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Sustainable beef cattle production: A comparative review between Australia and Indonesia

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ABSTRACT
Background: Beef cattle farming is an important production activity to meet the protein needs of the community. Livestock produces carbon emissions that contribute to increasing global warming. The purpose of this article is to discuss the conditions of Indonesian beef cattle farming compared to the beef cattle farming system in Australia. **Method:** The method used in writing this paper is the Systematic Literature Review (SLR) with bibliometric content analysis. This study analyzes "keyword maps", "map of countries", and Scopus document publishing trends in sustainable beef cattle production studies for the period 2020 to 2025. The next stage, a comparison was made between two countries, namely Indonesia and Australia in the beef cattle production sector. **Finding:** The results of the bibliometric analysis showed that the top three countries with the highest link strength and leading in the study of sustainable beef cattle production were the United States, Brazil, and the United Kingdom. In terms of quantitative document publication, Indonesia is ranked fourth and Australia is ranked fifth. The results of the discussion showed that Indonesian beef production comes from small-scale beef cattle farms with slightly different cattle ownership from Australia, which is mostly industrial scale. **Conclusion:** One of the developments of sustainable beef cattle farming applied in Indonesia is the concept of integrating agricultural crops - cattle where plant waste is used as animal feed and livestock waste is processed into fertilizer for agricultural land. **Novelty/Originality of this article:** This study provides a contemporary bibliometric mapping (2020–2025) that identifies Indonesia as a top-tier contributor (ranked 4th globally) in sustainable beef production literature.

KEYWORDS: livestock; environment; meat; beef cattle; sustainability.

1. Introduction

Beef cattle farming is an important sector that produces commodities in the form of meat to meet food needs. Meat is an important source of protein in human food (Font-i-Furnols, 2023). Increased meat consumption affects livestock production (Van Der Laan et al., 2024). Beef cattle farming activities not only produce meat as the main product but also produce waste and greenhouse gas emissions. Livestock production is partly responsible for increasing greenhouse gas emissions and environmental impacts (Morais et al., 2023). The increasing demand for high-quality meat products and changing dietary patterns are leading to huge greenhouse gas emissions from livestock, which is a burden on the environment (Guo et al., 2022). Greenhouse gas emissions come, among other things, from enteric methane gas in cows (Berdos et al., 2023). Rumen fermentation and livestock waste management are the primary sources of carbon emissions in the production of beef cattle (Zhang et al., 2024). Efforts to control methane gas emissions are important because the

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livestock sector contributes to 14% to 16% of global emissions (Nejad et al., 2024). Livestock activities also have an impact on increasing the water footprint resulting from the production of animal feed, drinking water for livestock, and maintenance (Wisser et al., 2024). The amount of waste produced from livestock also creates problems of disposal and potential water pollution. Degradation of grasslands and grazing lands contributes to soil erosion (Solomon et al., 2023).

Sustainable beef cattle production can be linked to the “triple bottom line” (TBL) concept which considers environmental, economic and social aspects (Casagranda et al., 2023). There are eight critical points in sustainable beef cattle production including grazing and soil health, waste management and soil fertility, feed efficiency and meat production, water use, culture and community participation, energy use, climate policies and carbon sequestration, and environmental impacts (Tedeschi et al., 2024). To guarantee the cattle industry's sustainability and support farmers and policymakers in making informed decisions, the holistic concept was created. Environmental impact, social welfare, and economic profitability are the three key pillars of sustainability (Díaz De Otálora et al., 2021). Particularly in public policy design and business sustainability reporting, the three pillars serve as a framework. TBL concepts can be incorporated by policymakers into regulatory frameworks, such as those pertaining to social justice, environmental sustainability, and corporate social responsibility (Nica et al., 2025).

Beef cattle production faces major challenges in balancing meat output with environmental protection through a holistic sustainability approach, including the mitigation of greenhouse gas emissions to prevent global warming (Chandra, 2025). Environmentally based beef cattle farming represents a key concept in modern agricultural systems oriented toward sustainable development, aiming to meet global animal protein demands without compromising ecosystem quality. Greenhouse gas emissions from cattle production are strongly influenced by livestock management practices, and improvements in production efficiency are therefore central to achieving environmental sustainability (Nieto, 2018). The efficiency of the beef production chain can be enhanced through precise livestock management practices that optimize slaughter age and improve average daily weight gain at both the individual animal and land-use levels.

These improvements can be achieved through effective pasture management combined with targeted nutritional supplementation, thereby contributing to a reduction in greenhouse gas emissions from beef cattle production (D’Aurea, 2021). Solutions such as enhancing feed nutritional value and improving feed conversion efficiency into meat products represent critical leverage points for strengthening both ecological and economic sustainability in the beef cattle sector while simultaneously reducing the carbon footprint of livestock production (Lancaster, 2022). Climate resilience and adaptive livestock practices, including targeted feed management and the development of climate-resilient forage grass varieties, are critical elements for maintaining beef cattle productivity amid increasingly extreme global climate challenges (Ranta, 2024).

Sustainability assessments at the farm level further indicate the need for indicators that integrate economic performance with ecological impacts in order to comprehensively measure and guide sustainable development strategies (Cerrato et al., 2023). Public policies that support sustainable beef cattle production have also proven essential in addressing deforestation and other environmental pressures arising from the expansion of production areas, particularly in major producing countries such as Brazil. Interventions focused on the protection of secondary forests and environmental conservation help preserve ecosystem services while simultaneously enabling responsible intensification of beef production systems (Molossi et al., 2023).

The beef cattle sector in Indonesia plays a strategic role in supplying animal protein and supporting national food security, particularly in meeting the continuously increasing domestic demand for beef. Beef production systems in Indonesia are still predominantly characterized by smallholder farming with limited herd ownership and relatively traditional management practices. Husbandry practices are generally extensive to semi-intensive, with a high dependence on local forages and agricultural by-products as the primary feed sources. National beef cattle productivity remains relatively low due to constraints in feed quality, suboptimal reproductive management, and limited adoption of livestock production technologies. In addition, Indonesia's beef cattle supply chain continues to face efficiency challenges, including high production and distribution costs. As a result, Indonesia remains reliant on imports of breeding stock and beef to bridge the gap between domestic production and national consumption.

In contrast, the Australian beef cattle industry has developed on a large scale with a strong export orientation and a high level of production efficiency. Australia's beef production systems are supported by extensive land availability, well-managed grazing systems, and the application of modern technologies in breeding and livestock management. Beef cattle farming in Australia is generally managed professionally, with strict implementation of biosecurity measures and animal welfare standards.

Vertical integration along the value chain from upstream to downstream enables the Australian beef industry to maintain strong competitiveness in global markets (OECD, 2021). In addition, environmental sustainability has become a major focus through the management of emissions, land conservation, and efficient use of natural resources (Wiedemann et al., 2016). Differences in agroecological conditions, farm structure, and technological capacity have positioned Australia's beef cattle systems as significantly more advanced than those in Indonesia.

However, best practices from Australia have the potential to serve as valuable references for the sustainable development of the Indonesian beef cattle sector. This paper aims to discuss sustainable beef cattle production systems using bibliometric analysis of various literatures. Bibliometrics are used to produce objective analysis related to trends and developments in studies in the field of sustainable beef cattle production in various countries. Specifically, this paper compares the conditions of beef cattle farming in Indonesia with beef cattle farming in Australia. Indonesia is a country that is still developing in the field of cattle farming, while Australia is quite advanced in the field of cattle farming. Indonesia is still a beef importer, while Australia is a beef exporter.

2. Methods

2.1 Data collection and search strategy

The method used in writing this paper is the Systematic Literature Review (SLR) method with bibliometric content analysis. The data analyzed came from secondary data and scientific journals. The document materials were carried out using the Scopus website to obtain the latest developments in sustainable beef cattle production research. Literature analysis was carried out for the publication period between 2020 and 2025. The search term in Scopus uses the term "sustainable AND beef AND cattle AND production" as a specific term in the literature review.

2.2 Bibliometric analysis and comparative study

This study analyze several bibliometric studies and consider various types of documents that appear in the database. The types of documents to be analyzed are limited to articles, reviews, conference papers, book chapters, conference reviews, notes, and letters. Bibliometric analysis uses VOSViewer. This study analyzes "keyword maps", "map of countries", and publishing trends in sustainable beef cattle production studies. The next stage is a comparison between two countries, namely Indonesia and Australia in the beef cattle production sector. The data taken comes from government data from both countries.

3. Results and Discussion

3.1 Results of bibliometric analysis

Bibliometric analysis was used to determine the development of sustainable beef cattle production studies in various countries from 2020 to 2025. The results showed that there were 396 documents published during that period. The bibliometric coupling mapping used was the country mapping option. The number of document thresholds used in bibliometric coupling is 5 documents. There are 30 countries that reach the document threshold. Each country will have its bibliometric coupling link strength calculated. Countries are sorted from the largest to the smallest total link strength. Apart from mapping, bibliometrics can also reveal new trends, themes, and author partnerships (De Oliveira et al., 2024). Below is an image of a country map showing the links for each country.

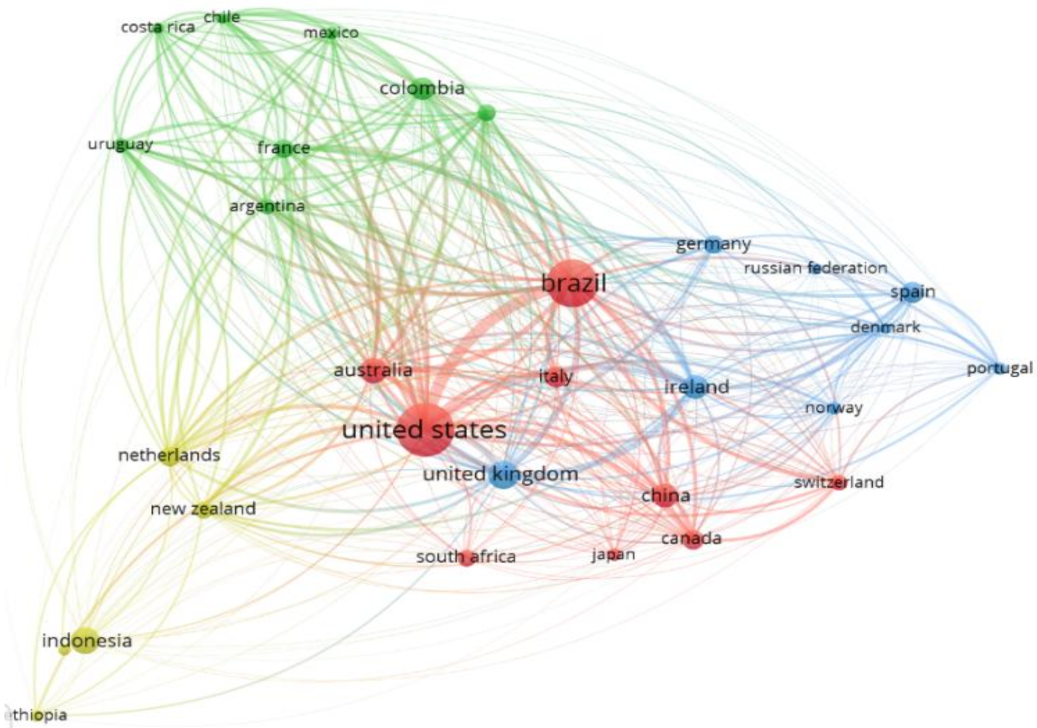

Fig. 2. Country maps

According to the analysis's findings, the United States, Brazil, and the United Kingdom have the strongest link strengths among the three nations studied in the study of sustainable beef cattle production from 2020 to 2025. The US released 100 papers over this period with 918 citations and a total link strength of 9868. Brazil released 83 papers with 870 citations and 8962 link strengths overall. The UK released 28 papers with a total link strength of 4166 and 378 citations. In contrast to Australia, which published 24 papers with 333 citations and a total link strength of 3350, Indonesia published 25 papers with 38 citations and a total link strength of 269. Quantitatively, the number of documents published by Indonesia is greater than Australia, but in terms of link strength, Australia is stronger because there are more citations, which shows the superior quality of the journals published. Global perspectives on teaching, learning, and research development can be obtained by expanding collaborative networks through mapping analysis (Ghani et al., 2022). The top ten countries that published the most documents related to sustainable beef cattle production studies are shown in the figure below.

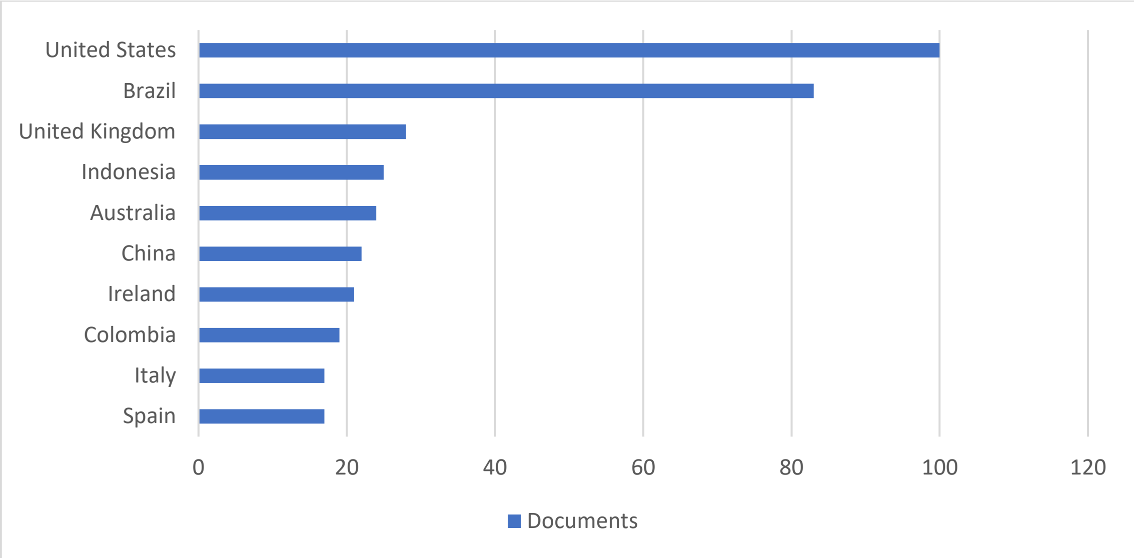

Fig. 3. Number of documents per country

Countries included in the top 10 publications of sustainable beef cattle production study documents during the period 2020 to 2025 include: United States 100 documents, Brazil 83 documents, United Kingdom 28 documents, Indonesia 25 documents, Australia 24 documents, China 22 documents, Ireland 21 documents, Colombia 19 documents, Italy documents, and Spain 17 documents. An interesting finding is that in the top 5 rankings, four countries are beef exporters, namely the United States, Brazil, United Kingdom, and Australia, while Indonesia is a beef importer. As a beef importer, Indonesia is one of the countries that pays attention to the development of sustainable beef production studies during the period 2020 to 2025. This shows that academics in Indonesia are not only focusing on production studies to achieve meat self-sufficiency but are also starting to pay attention to aspects of environmental balance in the beef production process as an effort to prevent climate change. Although adaptation methods are crucial in the context of climate change to maintain the rising demand for animal products, their applicability frequently varies depending on the local circumstances. Limiting the effects of future climate change requires mitigation, and there are several potential approaches (Cheng et al., 2022). Environmentally based cattle production is impacted by several factors, including infrastructure, feeding techniques, waste management, biodiversity, productivity, and sustainability (Anciones-Polo et al., 2024). The following figure shows the trend of publication of sustainable beef cattle production study documents during the period 2020 to 2025.

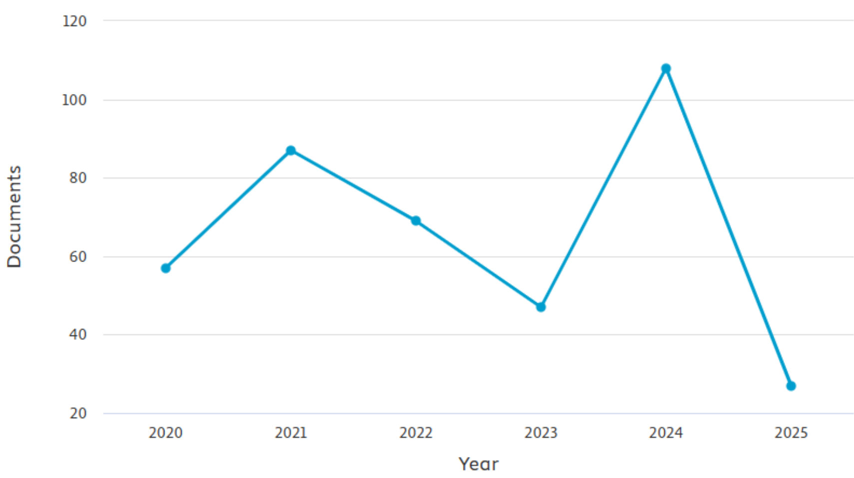

Fig. 4. Document publishing trends

The trend of publication of Scopus documents on sustainable beef cattle production studies shows a fluctuating graph. In 2020, there were 57 documents, then increased in 2021 to 87 documents, then decreased in 2022 to 69 documents. In 2023, the number of publications decreased to 47 documents. A significant increase occurred in 2024 with the number of publications being 108 documents. In 2025 until the first quarter, the number of publications reached 28 documents. Research discoveries, trends, and their possible advantages can all be examined using bibliometric analysis approaches (Kushartadi et al., 2023). However, in this paper, trend analysis uses automatic analysis from the Scopus website.

Further analysis of publications in 2025 showed that the four countries with the most documents on sustainable beef cattle farming studies were the United States with 7 documents, Brazil with 5 documents, China with 4 documents, and Indonesia with 3 documents. An interesting finding is that these four countries are the countries with the largest populations in the world. This shows that these four countries have more attention to sustainable beef cattle production than other countries to meet the food needs of their population. India is also one of the countries with a large population in the world, but there are very few documents on beef cattle production studies, throughout the period 2020 to 2025 there were only 4 documents. This is thought to be due to the habits of most Indians who prohibit the consumption of beef. India has historically consumed less meat, but since red meat contains iron, it should only be consumed by individuals, such as young women and children (Giromini & Givens, 2023).

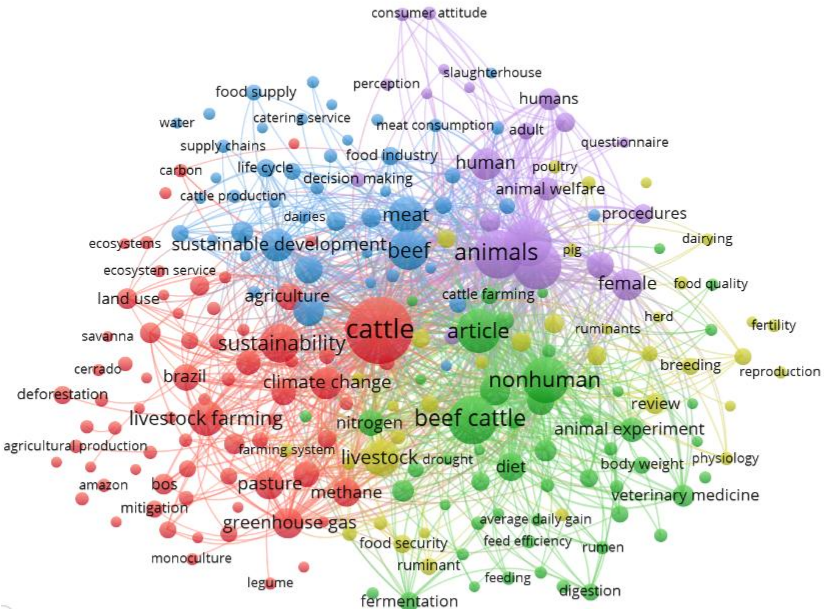

Fig. 5. Keyword maps

The results of the bibliometric analysis show that "cattle" is the most influential keyword in the map. The top three keywords that have the largest total link strength are the keyword "cattle" with the number of occurrences of 170 and the total link strength of 1943, the keyword "bovine" with the number of occurrences of 91 and the total link strength of 1440, the keyword "animals" with the number of occurrences of 93 and the total link strength of 1439. Other keywords related to environmental sustainability have quite strong total link strengths including the keyword "environmental impact" with a total link strength of 631, the keyword "sustainable development" of 638, the keyword "sustainability" of 523 and the keyword "greenhouse gas" of 577. This shows that the selected study documents are in accordance with the objectives of the paper which discusses the development of sustainable beef cattle production studies. The need for climate-resilient and sustainable livestock systems is growing to strike a balance between environmental preservation and the demand for food supply (Ranta and Mălinaş, 2024). Because environmental balance increases environmental complexity to enable a range of natural behaviors, it can improve animal welfare (Dickson et al., 2022).

The analysis results show that there are 5 clusters in the keyword. Cluster division is done to group keywords that have similarities or relationships. This division is done by using different colors for each cluster. The first cluster is red consisting of 72 items, the second cluster is green consisting of 54 items, the third cluster is blue consisting of 46 items, the fourth cluster is purple consisting of 36 items, and the fifth cluster is greenish yellow consisting of 21 items. The keyword "cattle" has the strongest link among other keywords in the red cluster. The red cluster contains more keywords related to sustainable production where there are keywords related to environmental conservation such as "sustainability", "greenhouse gas", "climate change", "carbon emission", "global warming", "deforestation", "carbon" and so on. In this paper, the red cluster can be said to be the main cluster that discusses the study of sustainable beef cattle production. Enteric methane and other greenhouse gas emissions from ruminants can be reduced by various means such as available knowledge on methane evaluation and mitigation strategies, as well as dietary supplements (Bačėninaitė et al., 2022).

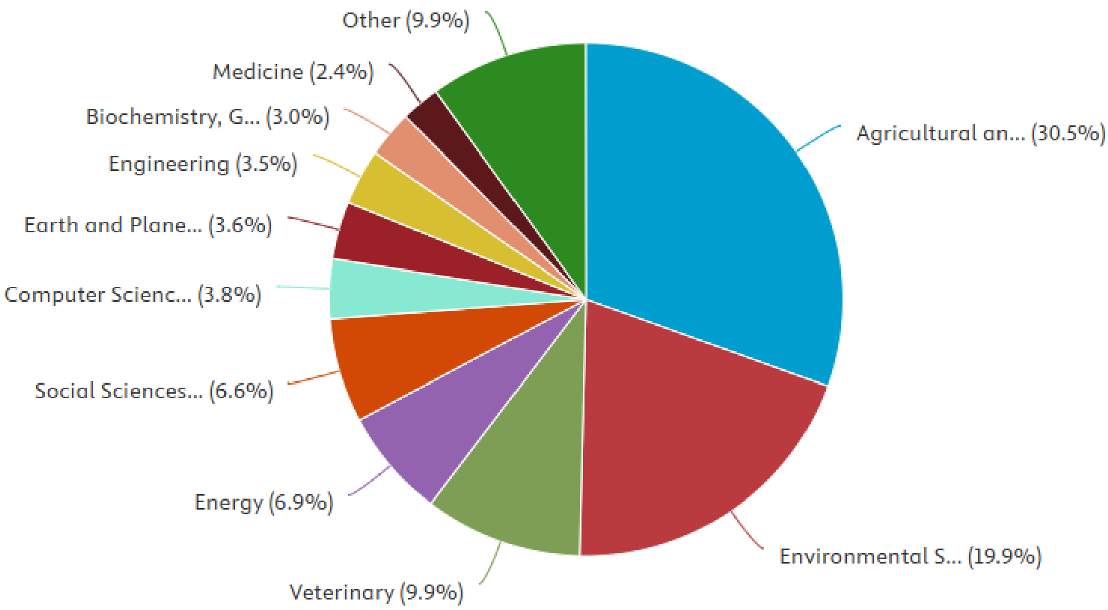

Fig. 6. Subject area study

The results of the subject-area analysis indicate that the distribution of research documents related to sustainable beef cattle production during the 2020–2025 period was dominated by the fields of Agricultural and Biological Sciences, accounting for 227 documents out of a total of 396 documents analyzed. This dominance suggests that studies on sustainable beef cattle production remain heavily focused on the technical and biological aspects of production, including feed management, livestock genetics, animal health, reproductive efficiency, and productivity enhancement based on local resource utilization. Scientific approaches within the agricultural and biological sciences therefore constitute the primary foundation for designing beef production systems that are capable of increasing meat output while simultaneously improving resource-use efficiency.

Environmental Sciences ranked second with 148 documents, reflecting substantial research attention to the ecological impacts of beef cattle production systems. Research in this field focuses on greenhouse gas emissions analysis, carbon and water footprint assessments, land degradation and land-use change, livestock waste management, and biodiversity conservation. This emphasis underscores that beef cattle production is no longer viewed solely as an economic activity, but rather as a production system with direct implications for ecosystem carrying capacity and sustainability, thereby necessitating the adoption of more efficient, low-emission, and responsibly managed livestock practices in response to increasing global pressure to achieve sustainable development goals (Steinfeld et al., 2006).

Furthermore, the field of Veterinary Medicine accounted for 75 documents, highlighting the important role of animal health and welfare aspects in sustainable beef cattle production systems. Research in veterinary medicine contributes to disease prevention and control, the strengthening of biosecurity measures, the responsible use of veterinary drugs and antibiotics, and the implementation of animal welfare standards. Optimal animal health not only has a direct impact on productivity, but is also closely associated with resource-use efficiency and societal acceptance of livestock products. Therefore, despite its smaller volume compared with agricultural and environmental sciences, veterinary medicine remains a key component of an integrated sustainability approach (OIE, 2019).

The fields of Energy and Social Sciences contributed 51 and 49 documents, respectively, which, although relatively fewer in number, play a strategic role in broadening the sustainability perspective. Energy-related studies within sustainable beef cattle production systems generally emphasize improvements in energy-use efficiency, the adoption of renewable energy sources, and the production of bioenergy from livestock waste, such as biogas, which have the potential to reduce greenhouse gas emissions and facilitate the transition toward low-carbon livestock systems (Bond & Templeton, 2011). This approach has become increasingly relevant given the significant contribution of the livestock sector to overall energy consumption and emissions, making the integration of clean energy technologies an important strategy for climate change mitigation in agriculture (Gerber et al., 2013). Meanwhile, contributions from the social sciences encompass analyses of policy and institutional frameworks, farmers' behavior and capacity to adopt innovations, levels of societal acceptance, and the dynamics of beef cattle markets and value chains, all of which determine the successful implementation of energy technologies and the economic and social sustainability of livestock systems (Pretty et al., 2018).

Overall, the composition of subject areas indicates that research on sustainable beef cattle production is predominantly focused on agricultural and environmental aspects, accounting for more than 50% of the total documents analyzed. This finding suggests that the sustainability paradigm in beef cattle production remains strongly shaped by biophysical approaches, while integration with social, economic, and energy dimensions still requires further strengthening. Therefore, a more balanced multidisciplinary approach is needed to ensure that the development of sustainable beef cattle production systems can address complex challenges in a more comprehensive and effective manner.

3.2 Comparative discussion of the beef cattle farming sector in Australia and Indonesia

The objective of high-quality agricultural growth is consistent with efforts to lower emissions from the agriculture sector (Jiang et al., 2025). There are worries, though, that these results would necessitate a scaleback in agricultural activity, which would be detrimental to nations that rely on agriculture. Numerous programs aim to boost agricultural productivity, or the amount of output produced from a specific set of inputs, but it's unclear how these policies will affect emissions or economic activity. The decrease of emissions and favorable effects on economic variables are mostly attained by lowering the amount of capital in the cattle industry (Allan et al., 2025). Total factor productivity and emission reduction, particularly methane efficiency, are positively correlated (Chung & Hadi, 2025).

Beef is an important food source to meet the population's protein needs. Data from the OECD-FAO (2023) shows that Australia's meat consumption reaches 23.7 kg/capita and Indonesia's is only 2.25 kg/capita. The population of Indonesia in the first semester of 2024 reached 282.4 million people, while in the same year the beef cattle population was 11.75 million head. Even though per capita meat consumption is very low, Indonesia's meat production is not yet sufficient for national needs, so beef imports are necessary (Heatubun & Matatula, 2023). Therefore, to reduce the impact of greenhouse gas emissions, a larger beef cattle production activity must be conducted while taking environmental factors into account. Effective pasture management and animal supplementing can lower greenhouse gas emissions in the production of beef cattle, or suitable livestock management techniques can lower the age of slaughter and daily weight gain separately (D'Aurea, 2021) .

Agriculture has a major impact on emissions, which must be drastically decreased to help nations get closer to meeting their emissions reduction goals. To do this, significant adjustments must be made to the kinds of diets that people around the world eat as well as to the methods used to produce food. Given the importance of agriculture in sustaining livelihoods worldwide, policies aimed at achieving these goals must consider both the economic effects of such policies and attempts to reduce emissions (Allan et al., 2025).

A promising GHG mitigation technique that increases production efficiency while indirectly lowering GHG emissions is Precision Livestock Farming (PLF) technology. Next, a model was created to show how the use of various PLF technologies might affect overall farm emissions and output. Among the scenarios were the deployment of an automated weighing platform, fertility sensors that use accelerometers to identify estrus, and health sensors that use accelerometers to detect diseases early. Expert perspectives, firsthand agricultural experience, and validated technology served as the foundation for the model's assumptions (McNicol et al., 2024).

Beef production in Australia today is a complex business. European farming methods first introduced to the country have had to be modified to consider Australia's unpredictable climate and very different soil and vegetation conditions. Consumers today want natural, chemical-free food that is produced without endangering the environment or the welfare of animals, as market dynamics have drastically shifted in recent decades. Farmers are essential in co-managing biodiversity and climate outcomes (emissions and sequestration) since they are land managers and stewards. In addition to offering suggestions for integrating climate and biodiversity credentials in Australia's grass-fed beef industry, this analysis details the use of design standards created through stakeholder interaction. Several business-related factors will affect how cattle producers use these credentials, and the credentialing system's design and implementation are crucial. Important elements for the growth of credentials in grass-fed beef production include a good value proposition as an incentive, ease of implementation, and belief in the importance of earning the credential (Thomas et al., 2023).

Due to both home and international markets, as well as expanding export markets, especially in Asia, the Australian beef market forecast is still favorable. The profitability of the Australian cattle industry will continue to depend heavily on the market's stability and growth as well as the capacity of beef producers to better meet consumer demands. Producers will be better able to boost productivity and profitability if objective measurement and pricing signals of beef quality, carcass, production, and efficiency attributes are improved. Furthermore, preserving and improving Australia's standing as a reliable provider of "disease-free" goods that meet market requirements is still essential for gaining entry to new markets. The sustainability, efficiency, and productivity of improved production techniques will enable long-term market expansion and the continuous growth of the Australian beef industry (Greenwood et al., 2018). Decarbonization must happen quickly to slow down climate change. Climate overshoot, biodiversity, indigenous and local community rights, and food production are all at risk from an over-reliance on land-based carbon capture. To effectively calculate the amount of land needed to offset inevitable emissions and monitor progress toward net-zero goals, accurate emissions estimates are crucial (Bowen Butchart et al., 2025).

Most of the Indonesia's meat supply comes from less productive people's farms, which means that the country's growing demand for beef has not been satisfied by the expansion of local cattle production. There is a negative price adjustment at the farmer level since imported meat is less expensive than local beef (Widiati, 2015). The following is data on meat imports and production in Indonesia in 2020-2023 (Badan Pusat Statistik, 2024).

Table 1. Beef production and imports in Indonesia

No	Year	Production (tons)	Import (tons)	Beef cattle population (heads)
1	2020	453,418.44	167,128.6	17,489,333
2	2021	487,802.21	211,429.6	17,977,214
3	2022	498,923.14	225,650.1	17,245,043
4	2023	503,506.80	238,433.6	10,828,733

(Badan Pusat Statistik, 2024)

Based on the data, Indonesian beef production continues to increase where import needs also increase. However, there is a significant decline in the number of cattle population in 2023 which is influenced by various factors such as disease outbreaks, dynamics of livestock farmers' economic conditions, and declining production levels. To meet national meat needs, more production is needed. Penurunan populasi sapi berpengaruh pada penurunan produksi daging. In addition, the productivity of beef cattle in Indonesia is also relatively low. Lubis et al. (2025) state that low productivity is caused by several factors, such as feed quality, maintenance methods, and livestock genetics. Local cattle, such as Bali cattle, have the advantage of adapting to tropical environments, but their productivity is still lower than imported cattle, such as Brahman or Limousin.

Beef cattle in developed countries such as Australia generally achieve body weights exceeding 500 kg due to more intensive and standardized production systems. These differences in productivity indicate a significant gap in resource management, technological application, and livestock management practices across countries (OECD, 2021). The low productivity of beef cattle in Indonesia is closely associated with feed quality that does not adequately meet the optimal nutritional requirements of livestock. Most smallholder farmers continue to rely on natural forages and agricultural by-products that are limited in protein and energy content. This condition directly results in low average daily weight gain and poor feed conversion efficiency in beef cattle production systems (Devendra, 2018).

The low adoption of systematic health management, reproductive management, and performance recording further exacerbates the achievement of national productivity levels. Simple housing systems and limited access to veterinary services also represent major constraints for smallholder farmers. In contrast, developed countries have widely implemented technology-based management systems, including precision feed formulation and digital monitoring of animal health and performance.

Genetic factors also play an important role in determining national beef cattle productivity. Indigenous Indonesian cattle, such as Bali cattle, are well known for their high adaptability to tropical environments and low-quality feed resources (Purwantara et al., 2012). These adaptive advantages make local cattle more resilient to climatic stress and endemic diseases. However, indigenous cattle generally exhibit lower growth potential and body weight compared with genetically selected breeds developed in advanced production systems. In contrast, imported breeds such as Brahman and Limousin possess higher genetic potential for growth and meat production (Taylor et al., 2021). Nevertheless, the performance of imported cattle is often suboptimal under Indonesian conditions due to limitations in feed availability and production environments that are not yet fully supportive. Therefore, improving beef cattle productivity in Indonesia requires an integrated approach that combines improvements in feeding, management, and breeding in a sustainable manner.

The problems currently faced by farmers are farmers are starting to have difficulty in providing green fodder, especially during the dry season, cow feces are piling up around the pen, disrupting cleanliness and polluting the environment and disturbing aesthetics, the cost of electricity bills for farmers lately is considered quite expensive. The solutions offered are: utilization of plantation and agro-industrial waste, such as oil palm leaf stalks and palm kernel cake processed as feed for beef cattle, waste from beef cattle in the form of cow feces processed as manure through an organic fertilizer management unit and biogas to produce and meet energy needs in the form of electricity and gas (Suyitman et al., 2019). The main challenge currently faced by beef cattle farmers in Indonesia is the increasingly limited availability of forage due to climate change and the conversion of agricultural land (Thornton et al., 2015). Prolonged dry seasons lead to a drastic decline in forage productivity, resulting in feed supplies that are insufficient to meet the optimal nutritional requirements of livestock (Herrero et al., 2016). Farmers' reliance on natural forage without a feed reserve system increases the risk of reduced body weight gain and lower beef cattle productivity (Devendra, 2011).

As a solution to these challenges, the utilization of plantation and agro-industrial by-products as alternative feed represents a key strategy to enhance feed security for beef cattle (Makkar, 2016). Palm oil residues, such as fronds and palm kernel cake, have significant potential as sources of fiber and protein when processed using appropriate technologies (Wan Zahari et al., 2018). Processing agro-industrial by-products through fermentation or ammoniation has been shown to improve both digestibility and the nutritional value of feed materials (Schiere et al., 2004). The use of non-conventional feed sources can also reduce feed costs and improve the overall efficiency of livestock production systems (Mottet et al., 2017). This strategy simultaneously contributes to the reduction of industrial waste that might otherwise pollute the environment (Steinfeld et al., 2006). Integration of livestock with plantation sectors facilitates the development of more sustainable circular production systems (Pretty et al., 2018).

Manure management through organic fertilizer production units constitutes an effective solution to address livestock waste at the farm level (Bernal et al., 2017). Cow manure converted into organic fertilizer can enhance soil fertility while reducing dependence on synthetic chemical fertilizers (Palm et al., 2014). Additionally, utilizing cattle manure as a raw material for biogas provides added value in the form of renewable energy for farm households (Bond & Templeton, 2011). The use of biogas as a source of electricity and cooking fuel can lower energy costs and improve farmers' welfare (Katuwal & Bohara, 2009). Implementing an integrated system of feed, fertilizer, and energy makes beef cattle farming more environmentally friendly and economically viable (FAO, 2018). Thus, strategies based on the utilization of agricultural and livestock waste represent a strategic approach to simultaneously address feed, environmental, and energy challenges in the development of sustainable beef cattle production (UNEP, 2021).

According to Supriadi et al. (2024), agriculture is based on the idea that everything generated will eventually return to nature, meaning that waste will be converted back into resources that may be used. The "zero waste production system" idea, in which all waste from plants and livestock is recycled and reused in the production cycle, is the focus of the livestock crop integration model created in many locations and nations. Technological innovations to support this model have been carried out, including: agricultural waste storage/processing technology (rice straw) for feed production; organic fertilizer manufacturing technology; cow dung processing technology for household-scale biogas production; and straw preservation technology has been practiced, especially in cattle farming areas with dry climate conditions. The concept of sustainable livestock-agriculture integration is one that can answer this demand so that it becomes very important in every implementation of development in all fields including livestock. Sustainable livestock must have 3 (three) main pillars, namely economic, social and environmental. The integration of agricultural systems that prioritize these 3 pillars helps the direction of community livestock management to be more environmentally friendly and sustainable (Alimudin, 2024).

Overall, the primary challenges faced by beef cattle farmers in Indonesia stem from the limited availability of forage due to climate change and the conversion of agricultural land, which negatively affects livestock productivity and increases production costs. Reliance on natural forage without a feed reserve system exacerbates the vulnerability of cattle farming operations, particularly during increasingly prolonged dry seasons. Additionally, suboptimal management of livestock waste creates environmental issues, including soil and water contamination, reduced farm sanitation, and elevated risks of animal disease. These challenges are further compounded by rising energy costs, particularly electricity, which place additional burdens on smallholder farmers and reduce the overall efficiency of beef cattle enterprises.

Various solutions based on the utilization of agricultural and livestock waste demonstrate significant potential to address these challenges in an integrated manner. The use of plantation and agro-industrial by-products as alternative feed can enhance feed security, reduce production costs, and simultaneously mitigate environmental pollution. Processing cattle manure into organic fertilizer and biogas not only improves the environmental quality of livestock farms but also generates added value in the form of enhanced soil fertility and the provision of renewable energy for farm households. The crop–livestock integration approach, guided by the concept of a zero-waste production system, emphasizes that all waste can be recycled and reintegrated into the production cycle. Grounded in the three pillars of sustainability—economic, social, and environmental—the development of integrated beef cattle systems represents a key strategy to promote more efficient, environmentally friendly, and sustainable livestock production in Indonesia. In addition, Widiati (2015) stated that the strategies needed to build a people's beef cattle industry include Provision of livestock market facilities to facilitate access to obtain production facilities; Availability of technology that can be applied by livestock farmers and provide welfare improvements through increased productivity; Creating a livestock product market that is profitable for livestock farmers; and Formation of a subsystem of village-level financing institutions to fund increased production and business productivity. There needs to be a synergistic relationship between these strategies accompanied by operational government policy support.

4. Conclusions

The results of the analysis show that the three countries with the strongest link strength in the study of sustainable beef cattle production during the period 2020 to 2025 are the United States, Brazil, and the United Kingdom. Countries included in the top 10 publications of documents on sustainable beef cattle production studies during the period 2020 to 2025 include: United States 100 documents, Brazil 83 documents, United Kingdom 28 documents, Indonesia 25 documents, Australia 24 documents, China 22 documents, Ireland 21 documents, Colombia 19 documents, Italy 17 documents, and Spain 17 documents. Quantitatively, Indonesia is ranked fourth in document publication while Australia is ranked fifth. However, qualitatively, Australia is superior with a total link strength of 3350, while Indonesia has a total link strength of 269.

In terms of publishing trends in 2020, there were 57 documents, then increased in 2021 to 87 documents, then decreased in 2022 to 69 documents. In 2023, the number of publications decreased to 47 documents. A significant increase occurred in 2024 with the number of publications of 108 documents. In 2025 until the first quarter, the number of publications reached 28 documents. Furthermore, the results of the bibliometric analysis showed that "cattle" was the most influential keyword with the number of occurrences of 170 and the total link strength of 1943. The subject area of study of most documents is included in the field of Agricultural and Biological Sciences with 227 documents and the field of Environmental Science with 148 documents.

Based on the results of the literature review, it hightlights that most of the meat production in Indonesia comes from small-scale beef cattle farms with small cattle ownership. This is different from Australia which is more dominated by industrial-scale livestock farms. One of the developments in sustainable beef cattle farming is the concept of integrating agricultural crops - cattle where crop waste is used as animal feed and livestock waste is processed into fertilizer for agricultural land. Several strategies are needed to build a small-scale beef cattle industry, including the provision of livestock market facilities to facilitate access to obtain production facilities, the availability of technology that can be applied by farmers and provide welfare improvements through increased productivity, creating a profitable livestock product market for farmers, and forming a subsystem of village-level financing institutions to fund increased production and business productivity. Australia's beef cattle farming sector is more advanced and its production is much higher, so Indonesia needs to learn from Australia in order to achieve beef self-sufficiency.

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