Enduring Legacies of Agriculture: Long-term Vegetation Impacts of Ancestral Menominee Agriculture, Wisconsin, USA

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Abstract Agriculture significantly reshapes soils and ecology, often with lasting ecological impacts. For over a millennium, the Menominee Indian Tribe of Wisconsin have practiced maize agriculture in the upper Great Lakes. Though the vast majority of ancestral Indigenous agricultural sites have been destroyed in the American Midwest, the Menominee have documented numerous archaeological, raised garden bed sites at their Reservation, enabling an investigation into the lasting vegetation impacts of ancestral Menominee agricultural practices. Here, we report findings from our pilot vegetation surveys of three ancestral raised garden bed sites. Results show that all sites surveyed are high quality ecosystems. We observed differences in species richness between agricultural and non-agricultural places, although findings varied based on location. Overall, our surveys illustrate the complexity of these anthropogenic, biologically diverse landscapes shaped by past and contemporary Menominee land use and illustrate how today's ecology is in part an enduring legacy of past practices.

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Introduction

Agricultural spaces are emblematic anthropogenic landscapes. By constructing and maintaining these places, humans often radically alter vegetation, soils, and even waterways. They reshape ecology and possibilities for future ecological systems, sometimes for millennia (Erickson 2006; Morrison et al. 2021). Worldwide, past agricultural pursuits have had long-term ecological consequences ranging from the salinization of soils (Flannery 1969; Jacobson 1982) to deforestation (Kirch 2005) to changes in vegetation (Briggs et al. 2006; Ellis et al. 2021; Ford and Nigh 2015; Larson et al. 2021). Moreover, vegetation changes associated with ancient agriculture and other past land use often remain observable on the landscape today, with distinct vegetation differences occasionally evident at archaeological sites (Abrams and Nowacki 2008; Armstrong et al. 2021; Campbell et al. 2006; Ceschin et al. 2016; Dunn 1983; Erickson 2006; Feinman and Nicholas 2020; Harris 2018; Pavlik et al. 2021; Wykoff 1991; Zeiner 1946; Zou et al. 2019).

The now densely forested Reservation of the Menominee Indian Tribe of Wisconsin (MITW) in Menominee County, Wisconsin (Figure 1), contains dozens of confirmed and suspected archaeological garden bed sites. Established in 1854, it is located in the northeast section of the state on ancestral Menominee territory (Beck 2002). For millennia, the MITW have utilized the region, resulting in a rich archaeologically and biologically diverse landscape that was and continues to be managed, maintained, and preserved by the Tribe. For example, today, roughly 87% of the Reservation lands are managed by the Menominee's forestry business, Menominee Tribal Enterprises (Mausel et al. 2017), whose efforts have increased the forest canopy over the past century (Trosper 2012) and whose lumber is sought after for its high quality (Buckley 2023). The ancient, long-term ecological management by the MITW remains visible

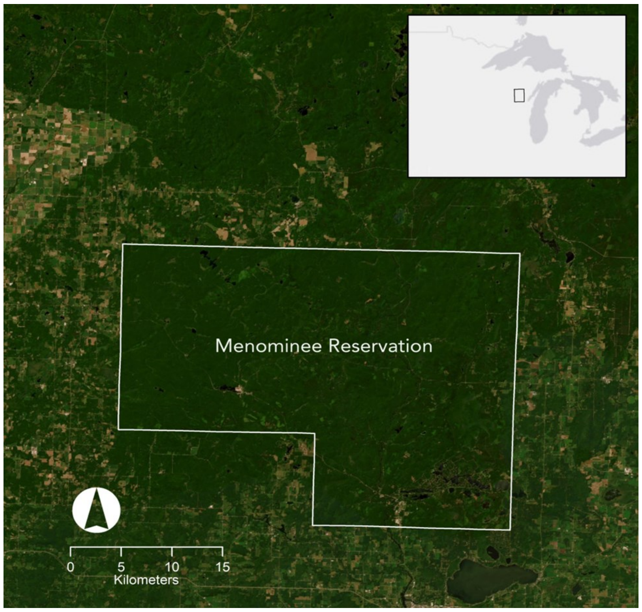

Figure 1 Location of the Menominee Reservation (outlined in white).

today at the Reservation in the topographic expressions of archaeological features including agricultural storage features, burial mounds, subterranean house basins, and dozens of confirmed raised agricultural garden bed sites. These preserved archaeological expressions provide increasingly rare glimpses into the scale of ancestral Indigenous land use that have elsewhere been largely erased in the American Midwest (McLeester and Casana 2021).

Ongoing archaeological investigations of ancestral agriculture at the Menominee Reservation and elsewhere in the northern Great Lakes show that for roughly a millennium, ancestral Indigenous communities in the region conducted agriculture in raised beds, a practice common throughout eastern North America (Doolittle 2000; Overstreet and Grignon 2021; Overstreet et al. 2020; Sasso 2003; Sasso and Joyce 2006). Raised beds at the Reservation (Figure 2) are primarily constructed in rows created either by hilling the surrounding dirt or bringing in sediments from wetter, nutrient-rich environments (Gallagher et al. 1985; Gallagher and Sasso 1987; Gartner 1999; Munson-Scullin 2022; Sasso 2003). Excavation of beds at the Reservation and regionally has shown that they were primarily used for growing maize, beans, and squash, along with additional plants based on preference (McLeester and Casana 2021; Overstreet and Grignon 2021; Overstreet et al. 2020; Sasso 2003).

Agriculture practiced under marginal cultivation conditions, like those at the Menominee Reservation, leaves little room for error. With its cold climate and short growing season, the northern United States is inhospitable to many crops, including maize, and ridged fields were a critical technology for the cultivation of maize near its northernmost extent. These raised beds helped mitigate risks by improving soil fertility, moisture, nutrient cycling, and suppressing diseases and pests (Gartner 2003). They additionally extended the length of the growing season by absorbing more sunlight (Munson-Scullin and Scullin 2023) and draining radiation frost (Boyd and Surette 2010; Gartner 1997; Riley and Freimuth 1979). The construction of ridged beds involved not only a topographic reworking of the earthen surface, but often a reworking of the soil itself, with the addition of a variety of amendments, like charcoal, to ensure a successful harvest (Gallagher et al. 1985; Munson-Scullin 2022; Munson-Scullin and Scullin 2023).

The widespread destruction of archaeological sites, including archaeological garden beds, in the American Midwest poses significant challenges to investigating the long-term ecological impacts of ancestral Native American farmers. Central to this study, the dozens of confirmed ancestral Menominee raised agriculture bed sites and numerous suspected past agricultural sites at the Menominee Reservation (Overstreet and Grignon 2021) provide a unique opportunity to explore whether or not past Menominee agricultural practices have lasting ecological impacts. Here, we report on a pilot study of the long-term impacts on vegetation associated with ancestral Menominee agriculture at the Menominee Reservation. Results obtained from observational data demonstrate that vegetation differences are evident between agricultural beds and off-bed cultural spaces; however, the impacts varied at each location. Overall, data suggest that ancestral Menominee farmers have had lasting impacts on the local ecology.

Site Background

Vegetation surveys were conducted at three of the more prominent ancestral agricultural sites at the Reservation: Joe Dick Road, Five Islands, and Wayka. All three archaeological garden bed sites are located along the Wolf River, which runs through the Reservation (Figure 3). While there are dozens of confirmed and unconfirmed ancestral agricultural sites, the three sites for this study were selected

Figure 2 Photograph of garden bed ridges at the Wayka Creek archaeological site. Two beds indicated by pink arrows (Photo taken by McLeester).

because the College of the Menominee Nation has conducted archaeological research at each and confirmed their use for agriculture through phytoliths, macrobotanical analysis, and/or bed construction techniques (Overstreet et al. 2020). At all sites, the College has ruled out any other use than agriculture at these locations. Moreover, the sites are associated with the Wolf, Deer, and Sturgeon clans, whose families have passed down accounts of agriculture at them. Joe Dick Road, Five Islands, and Wayka are all ridged bed sites, and they are all forested today.

While significant time has passed since their agricultural usage, there is no record of forestry, road, or settlement history directly at the surveyed garden sites or areas selected for controls, to our knowledge. There were also no prescribed or other fires per Menominee Forestry Department records. Additionally, there were no floods and no grazing animals recorded at or near the sites, and large trees indicate that this was the case for at least 100 years. In the past when agriculture was being practiced at the study locations, the canopy would have been open and free of trees. A shift to a forested environment is evident within the stratigraphic phytolith record, yet clear dates on agricultural efforts and forest growth (or regrowth) remain to be established (Munson-Scullin 2022).

Joe Dick Road is an agricultural village site occupied around 1000 to 1200 CE (Overstreet et al. 2020). It comprises several house basins, over a dozen ridged beds, and a collection of over 1,000 surface depressions that are interpreted as subterranean storage features, primarily used for storing agricultural products. There are two separate areas of the site that contain garden beds, described as east and west beds, together comprising a known area of about 700 square meters. Our analysis took place at the eastern group. Timber was recently harvested in areas directly outside of the archaeological site boundaries closer to the western group, resulting in closer sampling on and off garden beds than at other sites.

The Five Islands archaeological village contains a similar composite of house basins, storage features, and ridged garden beds as well as a tapered burial mound. The site dates to approximately 800 to 1100 CE and may have an earlier component (Overstreet et al. 2020). The area of ancestral agricultural ridges measures approximately 2,000 square meters. Our sampling occurred at the northernmost ridges near the Wolf River.

The Wayka site is located along Wayka Creek. The site is not dated, and no diagnostic artifacts have been uncovered. A precontact village is documented on the other side of Wayka Creek; a historic medicinal lodge and lacrosse field are also located nearby. Wayka contains the largest ridged beds of the study (Figure 2). The estimated area is approximately 2,500 square meters.

Methods

All surveys were conducted by McLeester and Anastasio over several days in mid-June 2022, following a preliminary study undertaken in 2021 by McLeester, Anastasio, and Grignon. At each site, 2mx2m quadrats were laid out along field ridges and compared to 2mx2m quadrats off of the ridges in areas with similar ecology. The location of the subsequent quadrat was determined at random by flipping a coin for north-south, then again for east-west. Quadrats were at least 5m from each other; the minimum distance between an on- and off-bed quadrat was at least 30m. At each site, all vascular plants in at least five quadrats (i.e., a minimum of 20m^2) were identified. Additional quadrats were added until no new plant species were identified (Armstrong et al. 2021), to maximize likelihood of surveying rare species. The maximum number of quadrats needed for repetition was six (Figure 3), which provided us with a means to ensure that we were capturing the vast majority of plant species at these ancestral agricultural sites. Not all plots were selected at random, but instead placed to maximize plant diversity. In other words, we walked the sites looking for new plants and added plots as needed after our efforts at randomization. Thus, we do not expect plot size to have influenced our ability to locate rare plants. However, the time of year would have influenced this count, given the short sampling window. Future studies should consider multiple site visits. No plots contained trees, to maximize vegetation coverage. Instead, the closest trees to each corner of each plot (n=4 per plot) were identified to provide a preliminary assessment of forest composition. As such, tree data presented here is far from comprehensive, as we focused this study on ground coverage.

Any plants unidentifiable in the field were pressed for later identification. Those that were still

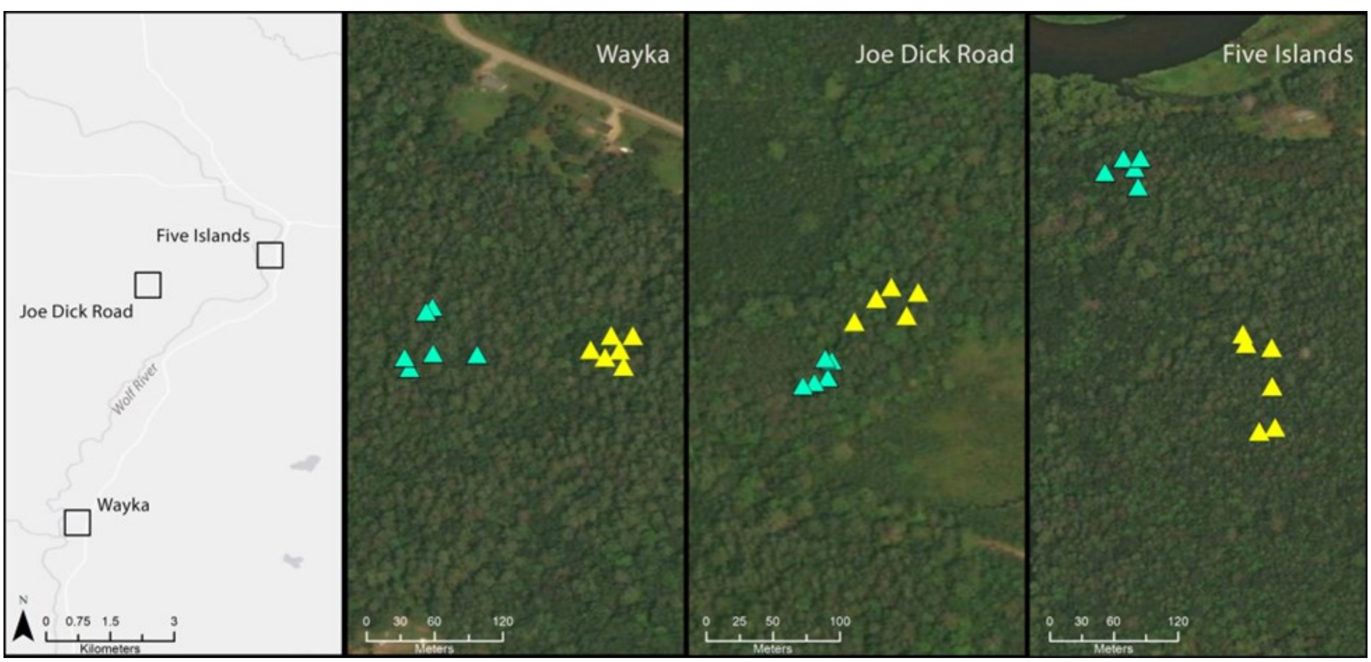

Figure 3 Location of plant surveys with on-bed quadrats in turquoise and off-bed quadrats in yellow.

unidentifiable at the species level were recorded as unique unknowns. Coefficients of conservatism (C value, ranging from 0–10), or the degree of fidelity a plant species has to specific habitats (Swink and Wilhelm 1994), for all identified plants were based on values provided in *Wisconsin Flora* (Chadde 2019). The C value assigned to a plant species reflects the probability that the species is likely to occur in high quality habitats (Chadde 2019). That is, a low C value indicates that a species can tolerate disturbance and potentially novel conditions, being found in a wide variety of habitats and conditions. Alternatively, species with a high C value are able to persist only in the narrow conditions found in high quality habitats. Generally, a mean C value of 0–3 indicates poor quality or disturbed habitat; an area of "high natural quality" would have a mean a C value of 4–7, while an average >8 suggests undisturbed habitat (Swink and Wilhelm 1994; Wilhelm and Rericha 2017). Relying on expert opinion to determine C values has been criticized as subjective methodology, and notably, Bauer et al. (2018) found that C values were correlated with life-history strategies such that highly productive, short-lived, early successional species had low C values, and long-lived late-successional species not often seen in disturbed areas had high C values (Bauer et al. 2018).

Plants with economic value to the Menominee were the most difficult category to establish, since knowledge and use, particularly of medicinal plants, can be highly personalized and varies from one individual to another (McLeester 2017; Smith 1923). Thus, we chose to be conservative in this category, and only identified plants as economically useful if they were recorded as such by Huron Smith, an ethnobotanist who worked closely with tribal members in the 1920s (Smith 1923), or listed by Frances Densmore, an anthropologist who worked with the Menominee on several occasions from 1925 to 1929 (Densmore 1932). No more recent ethnobotany specific to the Menominee has been published. While ethnobotanical texts exist for neighboring tribes and could be useful for a broader study, our focus here was specific to ancestral Menominee practices, since our research is located on ancestral Menominee land. Fuel wood was also excluded, since these sources were not recorded by Smith or Densmore, and it is difficult to know without archaeological evidence what woods were preferred for fuel.

Results

A total of 95 distinct species were identified across all sites. Of these, 81 specimens were identified to genus, 71 to species, and 14 were unknown. Eight species were located at all three sites in on- and off-bed contexts: *Acer saccharum*, *Anemonoides quinquefolia*, *Carex pensylvanica*, *Maianthemum canadense*, *Oryzopsis asperifolia*, *Pinus strobus*, *Trientalis borealis*, and *Viburnum acerifolium*. Twenty-six species were found on-bed at one site and never off-bed, but no species was unique to the agricultural beds at more than one site. Twenty-four species were found off-bed at one site and never on-bed; two species, *Rubus occidentalis* and *Smilax tamnoides,* were unique to off-bed contexts at two and three sites respectively (Table 1).

When comparing between on-bed and off-bed contexts, there is a clear distinction in total species identified (species richness) between contexts. At both Five Islands and Wayka, off-bed contexts had more species. The opposite trend was observed at Joe Dick Road, where on-bed contexts had more observed species than off-bed (Table 2, Figure 4).

The coefficient of conservatism (C value) at all sites were comparable, with means ranging from 5.41 to 5.78, indicative of high-quality habitat at all locations (Table 2). Of the eleven identified species with a C value of 8 or 9, seven were found both on- and off-bed, two were found only on-bed, and two were found only off-bed (Table 1).

The presence of economic plants varied. Overall, more economic plants were found in areas with higher species richness. At Wayka, 48% of the off-bed plants were identified as economic versus only 35% on-bed. At Joe Dick Road, 52% of plants on-beds were economic and only 44% were off-bed. The percentage of identified economic plants were only 3% different at on and off bed contexts at Five Islands (Table 2).

Discussion

The ancestral agricultural sites analyzed here have complex land use histories and remain dynamic landscapes today. Beyond their own land use histories, what we know of ancestral Indigenous raised bed agriculture is limited, and flexible practices of raised bed farming likely varied from place to place and farmer to farmer (Munson-Scullin 2022). Therefore, it is impossible to conclusively unpack the likely many interconnected causes of the preliminary patterns identified. However, our findings provide details of

Table 1 Plants identified to species level found at each site.

			Wayka Creek		Five Islands		Joe Dick Rd.	
Species	**C value**	**Economic**	**on-bed**	**off-bed**	**on-bed**	**off-bed**	**on-bed**	**off-bed**
Acer nigrum	5			x				
Acer rubrum	3		x	x				
Acer saccharum	5	y	x	x	x	x	x	x
Amphicarpaea bracteata	5							x
Anemonoides quinquefolia	6		x	x	x	x	x	x
Aralia nudicaulis	6	y			x	x		x
Asarum canadense	7	y					x	
Carex intumescens	5		x					
Carex pensylvanica	3		x	x	x	x	x	x
Carex rosea	4						x	
Carya ovata	5	y						x
Caulophyllum thalictroides	8	y		x			x	
Chimaphila umbellata	8	y	x			x		
Clintonia borealis	7	y		x		x	x	
Cornus alternifolia	7	y	x	x	x		x	x
Corylus cornuta	5	y	x	x				
Dendrolycopodium dendroideum	7							x
Diervilla lonicera	6	y		x	x			
Diphasiastrum digitatum	6					x		
Dryopertis expansa	8		x					
Dryopteris carthusiana	7		x	x		x		
Dryopteris expansa	8			x	x		x	x
Enemion biternatum	7		x					
Epifagus virginiana	9		x					
Fagus grandifolia	8	y	x	x		x	x	x
Fraxinus pennsylvanica	2			x	x		x	
Galium aparine	2		x			x		
Galium triflorum	5	y			x	x	x	
Gaultheria procumbens	6	y			x	x	x	
Goodyera oblongifolia	8					x		
Hepatica americana	7	y	x	x				x
Impatiens capensis	2				x			
Lactuca biennis	3		x					
Leersia virginica	5							x
Lonicera canadensis	8	y	x	x	x	x	x	
Lycopodium obscurum	7				x			
Maianthemum canadense	5		x	x	x	x	x	x
Mitchella repens	6	y	x	x	x	x	x	
Mitella diphylla	8	y		x	x	x		
Oryzopsis asperifolia	6		x	x	x	x	x	x
Ostrya virginiana	5				x			
Parthenocissus vitacea	4					x		
Pinus strobus	5	y	x	x	x	x	x	x
Polygonatum biflorum	4	y			x	x	x	x
Populus deltoides	2				x			
Populus tremuloides	2			x		x	x	
Prunus serotina	3					x		

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			Wayka Creek		Five Islands		Joe Dick Rd.	
Species	**C value**	**Economic**	**on-bed**	**off-bed**	**on-bed**	**off-bed**	**on-bed**	**off-bed**
Prunus virginiana	3	y	x	x	x	x	x	
Pteridium aquilinum	2			x	x	x	x	x
Pyrola elliptica	6		x	x	x	x		x
Quercus alba	7	y	x	x		x		
Quercus bicolor	7					x	x	
Quercus ellipsoidalis	5	y		x				
Quercus rubra	5		x	x	x	x	x	
Quercus velutina	5	y				x		
Ranunculus recurvatus	5					x		
Ribes lacustre	9	y		x				
Rubus occidentalis	2	y		x		x		
Rubus pubescens	7			x				
Schizachne purpurascens	7					x		
Smilax tamnoides	5			x		x		x
Staphylea trifolia	7			x	x			
Tilia americana	5	y		x		x	x	
Toxicodendron radicans	4			x	x			
Trientalis borealis	7		x	x	x	x	x	x
Trillium grandiflorum	6	y	x	x	x		x	x
Tsuga canadensis	8	y			x	x	x	x
Vaccinium angustifolium	4	y				x		
Viburnum acerifolium	7	y	x	x	x	x	x	x
Viola labradorica	4		x					

vegetation from archaeological agricultural sites and differences among them, and the results present an opportunity to highlight features of the raised bed agricultural technique that will add to a rapidly growing literature on long-term Indigenous ecosystem impacts (e.g. Ellis et al. 2021; Ford and Nigh 2015; Hecht et al. 2014; Larson et al. 2021; Lightfoot et al. 2013; Slade et al. 2021).

At all sites analyzed at the Menominee Reservation, the coefficient of conservatism (C value) indicates high quality habitat in both on- and off-bed contexts. High quality habitat across sites is consistent with our field observations as well as a credit to the MITW who for millennia have practiced sustainable land use at these spaces. While these data are most likely to be affected by whether or not we could identify a plant to species level, the mean C values ranging from 5.4 to 5.8, suggest that individual plant species do not affect the general ecosystem health interpretation. That said, Five Islands had a slightly lower coefficient of conservatism across bed contexts when compared to the other archaeology sites (Table 2).

Upon undertaking this study, we anticipated clear patterns in terms of species richness and expected that garden beds would either enhance or limit growing conditions for plants; however, no definitive pattern was observed. At two sites, Five Islands and Wayka Creek, we observed garden beds had fewer total species than uncultivated spaces (Figure 4). One possible explanation for this finding is decreased nutrient availability of soils from past agricultural practices. Garden beds were active spaces that had to first be constructed and then regularly maintained, recharged, and rebuilt in order to ensure a successful harvest. For both construction and maintenance, earth was mounded using nearby soils and/or soil was imported from nutrient rich spaces, like wetlands (Gallagher 1992; Munson-Scullin and Scullin 2021). Soil amendments, including “muck soils” (Munson-Scullin 2022), like those from wetlands, and charcoal, helped retain moisture and increase nutrient availability. Garden beds required regular rebuilding and reshaping, especially after winter or strong storms (Munson-Scullin 2022). The longer a bed was in use, the more maintenance it could require, as soils

Table 2 Summary of species richness, C values, and % economic plants at each site.

Site	On-Bed Species Richness	Off-Bed Species Richness	Species shared at on and off-bed contexts	On-Bed Mean Coefficient of Conservatism	Off-Bed Mean Coefficient of Conservatism	% On-Bed Economic Plants	% Off-Bed Economic Plants
Joe Dick Rd.	33	25	15	5.59	5.78	52%	44%
Five Islands	40	44	20	5.39	5.41	38%	41%
Wayka Creek	34	42	21	5.73	5.59	35%	48%

become less productive over time (Arnáez et al. 2015; Ghanem et al. 2011; Munson-Scullin and Scullin 2005; Sandor et al. 1990, but see Mt. Pleasant 2015). While this hypothesis is intriguing, anthropogenic soils can sometimes *increase* soil fertility for centuries, such as in locations throughout the Amazon where observed anthropogenic *terra preta* soils are more fertile than surrounding unaltered soils (Glaser et al. 2001). Here, the Menominee farmers were recharging and shaping soils with various amendments throughout the fields' use, and it is impossible at this stage to untangle soil fertility from other factors that may affect this area over the past centuries.

Economic plants were observed to concentrate areas with higher numbers of species at all three sites. Thus, areas with higher quality environments have a larger proportion of species with economic value, but it is not clear why this is the case. In addition, all the plots are located in actively managed environments that have been part of the Menominee landscape for millennia and remain so, providing an additional variable to our analysis. Further, some of these

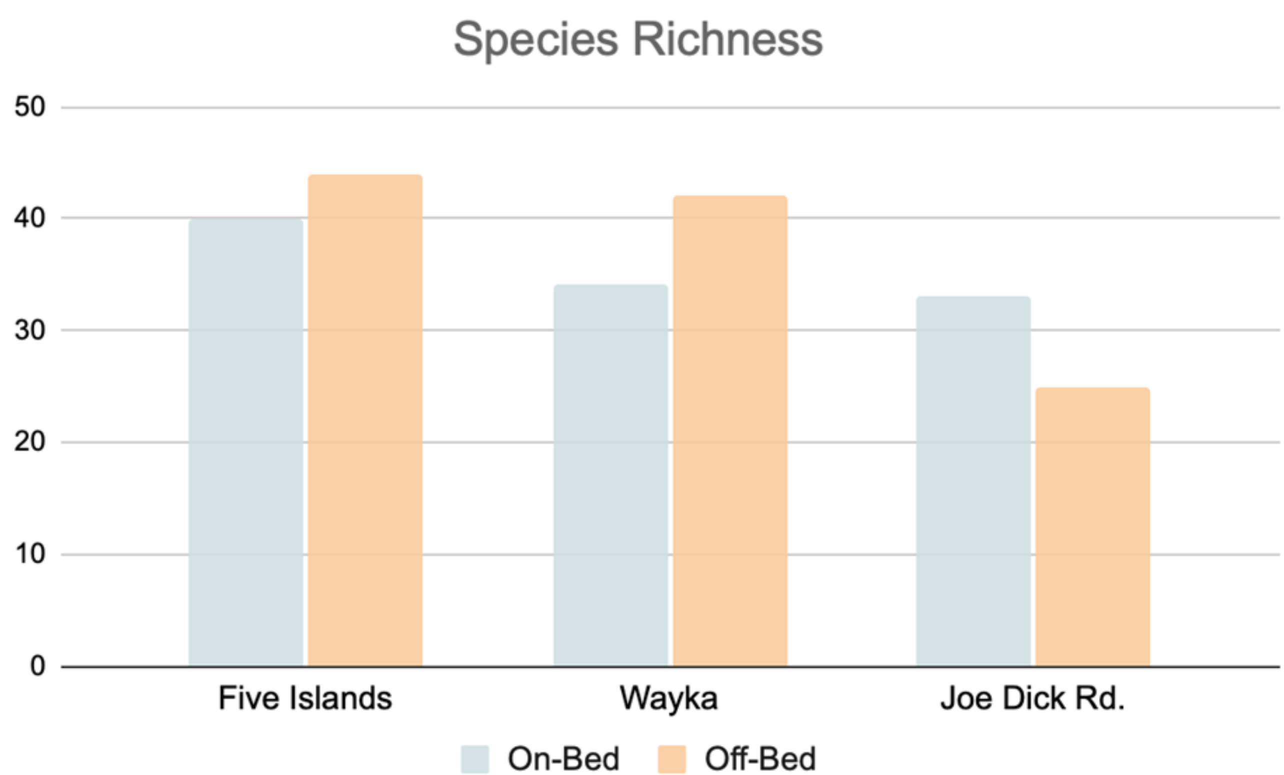

Figure 4 Total species identified at each sampling location.

economic plants may have been encouraged at different points in time.

Conclusion

Ancestral Menominee maize farming near its northernmost extent required significant investment of time and labor and a tremendous reworking of the earth surface and soils. These efforts appear to affect vegetation long-term, seemingly impacting vegetation patterns up to a millennium later. However, the variety of techniques, range of ecosystems in which they are practiced, and length of agricultural efforts likely influence the severity and nature of these impacts. Centrally, the Menominee Indian Tribe of Wisconsin have preserved these now-rare agricultural archaeological sites making analyses like this and future investigations possible. Overall, our findings illustrate that the long-term ancestral and contemporary land use of the Menominee people shaped the biologically diverse ecosystems and dynamic anthropogenic landscape we see today.

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Declarations

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