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Community Orchards for Food Sovereignty, Human Health, and Climate Resilience: Indigenous Roots and Contemporary Applications

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Abstract: Community orchards could play a valuable role as nature-based solutions to complex challenges we face today. In these unique plantings, a variety of nut- and fruit-producing trees and berry shrubs are often established together on public spaces to provide the community with healthy, fresh food. Interest in these plantings has been increasing in the United States, even more so since the COVID-19 pandemic highlighted vulnerabilities in our food systems. However, the roots of community orchards can be traced back to Indigenous foodways which have persisted for millennia. Then and now, community orchards support an array of functions, positioning them to contribute to solutions to major challenges related to food security, human health, and climate resilience. In this paper, contemporary applications are considered for Indigenous communities in the US that seek to care for their communities and the environment. A case study of the Osage Orchard project in Pawhuska, OK, USA, highlights the value of reconnecting with cultural foods and practices of Osage ancestors, to meet the needs and preferences of a contemporary Indigenous community.

Keywords: multifunctional landscapes; traditional ecological knowledge; food forests

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1. Introduction

Community orchards are plantings of fruit and/or nut trees that are managed by a group of individuals who consider themselves a community. As "orchards", they are often organized in linear patterns for the utilitarian purposes of managing the trees and the spaces between them. The concept of a Community (or Urban) Food Forest is similar except that the plantings are often structured in patterns that mimic a natural forest ecosystem [1], typically with greater complexity in the species and in the layers of canopy vegetation compared with a community orchard. In fact, community orchards may be thought of as a specific type–a formal type–of community food forest [2]. Community orchards are often incorporated into public green spaces such as parks and schoolyards, or on vacant lots in urban areas [3,4]. Despite the growing body of work on related topics such as agroforestry and urban agriculture, and the expanding interest in food forests, the extent of literature on applications of community orchards for addressing our current environmental and human health concerns remains limited [5]. A 2019 review of urban, multistory agroforestry in North American and Europe, for example, identified only eight peer-reviewed papers on the topic [6].

The scholarly work that does exist and the literature from allied fields suggests that multistory community orchard systems may offer a greater range of ecosystem services than other forms of community food production, such as community or allotment gardens,

though this is more of a hypothesis than a claim substantiated by empirical data [7]. Because of their greater vegetative complexity and their perenniality, these systems can be expected to support higher levels of biodiversity above- and below-ground than the annual crop plants, particularly if the former include native plant species [7]. The trees and shrubs in these systems contribute to valuable ecosystem services including microclimate control, carbon sequestration, and nutrient cycling [8]. The literature on landscape preference suggests community orchards may be psychologically preferred over annual systems because of the inclusion of trees and may offer more opportunities for psychological restoration [7,9]. Their distinctiveness may engender a sense of being away and of extent, while the internal spatial organization with clear edges created by woody vegetation may create a sense of extent [7]. The vegetative complexity of these environments, with layering of leaves and plants of different shapes, colors, and textures, may also afford opportunities for "soft fascination." All three of these qualities are associated with psychologically restorative environments [10].

At the same time, developing and maintaining community orchards, particularly in urbanized areas, comes with unique challenges. Initial costs may be higher than those for annual systems because of the greater investment in herbaceous perennial and woody transplants [3]. The perennialism of the plants demands long-term land tenure, which is often an issue in urban production [11]. Another challenge shared with urban agriculture is the potential for pollutants from soil or air to contaminate the edible products, although the translocation from soil to edible fruit and nuts may be less than with vegetable crops, for example [12]. Finally, broad public support for community orchards and food-producing trees in urban areas may be dampened by those who consider the trees to be "messy" or "hazardous" due to the dropping of unharvested fruit or nuts [3]. While challenges do exist, the case could be made that the wide range of benefits provided by community orchards outweigh the costs.

The purpose of this paper is to stimulate greater interest among scholars, policymakers, and activists in community orchards as a nature-based solution which can contribute to resolving complex challenges related to food security, human health, and climate resilience. We explore the historical roots of community orchards and other food-producing forms of agroforestry in pre-colonial and colonial North America and the early US, linking them to contemporary applications. Approaches to the design and management of community orchards are proposed, emphasizing those that would best address food system and environmental challenges. The paper also investigates the potential for community orchards to address the needs and preferences of contemporary Indigenous communities in North America, in a way that simultaneously creates meaningful connections with ancestral foodways. Finally, a case study of the establishment of the Osage Orchard demonstrates how these systems might be applied in practice.

2. Methods

Because of the limited extent of the existing scholarly literature on community orchards as nature-based solutions, we surveyed both the scholarly and gray literature on history of food-producing forms of agroforestry for Section 3. The review has been confined primarily to literature on the geographic region currently defined by the boundaries of the US, with a brief excursion to the UK. Databases and search engines used in data collection included Google, Google Scholar, and Web of Science. Depending on the subtopic of research interest, e.g., pre-colonial Indigenous agroforestry, we selectively combined the following search terms with Boolean AND/OR operators: orchard, community orchard, food forest, forest garden, fruit tree, agroforestry, Indigenous, Native American, pre-colonial, colonial, North America, United States. We used snowballing to identify additional sources based on the reference lists of initially identified sources to construct a narrative account in Section 3 of community orchards in the US from the precolonial era to the present, with a focus on the food-producing agroforestry in Indigenous communities. For Section 4, we selectively drew on and synthesized literature on a wide range of topics from diverse disciplines—

traditional ecological knowledge, Indigenous food systems and food sovereignty, adaptive ecosystem management, and climate change adaptation and mitigation—to hypothesize about the ways in which appropriately designed and managed community orchards could be informed by Indigenous communities' cultural resources to address the food system and environmental challenges they face. Finally, for Section 5, we present a case study of a project involving investigators at the University of Missouri Center for Agroforestry and the Osage Nation, located in Pawhuska, OK. The work on the community orchard project began in May 2020, following previous collaborative engagements. The development of the community orchard is still ongoing, as of October 2021.

We do not claim that our account of the historical roots of community orchards in the US or our hypotheses about the potential contributions of community orchards to addressing food system and environmental challenges are exhaustive. Instead, we intend this work—and the case study discussed in Section 5—to provide a framework, a foundation, and guidance for future scholarship.

3. Historical Roots of Community Orchards in the United States

3.1. Pre-Colonial Indigenous Agroforestry

Throughout much of the land we now call the United States, Indigenous tribes practiced communal land management activities for food, prior to colonization [13,14]. While not the formal arrangements of orchards introduced later, the forest area itself might be considered a community orchard, supplying fruit and nuts for food for Indigenous communities. Hedrick (1950) stated the situation plainly in A History of Horticulture in America to 1860:

> "North America is a natural orchard. More than two hundred species of tree, bush, vine and small fruits were in common use by the Indians when the Whites came. Besides these, there were at least fifty varieties of nuts, and an even greater number of herbaceous plants." (p. 4)

Most European settlers did not seem to recognize the active management of the forested land for food production and horticultural purposes. The persistent wilderness ideology generated and sustained by Euro-American settlers is a legacy of this lack of awareness of relational and integrated land use by Indigenous peoples [15,16]. Evidence exists, however, that some European settlers did indeed find and document orchard-like plantings in some tribal villages of the eastern US when they arrived in the mid-16th century. While species of many small fruits grew abundantly without being planted by human hands, Indigenous tribes were known to plant preferred species such as red mulberry (*Morus rubra* L.) and American persimmon (*Diospyros virginiana* L.). Wild plums (*Prunus americana* Marshall var. *americana*) were particularly common in the planted areas near villages and camp sites. According to European observations, the orchard and garden spaces were considered community property (within a certain tribe), typically with women as the primary horticulturalists tending them [17].

The writings of Captain McGill (circa 1792) documented a site in northwest Pennsylvania that appeared to be a purposefully managed orchard-type planting that had existed before settlers arrived [18]. This site was described as a "wonderful park" with a "veritable orchard of wild plums bearing a great variety of large red and yellow fruit", along with plantings of hawthorn, crabapple, hazelnut, blackberry, and raspberry (pp. 115–116). In fact, it was this "charming woodland", an Indigenous community orchard, that provided the cues to settlers that this location would be for a settlement [18].

Archaeologist Gail Fritz, who studies precolonial agricultural practices at Cahokia (in present day Collinsville, Illinois) also suggests that the large and diverse Indigenous community, which thrived until approximately 1300 AD, created tree nut orchards by favoring high yielding masts of preferred hickory and oak trees, girdling inferior individuals, and routinely burning the underbrush in these spaces [19].

3.2. Establishment of Formal Settler Orchards with Colonization

With the European quest and colonization of land in the United States, non-native fruit trees were introduced throughout the period from 1600 to 1800, mostly on individual farms for subsistence or even as a claim to the land [20]. Orchards also appeared on landscapes of the wealthy, for the pleasure of gardening and enjoyment of fresh fruit [21]. Some of these "gentleman's fruit farms" likely had a communal aspect to them, but also relied on forced labor. Thomas Jefferson, for example, relied in part on slave labor to establish and maintain the fruit garden at Monticello [21]. This purposefully designed orchard began with the planting of experimental selections around the year 1769, and ultimately included more than 1000 fruit trees, with collections of different species and cultivars [22].

During the period of colonization, Native Americans introduced European settlers to native species such as plum [21]. Evidence suggests, for example, that Native Americans were promoting fruit and nut trees in the eastern US [23]. Just as settlers were interested in native tree fruit species, some Native American tribes were early adopters of the newly introduced European fruit trees, although their management strategies for orchards differed [24]. One example is the Navajo peach orchards found in Canyon de Chelly in Northeast Arizona and scattered throughout Navajo country. Evidence of the likely origin of these orchards is found in the documentation of fruit trees including peaches (*Prunus persica* (L.) Batsch), apricots (*Prunus armeniaca* L.), and plums in New Mexico in 1629, following their introduction to the region by Spanish settlers. The New Mexico Pueblo Indians raised peaches, and those fruit were likely introduced to the Navajo by Hopi and/or Jemez tribes in the late 1600s. It is thought that the migration of the Navajo to the de Chelly canyons in the 1700s led to the establishment of the clustered peach orchards there [24]. Tragically, the orchards (along with other crops and livestock) were destroyed by soldiers in 1864, in a "scorched earth" effort to capture the Navajo. Captain John Thompson reported that in a single day, they cut down 500 "of the best peach trees I have ever seen in the country, every one of them bearing fruit". When the Navajo were subsequently released four years later, they returned to the canyon to find new shoots growing from the cut stumps [25]. With that, the narrative is flipped, as the orchard regrowth becomes a story of resilience and renewal.

Throughout most of the 19th century, European settlers and their descendants collected and developed fruit varieties for hobby and entrepreneurial activities. Grafted trees were sometimes grown, but were minimally managed with little pruning. Horticultural societies formed in the early 1800s to share information and plant materials [21]. The Stark Brothers Nursery was established in 1816 in northeast Missouri, and it gained a reputation throughout the country for superior fruit trees [26]. In Oregon Territory of the far west, several outposts were known to have traded seeds and fruit with Native Americans. In present day Washington state, Red Wolf of the Nez Perce tribe established a formal "farm" orchard in 1837 with seed obtained from the fur trading company, Hudson's Bay Company [21].

From the 1880s on, orchards in the US generally became more commercialized and technology-based. Plant materials depended on varieties grafted onto seedling rootstock, and management relied on intensive pruning, pesticides, synthetic fertilizers, and often irrigation. Growers planted a decreasing number of varieties, which resulted in more uniformity but a loss in genetic diversity. Many orchards were lost during the Great Depression, but new ones were established at historic sites by the Civilian Conservation Corps (CCC) through F.D Roosevelt's New Deal programs. Orchard remnants exist today within the National Park Service, and these are considered to be important cultural sites that reflect the historical past and conserve genetic diversity [21].

3.3. Contemporary Community Orchard Movement

3.3.1. The Origins of the Contemporary Community Orchard Movement

The origins of the contemporary community orchard movement have been traced to England in the late 1980s and the work of Common Ground, established as an arts and

environmental charity in 1983, and its Save Our Orchards campaign [27,28]. Movement organizers were motivated by a rapid decline in orchard area in the UK—from 62,200 ha in 1970 to 46,600 in 1980 to 22,400 in 1997. The decline was a result of development pressure and the importation of cheap fruit and by a desire to preserve everyday nature and greenspace, conserve traditional fruit tree varieties, enhance food access, and protect "local distinctiveness" [28,29]. More recently, the movement in the UK has transitioned to a focus on planting new orchards, including urban orchards. The Orchard Project, "a national charity dedicated to the creation, restoration, and celebration of community orchards" has established over 540 community orchards in the UK with the aims of increasing food security and community resilience and building social capital [30]. The UK Orchard Network has documented over one thousand community orchards in the British Isles [31].

Interest in conserving existing orchards as part of a shared cultural landscape is not limited to the UK. The loss of orchard meadows in Germany, Switzerland, and other European countries and the loss of associated ecosystem services—not only provisioning but also cultural and ecological—are of growing concern [32]. A form of agroforestry usually under private ownership but sometimes owned by local governments, these systems are characterized by widely scattered fruit trees of diverse varieties which may be pruned to allow livestock to access the herb layer—often dominated by grasses—in an area in southwestern Germany.

3.3.2. Community Orchards in North America

Common Ground and its work in the UK are commonly cited as the inspiration for the movement in North America [28]. While no comprehensive census of community orchard projects has been conducted in the U.S. or Canada, Clark and Nicholas [2] documented 37 urban food tree initiatives dating to the 1998 founding of the Dr. George Washington Carver Edible Park in Asheville, NC, the first urban community food forest in the U.S. The actual number of projects is likely much higher. In 2021, the NGO Kansas City Community Gardens (KCCG) alone reported having founded over 200 community orchard sites or "Giving Groves" in Kansas City, MO with an average of more than 16 fruit trees per site [33].

While groups in the UK initially focused on conserving abandoned commercial orchards as community orchards, the movement in the U.S. and Canada has from the beginning focused on the de novo development of orchards in a wide range of land use contexts, including public parks, schoolyards, church-owned properties, public housing developments, and formerly vacant lands in residential neighborhoods [3,28]. Orchards may be founded and managed by grassroots groups, NGOs, and local governments for a wide range of provisioning, ecological, and cultural purposes. These purposes include increased food security and sovereignty, education, recreation, biodiversity conservation, aesthetics, and community development [3,32]. NGOs promoting community orchards in U.S. cities include, in addition to KCCG, the Baltimore Orchard Project, the Philadelphia Orchard Project, and the Portland Fruit Tree Project.

3.3.3. Community Orchards in Transition

Some community orchards and their sponsoring organizations appear to be transitioning from a traditional, single-layer orchard model to a multi-layered food forest model with its origins in permaculture. In the UK, The Orchard Project—motivated by concerns about climate change and system resilience—announced in 2021 that it was broadening its definition of community orchards and its mission to include food forests because of the benefits of the latter compared to traditional orchards, including increased carbon sequestration, system resilience, and planned and associated biodiversity [34]. This trend also appears to extend to the United States. Echoing The Orchard Project's announcement, the Philadelphia Orchard Project's website notes that the organization "plants orchards according to permaculture forest gardening techniques, with a canopy of dwarf or semi-dwarf trees, middle 'layers' of berry bushes, and an under-story of perennials that help attract beneficial insects, deter pests, build soil fertility, and avoid the need to spray toxic

chemicals" [35]. Some independent community orchards, including the Rosewood Public Orchard in Columbia, SC and the Eggleston Park Food Forest and Orchard in Evanston, IL have consciously transitioned from an existing, traditional fruit tree orchard with trees arranged in an orthogonal grid to a layered forest garden model with an informal design [36,37]. Community food forests are also being established de novo across the U.S., with major new projects including the 2.8-ha Beacon Food Forest in Seattle, WA and the 2.9-ha Urban Food Forest at Browns Mill in Atlanta, GA, said to be the largest food forest in the country.

The layering of woody and herbaceous perennial and annual crops which characterized food forests, however, may not be a new phenomenon even in U.S. cities. While Clark and Nicholas [2] claim "the cultivation of woody perennial plants in conjunction with crop or animal farming . . . is rarely practiced in cities" (p. 1651), anecdotal evidence suggests at least some mixing of woody and herbaceous crops in community gardens and other forms of urban agriculture not formally labeled as community orchards or food forests. The authors, for example, have observed perennial woody fruiting species in older, more permanent community gardens such as the Rainbow Beach Victory Garden in Chicago, IL, founded in the 1940s and La Plaza Cultural de Armando Perez in the East Village neighborhood of Manhattan, established in 1976.

3.3.4. Indigenous Community Orchards and Food Forests

Paralleling the development of community orchards in the U.S. in general, several tribal groups across the United States have begun to recover cultural traditions of orchard tending, developing communally owned orchards as a means of increasing tribal food sovereignty, reproducing traditional foodways, and generating income. Documentation of this phenomenon is largely absent from the peer-reviewed literature [13]. Consequently, we draw on gray literature and internet sources to describe four of these tribal, fruit-based agroforestry projects.

In 1994, the Oneida Nation of Wisconsin, who in the early colonial era maintained large orchards of apple, peach, and pear around their villages before being forced from their ancestral lands in central New York [38], purchased a 2400-tree apple orchard within the original boundaries of the tribe's reservation in Oneida, WI [39]. The tribe subsequently expanded the original 30-acre parcel with the acquisition of 10 additional acres, and diversified the crops grown to include small fruit (strawberries, blackberries, and raspberries) and annual vegetables [39]. The orchard re-asserts the tribe's claims to the land while stimulating local interest in sustainable agriculture and healthy foods [39].

In 2009 in northern Maine, the Aroostook Band of Micmacs founded a 28-acre farm as a community garden with fruit tree orchards, small fruit, and annual vegetable crops [40]. The farm is now part of a larger system of integrated multitrophic agriculture which includes a 36,000-gallon indoor fish hatchery for Maine brook trout. Orchard and row crops are irrigated and fertilized with hatchery wastewater. The hatchery and farm generate income for the tribe, help to conserve a culturally important food source, brook trout, and its associated foodways, and increase food sovereignty for both the tribe and for the rural community in which they are located [40].

Founded in 2009 on the Standing Rock Sioux Tribe Reservation in South Dakota by Robert and Beth White Mountain, Medicine Wheel Living Park, a 65-acre, community-managed park, includes a 350-tree orchard of apples, plums, cherries, apricots, and pears planted in the shape of a medicine wheel, a shelterbelt of native fruiting plants, and a community garden [41]. The goal of the park is "to offer ways of understanding how we can attain an eco-friendly, socially just and harmonious co-existence with each other and our sacred Grandmother Earth, and also to bring hope to the children and people of the 3rd poorest county in the nation" [41].

With funding from the United States Department of Agriculture, the Del Norte and Tribal Lands Community Food Council and the Tolowa Dee-ni' Nation have established four food forests in California at sites connected with schools and community activities [42].

As part of the nation's Srtaa~Shvm (hii) Mvlh Ghee-saa-ghit-na' (Good Food Makes Us All Healthy) Project, the food forests support the project goal of increasing access to healthy foods on tribal and adjacent lands through community-based production [43].

4. Contemporary Applications for Indigenous Communities

Community orchards could play a role in addressing contemporary issues for Indigenous communities. A strategy of reconstructing and reconnecting to traditional land use ethics could offer novel solutions with implications for adaptation to climate change, food insecurity, and declining human health.

4.1. Learning from Traditional Ecological Knowledge

Discussions of contemporary issues such as climate change often focus on the negative actions of human actors. Humans have undeniably had a dramatic impact on natural ecosystems, beginning with the development of agriculture and accelerating in extent and intensity over the past 250 years with the beginnings of the Industrial Revolution. However, recent research offers evidence that human modification of the landscape did not always result in negative environmental outcomes [44]. Rather than degrading the landscape, the historical land management practices of many Indigenous communities would be better described as relational stewardship through reciprocity [45]. Ellis et al. (2021) argue that these historical practices might offer a foundation for addressing contemporary environmental issues, claiming that: "efforts to achieve ambitious global conservation and restoration agendas will not succeed without more explicitly recognizing, embracing, and restoring these deep cultural and societal connections with the biodiversity they aim to sustain" [44].

Indigenous communities and their allies have sought to retain and protect this important ancestral knowledge of ecosystem management, or traditional ecological knowledge (TEK) which is defined as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (p. 1252) [46]. The study of TEK has found direct application through the need to identify and protect species, as through community-driven ethnobotanical studies (for plant species). However, from a broader "systems" perspective, important understandings of land management practices, nutritional properties of native plants, and harvest share arrangements that could contribute to restoring humans' connections to the natural world might be learned from the TEK of Indigenous communities.

Native American communities were actively managing the land "found" by European settlers. These communities' approaches sought to harmonize their needs with the health of the ecosystem, in order to maintain resources for future generations. Settlers appeared not to recognize this active land management, because they were more familiar with more intrusive approaches to controlling the environment and extracting natural resources. Native Americans' use of prescribed fire to clear understory vegetation from forested systems and to suppress woody species in grassland systems is an example of one widespread practice of active land management unrecognized by settlers [47]. This practice had implications for the availability of food from Native American agroforestry systems, as it encouraged growth of certain desirable plant species, such as those producing edible berries [14], fruit, and nuts [19,22]. Other agricultural activities such as integrated farming, polyculture planting, and land rotation were practiced by Native American tribes to increase food production while also promoting ecosystem renewal [46].

In addition to land management, TEK has much to contribute to contemporary knowledge of nutritional and medicinal properties of native plants [48]. In fact, the field of ethnobotany is focused specifically on the study of human uses of native plants for diverse purposes, both past and present [49]. Academic programs of study in ethnobotany might offer a valuable link between academia and tribal communities [50], particularly when tribal communities and native academics drive the needs and directions of ethnobotanical

research for the benefit of their people, culture, and health [51]. An example is the case of the recent joint project among ethnobotanists at the University of Kansas, traditional cultural Osage tribal members, and an Osage paleoethnobotanist. One relevant aspect of that project was to determine which wild plant species used by the Osage in the past might be sustainable for an annual tribal harvest at Pea Ridge National Military Park in Arkansas, today. The second aspect of the project was to create an inventory of documented plants used by the Osage, as referenced in historical literature and through archaeological evidence, along with their specific uses by Osage. The knowledge would be later developed into educational materials for the tribe. Apprising the nutritional properties of plants used by Indigenous peoples, Kindscher et al. [52] proposed that new crops and food products might be developed from "wild" species with the purpose of "improving modern diet, and the nutritional quality of food products" (p. 214).

Plants used in the past but underused in recent years [48] might serve as important sources of nutrition for a healthy, sustainable diet [52]. For the prairie region, pseudocereals such as amaranth (*Amaranthus* sp.) and greens such as lambsquarters (*Chenopodium* sp.) can contribute protein and fiber to the diet [52,53]. For Indigenous communities in the Arctic region, wild berries have traditionally served as a valuable and unique source of phytochemicals contributing to health and wellness and reducing diet-related illnesses (i.e., metabolic syndrome) [54]. These ethnobotanical traditions carry forward into culturally important nutrition and health outcomes today, as in the work of Valerie Segrest and Elise Krohn, authors of "Feeding the People, Feeding the Spirit: Revitalizing Northwest Coastal Indian Food" [55], and the efforts of Native chefs such as the "Sioux Chef" Sean Sherman who founded NATIFS, Native American Traditional Indigenous Food Systems, "to promote Indigenous foodways education and facilitate Indigenous food access" [56].

Traditional uses of food and medicinal plants offer important insights for human nutrition, but the knowledge that has been applied to harvesting and sharing edible plants brings another valuable cultural dimension to humans' relationship with those plants. For the Teetl'it Gwich'in in the Northwest Territories of Canada, knowledge about the distribution and abundance of berries, even from one year to another, guides community principles for accessing and harvesting the crop. This TEK is communicated between family members and friends through oral tradition, and there is an expectation that others will respect the shared rights to the harvest [57]. Access to a diverse, shared set of harvestable resources could contribute to the adaptive capacity of a family or community. In fact, subsistence harvest diversity could be a potential indicator of the extent of applied TEK in a community that might contribute to overall community resilience [58].

In addition to improving our understanding of precolonial practices, study of TEK could contribute to the development of adaptive management approaches to contemporary environmental issues [1]. Similar in some ways to other forms of scientific inquiry, TEK or "Native Science" synthesizes knowledge from incremental accumulation of long-term observations and intergenerational spiritual insights [59]. Like the concept of adaptive management, TEK depends on the "use of local ecological knowledge to interpret and respond to feedbacks from the environment to guide the direction of resource management" (p. 1251) [46]. Considering the complex challenges we face, TEK can be a guide for understanding and even designing for ecosystem processes and functions, to purposefully build system resilience. The approach requires acceptance of the uncertainty and unpredictability of ecosystems, which it builds into management practices through feedback loops. TEK approaches value local knowledge, flexible and adaptable responses based on environmental feedback, diversity of species and resources, and relational qualitative measures of success [46,60,61].

One important aspect of TEK and Native Science is the cultural and spiritual foundations born from the intimate connection between people and place through continuous inhabitation over millennia [46,59,61]. Social values of reciprocity and responsibility to live in harmony with the cyclical rhythms and abundance of the earth are central to the resulting land management practices. Where "resources" denote potential for economic

exploitation, relations with animate beings in the environment (e.g., plants and animals) define an economic system of reciprocity and relationality [45,61]. The reductionism of positivist Western science contrasts with this holistic view of complex systems understood through "traditional" scientific knowledges. This incompatibility has led to a great deal of skepticism and distrust from both Western Euro-American and Indigenous scientists [51,62]; however, there have also been calls for bridging these ways of understanding the world by redirecting research aims toward Indigenous self-determination, and by creating spaces where complementary knowledges can co-exist, as in agroforestry and other land management practices [51,62,63].

A relevant application of TEK for community orchards is through the "Indigenous Food Sovereignty" movement in the United States. Food sovereignty has been defined as "the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems" [64]. Indigenous food sovereignty seeks to restore cultural knowledge, protect environments, and regain health for Indigenous communities through changes in the food system [65]. This movement is in part a response to the many challenges faced by Native peoples as a result of colonization's historical and ongoing effects, including forced removals and relocations onto marginal and unfamiliar lands. Still today, the food produced on agricultural land and in fisheries by Native Americans is threatened by impacts on water resources through dams, diversions, and contamination that impact water quantity and quality [66]. As a part of the solution to contemporary complex challenges, Indigenous food sovereignty grows connections with the land and culture, where cultural restoration accompanies agricultural restoration [65].

4.2. Human Health, Wellbeing, and Survivance

In addition to (and in combination with) embodying living TEK, community orchards can play an important role in addressing health disparities affecting Tribal communities. Compared with the average US population, Native Americans experience significantly higher rates of diabetes [48] and other diet-related chronic diseases [67] as a direct result of the long-term impacts of colonization. Many Native families live under food apartheid; limited access to healthy food can result in a dependance on commercial food retailers such as convenience stores [67,68]. Food insecurity is a prevalent concern in both urban and rural Native American communities, with an overall rate double that of white Americans [69]. Diet-related health risks, as well as the limitations on food access, have at least in part resulted from a shift away from traditional foods [54].

Recommendations for a contemporary healthy diet could incorporate foods consumed regularly prior to colonization [48], including many from plant species that could be grown in a community orchard. Tree nuts, tree fruit, and berries would all have been part of the diet for many Native American communities, and several studies have highlighted their contributions to human health [52,54,57,70]. In fact, the often harsh environmental conditions that crop wild relatives were exposed to actually induce production of higher levels of phytochemicals beneficial to human health, such as those found in wild berries from places such as the arctic tundra of Alaska [71]. Cultivars of these same species have often been "improved" through breeding to increase yield and other traits that are more compatible with managed orchard conditions. Breeding for optimal concentrations of beneficial phytochemicals in food crops is another likely area of growing research interest [72].

Community orchards also have the potential to contribute to well-being through the restorative benefits of being in nature and interacting with other people, which contributes psychological health [54]. In tribal community contexts, they can contribute to greater movements of survivance, a term used originally by Anishinaabe cultural theorist Gerald Vizenor to describe the present continuance of native lifeways and "renunciations of dominance, tragedy, and victimry" [73] (p. vii). Survivance is an active survival and resistance, enacted in many ways, including through embodied practice of traditional foodways and

lifeways connected to place [74]. As much as community orchards can serve as a place to grow traditional healthy foods, they can also locate related Indigenous sovereignty efforts tied to food justice and food sovereignty: education, health care, language, land and water rights, and cultural vitality [75].

4.3. Climate Resilience

With regard to climate resilience, community orchards should be designed for both mitigation and adaptation, informed by TEK and community-specific contexts. Indigenous systems have been proposed as "models for modern resiliency" that could be applied to issues emerging from climate change [13]. The knowledge informing the Indigenous management of ecological systems has accumulated over very long time periods during which major climatic events have occurred [76]. This deep knowledge is woven into the cultural identities and practices of Indigenous peoples, which might serve as a framework for adapting to future changes [77]. In fact, these voices should be considered critical in developing and implementing nature-based solutions [78].

For climate change mitigation, community orchards can be intentionally designed to store carbon and reduce greenhouse gas (GHG) emissions compared with other agricultural systems. Selecting options with lower embodied energy, such as replacing synthetic fertilizer with local organic nutrient sources, is an example of a management strategy that could alter the overall carbon footprint of the food produced [79]. Like other treed habitats, community orchards hold the potential to store relatively large amounts of carbon on a small portion of land [80,81]. Forage crops, which can be grown at the base of woody plantings, can provide additional carbon storage [82]. Evidence suggests that increasing tree density and species richness can also improve carbon storage [83]. Trees and shrubs planted in multi-strata systems will allow species to occupy different niches both above- and below-ground, optimizing the carbon stored in biomass of these perennial woody plants [84].

As part of a climate change adaptation strategy, the diversity of species producing edible fruit and nuts allows producers to select the plants best suited to local climates, including projected future conditions [85]. The protection of natural resources is also an important factor in climate change adaptation, as stress on them will increase with extreme conditions. Compared with annual forms of agriculture, perennial systems such as community orchards can contribute to clean water, air, and soil [86]. Deep roots of trees and shrubs stabilize the soil and remove nutrients that might otherwise contaminate nearby waterways, ultimately leading to hypoxia in the gulf zones. Above-ground, trees filter volatile contaminants, unpleasant odors, and dust particles from the air [87]. Community orchards can serve as a buffer to protect natural areas, providing wildlife habitat and conserving biodiversity.

The link between climate resilience and human dimensions should also be considered. Botanist and author Robin Wall Kimmerer's concept of "biocultural restoration" recognizes that cultures can be revitalized through a link to ecological restoration of the land [88]. This concept is powerful and even more relevant considering that disadvantaged groups (low income and minoritized populations) are disproportionately impacted by the devastating outcomes of climate change [89]. Indigenous peoples relying on land-based resources, or located in vulnerable environments, are particularly sensitive to the impacts of climate change [76]. Furthermore, the mental and physical health of members of the most vulnerable populations are likely to be exacerbated as climate extremes become more frequent [90]. Cochran et al. (2013) propose that "[a] multi-pronged approach to broadening indigenous participation in climate-change research should: (1) engage communities in designing climate-change solutions; (2) create an environment of mutual respect for multiple ways of knowing; (3) directly assist communities in achieving their adaptation goals; (4) promote partnerships that foster effective climate solutions from both western and indigenous perspectives; and (5) foster regional and international networking to share climate solutions" [77].

5. Case Study of Osage Orchard

5.1. Brief Osage History

Based on evidence from archaeological findings, oral traditions, and historical data, the ancestral Osage inhabited much of the area in the Ohio River valley and some of the Mississippi River valley. Water systems and watersheds were and continue to be powerful life forces for the Osage. Water was so important that the Osage ancestors named the tribe as a whole Children-of-the-Middle-Waters. Although the specific reference is not known, it is believed this refers to the early homelands in the Ohio and Mississippi rivers. The ancestral Osage geography is broad, including areas in states as far east as what is now known as Pennsylvania and as far north as Wisconsin and including parts of at least 15 states. With substantial populations west of the Mississippi River in the states of Missouri, Oklahoma, Arkansas, and Kansas at the time of European colonization, the Osage are considered to be one of the Great Plains tribes. The Osage were forcibly removed from different territories over time, to the current location in northeast Oklahoma [91].

Prior to removal from their broad territory, the Osage were successful at hunting wild game, and frequently traveled to the western part of the territory on buffalo hunting expeditions. They were involved in agriculture as part of established villages, cultivating crops such as squash (*Cucurbita* spp.), corn (*Zea mays* L.), beans (*Phaseolus vulgaris* L.), and other annual species [92]. From the forested land in the river valleys, the Osage would harvest fruit, nuts, and berries that would be processed and stored for various food uses [93]. Increasingly, the Osage community is interested in recovering and sharing traditional knowledge of plants and land management practices with their younger generation, to address contemporary issues such as climate change and food insecurity.

Dr. Andrea Hunter, enrolled member of the Osage Nation from the Grayhorse District and the Director of Tribal Historic Preservation Office, draws on her background in anthropology, archaeology, and paleoethnobotany to contribute to the important understandings of cultural uses of plants. Many of the species that were used historically could have important applications for a contemporary community orchard. Documented tree and shrub species with edible products used by Osage include but are not limited to [94–96]:

- Fruit: pawpaw (*Asimina triloba* L.), American persimmon, prairie rose (*Rosa arkansana* Porter), wild plum
- Berries: elderberry, American mulberry, wild grape (*Carya illinoinensis* L.), blackberry, raspberry, and dewberry (*Rubus* sp.), and strawberry (*Fragaria vesca* L.)
- Nuts: Black walnut (*Juglans nigra* L.), pecan (*Carya illinoinensis* Wangenh. K. Koch), hickory species (*Carya* sp.), oak species (*Quercus* sp.), American hazelnut (*Corylus americana* Marshall)

5.2. Osage Strategic Plan Focuses on Indigenous Food Sovereignty

The "Strategic Plan Update (2020–2025)" prepared by the Osage Nation in December 2020 addresses the issue of Indigenous food sovereignty in several sections [97]. The plan specifically highlights the development and then expansion of Bird Creek Farm, the existing community farm (since renamed to Harvest Land), to include a greenhouse and general use building. Many of the specific priorities of the future plan were based on a survey of the Osage community members. In the section on Economic Development, for example, the item "explore expanding Osage Nation agriculture to generate food and revenue" was selected in the survey as the highest priority. Another relevant item was also included in that section: "grow and process food produced at the Osage's Ranches and Farms, and vertically integrate the supply chain (i.e., own cattle, meatpacking facility, and distribution)". Within the "Health" theme, plans to "increase access to healthy foods by supporting local grocery stores, food hubs, or Farmer's Markets" and "increase access to healthy food grown by the Osage Nation" were emphasized. Several priorities in the "Sovereignty" section focused on food sovereignty or related topics, emphasizing the potential to:

- "develop food sovereignty initiatives in order to contribute to priorities in health, economic development, natural resources and cultural preservation"
- "expand food sovereignty by growing healthy and culturally appropriate food"
- "continue to buy land back"

5.3. Osage Orchard Designed for Contemporary Needs

In 2020, as a response to the COVID-19 pandemic, a unique opportunity emerged. The spread of disease throughout the United States had caused disruptions in the food system, revealing vulnerabilities in the food security of rural communities including Osage Nation. Even for some products that the Osage typically provided locally, such as meat from livestock raised at their ranch, they were unable to access facilities to process the meat for human use. In response, the community committed to filling gaps in their own food system by building a meat processing facility and establishing a community orchard. Those projects were led by Jann Hayman, Director of the Department of Natural Resources.

The design for the orchard was developed by a team that included most of the authors of this paper, along with input from other experts. The site for the orchard was adjoining Bird Creek Farm, located in the southeast portion of Pawhuska, approximately 1.5 km from the schools and 1.1 km from the downtown area (Figure 1). The goals for the design centered around the desire to expand and diversify the production of healthy food for the community. An Osage cook, which is a respected position within the Osage community, provided guidance on the fruit and nuts that tend to be preferred by those who attend cultural events. Apples and peaches fit into that category. Other species were selected based on their cultural relevance, particularly considering edible products that were historically gathered by the Osage during the period when the tribe inhabited the land we now call Missouri, and surrounding areas. Emphasis was placed on species that have the greatest benefits for human health, including nutrient-dense berries and heart-healthy nuts. Finally, an important goal was for the design to be practical and utilitarian in terms of managing the trees for production over time. For this aspect, spacing the tree rows to allow for mechanized equipment was the primary consideration.

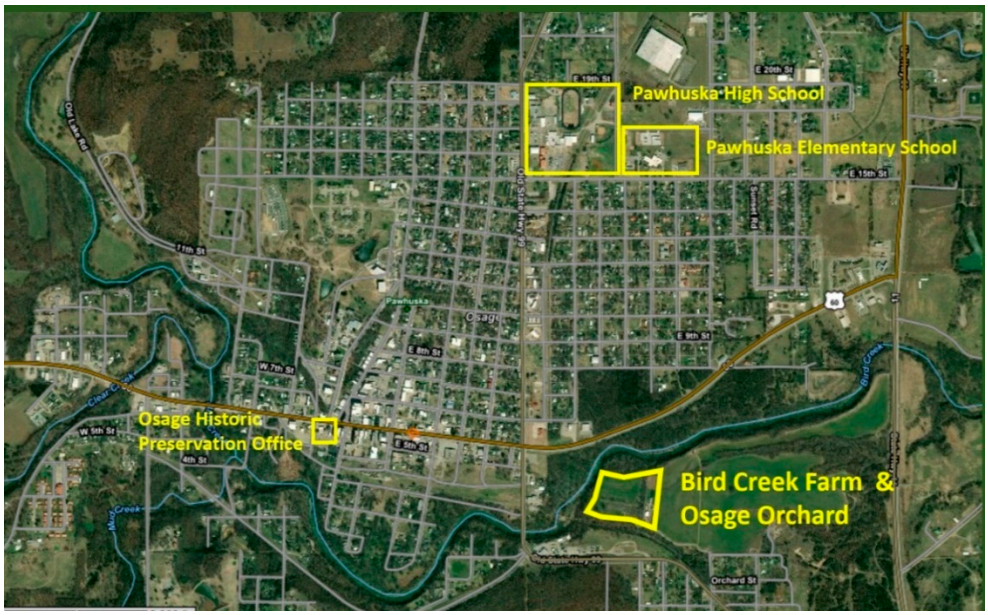

Figure 1. Aerial image of the town of Pawhuska shows the relationship of the Osage Orchard to other important community features.

The design of the Osage Orchard, shown in Figure 2, responds to the existing features of the site including the adjacent Bird Creek and nearby treed habitats. The linear orientation allows for an efficient drip irrigation system that will improve the establishment

success of tree seedlings. Most of the trees were planted in fall 2020, except those species that were in short supply due to the high demand for transplants of food-producing crops following the pandemic. In addition to the rows of trees and shrubs, patches for mixed cultivars of strawberries and blackberries are designated, along with a pond in the southwest corner for growing lotus. Between those features, a multi-story food forest is planned, to be added in future years.

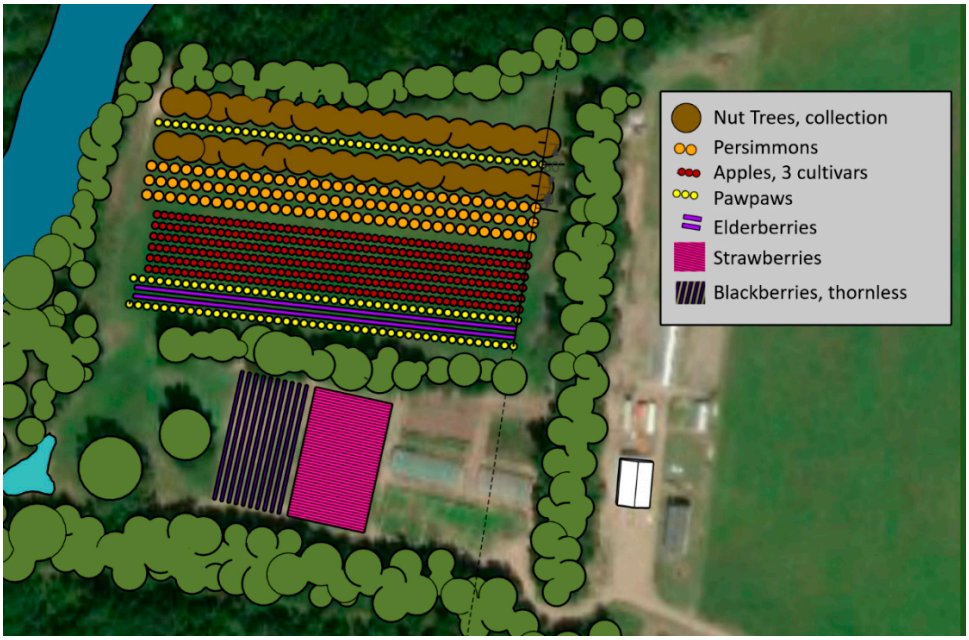

Figure 2. Plan view of the landscape design for Osage Orchard, established in Pawhuska, OK beginning in 2020.

While the Osage Orchard is in the early stages of establishment (as of the publication of this article), and peak production is years away, we are already beginning to explore the opportunities for the orchard to re-connect the Osage community with foods and practices from when the ancestors were stewarding forested lands throughout much of the lower Midwest region. We are working to obtain fruit of lesser-known species (e.g., pawpaw and elderberry) from other sources in order for the Osage members to sample and experiment with them in recipes, in advance of the harvests from Osage Orchard. We also have an opportunity to link this work with nutrition and cultural education with the schools.

6. Discussion

This paper is intended to contribute to a broader discussion on nature-based solutions to complex challenges, considering the unique structures and functions of community orchards. From a review of the historical roots of community orchards in the US, we demonstrated that these features are not only constructs of a colonized landscape but actually existed in some form with Indigenous land use. We also recognize the influences from other countries, such as the United Kingdom, on the modern forms of a community orchard. We identified ways in which newly established plantings could be informed by traditional ecological knowledge, to improve to human health, wellbeing, and survivance of Indigenous communities, while also contributing to climate resilience. A newly established orchard at Osage Nation offers an opportunity to investigate the various benefits and challenges with contemporary community orchards.

Based on our study, we can offer several recommendations that might be considered for community orchards intended to contribute to food security, human health, and climate resilience. First, in determining the site for locating the planting, easy access for community members should be prioritized, and physically linking to other community-based land

uses could be particularly valuable. The programming of the site might also be linked to existing activities and priorities such as youth education, community wellness, and economic development. In the selection of species, those that are well-adapted to current and projected future climate conditions should be encouraged, to reduce the need for unsustainable inputs such as long-term irrigation. Species should also be selected for their cultural significance, such as native plants from the territories once occupied by the communities, and for their human health benefits. Finally, as the community orchard projects grow and expand, they might serve as a space for stimulating partnerships between Indigenous communities and educational institutions or other organizations.

While this study makes a valuable contribution to the literature, several limitations should be noted. The framework developed through a review of the literature is limited primarily to the context of the United States and the specific planting structure of community orchards. However, some of the themes could be relevant for other regions and different land uses. Additionally, the case study is inherently limited to the experiences of one project, and in this example, one that is still in the early stages of development. The longer-term outcomes are yet to be realized. This study provides a foundation for future research and relationship-building. We intend to follow the progress of the Osage Orchard over time, studying the success in the establishment of the planting and benefits for the community. We anticipate developing reciprocal work at one of the University of Missouri research farms–Land of the Osages Research Center. Plantings that allow for education and demonstration of the Indigenous roots of agroforestry are planned. We will seek to characterize the ways in which community orchards support a reconnection with the ancestral land and land-based activities.

7. Conclusions

This study demonstrates that community orchards have the potential to contribute as nature-based solutions to complex challenges related to food security, human health, and climate resilience. We explored the roots of community orchards in Indigenous foodways, and then propose contemporary applications for Indigenous communities in the US that seek to care for their communities and the environment. The case study of the Osage Orchard project highlights the value of reconnecting with cultural foods and practices of Osage ancestors, to meet the needs and preferences of a contemporary Indigenous community. This project might serve as a model for other communities who are interested in producing their own healthy fruit and nut products for multiple benefits.

As with any proposed approaches to land use change and sustainable food production, community orchards are not a silver bullet. They do have great potential, however, as an entry point for realizing solutions that seek to simultaneously contribute to food security, climate resilience, and healthier humans. Daniel Wildcat of Muscogee (Creek) Nation suggests that Indigenous peoples should take on leadership roles for climate change adaptation beyond the boundaries of currently designated reservations, to include traditional territorial regions [76]. The establishment of culturally relevant community orchards may be one avenue to expand this reach. At the University of Missouri Land of the Osages Research Center, this extension and reconnection is on the horizon, where Osage-directed land-based activities may open pathways for climate resilient agroforestry systems understanding and application with, by, and for the original stewards of this land. These activities are positioned to be in conversation with those at Bird Creek Farm/ Harvest Land to continue to enliven traditional land management practices on Osage ancestral territory.

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