conditions. Smartphone images of lesions, wounds, skin or eye abnormalities, and body-condition changes could support veterinary assessment; however, performance depends on image quality, lighting, and training data representing local species, breeds, ages, production systems, disease stages, and field conditions. Models developed from other regions or commercial farms may not perform reliably under Bagalkot's smallholder conditions, and similar visual signs may occur in different diseases. Therefore, image-based AI should be used for AI-assisted screening and diagnostic decision support, not autonomous veterinary diagnosis, with veterinary examination and laboratory testing used when confirmation is required.

6.5 Tele-Veterinary Consultation, Triage, and Referral

Tele-veterinary services can connect livestock owners with veterinarians through calls, video, photographs, messaging, and digital records for consultation, triage, referral, and follow-up. AI can assist in organizing case information and prioritizing high-risk cases, while diagnosis and treatment remain under veterinary supervision.

A potential service pathway is:



AI can organize case information, identify high-risk cases, summarize animal records, and support veterinary case prioritization. However, tele-veterinary services cannot replace physical examination, vaccination, surgery, emergency treatment, sample collection, or laboratory testing. Cases involving sudden mortality, suspected outbreaks, severe clinical signs, or potential zoonotic diseases should be immediately referred to qualified veterinary authorities.

6.6 Kannada Mobile App (Dairy Kannada) and Voice-Based Advisory

Kannada-language mobile platforms such as Dairy Kannada can improve access to livestock and dairy advisory services in rural areas through text-based information, voice support, speech recognition, and interactive communication. Potential applications include vaccination and deworming reminders, heat and weather alerts, fodder and water management information, biosecurity guidance, disease reporting, veterinary referral, and follow-up support. Routine advisories and reminders may be digitally automated, while diagnosis, treatment, dosage recommendations, antibiotic use, outbreak management, and serious animal-health cases require veterinary supervision. Therefore, veterinarian-reviewed content and regular updating are essential for safe and reliable use.

6.7 Role of Veterinarians and Laboratory Confirmation

Veterinarians remain central to AI-supported veterinary services, as AI can organize information, identify patterns, generate alerts, and support preliminary screening but cannot replace professional clinical judgement. Veterinarians must interpret AI outputs, confirm diagnoses, determine laboratory requirements, prescribe treatment, and make referral or outbreak-control decisions. A human-in-the-loop model is therefore appropriate for Bagalkot, with AI providing decision support while clinical accountability remains with qualified veterinary professionals; where required, samples should be tested through appropriate diagnostic facilities to reduce risks from false-positive and false-negative AI outputs.

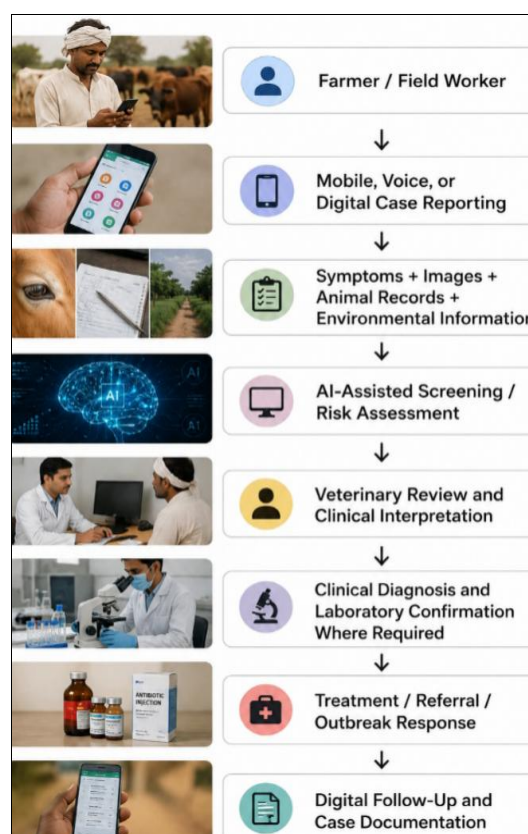
6.8 Institutional Integration, Interoperability, and Data Governance

AI-enabled veterinary services should integrate with existing veterinary hospitals, field veterinarians, disease-surveillance programmes, diagnostic laboratories, extension services, and digital livestock systems. Effective integration

requires standardized animal and disease records, database interoperability, regular data-quality checks, timely updates, and clear responsibilities among stakeholders. Data governance should ensure access control, privacy, cybersecurity, data quality, and clear rules for data ownership and use. AI systems should also be periodically evaluated for accuracy, false alerts, bias, usability, affordability, and performance under local field conditions.

6.9 Proposed AI-Supported Veterinary Service Pathway

Based on the reviewed evidence, a potential AI-supported veterinary service pathway for Bagalkot can be conceptualized as follows:



This pathway places AI between information collection and professional decision-making rather than treating AI as an autonomous diagnostic authority. Such a model can potentially improve information flow and case prioritization while retaining veterinary oversight and laboratory confirmation.

6.10 Practical Feasibility and Implementation Priorities

For Bagalkot, AI implementation should consider local infrastructure, affordability, data availability, digital literacy, and veterinary capacity. Priorities include strengthening digital disease reporting and livestock records; integrating disease-risk alerts with veterinarian-supervised communication; developing Kannada-language and voice-based advisory and referral services; piloting AI-assisted symptom and image screening under veterinary supervision; evaluating accuracy, usability, affordability, acceptance, equity, and veterinary workload; and introducing advanced sensors only where connectivity, maintenance, affordability, and technical support are adequate. A phased approach is more suitable, beginning with low-cost digital communication and decision-support services before considering advanced sensor-based and automated technologies where institutional or cooperative support is available.

7. Contextual Opportunities and Potential Benefits of AI and ML for Livestock Systems in Bagalkot District

The potential use of AI and ML in Bagalkot was assessed through a contextual feasibility framework considering local livestock and veterinary needs, potential beneficiaries, data requirements, affordability, connectivity, equipment needs,

veterinary supervision, institutional readiness, and suitability for smallholder systems. Key opportunities include disease surveillance and risk forecasting, tele-veterinary communication, digital livestock records, Kannada-language and voice-based advisories, poultry mortality reporting, fodder and water planning, heat, drought and flood alerts, and farmer decision support. AI can combine livestock, disease, weather, environmental, and historical data to support early risk identification, preventive-health communication, case prioritization, resource planning, and climate preparedness. NADRES v2, developed by ICAR–NIVEDI, provides a relevant national example of AI-supported livestock disease-risk forecasting. For Bagalkot's smallholder and mixed crop–livestock systems, low-cost, mobile-first, Kannada-language, and veterinarian-supervised services are likely to be more immediately feasible than sensor-intensive or fully automated technologies. AI outputs should support rather than replace veterinary examination, laboratory confirmation, treatment, and professional judgement. The priority classification is based on secondary evidence and contextual feasibility, not measured effectiveness, diagnostic accuracy, adoption, economic return, or livestock-health outcomes in Bagalkot.

Table 4: Priority Opportunities for AI and ML in Bagalkot Livestock Systems

AI/ML Application	Priority	Primary Beneficiaries	Delivery Model	Key Requirements
Disease surveillance and risk forecasting	High	Veterinary services, livestock owners	District/institutional system	Accurate disease, livestock and weather data
Mobile and tele-veterinary advisory	High	Smallholder farmers	Veterinarian-supervised mobile service	Connectivity, Kannada support, veterinary availability
Digital livestock records	High	Farmers, veterinary institutions	Government/cooperative platform	Standardized animal and health records
Kannada voice-based advisory	High	Low-digital-literacy users	Mobile/IVR/voice system	Locally validated content
Heat, drought and flood alerts	High	Livestock-owning households	Weather/disaster-warning integration	Localized forecasts and response capacity
Fodder-planning support	High	Farmers, extension workers	Mobile/extension advisory	Fodder, livestock and weather information
Poultry mortality reporting	Moderate–High	Poultry keepers, veterinary staff	Mobile reporting and response	Timely reporting and escalation
AI-assisted image screening	Moderate	Farmers, veterinarians	Veterinarian-reviewed platform	Quality images and local validation
Water-quality sensor monitoring	Moderate	Communities, local institutions	Shared monitoring system	Sensors, maintenance and technical support
Wearable animal sensors	Moderate–Low	Organized farms/cooperatives	Shared or farm-level system	Cost, maintenance and connectivity
Automated precision feeding	Low–Moderate	Commercial/organized farms	Farm-level technology	High-quality data and specialized equipment

The applications should be introduced through a phased strategy. Phase 1 should prioritize digital disease reporting, mobile/tele-veterinary communication, Kannada voice/SMS advisories, preventive-health reminders, basic livestock records, and localized climate alerts. Phase 2 should strengthen integration of veterinary records, disease surveillance, laboratories, weather data, tele-triage, referral systems, disease-risk forecasting, and fodder planning. Phase 3 may introduce AI image screening, wearable monitoring, water-quality sensors, reproductive/productivity tools, and precision livestock technologies through selected pilot sites. Before wider deployment, systems should be

locally validated and evaluated for accuracy, usability, affordability, data quality, farmer trust, veterinary acceptance, equity, reliability, connectivity, maintenance, and institutional readiness.

8. Barriers, Adoption Constraints, and Enabling Conditions for AI and ML in Bagalkot Livestock Systems

The adoption of AI- and ML-enabled livestock services in Bagalkot depends on interconnected farmer-level, technological, institutional, and governance factors. Key barriers include digital literacy and device access,

connectivity and power supply, awareness and perceived usefulness, Kannada-language accessibility, affordability, technical capacity, data quality, local validation, interoperability, privacy and cybersecurity, trust, accountability, and institutional coordination. Adoption should consider smartphone and mobile-data access, simple interfaces, voice/SMS and offline services, practical training, and inclusive access for women livestock keepers. AI services should use locally relevant Kannada terminology and be integrated with existing veterinary, laboratory, extension, livestock-record, and disease-surveillance systems. Reliable and representative data, standardized animal and disease records, local model validation, veterinary oversight, secure data governance, and periodic monitoring are essential to ensure accuracy, reliability, and responsible use. Costs should include devices, data, training, maintenance, technical support, cybersecurity, model validation, and system upgrades; therefore, low-cost, cooperative, and government-supported models may be more sustainable for smallholders. Based on qualitative prioritization of occurrence, likely influence, and difficulty of addressing barriers—not a statistically representative farmer survey—the immediate priorities are digital-literacy support, Kannada mobile and voice services, digital disease reporting, preventive-health reminders, and climate alerts; medium-term priorities include interoperable livestock records, veterinarian-supervised tele-triage, disease-risk forecasting, and strengthened data governance; and advanced technologies such as AI image screening, continuous sensors, and automated decision support should be piloted and locally validated before wider deployment. AI should remain a decision-support tool, with diagnosis, treatment, laboratory confirmation, outbreak investigation, and professional accountability under qualified veterinary supervision.

9. Discussion and Interpretation of Findings

The findings indicate that AI and ML in Bagalkot are most relevant as veterinarian-supervised decision-support tools for digital disease reporting and surveillance, livestock records, mobile and tele-veterinary communication, Kannada-language advisories, climate and heat-stress alerts, fodder and water planning, and case prioritization. Their suitability for smallholder and mixed crop–livestock systems depends on affordability, connectivity, digital literacy, local livestock species and breeds, data quality, veterinary infrastructure, and field validation. A phased approach is recommended, beginning with low-cost digital reporting, advisories, preventive-health reminders, and basic records, followed by interoperable records, tele-triage, disease-risk forecasting, and fodder planning, while advanced image screening, wearable sensors, automated prediction, and precision feeding should initially be tested through pilot programmes. Sustainable implementation requires coordination among veterinary departments, laboratories, universities, ICAR and research institutions, extension services, technology providers, cooperatives, farmer organizations, and disaster-management agencies. Kannada-language, voice-based, pictorial, inclusive, and farmer-participatory services should be prioritized, including participation of women livestock keepers. AI should complement rather than replace clinical examination,

diagnosis, treatment, laboratory confirmation, outbreak investigation, and professional veterinary judgement. AI can contribute to sustainable and climate-resilient livestock development through earlier risk identification, improved veterinary communication, climate preparedness, and better fodder and water planning. However, this secondary-data study does not establish actual adoption, diagnostic accuracy, economic benefits, or causal health improvements; therefore, future research should include farmer surveys, stakeholder interviews, infrastructure assessment, and field pilots evaluating model accuracy, cost-effectiveness, data quality, interoperability, inclusion, trust, reporting time, veterinary response, and livestock-health outcomes.

10. Policy and Implementation Recommendations

AI and ML livestock services in Bagalkot should be affordable, accessible, Kannada-language, locally relevant, veterinarian-supervised, secure, interoperable, accountable, and sustainable. They should complement existing veterinary, laboratory, extension, and disease-surveillance systems.

Rural infrastructure should support mobile, low-bandwidth, offline, SMS, voice, and smartphone-based services. Farmer-centred platforms should provide simple Kannada communication, pictorial information, and clear veterinary referral guidance. Continuous training should improve digital literacy among farmers, women livestock keepers, veterinarians, para-veterinary workers, and extension personnel, covering disease reporting, AI alerts, tele-triage, privacy, data quality, and emergency referral.

Integrated livestock databases should include animal identification, species and breed, vaccination, clinical and mortality records, veterinary visits, laboratory results, and weather information. Tele-veterinary services should support reporting, consultation, triage, referral, and follow-up, while diagnosis, treatment, and drug decisions remain under qualified veterinary supervision.

AI should support climate-resilient livestock management through heat, drought, flood, fodder, water, and disease-risk advisories. Implementation should involve veterinary departments, laboratories, universities, ICAR institutions, extension services, cooperatives, farmer organizations, and technology providers. AI systems should be locally validated and monitored for accuracy, false alerts, missed cases, data quality, privacy, reliability, equity, and maintenance.

Implementation should be phased: Phase I (0–2 years) for digital reporting, Kannada voice/SMS advisories, preventive reminders, training, and tele-veterinary pilots; Phase II (2–5 years) for interoperable records, climate/fodder advisories, tele-triage, disease-risk analytics, and data governance; and Phase III (beyond 5 years) for validated image screening, sensor monitoring, advanced forecasting, and precision livestock management.

Monitoring should assess access, inclusion, user adoption, veterinary response time, data quality, system reliability, privacy, farmer satisfaction and trust, cost-effectiveness, equity, disease-reporting timeliness, mortality, disease incidence, and productivity. Clinical outcomes should be evaluated through prospective studies with appropriate comparison groups before large-scale deployment.

11. Conclusion

11.1 Conclusions and Practical Implications

This study examined the potential relevance of Artificial Intelligence (AI) and Machine Learning (ML) for livestock management and veterinary diagnostics in Bagalkot district, Karnataka, using secondary evidence from research literature, government records, institutional documents, and digital livestock initiatives. The findings indicate that AI and ML can potentially support disease surveillance, digital livestock records, mobile veterinary communication, tele-veterinary services, climate-risk and heat-stress alerts, fodder and water planning, farmer advisories, case prioritization, referral support, and livestock-health monitoring. However, the study does not establish that these technologies have already been successfully implemented or produced measurable improvements in livestock health, productivity, or rural livelihoods in Bagalkot.

The most practical near-term applications are likely to be low-cost, mobile-accessible, Kannada-language, and veterinarian-supervised services. Digital disease reporting, preventive-health reminders, climate and heat-stress alerts, fodder and water-planning information, tele-veterinary communication, referral support, and basic livestock-record digitization may be more suitable for smallholder and mixed-livestock systems than costly sensor-intensive or fully automated technologies. AI should therefore be used primarily as a decision-support mechanism to improve information flow, risk identification, case prioritization, and communication rather than replace veterinary judgement, laboratory confirmation, emergency treatment, or established disease-control systems.

Responsible AI and ML adoption requires reliable and locally relevant data, local validation, affordability, digital literacy, farmer trust, Kannada-language communication, data privacy and security, veterinary oversight, technical capacity, and institutional interoperability. Advanced applications such as AI-assisted image screening, continuous sensor monitoring, disease-risk forecasting, precision livestock management, and automated decision-support should be introduced through phased pilot programmes and evaluated for accuracy, usability, affordability, equity, maintenance, reliability, and field performance. Collaboration among government veterinary departments, laboratories, research institutions, extension services, cooperatives, farmer organizations, and technology providers can provide a sustainable pathway for strengthening livestock management and veterinary services in Bagalkot.

11.2 Future Research Directions

Future research should include primary surveys, stakeholder interviews, and field pilots with farmers, veterinarians, and related institutions. Studies should assess AI awareness, affordability, digital literacy, connectivity, trust, and institutional readiness. Pilot projects can evaluate local-language advisory systems, digital disease reporting, tele-triage, AI image screening, and disease-risk forecasting using local data. Further research should assess usability, accuracy, cost-effectiveness, reliability, equity, and animal-health outcomes before large-scale implementation.

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