A New Paradigm for Pre-Columbian Agriculture in North America

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ABSTRACT Indigenous farmers in pre-Columbian North America have frequently been characterized as shifting cultivators whose agricultural productivity was marginal and unstable, and whose actions were damaging to the environment. In this article I challenge this assessment. The presence of large tracts of highly productive soils in eastern and central North America suggests that farmers here would not have engaged in shifting cultivation, but, rather, practiced permanent, intensive cropping. The lack of plows, often cited as an impediment for Native American farmers, was in fact an advantage. Agricultural systems using hand tools cause less destruction of soil organic matter and reduce soil erosion; they enable sustained crop yields over longer periods compared to plow-based systems. Indigenous farmers in North America also grew a highly productive cereal grain, maize, uniquely suited to no-plow conditions because of its large seed size. Maize yields of twenty-five to fifty bushels per acre were both realistic and stable, which allowed indigenous farmers to support modest populations for extended periods. This combination of access to fertile soils, a cropping system that preserved soils, and a high-yielding grain crop enabled an agricultural system that was largely productive and stable and had limited negative effects on the environment.

Cahokia, the site of the largest and most complex pre-Columbian settlement north of Mexico, has attracted the interest of scholars for more than 150 years. Since the 1980s researchers have struggled to explain Cahokia’s emergence in the eleventh century and its decline some 150 to 200 years later. Scholars have hypothesized that intensive maize production was a key factor in supporting the high population surrounding Cahokia and enabling the development of its complex physical, social, and political institutions. Researchers have also identified Cahokian agricultural practices, and their

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subsequent negative effects on the environment, as a probable cause for its decline.¹

Most researchers assume that agricultural practices in Cahokia were typical of indigenous farmers throughout much of eastern and central North America and were reflective of crop production at other Mississippian sites. They generally characterize Native farmers as shifting cultivators who cut forests, burned the vegetation, and then planted in the ash for one or more growing seasons. These farmers opened new lands when soil fertility declined in the original field, returning to the field only after it had been fallowed for many years to allow nutrients to accumulate in the forest regrowth.² Researchers have further hypothesized that these agricultural


systems in eastern North America, primarily maize-based, seldom produced more than marginal yields. When populations increased, indigenous farmers cleared additional forest, which led to erosion and flooding. Or they shortened the length of fallow periods, creating a downward spiral of crop yields because soil fertility was never allowed to fully regenerate. Within this paradigm, indigenous farmers are described as marginal producers who often sowed the seeds of their own downfall through their negative effects on the natural resources on which they depended.

I argue that almost every aspect of this framing of Cahokian agriculture is wrong, and, by extension, characterizations of pre-Columbian agriculture in central and eastern North America are likewise inaccurate. Researchers have gotten this story wrong because of two factors: they lack fundamental agronomic knowledge, and they have been blinded by Eurocentric assumptions and thinking. Most scholars who write about pre-Columbian agriculture have expertise in archaeology, anthropology, geography, history, and paleobotany. They often have extensive knowledge about specific plants and the changes that occurred in them as humans moved from incipient agricultural activities, through plant domestication, and into full-scale agricultural systems. But they lack knowledge about critical aspects of agricultural production, such as planting methods, including field preparation, plant population, and spacing; soil and nutrient management; and pest control. These factors determine the productivity and stability of all agricultural endeavors and should be central to an analysis of pre-Columbian agriculture. My training as an agronomist and soil scientist enables me to understand and evaluate agricultural systems more fully than scholars without this expertise. I bring this perspective to my analysis of these pre-Columbian cropping systems and consequently arrive at much different conclusions.

Most scholars of pre-Columbian agriculture function within a worldview that privileges Western knowledge and the societies that arose in the Near East and Europe. While many academics strongly assert their own objectivity, viewing their research as value-neutral and an unbiased search for truth, others argue that knowledge is always socially constructed, reflecting the cultures, institutions, and priorities of the communities from which one comes. In his 1978 book, Orientalism, Edward Said provided one of the


first and most articulate explanations of the ways in which Western scholars, embedded within a worldview that assumes a central and superior position for Western civilization, intrinsically see all others as inferior. Though Said specifically addressed the analytical problems within much Western scholarship on the “Orient,” multiple researchers have extended his analysis, critically examining relationships between Western scholarship and other non-Western peoples. Moustafa Bayoumi and Andrew Rubin write, “Native Americans, Africans, Asians, Latin Americans, and other colonized peoples and oppressed groups located in Orientalism a method to challenge a chronic tendency of the West to deny, suppress, and distort their cultures and histories.” Bruce Trigger, a senior North American archaeologist, asserted in 1984 that archaeological studies of Native Americans had been complicit in the colonial process: “Colonialist archaeology, wherever practiced, served to denigrate native societies and peoples by trying to demonstrate that they had been static in prehistoric times and lacked the initiative to develop on their own. Such archaeology was closely aligned with ethnology, which . . . also documented the primitive condition of modern native cultures. This primitiveness was seen as justifying European colonists assuming control over such people or supplanting them.” More recently Ian McNiven and Lynette Russell have argued, “The discipline of ‘prehistoric’ archaeology, as practiced on Indigenous cultures, is founded upon and underwritten by a series of deep-seated colonialist and negative representational tropes of indigenous peoples developed as part of European philosophies of imperialism over the last 2500 years.” In Decolonizing Methodologies the Maori scholar Linda Tuhiwai Smith vigorously critiques the Western research agenda from an indigenous perspective; she describes “research as a significant site of struggle between the interests and ways of knowing of the West and the interests and ways of resisting of the Other.”

Scholarship on indigenous peoples’ interactions with their environments is a significant site of conflict. Westerners have historically categorized

North American Native peoples and their interactions with the environment in dichotomous terms: either as primitive beings who were incapable of managing their natural resources to advance their communities, or as Noble Savages who lived in a primitive but harmonious relationship with the land. More recently, in the latter decades of the twentieth century, many have described indigenous peoples of North America as ecological Indians, possessing deep environmental knowledge that allowed them to live sustainably on their lands. In this view, ecological Indians were the first conservationists. This idea has been contested by multiple scholars who claim that Native people frequently altered their environments, often causing significant environmental degradation. These scholars argue that characterizing Native peoples as inherently attuned to their environments ignores substantial contradictory evidence. The anthropologist Paul Nadasdy suggests that placing Native peoples' environmental practices on a continuum from exploitative to conservationist simply represents another attempt to judge them from an imperialist perspective; it requires a Western paradigm for evaluating human use of natural resources, without any reference to or knowledge of indigenous peoples' standards or criteria for how they evaluate their environmental interactions.

Scholarship on the development and practice of agriculture presents yet another area where unacknowledged European-based values shape the analytic paradigm employed. Deliberate and intensive crop production represents a profound change in human societies, allowing for increased human populations, the emergence of cities, and the development of more complex social, political, economic, and cultural institutions. Agriculture also dramatically alters peoples' interactions with their environments, often leading to extensive clearing of forests, disruption of native plant communities, soil disturbance, and effects on water. Western scholars have examined the


development of indigenous agriculture in the Americas in both of these contexts, as an indicator of the development of complex social and political lifeways, and for its effects on the environment. In North America, as noted above, they have acknowledged the role of agriculture in the development of complex societies such as that of Cahokia, and they have also claimed that intensive agriculture led to the fall of the Cahokia as a result of environmental degradation directly linked to farming.

In both instances, I argue that these scholars are mired in a worldview that blinds them to a more accurate analysis of indigenous agriculture. Specifically, these scholars position Western agricultural traditions and practices as the standard against which all others are judged; the history of agricultural development in the Mediterranean and Europe is used to represent the pathway of agricultural and human progress. Indigenous agriculture is described in terms of what it lacks: plows, draft animals, manure, and inorganic fertilizers. I challenge this framework because it privileges a Western paradigm of agricultural development without providing evidence that supports the implicit assertion that there is only one (Eurocentric) model of agricultural progress. These scholars have been unable to observe indigenous forms of agricultural practice without cloaking them in universalist paradigms about development that position indigenous peoples on a scale ranging from primitive to advanced, solely on the basis of Western criteria.

The consequences of this can be seen in Paul Delcourt and Hazel Delcourt’s 2004 book, *Prehistoric Native Americans and Ecological Change*, where they claim they are “developing a new synthesis forged from the extensive literature in ecology, archaeology, and Quaternary paleoecology” to describe Native Americans’ effects on the environment more accurately. Implicit in

their analysis is the categorization of indigenous peoples as ecological Indians or environmental degraders. They reject the model of ecological Indian, concluding that “prehistoric Native Americans also contributed to environmental degradation by over-exploitation of wood resources and intensive cultivation on non-indigenous crops.”¹⁵ As I elaborate below, their work demonstrates the analytical weakness in much current scholarship on pre-Columbian agriculture that my essay seeks to reveal: their scientific analysis of agriculture is flawed, their reliance on Western standards for evaluating agriculture distorts their analysis, and their framework of environmental sustainer versus exploiter has limited explanatory value for indigenous peoples in pre-Columbian America.

As a scientist of Haudenosaunee heritage,¹⁶ I have spent much of my professional life working with scholars across multiple disciplines who deconstruct the assumptions that underlie the ways in which researchers portray and evaluate indigenous peoples and their communities, both in modern times and historically. We challenge the historical narratives about indigenous peoples that spring from Eurocentric beliefs and assumptions for two reasons: first, these narratives are frequently inaccurate, and, second, inaccurate representations can have profound negative consequences for present-day indigenous communities. Many non-Native researchers who study Native Americans see their scholarship as based in the past; they examine peoples, institutions, events, and things long disappeared. These scholars often assume their research is a neutral pursuit of knowledge, devoid of power and politics; they see no connection between the ancient peoples they study and existing indigenous communities. Native scholars see it differently. Indigenous communities in North America today face profound challenges that stem directly from five hundred years of colonization; the past and present are tightly connected. We struggle to assert independent political status and to preserve languages and social, political, and economic institutions. We live on vastly diminished land resources, often polluted and degraded by the larger settler states that surround our territories. Our struggles play out in courtrooms and federal and state agency hearings, frequently focused on three issues critical to indigenous communities:

¹⁶. *Haudenosaunee* is another term for Iroquois, or Native peoples who belong to one of the Six Nations (Mohawk, Oneida, Onondaga, Cayuga, Seneca, and Tuscarora) of the Iroquois Confederacy. My paternal grandmother was Seneca, from the Grand River Territories in present-day Ontario, Canada, and my paternal grandfather was Tuscarora, from their territories near Niagara Falls. My father was born
political recognition, land claims, and environmental regulations. Local and state governments, and often the federal government as well, vigorously contest attempts by Native nations to assert control over land and resources. Government officials use this research to challenge Indigenous peoples’ understanding of their own histories and belief systems. It provides a rationale to discredit Native land claims and to deny Native peoples the power to establish environmental (and other) regulations within their traditional territories. As Darren Ranco, a Penobscot scholar, explains in his critique of Shepard Krech’s “Ecological Indian,” “Scholars … by claiming interest only in truth . . . are understood as experts by courts of law around the world.”

Western experts who portray pre-Columbian farmers as environmental degraders support government agencies determined to portray modern-day Native peoples as little different from non-Natives. When scholars conclude that Native peoples degraded their environments, they contest current Native nations’ claims of traditional environmental values and practices. Scholarship regarding maize is especially significant. Maize occupies enormous cultural space in many present-day Native communities, a fact that reflects deeply held traditions that describe and shape our relationships with the natural world and each other. The history of maize agriculture has immense importance to indigenous communities across North America.

In this essay I challenge the authority of numerous archaeologists, anthropologists, historians, and ecologists and their characterizations of pre-Columbian agriculture in North America. I bring to this discussion extensive knowledge of how people grow crops and manage soils, and I operate within a worldview that places indigenous farmers on equal footing with those in Western traditions. This combination of agronomic expertise and a critical lens on Eurocentric theoretical paradigms has been absent from the scholarship and discourse on pre-Columbian agriculture in North America.

I claim that indigenous cropping systems in North America were predominantly permanent and intensive, rather than fallow-based shifting cultivation. Furthermore, indigenous maize agriculture was highly productive and raised at Tuscarora. Although I am not an enrolled member of the Nation, I identify as Tuscarora.

and stable; there was little negative effect on the environment, largely because of the presence of fertile soils and the absence of plows. I develop this argument on multiple fronts. First, the underlying rationale for fallow-based agriculture assumes that farmers are located on infertile soils. But in eastern North America, indigenous farmers had access to hundreds of thousands of hectares of enormously fertile soils. They would not be likely to abandon productive fields to cut down large tracts of forest, labor intensively to clear new fields, and then repeat the process a few years later. Second, many scholars argue that even on fertile soils, indigenous farmers who cropped the same fields for multiple years would have depleted soil nutrients and been forced to open new lands. They base their reasoning on the experiences of Euro-American farmers, who during (and after) colonization suffered dramatic declines in crop yields after several years of continuous cultivation if they did not apply manure or other fertilizers. Many scholars have incorrectly assumed that declining soil fertility under Euro-American plow agriculture can be used to model soil fertility in cropping systems of indigenous peoples who didn’t use plows. But the oxidation of soil organic matter, which controls plant-available nutrients in subsistence agricultural systems, depends largely on the extent and intensity of tillage. As a result, fields under hoe culture would not experience the same fertility dynamics that occur in plowed lands.

Finally, numerous scholars have claimed that even in the best of times indigenous farmers produced marginal maize. With modest increases in population, they argue, farmers would have been forced to clear larger areas of forest or shorten the length of fallow periods (or both) in order to feed their communities. These actions would cause soil erosion and flooding and result in lower crop yields that further destabilized both the natural environment and the associated social and political institutions of indigenous communities. But significant evidence contradicts this assumption of marginal crop yields, particularly in areas with fertile soils. Ethnohistorical

records and modern field experiments suggest that indigenous maize agriculture was both highly productive and stable.

I begin my argument with an in-depth examination of shifting cultivation from a global perspective because this discourse has largely shaped how scholars have viewed and analyzed indigenous agriculture in North America. For many scholars, indigenous agriculture and shifting cultivation are almost synonymous; they can’t discuss one without invoking the other. The mischaracterization of indigenous agriculture begins with false assumptions about shifting cultivation. Thus, to describe Native agriculture in North America more accurately, I start with an analysis of shifting cultivation, which requires an explanation of agronomic factors, including the interaction of crop characteristics (seed size, yield potential, growth habit), field preparation (tillage), and soil dynamics (nutrients and water) that shape all cropping systems.

In North America the soil resources available to pre-Columbian farmers in the midcontinent determined the characteristics of their agricultural systems. Familiarity with soil orders (specifically the presence of Mollisols, Alfisols, and Inceptisols, the most agriculturally productive soil orders in the United States) and maps detailing the location of Prime Farmland provide broad estimates of the soil resources available to pre-Columbian farmers in North America. In addition, maize productivity indices developed by the Natural Resource Conservation Service (NRCS) provide a valuable tool to characterize and assess potential productivity of specific sites. I use these productivity indices, combined with Iroquois maize yields during the colonial period, to provide a more accurate estimate of the agricultural potential of Cahokia and Moundville, two of the largest Mississippian sites. Finally, I identify and discuss Eurocentric assumptions that have interfered with an objective analysis and interpretation of indigenous agriculture in North America.

**SHIFTING CULTIVATION**

Shifting cultivation (also referred to as swidden, slash-and-burn, milpa, or fallow-based cropping) has been the overarching framework within which scholars have placed indigenous agriculture in the Western Hemisphere.21

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21. Although indigenous agriculture in the Western Hemisphere is most commonly described as shifting cultivation, many scholars have recognized and studied more intensive or permanent forms of indigenous agriculture, including terrace agriculture, irrigated systems, and, more recently, raised beds and systems using enriched dark earth soils. See Scott L. Fedick, “Indigenous Agriculture in the
In this agricultural system, farmers cut the forest, burn the vegetation, and then plant in the ash, which provides nutrients for the crop for one or more growing seasons. Farmers abandon the field when crop yields decline, leaving them fallow for twenty, forty, or more years as they wait for the forest to regenerate. Nutrients accumulate within the vegetative biomass, which are released when the vegetation is cut and then burned, driving the next cycle of crop production. But within this apparently simple and straightforward explanation of a cropping system practiced by millions of farmers, from prehistory through modern times, lie a multitude of anomalies, contradictions, and outright errors that undermine this explanatory narrative at every step. Unraveling the assumptions of the paradigm of shifting cultivation requires agricultural science and a critical analysis of Eurocentric bias.

In 1919 O. F. Cooke, one of the earliest anthropologists to observe shifting cultivation and describe it for an academic audience, reported on a system that he called *milpa*, used by contemporary Mayan farmers in Guatemala. He identified these central characteristics: (1) it occurred in tropical regions where temperatures allowed year-round crop growth; (2)

trees and other vegetation were cut with axes, allowed to dry, and then burned; (3) the soil was not worked before or after planting, and seeds were planted directly in the ash with a digging stick; (4) fields required decades of fallow to restore soil fertility; (5) if farmers attempted to crop more intensively, the system collapsed within a few years, as crop yields decreased and landscapes were denuded; (6) it could not support high populations, as it required large amounts of land per capita, but was stable and reasonably productive if sufficient fallow periods were maintained.23

Cook observed similarities between this Mayan system of the early twentieth century and agriculture as practiced by “primitive” peoples in Asia, Africa, and other parts of the Americas. He suggested that it was a traditional form of agriculture that had been in place for centuries or longer. Cook surmised that Inca agriculture in the highlands of Peru had evolved from shifting cultivation, where the use of terraces, tillage, and fertilizers allowed them to crop their fields continuously and advance to a higher level of agricultural development. In contrast, he argued that the Mayas had brought on their own destruction because they were unable to modify shifting cultivation practices as their population increased. Cook’s descriptions and explanations established the academic baseline for the study of shifting cultivation. Today, with some exceptions, few scholars would find much to contest in his analysis. Over the last century, researchers across many fields have examined the system more closely, expanding and refining our understanding. Agronomists, anthropologists, archeologists, ecologists, economists, geographers, historians, and soil scientists have studied shifting cultivation to (1) describe the origins of agriculture and the development of human societies over time; (2) explore relationships between human communities and the environments in which they live; and (3) determine agricultural sustainability in past and modern communities. I review this literature below.

By the middle of the twentieth century researchers had begun to examine shifting cultivation systematically and to place it within a larger conceptual framework. Betty Meggars, an anthropologist, linked shifting cultivation to infertile soils and argued that people who depended on marginal soils for food production could not develop more complex social, political, and economic systems.24 In other words, shifting cultivators would have limited

food production capacity, and as a result would be unable to support large populations and more complex cultures. But this led to an immediate paradox, which was not resolved. Pre-Columbian Mayans apparently practiced shifting cultivation, but they supported large, dense populations in cities with complex social, political, and economic institutions.\textsuperscript{25}

About the same time, several researchers initiated in-depth fieldwork, studying present-day shifting cultivators to better understand the system as it functioned in modern times and as a tool for expanding knowledge about the development of agriculture across time. Harold Conklin’s work with the Hanunoo in the Philippines in the 1950s represented the first systematic effort to describe and characterize shifting cultivation through close, extended observations of farmers and their practices. Conklin, an anthropologist by training, also had considerable knowledge of botany, economics, and linguistics. He cataloged every stage of shifting cultivation, including site selection, cutting, burning, crop selection, planting methods, pest management, harvest, and storage. Conklin concluded that shifting cultivation as practiced by the Hanunoo was a relatively productive and very stable form of agriculture. But despite his intimate knowledge of shifting cultivation, Conklin didn’t question why these farmers fallowed their fields, rather than cropping them continuously. Why were they practicing shifting cultivation, rather than more permanent or intensive forms of crop production? Although he recognized the importance of soils and noted that they differed greatly across the areas that he studied, he made no explicit connection between soil characteristics and the need to fallow fields to allow them to accumulate nutrients for subsequent crop production. Conklin advocated further examination of shifting cultivation, including its ecological characteristics.\textsuperscript{26}

Two soil scientists, P. H. Nye and D. J. Greenland, took up the challenge of studying the relationship between soils and shifting cultivation. They observed that under low populations, shifting cultivation was a benign, although not very productive, form of agriculture. But when human populations increased, farmers reduced the fallow period to meet increased demand for food. Frequently, fields with decreased fallow periods became increasingly less productive and crop yields plummeted. A system that had been moderately productive and stable collapsed. As soil scientists, Nye and


\textsuperscript{26} Conklin, \textit{Hanunoo Agriculture}. 
Greenland wanted to determine the role that soils played both in the productive capacity of shifting cultivation and in its degradation. Examining shifting cultivation in tropical regions of Africa, Asia, and the Americas, they noted that shifting cultivation occurred primarily on the highly weathered upland soils (latosols, as they were classified then), found in large expanses across the tropics. The fallow period was essential to allow the accumulation of nutrients in the forest biomass, which were absent in the soil, to feed crops in the next cycle. Critically, they noted that younger soils with more nutrients often supported continuous cropping.\textsuperscript{27} Soil scientists today classify these highly weathered soils as Ultisols and Oxisols, acid soils with very low levels of nutrients for crop growth.\textsuperscript{28}

Ester Boserup, an economist, entered the discussion in 1965 with her book \textit{The Conditions of Agricultural Growth}. In opposition to Malthus, who claimed that food production ultimately constrained human populations, Boserup argued that increasing population actually drove the advancement of agriculture. As a measure of agricultural development, Boserup characterized cropping systems in terms of the intensity of land use, the length of a fallow period being the distinguishing feature. According to Boserup, long fallow periods characterized the earliest stages agriculture. Using this framework, she identified five stages of agricultural land use: (1) forest-fallow cultivation; (2) bush-fallow cultivation; (3) short-fallow cultivation; (4) annual cropping; and (5) multi-cropping. She further hypothesized that agricultural development globally followed this scenario, citing evidence that European farmers engaged in shifting cultivation in the Middle Ages, before they shortened their fallows and eventually developed annual cropping systems. In other words, shifting cultivators represent the beginning stages of agricultural development; we can observe the advancement of agriculture through the adoption of practices that systematically reduce the length of the fallow period. Farmers who reduce the length of the fallow reach the zenith in agricultural development: continuous annual crops planted with plows.\textsuperscript{29} Boserup further argued that when we focus on the frequency of cropping, the role of soils in explaining agricultural development becomes less important: “Thus, soil fertility, instead of being treated

\textsuperscript{27} Nye and Greenland, \textit{Soil under Shifting Cultivation}, 19.
as an exogenous or even unchangeable ‘initial condition’ of the analysis, takes its place as a variable, closely associated with changes in population density and related changes in agricultural methods.”30

The dichotomy between Nye and Greenland’s and Boserup’s views of shifting cultivation is striking. The soil scientists viewed shifting cultivation as a management strategy for growing crops on acid, infertile soils, with little or no connection to the arc of agricultural development. Boserup, on the other hand, identified shifting cultivation as a developmental stage, in which shifting cultivators were at the primitive origins of agriculture, in contrast to more advanced farmers who planted their crops continuously. Not surprisingly, European farmers were in the advanced group, while indigenous farmers in Latin America, Asia, and Africa occupied the inferior category. Scholars across a range of disciplines continued to examine shifting cultivation through the latter half of the twentieth century. Agricultural scientists focused on soils and nutrient dynamics within the ecosystem, building on the work of Nye and Greenland.31 Scholars in archaeology, anthropology, geography, and economics critiqued and revised Boserup’s framework, although much of her work has been largely accepted.32

30. Ibid., 13.
32. Most of the literature on Boserup has focused on the role of population as a driver of agricultural development (referred to as intensification since the 1970s), either agreeing with Boserup or aligning with Malthus. Several researchers, while accepting population as the primary driver for intensification, have argued for increased consideration of markets, labor, and other social factors in agricultural development. See David Grigg, “Ester Boserup’s Theory of Agrarian Change,” *Progress in Human Geography* 3 (1979): 64–84; Robert L. Hall, “An Interpretation of the Two-Climax Model of Illinois Prehistory,” in David L. Browman, ed., *Early Native Americans: Prehistoric Demography, Economy, and Technology* (New York: Mouton, 1980), 442–43; Robert C. Hunt, “Labor Productivity and Agricultural Development: Boserup Revisited,” *Human Ecology* 28 (June 2000): 251–77; Harold Brookfield, “Intensification, and Alternative Approaches to Agricultural Change,”
none of the scholars, whether agricultural or social scientists, recognized the fundamental contradiction between these two views of shifting cultivation. Soil scientists view shifting cultivation as a management strategy for infertile soils, whereas social scientists see it as an indicator of agricultural development.

David Harris significantly expanded our understanding of shifting cultivation systems in several papers written in the early 1970s. He focused on the characteristics of the specific crops and their relationships to one another in shifting cultivation systems. Although he failed to recognize the fundamental role of soils, he identified important ecological relationships within the system. J. Desmond Clark and Carl Sauer had earlier grouped crops in agricultural systems into two categories: seed cultures, which rely on seeds to reproduce, and vegecultures, where plant parts are used for reproduction. They classified cereal and legume grains such as wheat, rice, corn, and beans as seed cultures and root and tuber crops such as cassava, sweet potatoes, and yams as vegecultures. Harris noted that vegecultures in Latin America were more likely to be found in humid, tropical lowlands and incorporate a wider diversity of species, whereas seed cultures were found

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in the drier subtropics and exhibited significantly less plant diversity. Consequently, vegecultures comprised more complex ecosystems, which were inherently more stable than seed cultures. Harris also observed that crops like corn and rice make heavy demands on soils because they require significant amounts of nutrients, especially nitrogen, to produce grains with protein. In contrast, tuber and root crops have little or no protein but large amounts of carbohydrates (energy), and they can be grown successfully in soils with limited plant-available nitrogen. Seed-culture farmers remove a significant portion of the system’s nutrients, particularly nitrogen, when they harvest cereal grains. But harvested tuber and root crops contain only small amounts of nitrogen. From this he surmised that shifting cultivation systems based on seed cultures would be less stable than vegecultures and more likely to exhibit declining yields and other symptoms of ecosystems that were no longer in balance.35

Harris got several things right. He recognized that grain crops have much higher nitrogen requirements than tuber crops such as cassava. He also correctly observed that when grain crops are planted continuously on the same field, yields often decline, as soil nitrogen is depleted. In contrast, root and tuber crops can be grown continuously for longer periods in the same field without yields being affected. But he failed to accurately describe and account for two key elements in the system: soil fertility dynamics and tillage.

SOIL FERTILITY

For agronomists like myself, shifting cultivation addresses soil constraints faced by farmers who grow crops on acid, infertile soils and lack access to animal or green manures, forage legumes, or inorganic fertilizers. Today, shifting cultivators are typically poor farmers on poor soils who must rely on nutrients that accumulate in plant biomass during fallow periods to supply crop nutrients that are not available in their soils. But many farmers across the globe plant their crops in very fertile soils. These soils have pH values near neutral, which indicates the presence of substantial amounts of the basic cations needed by plants, and they contain modest to large amounts of soil organic matter. Farmers on these soils do not fallow their fields because the soils, at least initially, provide sufficient nutrients to meet crop needs. Consequently, a major determinant of any agricultural system is the initial fertility of the soils to which farmers have access. Farmers who

have infertile soils must immediately institute practices to provide nutrients that are not available in the soil. Those who start with fertile soils will plant their crops repeatedly in the same field, but over time they may experience declining yields.

The length of time farmers on fertile soils can plant their fields repeatedly before experiencing yield reductions depends largely on one factor: how frequently they plow. In fact, we can roughly estimate how long initially fertile soils will maintain their nutrient-supplying capacity by grouping cropping systems into those that use plows and those that don’t. Farmers who plow will run out of nutrients much more quickly than farmers without plows.

PLOWS AND SOIL ORGANIC MATTER

When farmers plow fields in preparation for planting, they oxidize soil organic matter. Plowing increases the oxidation of soil organic matter by breaking down soil aggregates and exposing more of the soil and particles of organic matter to air. When this organic matter oxidizes, it releases nutrients in forms that are available to plants. For example, when a fertile soil that has never been cropped, or has been in pasture or meadow for many years, is plowed, the oxidation of soil organic matter provides a flush of inorganic nitrogen (nitrates) that can be immediately used by cereal grains. Farmers will obtain high grain yields from these fields. But this mechanism of oxidizing soil organic matter to release nitrates does not work indefinitely. Large amounts of nitrates are released the first year, but in subsequent years, when the field is repeatedly plowed, soil organic matter levels gradually decline, and fewer nitrates are available each year. Grain yields decrease over time because eventually there is insufficient nitrogen for crop growth. When fields are plowed repeatedly, organic-matter levels decline until they reach a stable level, usually within two to four decades, when soil organic matter becomes very resistant to further oxidation. Soils with these lower levels of organic matter present many problems for crop growth: they have little ability to supply nutrients (nitrogen and others) for crops; they have poor structure and decreased water-holding capacity; and they are more prone to erosion and compaction. Farmers often refer to them as “worn out.”


37. Brady and Weil, The Nature and Properties of Soils, 528, describe the conflicting processes of soil organic matter accumulation and its decomposition as “the
Surprisingly, the grain crop captures only a portion of the nitrates released when fertile soils are plowed. Many of these nitrates are lost through leaching, volatilization, and erosion. Nitrogen held within soil organic matter is relatively immobile and stable, but once oxidized, the nitrates are soluble, moving with water through the soil profile. Nitrates are also vulnerable to volatilization and escape to the atmosphere as nitrogen gases. And they are lost in large quantities through soil erosion, as is organic matter itself. In other words, repeated plowing oxidizes soil organic matter, which releases many more nitrates than the crop can take up. Nitrates that are not captured by the crop are lost from the soil, eventually depleting the soil organic matter of a critically important plant nutrient. The lower the soil organic matter, the lower the ability of the soil to store other key nutrients in plant-available forms, especially calcium, magnesium, potassium, and a number of micronutrients. Phosphorus, oxidized from soil organic matter, can be rendered unavailable to plants through chemical reactions in the soil and will also be lost, along with organic matter, as soils become more susceptible to erosion.

In cropping systems that don’t use plows, oxidation of soil organic matter still occurs, but on a much smaller scale because much less of the soil is disturbed, fewer aggregates are broken up, and less organic matter is exposed to soil organisms. If the soil initially has high levels of organic matter, manipulating it with hand hoes or other small tools will encourage oxidation, releasing nitrates that are then available for crop uptake. But many fewer nitrates are produced than when the soil is aggressively worked with a plow. As long as sufficient nitrates are produced to meet crop needs, grain yields will be high. But, more important, the soil organic matter retains more nitrogen in a stable, immobile form; fewer nitrates are lost though leaching, volatilization, and erosion. Less organic matter in general is lost through erosion as well, which helps preserve other plant nutrients. Consequently, in cropping systems without tillage, loss of nitrogen and other essential nutrients by oxidation of soil organic matter or erosion is much slower; the soil releases nutrients over a much longer time frame.

38. One bushel of corn contains 0.8 lbs. of nitrogen; 25 bushels per acre would take up 20 lbs. of nitrogen. But soils can mineralize 46–267 lbs. per acre of nitrogen, depending on the amount of soil organic matter present and temperature and moisture levels.
When grain crops are planted repeatedly in these fields, soils are not depleted of nitrogen as quickly as in fields that are plowed.

Both farmers who start with low-fertility soils and those whose fertility has diminished over time with continuous cropping face the same problem; they must add nutrients to support crop growth. To many observers, these situations look very similar: the soils lack sufficient nutrients to support crop growth. But the underlying agricultural systems are fundamentally different. Most of the world’s low-fertility soils, Ultisols and Oxisols, are found in the humid and subhumid tropics. In contrast, farmers in temperate areas are more likely to farm Alfisols, Mollisols, and Inceptisols, which are among the world’s most productive agricultural soils.41

**SEED SIZE AND PLOWS**

Thus, all farmers operate within a matrix of soil properties and climate, which is further complicated by the intensity of their tillage operations. And, as Harris noted, crop characteristics also shape these systems; cereal grains require much more nitrogen than tuber and root crops. Harris, however, failed to understand the critical connection between crop characteristics and tillage. Most cereal grains must be planted in a finely prepared seedbed to facilitate germination, whereas tuber and root crops can be successfully grown in fields that are only roughly worked.42 Farmers who plant small-seeded cereal grains intensively plow their fields to create seedbeds that ensure successful germination of the small seeds. But farmers who plant vegetative plant parts, such as cassava or potatoes, do not need a finely prepared seedbed. These plants will thrive in very roughly worked fields. So it was that the earliest European farmers used plows to plant wheat, but the earliest farmers in South America planted cassava and sweet potatoes with nothing more than digging sticks.

Harris’s description of seed culture versus vegeculture seems to capture this distinction. But one crop, maize, does not fit the pattern. Maize, even though it is a cereal grain, thrives in roughly prepared fields that have not been worked with a plow. This apparent exception occurs because it is the size of the seed (or the plant part) that determines the kind of seedbed needed, not whether it is a cereal or a tuber. Maize kernels are almost ten

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times larger than wheat kernels.\textsuperscript{43} With large amounts of stored endosperm, maize kernels are hardy and vigorous; they can germinate and develop in soils where wheat and other small-seeded cereals would not survive. Thus, unlike wheat and most other cereal grains, maize can be successfully grown in fields prepared with hand hoes or planted without hoeing, using just a digging stick.

The central factors that shape cropping systems globally are soils, climate, tillage, and crops. Farmers on low-fertility soils are likely to be farming on Ultisols or Oxisols in the humid tropics. They can grow root and tuber crops, which have low nitrogen requirements, for relatively long periods on infertile soils without compromising yields. Because these crops can also be grown without intensive tillage, soil nutrients are further preserved, which enables farmers to use the same field continuously. But if these farmers grow maize, they will need to provide soil nutrients, primarily nitrogen, to obtain even modest yields. Farmers on infertile soils obtain these nutrients by cutting and burning vegetation accumulated during long fallow periods. In a field where the trees have been cut and burned, they may initially plant corn or rice, crops with high nitrogen requirements, to capture the nitrates release by burning the accumulated vegetation. After one or two grain harvests, they plant tuber and root crops with much lower nitrogen needs, harvesting them for several years, while the forest gradually regrows.\textsuperscript{44}

Farmers who have depleted their fertile soils through continuous cropping of cereal grains are more likely to be found in temperate areas, on Alfisols, Mollisols, and Inceptisols. But farmers who plow in order to plant cereal crops face a daunting problem. Their system is relatively unstable, as much nitrogen will be lost through the leaching, erosion, and volatilization that accompany tillage and decomposition of soil organic matter. As long as they plow intensively, they will have to add soil nutrients regularly or suffer significant reductions in grain yields. This describes the situation of most farmers in Europe, from the beginnings of agriculture there through the nineteenth century, when they finally identified practices that enabled them to maintain soil nutrients, even as they plowed.\textsuperscript{45}


\textsuperscript{44} Harris, “Ecology of Swidden.”

\textsuperscript{45} Mt.Pleasant, “Paradox of Plows.”
Ages through the eighteenth century, European farmers struggled to produce even ten bushels per acre of wheat. Many farmers discovered that resting their fields for one or two years allowed them to regain some fertility, but yields immediately declined again after just one or two grain harvests.

European farmers finally solved this problem by incorporating a forage legume, that is, clover (*Trifolium* spp.) into their cropping systems. Perennial legumes like clover mitigated the damage from intensive plowing, rebuilding the soil organic matter lost through plow-induced oxidation. Forage legumes replaced the nitrogen lost through soil organic matter oxidation and enabled farmers to produce wheat yields of twenty to thirty bushels per acre. Forage legumes also allowed them to dramatically increase their livestock, thereby producing much more manure than previously, and this was also applied to cropland. With these practices, European farmers were able to replace soil nitrogen lost through tillage with a cropping system that was productive and sustainable, even under plow agriculture. But rotating wheat with clover and other crops, commonly called the Norfolk rotation, did not become common in England until the latter half of nineteenth century and was adopted even later in Europe.

NORTH AMERICAN AGRICULTURE

We can make broad generalizations about agricultural productivity in a particular location simply by knowing the soil order. Within the United States, Mollisols and Alfisols, our most productive agricultural soils, are found over large sections of the midcontinent and account for the enormous agricultural productivity of today’s farmers in these regions. Inceptisols, found along or near rivers, also have high natural fertility and are present throughout the central and eastern portions of the continent. Less fertile Ultisols, located in the southeast, have a lower yield potential (figure 1).

But not all Mollisols, Alfisols, or Inceptisols will be agriculturally productive. They may be located in areas where crop growth is limited by lack of

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47. Mt.Pleasant, “Paradox of Plows.”
Figure 1. Mollisols, Alfisols, Inceptisols, and Ultisols in the United States. Source: www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053589.
water or in very wet areas where soils are frequently flooded or permanently wet. To more readily identify soils that are agriculturally productive, the NRCS (an agency within the United States Department of Agriculture [USDA]) uses the term *Prime Farmland*, defined as “land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops.” Enormous acreages of Prime Farmland are found throughout central and eastern North America. Thus, the presence of Alfisols, Mollisols, and Inceptisols, as well as soils classified as Prime Farmland (figure 2), indicate that many pre-Columbian farmers would have had ready access to large expanses of fertile soils.

Since shifting cultivation is a management strategy to address infertile soils, large areas of productive soils are strong evidence that farmers in North America would not have engaged in shifting cultivation. William Doolittle, a historical geographer, provides further support for this argument. In an extensive survey of all the documentary and archaeological evidence in North America for shifting cultivation, Doolittle concludes: “The overwhelming corpus of evidence clearly and convincingly indicates that although Native Americans cleared the forest by slashing-and-burning, they did so for permanent clearance. Cultivation typically involved little, if any, field rotation; perhaps biennial fallowing, but rarely, if ever, regular shifting of fields to new locations. The notion of swidden should perhaps be more appropriately labeled a myth.”

### MAIZE AGRICULTURE AND ENVIRONMENTAL DEGRADATION

But even if shifting cultivation in North America can be dismissed as a myth, many scholars claim that pre-Columbian farmers damaged the environment through extensive clearing of forests and exploitation of soil resources, which resulted in flooding and erosion. According to these scholars, Mississippian farmers, under increasing population pressure, exacerbated the negative effects on the environment by repeatedly cropping the same fields or clearing forests in marginal areas in an attempt to increase maize production. Maize yields spiraled down, leading to political and social instability in Cahokia and other Mississippian sites. William Baden

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provided a detailed assessment of maize productivity during the Mississippian era in the Little Tennessee River Valley. His model predicted that if maize was planted continuously, yields would decline steadily from a high of twenty-seven bushels per acre, when the field was first planted, to fewer than seven bushels per acre, when farmers would no longer be willing to invest labor for such low return. According to Baden, the combination of decreasing maize yields over time, increasing population, and insufficient land for agriculture resulted in widespread instability in this area during two periods, 900 to 1000 A.D. and again in 1300–1400 A.D. David Rindo and Sissel Johannessen suggested that maize production in the American Bottom initially led to increased human populations. But as more land was brought under cultivation, the maize-based system was associated with environmental degradation and increased flooding, all of which resulted in unstable maize yields. The system collapsed under these conditions. Neil Lopinot and William Woods argued that land clearing for agriculture, along

Figure 2. Prime Farmland in the United States. Each dot on the map represents 25,000 acres of Prime Farmland. Source: www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/?cid=nrcs143_013752.
with increased forest harvest for construction, caused flooding and environmental degradation that led to the collapse of Cahokia. Delcourt and Delcourt, relying extensively on Baden’s analysis, concluded that Mississippian farmers, in an attempt to cope with rising populations, cleared more land or decreased the fallow period on their cropped lands (or both). These actions degraded the soil, caused increased flooding, and resulted in a downward spiral of the crop yields, which ultimately led to the demise of Cahokia and other Mississippian settlements. Woods claimed that “the seeds for the destruction” of Cahokia can be found in its maize-based agriculture, rising population, and ensuing environmental degradation.51

These scholars make multiple errors in developing this narrative of environmental degradation associated with maize-based agriculture in Cahokia and the American Bottom. In addition to inaccurately characterizing Mississippian agriculture as shifting cultivation, they assume a marginalized agricultural system, implemented on vulnerable soils that were degraded under more intensive cropping with a grain crop—maize—characterized by low, unstable yields. These assumptions are incorrect.

Most Mississippian researchers acknowledge that alluvial soils (many of them Inceptisols), which are subject to intermittent flooding, could have been used continuously for crop production without yield declines. But they identify the scarcity of these soils and their vulnerability to flooding as major constraints for Mississippian farmers. With increased population, they argue, farmers would have been forced to cultivate less productive upland soils, which would need extensive fallow periods to permit regeneration of soil fertility. Baden calculated that agricultural soils in the Little Tennessee Valley would have required fallow periods of one hundred years or more to regain their fertility after continuous maize cropping. He based this estimate on research from the Rothamsted Agricultural Station in England and from experiments in Ohio, Kansas, and California. In these trials, cereal grains (barley, wheat, maize) were grown continuously without manure or fertilizers. Yields declined steadily over time, but the results could be reversed if the fields were fallowed or received manure applications, or if the cereal grains were rotated with a forage legume.52

Baden correctly identified soil nitrogen depletion as the major cause of the yield reductions. But in every experiment that he cited, fields were prepared using plows. Baden didn’t know that plowing, rather than crop uptake, was the primary cause of soil nitrogen depletion in these experiments. These fields were plowed annually to prepare them for seeding, and every year more soil organic matter was oxidized and lost, until eventually there was insufficient nitrate production and nutrient-storage capacity to support plant growth. Baden first incorrectly attributed nitrogen depletion to crop uptake. Then he assumed that soil nitrogen dynamics in fields worked with hand hoes would follow the same patterns as fields under plow culture. But fields that were initially fertile and then worked with hand hoes would maintain their fertility for decades longer than the same soils under plow culture. Soil fertility dynamics in plowed fields cannot be used as a template for predicting nitrogen fertility in soils that are not plowed.

Perhaps more important, it was not indigenous farmers, with their hand hoes and maize fields, who have caused the most extensive, serious, and long-lasting damage to soils and landscapes in North America. That award goes, without contest, to Euro-American farmers with their plows, as I discuss below. In contrast, Mississippian farmers in North America practiced what today is called conservation tillage, which minimizes or eliminates plow tillage. Today growing crops without plows is a primary characteristic of environmentally sustainable farming.

MAIZE

Mississippian researchers have also significantly underestimated maize productivity because they have tried to compare indigenous maize with that grown by North American settler farmers using plows in the eighteenth, nineteenth, and twentieth centuries. In every case, researchers have based their estimates on a plow-culture model of declining fertility when crops are planted continuously. They have argued that without manure, inorganic fertilizers, or the ability to clear new lands endlessly, Native maize yields were inherently low and unstable. Sissel Schroeder summarized this literature and argued that yields were seldom higher than twenty-five bushels per acre and frequently yielded no more than ten to fifteen bushels per acre.53

To obtain an accurate estimate of indigenous maize yields in the colonial Northeast, my colleague Robert Burt and I conducted replicated field experiments at two sites over four years using a traditional Iroquois open-pollinated maize variety that is typical of maize planted here since colonial

53. Schroeder, “Maize Productivity.”
times. Over two years and two locations, maize was harvested from more than sixty-five individual three-meter-square plots. These experiments provide the most extensive and reliable empirical estimates for Iroquoian maize yields. In these field trials, with agronomic practices similar to those Iroquois farmers would have used, we obtained maize yields of thirty-one to seventy-one bushels per acre; the highest yields were in Cayuga County on fertile Alfisols associated with Iroquois village sites in the sixteenth, seventeenth, and eighteenth centuries (table 1). These yield levels are congruent with multiple historical and ethnographic documents that describe an enormously productive agriculture in the region. On the basis of this research, a careful examination of the historical and ethnographic literature, and a thorough analysis of the agronomic factors that determine maize productivity, we vigorously disputed Schroeder’s rationale and yield estimates.54

Maize has other characteristics, invisible to most scholars, which made it uniquely productive within indigenous cropping systems in North America. These advantages emerged when I compared yields of Iroquois maize with European wheat in the seventeenth and eighteenth centuries. I found that Iroquois maize growers produced three to five times as much grain per acre as European wheat farmers in the same time period (figure 3 and table 2).

I attributed much of the yield differential to soil fertility dynamics: Iroquoian maize growers who planted with hoes did not face the challenge of declining soil fertility inherent in European plow agriculture, which as I noted above, European farmers were unable to solve until the nineteenth

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### Table 1

Traditional Iroquois Maize Yields

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Yield (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tompkins County</td>
<td>1993</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>1994</td>
<td>39</td>
</tr>
<tr>
<td>Cayuga County</td>
<td>1996</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>1997</td>
<td>72</td>
</tr>
</tbody>
</table>

*Source: Mt.Pleasant and Burt, “Estimating Productivity of Traditional Iroquoian Cropping Systems.”*
Figure 3. Comparison of European (wheat, barley, rye) and Iroquois (maize) grain yields in bushels per acre. Sources: D. H. Slicher van Bath, *Agrarian History of Western Europe*, and Jane Mt.Pleasant and Robert Burt, “Estimating Productivity of Traditional Iroquoian Cropping Systems.”

But other factors associated with maize enabled indigenous farmers in North America to develop a productive and stable agricultural system. First, maize has a higher yield potential than wheat because of its C4 photosynthetic pathway and lower protein content. Regardless of environment or management practices, maize often outyields wheat by at least 50

<table>
<thead>
<tr>
<th>Yield Level</th>
<th>Wheat (bu/acre)</th>
<th>Maize (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>8–12</td>
<td>40–49</td>
</tr>
<tr>
<td>Moderate</td>
<td>13–17</td>
<td>50–59</td>
</tr>
<tr>
<td>High</td>
<td>18–25</td>
<td>60–76</td>
</tr>
</tbody>
</table>


percent. Consider that one kernel of maize typically produces an ear with two hundred to five hundred kernels, an amazing return on investment. In comparison, one wheat seed produces a plant with just ten to seventy seeds. This at least partly explains why many farmers all over the world have so readily adopted maize as their subsistence grain. And, as noted above, maize kernels are approximately ten times larger than wheat seeds. The larger seed size makes it more vigorous and less vulnerable during germination, emergence, and throughout its seedling stage. It can also be planted deeper to take advantage of moisture below the surface. Large kernel size accounts for the ability of maize to thrive in roughly prepared fields, which enabled Native farmers to plant maize without plows. Seed size also affects seeding rates: farmers plant just eight to sixteen pounds per acre of maize, but they need 60 to 180 pounds per acre to seed wheat. The combination of low yields and high seeding rates crippled European wheat farmers for centuries. With wheat yields of ten bushels per acre, European farmers had to save 10 to 30 percent of their crop to plant the next season. At the same yield level, Iroquois farmers would have had to set aside less than 3 percent of their harvest for planting the next maize crop. At higher yields of fifteen to fifty bushels per acre, they needed to save less than 1 percent of their harvest (table 3).

MISSISSIPPIAN MAIZE PRODUCTIVITY: CAHOKIA AND MOUNDVILLE

We can observe how all these factors might play out in pre-Colombian North America by examining the potential for maize production at two high-profile Mississippian sites, Cahokia, located in Illinois on the Mississippi River, east of St. Louis, and Moundville, in western Alabama. The NRCS designation of Prime Farmland is a qualitative estimate of agricultural productivity, useful for identifying productive soils within each state, but it does not provide accurate comparisons across state boundaries. In 2008 the NRCS developed a more precise tool, the National Crop Commodity Productivity Index (NCCPI) for three crops: wheat, maize, and cotton. Using complex models, these indices differentiate soils according to their inherent ability to produce wheat or maize or cotton. The index predicts crop productivity across all regions within the United States. The

57. Mt.Pleasant, “Paradox of Plows.”
Table 3
Portion of Wheat and Maize Yield Saved for Seed at different Yield Levels and under Varying Seeding Rates

<table>
<thead>
<tr>
<th>Yield (bu/acre)</th>
<th>Wheat</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeding Rate (lbs./acre)</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Percent of Yield Saved for Seed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Mt.Pleasant, “Paradox of Plows.”

index is stable over time and across large geographic regions. Management practices and annual weather changes that might dramatically affect maize yield in a single year are not included in the model.  

Working with James Mastroianni, an independent Geographic Information Systems consultant, we obtained maize productivity indices for Cahokia and Moundville from the National Soil Survey Center in Lincoln, Nebraska. Cahokia soils are mostly Mollisols, located today on some of the best maize-growing land in the country. Moundville soils, on the other hand, are predominately Ultisols, which today require lime and fertilizer for maize production. We divided Cahokia into two sections: Cahokia proper, which includes its central plaza and mounds, and Cahokia Uplands, a series of settlements on the bluffs to the east of Cahokia proper, identified as a center of agricultural production for Cahokia proper. We established a five-mile radius (approximately 50,000 acres) around each area (table 4).


59. James Mastroianni can be contacted at jdmastro@gmail.com.

Table 4
Cahokia and Moundville: Areas Mapped and Location by State

<table>
<thead>
<tr>
<th>Sites</th>
<th>State</th>
<th>Area mapped (acres)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cahokia</td>
<td>Illinois</td>
<td>39,052</td>
</tr>
<tr>
<td>Cahokia Uplands</td>
<td>Illinois</td>
<td>114,108</td>
</tr>
<tr>
<td>Moundville</td>
<td>Alabama</td>
<td>48,012</td>
</tr>
</tbody>
</table>

*The Cahokia Uplands includes five archaeological sites, Copper, Emerald, Knoebel, Lienesch, and Pfeffer, which were treated as one site by merging the intersecting five-mile circles around the individual sites and forming an irregular shape comprising more than 50,000 acres. Mapped areas exclude soils within urban areas or under water.

The NCCPI crop index values range from 0.001 to 0.99, the higher values being more productive. We divided the crop indices into four productivity classes: 0.001–0.24, very low; 0.25–0.49, low; 0.50–0.74, moderate; and 0.75–0.99, high. Soils in the very low category would probably not have been used for maize production, but soils in the other three groups could have been used, depending on the needs and constraints of each community. Cahokia and Cahokia Uplands have a total of more than 115,000 acres of moderately and highly productive farmland. Of this, more than 78,000 acres are highly productive. But Moundville has no highly productive soils and just over 3,800 acres of moderately productive soils. Most of its soils are classified as being of low or very low productivity (figure 4).

To determine the ability of Cahokian farmers to supply their communities with maize, I first estimated how much maize they would need, depending on the portion of the diet supplied by maize and population levels. Assuming that each person requires 2,500 calories per day and that one pound of maize provides approximately 1,470 calories, the annual amount of maize needed at three population levels (10,000, 20,000, and 40,000), where maize supplies either 50 percent or 75 percent of the daily calories, can be calculated. If Cahokia had a population of 10,000, and maize provided 50 percent of the population’s caloric requirement, the community would need 55,429 bushels of maize every year. This jumps to 332,600 bushels if 40,000 were being fed and maize provided 75 percent of calories (table 5).

62. A bushel of maize weighs 56 lbs.
Figure 4. Amount of soils of varying productivity for maize at Cahokia, Cahokia Uplands, and Moundville, determined using NRCS Maize Productivity Indices.

I then calculated the amount of land needed for these scenarios using maize yields of twenty-five and fifty bushels per acre, a realistic yield range that is based on my research with Iroquois maize, historic and ethnographic records, and the yield potential of maize in this region, considering the presence of highly productive soils.63 If Cahokian farmers obtained yields of fifty bushels per acre, just 1,109 acres were needed to provide maize for

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Amount of Maize Needed Annually to Feed Cahokians, Depending on Population and Portion of the Diet Provided by Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maize: bu (x 1000)</td>
</tr>
<tr>
<td>Population</td>
<td>10,000</td>
</tr>
<tr>
<td>50</td>
<td>55.4</td>
</tr>
<tr>
<td>75</td>
<td>83.1</td>
</tr>
</tbody>
</table>

Table 6
Amount of Land Needed for Cahokian Maize Production, Depending on Population, Portion of Diet Supplied by Maize, and Maize Yields

<table>
<thead>
<tr>
<th>Maize yields (bu/acre)</th>
<th>50% of Calories</th>
<th>75% of Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>10,000</td>
<td>20,000</td>
</tr>
<tr>
<td>25</td>
<td>2,217</td>
<td>4,434</td>
</tr>
<tr>
<td>50</td>
<td>1,109</td>
<td>2,217</td>
</tr>
</tbody>
</table>

10,000 people who obtain 50 percent of their calories from maize. But if their yields were only twenty-five bushels per acre, and 40,000 people obtained 75 percent of their calories from maize, more than 13,300 acres would be needed (table 6).

But even the highest estimate of the land required represents less than 20 percent of the 78,000 acres of highly productive soils that were available (Cahokia and Cahokia Uplands), without even considering the additional 37,700 acres of moderately productive soils in the Cahokia region. It is hard to imagine a scenario in which Cahokia would suffer from food shortages given the enormous quantities of highly fertile land and the productive capacity of maize. Even if crops suffered from drought or other catastrophic events, maize can be stored safely for years. Cahokia’s leaders, with their complex and hierarchical governance structures, would surely have stored excess grain for less agriculturally productive years.

The situation at Moundville is much different, as this site has only 3,800 acres of moderately productive soils (see figure 4). Population levels at Moundville were also much lower than at Cahokia; most estimates range from 1,500 to 3,000 inhabitants at its zenith.\(^64\) I determined the amount of maize needed at this site using the same assumptions and calculations as I used above. Fifteen hundred people for whom maize provided 50 percent of their calories would need approximately 8,300 bushels of maize each year,

Table 7

<table>
<thead>
<tr>
<th>Portion of Diet (%)</th>
<th>Maize (bu x 1000)</th>
<th>Population</th>
<th>Land (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1,500</td>
<td>3,000</td>
<td>332</td>
</tr>
<tr>
<td>75</td>
<td>8.3</td>
<td>16.6</td>
<td>499</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td>24.9</td>
<td>997</td>
</tr>
</tbody>
</table>

which would increase to almost 25,000 bushels with a population of three thousand people who obtained 75 percent of their calories from maize. Since none of the soils around Moundville are highly productive, I assumed that twenty-five bushels per acre is a realistic maize yield. To provide these quantities of maize each year, Moundville farmers would have needed between 332 and 997 acres (table 7). This would leave more than 2,800 acres of moderately productive soils uncultivated. At both sites, these calculations indicate that Mississippian farmers could easily have grown more than sufficient maize to supply their communities with food, given the presence of fertile or moderately fertile soils and realistic estimates of maize yields.

EUROCENTRIC BIAS AND ITS EFFECTS

Lack of fundamental agronomic knowledge has greatly limited scholars’ ability to evaluate pre-Columbian agriculture. The effects of this ignorance have been exacerbated by a scholarly worldview that reflexively privileges Western agriculture and promotes evolutionary models that automatically place Western farmers at the apex of agricultural development. My examination of two topics usually assumed to be uncontroversial, shifting cultivation and plow-based agriculture, highlights the effects of this bias. Many scholars in the field have uncritically accepted Boserup’s claim that intensity of cropping reflects the stages of agricultural development, allowing us to categorize the world’s farmers in a universal evolutionary progression from primitive to more complex. In Boserup’s paradigm, all farmers start as shifting cultivators and then advance to more intensive systems, but others, notably Katherine D. Morrison and her colleagues, point out that evidence
for this is lacking. In fact, it would be hard to identify an actual historical example of a people who have advanced through Boserup’s stages of agricultural development. But I focus here on Boserup’s ideological framework, which has so distorted the analysis of indigenous agriculture: “The digging stick is the most primitive of the main agricultural tools and the people who use digging sticks are the most primitive among the primitive agricultural tribes living today. By contrast, the highest levels of pre-industrial civilization have usually been reached by peoples with plough cultivation.” In this passage Boserup reminds us repeatedly that farmers without plows are primitive. Primitive people use digging sticks, but under appropriate conditions, they advance, eventually reaching the pinnacle of agricultural development, the adoption of plows. By failing to consider the wide range of factors in which agriculture develops and operates, she forces all farmers into a universal evolutionary progression that aligns with her views of what is primitive and what is advanced.

When scholars view shifting cultivation as a developmental stage (rather than a management strategy to address low-fertility soils), they conflate shifting cultivation with the primitive, unable to distinguish between them. All shifting cultivators are labeled “primitive”; conversely, if people have been classified as “primitive,” they must also be shifting cultivators in their agricultural practices. This tautology describes the current state of academic discourse on indigenous agriculture in North America. Scholars assume that Mississippian farmers were shifting cultivators because they were at the beginning stage of agriculture, and they simultaneously label Mississippian farmers’ agriculture as primitive and unproductive because they were shifting cultivators. As I have argued above, most pre-Columbian farmers in North America were not shifting cultivators because of the abundance of fertile soils. Considerable evidence also indicates that their agriculture was very productive, much more so than European farmers at the same time. Researchers who frame shifting cultivation as a developmental stage are not just incorrect; they fundamentally compromise our ability to evaluate past and present indigenous agriculture accurately.

For the most part, scholars currently view plow-based agriculture as the standard by which all others should be judged. Plows are typically seen as the mark of advanced civilizations, and many scholars are unable to imagine a developed agriculture without plows. Consider this 1966 quote from G. E.

Fussell, one of Europe’s most distinguished agricultural historians: “Farming began in the Middle East. . . . Perhaps it was a sort of hoe culture, but a traction plough was used from about 4000 B.C. . . . This change is fundamental. It marks the passing of the nomadic food-gathering and hunting stage and the beginning of settled life.” Or this, from R. D. Hurt, a U.S. agricultural historian, who wrote in 1982: “Through the ages the plow has been the most important agricultural tool. Indeed, without it farmers could not till the soil and prepare their fields for extensive agriculture.”67 Scholars across many disciplines have accepted these characterizations of plows and agriculture, even in the face of evidence that directly contradicts it. For example, in Mexico and Central America, before colonization, indigenous farmers grew sufficient maize for 18 to 20 million people.68 They lived in large, complex cities and productively farmed expansive areas of land. But they did not use plows. Scholars have ignored this glaring anomaly.

I find the view of plow agriculture as inherently superior most troubling when comparing the environmental effects of plow and hoe cultures. Agricultural scientists have known for more than fifty years that plowing causes enormous damage to agricultural landscapes. Plow-based agriculture, first in Europe and later in the United States, degraded soils through destruction of soil organic matter and soil structure and led to erosion, gravely threatening the ability of farmers to feed populations that depended on them. The destructive effects of plow agriculture are well documented.69 Today agronomists across the globe urge farmers to use conservation tillage systems that significantly reduce the amount of soil disturbance, conserving

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soil organic matter and soil structure while reducing erosion. Pre-Columbian farmers using only hand tools in their conservation tillage systems had far less negative effect on their soil resources than did farmers with plows. The lack of plows meant that these farmers in North America were able to conserve soil organic matter, essential for supplying nitrogen and other nutrients to their cereal grain, maize. Not only were their agricultural systems productive; they were environmentally sound and sustainable.

**SUMMARY**

Many scholars have characterized indigenous farmers in North America as shifting cultivators who obtained marginal yields of maize and engaged in exploitative agricultural practices that contributed to environmental degradation and political and social instability. But the presence of large amounts of fertile soils across large areas of eastern and central North America contradicts the assertion of a widespread implementation of shifting cultivation, a practice used primarily by farmers on acid, infertile soils. The absence of plows, often cited as an indication of backward or primitive agriculture, was instead an enormous advantage for pre-Colombian farmers. Conservation tillage systems, those that reduce intensive soil disturbance, preserve soil organic matter and enable continuous crop production for much longer periods than plow agriculture. Scholars have also significantly underestimated the yield potential of maize, one of the world’s most productive grain crops. Although settler farmers in North America in the seventeenth, eighteenth, and nineteenth centuries experienced dramatic yield declines when they planted maize continuously in plowed fields, Native farmers would not have experienced these reductions because they were not intensively tilling their fields. I claim that maize yields of twenty-five to fifty bushels per acre would have been both realistic and relatively sustainable over long periods. Cahokia and Moundville, the two largest Mississippian sites in North America, were located on very different soil resources, and they had different population levels dependent on maize production. But using these maize yields and assuming the stable productivity over time, farmers at both sites, cultivating only a fraction of the productive land available to them, could have produced well in excess of what their populations required.

Much of the mischaracterization of indigenous agriculture in North America is due to a lack of understanding of the sustainability and productivity of pre-Columbian agricultural systems. The use of conservation tillage methods allowed these farmers to conserve soil organic matter, which is essential for supplying nitrogen and other nutrients to their cereal grain, maize. Not only were their agricultural systems productive; they were also environmentally sound and sustainable.

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America can be attributed to lack of knowledge about soil and crop science, as I described above. But in addition to a deficiency of agronomic knowledge, the academic scholarship on Native American agriculture has rested largely on a foundation of cultural bias; it has labeled the practices of indigenous farmers as backward, while automatically privileging that of Western populations. Although many scholars have vigorously critiqued Ester Boserup’s claim that population is the driver of agricultural development, few have questioned her embedded assumption of a progressive evolutionary model of agriculture, which places indigenous farmers and their hoes at the primitive beginnings, and European farmers and their plows at the summit. This unquestioned and unsupported bias continues to frame the discussion on indigenous agriculture in North America, the result being that scholars are unable to evaluate the agricultural practices of pre-Columbian farmers accurately. By using NRCS data on soil productivity, replicated field tests on yield rates of Iroquois maize, and fundamental agronomic science, I arrived at a much different assessment. Pre-Columbian farmers in North America had access to large acreages of some of the world’s most fertile soils. Using hand tools that preserved this soil resource and an amazingly productive cereal grain, maize, they were probably among the world’s most sustainably productive farmers in this era.