

Review

Balancing Livestock Environmental Footprints with Forestry-Based Solutions: A Review

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Abstract: Livestock production, as one of the oldest and most significant human activities, plays a vital role in fulfilling the global demand for human nutrition and other animal-related products while contributing to poverty reduction. However, it is also important to address the environmental impact of livestock animals. Over 60% of the global biomass harvested annually to support human activity is directed towards this sector, raising concerns about its sustainability. In addition to substantial water and fertilizer usage reported in recent years, it is estimated that 14.5% of global greenhouse gas emissions are generated by the livestock sector. Furthermore, the increasing amount of manure resulting from intensive animal farming raises concerns about its disposal and potential water pollution. The degradation of pasture and rangeland is another significant contributor to soil erosion. Multiple approaches are being studied to reduce the environmental impact of livestock production, but a sustainable alternative may be through forestry. Forests play a vital role in countering livestock emissions by absorbing billions of tons of carbon dioxide each year, and they act as a crucial carbon sink. Furthermore, the diversity and age of forests impact the carbon sequestration process. Forests also help to combat climate change by reducing soil erosion and regulating the water cycle. As such, sustainable forest management is essential as forests provide multiple benefits, including economic, environmental, and social benefits, while also sequestering carbon. In this review, the current impact of modern livestock production is described, along with the potential for mitigating it through forestry-based solutions.

Keywords: livestock; environment; forestry; greenhouse gases; water and land use; climate change



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1. Introduction

The first known domesticated livestock animal, which was used as a food-producing animal by our ancestors, was the sheep, with this domestication dating back to around 11,000 years ago [1]. This domestication was even before our ancestors started cultivating plants [2]. Several other species of livestock are now reared across the globe which serve food, hide, and milk to humankind. Today, the livestock sector is one of the most flourishing and highly organized sectors in the world [3,4]. According to the World Bank report, meat production, which was around 45 million tons in 1980, jumped to 134 million tons in 2002, witnessing a three-times boom within 22 years [5]. Similarly, the recent forecast for meat production predicts approximately 360 million tons, reflecting a 1.2 percent increase compared with the 2021 estimates [6]. The world population is forecasted to touch the 10 billion mark by 2050. An increase in livestock farming ensures food availability to the ever-growing population. However, the other side of “animal agriculture” is now coming to light and creating an upcoming issue of environmental health. There are several pros and cons of livestock production on social equity, economic growth, and natural resources [5]. The detrimental effects of livestock farming impact the global temperature, biodiversity,

and quality of natural resources (air, water, and soil) [7]. These effects are attributable to the permuted biogeochemical cycles of carbon, nitrogen, and phosphorous [8,9]. The calamitous impact of livestock production on soil health [10,11], global warming [12–14], air quality [15,16], water pollution [7], and environmental stability [3] are well documented (Figure 1).

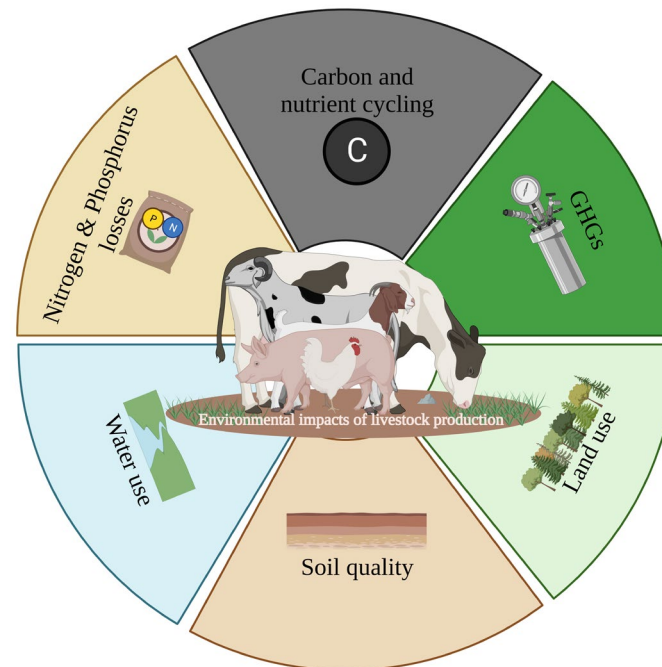


Figure 1. Summary of the potential impacts of livestock production on the environment. The figure was created with created with BioRender.com (accessed on 15 August 2020). The environmental footprint of livestock is discernible through their impact on various factors, including carbon and nutrient cycling, greenhouse gases (GHGs), nutrient losses, water and land use, and, ultimately, soil quality.

It is imperative to recognize the detrimental impacts of livestock farming on the environment and explore viable solutions to mitigate them. Reducing the consumption of meat could be one possible option [17] that aims to decrease the rearing and breeding of animals on a large scale. However, such a shift in diet cannot be based only on nutritional choices as there are multifaceted rationales for choosing food consumed by an individual [18]. Hence, more globally applicable, sustainable remedies are crucial. Forests, vital for life, produce oxygen, making them indispensable. For instance, a model developed in Turkey estimated that a forest management approach focused on timber could result in the production of 2.6 million tons of oxygen over 100 years [19]. Moreover, forests play a vital role in conserving natural resources, subduing several types of pollution (air, water, soil, noise, etc.), regulating biogeochemical cycles, and providing habitats for several species of plants and animals [20]. Past studies have highlighted the effectiveness of urban forests in Beijing, China in removing over 772 tons of PM₁₀ (particulate matter with an aerodynamic diameter smaller than 10 µm) and storing approximately 0.2 million tons of carbon biomass [21]. Similarly, earlier research in the UK demonstrated that good forestry management practices could significantly limit soil erosion, preventing unacceptable increases in turbidity and sedimentation in watercourses [22].

To our knowledge, there is no existing report that discusses the connection between afforestation and its potential impact on the environmental footprint of farm animals. Most studies focus either on afforestation or on the impact of farm animals on the environment. In this review, we aim to highlight the negative effects of livestock on various biodiversity resources and the environment and explore possible solutions using forestry. Additionally,

this review provides novel insights into the effects of animal production on different ecological realms, including the atmosphere, global water, and land use.

2. Overview of Environmental Impacts of Livestock Production

2.1. Impacts of Livestock Production on Greenhouse Gas (GHG) Emissions

In the current literature, six main gases are generally considered GHGs: perfluorocarbons, sulfur hexafluoride, hydrofluorocarbons, carbon dioxide, methane, and nitrous oxide [23]. Of these, over 50% of the greenhouse effect is directly linked to the last three [24]. The interaction between the sun's energy and these gases generates the greenhouse effect, as their ability to retain and capture heat is one of the main reasons for their special attention from researchers [25]. For example, after absorbing infrared radiation, carbon dioxide molecules vibrate and emit their radiation, which is then absorbed by another GHG molecule [26]. This cycle, known as absorption-emission-absorption, maintains heat close to the earth's surface [23]. Similarly, methane and nitrous oxide molecules, due to their constitutions, are also able to vibrate with the absorption of heat [27]. While the greenhouse gases in our atmosphere are essential for keeping living organisms on the planet, the continuous increase in their concentration is likely to be detrimental [28]. As a result, the latest meetings of the Intergovernmental Panel on Climate Change (IPCC) concluded that governments should not only assess their overall emissions but also find solutions to reduce further emissions [29]. In this sense, methane and nitrous oxide were found to be the most relevant GHGs in the livestock production sector.

2.1.1. Methane

Methane is a significant concern due to its global warming potential, which is estimated to be 25 times greater than that of carbon dioxide [30,31]. Different types of livestock, production regions, and systems contribute to varying degrees of overall methane emissions [30]. In modern agriculture, ruminants are the largest source of methane emissions, accounting for approximately one-third of global anthropogenic methane emissions [32]. This significant contribution is attributed to their large share in animal biomass and unique digestive system. Generally, ruminants generate methane through two primary channels [33]. Earlier studies have demonstrated that methane emissions arising from forage crops are minimal (less than 5%), and can therefore be disregarded [32]. While there is evidence of methane emissions from micro anaerobic soil conditions during grazing, soils with higher drainage can significantly slow down this process [34]. Therefore, the first channel, which accounts for the highest proportion of emissions, is directly through enteric fermentation [35]. This results in methane being emitted through flatulence and eructation [36]. The process of methane production during enteric fermentation is quite complex and involves actors of microbial origin [32–35,37]. Unlike monogastric animals, ruminants have the ability to digest fibrous plant material, mainly due to their stomach, which consists of four distinct compartments [38]. A large anaerobic chamber in the gut of cattle called the rumen, is responsible for fermenting plant materials [39–43]. Methane is produced by microorganisms in the rumen known as methanogens [44–46]. These microorganisms have unique characteristics that classify them as archaea. Methanogens are responsible for the final step of methanogenesis, which produces methane from hydrogen and carbon dioxide [47]. The production of methane is influenced by biological factors in the rumen, such as pH and microbial composition, which are linked to the type of feed provided to the animals [42,48–50]. In pastoral systems, natural pasture is the only feed source, resulting in higher methane output [51]. Intensive systems, which feed animals concentrate-based diets rich in grains and soybeans, generate lower methane emissions per animal [52]. However, overall, intensive systems have higher emissions when considering the livestock population in each system. Countries such as Brazil, China, and the United States, which rely on intensive systems, are the largest contributors to agricultural methane emissions [53].

The second channel in which ruminant animals contribute to methane emissions is through manure [54]. Specifically, the anaerobic decomposition of manure content and the

use of lagoons and holding tanks to manage the liquid phase of manure are localized areas of methane production [55]. In addition to odor pollution and hygiene hazards, poorly managed manure can also have negative consequences. Manure, which is composed of carbohydrates, proteins, and fats, is a complex type of substrate that is easily subjected to fermentation [56]. In an anaerobic digestion process, organic matter from manure is successively hydrolyzed and fermented, resulting in alcohols, fatty acids, hydrogen, and carbon dioxide [57]. Like in enteric fermentation, these two last components are used to generate methane, as ruminant manure is rich in microbes capable of methanogenesis [58]. However, the outputs are significantly lower due to moderate anaerobic biodegradability below the threshold of 50%. In particular, the rate can be even lower in cattle manure, depending on the levels of leftover lignin complexes from the diet [59]. Temperature is a factor that can influence methanogenesis from manure. More precisely, low temperatures can significantly decrease methane outputs [60]. In fact, when ambient temperatures fall below the optimal range for methanogen activity, it significantly decelerates methane production [61,62]. Previous studies have also shown a decrease in the decomposition rate of organic matter within manure linked with temperature, and directly impacting overall methane yield [63,64]. As such, it was proposed that in temperate and cold climates, methane emissions could be decreased at a low cost by frequent removal and outdoor storage [65]. Methane can also be oxidized by methane-oxidizing bacteria (MOB), which were found to be present in solid manure [66]. Previous reports highlighted the need to keep manure in a solid state to enhance the activity of MOB, as they might play a role in methane mitigation [67]. However, it is critical to mention that manure containing substantial water proportions with a relatively high buffer capacity can enhance anaerobic digestion [68]. This is the case with lagoons and holding tanks. During the filling of these facilities, there is a fast inoculation of new slurry material, which, depending on its chemical properties, can intensify methanogenic activity.

Fortunately, the IPCC developed a methodology to estimate and potentially limit methane emissions from liquid manure [69]. This methodology utilizes equations of varying complexity, which are categorized into tiers. To date, three tiers have been defined. The methods for estimating methane emissions from livestock require definitions of livestock subcategories, annual populations, and, for higher-tier methods, feed intake and characterization. The Tier 1 approach for estimating manure from livestock is based on a default emission factor per unit of volatile solid by livestock category and manure storage system. The Tier 2 method, which is more advanced, requires additional variables. This tier is country-specific and considers the impact of the interaction between manure management systems and livestock category during both excretion and storage. The Tier 3 method goes beyond country-specific methodology and is a measurement-based approach to quantify emission factors, which is the most accurate form of estimation but is not yet widely adopted due to the high input needed.

2.1.2. Nitrous Oxide

Nitrous oxide is a greenhouse gas that is emitted in large quantities, ranking third after carbon dioxide and methane [70]. The increasing concentration of nitrous oxide in the atmosphere has become a concern due to its role in regulating stratospheric ozone and the planetary radiation balance [71]. Previous research has also shown that nitrous oxide is involved in the formation of acid rain [72]. Human activities such as land use, fossil fuel combustion, wastewater treatment, and agriculture are sources of nitrous oxide emissions [73]. In the United States, agricultural and soil management activities were estimated to be the largest source of nitrous oxide emissions [74]. Livestock production, however, contributes only minimally to nitrous oxide emissions, with manure being the primary contributor [75]. The storage and management of manure lead to the formation of nitrous oxide through alternative nitrification and denitrification processes, and both aerobic and anaerobic reactions are involved [55]. The conversion of nitrogen from its oxidized form to its gaseous state during the application and handling of manure also contributes to nitrous

oxide emissions [76]. Nitrification, which yields nitrate from ammonia via nitrite in a two-step conversion reaction, is catalyzed by two categories of microorganisms: ammonia-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB) [77]. While the presence of ammonia-oxidizing archaea has been detected in manure and soil during composting, their role in nitrification has not yet been established [78]. On the other hand, denitrification involves a wide variety of microorganisms, with fungi, archaea, and especially heterotrophic bacteria being directly involved [79]. Denitrification can occur in either oxic or anoxic conditions, depending on oxygen availability, and microorganisms can produce nitrous oxide through different pathways [55]. Therefore, during storage and after field application of manure, factors such as oxygen gradients can influence the production rate of nitrous oxide [80]. Additionally, there is a correlation between chemical gradients and emission levels of nitrous oxide from manure [81]. The influence of decomposer activity on the development of chemical gradients, particularly the loss of carbon dioxide and ammonia near air-liquid interfaces, can cause a reduction in alkalinity and pH. This is primarily due to the acidifying process of ammonia oxidation, which may result in decreased rates of nitrification and denitrification [80]. However, it can also lead to an increased nitrite-to-nitrogen ratio in denitrification [82]. Overall, the current evidence suggests that livestock impact on atmospheric nitrous oxide concentration is mostly related to manure. Furthermore, net emissions not only depend on manure composition but also ambient climatic conditions. Therefore, specific attention should be given to manure properties and environmental conditions in order to develop appropriate mitigation solutions.

2.2. Impacts of Livestock Production on Water and Land Use

2.2.1. Water Use

The increasing demand for livestock-related products not only results in impacts on GHG emissions and nutrient cycles but also puts substantial pressure on natural resources such as land and water [8]. Large-scale feed crop cultivation, grazing land, and water use are among the factors that directly link livestock production with detrimental impacts on natural resource availability [83]. Given the finite and essential nature of water as a resource for life on the planet, the overall water usage of livestock production systems is a topic of ongoing debate [84]. Globally, freshwater resources are relatively scarce, accounting for only about 2.5% of the total water reserves, with a significant portion of these resources being inaccessible due to their storage in glaciers and permanent ice formations [85]. Addressing water use in livestock production appears to be vital for sustainable agriculture and environmental conservation. Water utilization within the livestock industry extends beyond direct consumption for hydration to a range of auxiliary functions and product processing, as well as the crucial need for water in feed crop growth [86]. While these additional water requirements are significant, direct consumption and feed crop growth remain the central components. Previous reports have provided a quantitative assessment of water usage in the livestock sector, shedding light on both direct and indirect water consumption [87,88]. It was highlighted that the water footprint of feedlot beef cattle ranged from 3.3 to 221 L H₂O kg⁻¹ of live weight [89]. Throughout the life cycle of a single broiler, at least 1 L of water is needed to maintain homeostasis [90], with the potential for even greater water requirements as temperatures rise [91–95]. Similarly, swine production under confined and dry feeding conditions had a water turnover rate of 120 mL/kg during the growing phase and 80 mL/kg of body weight for non-lactating adult pigs [96]. As a result, it appears that direct water consumption contributes to the overall water use in livestock production, primarily due to physiological functions such as growth, production, reproduction, and temperature regulation, which require substantial amounts of water. The use of water required for growing livestock feed seems to contribute the most to the overall water demands in the industry [97]. As the demand for livestock products continues to increase, the water demand will also increase since the livestock population will need to grow. However, there is not yet a standardized method to estimate the exact amount of evapotranspired water needed to produce 1 kg of feedstuff, and variations exist in the

quantities of feedstuff that can be produced per cubic meter of water [98]. Studies have shown that between 0.5 and 8 kg of dry matter forage can be generated per cubic meter of water, depending on the production system [98]. More specifically, forage maize, one of the most common feedstuffs, has been estimated to yield around 2.9 to 3.7 kg of dry matter per cubic meter [99]. Major differences exist among livestock production systems in various regions with differing levels of intensification, indicating the need for systematic consideration of livestock-water interactions and site-specific interventions. This approach is crucial for ensuring sustainable and productive use of water resources.

2.2.2. Land Use

Livestock primarily consumes food items that can otherwise be made available for human consumption. Additionally, there is a recent consensus that the production of feedstuff diverts arable land from food production [100]. Hence, finding the right balance between direct consumption of plant production and feedstuff is crucial to global food availability. Livestock production directly impacts land use through feed crops, grazing land, and to a lesser extent, land conversion. Most of the agricultural land is directed towards livestock nutrition, which is about twice as much as that for arable crops. Unfortunately, the majority of livestock production systems have a protein conversion efficiency of less than 0.5, which indirectly translates to the land needed to maintain specific livestock systems [100]. Milk and egg production have efficiencies estimated at around 0.25 [101], while lamb and beef have the lowest efficiency at 0.06 and 0.04, respectively [102]. Humans would thus benefit more from consuming grain-based protein directly rather than consuming grain-fed animal protein [103]. Despite the increasing interest in the use of inedible feed in livestock production, using land to produce such products would not necessarily eliminate competition if crops were simply grown instead [98]. In livestock production, inedible feed encompasses materials unfit for human consumption yet valuable as sources of nutrition for animals [104,105]. They consist of but are not limited to, straws, hays, hulls, and crop residues, as well as certain weeds and invasive plants. These materials are primarily utilized in ruminant nutrition as it is preferred that the use of potentially edible feed resources by livestock be restricted to those with the highest daily nutrient requirements [104]. Therefore, it appears that the large-scale cultivation of crops needed for animal nutrition necessitates extensive areas of land, causing habitat loss and a decline in biodiversity.

Grazing land, which can also be referred to as pastureland or grazing pasture, consists of natural or cultivated vegetation that serves as a food source for ruminant animals [106]. Like feed crops, grazing land has a significant impact on land use. Indeed, managed grazing covers more than 33 million square kilometers of the global land surface, making it the single most extensive form of land use on Earth [107]. It is important to consider the intensity and extent to which farm animals consume plants in a specific area over a given period to limit their impacts on the environment. In fact, the continuous presence of livestock on pastureland can hinder the natural generation of biomass, often resulting in vegetation degradation [108]. Additionally, certain plant species are often targeted by animals during grazing due to their nutritional profile and flavor, which can lead to negative impacts on biodiversity and disrupt ecosystems [109]. Changes are noticed in the abundance, cover, and configuration of life forms. These structural alterations are often associated with vegetal species invasion, water drainage, erosion, and the alteration of soil biochemical characteristics [110]. Grasslands have a natural ability to store large amounts of carbon dioxide. Recent research indicates that a diverse plant community contributes to increased soil organic carbon (SOC) levels by promoting the growth of belowground biomass and enhancing the contribution of microbial necromass to SOC storage [111–113]. Conversely, intensive livestock grazing has been found to significantly reduce plant and microbe-mediated SOC formation [110]. Eze, et al. [114] reported that grazing tends to decrease SOC stocks by an average of 15% globally, with the most significant reductions occurring in tropical regions and the least in temperate climates. Likewise, sheep grazing

has a generally stronger impact on SOC than cattle grazing, with SOC reduction occurring mostly in topsoil [115]. These findings suggest that livestock species, water availability, and temperature are confounding factors in the impacts of grazing on SOC storage.

The relationship between livestock production and land conversion is evident from the current literature. In this context, land conversion can be defined as the transformation of natural ecosystems, such as forests or grasslands, into agricultural zones [116]. The continuous expansion of these crops and pastures is the primary driver of livestock-related land conversion. In fact, the demand for animal products has been increasing globally, with meat production almost quadrupling between 1963 and 2015, and milk production more than doubling (from 340 to 818 Mt) over the same period [117]. As a result, more land is needed to meet these increasing demands. Indeed, not only more feedstuffs are required, but a significant number of infrastructures need to be built in order to accommodate the new herds [118]. This has led to deforestation in areas such as the Amazon, where cultivated soybean areas are expanding [119]. Hence, the business-as-usual approach of land conversion for livestock production is not sustainable, and strategies should instead focus on improving efficiency through higher product output with limited inputs.

3. Potential Impacts of Forestry on the Environmental Footprint of Livestock Production

Forests are typically represented as areas with a significant tree presence and specific characteristics, such as a canopy cover of over 10% and trees taller than 5 m [120]. More specifically, the Food and Agriculture Organization of the United Nations (FAO, Rome, Italy) defines a forest as an area greater than 0.5 hectares with such characteristics [121]. Afforestation is generally believed to alleviate environmental impacts from agriculture and livestock farming, as it is associated with positive effects such as nutrient cycling. Forests worldwide absorb billions of tons of carbon dioxide every year, which would require a significant economic subsidy to replicate with an equivalent carbon sink [122]. These forests take in carbon dioxide from the atmosphere and convert it into carbohydrates, leading to the accumulation of more tree biomass over time and its storage in the soil [123–126]. This process is termed as sequestering and storing of carbon for the mitigation of climate change [127,128] as forest plays a role in removing greenhouse gases from the atmosphere [129]. Hence, even though livestock farming emits greenhouse gases all year round, these gases can be offset through carbon sequestration (Figure 2).

The sequestration concept is very complex [130] and requires details in terms of compositions, as diversity in the forest ecosystem has a significant effect on carbon sequestration [131–134]. For instance, aged trees store more atmospheric carbon than young trees [135–137]. The potential for carbon sequestration also varies depending on the type of forest, shrubs, agroforests, and other life forms and soil under the species [134,138,139]. Global interest has recently been placed on nature-based solutions for climate change mitigation [140–142], highlighting the potential of forests in carbon dioxide removal from the atmosphere and carbon storage in the soil [127,143]. Therefore, it is crucial to consider afforestation and increasing forest cover through reforestation, as well as the management and preservation of existing forests to increase their carbon storage potential. Additionally, efforts to reduce emissions from deforestation due to livestock production [144–146], and the development of renewable energy sources and wood-based products as an alternative to fossil fuels, should be a priority in the next decades [147–150].

Forests might help mitigate the detrimental impact of livestock on climate change by slowing down soil erosion and regulating the water cycle. Indeed, trees play a vital role in improving the biophysical properties of soil, fostering healthier ecosystems, and supporting sustainable land use practices [151,152]. As tree roots grow and spread underground, they create a network that binds soil particles together, preventing erosion and promoting soil stability [153]. This root network also increases the soil's water-holding capacity by creating channels for water to penetrate, reducing surface runoff and enhancing water retention [154]. Additionally, the fallen leaves, branches, and other organic matter from trees contribute to a natural layer of mulch on the forest floor [155]. This mulch acts

as a protective cover, reducing the impact of rainfall on the soil surface and preventing compaction [156]. Over time, the decomposition of these organic materials enriches the soil with essential nutrients, enhancing its fertility [157]. Trees also promote increased soil microbial activity, fostering a diverse community of organisms that aid in nutrient cycling and decomposition processes [158]. The regulation of water cycles is primarily recognized by the phenomenon of transpiration. Transpiration occurs when trees release water vapor into the atmosphere through their stomata [159]. This moisture then forms clouds, leading to precipitation. Transpiration not only cools the surrounding air but also impacts local weather patterns [159]. By effectively capturing, storing, and releasing water, forests maintain balanced water levels, prevent floods, and ensure a consistent supply of water to rivers, streams, and other water bodies, benefiting both ecosystems and human communities downstream [160]. Therefore, the biophysical effects of forests on soil and water cycle promote, erosion control, water conservation, and nutrient cycling, making forests essential components of resilient and sustainable landscapes.

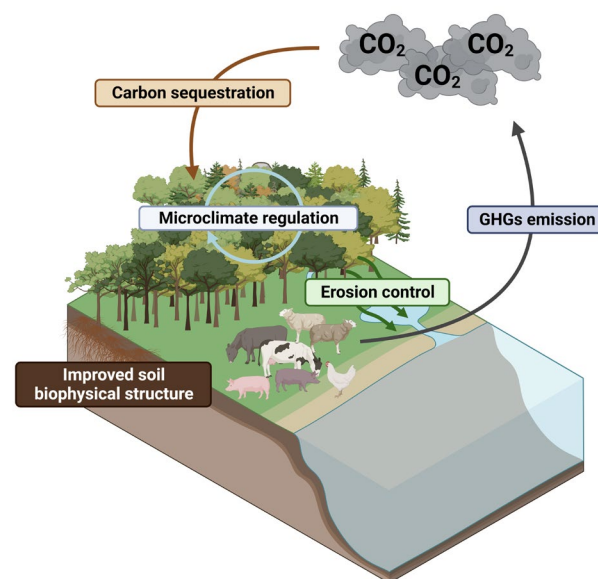


Figure 2. Selected established or suggested effects of forests in the mitigation of the environmental impacts of livestock production. The figure was created with BioRender.com (accessed on 15 August 2020). Forests play a crucial role in mitigating livestock environmental footprints by absorbing carbon dioxide emitted by livestock, acting as carbon sinks. Forests are also actively involved in erosion control and the improvement of the soil biophysical structure.

While there is strong evidence that forests can be a solution to mitigate the negative effects of livestock production on the environment, concomitant sustainable management is necessary. Forests are managed for their products, which are categorized into timber and non-timber products and services such as protection against water and wind erosion, carbon sequestration, or cultural and social benefits [161,162]. The demand for diverse benefits from forests can lead to the degradation of resources, caused by extensive harvesting of products that damages their service roles and results in the unsustainability of forest resources and the benefits gained [163,164]. Sustainable forest management is the practice for the continued supply of economic, environmental, and sociocultural benefits [165]. This requires monitoring and collecting information about their environmental, economic, and social impacts [166]. As forests sequester carbon in living biomass, deadwood, and forest soil [167], sustainable forest management can help to optimize their roles in increasing the diversity of natural forests [168–170], supporting the growth of biomass, and contributing to local socio-economic development [171]. Biomass, which increases with the age of the tree, is one of the limiting factors for the potential of carbon sequestration [129,130,172], as the large diameter at breast height has maximum biomass storage for a high amount

of carbon (Figure 3). This implies that the carbon sequestration potential concerning tree growth relationships at fine spatial scales is limited [173].

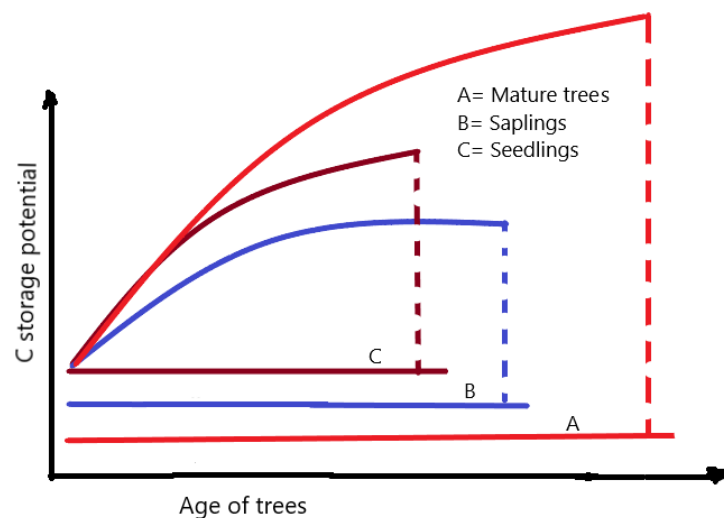


Figure 3. Potentials of trees in carbon storage according to their age. This graph explains the potential of trees for storing carbon in their biomass. Tree biomass, which is the result of the increment of sapwood through age, has a role in storing maximum carbon when the tree reaches maturation. This figure was made by figuratively illustrating the literature [125,126,165]. The curved lines depict the carbon storage potentials of each age class.

The relationship between forest and livestock production is also significantly linked to the assessment of the carbon footprint (CFP). CFP quantifies greenhouse gas emissions within specific boundaries, and is of utmost importance for individuals, organizations, processes, products, or events [174,175]. It plays a vital role in reducing greenhouse gas emissions. For organizations, understanding and calculating their CFP allows for the measurement of emissions resulting from human activities [176]. This knowledge empowers industries, particularly processing companies, to identify and optimize carbon-intensive steps, aligning their production with carbon neutrality goals as outlined in initiatives like the Green Deal [177]. Developing regulations and evaluation schemes for carbon emissions in manufacturing processes is crucial in this context [178]. As previously discussed, forests stand out as effective carbon sinks [124]. Introducing tree species resilient to future climate conditions is necessary, emphasizing nature-based solutions to combat climate change [179]. It is crucial to consider co-benefits such as biodiversity and livelihoods, promoting income diversification and supporting livelihoods [180]. Enhancing forest capacity for carbon sequestration through diversity should inform management decisions [181,182]. By incorporating this knowledge, forests can outweigh greenhouse gas emissions from animal agriculture, contributing significantly to the overall reduction in the carbon footprint [175]. Encouraging investments in forestry emerges as a viable strategy to control carbon emissions [183].

4. Conclusions

Given the escalating global population and increasing demand for livestock products, it is imperative to address the environmental implications of livestock production on our planet. Despite its crucial role in fulfilling humanity's dietary needs, the exponential growth of livestock production has exacted a substantial toll on the environment. The environmental impact of livestock production is a multi-faceted challenge, including greenhouse gas emissions, water usage, land conversion, soil erosion, and the sustainable use of finite resources such as water and land for feed crops. The adverse impact on biodiversity, including changes in vegetation, habitat loss, and disruptions in ecosystems, further underscores the urgency of finding viable solutions.

This short review highlights a promising avenue for reducing the environmental impact of livestock production, which is the implementation of afforestation and sustainable forestry management practices. Forests, which can be considered “the earth’s lungs”, have the remarkable ability to sequester carbon dioxide and act as vital carbon sinks. Through the promotion of afforestation and reforestation, it is possible to counterbalance the emissions from livestock farming, thereby lowering the overall carbon footprint. Forests provide numerous advantages, such as erosion control, water cycle regulation, biodiversity promotion, and soil fertility enhancement. However, the success of these initiatives is contingent upon the adoption of sustainable forest management practices. Achieving a harmonious balance between meeting the demands for timber and non-timber forest products while preserving forests’ ecological functions is vital. This requires a holistic approach that considers the complex relationships between tree species, forest biodiversity, and carbon sequestration potential. Furthermore, embracing nature-based solutions can significantly contribute to global efforts to combat climate change.

In conclusion, addressing the environmental challenges posed by livestock production necessitates a paradigm shift in our approach. By endorsing sustainable forestry practices and recognizing the crucial role of forests in mitigating the environmental footprint, we can create a more sustainable future. As we stand at a crossroads between environmental conservation and agricultural expansion, the decisions we make today will impact future generations. It is our collective responsibility to safeguard our planet, ensuring a harmonious coexistence between humanity, livestock, and nature. It is imperative to adopt an approach characterized by the implementation of strategic interventions and a commitment to sustainable practices to ensure that the needs of humanity are met while preserving the balance of our ecosystems.

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