

# Bridging the Gap: The Role of Education and Digital Technologies in Revolutionizing Livestock Farming for Sustainability and Resilience

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**Abstract**—Livestock farming remains a cornerstone of global agricultural systems, contributing significantly to food security, economic development, and rural livelihoods. However, the sector is increasingly challenged by environmental degradation, inefficient practices, and socio-economic barriers. Education serves as a pivotal solution, empowering farmers with the knowledge and skills required for sustainable livestock management. This bibliometric analysis explores the intersection of livestock farming and education, analyzing research trends, thematic clusters, and collaboration patterns from 2015 to 2024 using data from the Web of Science database and VOSviewer software. The analysis identifies critical themes, such as sustainable practices, climate resilience, zoonotic disease management, and socio-economic empowerment, underscoring the transformative role of education in addressing these issues. Additionally, the integration of digital technologies, such as mobile learning platforms, precision farming tools, and blockchain-based traceability systems, enhances the accessibility and effectiveness of educational initiatives in livestock management. The findings reveal a steady growth in research on this topic, with significant academic and practical implications. Targeted educational interventions, including Farmer Field Schools and tailored training programs, are recommended to enhance productivity, promote sustainability, and foster inclusivity in the livestock sector. By integrating education with livestock farming, the study contributes to achieving Sustainable Development Goals, particularly Goals 2 (Zero Hunger) and 4 (Quality Education). This research provides a comprehensive foundation for policymakers, researchers, and practitioners to advance the integration of education in livestock farming, fostering resilience and sustainability within the sector.

**Keywords**—Livestock farming; sustainable agriculture; digital technologies; farmer education; climate resilience

## I. INTRODUCTION

This research proposes a bibliometric analysis to examine the connections between livestock farming supply chain management and education, aiming to underscore the importance of education in supporting the livestock industry. In

Malaysia, livestock farming is a vital sector, contributing 14.9 per cent to the GDP in 2018, with SMEs playing a significant role. However, despite government support, the sector faces considerable challenges in supply chain management (SCM). These challenges include supply chain disruptions due to extreme weather, labor shortages, limited information technology, and transportation issues. Through bibliometric analysis, this study will identify and review key literature that connects these SCM challenges with educational solutions, illustrating how education can critically enhance the sector's resilience and long-term sustainability. This bibliometric analysis explores the intersections between livestock farming and education to understand global research trends, identify knowledge gaps, and propose actionable solutions for raising awareness and improving the sector [1].

Despite the critical role of livestock farming in ensuring food security and economic stability, the sector remains under-optimized in many regions, especially in developing countries. Limited access to education and training for farmers leads to poor management practices, low productivity, and increased vulnerability to diseases and environmental challenges [2]. Furthermore, a lack of awareness about sustainable farming techniques exacerbates overgrazing, greenhouse gas emissions, and resource depletion [3]. Formal and informal education has not been adequately integrated into livestock farming to address these challenges effectively. A significant gap exists in the research and implementation of educational interventions tailored to the needs of livestock farmers. This bibliometric analysis aims to identify the scope and impact of existing research to promote targeted education initiatives within the livestock sector.

The integration of education into livestock farming is crucial for several reasons. Firstly, it empowers farmers with knowledge about innovative techniques, including precision farming, disease management, and sustainable practices [4]. Educated farmers are better equipped to make informed decisions, reduce operational costs, and improve productivity.

Secondly, education is pivotal in addressing environmental concerns associated with livestock farming, such as methane emissions and land degradation [1]. By raising awareness about eco-friendly practices, education fosters sustainability in the sector. Additionally, education can drive social change by encouraging gender inclusivity and youth participation in livestock farming, thereby ensuring intergenerational knowledge transfer and workforce rejuvenation [2]. Understanding these dynamics through bibliometric analysis can highlight the impact of education in transforming livestock farming into a more resilient and sustainable industry.

This bibliometric analysis is significant because it provides a comprehensive overview of the current livestock farming and education research landscape. By analyzing patterns, trends, and collaborations in the existing literature, the study aims to identify areas that require further investigation. The findings will help policymakers, researchers, and practitioners develop targeted interventions to enhance the effectiveness of educational programs in livestock farming [3]. Furthermore, this study contributes to global efforts in achieving the United Nations' Sustainable Development Goals (SDGs), particularly Goal 2 (Zero Hunger) and Goal 4 (Quality Education). By integrating education into livestock farming, the sector can become a model of sustainable development, balancing economic growth with environmental stewardship and social equity [1]. This analysis will serve as a foundation for future research and policy development, creating pathways for a more sustainable and educated farming community.

## II. LITERATURE REVIEW

Recent studies have underscored the significant role of education in enhancing livestock productivity. A 2020 qualitative review analyzed the effects of Farmer Field Schools (FFS) on various domains, including human, social, natural, and financial capital. The study found that FFS participants exhibited improved decision-making skills and adopted better livestock management practices, increasing productivity and income [5]. Similarly, [6] investigated the impact of FFS on smallholder livestock farmers' perceptions of climate change in South Africa. The findings revealed that FFS interventions enhanced farmers' awareness and understanding of climate change, resulting in adopting climate-smart livestock practices.

### A. Education's Role in Sustainable Livestock Practices

Education has been pivotal in promoting sustainable livestock farming. Varijakshapanicker *et al.* [7] discussed how sustainable livestock systems contribute to human health, nutrition, and economic status. The study emphasized that educating farmers on sustainable practices, such as carbon sequestration and efficient resource utilization, can mitigate environmental impacts and enhance the sustainability of livestock farming. Furthermore, Vigors *et al.* [8] explored the importance of farm animal health and natural behaviors to livestock farmers. The research highlighted that educational initiatives focusing on animal welfare and natural behaviors can improve livestock health and productivity, aligning with sustainable farming objectives.

### B. Socio-Economic Benefits of Livestock Farming Education

Educational programs targeting livestock farmers have demonstrated significant socio-economic benefits. Maltitz *et al.* [9] examined the empowerment of smallholder female livestock farmers and its potential for enhancing food security in drought-prone areas. The research concluded that education and training programs enabled women to adopt better livestock management practices, increasing household income and improving food security [9]. Additionally, a 2024 article reported the partnership between Casino Food Co-Op and TAFE NSW to deliver training programs for meat processing and livestock industry workers. The initiative aimed to equip employees with practical skills, supporting economic prosperity in the Northern Rivers region [10].

### C. Challenges and Future Directions in Livestock Farming Education

Despite the benefits, challenges persist in integrating education into livestock farming. Dawkins's [11] article discussed the potential negative impacts of smart farming technologies on animal welfare. The study cautioned that technological advancements can improve efficiency, but they may also neglect individual animal welfare if not accompanied by proper farmer education and training [11]. Moreover, a 2024 news article highlighted the increasing interest of Generation Z in agricultural careers, influenced by media personalities and a desire for outdoor professions. This trend underscores the need for educational institutions to adapt curricula that align with modern agricultural practices and the aspirations of younger generations [12].

Thus, the recent literature above emphasizes the integral role of education in enhancing livestock farming practices. Educational interventions have improved productivity, promoted sustainability, and yielded socio-economic benefits. However, challenges remain, necessitating continuous adaptation and innovation in educational approaches to meet the evolving needs of the livestock farming sector. Therefore, this research seeks to fill a notable gap in the field and provide valuable insights into the historical, current, and future research directions related to the factors that influence livestock farming through education based on the following objectives:

- To assess the most influential past research and analyse current trends in livestock farming through education through co-citation analysis.
- To identify emerging trends in livestock farming through education through co-occurrence analysis.

### D. Digital Technologies as Enablers of Livestock Education

Agricultural pedagogy is rapidly incorporating digital technologies to enhance livestock education's socio-economic and environmental benefits. Particularly in isolated and resource-poor areas, the next section explores how technologies like mobile learning and the Internet of Things have revolutionized the delivery of livestock education. Key issues including disease outbreaks, wasteful resource use, and climate variability are addressed by precision farming tools, e-learning platforms, and mobile applications that give farmers access to real-time data, predictive analytics, and remote advisory services [13]. The accessibility of technical knowledge is

enhanced via mobile-based training programs and interactive digital content, especially in distant locations with limited access to traditional extension services [14].

Moreover, machine learning and Internet of Things (IoT)-enabled sensors enhance livestock health monitoring by providing early disease detection, optimizing feeding systems, and automating farm management, ultimately reducing mortality rates and improving productivity [15]. To maximize the benefits of digital technologies, governments and agricultural institutions should prioritize investments in digital literacy programs and ICT infrastructure, ensuring that livestock farmers can effectively adopt and utilize these tools. By integrating digital technologies into livestock education, the sector can improve efficiency, economic gains, and environmental sustainability, aligning with the United Nations' Sustainable Development Goals (SDGs), particularly Goals 2 (Zero Hunger), 4 (Quality Education), and 9 (Industry, Innovation, and Infrastructure). The convergence of education and digital tools in livestock farming not only enhances operational efficiency but also empowers farmers with the necessary skills to navigate evolving agricultural challenges.

### III. METHODOLOGY

#### A. Data Pre-Processing

Data from the Web of Science database is used in this methodical bibliometric analysis of livestock farming and education. To perform the bibliometric visualization, VOSviewer v1.6.20 was used. To guarantee clarity in cluster separation, the layout was adjusted using the default attraction and repulsion parameters in VOSviewer. Modularity-based methods served as the foundation for clustering, which made it possible to identify theme groupings within the network. A quantitative framework for evaluating research trends, networks of collaboration, and thematic development of a particular topic is offered by bibliometric analysis. It identifies prolific contributors, impactful publications, and knowledge gaps [16]. This study covers publications from 2015 to 2024, focusing on identifying temporal trends, thematic structures, and research performance. Table I presents the inclusion criteria adopted for bibliometric analysis, outlining the standards used to ensure the relevance, quality and consistency of the selected literature.

TABLE I. INCLUSION CRITERIA FOR BIBLIOMETRIC ANALYSIS

WoS Database	ALL
Time period	2015 to 2024
Search field	TS
Search keywords	(TS=("livestock farm*")) AND TS=("educat*")
Citation Topics Meso	ALL
Document type	Article or Review Article
Language	English

The bibliometric analysis focused on the intersection of livestock farming and education, utilizing the Web of Science (WoS) database. The initial search using the keywords "livestock farm\*" and "educat\*" yielded 320 articles. Following refinement and the application of inclusion and exclusion criteria, the number of relevant articles was narrowed to 232.

The search parameters were carefully defined, focusing on articles and review articles published in English between 2015 and 2024. The search targeted articles that addressed livestock farming and education explicitly. The inclusion criteria ensured that only English-language articles published in the specified time frame were analyzed. Additionally, articles needed to fall under the document types of research or review papers. The exclusion of articles outside these parameters guaranteed a focused and relevant dataset. This approach underscores the importance of precise criteria to ensure the extracted data aligns with the research objectives.

A total of 232 articles were identified, with significant engagement in the scholarly community. The dataset includes 2,131 citing articles (or 2,089 when self-citations are excluded). These figures highlight the scholarly reach of the articles, reflecting widespread interest in the intersection of livestock farming and education. The total number of times these articles were cited is 2,291, or 2,228 without self-citation. These citations result in an average citation rate of 9.88 per item. The citation data suggests the topic's relevance in academic discourse, particularly regarding sustainability, education, and innovation in livestock farming practices. The h-index of 24 further demonstrates the impact of these articles, indicating that at least 24 of them have been cited 24 times or more.

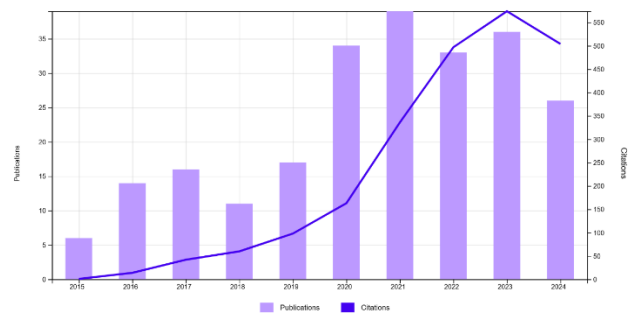


Fig. 1. Quantity of publications and citations between 2015 and 2024.

The "Trend Citation Diagram" provides insights into the growth of research in this field over time [17]. A steady increase in publications in Fig. 1 reflects the growing academic and practical interest in integrating education into livestock farming. This trend aligns with global priorities such as improving sustainability, food security, and rural development through educational initiatives. The citation patterns further suggest that recent articles are increasingly referenced, indicating a heightened awareness and urgency around this topic. The analysis highlights the critical role of education in transforming livestock farming practices. The average citation rate of 9.88 per item and the h-index of 24 underscore the academic influence of this body of work. Over time, the growing number of publications and citations reflects an increasing recognition of education as a key factor in addressing challenges in livestock farming, including productivity, sustainability, and climate adaptation.

### IV. RESULTS

Performance analysis evaluated the productivity and impact of researchers, institutions, and journals in this domain. Citation-based metrics, such as the h-index and g-index, were calculated

to assess scholarly influence. The analysis identified the most prolific authors, institutions, and countries contributing to livestock farming and education research. For instance, countries like the United States, China, and India emerged as leading contributors, reflecting their significant agricultural research and education investments. The findings provide insights into regional disparities and opportunities for international collaboration.

#### A. Documents Performance

The document analysis reveals the prominence of research focused on sustainable practices and education's role in livestock farming. Elahi *et al.* [18], the most cited paper with 148 citations, delves into the cognitive and socio-psychological drivers influencing farmers' decisions to adopt improved grassland practices. This study underscores how education and targeted policy interventions can bridge knowledge gaps and promote sustainable pasture production. Similarly, Ventura *et al.* [19], with 107 citations, examines public perceptions of animal welfare after visits to dairy farms. It highlights the transformative power of experiential learning in reshaping societal attitudes toward livestock farming.

The third-ranked study by Lindahl *et al.* [20] (76 citations) investigates brucellosis-related knowledge and practices among small-scale farmers in Tajikistan. It emphasizes the importance of farmer education in combating zoonotic diseases, illustrating how training programs can safeguard public health and livestock productivity. Additionally, Pfeiffer *et al.* [21] with 56 citations, explores societal acceptance of digital farming technologies in Germany, highlighting education's role in fostering trust and adoption of innovations. Tang and Hailu [22] (50 citations) focus on climate adaptation strategies, showing how educating farmers can enhance resilience against climate-induced challenges. These studies collectively affirm education's central role in addressing the diverse challenges of livestock farming.

#### B. Sources Performance

The analysis identifies Sustainability as the leading journal, with 11 documents and 81 citations. This reflects a significant focus on integrating environmental, economic, and social dimensions into livestock farming. With 8 publications and 38 citations, *Frontiers in Veterinary Science* contributes critical research on animal health and welfare, aligning with education-driven improvements in livestock practices. *Veterinary Medicine and Science and Animals*, both publishing seven articles, emphasize the intersection of veterinary knowledge and farmer education to improve livestock outcomes. Notably, the *Land Use Policy*, with six documents and 247 citations, demonstrates its influence in shaping sustainable practices through policy-oriented research. This distribution indicates a balanced focus across sustainability, veterinary sciences, and policy-making, with education as a unifying theme.

#### C. Authors' Performance

Among the top authors, Yonas T. Bahta emerges as a key contributor with four documents and 32 citations, focusing on the socio-economic impacts of livestock farming education in African contexts. Oene Oenema, with three documents and 50 citations, highlights nutrient management and sustainable

farming practices, advocating for better farmer education. Eugenio Demartini, Rosalia Filippini, and Anna Gaviglio, each with three documents and 63 citations, explore consumer attitudes and sustainable farming systems, emphasizing education as a bridge between farmers and consumers. The collective contributions of these authors reflect a growing recognition of education's role in promoting sustainability and innovation in livestock farming.

#### D. Organisational Performance

The University of the Free State leads with eight documents and 90 citations, demonstrating a strong focus on regional challenges and farmer education in South Africa. The University of Pretoria, with seven documents and 48 citations, specializes in veterinary research and farmer training. China Agricultural University contributes five documents and 43 citations, strongly emphasizing climate-smart practices and educational interventions. The University of Milan (86 citations) and the International Livestock Research Institute (ILRI) (38 citations) focus on consumer education and tailored farmer training programs, respectively. These institutions collectively highlight the diverse global efforts in research and practical applications of livestock farming education.

#### E. Countries Performance

The analysis shows that the USA leads research contributions with 29 documents and 252 citations, focusing on technological and sustainable advancements. With 25 documents and 182 citations, South Africa highlights region-specific challenges and education as a transformative tool for livestock farmers. Germany (16 documents, 120 citations) emphasizes digital technologies, reflecting its commitment to advancing smart farming. China (15 documents, 312 citations) focuses on climate-smart strategies, showcasing the role of education in resilience-building. Ethiopia (12 documents, 71 citations) highlights the benefits of farmer education for smallholders, emphasizing its impact on productivity and sustainability. These findings indicate a global interest in the role of education in improving livestock farming practices.

#### F. Co-Citation Analysis

The top ten most cited papers in Table II reflect the interdisciplinary nature of livestock research, addressing critical issues such as climate change, zoonotic diseases, behavioral science, and sustainable agricultural practices. Rojas-Downing *et al.* [23] lead the list, which provides a comprehensive overview of climate change impacts on livestock, emphasizing adaptation and mitigation strategies to enhance resilience. Similarly, Deressa *et al.* [24] and Martin *et al.* [25] delve into climate adaptation and sustainability. Deressa *et al.* [24] focus on Ethiopian farmers' choices of climate adaptation methods, and Martin *et al.* [25] highlight the benefits of multi-species farming systems. Addressing public health, several studies, including Musallam *et al.* [26], Çakmur *et al.* [27] and Lindahl *et al.* [20] explore the knowledge, attitudes, and practices (KAP) of livestock farmers regarding zoonotic diseases like brucellosis in diverse regional contexts such as Jordan, Turkey, and Tajikistan. Their findings underscore the necessity for targeted educational and policy interventions to reduce zoonotic risks.

TABLE II. CO-CITATIONS (TOP 10 ARTICLES)

Rank	Authors	Title	Citations	Total Link Strength
1	[23]	Climate change and livestock: Impacts, adaptation, and mitigation	8	31
2	[26]	Knowledge, attitudes, and practices associated with brucellosis in livestock owners in Jordan	6	48
3	[27]	Evaluation of farmers' knowledge-attitude-practice about zoonotic diseases in Kars, Turkey	6	35
4	[18]	A study of knowledge, attitudes and practices relating to brucellosis among small-scale dairy farmers in an urban and peri-urban area of Tajikistan	6	33
5	[28]	The Theory of planned behavior	6	6
6	[29]	Awareness, knowledge, and risks of zoonotic diseases among livestock farmers in Punjab	5	44
7	[30]	Human-livestock contacts and their relationship to transmission of zoonotic pathogens, a systematic review of literature	5	35
8	[31]	Risk factors for human disease emergence	5	26
9	[25]	Potential of multi-species livestock farming to improve the sustainability of livestock farms: A review	5	20
10	[24]	Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia	5	19

From a behavioral perspective, Ajzen's [28] "Theory of Planned Behavior" provides a theoretical framework widely applied in livestock research to understand decision-making processes, particularly in disease management and sustainable practices. Hundal *et al.* [29] and Klous *et al.* [30] extend this focus by evaluating zoonotic disease awareness among farmers and the broader relationship between human-livestock interactions and pathogen transmission, respectively. Additionally, Taylor *et al.* [31] offer foundational insights into the risk factors driving human disease emergence, linking environmental changes and human activity to the increased prevalence of zoonoses. These studies illustrate the global scope of livestock-related challenges and the need for integrated, multidisciplinary approaches to ensure sustainable livestock management, public health, and climate resilience. These influential works provide a roadmap for addressing the complexities of livestock systems, highlighting both the shared and unique challenges across different regions and thematic areas.

#### Co-Citation by Clusters

Co-citation analysis reveals the interconnectedness and influence of various scholarly works in a research domain. The document highlights six clusters based on thematic relationships and citation strengths, as seen in Table III. The following analysis from VOSviewer in Fig. 2 explores the thematic clusters within a co-citation network, highlighting the interconnectedness of various research topics and their contributions to the broader discourse.

**Cluster 1 (Red): Zoonotic Diseases and Public Health,** highlights the importance of understanding zoonotic diseases, diseases transmitted between animals and humans, particularly in livestock contexts. The works within this cluster examine the intricate dynamics between human health and livestock management. Hundal *et al.* [29] and Çakmur *et al.* [27] focus on farmers' knowledge, attitudes, and practices (KAP), identifying gaps that might contribute to the spread of zoonotic diseases. Lindahl *et al.* [20] extend this by evaluating small-scale dairy

farmers' behaviors in urban settings, emphasizing the need for tailored public health interventions. The systematic reviews, such as Klous *et al.* [30], consolidate findings across various studies, providing a macro perspective on human-livestock interactions and zoonotic pathogen transmission. Taylor *et al.* [31] and other broad analyses within this cluster point towards the emergence of zoonotic diseases as global threats, linking them to environmental and social factors.

**Cluster 2 (Green): Climate Change and Livestock Adaptation,** is a recurring theme in livestock research, and this cluster reflects its multifaceted impacts on livestock systems. In [23], the authors comprehensively analyze the risks posed by climate change, such as heat stress, reduced water availability, feed scarcity, and mitigation and adaptation strategies. Considering socio-economic and environmental factors, Deressa *et al.* [24] and Feleke *et al.* [32] explore farmers' adaptation choices. Thornton *et al.* [33] extend this discussion to the broader impacts of climate variability on livestock systems in developing countries, highlighting knowledge gaps that need addressing. Other works, such as Mulwa *et al.* [34] and Amamou *et al.* [35], focus on adaptation strategies, illustrating how diverse contexts—from Northern Ethiopia to Tunisia—shape farmers' decisions and the effectiveness of these strategies.

**Cluster 3 (Blue): Behavior and Biosecurity,** bridges theoretical models, such as Ajzen's [28] "Theory of Planned Behavior," with practical issues like disease control and biosecurity on farms. This fusion of behavioral psychology with veterinary science provides a novel approach for addressing persistent challenges in livestock management. Studies by Ellis-Iversen *et al.* [36] and Alarcon *et al.* [37] focus on how farmers' perceptions, motivations, and circumstances influence their decision-making around biosecurity practices. Thornton [38] and Wright *et al.* [39] examine the role of professional and institutional influences on farm-level behaviors. Together, these studies advocate for more tailored communication strategies and incentives that align with farmers' perspectives, improving compliance with disease prevention measures.

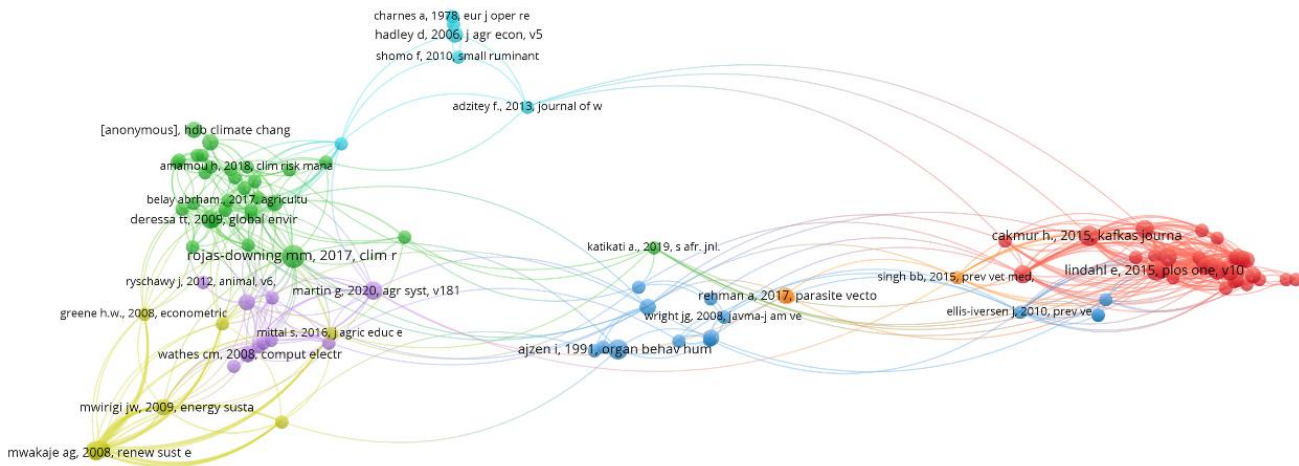


Fig. 2. Co-citations analysis (VOS viewer visualisation).

Cluster 4 (Yellow): Renewable Energy and Socio-Economic Constraints, focuses on renewable energy solutions, particularly biogas, as a sustainable alternative for rural communities. Studies like Mwirigi et al. [40] and Walekhwa et al. [41] identify the socio-economic barriers that hinder the adoption of biogas technology, such as high initial costs and lack of awareness. Yasmin and Grundmann [42] and Mittal and Mehar [43] emphasize the role of information and communication technologies in overcoming these barriers. Adopting renewable energy is framed as an environmental necessity and a means to improve rural livelihoods and reduce dependency on conventional fuels.

Cluster 5 (Purple): Sustainable Livestock Systems, looks into Sustainability, with works like Herrero et al. [44] advocating for mixed crop-livestock systems that balance productivity with environmental conservation. Nardone et al.

[45] research into the effects of climate change on livestock systems, advocating for strategies that enhance both resilience and sustainability. The studies within this cluster reflect a shift from intensive, monoculture livestock farming to integrated systems that maximize resource efficiency while mitigating environmental harm.

Cluster 6 (Turquoise): Efficiency and Livestock Production, focuses on efficiency in livestock production, particularly in resource-limited settings. Shomo et al. [46] and Dossa et al. [47] explore technical efficiency and socio-economic determinants of livestock management. These studies highlight the potential for optimizing livestock systems to improve productivity without additional resource input. This cluster’s findings are especially relevant for regions with constrained resources, where maximizing efficiency is crucial for economic and environmental sustainability.

TABLE III. CO-CITATION CLUSTER ON LIVESTOCK FARMING THROUGH EDUCATION

Cluster No and Colour	Cluster Labels	No. of Articles	Representative Publications
Cluster 1 (Red)	Zoonotic Diseases and Public Health	33	[20], [26], [27], [29], [30], [31], [48] [49], [50]
Cluster 2 (Green)	Climate Change and Livestock Adaptation	30	[23], [24], [32], [33], [34], [35], [51], [52], [53]
Cluster 3 (Blue)	Behavior and Biosecurity	14	[28], [36], [37], [38], [39], [54], [55]
Cluster 4 (Yellow)	Renewable Energy and Socio-Economic Constraints	13	[40], [41], [42], [43], [56], [57]
Cluster 5 (Purple)	Sustainable Livestock Systems	11	[44], [45], [58], [59]
Cluster 6 (Turquoise)	Efficiency and Livestock Production	7	[46], [47], [60], [61]

### V. CO-OCCURRENCE ANALYSIS

Co-occurrence analysis is a bibliometric method to explore the relationships between keywords in scholarly research. Keywords represent the core concepts of a study, and their co-occurrence indicates conceptual linkages, thematic relevance, and interdisciplinary connections. The co-occurrence analysis of keywords in livestock farming and education research reveals several key themes that provide a structured understanding of the field. Table IV illustrates the top 15 most frequent keywords, reflecting the domain's main focus areas.

At the forefront, livestock emerges as the most frequent keyword, with 29 occurrences and a total link strength of 76.

This highlights its centrality in health, management, and sustainability studies. Terms like management (22 occurrences, 85 link strength) and knowledge (22 occurrences, 76 link strength) emphasize the importance of effective handling practices and education in improving livestock farming outcomes. These keywords suggest that the field prioritizes operational efficiency and stakeholder empowerment through education.

Environmental sustainability is another significant focus, with keywords like climate change (16 occurrences, 65 link strength), adaptation (13 occurrences, 66 link strength), and impacts (14 occurrences, 50 link strength). These terms illustrate



Cluster 3 (Blue) focuses on sustainable livestock management, with keywords such as “management”, “sustainability”, and “farmers”. This theme explores how sustainable practices can balance productivity with ecological preservation. The cluster also examines the role of farmer perceptions and decision-making in adopting sustainable development goals. By linking farmer behavior to sustainability outcomes, this cluster emphasizes the need for policies and interventions that align with the socio-economic realities of farming communities. It reinforces the idea that sustainability is not just about environmental conservation but also about ensuring economic and social well-being for farmers.

Cluster 4 (Yellow) highlights technology adoption and behavioral factors, centering on keywords like “attitudes”, “adoption”, and “technology”. This cluster delves into the behavioral and informational barriers influencing farmers’ willingness to adopt innovative practices. It underscores the

importance of education, information dissemination, and tailored outreach programs in driving technology uptake in livestock farming. By focusing on attitudes and perceptions, this cluster provides insights into how behavioral science can inform strategies to encourage innovation, particularly in resource-constrained or traditional farming settings.

Cluster 5 (Purple) examines the livelihood impacts of livestock farming, with keywords like “livestock farmers”, “impact”, and “performance”. This cluster focuses on livestock systems’ economic and social dimensions, emphasizing the importance of improving farmer livelihoods and productivity. Studies within this theme evaluate how farming practices affect regional economic performance and individual farmer outcomes. The findings from this cluster highlight the need for localized interventions and performance metrics to optimize the economic viability of livestock systems, particularly in developing regions.

TABLE V. CO-OCCURRENCE ANALYSIS ON LIVESTOCK FARMING THROUGH EDUCATION

Cluster No and Colour	Cluster Label	Number of Keywords	Representative Keywords
1 (Red)	Livestock Health and Zoonotic Diseases	22	“livestock”, “knowledge”, “cattle”, “health”, “prevalence”, “zoonoses”, “awareness”, risk-factors”, “brucellosis”, “infection”
2 (Green)	Climate Change and Agricultural Resilience	14	“agriculture”, “climate change”, “impacts”, “determinants”, “adaptation”, “systems”, “resilience”
3 (Blue)	Sustainable Livestock Management	12	“management”, “sustainability”, “farmers”, “perceptions”, “sustainable development”
4 (Yellow)	Technology Adoption and Behavioral Factors	11	“attitudes”, “adoption”, “technology”, “livestock farming”, “information”
5 (Purple)	Livelihood Impacts of Livestock Farming	7	“livestock farmers”, “impact”, “area”, “performance”

The cluster analysis and network visualization reveal a well-integrated research domain addressing critical challenges in livestock farming. Themes such as health, sustainability, technology adoption, and climate resilience highlight the interconnected nature of the field. These insights provide a roadmap for future research and policy development, emphasizing the need for integrative approaches to address global livestock farming and education challenges.

## VI. DISCUSSION

The discussion focuses on the intersection of livestock farming and education, emphasizing their collective potential to address critical challenges within the agricultural sector. This analysis unpacks the role of education as a transformative tool in improving farming practices, enhancing sustainability, and mitigating environmental and socio-economic challenges. By integrating bibliometric insights, the discussion bridges theoretical perspectives with practical implications, exploring how knowledge dissemination fosters innovation, resilience, and inclusivity in livestock farming. Furthermore, it reflects on the gaps identified in research and implementation, offering strategic pathways to amplify the impact of educational interventions in creating a sustainable and productive livestock sector.

Although the literature supports the benefits of livestock productivity education, the findings of several studies were not fully generalizable due to a lack of cross-regional applicability or longitudinal validation. Interventions like Farmer Field Schools, for example, were frequently assessed on the basis of

short-term results, with little empirical monitoring of long-term behavioral change or economic implications. Social desirability bias was also a danger because many studies used self-reported surveys instead of triangulated data collecting. These methodological flaws show that in order to evaluate educational interventions more thoroughly, mixed-method, long-term studies are required.

### A. Theoretical Implications

The livestock farming and education study highlights significant theoretical implications for agricultural and educational frameworks. By examining the integration of education into livestock farming, this research broadens the understanding of how knowledge dissemination and skill development influence farming practices. Theoretically, it supports the notion that education is a critical enabler for sustainable development, aligning with concepts like human capital theory and the diffusion of innovation. For instance, Rojas-Downing *et al.* [23] discusses how education can facilitate the adoption of climate adaptation and mitigation strategies in livestock farming, highlighting the role of informed decision-making in enhancing resilience to climate change.

Furthermore, the diffusion of innovation theory underscores the importance of education in spreading new ideas and technologies within a community. In livestock farming, educational initiatives can accelerate the adoption of innovations such as precision farming and disease management techniques. Ajzen’s [28] Theory of Planned Behavior also provides a framework for understanding how education influences farmers’

attitudes, subjective norms, and perceived behavioral control, thereby affecting their intentions and behaviors towards adopting sustainable practices.

This bibliometric analysis extends the theoretical discourse on interdisciplinary research by showcasing how education intersects with environmental sustainability, socio-economic empowerment, and agricultural resilience. It highlights the role of education in addressing multi-dimensional challenges such as climate change, zoonotic diseases, and resource inefficiency through informed decision-making and behavior modification among farmers. By mapping research trends and thematic clusters, the study contributes to a refined theoretical model that integrates educational interventions with livestock farming systems, providing a roadmap for future academic exploration.

### B. Practical Implications

Practically, this study underscores the urgent need for targeted educational programs tailored to livestock farmers' specific needs and challenges. The findings highlight that education empowers farmers to adopt sustainable practices, improve productivity, and address critical issues such as environmental degradation, climate adaptation, and zoonotic disease prevention. For example, Musallam *et al.* [26] found that educational interventions significantly improved livestock owners' knowledge and practices regarding brucellosis prevention in Jordan, leading to better disease management outcomes. Thus, policymakers and practitioners can use these insights to design curricula incorporating precision farming techniques, climate-smart agriculture, and animal welfare standards, fostering a more sustainable livestock sector.

Moreover, educational programs can enhance farmers' awareness and understanding of climate change, enabling them to implement effective adaptation strategies. Deressa *et al.* [24] demonstrated that Ethiopian farmers with access to climate-related education were more likely to adopt adaptive measures in response to climate variability, thereby improving their resilience. Additionally, education plays a crucial role in promoting sustainable livestock systems. Martin *et al.* [25] highlighted that educating farmers about the benefits of multi-species livestock farming can lead to more sustainable and productive agricultural practices. The study's insights can guide international efforts towards achieving Sustainable Development Goals, particularly those focused on quality education (Goal 4) and zero hunger (Goal 2), by aligning educational efforts with sustainable livestock practices.

## VII. CONCLUSION

This bibliometric research emphasizes the value of education in transforming livestock farming into a resilient, sustainable, and inclusive sector. The study examines how education empowers farmers to adopt sustainable practices and innovative approaches while recognizing interrelated challenges ranging from resource efficiency to managing zoonotic diseases and climate change. It does this by analyzing global research trends and thematic clusters from 2015 to 2024. Both formal and informal education—through programs like Farmer Field Schools and localized training—has demonstrated promise in improving livestock results and fostering inclusivity by incorporating women, youth, and marginalized groups.

The findings also demonstrate that barriers still exist, particularly in regions with limited access to high-quality education, digital technologies, and agricultural infrastructure. Addressing problems requires a multi-stakeholder response. To ensure that all students have equitable access to educational resources, policymakers must make targeted investments in digital literacy programs, extension services, and context-relevant curricula. Development organizations and practitioners can enhance the dissemination and transfer of valuable knowledge by developing technologically advanced, culturally aware learning platforms. In particular, researchers need to close the gaps in longitudinal and cross-regional impact studies about technology uptake, behavioral change, and multidisciplinary educational paradigms.

This study uses theories such as the Theory of Planned Behavior and the Diffusion of Innovation to theoretically explain how educational interventions impact farmer attitudes, behaviors, and decision-making. Disparities in the literature's application of theory, however, indicate that further conceptual integration is required in future research. Integrating education with innovation and policy can ignite a global shift toward sustainable livestock systems in accordance with the Sustainable Development Goals, particularly Goals 2 (Zero Hunger), 4 (Quality Education), and 13 (Climate Action).

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