The Sustainability of Bison Production in North America: A Scoping Review

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Abstract: The American bison (Bison bison) is iconic of the Great Plains of North America, yet the genus has had to overcome near extinction in the recent past prior to being re-established for food production. This scoping review summarizes the literature on the Plains Bison as a large ruminant species adequate for modern-day meat production in order to evaluate the species’ appropriateness as a sustainable meat source and to identify knowledge gaps hindering the sustainability evaluation of bison production. To date, we can anecdotally assume that bison husbandry could contribute to sustainability based on its positive contribution to biodiversity, physiological robustness, economically higher price per kg, and nutritive values, despite their decreased growth and performance rates compared to beef cattle. However, targeted and system-based research is required in order to unequivocally assess the sustainability of bison production in North America.

Keywords: American buffalo; biodiversity; production performance; economic value; greenhouse gas emissions; life cycle assessment

1. Introduction

Livestock farming is increasingly criticized for its impact on the environment as it contributes from 8 to 10% of total anthropogenic greenhouse gas emissions [1], although estimates vary widely [2]. The largest contributor within the livestock sector are cattle with 62% of emissions attributed to dairy and beef husbandry systems [3]. Due to animal husbandry practices and the deforestation and conversion of forest areas and pastureland into arable land for the production of livestock feed, consumers worldwide, but especially in the West, are increasingly demanding animal-friendly as well as sustainably produced food [4]. In particular, sustainably produced alternative sources of red meat, such as bison meat, could therefore become increasingly important in the future.

The American bison (Bison bison) evokes a long and tangled history of Indigenous Peoples and settlers, standing as a symbol of hope for the future [5], a future in which bison, as the largest land mammal native to North America, could meet human needs for sustainably produced food. The principle of sustainability is based on the responsible use of the Earth’s resources [6], a sentiment well-aligned with the American bison’s iconic history. Therefore, the aim of this scoping review is to summarize the current literature on the American bison and its sustainability of (commercial) production, while identifying gaps in research hindering the evaluation of the genus as a potential sustainable meat source.

1.1. The Genus Bison

The American bison has two subspecies: The Plains Bison (Bison bison bison) is native to the grasslands of the North American prairies, and the Wood Bison (Bison bison athabascae) is native to the boreal regions of North America (i.e., Alberta, British Columbia, and Yukon, Canada, as well as Alaska, USA) [7]. In the North American lexicon, bison are also often referred to as (American) buffalo; however, bison are not directly related with the “true” buffalo that live primarily in Africa and Asia [8]. Together with the European Bison
Bison bonasus), there exist three species which form the genus Bison. It should be noted that in the scientific literature, it is disputed whether bison actually form a genus on their own—some authors include them in the genus of cattle (Bos) [9–11]. In the context of this paper, we refer to bison as their own genus.

1.2. Habitat and History of the Plains Bison

Prior to the arrival of European settlers, bison grazed across one-third of the entire North American continent, from the east coast to the west coast in the United States and from the Great Plains in southern Canada to northern Mexico [12]. For over 10,000 years, they were the dominant herbivore and keystone species of the North American Prairies [13]. It is estimated that at least 10 million bison grazed the Prairies until European settlement [14], with some estimates as high as 30 million [12] and 60 million bison [15]. Excessive commercial hunting, governmental policy, as well as competition for forage with domesticated livestock (introduced from Europe) reduced the population of Plains Bison to a few hundred animals by the late 19th century [14]. The Plains Bison was thus on the verge of extinction [12]; however, with the establishment of protected areas (e.g., National Parks) and governmental policy changes which prohibited illegal poaching of bison, small populations were initially established in private and public holdings, and bison populations gradually recovered within North America [12].

1.3. Commercial Bison Farming in North America

Today, nearly all (96%) of the bison in North America are kept for commercial purposes [14]. The remainder are raised as a part of conservation breeding programs in national parks and private reserves [5]. Due to it being well-adapted to its natural habitat [16] and increasing demand for its meat [17], the number of commercially raised bison has increased in recent history and remained relatively stable. In Canada alone, the number of commercially raised bison increased from 45,437 (1996) [18] to 119,314 (2016) commercially raised bison [19]. Combined with the approximately 183,780 bison kept in the U.S. [20], this translates to approximately 300,000 commercially raised bison in North America.

2. Methodological Approach

The present literature review focuses only on bison husbandry of the subspecies Plains Bison (Bison bison bison), as the only subspecies currently kept commercially for meat production in North America [21]. The Wood Bison (Bison bison athabascae), with a population of approx. 8500 animals in Canada, is still classified as an endangered subspecies [22] whose conservation is of a higher priority than potential agricultural use. European bison (Bison bonasus) do not play a role in North American bison husbandry and are therefore not addressed in this paper.

In order to summarize the literature and identify research gaps, an extensive literature search on the sustainability and (commercial) husbandry aspects of bison was conducted between 10 April 2020 and 30 June 2020. Various online databases were employed: Web of Science, AGRIS, AGRICOLA, and Google Scholar. Since bison husbandry is conducted primarily in North America, the search was conducted in English.

Multiple key words were used during the literature search. To cover aspects related to sustainability, the search terms “greenhouse gas”, “methane”, “climate change”, and “biodiversity” were entered together with the main key word “bison” in Web of Science. Additional explicit searches using key words such as “bison”, “bison farming”, and “American buffalo” in AGRICOLA and Google Scholar were also conducted.

We are confident that we found all relevant articles, as searches became redundant. For example, using “bison” and “biodiversity”, 74 available articles were suggested on Web of Science; 8 articles [14,23–29] were included in the literature search. Searching with “bison” and “extensive” resulted in 73 articles, of which 2 relevant articles were identified but were redundant from the previous search “bison” and “biodiversity” search, and so on.
Sources were considered relevant based on the abstract or keywords; relevant texts were read thoroughly, and potentially relevant sources cited within were then sought and included if appropriate. Overall, 88 pieces of relevant literature were identified (Table S1). Finally, various website portals were visited, such as those of the National Bison Association (https://bisoncentral.com/ accessed on 30 June 2020) and Statistics Canada (https://www.statcan.gc.ca/ accessed on 30 June 2020). Relevant websites complemented the peer reviewed literature with useful and specific practical and statistical information.

3. Results

3.1. Biodiversity through Grazing

Biodiversity across pastureland (also known as rangeland) can be divided into two categories: plant and animal biodiversity. Although the living organisms in these two categories are clearly distinguishable, the plants and animals of an ecosystem are interconnected and interdependent. It is generally assumed that the act of grazing increases the plant diversity of pastureland by consuming competing dominant plant species, resulting in indirect effects on plant composition [30]. In particular, grazing by large herbivores, such as bison and cattle, increases and promotes the biodiversity of an ecosystem to a large extent [31], as long as it is managed at a moderate level [24]. Bison range is particularly able to offer a variety of habitat types for other species [5].

3.1.1. Bison as a Keystone Species

Its grazing and wallowing behaviour, as well as its size, are what make bison a keystone species of the Great Plains. Paine [32] was the first to define keystone species as those that have an extremely high impact on a given ecosystem relative to their small population. Numerous studies conclude that bison, both historically and presently, play a crucial role in the conservation of biodiversity in the Great Plains and can therefore be considered as a keystone species [13,31,33]. From this, it can be deduced that the bison can promote the biodiversity of both plants and the animals on the Great Plains to a greater extent than modern-day cattle farming [14].

3.1.2. Plant Biodiversity and Bison Grazing

Bison (and cattle) are considered generalist foragers and feed predominantly on roughage [34,35]. Bison feed almost exclusively on graminoids, i.e., grass-like plants [23], and generally avoid forbs and woody species [36], which make up less than 10% of their food spectrum [31]. Cattle also feed on graminoids [34], but forbs and woody vegetation often account for more than 15% of their food spectrum [37]. Based on these differences in eating habits, it can be concluded that cattle graze and browse a wider selection of plants than bison [38]. The more preferential grazing by bison of the prairie-dominant grass creates a significant change in the plant composition of a pasture [31] and promotes an increased occurrence of forbs [39]. Although bison grazing reduces the biomass of grass-like plants [16], the increased availability of water and nutrients as well as increased availability of light leads to an increase in recessive species [39]. Specifically, the increased grazing of the dominant matrix grasses of the prairie landscape, such as big bluestem (Andropogon gerardii), Indian grass (Sorghastrum nutans), and switchgrass (Panicum virgatum), thus leads to an increase in subordinate species with less competitive power, such as leadplant (Amorpha canescens), white aster (Symphyotrichum ericoides), and western ragweed (Ambrosia psilostachya) [23]. In particular, these herbs are vital for maintaining biodiversity on the prairie [31], as these plants stimulate pollinators and generally influence the micro-environment to a greater extent than grasses [40].

It is not only the bison’s diet that promotes plant biodiversity; animal behaviour, such as roaming, also enhances plant biodiversity. Cattle prefer to graze close to water bodies, while bison prefer areas further away [41]; historical reports state bison can graze for several days over distances of up to a hundred kilometers between watering places [42]. The intensity of cattle grazing near water bodies can lead to poorer water
quality through increased fecal concentration, as well as decreased plant growth, both of which subsequently reduce floristic diversity [43].

Through activities such as horning and rubbing against small bushes and trees such as cottonwood (Populus angustifolia) and aspen (Populus tremuloides), bison limit the occurrence of woody vegetation on the prairie [26]. In the vicinity of watercourses, this slows or prevents colonization by beavers and other species, which in turn has cascading effects on plant communities, river morphology, and biodiversity [44]. On the other hand, by rubbing against woody vegetation, bison prevent forest succession [33]. By reducing forest expansion and regeneration, bison have an advantageous effect on the development of herbaceous and grass-like plants, which serve as their and other livestock’s fodder [27].

The fur of bison has more primary hairs than that of any other member of the Bovidae family—10 times more than that of cattle [35]. Plant seeds are more easily caught in the thick and fine fur on a bison head [45]. Plants such as cockle burs (Xanthium italicum) and buffalo grass (Bouteloua dactyloides) benefit particularly from bison grazing because their seeds have barbs that easily catch in the fur of the animals during grazing [46]. Since bison migrate long distances, when able [47], and move about 50 to 90% more than cattle [41], plant seeds can spread over greater distances in bison grazing systems than with cattle [48].

An abundance of seeds is also spread through the feces of bison [45]. Furthermore, bison influence the nitrogen cycle through their excretion of faeces and urine [31]. Grazing ungulates, such as bison, consume relatively high lignin-containing plant biomass and return unstable forms of nitrogen (i.e., urine) to the soil, thus avoiding the otherwise slow mineralization of nitrogen in plant litter [31]. This highlights another advantage derived from bison grazing further from water bodies [38,40].

Through the disturbance to the landscape caused by their grazing, bison also affect the primary production, reproductive performance, and species structure of plants, as well as the humus content of the soil and soil quality [27]. As herds graze, they trample and wallow the landscape in varying degrees of strength and intensity, creating strong mosaic effects, which increase spatial and temporal heterogeneity [23]. Thus, the diversity of microhabitats increases compared to ungrazed areas and ultimately enhances the diversity of plant species [49]. Increased floristic diversity, derived from bison grazing, generally leads to greater ecological resiliency towards environmental extremes, such as droughts [23].

Multiple studies have come to the conclusion that plant biodiversity is higher in bison grazing than cattle grazing systems [29,39]. Thus, Freese et al. (p. 4, [14]) state that “Restoring the ecological role of bison is a prerequisite to large-scale and comprehensive restoration of biodiversity in the Great Plains and other grassland regions of North America that bison once inhabited.” However, studies often fail to address critical factors such as stocking density, grazing intensity, and herd structure, which also influence rates of biodiversity. Little literature is available on the comparison of bison and cattle grazing for similar animal and environmental factors [34,50], and multiple studies describe the difference in biodiversity from bison or cattle grazing as marginal [43,50]. Steuter & Hidinger [37] state that biodiversity and the biological resources of pastureland are not only determined by the single choice between allowing bison or cattle to graze but also by the overall stocking rate and aligning intensive grazers, i.e., cattle, with intensive agricultural systems and extensive grazers, i.e., bison, with vast rangelands. Light to moderate grazing is found to be preferable to intensive grazing in the context of biodiversity considerations, regardless of whether it is combined with bison or cattle [24].

3.1.3. Animal Biodiversity and Bison Grazing

Bison, along with birds, small insects, arthropods, and various pollinators from these strains and classes, are all indispensable for the conservation of grassland biodiversity [16] and have a significant influence on the structure and stability of the ecosystem [51].

Bison grazing creates a landscape mosaic, which in turn provides more (micro)habitats for small mammals, birds, insects and other animal species, in contrast to a homogeneously managed landscape [52]. For example, an increase in flowering herbaceous plants, com-
pared to grasses, promotes pollinators [40]. Landscape mosaics are essential for most of the native bird species on the Great Plains [53]. The transformation of landscape mosaics into large uninterrupted areas, be it farmland or intensively used pastureland, generally reduces the range of these native birds [49]. The occurrence of grassland birds on the Great Plains has declined sharply in recent decades, mainly due to the intensive grazing practices [11]. Some bird species, such as upland sandpiper (Bartramia longicauda) [25], grasshopper sparrow (Ammodramus savannarum) [11], and bobwhite quail (Colinus virginianus) [49], benefit from the promotion and expansion of landscape mosaics through bison grazing. These species of birds reside, largely, on the ground and require a heterogenous landscape—large open spaces to find food in large quantities [11,54] as well as areas with high vegetation to shelter their breeding grounds [31]. However, not all bird species benefit from bison grazing and the resulting disturbance to the landscape. For instance, the henslow sparrow (Ammodramus henslowii) is disturbed by large ungulates grazing, and the bird is rarely found in these areas [35].

Other larger herbivores also benefit from landscape mosaics created through bison grazing. Especially browser species, such as the pronghorn antelope (Antilocapra americana) and the mule deer (Odocoileus hemionus), benefit from the subsequent diversity of forbs and shrubs promoted by bison grazing; these plants are the main food source for both browser species [49]. In addition, studies have shown that bison grazing increases the number of prairie dog colonies [56,57], which serve as a food source for some bird species, such as burrowing owl (Athene cunicularia) [58] and ferruginous hawk (Buteo regalis) [59]. Furthermore, prairie dog burrows provide shelter and protection for various small mammal species [49].

The significant decrease in grass-like plants and the increase in forbs with bison grazing results in sites with less biomass but increased nitrogen availability, which are generally preferred by herbivorous arthropods [28]. Furthermore, bison grazing promotes the growth of forbs more than cattle grazing. This leads to a greater heterogeneity of habitats, in terms of plant productivity, species composition and structure, for insects [60]. Therefore, bison grazing promotes arthropod abundance and diversity [28].

The distinctive wallowing behaviour of bison [10,14] is important for coat and skin care, insect repellency, sun protection, and social interaction of bison [61]. Wallowing of the animals on the same areas leads to topsoil displacement and compaction, which results in micro-sites with high soil moisture and clay content [27]. The resulting bare areas often have a diameter of 3 to 5 m and a depth of 10 to 30 cm [31]. Eventually, the abandoned wallows lead to microhabitats with altered physical resources and a distinct biodiversity [29]. Due to the high soil compaction, rainwater accumulates in the left-over walls in spring, which leads to habitat for wetland species [62]. The wallows are increasingly used as breeding grounds for amphibians [29]; for example, the Great Plains toad (Anaxyrus cognatus) and the Plains spadefoot toad (Spea bombifrons) often rely on these seasonal bodies of water for reproduction [63].

Wallowing and other bison behaviours initially lead to reduced plant biomass and growth rate [49]. Bison grazing can negatively impact plant diversity and arthropod diversity in the short term; however, the long-term effects are more complex and lead to increased heterogeneity and species richness [64]. Therefore, bison grazing has a long-lasting effect on the environment with wide-ranging effects on spatial function and biodiversity of the ecosystem [65].

### 3.2. Bison Production Performance

The animal growth rate is of great importance in the production of meat, reflecting the (marketable) performance of the animals. Performance is also central to sustainability, since the efficiency of the animals’ energy and nutrient utilization and the consumption of feed has a decisive influence on the environmental footprint of animal products [66].

The feeding requirements of bison are generally similar to those of cattle with some distinct differences in feed quantity and feed management [21]. In terms of metabolic body
mass, bison have a reduced feed intake compared to cattle, especially during cold winter months. Overall, bison have a lower growth rate and lower production efficiency [67,68]. A reduction in metabolic rate and growth are normal in wild ungulates during the winter months and is considered as an adaptive strategy in reaction to reduced food supply and poorer food quality [46,69]. In older bison, weight loss of up to 10–15% is common in the winter months [70]. Therefore, it is important that pasture fodder of good quality and quantity is available in spring to ensure rapid growth of animals [35].

Management strategies and philosophies vary widely in the bison industry [71]. Extensive grazing practices based on the year-round grazing of natural pasture with little or no inputs are widely accepted [72]. However, due to the increasing demand for bison meat in recent years, more and more cattle farming practices are being integrated into more intensive bison husbandry [16].

3.2.1. Intensive Bison Husbandry

Intensive husbandry is primarily characterized by fattening animals to a desired final weight in as short a time as possible. In feedlots, energy-rich, high-quality feed, such as concentrated feeds from corn and wheat, is primarily fed to ensure rapid growth in bison husbandry [73]. Finishing in feedlots usually takes place between 90 to 120 days pre-slaughter and is intended to ensure uniform fat storage in the muscles (marbling) and to promote a light red color of the meat [9]. Since bison meat is usually darker than beef, a lighter red color increases consumer acceptance of the meat [74]. However, the problem with intensive husbandry is that the individual animals usually have very little space and rarely have access to pastureland to exhibit natural behaviour [75] and bison develop severe ruminal acidosis with concentrate finishing diets commonly used in cattle finishing [35]. In terms of sustainability, a conflict arises because on the one hand the product efficiency may increase to a point leading to lower amounts of inputs for the same output. On the other hand, animal and environmental health may suffer. Animals are not granted sufficient space to behave in a species-appropriate manner, and land may be converted or cleared to produce the concentrated feed [4].

Several studies have compared the growth performance of bison and cattle in the recent past [67,76–78] and concluded that cattle have a higher dry matter intake per day and therefore also a higher daily gain than bison. For example, Koch et al. [78] found that during a 224-day fattening period, bison calves consume an average dry matter intake (DMI) of 6.35 kg DMI/day compared to 9.79 kg DMI/day for Hereford calves, which was reflected in increased daily live weight (LW). On average, bison calves gained 0.77 kg LW/day, whereas Herford calves gained 1.13 kg LW/day [78].

Cattle not only have a higher growth rate but also a higher birth and slaughter weight than bison [16]. The average birth weight of intensively raised bison is between 25 and 30 kg LW [79], approximately 10 kg LW lighter than most cattle breeds [80]. Due to their lower birth weight and slower growth performance, bison require more time to reach a desired slaughter weight. As a result, bison are slaughtered between 24 and 30 months of age with a slaughter weight of 450 kg [21] to 550 kg [17]. Beef cattle reach a slaughter weight of approximately 550 kg LW between 12 and 18 months of age [81]. Nevertheless, the dressing percentage of bison and cattle are roughly similar—approximately 60% [82].

In general, it can be said that in intensive conditions, cattle have a higher performance and growth potential than bison. However, it should be noted that most of the studies comparing performance of bison vs. cattle were conducted under feedlot conditions, with no access to pasture and a very high percentage of grain in the feed ration. Modern cattle breeds are very well adapted to intensive husbandry practices because, at least until recently, they have been selected for rapid growth and high feed conversion under feedlot conditions [40]. Bison breeding programs are limited and thus bison are not well adapted to feedlot conditions; the high stress of feedlots can negatively affect animal performance and growth [9]. Although it is possible to fatten bison in feedlots, research suggests that
bison are inferior to cattle within feedlot systems and that intensive husbandry is likely not a sustainable production system for bison husbandry.

3.2.2. Extensive Bison Husbandry

According to Sambraus & Spannl-Flor [72], extensive and nature-based management of bison should be the husbandry system of choice. The North American bison is very well adapted to a wide range of environmental conditions—both local weather conditions and native plant species [83]. In addition, the high sturdiness of the animals, such as their thick coat, may provide a first line of protection against diseases [35]. Antibiotics and growth hormones are not used in extensive bison husbandry [84]. Generally, bison are well-equipped to be self-sufficient out at pasture [35,83].

Because bison reduce their metabolic rate during winter and have much thicker coats than cattle, they can withstand ambient temperatures well below those for cattle [70,85]. Christopherson et al. [69] found lower critical temperatures of a minimum of $-20^\circ C$ for Highland and Hereford calves, whereas values for bison calves range from $-30^\circ C$ to nearly $-40^\circ C$. Because of bison’s hardiness, it is currently assumed that bison do not require housing during the cold winter months, whereas cattle do [35,86]. In addition, bison can graze in deep snow and thus require little supplemental feeding in winter [61]. Therefore, bison husbandry may save raw materials and fuels for shelter construction and feeding compared to cattle [40].

Bison heifers are usually bred for the first time at two years of age and give birth to their first calf at three years of age [87]. Cows continue to be regularly bred even until the advanced age of 12 to 13 years [88]; however, Sell [89] assumes a longer lifespan (“useful life”) of 20 years for bison cows is possible, which clearly exceeds that of beef cows. The birth weights of calves in extensive bison husbandry (LW between 14 and 22 kg) are well below those of bison in intensive husbandry systems [61,90]. Nonetheless, with the provision of a good quality and quantity of pasture forage and with good herd management, calving rates of 80% to over 90% can be achieved [68,89].

Furthermore, studies report that bison can digest and utilize low-quality, low-protein, high-fiber forages better than cattle, allowing them to graze a variety of habitats effectively [77,91,92]. Peden et al. [38] hypothesize that a higher internal recycling of urea via the rumino-hepatic cycle could explain the better digestion of low protein rations by bison. This points to the digestion and utilization of forage between bison, compared to cattle, should be greatest when nitrogen content in forage is limited. Therefore, the feeding of high quality feeds, such as concentrates, nullifies this advantage [93]. Although bison are more effective at digesting low quality feeds, the feed quality is reflected in the lower weights of extensively kept bison, even compared to those intensively kept. Extensive husbandry systems may produce bison that vary in age and therefore average LW prior to slaughter [94]. However, it usually takes 42 to 48 months to achieve a desired slaughter weight of 450 to 500 kg [95]. Other health and overall welfare components, such as increased risk of injury in intensive systems, need to be taken into account [35]. To reiterate, although it is possible to fatten bison in feedlots, in order to utilize bison’s physiological productive advantage over cattle, they should be kept in extensive husbandry systems [46].

3.3. Economic Value of Bison

The investment costs in bison husbandry are initially high, due to the vast land requirements, large and specialized handling facilities, and high costs for fence construction (durable and high fences required), as well as the high price for the animals themselves [35,96]. However, as pointed out throughout the previous sections: utilization of poor-quality forage results in inexpensive feed; robust health results in minimal veterinary costs; and shelter construction is not necessary; which all contribute to lowering production costs.

Bison meat is a niche product with a high value [83] given that it is perceived as a healthy red meat able to meet the demands of health-conscious consumers [83,86].
In addition, research shows that consumers are willing to pay high prices for bison meat, especially if it is labeled as free of hormones or growth-promoting agents [74,97].

One of the major obstacles for bison farmers in North America is the lack of an organized market, as there are few established national or regional marketing and distribution systems [71]. In the U.S., bison are marketed as wild game, whereas in Canada, a classification system for bison has been developed to provide a consistent product to consumers, resulting in a marketing advantage and promoting recognition in international markets [83]. Primary markets including wholesalers, restaurants, meat stores, and direct marketing to consumers are all avenues employed in marketing bison meat [71].

In addition to meat, bison hides, skulls, and leather goods can be sold for high prices [98]. Prepared bison hides are offered for sale online for prices as high as USD 1600 (as of 12 July 2021) online at www.clawantlerhide.com (accessed on 30 June 2020) [99]. The marketing and sale of these products provides some producers with a welcome additional income but is also associated with additional effort in terms of logistics and time. The aesthetic value of bison also makes the animals a popular and valuable tourist attraction, especially in private and public parks [46]. For millions of visitors, the sight of live herds of bison connects people deeply with the nature and history of the land [12]. This aspect should not be underestimated, as it generates income from tourism for hotels, tour operators, restaurants, and other industries [12].

As bison have other value outside of meat production, Aalhus & Janz [100] recommend not adopting a slaughter and marketing system that is identical to that of the beef industry; bison could not compete in terms of mass numbers. For example, Dave Carter, executive director of the (American) National Bison Association, stated that “We [bison producers] would rather continue to market our products to consumers who appreciate the value of delicious, nutritious meat produced from animals humanely raised in a sustainable manner, than to market large quantities of cheap bison meat” [86]. Therefore, bison meat should be marketed visibly different from beef, maintaining its reputation as a natural, safe, pristine, and almost iconic North American product [101].

3.4. Greenhouse Gas Emissions from Bison Husbandry

Methane produced by enteric fermentation from digestion causes by far the largest proportion of emissions related to ruminant production [66]. And although necessary in order to conduct sustainability analyses, such as life cycle assessments, for bison husbandry, two pieces of literature exist estimating the methane production of bison. While investigating intake, digestibility, and methane and heat production in bison, wapiti (Cervus canadensis) and white-tailed deer (Odocoileus virginianus), Galbraith et al. [102] found bison to emit approximately 6.6% of their gross energy intake as methane. This value is very similar to that of cattle consuming grass and hay, which is assumed to be 6.5% [103]. Additionally, Kelliher & Clark [104] reached a similar conclusion while estimating methane emissions from bison prior to European settlement in North America. They estimated that bison used to emit about 72 kg of CH\(_4\) per capita per year—a value nearly identical to the 71 kg of CH\(_4\) emitted per capita per year by grazing cattle [104]. Thus, extensively raised bison can be assumed to produce about the same amount of methane as extensively raised cattle through enteric fermentation, and in this aspect bison should not be considered more sustainable. However, grassland landscapes in particular, such as prairies, are globally important as carbon sinks [105], and simple methane emission estimations derived from enteric fermentation are not adequate to evaluate the sustainability of bison production.

4. Evaluating Sustainability Looking Forward

Literature across multiple disciplines is clear that in order for livestock production to keep up with growing demands, systems will need to innovate and become more sustainable [1,106]. Therefore, the goal of this review was not to provide a comprehensive overview of research on bison husbandry in general; rather, it outlines distinctive differences between and within cattle and bison production systems which could meaningfully
Contribute to understanding the sustainability of bison production. Increased diversity within plant communities and ecosystems, decreased performance, physiological robustness, and positive economic and health benefits characterize bison production compared to traditional cattle husbandry. In addition, extensive bison production systems appear to be more sustainable, based on the qualitative information available in this review. However, holistic sustainability analyses, including biodiversity and land succession, growth performance and economic value, and especially social aspects, such as cultural value, are required to make a definitive statement regarding the sustainability of bison production in North America.

A Web of Science search with “Life Cycle Assessment Beef Cattle” yielded 164 hits for peer-reviewed publications (as of 19 August 2020), whereas a similar search with “Life Cycle Assessment Bison” resulted in only one suggested article, which did not include an LCA of bison farming or bison meat production, but addressed the LCA of crop production on the North American Prairies [107]. In addition, only 6 out of the 88 identified pieces of literature in this review have been published within the past 5 years and 21 within the last 10 years. This, too, depicts the large research gap in understanding bison husbandry systems in general. Definitive research investigating the environmental, social, and economic impacts of bison husbandry is needed as a pre-requisite to comprehensively understand system sustainability. Evaluating the overall sustainability of bison husbandry in North America would assist in identifying “sustainability” leaks and advantages of bison husbandry, as well as guide policy makers towards appropriately supporting sustainable food systems. Filling the larger research gap in measuring and assessing the overall sustainability of bison farming should become a priority in order to best promote and manage livestock husbandry systems, as well as grassland resources in North America, moving forward.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su132413527/s1, Table S1: Alphabetical list of identified relevant literature on sustainability aspects (biodiversity, production performance, economic value, and greenhouse gas emissions) of bison production.

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