FOSSIL FOODSCAPES:

EXAMINING THE UNITED STATES' CARBON DIET

by

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While many are aware of the inputs required to maintain food production at an industrial level in the United States, we seldom reflect on the profound significance of a food system that is so deeply rooted in what Matthew Huber calls the "dead ecologies of fossilized energy." In order to more fully understand and critique the linkages between fossil fuels and agriculture, as well as their ecological and social implications, I examine the use of fossil fuels in agriculture through an eco-socialist framework. I employ Wim Carton's fossil fuel landscape and Marx as developed by John Bellamy Foster's concept of metabolic rift to illuminate the linkages between combustible carbons and the food we eat. Ultimately, these two concepts lead to a place of critical understanding in attempts to envision a more sustainable and resilient future. Such an inquiry is of the upmost urgency considering the dual threats of climate change and soil erosion. Both threats are exacerbated by our continued use of fossil fuels and the machines they power.

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This thesis was written on Kalapuya land. My life on this landscape is full of great privilege, and I am solemnly aware that this privilege interweaves with the forced removal of those who lived here before me. I commit myself to continuing to learn about and work towards decolonization of this landscape and all those I come across in the future.

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My family has supported me throughout all of my endeavors and I do believe that I owe my sense of curiosity, concern, perseverance, and empathy to my mom, dad and sister. They have been with me, even if from afar, as my thirst for knowledge and experience has taken me around the world, and ultimately through four years of college. Thank you for the love, support, and willingness to help me work through whatever my latest musings may be. Thank you to my other sister Sara Runkel for helping me populate my table of contents just before submitting this thesis (a great metaphor for our friendship). It would also be remiss to not mention my uncle Bobby too, whose annotated copy of the Nation introduced me to The Land Institute, as well as grandpa Jim whose generosity has allowed me to pursue the travel and education that have made me the young woman I am today.

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“In one sense, the farmer’s business is energy. The aim of his farming strategy is to divert as much of the sun’s energy as possible into useful chemical energy stored in his crops”

Hall

“Modern agriculture has essentially become the art of turning oil into food”

Clark and York

Introduction

A day spent in the heart of Kansas farming grain is a day spent under the hot sun, breathing humid air, bugs buzzing in your ears. The work’s physical nature is both tiring and rewarding. Perhaps this is owed to a deep knowledge that our survival, as individuals and as communities, is dependent on a shared commitment of tending crops. Whatever the source, the gratification of a day’s work evidenced in the landscape, whether this be a field free of invasive weeds or one cleared from harvest, makes any sort of sore feet, back pains, and weak arms worth it. Time invested into cultivating food fulfills a deep connection to the earth and to survival itself. I had the great fortune of learning this last summer while working on a project that may transform the very logic of agriculture itself.

Each hour I spent in the fields contributed a small but vital piece to furthering the Land Institute’s vision. Founded in 1976 by Wes Jackson, the Land Institute seeks to realize a more sustainable, resilient, and just agricultural system. Researchers' primary focus is on developing perennial varieties of some of the world's most important grain and oilseed crops such as wheat and sunflower.

It is because of this organization, over 40 years after its establishment, that I found myself in Salina, Kansas. As I worked out in the fields, tending to and collecting plants that comprise the breeding program's stock, I reflected on the mission I was now helping materialize: perennial futures. While I arrived at the Land Institute believing that a future with a perennial agriculture was the ultimate goal, I quickly understood that The Land Institute's critique is part of a much larger vision. Perhaps more importantly for my own understanding of the world's complex problems and efforts to address them, I understood that the importance of a comprehensive vision for perennial futures that moves beyond the plants themselves is urgent in today's context. Perennial crops represent the cornerstone of the organization's important critique of the United States' agricultural system, yet they are and must not be the end-all.

And why is this? A persistent and terrifying reality was on my mind while working in the Kansas heat. Climate change is no longer a condition of the future. Today, the impacts of human activity are already evidenced in complex yet clear patterns including warming temperatures, rising sea levels and shrinking ice sheets. While time remains to reduce anthropogenic greenhouse gas emissions on a scale meaningful enough to avoid the crisis's worst effects, that time is quickly disappearing. It is within this urgent context—our irrevocable disturbance of the very conditions that we depend on—that much of our activity drives this crisis. Throughout America's heartland and beyond, the underlying logics and mechanisms by which we organize our society – everything from how we move to how we eat – are undergirded by the access to and use of fossil fuels. In relation to food production and my own experience in Kansas, the vast majority of grain and oil seed crops are not tended to by hand like those I cared for throughout the summer. Rather, most of the crops in this global breadbasket live and die by the use of oil.

Surrounding the organization's small plots were vast fields of wheat, corn, and milo. Human presence on these enormous plots was only evidenced as combines drove up and down the long rows, harvesting massive areas of grain in a remarkably short amount of time. Or, when crop-dusting planes flew overhead, flying close to the ground in order to spray the plants below. Human interaction with this landscape was largely mediated through machine. To be sure, the impression of efficiency given by such mechanization made the efforts of me and the entire team of interns appear meagre at best. And it is important to recognize the ways in which these machines have allowed so many people the choice to dedicate the years of their life to activities other than growing food. One afternoon, for a project that did not require the precision of individuals, I helped operate a combine for threshing. We accomplished what could have been one week's worth of work in a single afternoon.

With such realities in mind, I started to believe that should we even succeed in perenializing agriculture, we are only part way there. If all of those crops were replaced with perennials, would anything else about this larger landscape and the methods used to cultivate it fundamentally change? Creating a more sustainable, resilient, and just agricultural system is not simply about crops, but it is also about *how* we grow them. Evidently, the modes of production in which we have invested in throughout history dictate the ways in which we grow our food and no matter the “progress” achieved through mechanization, such a paradigm carries with it a host of undesirable side effects.

Watching these machines work their way through fields, even in recognition that those very machines relieved hundreds of hours’ worth of work, my awareness that our time to reduce emissions is rapidly disappearing, I became fixated on energy. The more I thought about it, the more I became aware that energy shaped the landscapes producing our food while creating agricultural systems inherently threatening to the very ecosystem services they depend on.

While many are aware of the inputs required to maintain food production at an industrial level in the United States, we seldom reflect on the profound significance of a food system that is so deeply rooted in what Matthew Huber calls the “dead ecologies of fossilized energy.” In order to more fully understand and critique the linkages between fossil fuels and agriculture, as well as the ecological and social implications of these links, I am examining the use of fossil fuels in agriculture through an eco-socialist framework. While there is plenty of empirical evidence to position such an examination as worthy of inquiry, this framework allows a far richer understanding than numbers alone may offer. I use Wim Carton’s fossil fuel landscape and Marx’s, as developed by John Bellamy Foster, concept of metabolic rift to illuminate the linkages between combustible carbons and the food while providing a unique and comprehensive illustration of these relationships. Ultimately, these two concepts lead to a place of critical understanding in any attempts to envision a more sustainable and resilient future.

This inquiry is of the upmost urgency considering the dual threats of climate change and diminishing soil quality. Both threats are exacerbated by our continued use of fossil fuels and the machines they power.

Critiquing Agriculture, Energy, and Society

Figure 1

Kansas Wheat Harvest

For many Americans, this photo is largely unremarkable (see figure 1). Even those living in urban settings understand that this is what much of the food production in the United States looks like. Many are aware that this form of farming degrades the environment, or are concerned by the health issues playing out in a nation that focuses its agricultural subsidies on ingredients for processed foods rather than food itself. Both are examples of the realities: ways of life, culture, and knowledge, represented through this image. While such information is vital to understanding and critiquing America's food system, embedded in this photo and landscapes across the nation that are similar to it, is a driving force. Regardless of the outcomes of a food system like this one, the negative and the positive, its existence relies on the steady availability of cheap, dense energy.

Such a truth is not evident until it becomes obvious. One viewing this image without having deeply reflected may see nothing more than a field and combines, two normal features of America's industrial farming practices. But once an awareness of the story embedded in this photo comes into focus, the image takes on an entirely new meaning. One becomes focused on the field's scale, that it seems to stretch in every direction, requiring a mechanized harvest. Next one may become fixated on its uniformity, that it is covered with a single plant, a feat made possible by the addition of synthetic fertilizers, herbicides, and pesticides. One may realize the peculiar significance of a landscape that is simultaneously worked and seemingly devoid of humans. That combines have become a means by which this massive swath of land may be harvested and threshed in a fraction of the amount of time it would take for humans alone to do the same job.

After considering each of these aspect of the photos, the image no longer represents a simple, American wheat farm. Rather, the landscape represents, intentional or not, the logical outcome of a food system built upon the usage of fossil fuels as the primary means of energy. Through this process of reflection, a deeper exploration of the relationship between fossil energy and our food system begins to seem necessary. No longer is this simply a photo of a well-known landscape, but rather it has become representative of a carbon-based means of farming that carries along with it heavy implications for not only agriculture itself, but for our relationship with energy, the environment, and society.

In an effort to thoroughly explore the concepts embedded this landscape, I examine the use of fossil fuels in agriculture through a framework based on Wim

Carton's fossil fuel landscape and Marx's—as developed by John Bellamy Foster—metabolic rift. Fossil fuel landscapes describe the infrastructure in place for fossil fuel use. Carton's fossil fuel landscapes describe the physical infrastructure in place that creates a society's bias towards carbon-based fuel sources. Carton suggests that existing infrastructure determines the most efficient and/or economical fuel sources, and therefore societies will continue to rely on those sources they have historically invested in. Bellamy-Foster's metabolic rift, in its most basic conception, describes what happens when food is produced in one place and consumed in another: the food's energy builds up as human waste in the place it is consumed without ever returning nutrients to the soil.

Employing these concepts offers a unique and thoroughly rounded understanding of the links between fossil fuels and agriculture. Important to this exploration is an inquiry of the relationship between fossil fuels and food production, as well as the implications of that relationship.

Fossil Fuel Landscapes

While Carton's article from which I take the fossil fuel landscapes concept focuses on the shortcomings of market-based climate policy in mitigating greenhouse gas emissions, the concept proves a useful tool for exploring the aesthetic and theoretical relationship between fossil fuels and the food we eat.

Within Carton's discussion of market-based mechanisms and their lack of efficacy in reducing fossil fuel use, he points to the "concrete dynamics that predispose market-based mechanisms to undesirable environmental outcomes," as the culprit (Carton 44). It is in this assertion that market-based climate policy is not effective at moving human society towards renewables that Carton blames the existing system's "inertia" (Carton). If the fossil fuel landscape is the historical and socio-ecological legacy of fossil capitalism, that legacy has an enormous hold on the present and future state of that system (Carton 44). In economic terms, legacy impels us to continue to rely on the infrastructure that we have historically invested in because that infrastructure determines the most cost-efficient fuel source for all energy-requiring activities in any given society. Thus, the "normative function," of landscapes places them not as passive elements of the environment but powerful forces over the organization of activities ranging from transportation to industrial production to, of course, agriculture (Carton 47). In the author's own words, "the 21st century energy landscape […] embodies and therefore legitimizes a particularly fossil fuel-dependent mode of commodity production, resource extraction, ecological degradation, etc. through which historically specific socio-economic relations are reproduced." (Carton)

Carton's concept—fossil fuel landscapes—provides a new framework for thinking through today's industrial agriculture model. It is here that the initial imagery I presented begins to hold more gravity in terms of what it says about our society and its relationship to energy. The normative function of fossil fuels is plain in the scale of the field below, in the combines working that field, and in the widespread understanding that this is simply the way that we produce the food we need (see figure 1). Today's industrial farms *are* a fossil fuel landscape: they are the product of investment into machinery, fertilizer, and a farming ethos that is only possible in the context of cheap, abundant hydrocarbons (see figure 1.1). What I would like to highlight is that this is not a chance outcome, but rather the product of sustained investment in this particular system. For example, the United States' Farm Bill structure incentivizes large-scale production (Imhoff and Badaracco). Farms in the top decile in terms of crop sale value receive 20 percent more subsidies per acre than farms in the 70-80 and 80-90 percent deciles (Bekkerman et al). Between 1996 and 2016, 77 percent of the total money invested in commodity subsidies went to just ten percent of producers (Formuzis). Likewise, 68% of all crop insurance subsidies went to farms in the top ten percent of crop sales, usually for commodities like corn, wheat, cotton, and soybeans (Bekkerman et al.). Such patterns in funding drive a system that is inherently invested in the rise of big farming operations. This in turn incentivizes specialized heavy machinery, which in turn incentivizes mono-cropping, which in turn incentivizes chemical fertilizer use. Trends towards the ever-more industrialized place of food production may, in the United States, then be viewed as the specific outcome of farm policy. The underlying ingredient, the one that allows this trend in policy decisions and actual farming operations to occur, stems from a seemingly-advantageous access to dense, carbon-based fuels for that system.

As data on the planet's varied farm systems suggests, fossil foodscapes do not represent the end product of agriculture's teleological development towards a productive and efficient system. Rather, fossil fuel landscapes are in fact are less productive in terms of food produced per area and in terms of energy expended per amount of food (Arizpe et. al). Particularly damaging to the narrative that a fossil fuel landscape is necessary for "feeding the world" are reports that the world's small-scale farmers feed 70% of the global population with a quarter of the resources (ETC Group). If they are not representative of the most efficient or logical way of farming food, they may be seen as representative of investment in a particular mode of production. Fossil fuel machinery, large-scale irrigation, and massive fertilizer use are not *the* way to farm. They are *a* way to farm.

Looking across vast stretches of fields in America's Heartland, the expansive fields of wheat are not human landscapes. Carton's fossil fuels landscapes are powerful because they allow us to see the spaces in which we grow our food as a physical embodiment of our dependence on fossil fuels. Furthermore, they allow the conceptualization of these spaces as far more consequential than the standardized connotation that they usually carry. Fossil fuel landscapes accurately and critically describes industrialized agriculture, or what may better be called fossil foodscapes.

While I borrow this from Carton, there exists a considerable body of literature on the role energy, and in particular fossil fuels, has played in shaping physical landscapes and our social relationship to them.

The infrastructure that the United States has invested in throughout the course of history has resulted in a physical and social landscape that is dependent on fossil fuels throughout the society (Jones). In turn, this landscape becomes normalized as it becomes embedded in our social existence. Fossil fuels have played a central role in shaping every feature of American life from social relationships to the reproduction of capital. For this reason, Huber urges the literature to, "move from conceptions that understand energy as a 'thing' or a 'resource' towards a conception of energy as a 'social relation' enmeshed in dense networks of power and socioecological change" (Huber 106). Combustible carbons are thus so thoroughly entwined in humans' social relationship to the earth and to each other that it cannot be viewed as exterior.

Experiences and beliefs fundamental to the American psyche such as notions of individualism, freedom, may be seen as a byproduct of the dense energies that create the very fabric of American life. Take a typical suburban neighborhood, for example. Suburban landscapes are a “world beyond work.” Suburban Americans drive to the grocery store where they buy food produced by fossil energy (Huber). Social relations largely depend on driving, and individualized mobility is not only a feature of everyday life but a central component to ideas about what it means to be American.

Evidence of how energy shapes our relationship with food production specifically is expressed in many ways. Immediately evident is the fact that as farm size has gone up, the number of farmers on that land has gone down (USDA). This analysis returns us to the conversation on farm subsidies. In examining farming practices and the policies that incentivize them, fossil energies provide the invisible power to the logic propelling these policies. For example, the majority of US farm subsidies are directed to the largest industrial farms in America. By incentivizing this mode of production, United States policy effectively incentivizes farmers to move towards greater mechanization, monocultures, and ultimately greater reliance on fossil fuels to both power machinery and re-fertilize depleted soils (Imhoff and Badaracco).

Farm work represents a smaller share in the workforce despite the growing size of farms (USDA ERS). The 2017 census of agriculture reports a variety of trends further strengthening this assertion. The total amount of farmed land in the United States *decreased* between 2012 and 2017, however during the same period the average farm size *increased* by nearly two percent, and the largest farms (2,000 acres or larger) increased in number (USDA ERS). Perhaps even more illustrative is data reflecting land use; a full three quarters of American farmland specializes in either commodity grain or oilseed production (USDA ERS). In addition to trends in farm's physical sizes, the investment in fossil foodscapes is visible in the devaluation of farm labor (Magdoff). The median hourly wage for agricultural workers as of May 2019 was $12.52 (U.S. Bureau of Labor Statistics). This figure may not even convey undocumented workers' experience. That social and economic justice issues are a byproduct of an emphasis on energy over people is unsurprising and worthy of its own targeted exploration.

These phenomena cannot be disconnected from our relationship with fossil fuels. Such patterns could not be possible without fossil fuel's assistance. To be sure, the absence of fossil fuels would not ensure that farm work was a valued, well payed position in our society. Farm laborers are notoriously underpaid and over worked. However, this does not negate the reality that Americans' conceptions of farming and food itself have been deeply shaped by reliance on cheap, dense energy. The farm laborer has become invisible in the shadow of highly "productive" fossil foodscapes.

These social and justice-oriented consequences are byproducts of what Weis has called, "one of the most fundamental biophysical contradictions of industrial capitalism" (Weis 319). This biophysical contradiction exists in the paradoxical relationship between human systems and fossil fuel use: attempts to gain growth and efficiency through fossil fuel use threatens the ecological processes that our society depends on.

The biophysical contradiction in agriculture comes along with a diverse set of unintended consequences including and in addition to those already mentioned. Often called hidden costs, these are the negative outcomes spread throughout the environment and society that are not directly reflected in the price of a given food (Clapp). This ranges from the consequences associated with the trend towards the ever-increasing industrialization of farms, which will be further explored in the latter half of this paper, the previously mentioned devaluation of farm workers, and even health problems like obesity and heart disease. All of these outcomes are easily externalized and the result is a perpetuation of the biophysical contradiction producing them (Weis). There are additional externalized costs far more detrimental to food production itself. These include, "the undervaluation of the damage associated with: soil erosion and salinization; the overdraft of water and threats to its long-term supply; the loss of biodiversity and crucial 'ecosystem services' (e.g pollination, soil formation; and greenhouse gas emissions) (Weis 316; Clapp; Waltner-Toews and Lang). By framing these as subsidies for America's cheap and abundant food, Weis underlines that of all these ecological contradictions, "the failure to account for the atmospheric burden associated with fossil energy, and its impact on Earth's climate system, represents one of the most fundamental biophysical contradictions of industrial capitalism" (Weis 318-319).

Fossil fuels provide the basis for technological fixes that substitute labor, skill, and knowledge with mechanization at the cost of global climate and ecosystems. While cheaper in the short-term, the externalized costs of this system will catch up with us one day. As we continue in trajectory towards a more industrial model, we invest in practices that lead to climate change and soil degradation at future generations' cost.

Though this biophysical contradiction is evidently of enormous threat to humans and the systems that we depend on, Weis theorizes that because these contradictions have not yet destabilized the "operative logic of its dominant actors," they go on unconsidered. In other words, the crises resulting from a fossil agriculture have not yet affected production in a way significant enough to re-structure the system, it carries on. Climate change has not yet made America's heartland inhospitable to wheat production, just as a decline in soil quality has not yet caused a decline in production.

Weis centers his argument on fossil fuel use's biophysical contradiction over concerns on peak oil. However, concerns over the end of economically viable oil reserves are now dwarfed by the dual threats of climate change and soil degradation. In light of the IPCC's most recent report, it appears that although the limited nature of carbons as a resource poses a concern, climate change is of more urgent significance. Threats of peak oil have long been theorized and discussed, but this has not slowed investment in or expansion of fossil energy. On the contrary, fossil fuel infrastructure and use has expanded, ultimately positioning climate change and the existential consequences it carries as more urgent than the end of oil.

This ongoing process of investment and expansion embodies the institutional inertia Carton so clearly outlines. It illustrates the powerful function landscapes play in determining our use of a fuel source no matter its cost or longevity. Even in light of calls to reduce emissions in half by 2030 and reach net-zero by 2050, the landscape carries on functioning as it was designed (Intergovernmental Panel on Climate Change).

Climate change does not discount the fact that fossil fuels are a non-renewable resource but rather begs us to answer the question: can we *afford* to use these resources even if they are available? It demands that as a society we reflect on the most "fundamental biophysical contradiction" of our time, how our landscapes build this contradiction, and the ways in which it undermines systems and processes we depend on.

The Metabolic Rift

With a solid foundation for viewing landscapes as spaces built upon a particular set of ideas and resources, they move beyond passive spaces towards a powerful force shaping and representing our reality. To bring even more understanding to this phenomenon, we move to the metabolic rift. Initially based on Marx's writing and then gaining traction in contemporary sociology with John Bellamy Foster's work on the subject, this literature positions these landscapes as a mediating force between humanity and its connection with the ecological nutrient cycling processes. In this way, scholars' work defining and discussing Marx's metabolic rift aids the theorization of consequences resulting from investment the fossil fuel landscape.

The metabolic rift gained prominence with Foster's work in the late 90's when he argued that the classical sociological tradition is not devoid of environmental sociology (Foster). Rather, the assertion was that Marx's later work, particularly his writing in *Capital* in the early 1860s offers a starting point for a "comprehensive sociology of the environment" (Foster 398). This comprehensive sociology is theorized in terms of a metabolic relationship between humans and the planet. Embodied through the, "transfer of material energy from external nature to society," the feedback within this metabolism has varied in different stages of history. As the article's title "Marx's Theory of Metabolic Rift: Classical Foundations for Environmental Sociology suggests, the work focuses on the metabolism between humans and the earth "the metabolism between man and nature exists, as we have seen, in the transfer of material energy from external nature to society" (Bukharin quoted in Foster 27).

Where the rift in this metabolic relationship first occurs is in the break between humanity and the soils growing our food. With the onset of the Industrial Revolution, early industrial farms began to separate spaces of food production and spaces of food consumption. Concurrently, Europe's soils began to face a crisis of nutrient depletion (Foster and Magdoff). In hindsight, this moment represented a critical turn in agriculture, as the use of imported nutrients, at the time in the form of imported guano, became essential to the continuation of the budding industrial-agricultural model (Foster and Magdoff). Under these conditions, German chemist Justus von Liebig produced a collection of writing on, "the role of soil nutrients such as nitrogen, phosphorus, and potassium (N, P, K) in the role of plants" (Foster and Magdoff 44, abbreviations my own).

This work was taken up by Marx and quoted in *Capital,* the work in which he discusses the rift. Marx quotes Liebig's findings

> …large landed property reduces the agricultural population to a constantly falling minimum, and confronts it with a constantly growing industrial population crowded together in large cities. It thereby creates conditions which cause an irreparable break in the coherence of social interchange prescribed by the natural laws of life. As a result, the vitality of the soil is squandered, and this prodigality is carried by commerce far beyond the borders of a particular state.
>
> Liebig quoted by Marx in *Capital* 588

Upon Liebigs's work in explaining the physical and chemical processes involved in soil nutrient cycling, Marx built a critique on the social implications of this phenomenon. Marx's conception of the rift between humans and the earth began with acknowledgment of a basic process of food production in one place, and the flight of nutrients occurring when that food carries its nutrients to a distant place of consumption. His focus was on the accumulation of nutrients in the form of human waste in a locale distant from the food’s place of production. In this geographic separation, the soil is continuously depleted with nutrients shipped elsewhere rather than returned back to the soil. In his work *Capital*, Marx writes:

> Capitalist production ... disturbs the metabolic interaction between man and the earth, i.e. it prevents the return to the soil of its constituent elements consumed by man in the form of food and clothing; hence it hinders the operation of the eternal natural condition for the fertility of the soil.... All progress in capitalist agriculture is a progress in the art, not only of robbing the worker, but of robbing the soil; all progress in increasing the fertility of the soil for a given time is a progress towards ruining the more long-lasting sources of that fertility.... Capitalist production. therefore, only develops the techniques and degree of combination of the social process of production by simultaneously undermining the original sources of all wealth - the soil and the worker.
>
> Marx quoted by Foster and Magdoff 49

While Marx speaks of capitalist agriculture as the art of robbing the soil through a spatial break in nutrients, another important break is implied through his evaluation. The assertion that “progress in increasing the fertility in a given time is a progress towards ruining the more long-lasting sources of that fertility” brings forth a temporal element to the rift. In the present, soil and nutrients are separated physically, but the long-term result is a weakening of soils and a depletion of the resources used to replenish them. In the time of Liebig and Marx this resource was bat guano, however in modern era this resource is largely fossil fuel-based Nitrogen fertilizers. Both resources are of limited quantity and their sustained use ultimately translates to less concern for sustainable and ecological management and less availability later in time.

As is clear, Marx's observations were on what is seen as the first break in the metabolic relationship between humans and an external nature—humans' physical removal from the land. While this represented the first break, it certainly was not the last. The second break occurred with the removal of animals from the land. Under the rise of agribusiness during the Green Revolution, agriculture became even more compartmentalized with the removal of animals from grazing the land (Foster). Instead, these animals were now placed in placed in separate feedlots. With acknowledging that farming has never been an activity in complete harmony with Earth's natural processes, it remains significant that farming's most recent iteration disrupts relationships between plants and animals. A review focused on the cycling of microbial communities notes the importance of animals and animal waste in maintaining balanced nutrient cycling throughout an ecosystem (van Bruggen et al.). The study's focus on ecosystem health encompasses, "the health of plants and other organisms interacting with animals and humans, because the health conditions of all organisms in an ecosystem are likely interconnected (van Bruggen et al.). The multi-layered outcomes of removing animals from the landscape is complex and the subject of much research and discussion. Explorations of sustainable intensification and agroecology suggest that returning animals to land represents an important piece in overall ecosystem management (Dumont et al.; Campbell et al.). While the animal-soil ecological interdependence remains an opportunity for further research and understanding, it seems appropriate to employ a basic framing of the second break in the soil as the end of animals', and particularly ruminants', role in fertilizing the soil. With this element of the ecosystem effectively separated into feedlots, animal waste becomes a significant source of greenhouse gas emissions rather than a means of cycling nutrients back to the soil—original source of energy and nutrients.

While Foster focuses on the role fertilizers—first biological with the previously-mentioned Guano trade and then chemical with the invention of the Haber Bosch process—played in allowing agriculture to operate despite the metabolic rift, his work only briefly acknowledges the role fossil fuels have played in this rift throughout history. Here, Clark and York deepen Foster's analysis and apply it to the human influence on the global carbon cycle, and how this metabolic relationship drives climate change (Clark and York). Clark and York's examination of the global carbon cycle takes into account the whole biosphere in its consideration of carbon's presence in the air, rocks, soil, water, and all life forms. Carbon moves throughout our biosphere, cycling through each of these components as it is emitted by some and absorbed by others (Clark and York). Carbon in the form of fossilized biomass, as we have seen, plays an outsized role in constructing agriculture and other integral features of modern society (Weis; Huber). Humans, in harvesting and burning fossil energy, unleash many thousands of years' worth of stored carbon into the biosphere. For further clarification of this, Clark and York write,

> Just as the expansion of capitalist agricultural production globalized the metabolic rift of the soil nutrient cycle, capitalist expansion pushed forward technological development that allowed industrial production to take place at ever-greater levels. Previous modes of production primarily lived and operated within the "solar-income constraint," which involves using the immediate energy captured and provided by the sun. By mining the earth to remove stored energy (past plants and animals) to fuel machines of production, capitalist production has "broken the solar-income budget constraint, and this has thrown [society] out of ecological equilibrium with the rest of the biosphere.
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Clark and York's analysis moves beyond the immediate human-soil relationship and attempts to apply the same concepts at both a more fundamental and more expansive level. Why may carbon represent a more fundamental conception of the metabolic rift? While soil represents just one component of the earth's ecosystems, carbon is foundational to all components of life on earth. The consequences of a break in global carbon cycling may be seen as more expansive than a break in soil nutrient cycling because they apply on a planetary scale. In combusting "fossilized sunshine," the mining of the global carbon cycle contributes to an accumulation of greenhouse gasses in our atmosphere and ultimately global climate change as a catastrophic side-effect (Huber 107).

While the metabolic rift as explained thus far has been largely theorized in terms of breaks in the metabolic relationship between humans and the earth, another important example of relational breaking exists in the form of an epistemic rift (Schneider and McMichael). Rather than a rupture in solely the organization of social and ecological processes, the metabolic rift also encompasses a damaging of labor as a practice (Schneider and McMichael). Schneider and McMichael raise an important critique to a narrow conception of the metabolic rift in arguing that, "adding the practice of (agricultural) labour and how labour interacts with ecological processes would greatly enhance the analytical utility of the concept" (475). Including labor and the knowledge derived from that labor broadens the concept to include the flight of information resulting from urbanization when people relocate not only their bodies, but their cultural, historical, and geographically-specific forms of knowledge (Schnieder and McMichael).

In addition to explaining this process in terms of rural-urban migration, the inclusion of fossil fuel landscapes allows us to view it as a result from the privileging of fossil fuels over investment in people and the land. Such a lens once again brings us back to considering the diminishing numbers and devaluation of farm workers as a direct outcome of this rift. An even more consequential means of conceptualizing this epistemic rift exists in the experiences of immigrant farm workers in the United States. Farmworker Justice reports that around 72% of America's agricultural workers are immigrants, and that over half of our nation's 2 million seasonal workers do not have an authorized immigration status (Hernandez and Gabbard). An "illegal" status, that the majority of America's agricultural workers are considered "alien" highlights the devaluation of farm work and embodies the ultimate form of an epistemic rift. The critical knowledge gained by these workers likely will not be valued, nor does it have any promise of accumulating and informing sustained practice on America's farmland. With acknowledgement immigration and human rights issues' complexity and a call for avoiding a reductionist view of the complex interplay between people, food and the environment, it remains fair to suggest that the industrial mode of agricultural production encourages an agriculture that minimizes human knowledge of specific ecosystems and relationships with the land. As a result, we lose critical knowledge within an industrial model privileging scale and mechanization over sustainability and justice.

Fossil Fuel Landscapes and Deepening the Metabolic Rift

Building upon this discussion of the metabolic rift, I argue that an integral component of humanity's "second break" from the earth is access to and use of hydrocarbons to power agriculture. Foster notes that machines replaced animals and implies the continuous flight of humans from rural, agrarian environments to the city, but does not consider the most essential ingredient driving and expediting this process. Clark and York widen conceptions of the metabolic rift to include the global carbon cycle, but largely move away from a discussion of agriculture in doing so. Schneider and McMichael do not acknowledge how fossil fuels supply the energy and synthetic nutrients that allow these systems to perpetuate a mode of production that is not informed by ecological consideration or concern. Reliance on mechanical and chemical fixes is a unique product of fossil fuels and it is for this reason that I have taken the opportunity to further explore the specific relationship between each of these concepts, fossil fuels and food production. With the body of literature on the metabolic rift in its various applications strengthening a theoretical base, fossil-fueled agriculture remains an important and under-explored entry into examining humans' metabolic relationship with the soil, the carbon cycle, and the epistemology of food production.

Each of humanity's three agricultural revolutions that have occurred to date—the first over a span of many of hundreds of years with the transition from hunter-gatherer societies to early agricultural societies, the second with the break in soil nutrients as the industrial revolution spurred a migration of people from the country to the city, and the third with the Green Revolution and the replacement of animals with machines as the primary workforce—represents a new iteration of our relationship with energy . While each of these shifts is relatively straightforward, the role the availability and accessibility of energy has played in each of these revolutions is easily overlooked.

However, when taken together, fossil fuel landscapes and the metabolic rift offer a clear picture of the relationship between energy and changes in food production. Conceptualizing our fossil foodscapes in terms of a metabolic rift gives new life to each concept and ultimately provides profound vantage point by which to critique modern, industrial agriculture in the United States. Viewed as complimentary to one another, fossil foodscapes and the metabolic rift allow us to view the physical spaces that produce our food as the tangible manifestation of the energy that powers the system. Whether this manifestation occur in the presence of industrially sized fields, automated irrigation, or mechanized labor, the hallmark components of industrial agriculture are the direct embodiments of our investment into fossil fuels as a power source and as the operational logic for our food production.

With fossil fuels as a temporary fix allowing humans and animals to be relieved from their labor, allowing farms to increase in size and the overall yield, Americans have bought into the existence of industrial farming in its literal and figurative manifestations. The sustained investments in this model in the form of the adoption of mechanization and chemical input has created the unique faming geography described thus far. The figurative acceptance of this mode is evidenced through perhaps well-intentioned assertions that this is the only system capable of producing enough food to "feed the world." Each manifestation of the fossil fuel landscape parallels the various forms of metabolic rift outlined thus far. These landscapes mediate a continuation of the break in cycling on each level from soil quality to carbon cycling to knowledge accumulation.

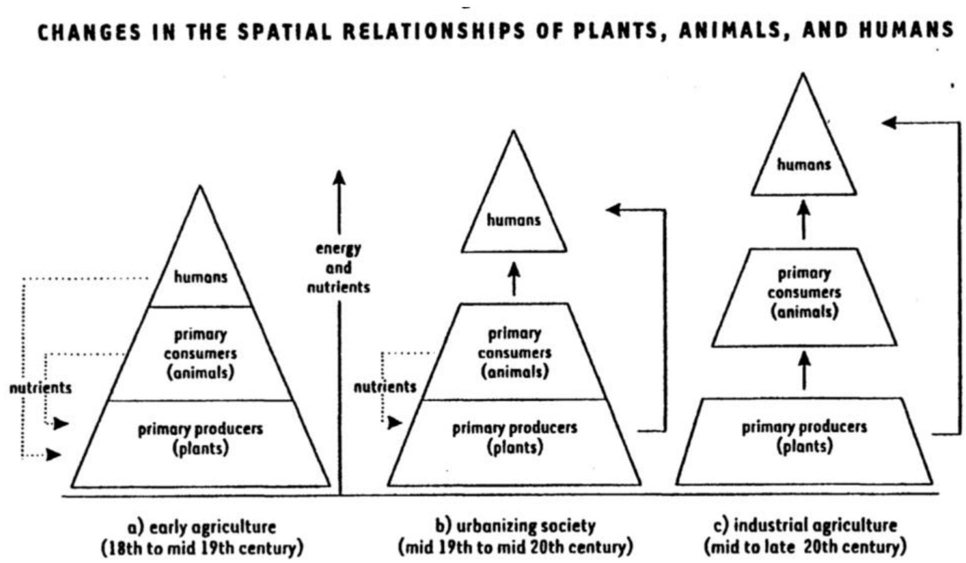

Figure 2

Changes in the Spatial Relationships of Plants, Animals, and Humans. Reproduced from Foster and Magdoff

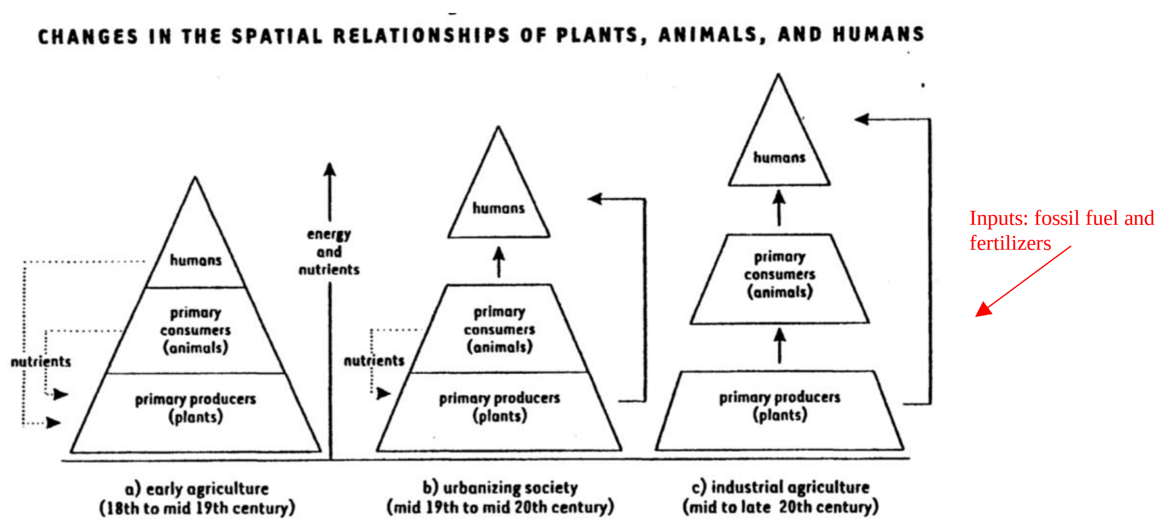

Figure 3

Spatial Changes and Inputs Reproduced from Foster and Magdoff. Annotations my own

Here I have reproduced two versions of a chart used by Foster and Magdoff in their paper *Liebig, Marx and the Depletion of Soil Fertility: Relevance for Today's Agriculture*. The chart describes changes in the spatial relationship of plants, animals, and humans in each successive agricultural revolution. The first is the original. In the second, I have added "inputs" to highlight the central role carbon-based assistance—whether it be in the form of labor or soil quality assistance—plays in maintaining a system wherein each element is spatially separated and no longer existing in direct relation to the others.

In an age of mechanization and carbon reliance, the scale of the metabolic rift has surpassed what Marx theorized in his day. Not only do we have an agriculture in which the break between humans and the land is a foundational characteristic, we have an agriculture that relies on and perpetuates a break in the global carbon cycle.

As visually represented through the below graphic, if the metabolic rift represents a break in the metabolic relationship between humans and the earth, and if fossil foodscapes are mechanisms for further driving this break, together they create a feedback loop of deepening the rift and reinforcing the landscape (see figure 4). These landscapes' embodiment of a break in the global nutrient and carbon cycle in order to produce our food consequentially harm the ecosystems and climate that make them viable in the first place, a reality that makes the existence of this feedback loop particularly worrisome to people considering the long term implications of these practices.

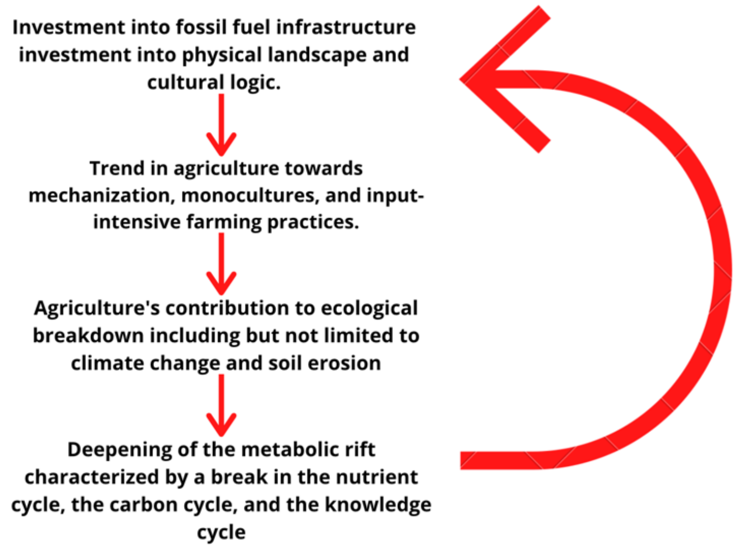

Figure 4

Accumulating effects of investment in carbon-based infrastructure and inputs in agriculture. Created by the author, Siena Polk

Historical Relevance

What makes the moment we are currently living in a time begging for discussion of fossil foodscapes and the role they play in deepening the metabolic rift? With the uniquely-constructed lens we have created, I will now outline the compounding and consequential crises entangled in today's fossil foodscapes.

Climate Change

Today's science increasingly warns about the impacts that human activity has on the environment we depend on. Despite the scientific community's longstanding consensus on climate change and the dangers it poses to life on earth, greenhouse gas emissions have continued to rise throughout the world.

In November 2019, over 11,000 scientists from 153 countries signed on to an article with a dire warning on the state of our climate. Scientists clearly outline the climate emergency's leading drivers. Among these are the continued increase in the three most abundant atmospheric greenhouse gasses – CO_2, methane, and Nitrous Oxide (Ripple et al.). In recent decades, increased energy consumption leading to increases in greenhouse gas emissions. The article states, "the climate crisis has arrived and it is accelerating faster than most scientists expected. It is more severe than anticipated, threatening natural ecosystems and the fate of humanity" (Ripple et. al 2). Greenhouse gasses like CO_2 and methane have already caused an average surface temperature change of 1 degree Celsius.

This warning clearly outlines the necessity of rapidly ending our relationship with carbon, "The world must quickly implement massive energy efficiency and conservation practices and must replace fossil fuels with low-carbon renewables and other cleaner sources of energy safe for people and the environment" (Ripple et. al 4). Nearly all sectors of industrialized human society are implicated in this call for a new relationship with energy that places sustainability as a priority. The outcomes of this brief yet consequential relationship with carbons, specifically the rapid accumulation of carbon dioxide in our atmosphere are, as I have already said, here today. For this reason, in addition to a rapid move away from the use of fossil fuels, we must begin to reinforce the earth's capacity to remove CO_2 from the atmosphere by strengthening forests and other natural ecosystems (Ripple et. al 4). The IPCC's 2018 report is in direct agreement. The report states that, should we continue to emit greenhouse gasses as the same rate, the Earth's average temperature will rise by 1.5º C sometime between 2030 and 2052 (Masson-Delmotte et al.). Although most previous studies used 2º C as the benchmark upper-limit increase before seeing catastrophic effects, this new report finds that many, "health, livelihoods, food security, water supply, human security, and economic growth" are threatened with a rise of just 1.5ºC (Intergovernmental Panel on Climate Change).

Thus, the IPCC calls for "massive and far-reaching transitions in energy, land, urban infrastructure, and industrial systems" (Intergovernmental Panel on Climate Change). The *only* model in this report that limits warming to 1.5º with little or no overshoot requires humanity to halve its CO_2 emissions by 45% from 2010 levels by 2030, and it requires the planet to reach net-zero emissions by 2050 (Intergovernmental Panel on Climate Change). A process of de-carbonization should have begun long ago.

The world's scientists have produced a clear and dire warning (Masson-Delmotte et al.). It is time for humanity to end its relationship with climate-changing fossil fuels before it's too late. Critical to this reality is the fact that not all nations have an equal role in producing today's climate reality. Of the planet's nations that have industrialized and amassed great wealth—largely at the expense of the environment and people in the Global South—the United States of America stands as the largest single-country source of Carbon Dioxide emissions throughout history (Gillis and Popovich). Although China now leads in terms of yearly emissions rates, the United States has contributed one quarter of the planet's cumulative anthropogenic Carbon Dioxide emissions (see figure 5) (Ritchie and Roser).

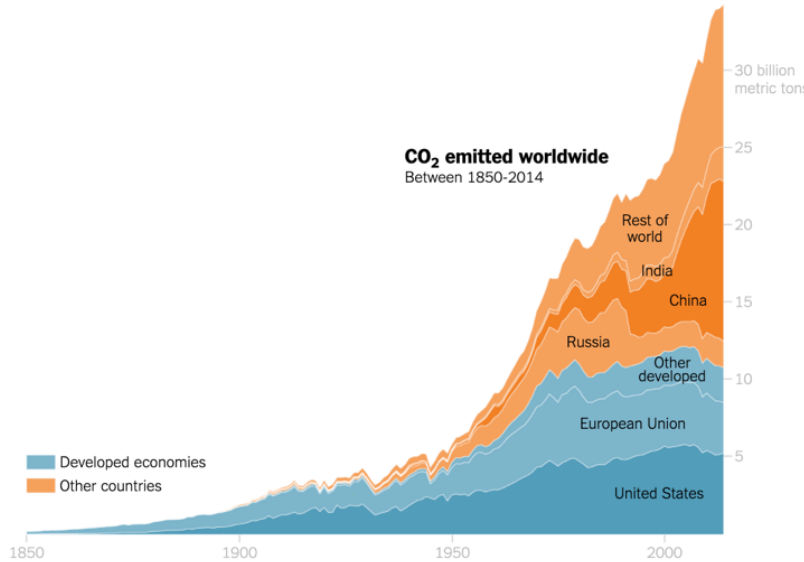

Figure 5

Tons of CO_2 Emitted since Industrial Revolution, New York Times, Data via Carbon Dioxide Information Analysis Center

While it is true that the United States is no longer the yearly global leader in Carbon emissions, it is also true that climate change remains a disproportionately American problem. I wish not to suggest that this nation is the first or most impacted by this crisis's worst effects, but rather that it has played an outsized role in catalyzing the changes occurring today and into the future. The United States' responsibility in terms of reparations and assistance is a topic rightfully discussed on local and international levels. However, for the purpose of my exploration into fossil fuels and agriculture, my focus is set on local use.

All sectors currently reliant on fossil fuels are due for a swift transition. When focusing on agriculture the paradox of organizing our society around energy sources that are inherently detrimental to that society is particularly clear. Instability in weather patterns already affects food production in the United States and beyond (Simmons).

Within an industrial system, the methods used to produce food are in part responsible to the very destabilization of that system. Agriculture relies on a stable climate yet within the industrial paradigm it paradoxically destabilizes that climate.

As I have outlined, there are two urgent and consequential items for action: lessening our dependence on carbon and working to mitigate the consequences of this relationship. Both, as I will explain, are fundamentally interconnected with industrial agriculture, positioning this human activity as uniquely situated for exploring and addressing humanity's relationship with fossil fuels.

Soil Quality and Soil Erosion

Soil quality is less politicized and less frequently discussed than carbon emissions climate change. However, sustained soil erosion is of the upmost concern to agriculture. While agriculture stands as just one factor contributing to climate change, food production throughout the ages is largely responsible for soil erosion in agricultural systems globally.

This phenomenon has been the cause for the decline of civilizations. Montgomery reports that, "few societies managed to conserve their soil" (50). Despite a romanticized vision of harmony between past civilizations and their relationship with the environment, geoarchaeological projects have demonstrated that where there has been farming, there has been soil disruption and erosion (Kutilek and Nielsen). For example, studies on ancient Greece show, "that soil erosion episodically disrupted local cultures, forced settlements to relocate, led to changes in agricultural practices, and caused periodic abandonment of entire areas" (Montgomery 54; Dotterweich; Jackson). Likewise, observations of land just north of Rome suggest an erosion rate that was just a fraction of an inch per year but over the centuries could have removed six inches of topsoil in less than 1,000 years (Montgomery 63).

Although humans have depleted the soil since the dawn of the agricultural revolution, the rate at which humanity has degraded and depleted the soil has increased with industrial practices (Crews et al.; Dotterweich). Today, despite massive technological transformation and no shortage of research on the threats soil erosion poses, we remain at risk of the same processes. Every year, the planet loses 24 billion tons of topsoil (Crews et al. 3).

Much like the disparity between nations in cumulative carbon emissions, different forms of agriculture have different impacts on the rate of soil erosion. Under the industrial, fossil-fueled model, mechanization drives crop uniformity. Industrial agriculture's monoculture crops are annual plants that are planted, grown and harvested each year. Before this process can repeat itself, the soil is tilled. Such a routine has little resemblance to soil building ecosystems that are characterized by diverse, perennial crops. In these systems, soil forms at a slow but steady rate. Contrastingly, studies find that, industrial, yearly-till loses topsoil at up to 360 times the rate of soil formation (Crews et al.; Veum). To be sure, rates of soil formation and loss vary broadly across ecosystems, but even given these variations, global soil production averaging less than 0.2mm/year and the loss averaging greater than 1mm/yr the consequences of such practices are seen on a human timescale. For this reason, the FAO reports that soils throughout the world are in generally poor condition (Crews et al.; Veum).

While climate change and soil erosion may appear distantly related, they are interconnected through the ways in which human interactions with the environment carry multi-layered, complex consequences. With the configuration of our agriculture as one that has developed to rely on mechanization and chemical inputs, we have also developed a reliance on, as articulated by Crews et.al,

> “The energetic opportunities provided by fossil energy, together with the reduction of agroecological complexity and diversity that mechanization required, is one of the underlying drivers behind the rate at which natural ecosystems have been degraded and polluted, and the topsoils have been lost”
>
> (Crews et. al 2)

Soil loss represents but one of several phenomena affecting the quality of the environment in which we grow our food. This physical process of depletion is accompanied by other biological processes such as the cycling of organic matter and the depletion of nutrients like Carbon and Nitrogen (Veum et al.). Soil’s quality is not only a matter of how much soil exists, but a complex interaction between chemical and biological matter (Glover et al.).

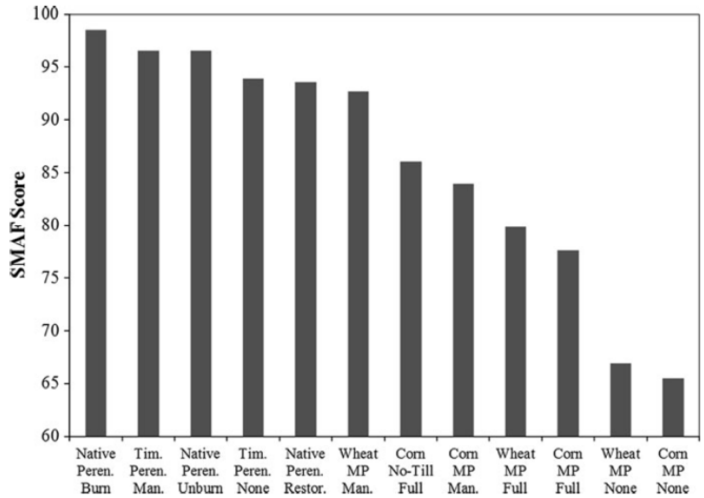

Figure 6

Results of Soil Management Assessment Framework (SMAF) in various landscapes. Reproduced from Veum.

The above figure illustrates the results of a study scoring the quality of various soils in Missouri using the soil management assessment framework (see figure 6) (Veum et al.). As evidenced by the long-term study's findings, native perennial landscapes score the highest while annual monocultures score the lowest.

Both climate and soils are affected by food production. Each may initially appear disconnected to my initial concerns about energy, but under close scrutiny the systems growing our food and threatening these precious conditions are the logical product of a system based on fossil fuels. Linking each of the issues outlined thus far is the cheap, abundant, and perhaps most importantly, dense energy used to fuel this system.

Energetic History

An examination of The United States' historical relationship to energy is useful for a better understanding of the ways in which fossil fuels shape our lives, and particularly how we grow our food. For humans living in a modern, industrialized world, the amount of energy that we consume and expend on a daily basis is not necessarily of direct concern. While many workers in industrialized nations continue to earning a living through manual labor, even those more closely connected with their physical energy consumption and expenditure likely supplement their basic needs such as shelter, food, and transport with energy sources that do not come from their own bodies. For most people, it holds true that today we acquire, consume, expend, and trade energy with a degree of abstraction from our physical selves. For example, we pay for our energy every time we pay a utilities bill or go to the gas station. The energy we expend is not limited by the solar energy embodied in the food we eat or resources that we burn.

As we have seen, energy and humans' ability to harness it has dramatically shaped history. While this relationship is ever shifting and evolving, we can see humans' relationship to energy have fundamentally changing in two distinct shifts (Huber). The first shift occurred with the agricultural revolution, wherein agriculture allowed humans to concentrate food's caloric energy into a fixed space (Huber). This first agricultural revolution freed up time and resources, ultimately allowing people and societies to expend time and resource in other pursuits than agriculture, all thanks to surplus energy.

When thinking about energy, it is important to consider that early agriculture was a system almost entirely powered by sunshine: the sun's energy was turned into food by plants which in turn fed animals and humans: the two primary sources of labor in traditional farming systems. Between 80-85% of all mechanical energy came from either humans or animals before the industrial revolution, with the energetic balance supplied by renewable forms of energy such as water and wind (Huber 107). It is within this solar regime that, "it was a thermodynamic necessity that more food calories were produced on farms than farmers invested in growing the food" (Crews et al. 2). This thermodynamic necessity is well theorized as the Energetic Return on Investment, or EROI. For our purposes, the EROI describes the ratio between the energy invested into producing a particular food and the amount of energy that that food supplies (Madison). This represents the same thermodynamic necessity described by Crews: more calories needed to be produced than invested in order to sustain individuals and communities alike (Crews; Madison).

The constraints imposed by the EROI in solar agricultural regimes are dramatically different in the context of the second shift, the industrial revolution (Hall). This shift in human/energetic relations radically transformed all of the rules and restrictions that existed in the solar regime because, for the first time, human and animal power could be supplemented by dense fossil energy. Such a change allowed for the thermodynamic restraints imposed by the solar regime to be broken (Hall).

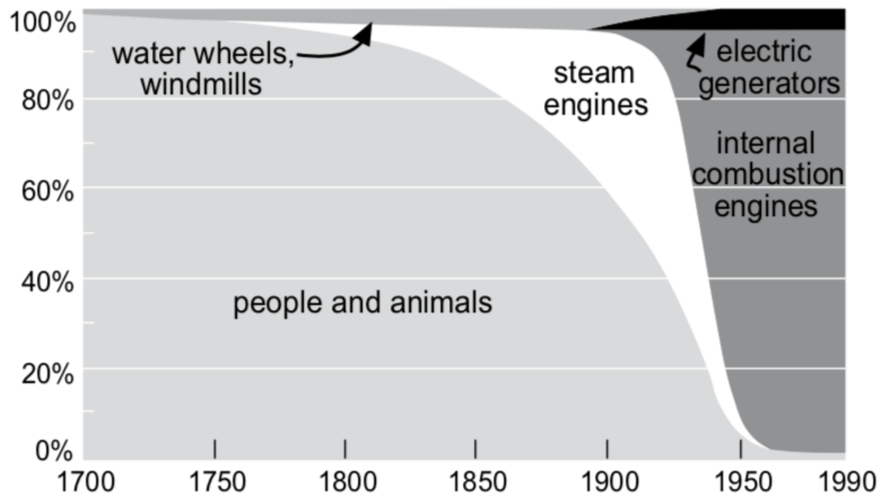

Figure 7

Global Shares of prime mover capacity since 1700. Reproduced from Huber, adapted from Smil.

With initial fuel coming from coal and eventually the replacement of coal with oil, fossil energy dramatically reshaped agrarian landscapes (Crews et. al). In concrete terms, this translates to the freeing up of 100 hours of manual labor in one gallon of gas (Crews et. al 2). In consequence, such an energetic freedom allowed for an unprecedented change in human energetic relationship. Whereas before the industrial revolution, the metabolic relationship between humans in the land had to require less energy for production than was needed for consumption, today's agriculture may consume as much as four times the energy to produce food than the food contains (Crews et. al 2).

Under a fossil fuel regime, the EROI is either lower or inverted as the energetic inputs from fossil fuel increase the energy invested into agriculture without a proportionate increase of yield. The following figure, although not based directly on empirical measurements, proves helpful for understanding overall trends in energy use and modern agriculture (see figure 8). The curve represents the balanced ration between yield per area, and calories produced per area. In a “highly developed solar-based agriculture,” the yield per area is moderate, with a large number of calories produced in comparison to the energy input. If one considers the application of carbon-based forms of energy into this system the beginning of the downward slope, it becomes evident that although yield per area increases, the ratio of energy input/output becomes less favorable.

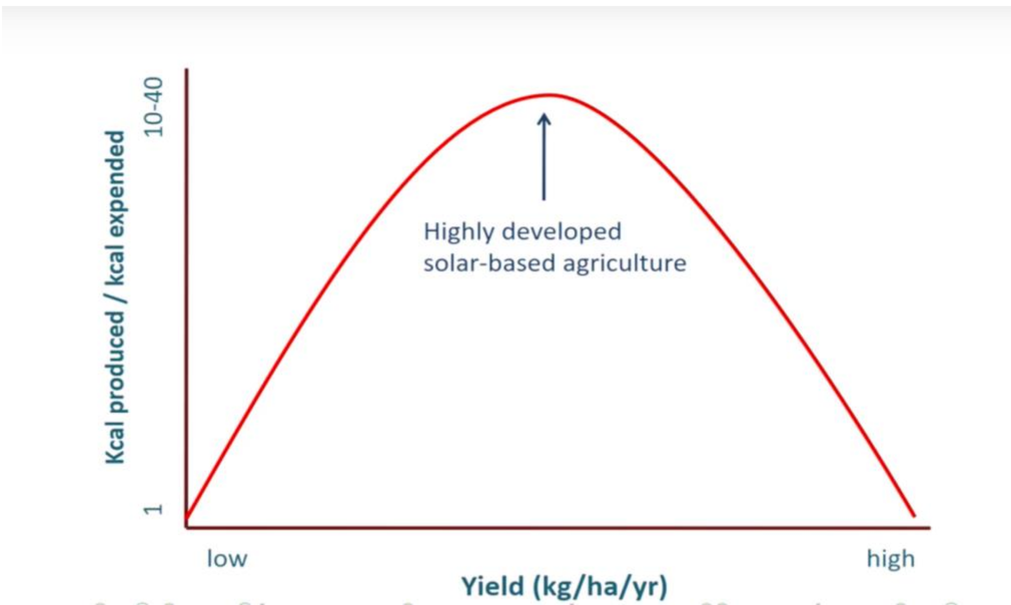

Figure 8

Reproduced from Crews.

Even if fossil fuels never cease to be a valuable resource, their careless or assumed use, at a certain point, is not even in the interest of increased production. An inverted EROI suggests a lack of regard for the dangerous phenomena that I have described. It suggests a lack of foresight for future generations in terms of contributing to deteriorating environmental conditions as well as an unnecessary squandering of the resources themselves. This short-sighted reasoning will be further explored in the following section as I focus on energy use in modern agriculture.

Energy Use in Modern Agriculture

With a preliminary understanding of how agriculture's relationship to energy has shifted, an examination of energy in the United States modern, industrial system is better contextualized. Today, United States' agriculture is intimately linked with fossil fuel. The operation of farm machinery such as tractors, combines, mowers and balers, operation of small farm vehicles, irrigation equipment, climate control for commodities like fruits and grains, processing, transportation, fertilizers, and pesticides are just a few of the components of a modern, industrialized systems that are dependent on some sort of fossil fuel (Schnepf). Dr. Galen Martin refers to this combination of fossil fuel-based inputs as a "carbon package," an image that ties nicely to the fossil fuel landscape (Martin). While substantial gaps exist in data on the prevalence and consumption at each part of this carbon package and each stage of the food system, as well as in our understanding of how various energy forms are used and their contribution to greenhouse gas emissions at each part of the system, the general trends in energy use in the food sector illustrate patterns in the linkages between fossil fuel and our food. While there remains a need for the examination of the linkages that exist in each part of the food system—from production to transportation to processing to consumption—my focus in terms of the data that I will present and the analysis that I will provide is on agricultural production.

The USDA's 2017 study on the role of fossil fuels in the US food system and diet examines food produced and consumed in the United States and this food's relationship with fossil fuels (Canning et al.). The study reveals that, even in comparison with economy-wide fossil-fuel use, food systems are disproportionately reliant on this fuel source. The researchers report, "whereas 86% of nationwide energy consumption in 2007 came from fossil fuels, the share of U.S food system energy from fossil fuels was 93 percent" (Canning et al. iii). In total, the fossil fuels burned in the same year to produce American foods and beverages was produced 13.6% of economy wide fossil fuel-originated CO_2 emissions (Canning et al.).

The measurable dependence that American food systems have on fossil fuels have been on the rise since even before the Green Revolution of the 1970s. In the nearly forty years between 1963 and 2003, food system's share of the "national energy budget" increased by 25 percent (Canning). Around one half of this increase in energy consumption is explained by the shift from human labor towards mechanization. Over the same period, however, the share of the US food system in the nation's economy declined by one-third. This pattern indicates that, even in recent years, the resources throughout the food system including for food production and distribution have increased without a similar increase in economic importance. The fact that a half share of this increase in resource expenditure is explained by mechanization could offer a starting point for the exploration of the agricultural sector's economic importance: investment is in machinery rather than people.

The USDA's study also found that a lower price of fossil fuels correlates with higher fossil fuel use (Canning). This reflects how market forces incentivize the use of this fuel source, and it may be tempting to believe that by simply raising or taxing fuel prices, the issue of fossil fuels in agriculture may be resolved. I will address this claim later on. Although the USDA's 2017 study does not provide a detailed focus on agricultural production, it empirically illustrates the tight bond between American food and fossil fuels, and indicates that so long as this energy source is economically viable, it will continue to play an important role throughout food systems.

Pimentel et. al further illustrate this close relationship between American food and fossil energy. In their paper "Reducing Energy Inputs in the US Food System," the authors calculate that each American requires an average of the equivalent of 2,000 liters of oil per year in order to supply their food (Pimentel et. al 459). Agricultural production, food processing, and food packaging make up 14% of the country's energy use. In terms of energy in food production, Pimentel et. al find that around one third of all the energy to produce a hectare of crops is invested into machinery. Mechanization allows workers to reduce their time input for producing crops by 110 times (Pimental et. al). Most crops require around 1,200 hours of manual labor per hectare to produce, and mechanization shrinks this number to around 11 hours per hectare.

Although the article proposes a number of changes that could reduce our dependence on oil in the food sector without necessarily abandoning current systems of production (such as eating less meat and fewer processed foods), the authors explicitly state: "an increase in human and animal labor as well as a decrease in fuel-powered machinery is necessary to decrease fossil fuel use in the US food system" (Pimentel et al. 464). These researchers do not call for a dismantling of the entire system, they instead offer relatively-modest changes that could be made such as using less machinery, cover cropping, reducing tillage, and consuming less meat. These prescriptions are similar to those in the USDA study which includes a carbon tax and changes in dietary behavior. However, given the data presented in both of these studies, it both appear to argue that links between American's food and hydrocarbons, the connections between the two will not be fundamentally addressed or even questioned without considering the characteristics of the entire system.

A common counter-argument in the defense of fossil fuels is the point that these resources are necessary in order to increase yields and, ultimately, "feed the world." Such a defense of fossil fuels either overlooks or willfully ignores the consensus that, globally, it is understood that the increase in yield achieved since the Green Revolution is the result of the "massive injection of fossil energy associated with modern techniques of agricultural production that do not correlate with a proportionate increase in yield (Arizpe et. al 3). As Pfieffer found, "Between 1945 and 1994 energy input to agriculture increased fourfold while crop yields only increased threefold. Since then, energy input has continued to increase without a corresponding increase in crop yield" (Pfieffer 9).

Arizpe et. al. build upon this claim through their research on efficiency in different agricultural regimes around the world. Their findings show that the injection of fossil energy into agricultural systems in industrialized nations has not served to increase energy efficiency when it comes to producing food. Rather, industrial agricultural systems have a reduced output/input energy ratio: while the energetic input in these systems has increased, there has not been a symmetrical increase in energetic (caloric) output (Arizpe et. al).

Azripe et. al demonstrate that the EROI ratio is inverted, and this inverted relationship correlates with the level of industrialization and, therefore, the level of fossil fuel use in any given nation. While it is true that the United States is among the most “productive” nations when it comes to agriculture, this productivity is owed to fossil fuel use. The nation has a high labor productivity, meaning there exists a small number of laborers in comparison to the amount of agricultural land. However, this high productivity also conveys that United States also has the highest dependence on machinery to farm so much land with so few people (Arizpe et. al 15).

Taken together, the findings of these diverse studies strongly argue for the re-thinking of the notion that the current industrial-agricultural model is the only one capable of “feeding the world.” When coupled with the acknowledgement that between 30 and 50 percent of the food produced globally is wasted, we are left with considerable leeway for re-thinking and re-structuring agricultural systems so that they are less energy intensive and less of a burden on the planet’s climate and ecosystems.

Nitrogen

While mechanization is the most visible embodiment of the relationship between fossil fuels and agriculture, the use of nitrogen fertilizers presents another example of the importance of energy use in modern agriculture.

The need for outside inputs to maintain fertile soils played a large role in the second agricultural revolution. Today, nitrogen use in industrial agriculture allows crop production to “keep up” with food demands while perpetuating practices that continue to remove nutrients from the soil without a concerted effort to maintain or replace it through farming (Stuart et al; Cao et al.).

In 1999, between 43 and 50 percent of the Nitrogen fertilizer used on the world’s cropland was of synthetic origin (Smil). Energy use expert Vaclav Smil writes, “While there are many energy sources that can replace fossil fuels, whose combustion is the main cause of human alteration of carbon cycle, there appears to be no imminent alternatives to our high, and increasing, reliance on the nitrogen fixed by the Haber-Bosch process” (Smil 658).

The Haber-Bosch process was first introduced for commercial application in 1913. The process uses natural gas in order to make ammonia out of nitrogen gas. Smil writes, “Ammonia is then used either directly as the most highly concentrated (82% N) and the cheapest N fertilizer (applied as gas or in aqueous solutions) or converted to urea, the most concentrated solid fertilizer (46%)” (Smil 652). The specifics of the Haber-Bosch processes position synthetic Nitrogen fertilizers simultaneously as reliant on fossil fuel for its production *and* a contributor to greenhouse gas emissions.

As illustrated below, the world’s use of nitrogen fertilizer increased by approximately ten times between 1950 and 2008 (see figure 9).

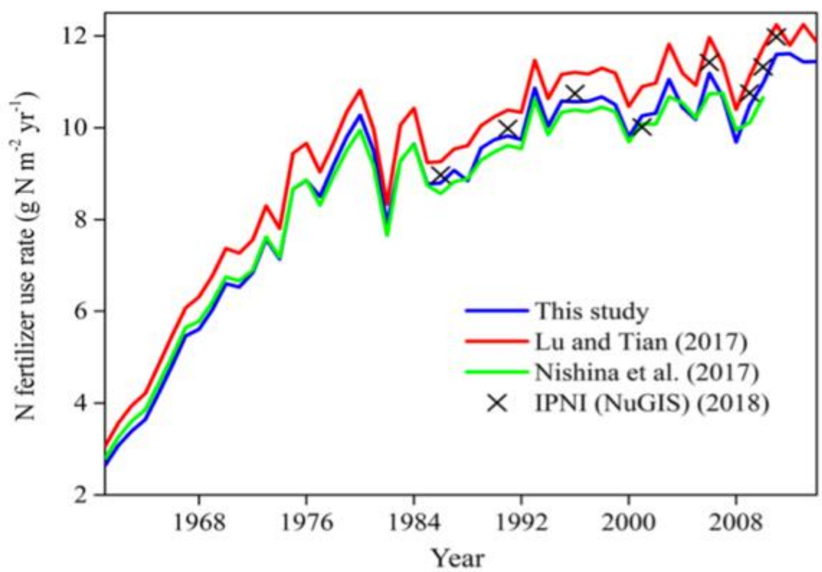

Figure 9

Depicts Nitrogen Fertilizer use rate throughout time as found by various studies. Reproduced from Cao et al.

While an abundance of negative outcomes for various ecosystems relates to the use of nitrogen fertilizers such as damage to aquatic and land ecosystems when carried away with runoff, the primary concern here is the way in which they further industrial agriculture's dependence on fossil fuels and the implications of this dependence.

Nitrogen fertilizers are yet another element of the carbon package positioning the United States as the number one consumer of oil in the world, and the nation's agriculture offers a powerful reflection of this relationship (Huber 2013, viii).

Within agriculture, I have demonstrated that the trend towards reliance on dense fossil energy has implications that inform the way we farm and think about agriculture. In thinking back to the damage to physical and chemical composition of soils, one can see that the soil's Nitrogen is threatened by annual monocultures produced on an industrial scale. It is with this in mind that the practice of replenishing this Nitrogen via a fossil-fuel derived process is visibly short-sighted.

Ecological Breakdown

When carbons combust, they release CO_2, the primary driver of climate change, into the atmosphere. Fertilizers convert to nitrous oxide (N_20), another powerful greenhouse gas up to 298 times more effective at trapping heat in the Earth's atmosphere than CO_2 over a 100-year period (Stuart et. al 2013). As agriculture has increased its dependence on machinery and synthetic fertilizers, it has simultaneously increased its dependence on fossil fuels and weakened the very climactic systems agriculture depends on.

Humans have released so much of this greenhouse gas into the atmosphere that its high concentrations are raising and will continue to raise global average temperatures. While popular media, politicians, and economic interests may work to obfuscate the relationship between burning carbon and climate change, science is clear that combustion is the primary cause and the solution is to stop it. In its 2017 report the IPCC writes:

> Rapid reductions in anthropogenic GHG emissions across all sectors following ambitious mitigation pathways reduce negative impacts of climate change on land ecosystems and food systems (medium confidence). Delaying climate mitigation and adaptation responses across sectors would lead to increasingly negative impacts on land and reduce the prospect of sustainable development (medium confidence) […] "Delaying action as is assumed in high emissions scenarios could result in some irreversible impacts on some ecosystems, which in the longer-term has the potential to lead to substantial additional GHG emissions from ecosystems that would accelerate global warming (medium confidence)

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Even if agriculture does not represent highest source of carbon emissions on the state or global level, the scale of the climate crisis demands that we evaluate and address the fact that fossil fuels serve as the primary basis for agriculture. The agricultural system as we know it cannot continue to exist if we are to address science's demands for avoiding climate catastrophe.

As I have established, climate change is not the only example of ecological breakdown related to agriculture. Soil quality is also implicated in this set of problems. Because of the system's sustained dependence on fossil fuels and overall investment in the infrastructure to maintain it, farms trend towards large, mechanized operations focused on annual monocrops. As evidence by the ever-lessening quality and quantity of our soils under carbon regimes, the organization of today's industrial agriculture inherently degrades environments crucial to our survival.

Despite gaps in the research describing how fossil fuel inputs feed the nations agriculture, data paints a picture of the links between combustible carbons and the food we eat. If we look closer and more thoughtfully, these links become self-evident. Take our use of nitrogen, for example. With the availability and accessibility of this synthetic fertilizer, no longer is it necessary to replenish soil nitrogen through careful stewardship. Cover cropping, crop rotation, and other methods of soil quality maintenance may be side-stepped thanks to technical "solutions." In becoming more dependent on this synthetic crutch, our dependence on fossil fuels likewise becomes greater. In turn, "standard practice" that includes synthetic fertilizer use sets off environmental degradation at multiple scales, whether that be depletion of soil quality, the release of greenhouse gasses such as nitrous oxide, or the compromising of the land from which the fossil fuels were harvested, these issues are all interconnected. The feedback between each issue presented thus far is evidenced in measurable and mutually-reinforcing negative repercussions. These processes threaten the planet's vital ecosystem services, making further inquiry and action pressing.

Conclusion: Fossil Foodscapes and the 50 Year Farm Bill

That our fossil foodscapes carry along with them no shortage of threats is now abundantly clear. Perhaps the brightest spot in our current oil-slicked reality is that it does not have to be this way. Nothing about fossil foodscapes is necessary should we will an alternative model. Because imagining a more vibrant future may be more difficult now than ever, our ability to envision a world whose landscapes are characterized by sustainability and resiliency remains as important as ever. The system's immense inertia will never be overcome without an ability to see beyond the current paradigm we are living in to one not dictated by a destructive dependency on dense carbons. To achieve this, we must break out the of 5-year cycles our current Farm Bill locks us into. Each iteration of this policy and planning routinely privileges large-scale operations over ecologically-sound production. Five years is far too myopic when considering the existential threats facing us today. It is here that my inquiry ultimately brings me back to where I started: thinking about the perennial futures. Over a decade ago, the Land Institute set forth a framework for long-term planning called the 50-Year Farm Bill (Jackson). The vision offers a half-century approach for perennializing and diversifying the United States' grain and oilseed production. Our resolve represents but the first step in change, and a thoughtfully future-forward a promising next.

In light of my research and reflection on energy, I see that such a vision must be accompanied by a similar effort targeted towards lessening our fossil fuel dependence. I do not wish to make light of a call for a more agrarian future. Farming is difficult work, and humanity has accomplished a great feat in producing so much food with so little labor. In this disconnect between us and our food, however, the compounding crises produced by the fossil foodscape boils up as a threat requiring urgent attention. Let us think about dismantling our fossil foodscapes in terms of justice for the earth and all those tending it. Let us find the power to overcome our ancestors' short-sighted investments in the name of repairing rifts and producing food for generations to come.

Works Cited

Arizpe, Nancy, et al. "Food Security and Fossil Energy Dependence: An International Comparison of the Use of Fossil Energy in Agriculture (1991-2003)." *Critical Reviews in Plant Sciences*, vol. 30, no. 1–2, Jan. 2011, pp. 45–63. *DOI.org (Crossref)*, doi:10.1080/07352689.2011.554352.

Bekkerman, Anton, et al. "The Distribution of Crop Insurance and Other Farm Subsidy." *American Enterprise Institute*, p. 17.

Campbell, Bruce M., et al. "Sustainable Intensification: What Is Its Role in Climate Smart Agriculture?" *Current Opinion in Environmental Sustainability*, vol. 8, Oct. 2014, pp. 39–43. *DOI.org (Crossref)*, doi:10.1016/j.cosust.2014.07.002.

Canning, Patrick, et al. "The Role of Fossil Fuels in the U.S. Food System and the American Diet." *U.S Department of Agriculture, Economic Research Service*, Jan. 2017.

Cao, Peiyu, et al. "Historical Nitrogen Fertilizer Use in Agricultural Ecosystems of the Contiguous United States during 1850–2015: Application Rate, Timing, and Fertilizer Types." *Earth System Science Data*, vol. 10, no. 2, June 2018, pp. 969–84. *DOI.org (Crossref)*, doi:10.5194/essd-10-969-2018.

Carton, Wim. "Dancing to the Rhythms of the Fossil Fuel Landscape: Landscape Inertia and the Temporal Limits to Market-Based Climate Policy: Dancing to the Rhythms of the Fossil Fuel Landscape." *Antipode*, vol. 49, no. 1, Jan. 2017, pp. 43–61. *DOI.org (Crossref)*, doi:10.1111/anti.12262.

Clapp, Jennifer. "Distant Agricultural Landscapes." *Sustainability Science*, vol. 10, no. 2, Apr. 2015, pp. 305–16. *DOI.org (Crossref)*, doi:10.1007/s11625-014-0278-0.

Clark, Brett, and John Bellamy Foster. "The Dialectic of Social and Ecological Metabolism: Marx, Mészáros, and the Absolute Limits of Capital." *Socialism and Democracy*, vol. 24, no. 2, July 2010, pp. 124–38. *DOI.org (Crossref)*, doi:10.1080/08854300.2010.481447.

Clark, Brett, and Richard York. "Carbon Metabolism: Global Capitalism, Climate Change, and the Biospheric Rift." *Theory and Society*, vol. 34, no. 4, Aug. 2005, pp. 391–428. *DOI.org (Crossref)*, doi:10.1007/s11186-005-1993-4.

Crews, Tim. *Tim Crews, The Land Institute: Is the Future of Agriculture Perennial?* 2019, https://www.youtube.com/watch?v=iqvMmKjP6pc&list=PLkdIyKze00hBpaHahCZnR9MFZSWqfmkOm&index=2.

Crews, Timothy E., et al. "Is the Future of Agriculture Perennial? Imperatives and Opportunities to Reinvent Agriculture by Shifting from Annual Monocultures to

Perennial Polycultures." *Global Sustainability*, vol. 1, 2018, p. e11. *DOI.org (Crossref)*, doi:10.1017/sus.2018.11.

Dotterweich, Markus. "The History of Human-Induced Soil Erosion: Geomorphic Legacies, Early Descriptions and Research, and the Development of Soil Conservation—A Global Synopsis." *Geomorphology*, vol. 201, Nov. 2013, pp. 1–34. *DOI.org (Crossref)*, doi:10.1016/j.geomorph.2013.07.021.

Dumont, B., et al. "Review: Make Ruminants Green Again – How Can Sustainable Intensification and Agroecology Converge for a Better Future?" *Animal*, vol. 12, no. s2, Dec. 2018, pp. s210–19. *DOI.org (Crossref)*, doi:10.1017/S1751731118001350.

ETC Group. *Who Will Feed Us: The Industrial Food Chain vs. The Peasant Food Web*. ETC Group, 2017, https://www.etcgroup.org/sites/www.etcgroup.org/files/files/etc-whowillfeedus-english-webshare.pdf.

Formuzis, Alex. *EWG: Mega-Farms Reap Billions from Taxpayers in Farm Subsidies*.

Foster, John Bellamy. "Marx's Theory of Metabolic Rift: Classical Foundations for Environmental Sociology." *American Journal of Sociology*, vol. 105, no. 2, Sept. 1999, pp. 366–405. *DOI.org (Crossref)*, doi:10.1086/210315.

Foster, John Bellamy, and Fred Magdoff. "Liebig, Marx and the Depletion of Soil Fertility: Relevance for Today's Agriculture." *Monthly Review*, vol. 50, no. 3, July 1998, p. 32. *DOI.org (Crossref)*, doi:10.14452/MR-050-03-1998-07_3.

Gillis, Justin, and Popovich Nadja. "The U.S. Is the Biggest Carbon Polluter in History. It Just Walked Away From the Paris Climate Deal." *The New York Times*, 1 June 2017, https://www.nytimes.com/interactive/2017/06/01/climate/us-biggest-carbon-polluter-in-history-will-it-walk-away-from-the-paris-climate-deal.html.

Glover, Jerry D., et al. "Harvested Perennial Grasslands Provide Ecological Benchmarks for Agricultural Sustainability." *Agriculture, Ecosystems & Environment*, vol. 137, no. 1–2, Apr. 2010, pp. 3–12. *DOI.org (Crossref)*, doi:10.1016/j.agee.2009.11.001.

Hall, Charles A. S. *Energy Return on Investment: A Unifying Principle for Biology, Economics, and Sustainability*. Springer, 2016.

Hernandez, Trish, and Susan Gabbard. *Findings from the National Agricultural Workers Survey (NAWS) 2015-2016*. U.S Department of Labor, Jan. 2018, https://www.doleta.gov/naws/research/docs/NAWS_Research_Report_13.pdf.

Huber, Matthew T. “Energizing Historical Materialism: Fossil Fuels, Space and the Capitalist Mode of Production.” *Geoforum*, vol. 40, no. 1, Jan. 2009, pp. 105–15. *DOI.org (Crossref)*, doi:10.1016/j.geoforum.2008.08.004.

---. *Lifeblood: Oil, Freedom, and the Forces of Capital*. University of Minnesota Press, 2013.

Imhoff, Daniel, and Christina Badaracco. *The Farm Bill: A Citizen’s Guide*. Island Press, 2019.

Intergovernmental Panel on Climate Change. *Global Warming of 1.5°C*. 2018. *Open WorldCat*, http://www.ipcc.ch/report/sr15/.

Jackson, Wes. *A 50-Year Farm Bill*. The Land Institute, June 2009.

---. *Natural Systems Agriculture: A Truly Radical Alternative*. 2002.

Jones, C. F. “A Landscape of Energy Abundance: Anthracite Coal Canals and the Roots of American Fossil Fuel Dependence, 1820-1860.” *Environmental History*, vol. 15, no. 3, July 2010, pp. 449–84. *DOI.org (Crossref)*, doi:10.1093/envhis/emq057.

Kutilek, Miroslav, and Donald R. Nielsen. *Crumbling of Soils: The Skin of the Planet Earth*. Springer, 2015, https://link-springer-com.libproxy.uoregon.edu/chapter/10.1007/978-94-017-9789-4_6. 8 May 2020.

Madison, Mike. *Fruitful Labor: The Ecology, Economy, and Practice of a Family Farm*. Chelsea Green Publishing, 2018.

Magdoff, Fred. “A Rational Agriculture Is Incompatible with Capitalism.” *Monthly Review*, vol. 66, no. 10, Mar. 2015, pp. 1–18.

Martin, Galen. *The Fossil Fuel Landscape in Agriculture*. 11 May 2020.

Marx, Karl. *Capital: A Critique of Political Economy*. International Publishers, 1894, https://www.marxists.org/archive/marx/works/download/pdf/Capital-Volume-III.pdf.

Masson-Delmotte, V., et al. *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. IPCC, 2018.

Montgomery, D. R. “Soil Erosion and Agricultural Sustainability.” *Proceedings of the National Academy of Sciences*, vol. 104, no. 33, Aug. 2007, pp. 13268–72. *DOI.org (Crossref)*, doi:10.1073/pnas.0611508104.

Montgomery, David. *Dirt: The Erosion of Civilizations*. University of California Press, 2007, https://ebookcentral-proquest-com.libproxy.uoregon.edu/lib/uoregon/reader.action?docID=291508.

Pfeiffer, Dale Allen. *Eating Fossil Fuels: Oil, Food, and the Coming Crisis in Agriculture*. New Society Publishers, 2006.

Pimentel, D., et al. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." *Science*, vol. 267, no. 5201, Feb. 1995, pp. 1117–23. *DOI.org (Crossref)*, doi:10.1126/science.267.5201.1117.

Pimentel, David, et al. "Reducing Energy Inputs in the US Food System." *Human Ecology*, vol. 36, no. 4, Aug. 2008, pp. 459–71. *DOI.org (Crossref)*, doi:10.1007/s10745-008-9184-3.

Ripple, William J., et al. "World Scientists' Warning of a Climate Emergency." *BioScience*, Nov. 2019, p. biz088. *DOI.org (Crossref)*, doi:10.1093/biosci/biz088.

Ritchie, Hannah, and Max Roser. *CO2 and Greenhouse Gas Emissions*. Online Resource, Our World In Data, 2020, https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

Schneider, Mindi, and Philip McMichael. "Deepening, and Repairing, the Metabolic Rift." *The Journal of Peasant Studies*, vol. 37, no. 3, July 2010, pp. 461–84. *DOI.org (Crossref)*, doi:10.1080/03066150.2010.494371.

Schnepf, Randy. *Energy Use in Agriculture: Background and Issues*. p. 44.

Simmons, Daisy. "A BRIEF GUIDE TO THE IMPACTS OF CLIMATE CHANGE ON FOOD PRODUCTION." *Yale Climate Connections*, 18 Sept. 2019, https://www.yaleclimateconnections.org/2019/09/a-brief-guide-to-the-impacts-of-climate-change-on-food-production/.

Smil, Vaclav. "Nitrogen in Crop Production: An Account of Global Flows." *Global Biogeochemical Cycles*, vol. 13, no. 2, June 1999, pp. 647–62. *DOI.org (Crossref)*, doi:10.1029/1999GB900015.

---. "Science, Energy, Ethics, and Civilization." *Visions of Discovery: New Light on Physics, Cosmology, and Conciousness*, Cambridge University Press, 2010, pp. 709–29, http://vaclavsmil.com/wp-content/uploads/docs/smil-articles-science-energy-ethics-civilization.pdf.

Stuart, D., et al. "Reducing Nitrogen Fertilizer Application as a Climate Change Mitigation Strategy: Understanding Farmer Decision-Making and Potential Barriers to Change in the US." *Land Use Policy*, vol. 36, Jan. 2014, pp. 210–18. *DOI.org (Crossref)*, doi:10.1016/j.landusepol.2013.08.011.

U.S. Bureau of Labor Statistics. *May 2019 National Occupational Employment and Wage Estimates United States*. United States Department of Labor, May 2019, https://www.bls.gov/oes/current/oes_nat.htm#45-0000.

USDA. *2017 Census of Agriculture: Farms and Farmland*. USDA NASS, Aug. 2019, https://www.nass.usda.gov/Publications/Highlights/2019/2017Census_Farms_Farmland.pdf.

USDA ERS. *Farm Labor*. United States Department of Agriculture Economic Research Service, https://www.ers.usda.gov/topics/farm-economy/farm-labor/#size. Accessed 10 May 2020.

van Bruggen, Ariena H. C., et al. "One Health - Cycling of Diverse Microbial Communities as a Connecting Force for Soil, Plant, Animal, Human and Ecosystem Health." *Science of The Total Environment*, vol. 664, May 2019, pp. 927–37. *DOI.org (Crossref)*, doi:10.1016/j.scitotenv.2019.02.091.

Veum, Kristen S., et al. "Biological Indicators of Soil Quality and Soil Organic Matter Characteristics in an Agricultural Management Continum." *Geoderma*, vol. 305, Nov. 2017, pp. 53–61. *DOI.org (Crossref)*, doi:10.1016/j.geoderma.2017.05.031.

Waltner-Toews, David, and Tim Lang. "A New Conceptual Base for Food and Agricultural Policy: The Emerging Model of Links between Agriculture, Food, Health, Environment and Society." *Global Change*, vol. 1, no. 2, 2000, p. 15.

Wark, Jim. *Kansas Wheat Harvest*. 23 June 2007, http://www.airphotona.com/nextimg.asp?imageid=10046&catnum=0&keyword=&country=&state=&pagenum=345. Airphoto.

Weis, Tony. "The Accelerating Biophysical Contradictions of Industrial Capitalist Agriculture: The Contradictions of Industrial Capitalist Agriculture." *Journal of Agrarian Change*, vol. 10, no. 3, June 2010, pp. 315–41. *DOI.org (Crossref)*, doi:10.1111/j.1471-0366.2010.00273.x.