

Effects of Livestock Grazing on Soil Erosion and Sustainability: A Bibliometric Review

Jam Marrie Nanche M. Paulin

West Visayas State University- College of Agriculture and Forestry, Jayobo, Lambunao, Iloilo, Philippines.

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ABSTRACT

This bibliometric analysis identified major themes for climate change and ecosystem-related research through the network, thus showing how interdisciplinary these areas are. Co-occurrence maps indicated that climatic change serves as a sort of central theme linking many separate disciplines, from land management to biodiversity preservation and environmental sustainability. The analysis provided three important clusters: the red cluster, which focuses more on biodiversity and agriculture for land-use changes and management of carbon; the green cluster, which emphasizes studying soil quality, erosion, and human impacts on environmental stability; and the blue cluster, in which sustainable development and ecosystem services are cited as being essential in mitigating the effects of climate change. Overall, these clusters show how those research themes are inter-related to better understand climate challenges. However, the analysis here also reveals gaps in making technological tools, such as remote sensing, an integrative tool for sustainable policy-making on biodiversity conservation. Future research areas should focus on the incorporation of technology to improve land-use change and ecosystem degradation monitoring, the formulation of implementable policies that synchronize agricultural productivity with biodiversity conservation, and climate resilience strategies in such areas as grassland restoration and soil carbon

sequestration. These focus areas are essential for developing the right approaches to address these challenges of climate change.

Keywords: climate change, ecosystem services, biodiversity conservation, land-use change, sustainable development

INTRODUCTION

Livestock grazing is an essential part of agriculture worldwide, providing significant economic benefits while also posing environmental challenges. The relationship between grazing animals and soil health is complex—moderate grazing can support biodiversity and improve soil structure, but overgrazing often leads to problems like soil erosion, loss of organic matter, and reduced vegetation cover. Finding a balance is key to ensuring that grazing practices support both agricultural productivity and environmental health (Briske et al., 2011; Teague et al., 2013).

This study takes a fresh approach by using bibliometric analysis to explore how livestock grazing affects soil erosion. By systematically reviewing existing research, this study aims to track key trends, understand how different levels of grazing impact soil, pinpoint gaps in current knowledge, and identify practical management strategies to reduce soil erosion. Bringing together insights from a range of studies, this research offers a clearer picture of how grazing influences soil sustainability and what can be done to

improve long-term land management practices.

To achieve these goals, this study draws from a variety of foundational research that sheds light on the effects of livestock grazing on soil health. For example, a global meta-analysis by Lai and Kumar (2020) found that heavy grazing significantly decreases soil organic carbon (SOC), a critical measure of soil health. Similarly, Silva et al. (2023) emphasize that well-managed grazing can help prevent soil erosion, while overgrazing exacerbates the problem. Other studies have used geospatial modelling to assess how grazing impacts ground cover and contributes to soil loss, while some have examined broader ecological consequences, such as land degradation and declining water quality (Donovan and Monaghan, 2021).

Other research highlights specific challenges that come with different grazing practices. Bilotta et al. (2007) found that excessive grazing, particularly by small ruminants, can lead to severe soil degradation and increase the risk of flooding. Meanwhile, Evans (1997) explored how soils recover from the impact of livestock treading and examined how different types of livestock affect water quality. Minea et al. (2021) discussed ways to minimize phosphorus and sediment runoff from irrigated cropland grazed by cattle and sheep. Studies on agricultural expansion in Brazil have also demonstrated how livestock grazing contributes to soil erosion across diverse landscapes (Merten and Minella, 2013). Together, these studies reinforce the urgent need for sustainable grazing strategies that balance economic productivity with environmental conservation.

By addressing these issues, this research aims to provide a deeper understanding of how livestock grazing impacts soil erosion and sustainability. The findings will contribute to more effective land management practices that promote soil health, reduce environmental degradation, and support sustainable agriculture.

LITERATURE REVIEW

Historical Context of Livestock Grazing Practices

Grazing has been a fundamental aspect of animal husbandry since the domestication of livestock around 7000 BC. Early practices involved free-ranging animals, such as sheep and goats, which were managed by nomadic peoples. These methods were often unsustainable, leading to overgrazing and environmental degradation (Filazzola et al., 2020). Continuous grazing was prevalent, where livestock had unrestricted access to pasture year-round, resulting in soil degradation and reduced biodiversity (Goodwin, 2023).

The late 19th and early 20th centuries saw a growing awareness of the negative impacts of uncontrolled grazing. Pioneers like Aldo Leopold began advocating for more sustainable practices. The Dust Bowl of the 1930s highlighted the need for better land management, leading to the establishment of conservation programs (Zhao, 2016). This period marked a turning point where traditional grazing methods were critically reassessed.

One of the most significant advancements in grazing management has been the development of rotational grazing systems. This method involves dividing pastures into smaller paddocks and rotating livestock among them. This practice allows for periods of rest for the land, promoting soil health and pasture recovery (Sharpe and Kenny, 2018). The introduction of rotational grazing in the 20th century marked a shift towards more sustainable agricultural practices.

The 21st century has seen a further transformation with technological advancements. Tools such as satellite imagery and data analytics platforms have enabled farmers to monitor pasture health more accurately, leading to data-driven decisions that optimize grazing management (Gebresenbet et al., 2023). These technologies help mitigate issues associated with traditional practices by enhancing efficiency and sustainability.

Modern grazing systems can be categorized into several types, each designed to optimize land use and promote sustainability. Continuous grazing allows livestock year-round access to the same area, while seasonal grazing restricts animals to specific areas only during certain seasons. Rotational grazing involves moving livestock between paddocks to facilitate pasture recovery, enhancing soil health and forage quality. Additionally, ley farming alternates between fodder crops and arable crops, providing diverse benefits to the ecosystem (Chaudhary et al., 2023). Lastly, patch-burn grazing incorporates the practice of burning sections of pasture to encourage new growth and increase biodiversity (Boughton et al., 2022). Together, these systems reflect a strategic approach to grazing that balances productivity with environmental stewardship.

The evolution from traditional to modern grazing practices reflects a growing recognition of the need for sustainable land management (Robinson, 2024). Modern approaches not only enhance livestock productivity but also contribute positively to environmental goals such as carbon sequestration and biodiversity conservation (Muhie, 2022). The integration of regenerative principles into grazing management emphasizes the interconnectedness of soil health, animal welfare, and ecosystem stability.

Grazing Intensity and Its Effects on Soil Properties

Grazing intensity is a critical factor influencing soil organic carbon (SOC), nutrient availability, and soil structure. Research indicates that heavy grazing often leads to detrimental effects on soil quality. A global meta-analysis revealed that heavy grazing significantly increases soil bulk density (BD) and penetration resistance (PR), while reducing SOC, total nitrogen (TN), and water content (WC) at various soil depths. Specifically, heavy grazing resulted in a 10.8% reduction in SOC at the

0–10 cm depth and a 22.5% reduction at the 10–30 cm depth, compared to ungrazed conditions (Lai and Kumar, 2020). In contrast, light grazing was associated with an increase in SOC by 10.8% and ammonium levels by 28.7% at the same depth, suggesting that lower grazing pressures can enhance soil health and nutrient availability (Lai and Kumar, 2020; Fenetahun et al., 2021).

Moderate grazing exhibited mixed effects; while it increased BD and PR, it also decreased SOC and TN at deeper soil layers (Lai and Kumar, 2020). Studies conducted in specific regions, such as Ethiopia's Teltele rangelands, further support these findings, showing that different grazing intensities significantly affect soil physicochemical properties, including organic matter and nutrient availability (Fenetahun et al., 2021). For instance, overgrazed areas demonstrated reduced vegetation cover and increased soil erosion, leading to long-term degradation of ecosystem services (Skoulikidis, 2021; Fenetahun et al., 2021).

The relationship between grazing intensity and soil degradation has been widely studied, revealing a clear trend: increased grazing intensity correlates with greater soil degradation. Research indicates that heavy grazing not only compacts the soil but also leads to a significant decrease in SOC density over time. In one study, long-term heavy grazing resulted in a total SOC density loss of 17.69%, while moderate grazing caused a loss of 5.21% (Liu et al., 2024). This degradation is attributed to the trampling effects of livestock, which disrupts soil structure and promotes erosion. Moreover, studies utilizing methods such as the Visual Evaluation of Soil Structure (VESS) have shown that heavy grazing leads to notable structural degradation compared to light grazing systems (Auler et al., 2017). The VESS method indicated that soils under heavy grazing exhibited compromised structural quality, which is essential for maintaining healthy ecosystems. Similarly, research on

integrated crop-livestock systems highlighted that increased grazing intensity negatively affected both soil structure and nutrient dynamics, emphasizing the need for sustainable management practices (Yang et al., 2023; Tambong, 2025).

In summary, the examination of different grazing intensities reveals significant impacts on soil organic carbon, nutrient availability, and overall soil structure. The comparative analysis underscores the detrimental effects of heavy grazing on soil health and highlights the importance of adopting moderate or light grazing practices to mitigate degradation and promote sustainable land management strategies.

Soil Erosion Mechanisms Related to Livestock Grazing

Livestock grazing significantly contributes to soil erosion, primarily through mechanisms that disrupt soil structure and reduce vegetation cover (Donovan and Monaghan, 2021). Overgrazing leads to the removal of protective plant cover, which is essential for preventing erosion by wind and water (Skoulikidis, 2021). Excessive livestock grazing depletes nearly all available vegetation, leaving soil exposed and vulnerable to erosion. This exposure can lead to increased soil erosion rates; studies show that overgrazed lands can experience erosion rates of 1 to 5 tons per hectare per year, significantly higher than those in ungrazed areas (Aubault et al., 2015). Additionally, livestock trampling compacts the soil, increasing bulk density and reducing porosity, which impairs water infiltration and worsens surface runoff. This combination creates a feedback loop where increased erosion further degrades the land, reducing its ability to support vegetation and negatively impacting overall ecosystem health (Xu et al., 2018; Lai and Kumar, 2020).

The impact of grazing on soil erosion is also influenced by various environmental factors (Hancock et al., 2019). For instance, heavy rainfall events can exacerbate erosion in grazed areas where vegetation has been

removed, as raindrops hit bare soil with greater force, dislodging particles more effectively than in vegetated areas (Deore and Pethkar, 2023). Climate change can alter precipitation patterns and increase the frequency of extreme weather events, exacerbating the impact of grazing on soil erosion (Kosmas et al., 2015).

Erosion rates are affected by various factors that differ significantly between grazed and ungrazed lands. Vegetation cover is a key determinant; ungrazed lands usually maintain dense vegetation that protects against erosion. In contrast, heavily grazed areas experience a significant reduction in plant cover, increasing soil exposure to wind and rain (Xu et al., 2018; Fenetahun et al., 2021).

Soil properties also play a vital role in determining erosion susceptibility. Soils rich in organic matter tend to have better structure and cohesion, making them less prone to erosion. In contrast, overgrazing often leads to decreased organic matter content and increased soil compaction, elevating erosion risks (Lai and Kumar, 2020). Studies have shown that moderate grazing can help maintain better ground cover compared to continuous heavy grazing practices, thereby reducing erosion rates (Xu et al., 2018; Fenetahun et al., 2021).

In summary, livestock grazing contributes to soil erosion through mechanisms such as vegetation removal and soil compaction. The comparison between grazed and ungrazed lands highlights the importance of maintaining adequate vegetation cover and healthy soil properties to mitigate erosion risks. Sustainable grazing practices are essential for preserving soil health and preventing degradation over time.

Ecological Impacts of Livestock Grazing on Biodiversity

Livestock grazing is a prevalent land-use practice that significantly influences biodiversity across various ecosystems. The effects of grazing on plant and animal communities are complex, often leading to

both positive and negative outcomes depending on the intensity and management of grazing practices.

Grazing can alter plant community composition, often reducing species richness and abundance. Overgrazing tends to favor the growth of less palatable, invasive species while diminishing native flora. A meta-analysis revealed that livestock exclusion consistently increased plant abundance and diversity, particularly in temperate climates where the effects were most pronounced. This study highlighted the indirect impacts of livestock grazing on multiple trophic levels, emphasizing the potential long-term consequences for biodiversity conservation as grazers directly affect herbaceous plants that support higher trophic levels, including pollinators and other fauna (Filazzola et al., 2020).

Conversely, moderate grazing can promote biodiversity by preventing certain dominant species from monopolizing resources (Guan et al., 2023). In California grasslands, targeted grazing has been shown to benefit native forbs by reducing competition from invasive grasses, thereby maintaining a mosaic of vegetation that supports diverse wildlife (Davy and Rinella, 2019). This indicates that under controlled conditions, livestock grazing can play a role in enhancing ecological diversity rather than detracting from it.

Soil microbial communities are critical for nutrient cycling and ecosystem health, and they are significantly affected by grazing practices. Research indicates that heavy grazing negatively impacts soil organic carbon (SOC), microbial biomass carbon (MBC), and overall microbial diversity. In contrast, lighter grazing intensities often enhance soil microbial communities by improving nutrient availability and soil structure (Zhang et al., 2023; Lai and Kumar, 2020). The relationship between soil biodiversity and ecosystem multifunctionality becomes particularly important in grazed ecosystems; as plant communities are altered by livestock, soil

biodiversity may take on a more prominent role in supporting ecosystem functions.

The overall health of ecosystems is intricately linked to the balance between grazing pressures and biodiversity (Bi et al., 2024). Grazing can lead to soil erosion, compaction, and degradation if not managed properly, which further threatens plant communities and the animals that depend on them (Skoulikidis, 2021). In arid regions, for instance, livestock grazing has been associated with severe degradation of riparian zones—critical habitats known for their high biodiversity (Capon, 2019). These areas have suffered significant losses due to improper grazing management practices, highlighting the need for sustainable approaches to livestock management.

Grazing practices do not occur in isolation; they interact with various environmental stressors such as climate change, drought, and land-use changes. For example, increased aridity exacerbates the negative impacts of grazing on biodiversity and ecosystem multifunctionality. Studies have shown that in more arid grasslands, long-term grazing leads to greater declines in both plant diversity and ecosystem functions compared to less arid regions (Zhang et al., 2023). Furthermore, climate change may alter precipitation patterns and increase the frequency of extreme weather events, further complicating the relationship between grazing practices and biodiversity outcomes.

To summarize, livestock grazing has a significant impact on biodiversity because it affects plant communities, soil microbial health, and overall ecosystem functioning. While moderate grazing can improve certain aspects of biodiversity under particular situations, overgrazing offers serious threats to ecological integrity. Sustainable management strategies that take into account both grazing intensity and environmental context are critical for maintaining biodiversity in grazed landscapes.

Management Strategies for Sustainable Grazing

Effective pasture management is important in reducing soil erosion and increasing sustainability in grazing systems. Rotational grazing and controlled stocking rates are well-known for improving soil health, plant diversity, and overall ecosystem resilience.

Rotational grazing involves dividing grasslands into separate paddocks and alternating animals between them. This helps forage plants recover, resulting in healthier grass growth and less soil erosion. Rotational grazing has been shown in studies to promote biodiversity by limiting overgrazing in any one area, resulting in a more diverse plant environment that supports a wide range of wildlife species. It also improves soil structure by providing times of rest for vegetation, which can boost root development and soil organic matter content (Zhang et al., 2023; Cherlinka, 2024).

Adjusting the amount of cattle based on pasture availability is critical for avoiding overgrazing. Controlled stocking ensures that pasture is not drained beyond its capacity to recover, preserving soil integrity and plant health. According to PastureIo (2019) and Moses (2024), appropriate stocking rates can boost pasture productivity and lower erosion rates.

Implementing practices such as contour plowing, planting cover crops, and using buffer strips can significantly reduce soil loss (He et al., 2017). These methods help maintain soil structure and fertility while providing additional habitat for wildlife.

Regular soil testing allows farmers to identify nutrient deficiencies and apply appropriate amendments, such as lime or organic matter, to enhance soil health. Healthy soils are better able to retain moisture and support diverse plant life, which in turn reduces erosion (Tahat et al., 2020).

Controlling weeds through mechanical, chemical, or biological means helps maintain pasture productivity. Weeds can outcompete desirable forage species,

leading to decreased biodiversity and increased erosion risk (Teague and Kreuter, 2020).

Case studies from various regions illustrate successful sustainable grazing practices that enhance ecosystem health while minimizing soil erosion. At the Tallgrass Prairie Preserve in Oklahoma, a patch-burn grazing strategy is employed where portions of the pasture are burned annually to stimulate fresh grass growth. This method mimics historical bison grazing patterns, promoting habitat diversity that benefits various prairie species (Ricketts and Sandercock, 2016). Similarly, research in the California grasslands has shown that moderate grazing can enhance native forb populations by reducing competition from invasive grasses. This approach not only maintains biodiversity but also supports critical pollinator communities, thereby contributing to overall ecosystem resilience (Bartolome et al., 2014; Reynolds, 1995).

In Australia, adaptive grazing management practices have been implemented to restore degraded rangelands. By adjusting grazing pressure based on seasonal conditions and forage availability, land managers have successfully improved vegetation cover and reduced soil erosion in vulnerable areas (Teague and Kreuter, 2020). Meanwhile, in Vanuatu, sustainable grazing practices focus on maintaining optimal grazing heights and controlling weed invasions through strategic grazing patterns. These practices have led to improved economic returns from livestock while preserving pasture health (Reynolds, 1995).

Collectively, these case studies demonstrate that effective pasture management techniques can significantly enhance biodiversity and sustainability in diverse ecological contexts.

Socio-Economic Implications of Grazing Management

The socio-economic implications of grazing management are multifaceted, influencing both the livelihoods of farmers and the sustainability of ecosystems. Effective

grazing management practices, such as written grazing management plans, have been shown to enhance productivity, reduce input costs, and improve overall financial well-being for livestock producers. Likins et al., (2024) indicate that these plans contribute to adaptive management strategies that foster resilience in social-ecological systems, leading to desirable economic outcomes. For instance, producers who implement structured grazing management report increased productivity and reduced veterinary expenses, which collectively enhance their financial stability. Furthermore, payments for ecosystem services associated with sustainable grazing practices can provide additional income streams for farmers, thereby promoting economic viability while supporting environmental health (Sangha et al., 2024). Policy and regulation play a crucial role in shaping the socio-economic landscape of grazing management (Smith, 2024). Government interventions, such as subsidies and technical assistance programs, can incentivize sustainable practices that benefit both farmers and the environment (Barbosa, 2024). For example, the Common Agricultural Policy (CAP) in the European Union provides financial support to livestock producers who adopt environmentally friendly grazing practices (Emmerson et al., 2016). Such policies not only help mitigate the negative impacts of overgrazing but also promote biodiversity conservation and soil health. However, challenges remain; many pasture-based systems exhibit high dependence on public support, which can undermine long-term sustainability by perpetuating reliance on non-renewable resources. Thus, a comprehensive approach that integrates effective grazing management with supportive policy frameworks is essential for enhancing the socio-economic viability of livestock systems while ensuring ecological sustainability.

Gaps in Current Research

The intersection of livestock grazing, soil erosion, and sustainability is a critical area of study, particularly as global food systems face increasing pressures from climate change and environmental degradation. Despite significant research in these domains, several under-researched areas warrant further exploration.

Rivero et al., (2021) has shown that rotational grazing can enhance the distribution of cattle and improve grassland utilization compared to continuous stocking methods. However, most studies have focused on extensive rangelands, primarily in the U.S., leaving a gap in understanding how these methods perform in more intensive grazing systems (Piipponen et al., 2022). The behavioral patterns of cattle in smaller paddocks may differ significantly from those in extensive systems, suggesting a need for more research on intensive grazing management practices and their implications for sustainability and soil health (Fynn and Jackson, 2022).

Davies et al., (2024) indicate that strategically applied livestock grazing can mitigate wildfire risks and promote biodiversity in sagebrush steppe ecosystems. This challenges the traditional view that livestock grazing is inherently detrimental to such environments. Further research is needed to quantify the ecological benefits of grazing under varying conditions and to develop guidelines for its application as a tool for ecosystem management.

There is a notable lack of integrated systemic approaches that consider social, environmental, and economic aspects of livestock production (Varijakshapanicker et al., 2019). Norton et al., (2024) often emphasizes technological solutions aimed at productivity rather than holistic practices that enhance environmental sustainability. Investigating leverage points for transformational change in livestock systems could provide valuable insights into achieving sustainable outcomes.

Gebeyehu et al., (2021) has highlighted the existence of seasonal and location-specific

hotspots where fodder demand exceeds supply, particularly in pastoral areas like Nyangatom, Ethiopia. Understanding the dynamics of livestock mobility and its impact on soil erosion in these hotspots remains underexplored. This knowledge is crucial for developing targeted interventions to manage grazing pressure effectively.

While De Haan et al., (1997) have documented the negative impacts of overgrazing on soil health, there is limited research on how different grazing practices can either exacerbate or mitigate soil erosion. The variability in rainfall and its impact on forage availability complicates this relationship, necessitating long-term studies to assess how various grazing strategies influence soil stability across different climatic zones.

Understanding the policies and institutional frameworks that govern livestock grazing practices is essential for promoting sustainability. Stringer et al., (2020) indicate that there is often a disconnect between agricultural policies and environmental outcomes, particularly in arid regions where grazing pressures are high. Exploring how policy changes can facilitate better grazing management practices could be an important area for future research.

The literature reveals various underexplored topics at the interface of animal grazing, soil erosion, and sustainability. Addressing these gaps through targeted study will improve our understanding of sustainable livestock management techniques and their environmental repercussions, resulting in more resilient food systems.

Comparative Studies Across Different Ecosystems

Livestock grazing is a common land use that has a substantial impact on ecosystems throughout all ecological zones, including grasslands, forests, and arid regions. Understanding these effects is of vital importance for sustainable land use and biodiversity protection.

Zhang et al., (2023) has shown that livestock grazing can have profound effects

on grassland biodiversity and ecosystem functionality. Yu et al. (2024) discovered that higher grazing intensity reduced biodiversity and multifunctionality in more dry grasslands. In contrast, less arid environments exhibited minimal effects from grazing. This suggests that the ecological consequences of grazing are closely linked to the climatic conditions of the grassland.

Grazing also influences nutrient cycling within grassland ecosystems. While some studies indicate that cattle grazing can increase available nutrients like phosphorus and nitrogen, it may simultaneously decrease overall soil fertility due to compaction and erosion (Wallace and Dyer, 1996). The mixed impacts on nutrient cycling underscore the complexity of grazing effects on ecosystem health.

In forested ecosystems, livestock grazing can alter the composition and structure of understory vegetation. Overgrazing leads to a decline in palatable plant species, which can shift community dynamics towards less desirable species (De Haan et al., 1997). This change not only affects plant diversity but also has cascading effects on animal species that rely on diverse plant communities for food and habitat.

Excessive grazing in forest areas can exacerbate soil erosion and compaction, reducing water infiltration and organic matter content (Centeri, 2022; De Haan et al., 1997). The loss of ground cover due to overgrazing increases vulnerability to erosion, particularly on slopes where livestock trampling is prevalent.

Arid ecosystems face unique challenges related to livestock grazing. Prolonged heavy grazing can lead to significant ecological degradation, including the disappearance of palatable species and increased dominance by less desirable plants (Arroyo et al., 2024; De Haan et al., 1997). In these regions, the variability of rainfall plays a critical role in shaping vegetation responses to grazing, necessitating adaptive management

strategies that consider climatic variability (Tuoku et al., 2024).

Sandoval-Calderon et al., (2024) indicates that moderate grazing can enhance resilience in arid ecosystems by controlling shrub growth and promoting herbaceous plant diversity. However, this balance is delicate; overgrazing can lead to irreversible damage, requiring long recovery periods for affected ecosystems.

The impacts of livestock grazing vary significantly across ecological zones, influenced by factors such as climate, vegetation type, and soil characteristics. For instance, while moderate grazing may benefit certain grassland ecosystems by maintaining plant diversity, similar practices in arid regions could lead to detrimental outcomes if not carefully managed (Sandoval-Calderon et al., 2024; Zhang et al., 2023).

The literature emphasizes the necessity for integrated research approaches that consider the multifaceted interactions between livestock grazing practices and ecological health across different environments. Future studies should focus on long-term effects and adaptive management strategies tailored to specific ecological contexts to mitigate negative impacts while enhancing positive outcomes.

MATERIALS & METHODS

Research Design

This study employed a bibliometric analysis to systematically review and synthesize the existing literature on the effects of livestock grazing on soil erosion and sustainability. The research focused on identifying trends, gaps, and key themes in the literature from various ecological zones.

Data Collection

Database Selection. The major database chosen for literature retrieval in this study was Scopus. This database was selected based on its broad coverage of peer-reviewed literature and powerful citation analysis. Scopus is considered to be one of the largest abstracts and citation databases

that covers over 21,000 journals from various disciplines, making it possible to thoroughly research the impacts of livestock grazing on soil health metrics and management strategies of erosion. This extensive range of sources ensures that the review captured a diverse array of research findings, enhancing the reliability and depth of the analysis (Team Manuscript, 2024).

The sophisticated citation analysis tools in Scopus was one of the main advantages of using it, allowing for detailed evaluation of research impact through metrics such as the h-index and Field-Weighted Citation Impact (FWCI). These metrics provided insights into the influence and reach of individual publications, enabling effective assessment to trends in research related to grazing practices. The interface was user-friendly, and advanced search functionalities made it easier to find relevant studies and filtered the results by author, date, and document type.

However, one should have acknowledged that biases inherent in the database selection could have been a limitation. There was a notable bias in Scopus toward publications in the English language, which could have limited the inclusion of important research conducted in other languages. Second, although Scopus encompassed a vast range of journals, regional studies or niche topics might have been underrepresented. This might have led to gaps in the perception of local grazing practices and their impacts on soil health in specific contexts. While Scopus was a valuable source of primary information for this review, careful observation of such limitations was implemented, and supplementary databases or literature were considered where needed to ensure a balanced analysis.

Search Strategy. A systematic search of the ChatGPT was undertaken using specific terms relating to animal grazing, soil erosion, and sustainability.

The search terms for this study encompassed a range of relevant topics, including "grazing," "livestock

management," "pasture management," "rangelands," "land degradation," "soil degradation," "erosion," "sediment loss," "topsoil loss," "environmental sustainability," "sustainable agriculture," "ecosystem resilience," "land conservation," "bibliometrics," "citation analysis," "scientific literature," and "research trends." Boolean operators (AND, OR) were used to refine the search results. The search was limited to peer-reviewed articles published between 2000 and 2024.

Inclusion and Exclusion Criteria.

Inclusion criteria. Inclusion criteria consisted of peer-reviewed articles that focus on the impacts of livestock grazing on soil erosion and sustainability, studies conducted in various ecological zones (such as grasslands, forests, and arid regions), and articles published in English.

Exclusion criteria: Exclusion criteria included non-peer-reviewed articles, such as conference proceedings or editorials, as well as studies that do not directly address the relationship between livestock grazing, soil erosion, and sustainability.

Data Extraction

Bibliometric Information. From each selected article, the following bibliometric information was extracted: authors and affiliations, year of publication, journal name, geographic location of the study, ecological zone studied, and key findings related to livestock grazing impacts on soil erosion and sustainability.

Thematic Analysis. A thematic analysis was conducted to categorize the extracted data into key themes, including the effects of grazing intensity on soil erosion rates, comparative impacts across different ecological zones, and the long-term sustainability implications of various grazing practices.

Data Analysis

Bibliometric Analysis. The bibliometric data was analyzed using software tools such as VOSviewer to visualize publication trends, citation networks, and co-authorship patterns. This analysis helped identify influential authors, journals, and research clusters in the field by constructing and visualizing bibliometric networks based on citation, co-authorship, and other relations.

Narrative Synthesis. A narrative synthesis was performed to summarize findings across studies, highlighting common trends and discrepancies in results. This synthesis focused on how different ecological contexts influenced the effects of livestock grazing on soil erosion and sustainability.

RESULT AND DISCUSSION

The results section discussed the effects of livestock grazing on soil erosion and sustainability. This section was divided into two subsections: one detailing the computations performed using VOSviewer and the other focusing on the bibliometric study.

Effects of Livestock Grazing on Soil Erosion and Sustainability

The bibliometric analysis was conducted to assess trends, relationships, and co-occurrence of key terms within the field of climate change, ecosystems, and biodiversity studies. Using VOSviewer, keyword co-occurrence networks were generated to visualize clusters of related terms and highlight areas of research focus.

Results Based on VOSviewer Computations. The co-occurrence network maps were constructed to identify major thematic clusters and interconnections among research topics. The VOSviewer analysis yielded three distinct clusters, representing thematic concentrations: red, green, and blue clusters.

The "Red Cluster" was a research cluster focusing on the interconnections between agricultural practices (Bernués et al., 2022), land use changes, and carbon sequestration.

It addressed topics such as greenhouse gas emissions, the impact of land-use changes on biodiversity (Hasan et al., 2020), and the role of soils in climate change mitigation strategies (Da Gama, 2023). However, gaps existed in the cluster, including a lack of specific research on grazing systems (Folke et al., 2004), limited understanding of carbon sequestration potential (Muhie, 2022), and insufficient localized studies on biodiversity recovery (Fynn and Jackson, 2022). Additionally, regional variability and contextual factors were underexplored (Deng et al., 2020), and longitudinal studies were needed to capture long-term trends in species richness and ecosystem health (Sandoval-Calderon et al., 2024). Stakeholder perspectives were also significant, as the implications of biodiversity loss due to land-use change often overlooked local stakeholders (Donovan and Monaghan, 2021). Policy frameworks supporting biodiversity conservation were necessary, as current policies might not effectively incentivize sustainable grazing practices (Smith, 2024). Addressing these gaps was crucial for enhancing sustainable grazing strategies.

The Green Cluster centered on grazing and environmental management, aiming to develop sustainable grazing strategies that balanced agricultural productivity with environmental sustainability (Aggarwal et al., 2018). It emphasized the importance of understanding grassland ecosystems, addressing soil erosion (Bellocchi, and Chabbi, 2020), and promoting ecosystem services and promoting ecosystem services (Berkes, 2020). The cluster highlighted the link between grazing intensity and soil degradation, stressing the need for optimal grazing practices to minimize disturbance and promote vegetation cover. It also advocated for adaptive management

strategies that considered local ecological conditions and climatic variability. Additionally, the Green Cluster encouraged community engagement and knowledge sharing, recognizing the value of traditional knowledge about rangeland ecosystems (Aggarwal et al., 2018). It identified knowledge gaps and promoted ongoing research to address emerging challenges in grassland management (Liu et al., 2024). Overall, this cluster played an important role in shaping effective grazing practices.

The "Blue Cluster" framework for sustainable development and ecosystem services was crucial for integrating ecosystem services into grazing systems (Sangha et al., 2024; Teague and Kreuter, 2020). However, gaps existed that needed to be addressed to improve the application of these services (Emmerson et al., 2016). These gaps included a lack of integration between theoretical frameworks and practical applications (Berkes et al., 2000), a lack of understanding of trade-offs (Deng et al., 2020), a focus on regional variability and context-specific research (Fenetahun et al., 2021), a lack of longitudinal studies (Kosmas et al., 2015), and a lack of social-ecological interactions (Varijakshapanicker et al., 2019). The Blue Cluster often overlooked the importance of understanding the social dimensions that influence grazing practices (Emmerson et al., 2016), which were important for developing sustainable grazing strategies. Additionally, clearer policy frameworks were needed to incentivize sustainable practices and recognize the value of ecosystem services provided by pastoral systems (Bernués et al., 2022). By addressing these gaps, researchers can enhance the effectiveness of sustainable grazing strategies that leverage ecosystem services for ecological and economic benefits.

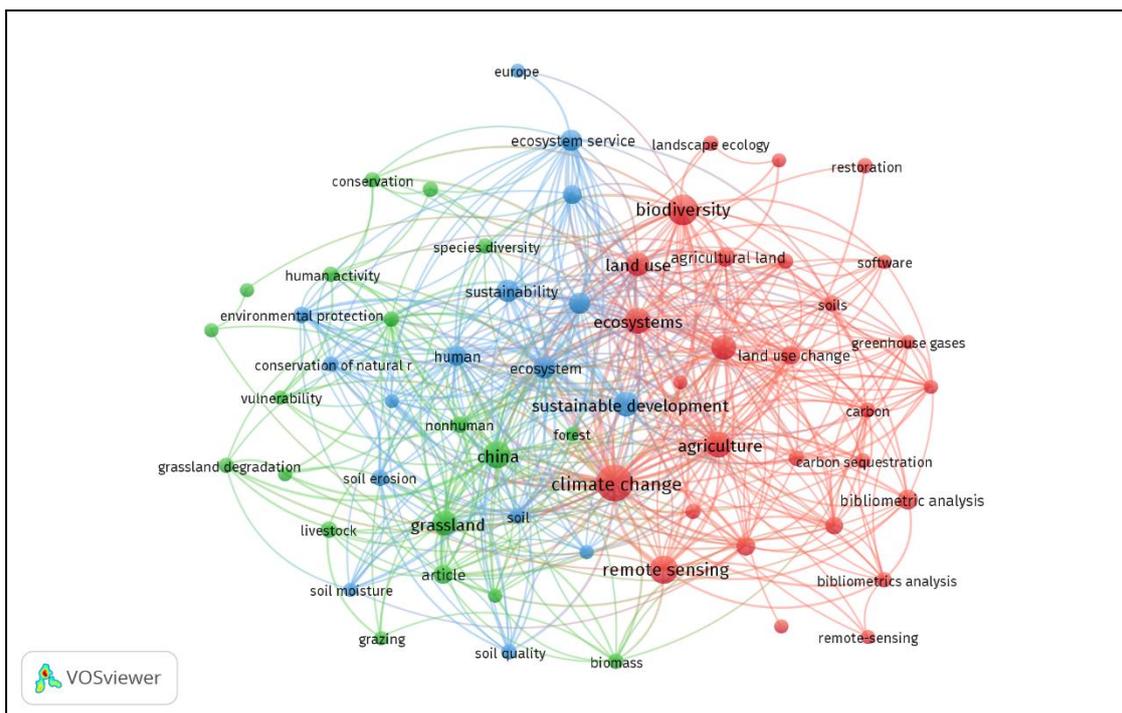


Figure 1. Keyword co-occurrence map showing clusters (red, green, and blue), their relationships, and connections

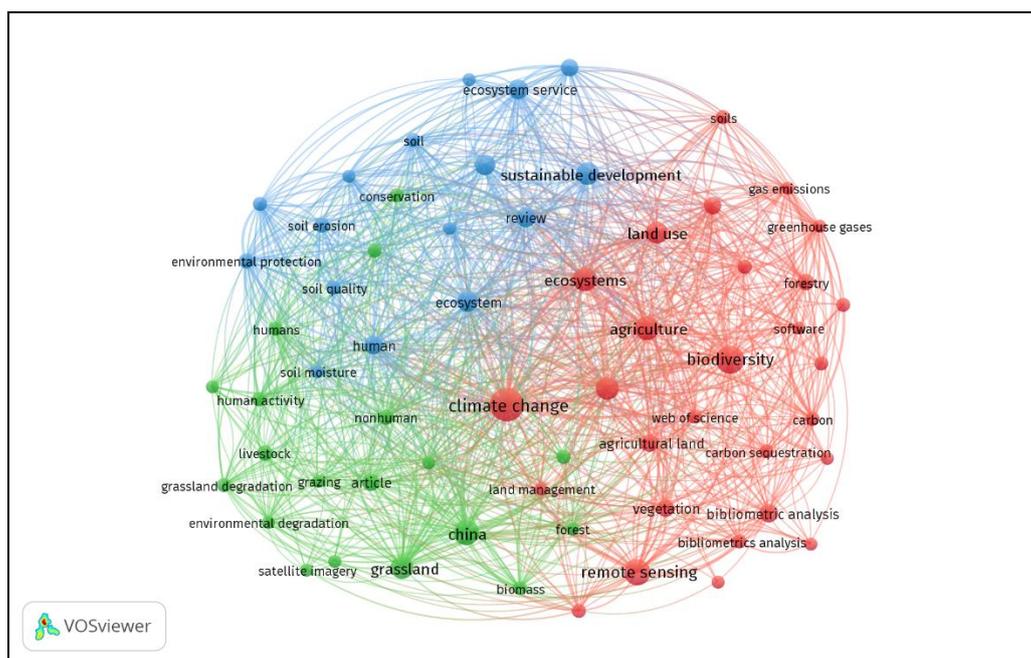


Figure 2. Detailed cluster visualization with a denser network of connections among primary terms.

The keyword network in Figure 1 showed strong interconnections between climate change (central node) and other topics such as biodiversity, land use, and grassland. The central positioning of terms like "climate change" and "remote sensing" reflected their cross-cutting importance across multiple clusters. The density of connections

between land management, carbon emissions, and soil quality revealed integrated research priorities, particularly in agricultural and conservation strategies. Key findings from the analysis included Climate Change as a Central Focus, Biodiversity and Agriculture, Grassland and Ecosystem Services, and the Role of

Remote Sensing. Climate change served as a unifying theme, linking to subtopics such as land use, ecosystem management, and carbon sequestration. Research on biodiversity, soil conservation, and agricultural systems was heavily interconnected, emphasizing their relevance to climate mitigation. Ecosystem degradation, particularly in grasslands, was a prominent focus, suggesting increased efforts towards sustainable management and conservation. Moreover, the keyword "remote sensing" highlighted advancements in monitoring land degradation, biomass, and environmental changes.

CONCLUSION

Based on the results of the bibliometric analysis, several key conclusions can be drawn. The analysis highlighted essential research themes and clusters related to climate change, ecosystems, and biodiversity. Visualized networks underscored the interconnected nature of these fields, emphasizing their relevance to one another. The findings indicate a pressing need for interdisciplinary collaboration to effectively address global challenges. Additionally, the study emphasizes the necessity for innovative technologies to enhance research efforts and tackle complex environmental issues effectively.

Declaration by Author

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