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The Potential of Bison Restoration as an Ecological Approach to Future Tribal Food Sovereignty on the Northern Great Plains

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Future climate projections of warming, drying, and increased weather variability indicate that conventional agricultural and production practices within the Northern Great Plains (NGP) will become less sustainable, both ecologically and economically. As a result, the livelihoods of people that rely on these lands will be adversely impacted. This is especially true for Native American communities, who were relegated to reservations where the land is often vast but marginal and non-tribal operators have an outsized role in food production. In addition, NGP lands are expected to warm and dry disproportionately relative to the rest of the United States. It is therefore critical to identify models of sustainable land management that can improve ecological function and socio-economic outcomes for NGP communities, all while increasing resilience to a rapidly changing climate. Efforts led by Native American Nations to restore North American Plains bison (*Bison bison bison*) to tribal lands can bring desired socio-ecological benefits to underserved communities while improving their capacity to influence the health of their lands, their people, and their livelihoods. Ecological sustainability will depend on the restoration of bison herds and bison's ability to serve as ecosystem engineers of North America's Plains. The historically broad distribution of bison suggests they can adapt to a variety of conditions, making them resilient to a wide range of management

systems and climates. Here we review bison's ecological, cultural, and economic value using four case studies from tribal communities within the NGP. We discuss the potential contributions of bison to food sovereignty, sustainable economies, and conservation of a working landscape with limited protections and significant risk of conversion. The ecological role of bison within this setting has potential due to cultural acceptance and the vast availability of suitable lands; however, it is critical to address tribal needs for funding support, enhanced community capacity, and solving complex landownership for these goals to be achieved.

Keywords: food sovereignty, Northern Great Plains, plains bison, Plains Indians, rewilding, restoration

INTRODUCTION

Climate projections for the Northern Great Plains (NGP) forewarn of warming, drying summers, erratic rainfall patterns with increased spring flooding, and increased winter snow cover (Shafer et al., 2014; Wuebbles et al., 2017; Adams et al., 2020). As changes occur, common agriculture (Ariel et al., 2021) and production practices will become less sustainable (Joyce et al., 2013; Ariel et al., 2021; Martin et al., 2021), both ecologically and economically (Whitlock et al., 2017; Boone et al., 2018; Holechek et al., 2020). In addition, the severity of adverse impacts on communities will differ depending on regional socio-economic circumstances (Lal et al., 2011; Adams et al., 2020). It is therefore critical to identify models of sustainable land management that can improve socio-economic outcomes for NGP communities and increase ecosystem resiliency to ensure future food security (Doyle et al., 2013; McNeeley, 2017).

Communities with persistent poverty are less likely to possess the resources needed to prepare for the future and, therefore, are considered more vulnerable to climate change (Lal et al., 2011). This is true of rural Native American communities, where poverty is two to three times higher than in white rural communities (Harvey, 2017). Land dispossession and forced migrations of indigenous peoples have culminated in scattered tribal governed lands having increased climate vulnerability and offering diminished economic opportunities (**Figure 1**; Farrell et al., 2021).

As of 2014, less than 50% of Native Americans from federally recognized Tribes were employed, and approximately 25% of Native American families earned incomes below the poverty line (U. S. Department of the Interior, 2014). Income disparities are particularly pronounced in NGP tribal communities, where income is 20–40% less per capita than the national average for Native Americans (Feir et al., 2018; Johns, 2020). Years of disenfranchisement have resulted in little economic development, underfunded learning institutions, and limited economic opportunities on reservations, especially in the private sector (Miller, 2018; Short et al., 2020). Often, tribal management is hindered by non-tribal regulatory frameworks that are not inclusive of tribal systems and sovereignty (Ranco et al., 2011). These issues further exacerbate the vulnerability of communities dependent on commodity-based agriculture in a region where ∼50% of available NGP lands are privately managed intact rangelands (e.g., native and planted grass, sage steppe) primarily used for conventional cattle grazing and dryland cropping (Haggerty et al., 2018a).

Despite their proximity to food production, Native Americans are twice as likely to be food insecure than white people and are 25% more likely to remain food insecure in the future (Jernigan et al., 2017). Across Montana's seven reservations, 60% of households rely on the Food Distribution Program on Indian Reservations as their primary food source (Miller, 1998). These systemic income and food insecurities suggest the value of community-based initiatives to address vulnerabilities to climate change and food sovereignty in NGP communities.

For more than 10,000 years, Native Americans hunted and lived alongside an estimated population of tens of million Plains bison (*bison bison bison*) roaming between the Rocky and Appalachian Mountains (Gilmore et al., 1999; Kornfeld et al., 2016; **Figure 2** and **Supplementary Material 1**). Bison were an integral part of life, and many origin stories tell of the connection between the people and their kin, the "buffalo" (Goble and Crow, 2009; Hubbard, 2016). With the near extinction of bison in the late 1800s, Native Americans were relegated to reservations without their primary cultural food source (**Figure 1**). In some cases, this reservation land is marginally productive, and non-tribal agricultural operators often lease substantial portions of tribal agricultural lands (**Table 1**; Anderson and Lueck, 1992; Whyte, 2013; USDA National Agricultural Statistics Service, 2019).

Over the past few decades, Tribes have worked toward the reclamation of food security and sovereignty. For Plains Indians, food sovereignty is directly tied to re-establishing bison herds within their reservations and traditional lands. While food security can be enhanced through U.S. government programs, food insecurity over the long term can inadvertently be perpetuated through these programs by preventing re-ownership of food procurement practices; combined with meager inclusion of traditional Native foods, this can disrupt tribal food sovereignty (Bye, 2009; **Box 1**). Achieving both will require developing sustainable land management strategies to conserve and enhance ecosystem resiliency and reclaim traditional foods systems (Sunderland, 2011; Berry et al., 2015).

Beginning in the 1990s, Native American Tribes organized and worked collaboratively to establish bison herds on sovereign lands (**Figure 2**). The Inter-Tribal Buffalo Council (ITBC), founded in 1991, includes members from 76 federally recognized Tribes in the U.S. ITBC acts to facilitate education and training

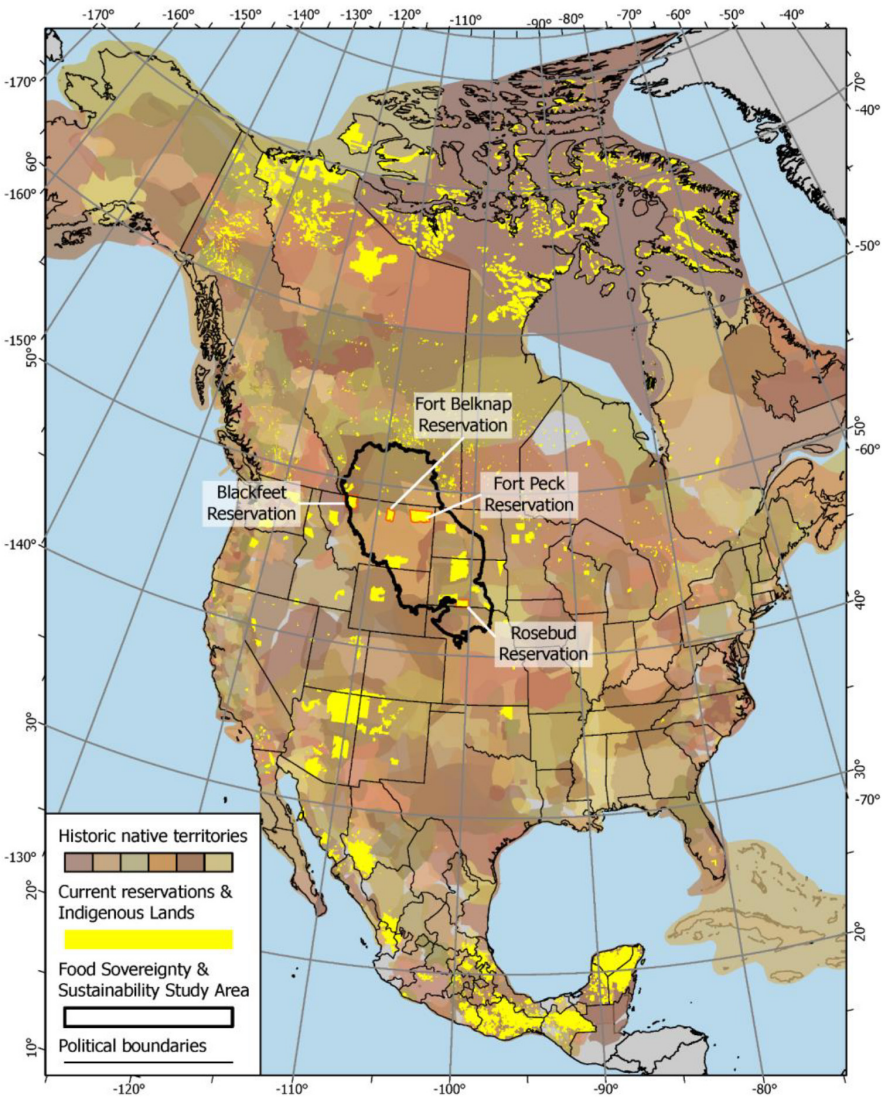

FIGURE 1 | Native territories were derived from Native Land Digital (https://native-land.ca/). Reservations and Indigenous Lands are from National Atlas of the United States (US), Indigenous communities (60–100% of population) from Mexico Indigena, and Aboriginal Lands of Canada from Geobase. Colors represent a gradient of historic native territories throughout North America, to emphasize the scale and diversity of Native American societies prior to being forced onto reservations. We note that tribal territories were fluid and underwent many shifts prior to, and during, European colonization, thus this map is only one such snapshot in time. For this reason, we omit the names of specific Tribes, instead using a gradient of tribal territories to highlight amount of land lost in comparison to where these communities currently reside.

programs, marketing strategies, transfer of surplus bison from U.S. Department of Interior to U.S. tribal lands, and technical assistance for the development of self-sustaining programs (ITBC Today). ITBC led the transfer of wild bison from Yellowstone National Park (YNP) to Native American Tribes (ITBC Today; Voggesser, 2000). In 2014, 10 Tribes and First Nations from the United States and Canada signed the "Buffalo Treaty" and committed to work together to restore bison to their historic range (Johns, 2020). Today there are 31 signatories from the United States and Canada.

Current efforts to re-establish bison herds across the United States fall on a spectrum between conservation and commercial herds. Conservation herds are established to conserve the long-term genetic health of the species and serve to engage people through cultural and educational experiences. Commercial herds serve as an alternative meat product for public consumption and economic benefits. These efforts are not mutually exclusive, as some entities manage a single herd to achieve both goals. Across North America, there are approximately 350,000 bison in private sector herds, over 30,000 in public sector (Jones et al., 2020) and not-for-profit non-governmental organization herds (NGO; i.e., American Prairie Reserve and The Nature Conservancy)

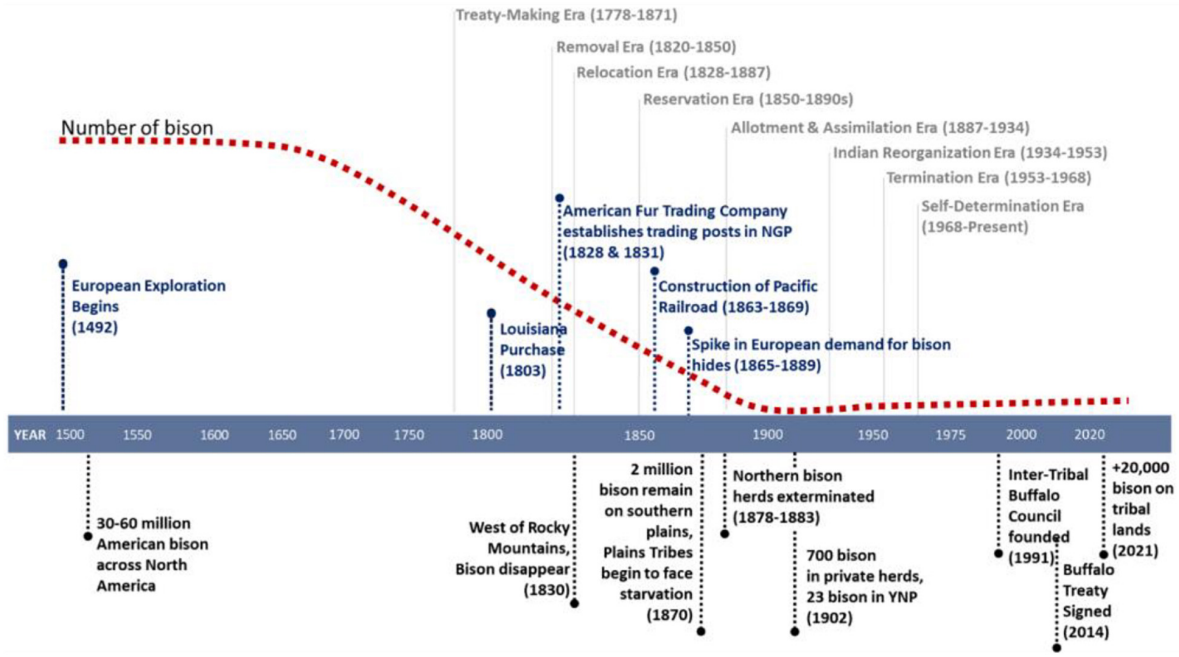

FIGURE 2 | Major events leading to decline of American bison (*Bison bison*) run in parallel with settler colonialism and the disenfranchisement of Plains people. Full details are given in **Supplementary Materials (1)**. Light gray lines differentiate between Native American eras during European expansions to the West. Dashed blue lines highlight key colonial events that contributed to decline of bison. Black dashed lines highlight key events in the near extermination of American bison (beginning with population estimate). Red dashed line illustrates the decline of bison from 30 to 60 million animals to only a few hundred in the early 1900s.

(Martin et al., 2021), and approximately 20,000 in tribal sector herds (ITBC Today InterTribal Buffalo Council, 2021).

Re-establishing bison on reservations can contribute to change in Native American communities in multiple ways: (1) spiritual, by healing the spirit of the buffalo and the people (Haggerty et al., 2018b); (2) cultural, by restoring people's connection to their heritage (McClintock, 1910) including enabling food sovereignty and security on reservations; (3) economic development (e.g., tourism, bison hunts, sale of live bison, or bison meat); (4) and ecological, by supporting ecosystem resiliency through sustainable bison grazing. Conservation herds can provide the first two benefits, but since herds are generally limited in size, they typically provide limited revenue. The third and fourth benefits involve sustainable management for both economic and ecosystem health. Commercial herds generate revenue and food, but food sovereignty and ecological benefits depend on the size and management of the herd. As Tribes work to achieve these benefits, we recognize both the economic and ecological role of each type of herds.

We argue that only when bison herds move closer to their traditional role in the NGP ecosystem can they fulfill all these roles. We refer to this process as the restoration of bison, sometimes referred to as rewilding due to existing constraints of "true" restoration (du Toit and Pettorelli, 2019; **Box 2**). It is important to recognize that these processes are bound to an existing land tenure system and jurisdictions. Thus, initiatives will be informed by the goals and diverse desires of the tribal buffalo programs and the communities they serve.

Bison were not only central to the Plains Indians' way of life, but also central to the ecosystem. Bison are considered ecological keystone species, defined as having a disproportionately large influence on their environment relative to their abundance through their coevolution with all life forms and land use behavior (Mills and Doak, 1993). For example, bison grazing promotes plant functional-group and species richness, alters patch structure across tallgrass prairie landscapes (Knapp et al., 1999; Koerner and Collins, 2013; Eby et al., 2014), and promotes higher species richness and compositional diversity in mixed-grass prairies (McMillan et al., 2019). Bison also modify their environment by moving across the landscape and creating disturbance in the form of stomping, wallowing, seed dispersal, and grazing (Harvey and Fortin, 2013); behavior that results in increased landscape arthropod, amphibian, and plant heterogeneity (Polley and Collins, 1984; Gerlanc and Kaufman, 2003; Nickell et al., 2018). Bison are migratory herbivores that can and need to move across large landscapes (Bolger et al., 2008; Plumb et al., 2009), and by altering widespread vegetation structure and composition, bison grazing subsequently impacts prairie wildlife communities (Truett et al., 2001). However, when densities are manipulated and movements are constrained, the ability of the species to have positive impacts on the landscape may be limited (Boyce et al., 2021; Kaplan et al., 2021). Modern prairie conservation relies on the keystone traits of bison to restore ecological function of grasslands; therefore, conservation measures should explore ways to allow bison to move and migrate.

TABLE 1 | Description of communities featured in case studies, with WWF Plowprint Report 2018 Area summaries for Native Nations in the Northern Great Plains (NGP) (World Wildlife Fund, 2018).

Reservation	Tribes	State	Pop.[a]	Size (km^2)		Plowprint[c] (km^2)		Intact habitat (km^2) (%)	Farm operation	
				Total area[b]	within NGP	Extent	Expansion 2009–2018		Total (km^2)[d]	Operated by Tribe, km^2 (%)
Fort Belknap	Nakoda (Assiniboine); A'aninin (Gros Ventre)	MT	3,429	2,526	2,526	248	46	2,215 (87.7)	1,799	1,668 (93)
Fort Peck	Nakoda (Assiniboine); Dakota Sioux	MT	6,800	8,564	8,564	3,667	637	4,656 (54.4)	4,524	1,367 (30)
Blackfeet	Blackfeet Nation	MT	7,000	6,317	525.6	1,227	172	4,803 (76.6)	3,663	2,026 (55)
Rosebud	Sicangu Lakota (Rosebud Sioux)	SD	21,245	3,622	3,622	226	123	3,285 (90.7)	2,499	944 (38)
All 15 NGP reservations				72,296	63,365	12,661	2,869	56,037	404,273	21,798 (54)

Farm operation (km^2) on reservations and the percentage operated by tribal members; data from 2017 USDA Census of Agriculture (USDA National Agricultural Statistics Service, 2019); data extracted by World Wildlife Fund. Market value:% market value of agricultural products sold operated by.
[a]Enrolled tribal members living on or near reservation.
[b]Total Area refers to main reservation and does not include trust lands outside of the reservation boundary.
[c]Plowed land as of 2018.
[d]Total farm km^2 includes rangelands and croplands.

BOX 1 | Definition Box 1:

1. **Food security** is the interplay between food availability, food accessibility and food utilization that varies across organizational levels: individual, household, community, national, regional, and global; we include cultural ideals such as traditional foods (Leroy et al., 2015) and the nutritional standards of food (Pinstrup-Andersen, 2009).
2. **Food sovereignty** is the right to access healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and the right to define food and agriculture systems (Patel, 2009). The emphasis is on the right to produce foods and control how food is celebrated, consumed, and managed, not limited to economic and physical access to food (Bye, 2009).

BOX 2 | Definition Box 2:

1. Restoration aims to return an ecosystem to its former state, which is a challenging standard due to complex socio-ecological landscapes (Davenport, 2018). With this in mind, here we define restoration to reflect what is sometimes referred to as rewilding—the reorganization and redevelopment of species and ecosystems under new environmental conditions while sustaining ecosystem services (du Toit and Pettorelli, 2019). It is differentiated from conventional ranching practices that focus on optimizing production of provisioning ecosystem services (i.e., protein, hide and leather, hair and fiber, and bone procurement), but rather to balance emphasis on non-provisioning services (i.e., cultural, regulating, and supporting) with provisioning services (Briske, 2017). Within the context of this paper, restoration is the development of novel management practices that balance the dual roles of bison while acknowledging existing constraints. As is similarly done for conservation translocations (IUCN/SSC, 2013), we suggest conducting a feasibility assessment prior to any rewilding initiative, with additional consideration given to cultural, economic, and food sovereignty conditions, since available habitat and community objectives are likely to differ from one reservation to another.
2. Trust lands are defined as lands "in which the federal government holds legal title, but the beneficial interest remains with the individual or tribe" (U. S. Department of the Interior, 2021), and trust lands held on behalf of individuals are known as "allotments."

Furthermore, in the face of climate change, bison may be a more sustainable large grazer than cattle (Martin et al., 2021). The NGPs' mean annual temperatures are projected to increase by 2.3–2.9°C over the next few decades (Wuebbles et al., 2017). Bison respond to warming and drought by shifting diet (Craine et al., 2015; Craine, 2021) and reducing asymptotic body mass (i.e., mature body size) (Martin et al., 2018; Martin and Barboza, 2020a,b). Moreover, bison are more tolerant of extreme heat and seek shade and water (i.e., stock ponds and riparian areas) less frequently than cattle, which in turn reduces sediment load in the sensitive streams that meander through grasslands (Steuter and Hidinger, 1999; Dodds et al., 2000; Allred et al., 2013; Grudzinski et al., 2018). Bison enable stream vegetation to regenerate, enhancing the capacity of the ecosystem to support people and wildlife throughout seasonal and long-term droughts (Boyce et al., in review)[1].

[1]Boyce, A., Shamon, H., and McShea, W. J. (in review). Bison restoration to shortgrass(prairie) is associated with increases in vertebrate diversity and occupancy in riparian areas. *Front. Ecol. Evol.*

Bison and North American grasslands have been evolutionarily coupled for more than 160,000 years (Woodburne, 2004), and restoration of bison will enhance the cultural, economic, and ecological sustainability of Plains Tribes and their environment. Several teams of researchers have proposed that bison are essential for the restoration of NGP (Sanderson et al., 2008; Freese et al., 2014). It is possible that the current efforts to restore bison herds to Native American lands will be the key to this future restoration, but only if these efforts provide for the needs and aspirations of Tribes. Using four case studies, we review the successes and challenges of bison restoration programs on four Native American reservations in Montana and South Dakota, United States.

We propose that bison herds currently being restored to Native American lands have the potential to provide the food sustenance, cultural reconnection, and ecological sustainability needed to meet future climate challenges. We review case studies of current reintroduction activities at four Native American reservations in the NGP to assess their progress and potential to contribute to an ecological approach to future food sovereignty in the region that can be replicated on additional Native American reservations. We discuss the viability and longevity of these programs in communities with persistent socio-economic challenges and in the context of climate change. We provide recommendations for future development of management plans with the goal of maximizing the benefits of restoring bison herds to the cultural, economic, and ecological health of the Tribes and their lands. Native Americans generally refer to bison as buffalo and both terms are used in this paper.

CASE STUDIES

The four NGP communities featured here (referred to as reservations in **Table 1** and **Figure 3**) were bison-reliant societies that are currently working to re-populate bison onto tribal lands. The programs' overarching goals are to enhance the ecological, cultural, and economic sustainability of the people and lands, draw on Indigenous science and facilitate continuity of traditional knowledge, engage Native youth in buffalo restoration efforts, and restore food sovereignty. They offer vignettes of a sustainable ecological bison restoration framework for food sovereignty on tribal lands in the NGP.

Here we compare these programs to illustrate different approaches to accomplishing these shared goals and identify challenges to expanding efforts and building long-term resiliency. While examining challenges, we considered what additional resources could be needed to support bison management in the present and in the face of changing climates across the NGP. Moreover, we illustrate common threads that may offer a successful framework for additional communities to emulate, such as operating two independent herds with one emphasizing the cultural and ecological needs of Tribe (i.e., non-provisioning ecosystem services) and one emphasizing sustainable production (i.e., provisioning ecosystem services) or all as one herd operating to integrate both of these emphases. Detailed descriptions of each bison reintroduction initiative are included in **Supplementary Material 2**. For each case study reservation, we conducted a habitat suitability assessment of tribal lands to highlight the potential for further expansion of ongoing programs. We present a bison summer Habitat Suitability Index (HSI) model based on the productivity of habitat during the summer. The model was adapted from the summer HSI model developed by Steenweg et al. (2016) for Banff National Park, Canada, and was created to estimate the extent and relative quality of remaining habitat across the historic distribution of bison in North America; details are included in **Supplementary Material 3**.

Overview

The programs examined are located across northern Montana, from the eastern foothills of Glacier National Park through the central rangelands north of the Missouri River, and in South Dakota at the northern extent of the Nebraska Sandhills (**Figure 3**). At each reservation, there is some portion of the habitat that is characteristic of the NGP, a mosaic of mixed-grass prairie and croplands, of which 54–88% is unplowed and considered intact (**Table 1**). All reservations contain a mixture of private (both tribal and non-tribal) and trust lands, used mostly for ranching of beef cattle (*Bos taurus*). Currently, tribal members manage farm operations on between 30% (Fort Peck) to 93% (Fort Belknap) of the total agricultural land available on reservations (**Table 1**). We note that in the NGP indigenous operators only capture 59% of the market value revenue (USDA National Agricultural Statistics Service, 2019).

The earliest bison herds (Fort Belknap, Blackfeet) were established in the 1970s when individual Tribes purchased bison from private ranchers. Since the 2000s, bison are now sourced from established conservation herds managed on private and public lands across the NGP within the United States and Canada (**Table 2**). Some herds established on tribal lands in this study are currently stocked with certified Bovine-brucellosis-free bison from YNP and Elk Island National Park. To assist with this effort, the Fort Peck program manages a quarantine facility to receive bison from YNP. YNP bison are authorized for transfer to Native American sovereign lands by the U.S. Department of Interior, U.S. Department of Agriculture (USDA), the Animal and Plant Health Inspection Service (APHIS), and Montana Department of Livestock (MTDOL). Once they reach the Fort Peck facility, bison must complete additional surveillance testing for one year to confirm they do not carry the disease caused by *Brucella abortus* (Turner, 2020). Each of the highlighted programs now manages between 625–900 bison, though these numbers vary annually (**Table 2**).

Both Fort Belknap and Fort Peck divide their herds into two groups: (1) a conservation herd (sometimes referred to as cultural herd) with individuals originating from YNP, and (2) a commercial herd skewed toward females and managed for non-tribal hunts or sales. The Blackfeet program has two conservation herds that are separated to maintain genetic uniqueness of their newly established herd of Plains bison derived from Elk Island National Park in Canada. The Rosebud program manages one herd with a business plan maintained for conservation and cultural purposes as well as to generate revenue and food.

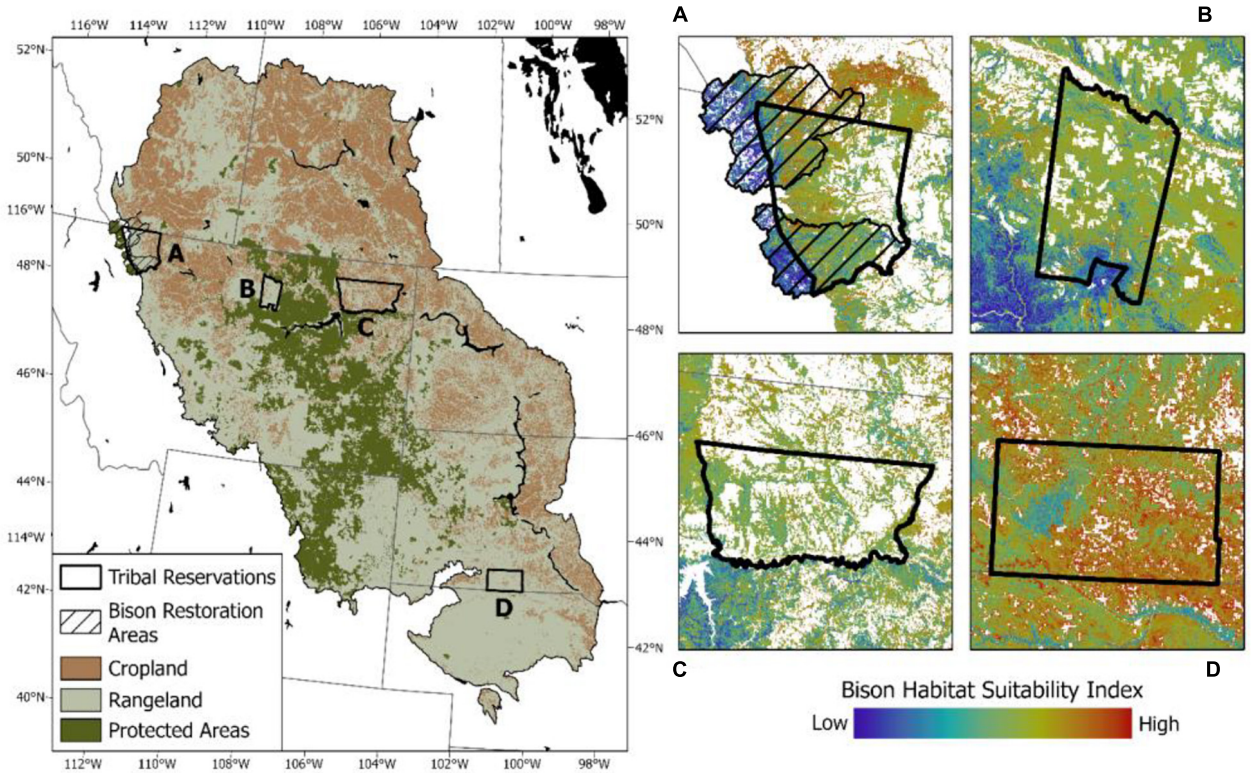

FIGURE 3 | Northern great plains study area based on Commission for Environmental Cooperation (CEC) terrestrial ecoregions—Northwestern Great Plains, Northwestern Glaciated Plains, and the Nebraska Sand Hills. Also included are the northern and southern bison reintroduction areas which extend west of Blackfeet Reservation in the northwest part of the ecoregion (hatched, **A**). Full map shows the extent of cropland (World Wildlife Fund, 2018), rangelands (World Wildlife Fund, 2018), and Protected Areas in IUCN categories I-V (Environment and Climate Change Canada [ECCC], 2020; U. S. Geological Survey [USGS] Gap Analysis Project [GAP], 2020). Individual maps show bison habitat suitability index (HSI) in the target Tribal Reservations: **(A)** Blackfeet Reservation (scale 1:2,000,000); **(B)** Fort Belknap Reservation (scale 1:1,250,000); **(C)** Fort Peck Reservation (scale 1:2,250,000); and **(D)** Rosebud Reservation (scale 1:1,250,000). HSI details in **Supplementary Materials (3)**.

Currently, each reservation has set aside between 36 and 112 km^2 for bison restoration programs, but all programs are interested in expanding pastures to further grow their herds (**Table 2**). The majority of unplowed lands within these reservations are used for cattle operations. From the HSI analysis, we estimated that between 1,828 and 4,354 km^2 of additional habitat is suitable for bison within the four tribal lands included in this study (**Table 2**).

Management Structure and Staff

Each program's management authority and support staff availability vary. Both the Fort Belknap and Fort Peck programs were originally nested under their respective Tribal Fish and Game Departments, with daily management overseen by a tribally appointed buffalo manager. This is still the structure of the Fort Peck Program, whose buffalo manager operates with part-time seasonal support from Tribal Fish and Game staff (i.e., game wardens). Fort Belknap's program became a separate tribal entity several years ago, with funds for two seasonal technicians (6-month contracts) to assist with routine maintenance and annual roundups. At present, neither program has a designated administrative secretary. Fort Belknap previously shared an administrative secretary with the Tribal Council, and Fort Peck previously had a program administrator whose salary was supported by outside partners.

The Blackfeet program is unique in that it functions as a partnership between the Buffalo Program and Iinnii Initiative (Johns, 2020), two programs that co-exist in their efforts to restore bison on the Blackfeet Reservation. The Buffalo Program is nested under the Tribal Land Department, consisting of a director, secretary, and two full-time field technicians that provide the on-the-ground management of the bison herds. The Iinnii Initiative is a separate entity consisting of a single program coordinator supported by the Wildlife Conservation Society, who coordinates collaborations with tribal organizations and neighboring sister bands in Canada. The Iinnii Initiative focuses on ecological restoration, cultural revitalization, youth engagement, and community healing, whereas the Buffalo Program is focused on direct management of herds and providing food sovereignty for the community.

The Rosebud program, or Wolakota Buffalo Range, is the most recently established of the four programs. In contrast to the previous three programs, it is overseen by the

TABLE 2 | Current status of bison herds and total suitable area for bison.

			Suitable area		Numbers[c]		Management				
Program	**Year Est**	**Origin[a]**	**Current area in pasture (km²)**	**HSI[b] (km²)**	**Conserv**	**Produc**	**Department**	**Grazing**	**Revenue**	**Plan**	**Ecol. monitoring**
Fort Belknap	1977	YNP, WCNP, TRNP, CSP	93	1,828	100	800	Separate tribal entity	No interior fences	Hunt; Sales	No	No
Fort Peck	2001	YNP, WCNP, EINP	97	3,037	370	300	Tribal Fish and Game	Few interior fences	Hunt	Yes	No
Blackfeet	1970	CSP, EINP	36	3,669	75	550	Separate Tribal Entity	Rotational grazing	Sales	Yes	Yes
Rosebud	2020	WCNP, EINP, BNP, TRNP	112	4,354	800		REDCO	Rotational grazing	Hay	Yes	Yes

Current management of bison herds.

Data includes, the year bison herds were established (Year Est.); the origin of translocated animals; suitable area: (1) current area of bison pastures and (2) area suitable for bison on each Reservation (HIS); additional information on current management.

[a]Origin of bison, Yellowstone National Park; Wyoming, United States (YNP); Wind Cave National Park, South Dakota, United States (WCNP); Theodore Roosevelt National Park, North Dakota, United States (TRNP); Custer State Park, South Dakota, United States (CSP); Elk Island National Park, Alberta, CA (EINP); Badlands National Park, South Dakota, United States (BNP).

[b]Habitat Suitability Index: potential restoration areas estimated by extracting cells from the upper 50th percentile of habitat suitability index values and summing the area of habitat within contiguous patches ≥ 120 km².

[c]Blackfeet manages two herds but does not define them as being for different purposes. "Conservation" represents bison herd of Elk Island origin, whereas "production" herd represents large herd established in 1970s.

economic arm of the Rosebud Sioux Tribe (Rosebud Economic Development Corporation Wolakota Buffalo Range, 2021), in collaboration with Rosebud Tribal Land Enterprise, the Tribe's land corporation. The project is also being advanced by a partnership with World Wildlife Fund and with support from the U.S. Department of Interior (Rosebud Economic Development Corporation Wolakota Buffalo Range, 2021).

Management

All herds are wide-ranging and minimally handled, but management varies between having pastures with no interior fences (Fort Belknap and Fort Peck) to having pastures divided up with herds rotationally grazed (Blackfeet and Rosebud) (**Table 2**). The reasoning for subdivision varies by reservation: the Blackfeet pastures are split-up because it was not possible to lease contiguous land large enough to sustain the herd year-round, whereas for Rosebud the division of pastures is by design to help control access to pastures (similar to cattle rotation). The buffalo managers determine when to move or cull the herd based on their experience and assessment of pasture–though on three reservations there is no formal protocol for monitoring rangeland. The exception is the Rosebud program (Wolakota Buffalo Range) which contracts outside expertise through the Ranch Advisory Partners (2021) with support from World Wildlife Fund. However, all programs are also advised by regional representatives from the USDA Natural Resources Conservation Service (NRCS) concerning rangeland health and estimation of Animal Unit Months (AUMs) within the context of standards for cattle ranching (Bureau of Indian Affairs, 2021).

Every year, a portion of each bison herd is culled to maintain sustainable stocking rates. Each program differs in their method for determining which animals to cull, though all programs reported considering family and herd dynamics, with selection preference of non-breeding females and older males. In programs managing commercial herds (Fort Peck, Fort Belknap), sex ratios lean toward maintaining a high number of females (e.g., less than 1:5 males to females). Surplus bison selected for removal are either harvested for the community or sold as a hunt to both tribal and non-tribal members. Calves may also be commercially sold at live fair-bid auctions, which generate revenue from non-tribal buyers living outside the community.

Apart from semi-annual rangeland assessments by NRCS staff, ecological monitoring is currently limited to more recent research collaborations with tribal colleges. Since 2020, Blackfeet Community College students have been conducting ecological monitoring of grassland plants, soil health, and biodiversity in a portion of bison pastures in collaboration with Montana State University, with hopes of expanding the program to all pastures. Both tribal colleges at Fort Peck and Fort Belknap have also worked to incorporate research focused on bison health and plant and wildlife biodiversity within pastures, and both are actively working to increase student research opportunities related to their respective bison repopulation programs. The Rosebud program differs from the other three programs in that regular ecological monitoring was included in the initial management plan to guide both implementation and future development.

For all programs, training is informal, however, most technicians and seasonal support staff come with some prior experience in cattle ranching. The ITBC also provides training opportunities during annual meetings throughout the NGP region. Currently, most programs do not support a larger team of long-term staff, apart from experienced buffalo managers.

Economic Development

Programs offset operating costs through either live sales or meat sales following in-pasture harvesting, and two programs—Fort Belknap and Fort Peck—generate revenue from selling hunting licenses to non-tribal members. The number of bison harvested during hunts varies annually, depending on the stability of herd populations (as assessed by the buffalo manager) and availability of buyers. At Fort Belknap, the program's primary revenue comes from the sale of live surplus bison from the commercial herd, but the program also sells 10–20 non-tribal hunting licenses each year ($2,000–$7,500/each) via a license raffle. In 2018, Fort Peck began an online hunting license system that manages the sale of all non-tribal hunts under the Tribal Fish and Game Department, which significantly increased applicants and overall revenue. In addition, non-tribal hunters must also pay to enter a raffle ($20/entry, up to five entries per person) for the opportunity to hunt a bison from the commercial herd (40 total hunts), plus additional conservation and administration fees. The overall price of a hunt depends on size and age-class ($2,500–$5,000), with trophy bulls (2–3 animals per year) sold through an online auction ($5,000 minimum bid). At both programs, tribal members are provided opportunities to hunt bison through a separate raffle at a substantially reduced rate, and thus are not considered a significant source of revenue. In contrast to these two programs, the Blackfeet program does not have a hunting program. Their main source of revenue instead comes from the annual auction of calves each spring.

As the newest program, the Rosebud program is currently supported by grants and private investors, however, it has a business plan in place designed to eventually cover all operating costs through the sale of surplus bison. Once the herd reaches carrying capacity, approximately 1,500 bison, an estimated surplus of over 400 bison will need to be culled annually and could then be field harvested and sold to external markets with an estimated annual net profit of $300,000–$400,000. Bison harvested for the local community will not be sent to feedlots, instead they will be field harvested with traditional ceremonial methods. However, Rosebud is still determining how many surplus bison will be retained annually to support their local food sovereignty initiative and how many bison might be transferred to support other Native Nation bison restoration efforts.

At all programs, ecotourism activities occur occasionally depending on the availability of staff and external tourism partners, but there is no regular programming. All communities report having an interest in developing ecotourism, both for outside revenue generating activities, as well as for more community-focused programs. It should be noted that some bison pastures are important historical sites and occasionally included as points of interest for outside tour groups.

Community Engagement and Access

The benefits bison programs can provide to the community depend on a program's capacity to conduct outreach, deliver programs, and coordinate with other tribal organizations. Educational activities are generally facilitated in collaboration with an established stakeholder group, and/or the presence of dedicated staff, such as an administrative assistant or program coordinator. Both the Blackfeet and Fort Peck programs have well-established stakeholder groups that are involved in community engagement, whereas Fort Belknap is still at the early stages of development. At Blackfeet, activities are coordinated under the Iinnii Initiative through regular community engagement, celebrations, and youth programs. Unique to Blackfeet, the Iinnii Initiative coordinates activities with bison restoration programs run by neighboring sister bands in Canada. At Fort Peck, activities are coordinated by a grassroots community-led stakeholder group, known as the Pté group, that meets monthly. In contrast to these, there is currently no community-led stakeholder group at the Rosebud program. However, the program does work closely with the Sicangu Community Development Corporation (SCDC), a sister non-profit focused on restoring community-driven systems centered on Lakota values that delivers a dedicated food sovereignty initiative that is beginning to incorporate bison meat.

Programs vary in terms of how meat is distributed, and the number of opportunities for direct participation in bison harvests. Bison meat donations and distribution programs increase public access to traditional foods and contribute to cultural education programs. At Blackfeet, Fort Peck, and Fort Belknap, tribal members have access to bison meat through occasional tribal sales and through distribution programs coordinated by other tribal organizations. All programs donate a portion of culled bison (processed meat) to tribal ceremonies, cultural immersion schools, food pantries, and senior centers. Bison harvests are also donated, on a case-by-case basis, to local schools and cultural programs for experiential learning activities. These programs also offer opportunities for the community to hunt bison selected for removal from the herd. As the most recently established program, Rosebud is still in the initial stages of determining how many surplus bison will be retained annually to support the SCDC food sovereignty initiative. A pilot program is being developed that will initially allow harvest of two bison per year and provide meals for the students at the Lakota immersion school. In addition, community members will have the opportunity to buy a share of the bison produced to either harvest for consumption or relocate to personal plots elsewhere to establish additional small herds.

All programs encourage visitors to the bison pastures and work with a variety of tribal organizations to arrange educational events. The frequency of these activities depends on each program's capacity to coordinate with outside groups and the availability of funding in the case of larger community-wide events. Two examples of successful regular programing centered on revitalizing a traditional relationship with bison are (1) Blackfeet's Iinnii Days, an annual 3-day community-wide event that celebrates the bison through ceremony, educational activities, and other cultural experiential learning opportunities;

and (2) Head Start Curriculum developed by Fort Peck's Pté group, where preschoolers learn the history and cultural significance of bison in the classroom, followed by a springtime visit with their local cultural herd. All programs are also in the process of creating infrastructure to provide a gathering place for visitors, workshops, and ceremonial harvests contributing to the concept of the transition to food sovereignty.

Tribal community colleges and tribal land-grant universities play an important role in supporting each bison program's long-term goals. All communities have tribal colleges, but each varies in extent of academic offerings and level of involvement. Tribal colleges at Fort Belknap (Aaniiih Nakoda College), Blackfeet (Blackfeet Community College) and Fort Peck (Fort Peck Community College) offer associate degrees and professional certificates, apart from a new Environmental Science BS at Fort Belknap and a Nursing BS at Blackfeet. Both Fort Belknap and Blackfeet colleges recently secured grants to support the development of research and education centers, largely focused on ecological research related to bison restoration efforts. The overarching goals of these centers are to connect the community with their bison programs and to develop occupational opportunities and capacity through training the younger generation to understand and manage bison. Rosebud's tribal college (Sinte Gleska University) offers a wide range of associates degrees, and a selection of bachelors and master's degrees, but is still at the early stages of engaging with the newly founded buffalo program.

ACTIONABLE RECOMMENDATIONS

We recommend that Buffalo Programs at each reservation develop an adaptive management plan that reflects the expressed goal of retaining the wild nature of bison for both conservation and commercial herds. These plans should incorporate Indigenous science and cultural knowledge. However, more studies are needed to investigate bison grazing patterns and behavior under different management schemes and future climate scenarios, e.g., different densities, genetic origin (across NGP climate gradient), and year-round grazing vs. rotation. As part of this investigation, Tribes will need to develop monitoring protocols to ensure bison grazing is creating desired outcomes, contributing to rangeland health, and including contingency plans for extreme events, like drought, thought to become more prevalent in the region. There is also a need to conduct baseline assessments, so programs can track the cascade of ecological effects that bison restoration has on biodiversity. At present, all programs have limited capacity (e.g., trained staff, equipment) for conducting regular ecological monitoring or disease testing, apart from some intermittent collaborations with local community colleges. Communities recognize this need and share many potential questions but need additional resources and expertise to implement regular monitoring.

Within established programs, many bison pastures have reached carrying capacity. To achieve food sovereignty, bison herds will need to grow significantly larger. However, across all sectors (public, private, tribal, and NGO), the growth of bison herds is limited by the availability of land through either grazing leases or purchase for expanding pastures (Martin et al., 2021). Acquiring additional lands will rely on transition of leases from common livestock use to bison grazing which requires additional funding for leases and infrastructure, and a need to facilitate stakeholder processes in each community to address the spectrum of social tolerance for bison (Pejchar et al., 2021).

While community surveys indicate that all communities desire greater access to herds and acquisition of bison meat (Haggerty et al., 2017; McElrone, 2017; Human Ecology Learning and Problem Solving [HELPS] Lab, 2018); there is an institutional need to increase staffing to expand community engagement programming. Currently, the primary limitation reported for establishing regular programing, both for generating revenue and cultural enrichment, is the lack of staff who can assist with coordination with outside partners and make a significant long-term investment. All programs rely on a few experienced people and seek to expand to a larger team of long-term staff. Likewise, many programs do not have formal management or safety training for seasonal roundup or regulation of a hunt. Training on best practices for bison handling and sustainable ranching would be valuable to foster young managers and technicians and sustain programs.

Program expansion is largely based on the ability to produce sustainable revenue. Across all programs, most bison sales are to non-tribal members after which the bison are processed outside the community, in part due to absence of appropriately scaled meat processing facilities which results in increased costs and limits local meat distribution. A successful example is the Quapaw Nation who established a meat processing facility on the reservation as part of the community's mission to exert food sovereignty and produce meat for its citizens. At present, the demands for the facility is higher than what the business can provide to both local and outside cattle operations, which illustrates the scale of potential opportunities these facilities can provide to rangeland communities. Establishment of such facilities will create jobs on reservations and make traditional protein subsidies more affordable and accessible to community members. Apart from Rosebud, most programs do not have an updated business plan in place. Economic development plans including modern food marketing are recommended to help guide programs toward becoming self-sustaining, including support for multiple long-term staff.

DISCUSSION

Since the near extermination of bison, Native Nations have worked to repopulate bison to sovereign lands, and these initiatives are important steps toward cultural revitalization and food sovereignty for Plains Indians. The four case studies herein are vignettes of successful bison repopulation and management and provide perspectives on the challenges of restoring herds to fulfill the socio-ecological needs of local rural communities. These projects also highlight tribal lands as potential sources for restoring the NGP both in terms of an expansion of bison range and a surplus of animals for restoration projects.

This is due in part to the predominant cultural acceptance of bison, the need for establishing food sovereignty, the vast availability of suitable pasture, and the potential ability of bison to reengineer the prairie landscape. At present, Tribes have focused efforts on cultural restoration of bison in their societies while addressing food sovereignty. However, if restoration of bison to provide ecological function and services is a goal, it is critical to address tribal needs for funding, enhanced community capacity (e.g., training of staff, food distribution frameworks), solving complex landownership interactions (cross boundaries management, *sensu lato*; Pejchar et al., 2021), and developing a well-defined adaptive management plan (Briske, 2017). These needs are not unique to bison conservation within the NGP, as each of these sociological factors has been found to limit wildlife reintroduction opportunities (Berger-Tal et al., 2020) and specifically, they have limited bison re-establishment across jurisdictions in the United States (Pejchar et al., 2021).

Community-Based Restoration

Effective bottom-up, community-based conservation projects must be built around a viable conservation target, but targets vary from community to community and even within communities (Souto et al., 2014; Wilkins et al., 2019). Each tribal community and buffalo program has unique needs and objectives, through which opportunities exist to support the eco-cultural restoration of bison (Johns, 2020). Engaging communities in co-designing and planning associated with buffalo programs can build social trust and help mitigate the risk of negative public perception (Watkins et al., 2021). To that end, as demonstrated in the case studies, each Tribe has initiated community engagement activities to gain public support and rebuild a constituency for bison, based upon the perception that reconnecting the community with bison herds will provide multiple benefits (Haggerty et al., 2017; Wilkins et al., 2019).

A key benefit to restoring herds is to enable community consumption and traditional relationship with bison (Haggerty et al., 2017; McElrone, 2017; Human Ecology Learning and Problem Solving [HELPS] Lab, 2018). Restoration of bison on tribal lands can, under appropriate vision and planning, support reclamation of traditional food systems by providing a sustainable protein source to communities with some of the greatest food insecurity in the United States (Bowers et al., 2019; Feeding America, 2019). Yet, today, discounted hunting licenses remain prohibitively expensive for some community members (Speakthunder and Magnan personal observation, 2021), and donations of meat are limited to a small number of bison each year. For Native Americans, reclaiming portions of their traditional practices within a modern economic system may be an important means of developing a more sustainable and future climate adapted economic framework (Crepelle, 2019). However, Native American food and agriculture sectors, and tribal wildlife departments are disproportionately under-resourced compared to state agencies, and they have limited access to federal funds (Wagner, 2007). Yet, food sovereignty is attainable within all the case studies examined if initial capital support is provided and the food pipeline to the community is improved.

Land Tenure and Capacity Needs

Although abundant suitable land exists within the reservations, land tenure issues, including highly fractionated lands in the NGP, make it difficult for Native Nations and Native community members to utilize all these lands for their benefit (Brewer et al., 2016). This speaks to economic challenges of buffalo programs or Native Nations securing tenure on lands for bison herd establishment or expansion. Because many Tribes do not have sufficient land mass to dedicate toward large genetically diverse herds (>1,000 individuals), Tribes adapted the U.S. Department of Interior metapopulation management strategy that involves exchange and translocations among conservation herds to conserve gene diversity (Hartway et al., 2020). Within the present context, tribal bison herds cannot achieve numbers sufficient for the dual purpose of food sovereignty and restoration.

In addition to land tenure challenges, there is a need for investment in capacity. As Tribes work to grow herds, they will need to build capacity within the community to sustain the herd and the ecological integrity of the rangeland (Martin et al., 2021). In some cases, training programs are in place, but reliant on availability of a few key personnel. Integration with tribal colleges to participate in rangeland monitoring and animal management activities could be a solution to some of the personnel shortages. Regional strategies for addressing these challenges could emerge, e.g., funding and sharing expertise of tribal staff with higher level of training such as veterinarians, rangeland botanists, rangeland management specialists, ecologists, animal scientists, wildlife biologists, and natural resource managers. Programs differ in their strengths, and different communities have varying resource demands and expertise to draw from. Huge advances have been made to increase collaboration and create training opportunities through the ITBC, and efforts to further increase collaboration and regular communication between communities should be supported.

Preparing for the Future

With all the challenges in mind, Tribes—and other sectors—need to prepare for the future and adapt their management goals in accordance with climate change (Martin et al., 2021). Whyte (2013) argues that Native American collective continuance (i.e., the capacity to adapt to probable futures) will require an interdisciplinary approach that applies science, policy, and traditional knowledge to develop community-tailored adaptive management strategies. From a biophysical perspective, bison are expected to decrease mature body mass between 63 and 115 kg in response to the combined effects of projected warming (per°C mean annual temperature rise) and increasing drought (per unit of annual Palmer Drought Severity Index). This will substantially reduce the amount of meat produced per animal (Martin and Barboza, 2020a). In addition, reproductive success may decline with warming and shrinking body size (Martin and Barboza, 2020a). Lastly, the longevity of bison may decline (0.3 y/kg of body mass loss) with warming and associated shrinking body size (Martin and Barboza, 2020a). Bison will adapt to maintain themselves on the landscape, however, the increasing demand

for bison meat and the changes to rangeland conditions will ultimately require allocation of more lands to bison management.

True restoration of bison on the NGP, as defined in this paper, will require additional herds, increased herd sizes, and reestablishment of migration corridors in some functional capacity (*sensu lato* "shared stewardship"; Aune and Plumb, 2019). The ecological benefit of landscape heterogeneity relies on exploiting a primary trait of bison—their desire to move. Currently, land tenure/ownership issues display a modern societal intolerance of big game movements across jurisdictions. This is true for bison as well as other species such as deer *(Odocoileus* spp.), pronghorn antelope (*Antilocapra americana*), and elk (*Cervus canadensis*), preventing formerly functioning NGP prairie ecosystems from fully reoccurring. To restore the function of migration, if not actual long-range movements, the management of bison for both production and conservation needs refinement of protocols regarding fencing and land ownership. Monitoring is essential to know whether ecological restoration is being achieved, particularly as the Tribes evolve in their management.

CONCLUSION

Native Nations hold an expanse of suitable habitat for bison, and their cultural heritage may be more conducive to bison restoration on tribal lands within the constraints of existing land tenure. Currently, the reviewed challenges outweigh the communities' capacity to fully restore bison and reconnect ecological services. However, with sustained and dedicated funding and management capacity, these initiatives can realize the outcomes desired by communities. In the near term, food sovereignty will mean an emphasis on production (i.e., provisioning ecosystem services and achieving food sovereignty). Other avenues to re-populate bison and support cultural revitalization should also be explored to complement the efforts on the reservations. For example, allowing bison onto large federal lands managed for wildlife while partnering with Native Nations in the process and decision-making may be an alternative route to restoration; this concept is loosely referred to as co-management or "shared stewardship" (*sensu lato*; Aune and Plumb, 2019).

In the future, restoration will be actualized by merging the concepts of conservation and commercial herds (with some capacity to extract surplus animals from the herd) or the growth of both herds until production meets local community food demands and conservation meets non-provisioning ecosystem service demands (e.g., carbon sequestration, water quality enhancement, facilitating increased biodiversity, and cultural connections). Both strategies rely on community support and robust expansion of staff, infrastructure, and funding. In summary, the success of restoring bison on tribal lands for the purpose of seeking ecological solutions to food sovereignty is dependent upon the acceptance and application of the pluralistic, intrinsic traits of bison being considered as both a culturally significant wildlife species and as the focus of a sustainable economic program. Acceptance of both roles may be what is needed to foster economic development and grow bison repopulation efforts, while avoiding placing a burden on the underserved communities already leading the way.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in **Supplementary Materials 2** and **3**. Further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

HS, BDM, WJM, DJ, MS, and TSA formulated the idea. HS structured the manuscript through consultation with the primary and secondary authors. HS and OGC wrote the first draft. All authors contributed to revisions of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2022.826282/full#supplementary-material

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