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Ecological Embeddedness, Agricultural "Modernization," and Land Use Change in the US Midwest: Past, Present, and Future

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In this essay, I examine how socio-technical and economic choices and changes have increasingly disembedded agricultural systems from their local ecologies and transformed agricultural land use and impacted soil and water conservation over the course of US history. I propose that the primary characteristic of land use change, and land degradation in particular, is a fundamental concept I term "agroecological disembeddedness." I begin with a definition and discussion of the concept of agroecological embeddedness. I then examine the history of North American agriculture up to mid-20th century, focusing primarily on what I consider to be the first major disembedding juncture, the "plow cultural revolution" that greatly disconnected agriculture from its agroecological foundations, and resultant impacts of that seismic shift in land use. The next section focuses on post-World War II fossil fuel–based technical and chemical "modernization," which further disembedded agriculture from its agroecological roots through the systematic promotion and spread of fossil fuel–based machinery, fertilizers, and agrochemicals that led to the current dominant model of agricultural land use: highly specialized, high-input, monoculture commodity production. The final section examines the rise of efforts to re-embed agriculture into its agroecological foundations, with a particular focus on soil health, and highlights the need for structural changes that promote diversity and regenerative agriculture.

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The term "embeddedness," as used in reference to social-ecological systems, has its roots in economic sociology and the field that was once called "political economy." Most often traced to the work of Polanyi (1944) and later Granovetter (1985), embeddedness refers to economic activity that is integrated in and governed predominately by social and cultural relations and institutions, while disembedded economic activity is that which is governed and directed primarily by market forces. More recently, the concept of "ecological embeddedness" has been extended to include spatial and ecological dimensions of economic activity, especially in the realm of agro-food system studies, as agricultural production, perhaps more than any other economic activity, comprises both (agro)ecological and social dimensions (Jones and Tobin 2018). Agrifood scholarship such as Morris and Kirwan (2011) and Jones and Tobin (2018) has refined understanding of ecological embeddedness as a multilevel concept that includes landscape and farm ecologies, farm enterprises, farmers, processors, distributers, consumers, other actors within agrifood networks, and ecological benefits that different farming approaches might realize. However, for the purposes of this discussion of land use change I focus only on landscape and farm ecologies and the agroecological processes that farmers manage through farm enterprises. For this essay, I combine the political economic concept of embeddedness with the concept of agroecology as defined by Gliessman (2007): "…the application of ecological concepts and principles to the design and management of sustainable food systems." I use this lens of agroecological embeddedness to examine the trajectory of agricultural land use and soil and water conservation in what is now the United States, past, present, and future.

Embedded Indigenous Agricultural Systems

Prior to European settler colonialism, indigenous agricultural systems were diverse and highly ecologically embedded. Indigenous peoples across North America practiced purposeful landscape management of grasslands, animal herds, and forest crops through use of fire, forest farming, and other management strategies (Mutel 2008; Mt. Pleasant 2015). Agriculture was led by the "three sisters" polycultures, with corn, squash, and beans providing excellent nutritional value while also maintaining soil fertility and managing pest and disease pressure. These were complemented by many other crops, including gourds, sunflowers, potatoes, and small native grains. By 1500, what is now the eastern and midwestern United States was dotted with agriculturally based villages with thriving village gardens as well as some large cities (Gallagher et al. 1985; Sasso 2003; Mutel 2008; Mt. Pleasant 2015).

As Schlebecker (1975) noted, many indigenous groups "…practiced a sophisticated and successful garden agriculture without plows." Indeed, native crop polycultures generally required little soil disturbance, allowing large quantities of food crops to be produced with low energy and time input and basic tools of wood, bone, and stone (Schlebecker 1975; Mt. Pleasant 2011, 2015). Early European settlers survived by adopting native agricultural practices, and corn and other native crops produced with little or no tillage were their principal food sources for at least a century. These cropping systems were well-adapted and "embedded" in local ecological conditions, and although they sometimes required conversion of forests, these changes in land use did not result in widespread soil degradation.

The "Plow Cultural" Disembedding

While the native systems of corn, beans, squash, and other native crops production were generally embedded in local ecological conditions and thus had little ecological footprint (Sasso 2003; Mutel 2008; Mt. Pleasant 2015), introduced nonnative crops such as wheat and barley required "extravagant" expenditures of time and energy. Farmers could grow these crops at scale only "…if they used plows, harrows, rollers, and similar animal-drawn equipment…" and "clod crushers" and other equipment to further "pulverize" the land before seeding (Schlebecker 1975). However, because wheat had a higher commercial value, settlers were keen to produce it for local and European markets alike (Schlebecker 1975). As iron and then steel works developed, agricultural implement industries sprung up, and soon use of steel plows, harrows, cultivators, and similar machines to work the soil was common, and tillage became the norm (Schlebecker 1975; Cochrane 1993). Thus, as settler colonialism displaced native populations, so did plow-tilled methods of planting predominantly monoculture crops replace low- or no-till diverse, polycultural native agricultural systems.

The shift to "plow culture" over the course of the 19th century was viewed as an adaptive response both following and driving the transformation from a largely subsistence agriculture to a commercially oriented agriculture (Coughenour and Chamala 2000). Coughenour and Chamala (2000) note that this shift was radical in two respects: First, it ushered in "new and different… technical frames for preparing a seedbed, cultivating, and harvesting…the iron plow was the centerpost of a fundamentally different technical system of agriculture. Second…the adoption of plow culture was adaptive only if at the same time the farmer created a different farming system oriented to the market sale of crops and livestock products." In other words, the shift to market-based commercial farming systems was accompanied by a cultural shift that viewed iron plow tillage as a necessary means to increase labor productivity, allowing farmers to prepare more extensive seedbeds more quickly.

By the end of the century, "…the iron plow was adopted nearly everywhere" (Schlebecker 1975).

The impacts of this "plow cultural revolution" and widespread change in land use from no-till native systems to intensive tillage were swift and devastating, and ultimately maladaptive, however. By the late 1930s, on the heels of the Dust Bowl, the first nationwide appraisal of the condition of agricultural land found some 60% of croplands "either subject to continued erosion or is of such poor quality as not to return a satisfactory income to farmers…" and one-fourth or more of the original surface soil had been lost to erosion (Cooper et al. 1938). As Cooper et al. (1938) note in the seminal work *Soils and Men*, "A system of farming that keeps much of the land in continuous cultivation generally is a destructive system, since too often it does not provide for a return to the soil of much-needed humus and plant nutrients." Even in the most fertile regions of the United States, such as the Midwest's central Corn Belt and the Pacific Northwest's Palouse region, in many areas, tillage along with monocropping or short rotations had depleted soil organic matter and fertility, damaged soil structure, and led to declining yields (Cooper et al. 1938) that were far inferior to those of the native systems that had been displaced (Mt. Pleasant 2015).

The Petrochemical Disembedding

The second major land use revolution in US agriculture, I argue, was driven by post-World War II shifts to a tripartite dependence on fossil fuels: mechanization powered by internal combustion engine, commercial fertilizers, and chemical pesticides. The impact of the advent of the fossil fuel-powered tractor on the reshaping of land use in the American agricultural landscape cannot be overemphasized. The vast increase in supply of farm power had two primary results. First, by replacing draft animals, tractors freed up some 40 million ha (100 million ac) of cropland that had been used to grow feed for work animals, and second, they provided the power required to till the acres that were shifted from pasture and hay production to row crops (Olmstead and Rhode 2001).

Despite the tillage transformation, however, prior to WWII most permanent crop production still required adherence to agroecological principles: extended rotations of diverse crops suppressed insects, weeds, and diseases and recycled and maintained organic matter. Biological diversity and rotations ensured modest but steady yields over time (Danbom 1997; Altieri 2000). The introduction of fossil fuel–derived fertilizers and chemical pest control disconnected crop production from the ecological processes that were once necessary, allowing a rapid transformation of agriculture to an even more specialized monocrop production of a handful of commodities. The ecological risks potentially associated with such a great ecological disembedding were attenuated by increasing reliance on agrochemicals while the economic risks were largely addressed through agricultural policies and programs. As Danbom (1997) articulated, "Farmers no longer needed to diversify carefully, rotate crops, or cooperate with neighbors to minimize their risks; thus, they imperiled the environment and contributed to community deterioration."

Indeed, post-WWII subsidized short-term risk minimization, whether through increased reliance on fossil fuels–based technology and agrochemicals or government programs, combined with overall increases in dependence on purchased inputs, had insidious side effects: it raised land values and tightened profit margins (Danbom 1997). This cost-price squeeze dynamic, along with rapidly changing technologies centered on increasing yields in specialized commodity production, led to overproduction and the "agricultural treadmill" effect that both spurred increases in farm size among operations that adopted new productivity-enhancing technologies, and hastened failure of farms that did not (Cochrane 1993). Simultaneously, monocrop specialization led to increasing pest and weed pressure and evolution of resistances to chemical controls and similar "pesticide treadmill" dynamics that required increases in chemical use over time (Gliessman 2007; Liebman et al. 2016).

Diffusion of Innovations

It is important to recognize that these radical transformations in production processes, from regenerative systems embedded in local ecologies to productivist systems dependent on external, mostly nonrenewable inputs, were not a natural evolution. In reality, the transformations required substantial efforts by social and biophysical scientists and extension staff at land grant universities, in partnership with the growing agribusiness sector, and state and federal policies and programs centered on "modernizing" agriculture through systematic promotion of adoption and diffusion of new technologies. As the products of agricultural research became available in the post-WWII era, social science researchers, particularly rural sociologists, sought to (1) understand the processes through which farmers adopted new technologies, and (2) use that understanding to promote the widespread diffusion of those technologies (Buttel et al. 1990; Rogers 1995).

Starting with hybrid seed corn, as more chemical and mechanical technologies were developed, diffusion studies were conducted to inform their promotion, for example fertilizers (Beal et al. 1958a, 1958b; Beal and Bohlen 1958) and pesticides (Beal 1956; Beal and Rogers 1958). Research focused on communication, socioeconomic, and social-psychological predictors of technology adoption "was premised not only on understanding the spread of new technologies . . . but also, in general, took a promotional posture toward technological change" (Buttel et al. 1990). Thus, adoption-diffusion researchers generally were part of a larger promotional effort to bring "improved" technologies to farmers whose socioeconomic (i.e., age, education, income, farm size) and social-psychological (i.e., attitudes toward change) characteristics determined their relative "innovativeness" or "backwardness" in relation to new technologies or practices. Investigation of the diffusion of new agricultural technologies occupied hundreds of researchers and produced nearly a thousand publications from the 1940s through the early 1970s when there was a precipitous decline in the number of new diffusion studies, from nearly 20 per year to less than 5 (Rogers 1995).

The main driver behind the relative abandonment of diffusion studies among sociologists was a rising awareness of the negative environmental and social consequences caused by the innovations that they had helped to diffuse (Buttel et al. 1990; Rogers 1995). Criticisms leveled at rural sociologists as lackeys of a "land grant college complex" who placed agribusiness interests ahead of those of the public (Hightower 1978; Newby and Buttel 1980) hastened the demise of diffusion research as a central activity in the field. Nevertheless, the land grant university-agribusiness partnerships that focus research and extension predominantly on high-input, specialized commodity production continue (DeLonge et al. 2016), and their results are reflected in long-term trends, such as the decline in crop species diversity (Aguilar et al. 2015) and historical indifference or even antagonism from the land grant university research and extension establishment toward more agroecologically oriented production systems (National Research Council 1989; Coughenour and Chamala 2000; Duffin 2007).

Toward a Return to Agroecological Embeddedness

As the brief discussion above indicates, the dominant trend over the last 75 years or so has been a disembedding of agriculture from local ecological processes, primarily through specialization in a handful of commodities undergirded by purchased inputs and government subsidies. And this has occurred, despite, as numerous chapters in this book describe, enormous efforts by the soil and water conservation community to address the negative impacts of the productivist model of agriculture on soils, water bodies, and wildlife habitat. That said, there is a deepening research base showing that specialization, monoculture, and lack of crop diversity are the root causes of our soil and water degradation problems (Hatfield et al. 2009; Hunt et al. 2019) and an increasing recognition that a return to diverse, ecologically embedded systems is the pathway to a truly sustainable agriculture (Gliessman 2016).

So how do we return to an ecologically embedded agriculture? I believe that a renewed commitment to soils and soil health is the cornerstone. As numerous authors in this book so eloquently state, healthy living soil is the ecological basis for a sustainable agriculture. The emphasis that the USDA Natural Resources Conservation Service has placed on soil health in their outreach strategies has resonated with farmers (Arbuckle 2017), many of whom see soil health management as key to increasing the resilience of their operations in a time of increasing weather extremes related to climate change (Roesch-Mcnally et al. 2018). Farmers are learning to pay attention to their soils and evaluate how different management practices can lead to improved or degraded soil health. This, in turn, can lead to longer-term thinking that allows farmers to see past the short-term return-on-investment mentality that specialized commodity production tends to privilege and motivates work toward more resilient, embedded systems that rely less on purchased inputs (Roesch-Mcnally et al. 2018), systems that are becoming known as "regenerative agriculture" (Gosnell et al. 2019).

While a renewed commitment to agroecological principles with soil health as a primary goal is a promising pathway to agricultural sustainability, the vast majority of farmers, however, are not on that path. Indeed, some argue that our dominant productivist agricultural production systems are more decoupled and disembedded than ever, are becoming less resilient to the impacts of climate change, and soil and water degradation are getting worse rather than better (Hamilton et al. 2020). Increasingly, such critiques hold that the voluntary approach that has been the compliance mechanism underlying the soil and water conservation programs and policies of the last 75+ years is woefully insufficient (Rundquist and Cox 2016). Invariably, calls for change emphasize that the policies and programs that shape the behaviors of farmers, agricultural researchers, agribusiness firms, and soil and water conservationists need to challenge the status quo. Indeed, because agricultural and environmental policies and programs set the structural boundaries of what is possible or not in our food system (e.g., shape markets), they must be reoriented to re-embed agriculture ecologically (and socially, for that matter). This is particularly important for farmers, who may understand the potential social, economic, and ecological benefits of transitioning to diversified systems that rely less on purchased inputs and more on agroecological processes, but perceive strong market and other structural barriers to change (Arbuckle 2015, 2017).

In 2009, Wes Jackson and Wendell Berry, two of the most influential thinkers in the realm of agriculture, published an op-ed titled "A 50-Year

Farm Bill" (Jackson and Berry 2009). The visionary proposal, which was developed through a series of meetings nationwide with farmers and farmer groups, outlined a "gradual systemic change in agriculture" (Jackson and Kirschenmann 2009) that would re-embed agricultural systems ecologically and socially through perennialization and increased diversity. A decade on, research-based evidence increasingly shows that diverse agricultural systems that incorporate perennials and continuous living cover are superior to specialized monocultures in terms of productivity, nutrient cycling, disease and pest management, habitat provision, soil health, and other metrics (Patel-Weynand et al. 2017; Schulte et al. 2017; Leandro et al. 2018; Hunt et al. 2019; Weisberger et al. 2019), yet we still have farm policies that privilege the status quo of specialized production of few commodity crops.

The evidence is clear that because the current dominant production systems rely on tillage that degrades soils, fossil fuel-based fertilizers that degrade water quality and contribute to greenhouse gas concentrations, and agricultural chemicals that harm biota and are increasingly ineffective as resistances mount, they are vulnerable and untenable over the long term. The evidence is also clear that the path to truly sustainable agriculture is through re-embedding agricultural systems in local ecologies. We need a policy pathway, such as a 50-Year Farm Bill, to move us decisively toward that goal.

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