Nikos Katsikis

The Horizontal Factory. The Operationalisation of the US Corn and Soy Belt

We all live in the city.
We all live in the country.
Both are second nature to us.[1]

WHAT IS THE CORN BELT?

"Imagine how much food
we could produce."[2]

The words of Don, a farmer who spent more than seven decades of his life in south-west Iowa, sounded quite paradoxical, considering we were standing amidst a green sea of corn-fields just outside Corning, Iowa. A largely continuous farming zone extended for hundreds of miles around, stretching from the state of Iowa to Illinois, Indiana, southern Michigan, western Ohio, eastern Nebraska, eastern South Dakota, and southern Minnesota. This is the Corn Belt,[3] [Fig. 1] a landscape where 80 million acres of cropland cover more than two-thirds of the land, producing more than 30% of all corn and more than 20% of all soybeans in the world. I had been slowly immersed in this landscape as I drove west from Chicago to meet Don. I crossed endless corn and soy fields that were only interrupted by grain storage towers, elevators, biofuel plants, and windmills. The uncanny feeling was amplified by the apparent minimal presence of living organisms, from humans to free ranging animals, or even insects, making the landscape feel less like an agricultural "countryside," and more like a "horizontal factory." What kind of landscape was that, and how could it be conceptualised?

The Corn Belt is undoubtedly a highly industrialised, monofunctional landscape of agricultural hyperproduction, consistently calibrated towards a particular set of outputs. In an early map from 1949, the United States Department of Agriculture (USDA) defined the Corn Belt as a region producing "predominantly feed and livestock."[4] [Fig.3] This relationship between grains, feed, and livestock has historically and continues to define the nature of the Corn Belt. While the Corn Belt has emerged,

and subsequently transformed, as an agricultural system configured to cultivate grains for animal feed, more recently, the system has also been geared towards the production of biofuel. In fact, while US corn production has almost doubled over the past three decades, the increased volume has been driven predominantly by the increase in bioethanol production, while the production of animal feed remained rather static.[5] [Fig. 6] Whether producing feed, or biofuel, the Corn Belt is hardly producing any food. Don was right.

How has such a vast area been configured in this way? To answer this question, we first need to contextualise the type of landscape the Corn Belt is within the global agri-food system. The analysis [Fig. 1–2] unveils a stark contrast in the composition of global cropland areas. On the one hand, specialised, cash-crop systems producing feed (such as corn and soybeans) dominate Western industrialised agricultural systems; on the other hand, areas predominantly producing food for direct human consumption (such as rice and wheat) dominate the global South.[6] The Corn Belt is, of course, highlighted as a seminal zone of the former. These landscapes can be characterised as "hinterlands of hinterlands" as they do not directly support human populations but supply zones of dense livestock concentrations. [Fig. 4] Depending upon high direct and indirect inputs of energy (mainly in the form of machine fuel, fertilisers, and pesticides), they can be seen as metabolic systems converting energy into livestock. In doing so, they rely on (so far) cheap energy to sustain a rather inefficient nutritional exchange due to the low-calorie conversion of livestock.[7]

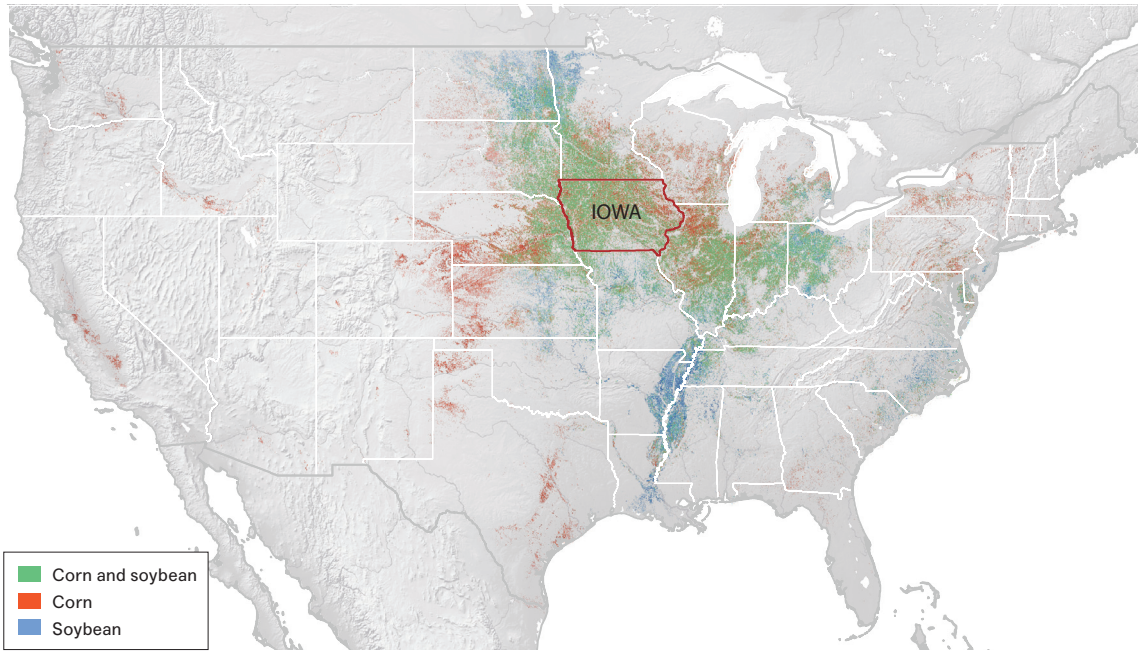
To complicate things even more, with increasing percentages of soy and corn yields directed to biofuel production, the recent metabolic structure of the Corn Belt can also be seen as a system metabolising one form of energy into another. Thus, positioning the Corn Belt within the food, feed, and energy nexus reveals its configuration's metabolic "irrationality": High-input farming transforms crops into nutritionally inefficient livestock and biofuels that embody more energy than they contribute. Why would such a huge area be sacrificed in producing this particular set of outputs through a significantly wasteful set of metabolic processes?

The Corn Belt has never been shaped by a meaningful metabolic logic but rather by the capitalist search for profit. It has always been and remains a profitable landscape. Or even better, an assemblage of landscapes, consisting of a system of spatial elements, configured and reconfigured, crystallised and "creatively destroyed" in search of profit maximisation.[8] This assemblage of profit landscapes extends beyond the sea of farms and monocultures. It comprises grain storage facilities and feed-production plants; ethanol and biofuel distilleries, fertiliser factories, pesticide plants, and seed production facilities; animal feeding operations and meat packing plants, windfarms, electricity grids, and natural gas pipelines; the rail corridors, highway networks, and intermodal freight nodes. [Fig. 5] The constant pressure to renegotiate the social, technical, and natural capacities of this assemblage in order to offer bundles of profitable commodities to the global markets, leads to increasing industrialisation, infrastructuralisation and intensive monofunctional specialisation, turning the landscapes that compose it into more and more operational landscapes: metabolic landscapes operationalised for the extraction of capitalist profit through shifting bundles of human and more-than-human systems.[9]

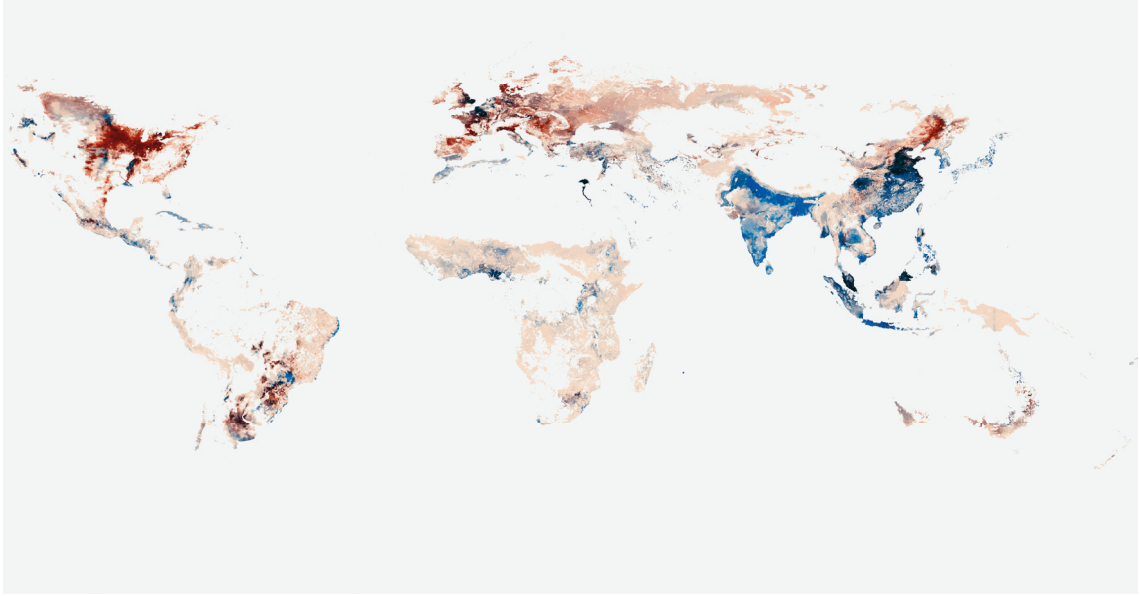
This contribution investigates the emergence, development, and eventual exhaustion of the operational landscapes of agricultural production across the US Corn Belt system, focusing on the state of Iowa. Building upon a historical geography of operationalisation of the Corn Belt, this contribution aims to reveal the socio-ecological struggles behind

F. 1 The corn and soy belt in the US revealed by the overlay of high corn (red) and soybean (blue) cultivation frequencies over a period of ten years (2008–2018).

F. 2 The global distribution of agricultural crop production for food (blue) and feed (brown) in 2015.



THE US CORN AND SOY BELT
Fig. 1



A SPECIALISED AGRICULTURAL
TERRITORY IN A GLOBAL CONTEXT
Fig. 2

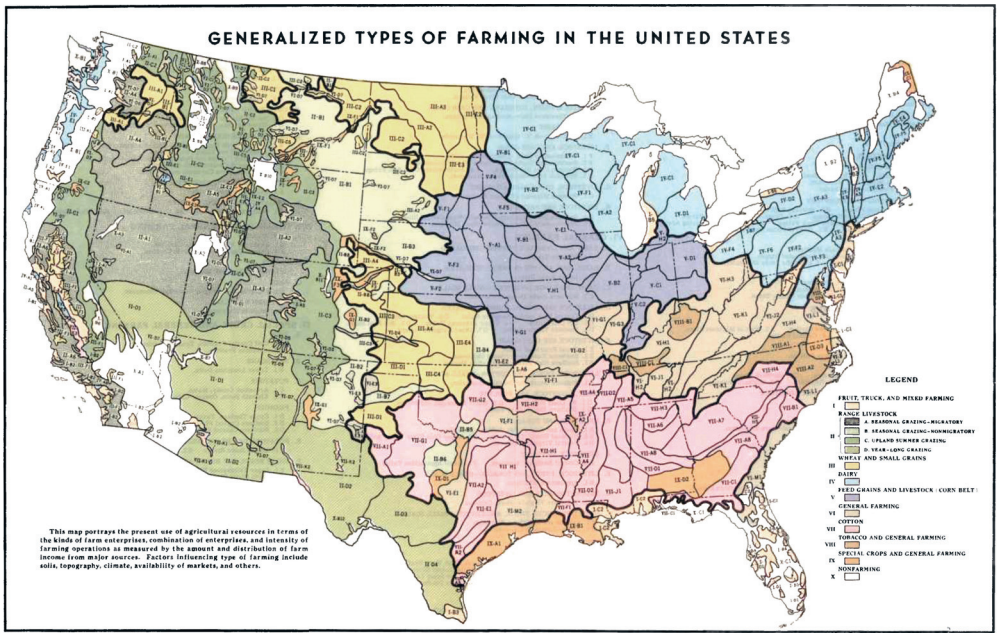


Fig. 3

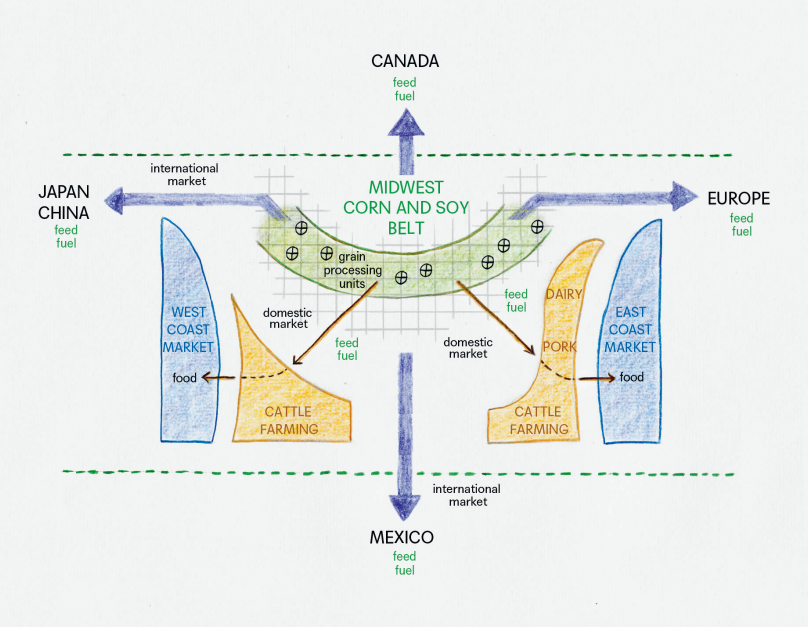
the constant race for increases in productivity, reflected on the exhausted soils, the contaminated hydrological systems, the genetically modified plants and animals, the shrinking settlements, and the still-persistent family farmers, who struggle to maintain their livelihood under the pressure of increasingly oligopolistic commodity chains. Behind the record-high yields are rapidly approaching yield plateaus, massive subsidies, extensive depopulation, and environmental degradation; signs of an overall exhaustion of the capacity to displace and obscure the negative externalities of capitalist agriculture and eventually reproduce and reinvent itself.

F. 3 The Corn Belt defined by the USDA in 1949: a specialised agricultural area producing feed grains and livestock.

F. 4 The Corn Belt as a cash-crop system producing animal feed and supplying zones of dense livestock concentrations.

LANDSCAPE OPERATIONALISATION IN THE CAPITALOCENE

The operationalisation of the Corn Belt can only be understood within the context of constructing a globalised, capitalist hinterland, that is part of the metabolic geographies of planetary urbanisation. The concept of operational landscapes aims to help conceptualise the complex processes of extended urbanisation that construct the material basis of contemporary urban life. Following Neil Smith, under capitalist development, the reproduction of material life is deeply interwoven with the production and reproduction of surplus value.[10] In the age of capital, the Capitalocene, and under conditions of planetary urbanisation, this relationship is generalised, amplified, and intensified.[11] Not only does the inherently expansive nature of capitalism constantly scan Earth for new opportunities to extract surplus value, but the continuous concentration of human populations and economic activities in agglomeration zones and other areas of

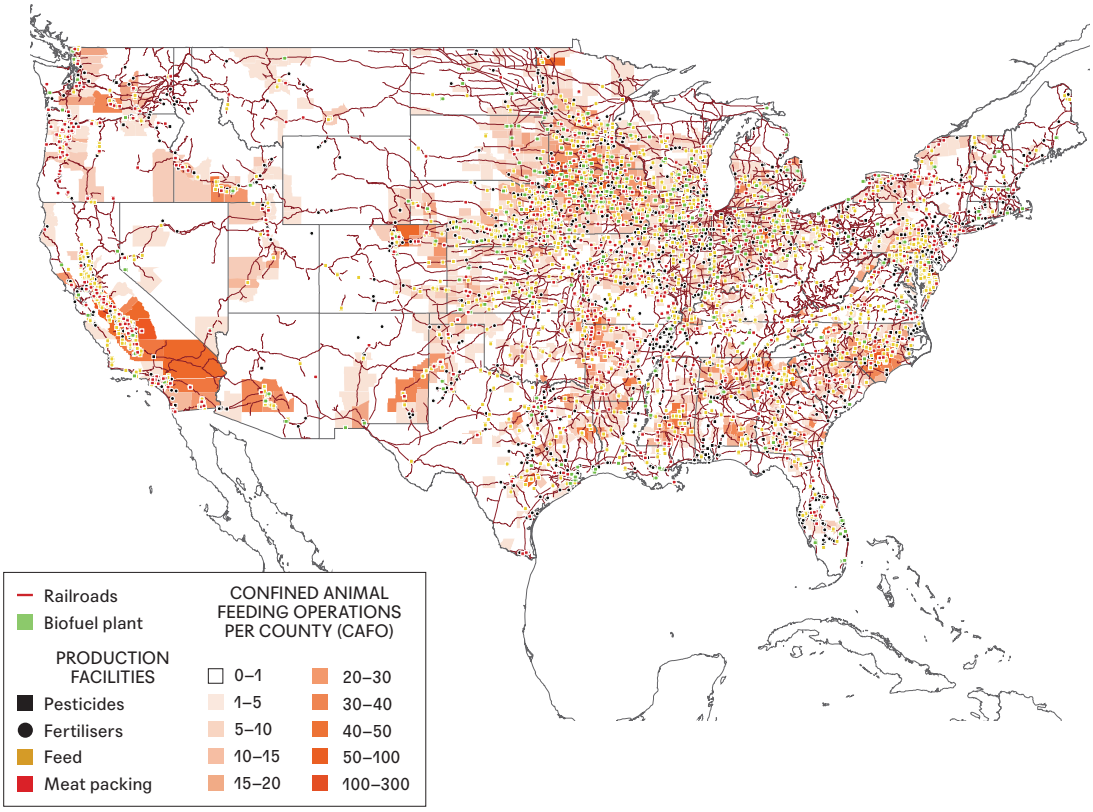


THE CORN BELT AS "HINTERLANDS OF HINTERLANDS"
Fig. 4

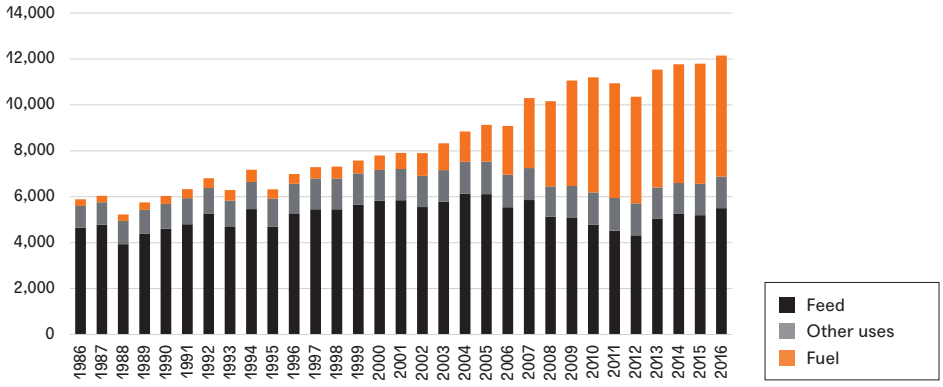
concentrated urbanisation depends upon a web of multiscalar, geo-metabolic interdependencies that extend across the planetary terrain. As this planetary urban metabolism is interwoven with the capitalist search for surplus value, it operationalises a wide variety of landscapes around the world, landscapes of primary production (agriculture, mining, forestry), circulation (transport, communication), and waste disposal.

Operational landscapes are the metabolic "hinterlands" of the Capitalocene, the landscapes that constitute the material basis of the urbanised geographies of planetary urbanisation.[12] As operational landscapes are predominantly dedicated to the production and circulation of primary commodities, they are deeply interwoven with more-than-human systems. They are the terrains where nature becomes "a universal means of production in the sense that it not only provides the subjects, objects, and instruments of production but is also in its totality an appendage to the production process."[13] Nature is produced through the operationalisation of landscapes, but also production across the operational landscapes happens through nature. Thus, operational landscapes play a central role in putting nature at work in the production and circulation of surplus value as part of the capitalist world ecology.[14]

The concept of the ecological surplus, introduced by Jason Moore, allows for a more precise investigation of this exact process.[15] Central to the concept is a distinction between labour and work, both of which are mobilised in the process of capitalist production. For Moore, capitalism not only extracts value from the exploitation of paid work (wage labour) but also through unpaid work or work embedded in the process of reproducing the labour force. What is important, however, is that unpaid work is not restricted to humans: it can also refer to processes of the natural environment. For example, the growth of a plant, photosynthesis in general, geological processes that produce minerals, and the water cycle all require some-kind of "work" to be performed. This is work that, when appropriated through the production process, remains unpaid. Based on this concep-



THE OPERATIONAL ASSEMBLAGE
OF THE EXTENDED CORN BELT SYSTEM
Fig. 5



US CORN PRODUCTION 1986–2016
Fig. 6

tualisation, the ecological surplus is defined as the ratio between the actual capital investment in paid work (wage-labour), fixed capital, and raw materials over the unpaid work that is mobilised through it from human and more-than-human agents.

The struggle for the successful appropriation of this unpaid work is what has historically allowed, and still allows, capitalism to develop upon the exploitation of what Moore frames as the "four cheaps": labour power, food, energy, and raw materials. It also guides the multidimensional operationalisation of production and circulation landscapes across scales and territories. As primary production is to a large degree grounded to the specificities of natural geographies and natural processes, the construction of operational landscapes of primary production can be conceptualised as a constant effort to extract ecological surplus across two frontiers: On the one hand, through the expansion of geographical frontiers, allowing access to areas of untapped resources; and on the other hand, through the conquest of the biochemical frontiers (such as through genetic engineering), allowing access to the processes of natural work, and thus its exploitation. The "frontier condition" can be conceptualised as a condition that allows the maximisation of ecological surplus and the appropriation of high amounts of unpaid work for relatively low amounts of capital investment. As nature's capacity to contribute free work to the system is exhausted and negative externalities are generalised, the ecological surplus has the tendency to fall.[16] Resource deposits are exhausted, soils cannot be replenished, and forests are logged, all leading to the need to substitute the exhausted "productivity" of natural systems through capital investment, which decreases the amount of ecological surplus and leads to pressure to reinvent novel bundles of the four cheaps. The endless search for profit through the constant reconfiguration of the four cheaps allow for high degrees of ecological surplus that construct and reconstruct assemblages of operational landscapes for primary production.

The shifting nexus between food, feed, and fuel, largely shaping the structure of agricultural systems, can thus be contextualised within this broader framework of the four cheaps. A generic scheme of operationalisation of primary production landscapes would see initial investments in surveying and transport to allow for the expansion of geographical frontiers, which, as they are slowly exhausted, would lead to increased investment in mechanisation and inputs to sustain productivity. With their initial ecological surplus exhausted, these landscapes would then depend more and more on the appropriation of new frontiers elsewhere across the geographical and geochemical domain. For instance, in agriculture, the exhaustion of the initial fertility of the soil would be countered through mechanisation, or expansion over biochemical and geographical frontiers around certain inputs (fertilisers, pesticides, energy), with high ecological surpluses in energy production eventually sustaining a high input agricultural metabolism, which would sustain cheap food and cheap labour, and thus a multitude of other opportunities for appropriating ecological surplus elsewhere in the system.

The question of the construction of the Corn Belt can thus be framed in a way that connects it to shifts in the composition of ecological surplus. An initial phase of expansion over

F. 5 The operational assemblage of the extended Corn Belt system: the map reveals the concentrations of corn and soybean cultivation, density of animal feeding operations, feed production facilities, pesticide and chemical production facilities, seed production facilities, bioethanol and biofuel plants, and railway networks.

F. 6 Corn production for feed, fuel, and other uses in the US, 1986–2016: the overwhelming majority of corn is geared towards the feed and fuel industry, with a minor percentage going to direct consumption, mostly in the form of corn syrup. Corn production has doubled from 7 billion bushels in the early 1990s to around 14 billion today, but most of the increase has been due to the rising demand for biofuels.

previously uncultivated lands in the Midwest allowed for the exploitation of an extremely high ecological surplus. This was made possible mostly through investment in transport infrastructure, which was soon followed by a continuous trend towards exhaustion through the gradual depletion of the soil's natural fertility. This has led to a continuous intensification of the production process through commodified inputs, such as energy and fertilisers, to compensate for it, which took advantage of areas of ecological surplus across distant geographies or geochemical developments. The exhaustion of several different bundles of ecological surplus across the Corn Belt has left one last frontier able to still contribute unpaid work into the system: the social structure of and around the family farm.

The role and nature of human work in the construction of the Corn Belt is very much connected to the persistence of the family farm as the dominant unit of production. Given its extreme degree of industrialisation, it might appear surprising that Corn Belt agriculture is, and has always been, predominantly based on family farms. It is thus crucial to offer a framework for understanding the role of the family farm in the construction of the Corn Belt. Following Harriet Friedmann, it is important to distinguish between the family farm, as a form of production, operating within a capitalist mode of production.[17] The form of production refers to the basic unit of productive organisation—the farm—and the particular social relations around it, and the range of techniques. The family farm, as a form of production, is embedded within a broader set of relationships dominated by the market logic of the various phases of the capitalist mode of production. Nevertheless, the family farm is not a capitalist unit of production (such as the enterprise) but rather a household unit of production (although there is a certain tendency to treat and even celebrate the farmers of the Corn Belt as entrepreneurs). The major difference is twofold: The family farm does not rely on waged labour relationships since almost all labour is done by members of the household, and it is not driven solely by profit, but rather by the goal of reproducing its personal and productive consumption base. Personal consumption refers to the costs of social reproduction, and productive consumption to the reproduction of the inputs of the production process (seeds, fertilisers, etc.). In this case, both are part of the same pool.

The blurred boundary between personal and productive consumption is also influenced by the particular condition of agricultural production, which theoretically allows (or allowed) a series of these processes to be internalised. With the cultivation of food, some part of personal consumption could be initially provided by the farm itself (theoretically even leading to complete subsistence). At the same time, the productive basis could be reproduced within the farm, as seeds used for the next crop or manure used as fertiliser. As it will be discussed, the history of the Corn Belt can be traced following the constant commodification of the elements of the productive and reproductive basis of the family farm, through constant corporatisation of all processes, except for the farmland itself. At the basis of these processes, we can try to trace shifts in the nexus of labour power, food, energy, and raw materials, which theoretically could have been part of a subsistence mode of existence, but under capitalism, have become part of the continuous search for profit.

In this struggle, the work relations within the farm constitute the last frontier of ecological surplus within the Corn Belt: As the household form of production has a much larger dedication to ensuring its reproduction and given the blurred lines between costs of social and productive reproduction, it allows for a much higher adaptability to shocks in the capitalist relations that surround it, through high degrees of self-exploitation. For Friedmann, this particular combination of factors has offered the family farm a certain robustness and competitive advantage over other capitalist organisations of agricultural production, allowing it to proliferate as the dominant unit. At the same time, as it was positioned within capitalist systems of production, the multiple combinations of the labour

power, food, energy, and raw materials it allowed, and the high degree of self-exploitation, offered several opportunities for extracting ecological surplus, which was then gradually exhausted by the commodification of almost all involved metabolic relations.

Building upon these two frameworks, the history and contemporary anatomy of the Corn Belt that follow are largely focused on unpacking the processes of exhaustion of ecological surplus within the Corn Belt and the dependence upon new frontiers of ecological surplus beyond its boundaries until it has reached its last frontier, the family farm.

GEOGRAPHICAL EXPANSION AND THE ORIGINS OF THE CORN BELT SYSTEM

Central to the history of the operationalisation of the Midwest is a narrative that describes the expansion of farming over an extensive, virgin, fertile land, following an almost "natural" process.[18] But the "fertility" of the Corn Belt, and thus its capacity to contribute ecological surplus, has been a much more dynamic condition, reshaped over long periods of time by geology and climate, but also, to a large extent, socio-technically constructed. The basis of the fertility of the Corn Belt is the soil, which is the result of two main processes: The depositions of several phases of glacial advances and the decomposition of tall and thick grassland that dominated for the past thousand years.[19] This combination has created thick layers of topsoil with a structure and texture able to absorb large quantities of water. The porosity allows the circulation of air and, thus, the reproduction of the micro-organisms responsible for metabolising the necessary nutritional elements for the plants.[20] Thus, the agricultural suitability of Corn Belt soils is not so much due to rich organic matter content (like in tropical soils), which was very early exhausted, but due to their structure and texture, making them still efficient under the more recent use of fertilisers.

While the latest glacial advance defines the latitudinal limit of the Corn Belt to the south, the average rainfall and levels of humidity largely define the longitudinal limit to the west, completing an "environmental envelope" of rainfed agriculture over fertile soils. But in the absence of human activity and agricultural cultivation, humidity, and annual rainfall also affect the prevalence of forests or prairies. Interestingly, the levels of humidity and precipitation across the Corn Belt could largely support the existence of more forested vegetation types. But when the first Western explorers appeared in the late seventeenth century, what they observed was extensive grassland prairies with scattered woodlands. What they were interpreting as pristine nature was actually an already anthropogenic "second nature."[21] Over hundreds of years, the native tribes had co-produced the grasslands together with nature by helping the prairie penetrate the forest through land clearings, and preventing the forest from reconquering the prairie, given the climatic conditions.[22] It was not just the work of nature that contributed to the high initial ratio of ecological surplus to the arriving settlers, but also the work of the indigenous populations. The eventual violent expulsion of the native tribes by the Western settlers would not only mean the expropriation of their lands but also the appropriation of generations-long embodied labour that their ancestors had contributed.

If the glacial deposits and the hydrological systems of the Mississippi and Missouri basins form the geographic basis of the Midwest and the contemporary Corn Belt, it was the corridors crossing the Appalachian range and the Ohio River valley that largely defined the trajectories of settlement towards the Midwest, but also the trajectories of diffusion of the model of Corn Belt agriculture. According to the geographer John Hudson, the origins of the model of cultivating feed for the fattening of livestock, the model that still defines the essence of Corn Belt agriculture, can be traced back to early nineteenth-century West Virginia. From there, it would eventually migrate westwards, together with the expansion of the frontier.[23] This system

could be characterised as cash-crop farming, but in this case, crops were not sold in the form of grain but in the form of livestock, either cattle or hogs.[24] In the early versions of the system, animals were the main commodity (besides the purchase of agricultural tools), both forward and backward in the chain: animals were bought as stock from grazing areas, then fed corn on the farm to gain weight rapidly, and eventually sold for cash.

The central role of livestock in the early logistics of the system can be associated with the restrictions of the early configuration of the food, feed, and fuel nexus in the absence of adequate transportation means. Crops are bulky commodities, costly to transport to the market. Embodied in the form of animals, the value of crops can literally walk to the market, consuming only some amount of the weight gained and feed used. Although both cattle and hogs were often raised on the same farms, their different metabolisms positioned them in very different roles in the system. Cattle were much more efficient at covering larger distances without losing considerable weight than hogs, which offered a more extensive line of products when processed (from lard to bacon).

Thus, the early nineteenth-century version of the Corn Belt system largely reflected the interplay between geography and the metabolism of hogs and cattle. The majority of the population was still concentrated in the east, along the Atlantic coast, while the majority of cattle were raised in the west, beyond the Appalachian mountains. Cattle walked eastward in large herds to the early Corn Belt farms that were at an intermediate location across the Miami and Ohio valleys, where they were fattened with corn. They then walked further east to the major markets, such as Philadelphia.[25] Processing facilities, mostly for swine products, were initially spread across the waterways of the Ohio valley, through which they could also be transported in barrels all the way down the Mississippi River, which already constituted the major north-south trade corridor.

The early Corn Belt farm suggested a system of mixed farming. The dominant cultivation model involved the rotation between corn, which was used for animal feed, wheat, which was used for household consumption (and to a certain degree as a cash crop sold to local mills), and oats, used to feed the draft animals, mostly horses. The livestock was fed in what could be described as an open feedlot, with cattle contained in open pens, feeding off stacks of corn, with hogs coming after them and consuming what was left behind. Animal waste was, to a large extent, used as manure and the whole farm had a considerable degree of self-sufficiency in terms of reproducing both the personal and productive consumption of the family that worked it. Feed for livestock and food for the family was largely produced at the farm (which also had dairy cows and chickens). The commodified relationships included the acquisition and selling of livestock, as well as the land itself.

While the early Corn Belt farm was already directed towards the production of exchange values, this particular metabolism also offered a certain robustness that allowed the family farm to respond to the volatilities of the market and to environmental risk. Depending on the level of production, the farmers still had some flexibility regarding what portion of the crop they would feed to cattle or hogs or even sell directly to the market and what portion of the production would be diverted to personal consumption. Significant pressure came mostly from the demand side, securing adequate markets in a state of limited transport options. But as the Corn Belt moved north and west, and levels of specialisation increased, a rescaled, splintered Corn Belt system eroded the internal, circular metabolism of the open feedlot farm, with more and more relationships of personal and productive reproduction becoming commodified.

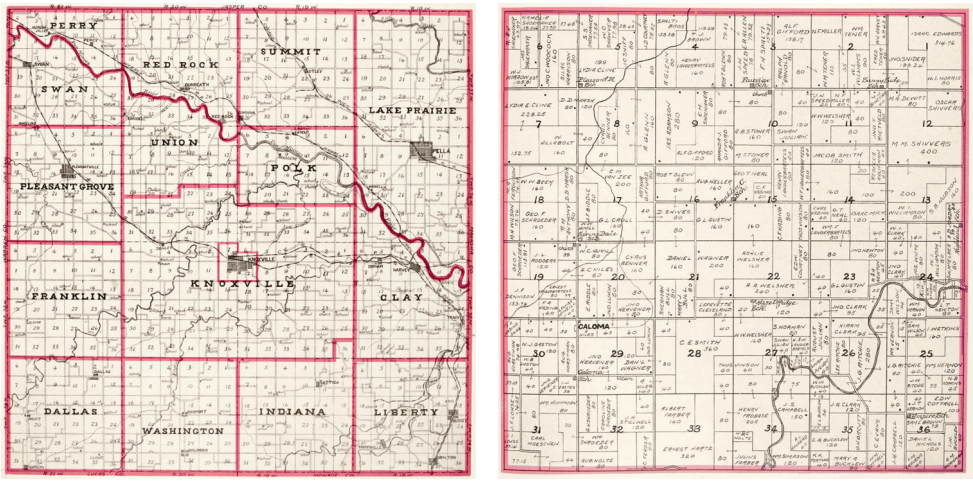


Fig. 7

LAYING THE GROUND INFRASTRUCTURES OF COMMODIFIED METABOLISM

Two major developments around the turn of the nineteenth century largely set the base infrastructures that facilitated the relocated, rescaled, specialised, and further commodified metabolism of the Corn Belt: The Public Land Survey System (PLSS) that served as the major tool for commodifying and transferring expropriated land from indigenous tribes to Western settlers; and the development of the railway network, which not only reshaped patterns of accessibility, but also acted as a device of land speculation and capital concentration setting the tone for the continuous corporatisation of the Corn Belt. What was also introduced with these two developments was the crucial and entangled roles both of state and corporate actors in the development of the Corn Belt.

The Land Ordinance of 1785 marked the beginning of the PLSS and is the basis of the familiar checkerboard pattern of the mid-western United States.[26] The conception and implementation of the PLSS are probably the most lucid examples of what Henri Lefebvre highlighted as the production of "abstract space."[27] What was eventually produced through surveying, quantification, and systematic representation was a space of exchange, not use value; a spatial condition favouring homogenisation, interchangeability, repetitiveness, and the erasure of difference, experiential visual, temporal, and sensual spatial relations. A space constitutive of the capitalist mode of production while, at the same time, reflective of capitalist power. A little more than three decades after the Enclosures Act in the UK, the PLSS formalised processes of enclosure at a previously unseen continental scale. The processes appropriated not just the land and embodied labour of indigenous populations, but also eradicated cultural values and historical practices of environmental coexistence and care, opening the way for ecological deterioration.[28]

The PLSS plates reveal this homogenised, but at the same time, centrally planned and hierarchically structured space of abstraction. [Fig. 7] Concealed were not just the socio-natural complexities that characterised

F. 7 Public Land Survey System (PLSS) plates for Marion County (left) and Washington township within Marion County (right) showing the subdivision of properties during the 1880s.

indigenous inhabitation, but also the variations of natural geography. At the same time, the system introduced a well-articulated idea not just of social order but also of the scales and forms of social and economic interaction that were neatly prescribed through the nested hierarchies of the PLSS grid. Based on this logic that celebrated Cartesian space, and with minimal ground surveying, the PLSS subdivided (on paper) almost the entire area west of the Ohio River in townships of 36 square miles, which were further subdivided into 36 parcels of 640 acres (64,000 m^2). In what could be characterised as the biggest land grab and land sale in human history since the end of the eighteenth century, these land subdivisions sold to the new settlers, offering both an incentive for new farmers to move west and a valuable income to the new state that was in financial distress. By 1868, when the Homestead Act provided the remaining agricultural land for free, less than 3% of land in core Corn Belt states such as Iowa was still available.[29]

But the theoretical rationality suggested by the Public Land Ordinance's checkerboard system was severely challenged in its implementation, and the actual settlement pattern of the Midwest rarely happened in an "orderly" fashion. Land speculation, already embedded in the original lower limit of 640 acres, distorted the presumed goal of creating a nation of self-sufficient farmers. Not only was the amount required to obtain it unaffordable for most farmers, but also the minimum purchasable area was more than ten times larger than what would be needed to support a family and impossible to cultivate to its full extent given its limited labour force.[30] Even the subsequent lower limits of 160 and 80 acres were still too much for a family to afford and efficiently work. The exuberant sizes reflected the interests of the East Coast and often overseas investors and opened a cycle of widespread land speculation, which led to intensified and unsustainable cultivation practices.[31] Farmers who were often heavily indebted to purchase the land were urged to produce more agricultural commodities, often exhausting the land, only to quickly sell it off and move further west to take advantage of higher ecological surplus.

At the same time, the homogeneous checkerboard grid was laid over a highly variable natural geography, leading early farmland development to leapfrog over extensive areas and concentrate at the edges of wooded zones (as wood was the main source of construction materials and energy), along major river systems (as they provided the only means of transportation), and away from zones that had poor drainage and required extensive investment in infrastructure.[32] Thus, the general direction of the north and west expansion of the Corn Belt in the early nineteenth century was not one of continuous, organised development. Rather, it was an unstable meshwork of pockets and corridors, mostly concentrated along waterways.

The gradual infilling and extensive homogenisation of the midwestern landscape were only made possible through the development of the railways in the mid-nineteenth century, which also completely reoriented the major trade routes of the Corn Belt. In its initial configuration, grain trade occurred along the Mississippi River, with St. Louis being the major transportation hub and New Orleans the major port connecting the Midwest to the world. By the 1850s major railway corridors linked Chicago directly to New York and the East Coast, with a secondary radial network extending around it, penetrating the Midwest.[33] This fuelled further expansion on agricultural land that was often less favourable and required higher investment but promised higher revenues through better access to markets. Overall, the railways decisively enhanced cash crop farming. Walking livestock to the market was not the only option anymore. Grain could be shipped directly to the market as a commodity.

But as the superimposition of the PLSS grid reflected the dominance of state power, so did the rapid expansion of the railways introduce its interplay with the interests of corporate actors. The private companies that developed the railways in exchange for long stretches of land along the lines also boosted migration and settlement since they had a dual incentive

to draw population to the regions they crossed. They could benefit both from the sale of agricultural land and from increased volume in freight traffic.[34] By the late nineteenth century, railways were the dominant mode of transporting grains and livestock across the Midwest. Their confluence in Chicago created an unprecedented concentration of the livestock industry around its terminals, reflecting the exuberant concentration of capital that characterised the Gilded Age.

Further centralisation and intensification of the industry were fuelled by the introduction of the refrigeration car in the late nineteenth century. This allowed meat processing operations to function all year round (and not just during the colder months), something that pushed farmers to speed up a continuous supply of livestock. The concentration and intensification of processing and manufacturing led to the generalisation of wage labour relations in the major agglomeration zones of Chicago and Saint Louis, where surplus value was extracted through their exploitation, as lucidly documented by Upton Sinclair.[35] At the same time, family farmers were increasingly getting caught up in the vicious cycle of overproduction, struggling to keep extracting ecological surplus out of a landscape that was already becoming exhausted. While still in control of the land, the family farm was engulfed fully within—and dependent upon—the emerging and increasingly corporate agri-food system without it ever becoming a corporate entity itself. This indirect "corporatisation" of the family farm continued to characterise Corn Belt agriculture ever since.

The Gilded Age signified the crystallisation and dominance of corporate capitalism that would become the dominant force in the operationalisation of the Corn Belt, while at the same time started recalibrating the role of the state away from distributive politics and toward regulative and redistributive solutions to the ensuing problems of overaccumulation that would become increasingly pressing in the early twentieth century.[36] By then, the Corn Belt had expanded north and west to Indiana, Wisconsin, Michigan, and Minnesota, and by the mid-twentieth century, it had largely stabilised in an area that roughly corresponds to its contemporary limits. Expansion was largely over, as was the initial phase of exploitation of high ecological surplus connected to the fertility of previously uncultivated land. After the 1920s, a long period of intensification and specialisation unravelled.

SPECIALISATION AND THE SPLINTERING FEEDLOT

Starting in the early twentieth century, the different elements of the Corn Belt metabolism that were once largely consolidated in a single farm were becoming decoupled. A threefold transformation of specialisation, rescaling, and splintering unfolded, together with the continuing industrialisation and commodification of the means and inputs of production, leading to more and more capital-intensive forms of production.

In the initial Corn Belt farm, besides the land and the cattle that had to be acquired, most other inputs for production, such as seeds, hogs, and manure (used as fertiliser), could be reproduced off the farm. Nevertheless, even during the first phases of cultivation of the mid-western grasslands, improved equipment was needed to plough the thick, hard-to-penetrate, sod-covered soil. Family farms did not have a shortage of land but rather, a shortage of labour. The invention of the steel plough by John Deere in Iowa unleashed a wave of innovation and production in agricultural machinery that directly addressed this problem. A farm's only means of increasing production was to extend the reach of human labour through mechanisation, thus acting as catalysts for the creation of an agro-industrial production complex that emerged in the Midwest during the early twentieth century.[37]

But the growth of productivity, both in manufacturing and in agriculture, also meant that farmers were entering a vicious cycle. As they invested more capital, they had to produce more revenue, and the only way to do that was to

produce more crops. This led to problems of overproduction and surplus, pushing prices down to where they could only respond by producing more and investing more capital since the labour supply of the family farm was inelastic. A crises of overproduction emerged, most notably in the 1920s and 1930s, constituting a continuous challenge for the region.[38]

Continuous mechanisation was also decisive for the specialisation and rescaling of agricultural production. As obtaining farming equipment required significant investment, the only way to offset the high costs was to disperse them over higher production acreages.[39] This also meant that, as equipment was often specific to certain crops, it became more and more cost-efficient to concentrate on one specific crop. Most importantly, mechanisation allowed family farms to escape their labour limitations. Before the diffusion of tractors, the acreage that could be planted was defined by the capacity to mobilise human and animal labour during the specific weeks of planting and harvesting (in spring and fall). For the family farm, this set a quite particular upper limit, which was pushed upwards with mechanisation.

Along with the general upscaling of farming operations, the shift from solar-powered farms (through photosynthesis) to fossil fuel-powered farms also released significant amounts of land to monoculture. As farms were initially horse-powered—and early agricultural equipment required a large amount of horse-power—a significant part of the production of the farm, mostly oats, was feed for the reproduction of draft animals.[40] But by 1950, almost all farms had at least one tractor, which also meant that producing feed for the draft animals was removed from the farm rotation, allowing for further specialisation. However, this also meant that besides the costs of machinery, one more input was commodified and added to the cost structure of the farm. Fuel for the tractors could not be produced on site as the feed for the horses had been, and agriculture started depending heavily on the provision of cheap energy.

As oats were removed from the rotation, a completely novel crop was imported from Asia, introduced as an alternative cash crop to help deal with problems of surplus corn production: soybeans. Soybeans were introduced in the 1930s and were often combined in annual rotations with corn since they helped restore the fertility of the soil that corn cultivation exhausted.[41] In 1930, only a few years after their introduction, more than 3 million acres of soybeans were planted across the United States, and by 2018 soybean acreage matched the acreage of corn.[42] Similar to corn, soybeans are used for the production of animal feed (and, more recently, biofuel). But in contrast to corn that could (at least initially) be directly consumed on the farm, soybeans needed to be crushed in order to produce protein-rich oil. Therefore, soybeans could only be traded as a cash crop, not used directly on the farm to feed animals, and this required an industrial facility to process them.

At the same time, livestock production was rapidly upscaled and transformed into a closed system detached from the farm, operating through industrialised facilities in increasingly specialised locations. In 1900 more than 60 million hogs were dispersed in over 4 million farms across the US, with the majority concentrated in the Corn Belt. In 2012 there were just 60,000 farms with hogs, roughly the same number of hogs (60 million), but now farms had at least 1,000 hogs on average. A similar consolidation and upscaling happened with cattle. In 1900, there were around 40 million animals dispersed over 4 million farms across the United States, and in 2012, just over 900,000 farms were feeding more than 90 million animals.[43]

While hog production was concentrated in areas of northern Iowa and Illinois, after WWII, cattle production started moving farther west, closer to the grazing areas that produced cattle stock. The dominance of truck transport, especially after the 1970s, with the development of the Interstate Highway system, allowed the meatpacking and processing industry to decentralise. Abandoning large cities not only meant more efficient logistics but also escaping labour disputes with strong labour unions, as well as stricter environmental regulations that were starting to emerge.[44]

The decentralisation of the meatpacking industry enhanced the concentration of feedlots around it, contributing to their general upscaling and the eventual domination of large-scale confined animal feeding operations (CAFOs) that largely emerged out of a new type of operation: the dry feedlot. The dry feedlot could be largely considered as a machine for fattening cattle. Its operations fed anywhere from 1,000 to more than 50,000 animals, each in densely packed, grassless compartments with specially mixed blends.[45] The CAFOs (both for hog and cattle) were a decisive step, not only in the upscaling of the livestock industry but also in the decoupling of the integrated metabolism that originally characterised the Corn Belt system. Feed was not grown but purchased, and manure was not recycled as fertiliser, but concentrated as waste, creating severe environmental problems.

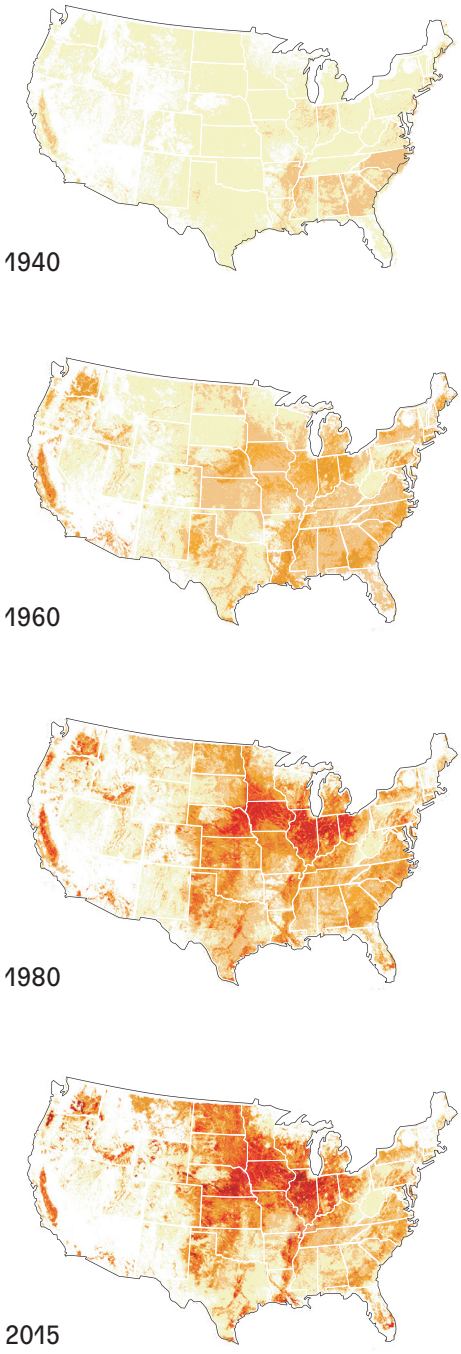
The effects of economies of scale started significantly transforming the structure of the Corn Belt farm towards larger-scale, specialised, cash-crop monocultures. As the total harvested area remained largely the same, farms got bigger and bigger, and the mode of production became increasingly capital-intensive while relying on less and less labour. Large farms, able to benefit from economies of scale, came to dominate Corn Belt (and US) agriculture, while acreage per farm and farmer increased exponentially.

INTENSIFICATION AND HOMOGENISATION BEYOND THE LAND

The continuous specialisation of the Corn Belt was starting to create a set of largely homogenised operational landscapes. But the homogenisation was not only due to the similar types of crop plantations and the concentrations of similar types of livestock. It was also due to the elimination of the biological variation of plants and animals. Since the early nineteenth century, the biological selection process at the farm level had reduced the hundreds of varieties of corn once found across the American continent to only a handful. Among them, the Southern Dent variety dominated, since it was delivering adequate yields, but most importantly its kernels were soft shelled, so animals could consume it directly without further processing.[46]

Productivity concerns also defined the selection of dominant livestock breeds. Farmers sought breeds that could gain weight rapidly on a corn diet and generate lean pieces of meat. However, before the diffusion of the railways, the ability of animals to walk to the market without losing considerable weight was also favoured. A handful of breeds ended up dominating the US livestock industry. In the cattle industry, Hereford and Angus still dominate the market. In hog production, breeds that were able to gain a lot of weight and produce a lot of leaner meat dominated, such as the Yorkshire, Duroc, Berkshire, and Hampshire.[47] Moreover, as CAFOs started spreading, livestock was bred for more efficient fattening and responding better to the vitamin supplements and antibiotics that became necessary in the abnormally densely stocked feeding pens.

While livestock has been highly modified through breeding, genetic modification of animals has generally been avoided, something that has not been the case with the development of seeds. Despite cross-pollination experiments by farmers at the farm level, corn yields had reached a plateau by the early 1900s. After the 1920s, efforts to develop higher yielding varieties started becoming more systematic, amplified by institutional actors, such as agri-cultural universities, and the research stations of the United States Department of Agriculture (USDA).[48] Through self-breeding, the first generations of hybrid seeds allowed for increases in yield and more sturdy plants that performed better under mechanised farming. But as hybrid seeds were self-pollinated (every plant reproducing itself), they were very weak in maintaining their productivity after the first generation. A system of specialised farms emerged for producing and supplying farmers with the hybrid seeds they now had to buy before every planting cycle. As a result, one more input was commodified and had to be added to the cost structure of the family farm.



GROWTH OF FERTILISER CONSUMPTION
Fig. 8

While hybrid seeds were only trying to improve seed productivity through still largely natural crossbreeding methods, after the late 1980s, and especially during the 1990s, bioengineering was used to modify the DNA of plants directly. Genetic modifications are aimed at improving the productive capacity of plants and addressing the complex problems emerging from the intensification of chemical inputs. Modifications were aimed at making plants more resistant to herbicides and pesticides or repelling and exterminating insects and bacteria, so that fewer chemicals would be used. Continuous hybridisation kept improving the capacity of plants to absorb nutrients from the soil and allowed for higher and higher densities of planting. In the late nineteenth century, corn fields across the Corn Belt had a density of around 10,000 plants per acre and every acre could produce around 40 bushels of corn. By 2017, densities were up to 35,000 plants per acre, and yields were up to 200 bushels.[49] Within a century, the same amount of land was hosting three times more plants, producing five times more corn. Similar to the overcrowded livestock feedlot, the overcrowded corn (or soybean) field, became part of a high-input metabolism.

None of the yield increases would be possible without the development and production of synthetic fertilisers. In the initial Corn Belt metabolism, the cycle of replenishing the soil included animal manure that was produced on the farm, which would soon be complemented by industrially produced fertilisers, which helped add the phosphorus (P) and nitrogen (N) necessary for plant growth. Early fertiliser production in the nineteenth century was centred either around mining N- and P-rich soils across the planet or around the by-products of the livestock industry (for example, grinding P-rich animal bones). Early twentieth-century mechanisation was accompanied by a considerable increase in the application of these industrially produced fertilisers that were still directly linked to biological and geological processes and had a natural organic base. This metabolic link would also break after the 1930s with the generalisation of the synthetic

production of N-based fertilisers from non-organic sources (mostly natural gas). The diffusion of the application of ammonia and urea-based fertilisers after WWII led to an unprecedented intensification of production and a critical modification of the nutrient and energy cycle, affecting not only the quality of soils but also the hydrological and atmospheric systems that were directly and indirectly connected to the Corn Belt's metabolic cycle as nitrates started leaking into the water system. [Fig. 8]

By the turn of the second millennium, the Corn Belt system, once tightly consolidated around the family farm, was spatially decoupled into specialised production landscapes across the United States. Certain regions—mostly across southern Illinois and Iowa—specialised in soybean production, while Iowa, Nebraska, and northern Illinois specialised in corn production, and several farms in northern Iowa, Illinois, and eastern Nebraska focused on swine. Cattle production was dispersed to Texas, Nebraska, Kansas, California, and Oklahoma. Moreover, as all metabolic relationships around the farm were commodified, corporate control over the complex commodity chains was turning the Corn Belt into a profit landscape, with the farm as a mere conduit. It was basically circulating capital in the form of inputs and outputs. In this capital-intensive system of high revenues, the farm was becoming less and less significant.

CORPORATISATION AND THE GEOPOLITICAL ECONOMY OF OPERATIONALISATION

Perhaps it is not so surprising then, that under the contemporary highly industrialised model of Corn Belt production, farms across the Midwest, are still not predominantly owned by corporations, but rather by families.[50] In Iowa and Illinois—the centre of the Corn Belt—more than 85% of the farms are still family-run.[51] But owning and operating the land is diminishing in importance, as profit is not emerging from it but through it. In the initial configuration of the Corn Belt system, most of the value came from the soil, and most productive factors could be reproduced off the farm, giving farmers relative control. Seeds, livestock (hogs), fertiliser (manure), draft animals, and farm animals (such as chickens) could be largely reproduced on site. With the industrialisation of the Corn Belt system and the rescaling and splintering of its metabolism, all inputs became commodified and controlled by increasingly oligopolistic corporate structures. Family farms became squeezed into a treadmill that imposed both downward pressure (on the demand side) and upward pressure (on the supply side) while undertaking all the risks of growing plants and animals.

The oligopolistic concentration of the US agribusiness has been remarkable on both ends. On the demand side, livestock production has been one of the older fields of oligopolistic control, with collusion between the big meatpackers dating back to the nineteenth century. In the early twenty-first century, four corporations (Tyson, Cargill, Swift, Smithfield) control more than 85% of the beef-packing and processing industry, and around 70% of the pork-packing and processing industry, while Smithfield and Cargill dominate the feedlot industry. Animal feed plants are also largely consolidated, with the four biggest companies (Land O'Lakes, Cargill, ADM, and Heiskell) controlling around 40% of the market.[52] Soybeans and ethanol production, which were initially presented as alternative markets to farmers, are also mainly controlled by the same companies, with soybean crushing dominated by ADM, Cargill, and Bunge, who control more than 70% of the market. ADM and Cargill also control almost 40% of ethanol production. At the same time, more than 60% of the US corn and soybean seed market has been

F. 8 Growth of fertiliser consumption across the US between 1940, 1960, 1980 and 2015: more than 5 million tonnes of N based fertilisers were applied systematically across the Corn Belt almost every year after 2010, roughly corresponding to 50 kg per acre of farmland.

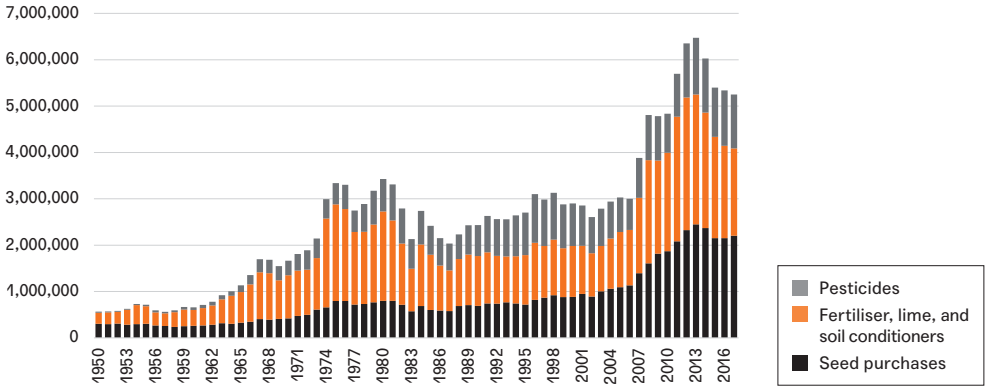
controlled by only two companies, Monsanto (now owned by Bayer) and Du Pont/Pioneer, who also hold the majority of patents related to genetically modified seeds. Similar concentration has characterised the fertiliser industry. Mosaic, a company controlled by Cargill, together with CF Industries, have been responsible for more than 60% of US production, competing with Canadian Nutrien. Finally, Du Pont, Monsanto (Bayer), and Syngenta (Novartis) are also dominating the agricultural chemicals market (herbicides and insecticides).[53]

Furthermore, several of these companies that often compete in the same sector are forming (formal or less formal) partnerships across sectors, creating what has been described as agri-food "clusters."[54] These clusters facilitate the entire process, from genetic engineering to fertiliser and chemical application, grain trade, feed, and livestock, even as far as the supermarket. These bundles are presented to the farmers as either best practices to increase productivity or as parts of contractual agreements, reducing farms into fully controlled, intermediate steps in the production process. Contract farming started to dominate the livestock industry in the late twentieth century (especially poultry). Livestock producers have to undertake investment in fixed capital to develop feedlots, only to raise feedstock that they do not even own, under contracts that also prescribe the feeding process, feed, antibiotics, hormones, and a fixed price for the final output. Given the licensing agreements that often accompany the use of genetically modified seeds, and the precision required in the combination of inputs for their best performance (specific fertilisers, pesticides, etc.), contract agriculture has also started to penetrate the corn and soybean cultivation sector.

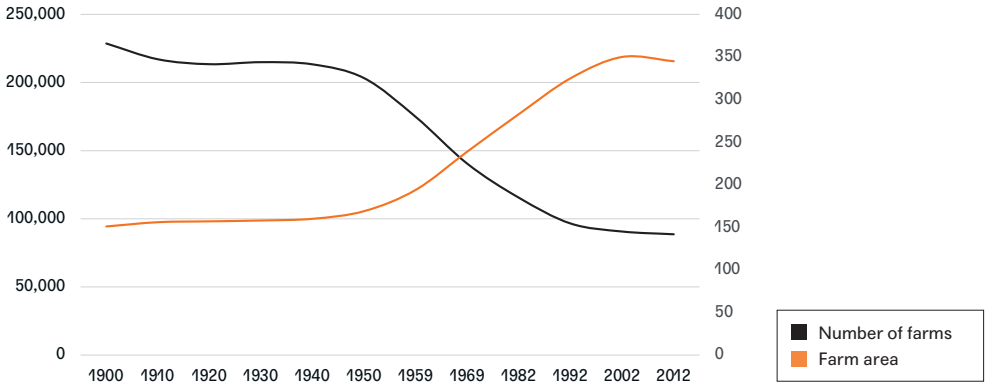
But even with increased capital inputs, farmers see diminished returns with initial productivity gains quickly exhausted, and several experts expect yield plateaus in corn and soybean production.[55] In fact, certain physical limits have been reached and are difficult to surpass. For example, the density of corn plantations is so extreme that it is challenging the capacity of the soil to physically support, process, and deliver moisture and nutrients, despite intense fertilisation. As the limits of soil and plant productivity are reached, agribusiness corporations are aiming to further increase productivity through the very precise, specialised, and integrated coordination of all means of production. Geospatial technologies and increased automation have a central role in this new paradigm of "precision agriculture."[56] Through the use of remote sensing, geospatial information is collected regarding the conditions of the soil, plants, atmosphere, and weather. This data is then used to define the planting of seeds, the application of fertilisers and chemicals, and, eventually, the harvesting process. Through GPS tracking, the location of machinery is also monitored and could lead to models of completely automated farming.[57]

With the agricultural machinery market in the United States largely saturated, these companies are pushing toward a structural shift in the business model of industrial farming, turning it into a service industry. Consulting through this accumulated geospatial knowledge and "expertise" is the more productive combination and application of the already assembled bundles of corporate commodities, thus providing an instantly consumed service commodity, integrating all others. Under the rubric of sustainability, since precision agriculture promises more efficient use of inputs (such as fertilisers and chemicals), farmers are threatened to lose the last non-commodified asset that they could still claim to master: their grounded, experiential knowledge of the situated complexities of cultivation of their farm. Precision agriculture is the last paradigm in the Corn Belt's long industrialisation process that started with a phase of mechanisation and was followed by a biochemical phase that unleashed the use of fertilisers and chemicals, leading to the final phase of genetic modification. Every phase promised advancements in productivity but was also signalling the exhaustion of previous gains.

In all these various phases, the tendency towards corporatisation has always been



COST STRUCTURE OF IOWA FARMS
Fig. 9



THE CHANGING SCALE OF FARMING IN IOWA
Fig. 10

F. 9 The operating costs of Iowa farms rose from an average of around $160 in the mid-1990s to $240 in 2015. The costs for seeds increased more than three times, from around $30 to $100, and the costs of fertilisers more than two times, from $50 to $120. In 2017, cultivating an average-size 350 acre farm in Iowa required on average over $200,000, with the major variable costs at around $40,000 for seeds, $50,000 for fertilisers, and $20,000 for pesticides.

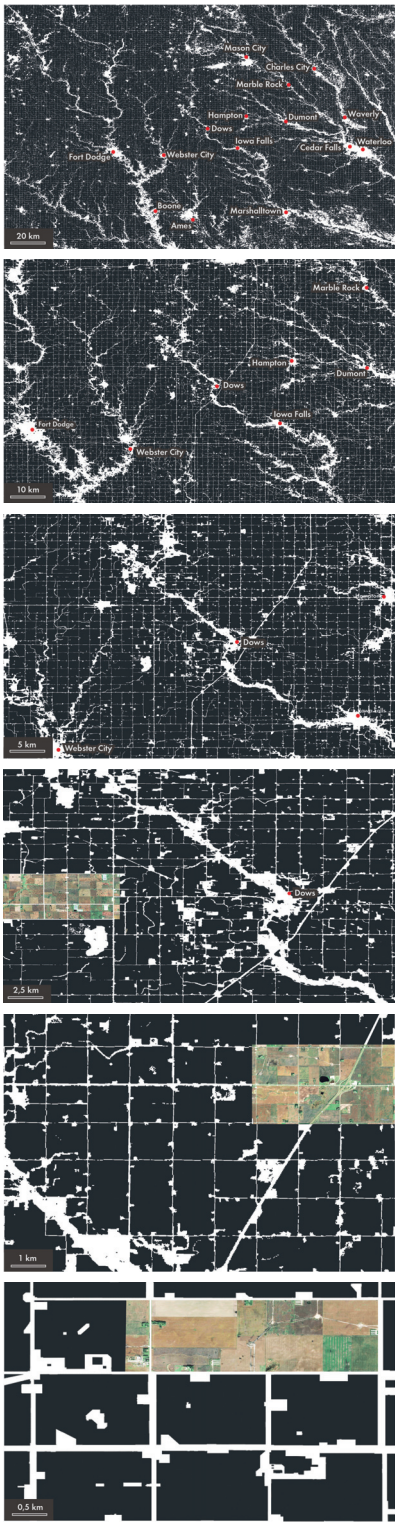
Depending on the yield and the price received, the average farm would see a revenue of no more than $240,000.

F. 10 The average farm size increased from 150 acres in 1900 to 350 acres in 2017. But these numbers are distorted by small farms close to agglomeration zones that are often just part-time farms and are not the ones driving production. Out of the 80,000 farms in Iowa, more than 75% of the land is operated by no more than 20,000 farms that are larger than 500 acres and dominate the landscape in the counties in the north and west, but also parts of the south. Around 8,000 of these farms are larger than 1,000 acres and operate almost 50% of all land. With this significant rescaling of farm operations, Iowa has lost more than 60% of its farms over the past century, with more than 120,000 disappearing since 1900 and more than 80,000 since 1960.

interwoven with the role of the federal government, instrumentalised largely through the USDA. Until the early twentieth century, the USDA was only indirectly contributing to the development of farming practices by advising and educating farmers. But after the crises of overproduction in the 1920s, the USDA established its central role in commanding the agricultural economy, which, for most of the twentieth century, was centrally planned.[58] The USDA started intervening directly in agricultural commodities markets with New Deal measures that introduced production ceilings as agricultural surpluses were becoming a structural problem. At the same time, the federal government was becoming instrumental in the process of agricultural industrialisation, either by investing directly in infrastructure or by subsidising investment in mechanisation and agricultural research.

After the two World Wars, two lines of policies were combined to address both internal problems of overproduction and geopolitical goals. The United States used its hegemony to establish an adequate system of world markets to channel its surpluses.[59] The most significant expression of capitalist power in the shaping of this "food regime" is that food and agriculture products were completely excluded from the General Agreement on Tariffs and Trade (GATT), and US surpluses were channelled through non-market, state-to-state exchange mechanisms in the form of food aid.[60] In this way, food aid served domestic agricultural policy—by solving the chronic problem of overproduction—and allowed the United States to pursue foreign policy goals in the context of the Cold War.

After the mid-1990s, and the inclusion of agricultural commodities in the GATT, agricultural policies in the United States changed dramatically, opening the way to the establishment of what has been coined as a "corporate food regime."[61] Instead of trying to regulate supply, starting with the 1996 Freedom to Farm act, the federal government encouraged farmers to produce as much as possible, securing that they could cover their costs as market-based



SCALES OF OPERATIONALISATION ACROSS IOWA
Fig. 11

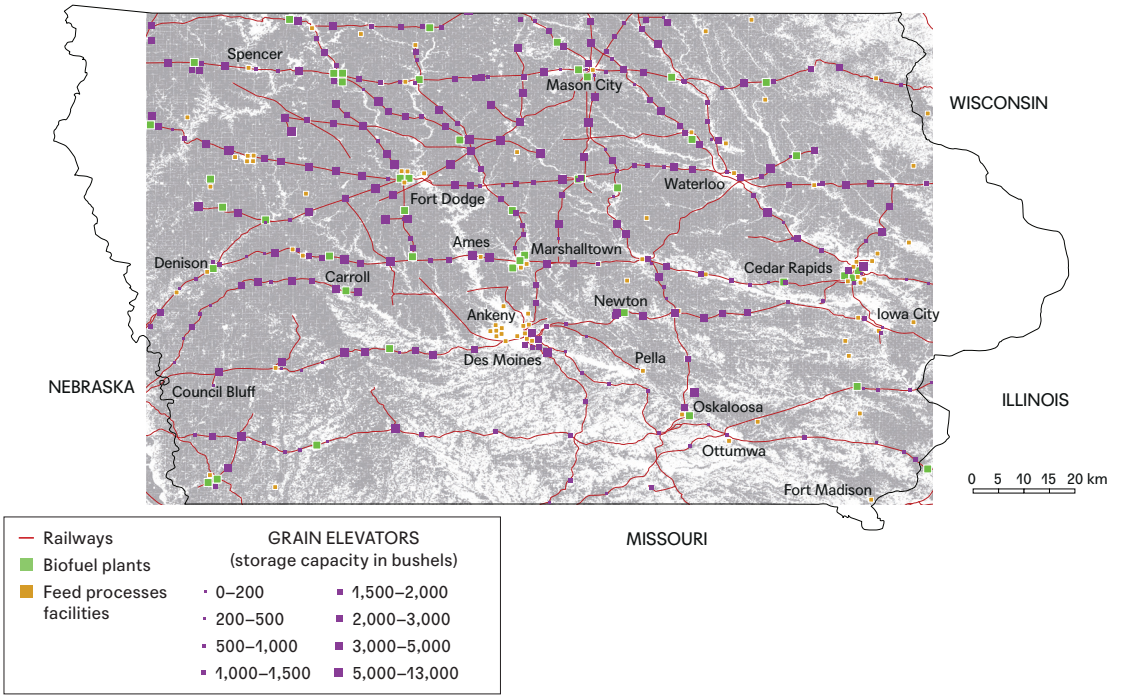
Fig. 12

loss-assistance payments were introduced.[62] These payments complemented the market prices in case they were too low, based on the historical production estimates of the farms, and thus encouraged farms that were historically overproducing to continue doing so. As this significant change in policies allowed for the market prices of agricultural commodities to drop, the ones that were subsidised were not really the farmers, but rather the corporations on both ends of production. On the demand side, the feed, livestock, and grain processing industries benefited by reducing the costs of their inputs, and on the supply side, seed, chemical, and fertiliser companies could benefit from the increasing demand without the reduced prices being reflected in the costs they imposed. The emphasis on biofuels in the early twenty-first century further enhanced this process by adding yet another subsidised outlet.

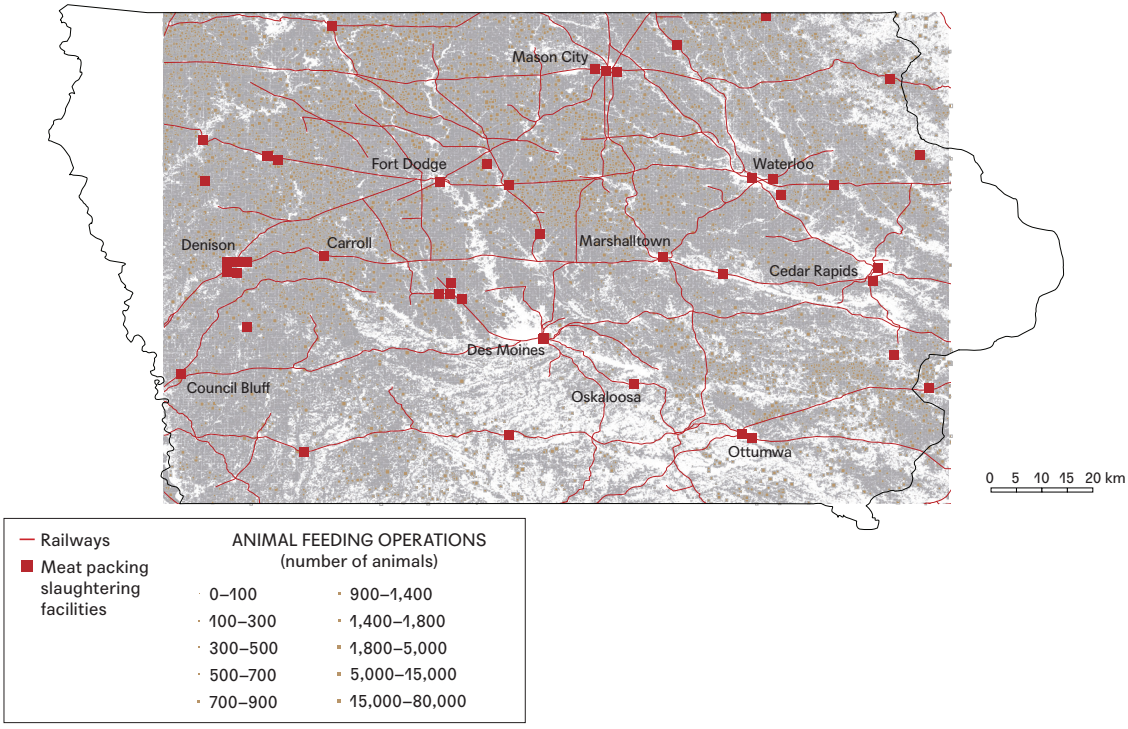
The system of subsidies at the beginning of the twenty-first century was, in fact, devised to sustain a flow of massive inputs to the farm, and cheap outputs from it, to be used as inputs to the livestock and food processing industry and, more recently, the energy sector. Through a lengthy interplay of corporate and state power, the landscapes of the Corn Belt have been transformed into a horizontal factory, turning the farm into a conduit in the process of capital circulation. The increasing entanglement of the Corn Belt farmer into more and more complex, closed and precise systems of commodified flows of production dissolves the illusion of the long-celebrated entrepreneur farmer. Farmers

F. 11 Cultivation areas cover more than 85% of the total area of the state of Iowa, following the checkerboard grid introduced by the PLSS. Only roads, surface water, and settlement areas disrupt the continuous carpet of corn and soybean farming.

F. 12 Aerial view of the Public Land Survey grid over Iowa.



THE GRAIN COMMODITY CHAIN IN IOWA
Fig. 13



THE LIVESTOCK COMMODITY CHAIN IN IOWA
Fig. 14

across the Corn Belt might still own the land, but under the contemporary mode of the corporatisation of Corn Belt agriculture, the soil is just a seedbed through which expensive inputs (bought from oligopolies) are turned into cheap outputs (sold to oligopolies). The farmer handles exuberant amounts of capital but is left with thinning returns and, at the same time, is solely undertaking all the risk. As the constant commodification of inputs has led to steep increases in cultivation costs across the Corn Belt, average farm income (adjusted for inflation) has remained largely stagnant, even as productivity has increased.[63] [Fig. 9]

Although not necessarily owned by any corporation, the operational landscapes across the Corn Belt are perhaps even more corporate than the typical central business district in any American city; it is a landscape where corporate capital has tried and exhausted ecological surplus out of various bundles of social, technical, and natural systems. The last frontier of ecological surplus has also been the most persistent unit in the Corn Belt system. This is the family farm itself; its reproduction is threatened by thinning profit margins, the prospect of full automation, and the overall erosion of its surrounding social fabric. [Fig. 10]

Fig. 15–17

ANATOMY OF AN OPERATIONAL LANDSCAPE

These transformations are deeply embedded and reflected in the physical configuration of the Corn Belt landscape. Perhaps in no other area is this more evident than across the state of Iowa. With a human population of just over 3 million, Iowa's area is covered almost completely by farmland, with more than 30 million acres of corn and soybeans covering more than 85% of its territory. This extensive farmland produces more corn than any other US state and is only second to neighbouring Illinois in the production of soybeans. Indeed, crossing the northern counties of Iowa, the intensive use of the land is striking. It seems that almost every square metre

F. 13 Major elements of the grain commodity chain in Iowa: farming areas, grain elevators, feed processing facilities, biofuel and bioethanol plants, and railways.
F. 14 Major elements of the livestock commodity chain in Iowa: animal feeding operations, meat packing and processing facilities, and railways.
F. 15 Genetically modified seeds waiting to be planted in a farm close to Corning, Iowa.
F. 16 Machine shed in a farm close to Corning, Iowa.
F. 17 Farm and farmstead close to Corning, Iowa.

Fig. 18

of land is in some way operationalised, either put into production or hosting a functional facility central to the Corn Belt system. The sense of a highly rational, instrumentalised, and machinic landscape is amplified by the regularity imposed by the subdivisions of the Public Land Survey system. [Fig. 11–12]

As the secondary system of state and county roads largely follows the boundaries of the original townships, county roads create parcels of 6x6 miles, subdivided by smaller (often dirt) roads every mile. The one-mile squares were originally meant to host four 160-acre farms. But as the farms in Iowa have grown bigger and bigger, and farmland consolidated into larger plots, farms have been eradicated and become more sparsely spaced. From an original density of around four farms per square mile, one might now often drive for more than a mile to see a farmhouse, and most structures that are found across the fields are not farmhouses, but rather metal boxes that host either grain or hog and poultry feedlots. [Fig. 11–12]

The regular checkerboard pattern of roads and farms is only slightly disrupted by the transport corridors of railways and interstate highways that organise the circulation of agricultural commodities. The five major railway corridors that intersect Iowa from east to west still form the backbone of Corn Belt logistics. These lines enable efficient, bulk transport and are positioned with grain elevators so that corn and soybeans can be collected, stored, and eventually loaded on railcars. They also connect to major grain processing facilities for ethanol, biofuel, and feed manufacturing plants. [Fig. 13] The same is the case for fertiliser, pesticide, and chemical plants, as well as meat-packing and processing facilities. [Fig. 14] It is quite easy to reconstruct the dominant commodity chain of corn and soybeans from this linear network of nodes and connections. From the farm, the farmer transports the grain by truck to the closest grain elevator or to the

F. 18 Hog feedlot in Pocahontas County, Iowa.

closest biofuel or feed-manufacturing facility, whichever offers the better price. From this point on, the farmers largely lose track of what happens to their produce as it is processed, loaded, and transported. Similarly, finished livestock is transported by truck to one of the meatpacking and processing facilities as new livestock enters. Overall, although the farmers operate in a global context, they experience only a local part of the chain. The rest of the process is completely concealed.

The farm remains the basic unit of production, but it is transformed into a small factory, and the major structures dominating its landscape are not the farmhouse, but rather the clusters of grain bins that are used to store corn or soy (and thus address the volatilities of the market), and the huge machine sheds that have replaced the stable or barn, and house hosting the collection of machinic equipment necessary to operate the farm. [Fig. 15–17] These structures often dwarf the farmhouse, which in the case of cash-crop farms, is still on site, something that is rarely the case when it comes to livestock operations. Hog and poultry feedlots are the most dominant in Iowa (especially in the north) and are housed in specialised, elongated metal buildings, often clustered in parallel lines, and built upon a covered manure lagoon, where animal waste is collected and deposited. [Fig. 18] Animals are rarely seen since they are confined, and their presence can be ascertained only through the distinctive odour. Neither are people since they are not necessary. This is predominantly a machine landscape, designed to put mostly nature—not humans—to work.

Indeed, visiting one of the machine sheds in a typical farm reveals how it is possible to need a mere couple of human labour hours to produce more than 200 bushels of corn per acre. [Fig. 16] What is most impressive is not so much the army of machines, consisting of giant combines and tractors with planting and spraying arms and large and smaller trucks, but the fact that all this equipment can be operated and assembled by a single person. This spans the whole process from planting and harvesting to loading grains into trucks. Considering that the capital invested in purchasing this equipment lies at the levels of several hundred thousand dollars (combines can cost more than half a million), it is apparent that farms on the scale of 500 acres are at the lower end of the size needed to produce enough revenue to sustain this model. Fuel tanks for the machinery and natural gas infrastructures for drying the grain in the corn bins reflect the high-energy dependency of Corn Belt farms, while containers of nitrogen fertilisers are a reminder of the exhausted fertility of the soil.

Since there are no animals grazing there are no fences, only signs with the seed company brands signifying the genetically modified variations that were planted. [Fig. 15] This also largely explains one more element that becomes noticed by absence: insects. It is striking that even in the middle of the summer, standing among billions of plants, there are only a few insects buzzing around. This results from insect-repellent variations of corn and soybean seeds acting as embodied insecticides. The obvious risk of environmental catastrophe is supposed to be addressed by the seed companies—they are supposed to place anti-insect genes in only small percentages of the plants, so insects are not completely eradicated.

What finally concludes the impression of a machinic landscape "void" of life, but full of productive capacity, is the apparent absence of humans. Across the state of Iowa, less than 100,000 people are working in agriculture, putting into production an estimated 80 million animals (cattle, hogs, and chickens), 400 billion corn plants, and 500 billion soybean plants.[64] The general change in the organic composition of capital towards more capital-intensive (and less labour-intensive) agricultural practices has led to farmland consolidation, farms being eradicated and upscaled, and animal breeding concentrated in larger and larger CAFOs. As populations working in agriculture and living on, or close to, farms diminish, the pattern of settlement and communal structure in Iowa is severely transformed towards a much more centralised form of inhabitation. More than 80%

of the population lives around the four major agglomeration zones. These zones include the area around the capital of Des Moines in the centre, the agglomeration corridors along the Cedar and Iowa rivers in the east, and a zone around the Nebraskan city of Omaha at the very south-western border of Iowa.

But similar to the rest of the Corn Belt states, the settlement pattern in Iowa has been much more decentralised and structured around the farm as the basic settlement unit. Around 1900, more than 60% of the population was not living in any form of concentrated settlement (towns, cities, or villages of any form and size). Rather, they lived on individual farmsteads that hosted more than one million people. At the time, there were less than 30 settlements with more than 5,000 inhabitants and most of the population was spread over a quite decentralised network of small towns. [Fig. 19] This regular and quite homogenous settlement pattern largely reflected the subdivisions of the Public Land Survey System, which also enabled a pattern of density and territorial organisation. As the land was commodified through townships, certain sections within the townships were reserved for the public in order to host social infrastructures, such as schools and cemeteries. Since these parcels were in predefined lots that were around the centres of the townships, they affected the regular organisation of settlements around them. Moreover, as townships were further aggregated to form counties, settlements that were closer to the centre of the counties were preferred as county seats so that the civil functions located there could be easily accessible from all parts of the county.[65]

The development of the railways, in most cases complemented this underlying structure, linking several of the more central settlements and amplifying their role. The construction of the railways also largely standardised the infrastructural layout of the towns, introducing a sequence of grain elevators that became central parts of the settlements and their economic life. Grain elevators and the associated infrastructure were often positioned on the north part of the rails. At the same time, the remaining economic activity was often extended to the south, as railways typically crossed the settlements along an east-west axis. This structure suggested a dispersed and rather hierarchical geography of central places, the basis of which was the family farm.

The economy of the small towns that were dispersed among the farms largely revolved around the metabolism of the Corn Belt system and served as markets for agricultural equipment, seeds, and fertilisers. They also hosted public services like schools, banks, and post offices, in so much as they were hubs for agricultural storage and transport, and these amenities were necessary. Moreover, they also offered complementary labour markets to the members of the family farm, allowing them to have employment outside the farm. Naturally, the upscaling of farms and the associated decline in farm population led to the gradual erosion of this settlement pattern after the 1930s and especially after the 1960s. For almost every decade after the 1950s, Iowa saw more than 70% of its counties lose population. Around 20 out of 99 counties lost more than 30% of their populations, some close to half, while the only counties that gained population were near the major agglomeration centres that continued to grow—similar to the trend in the settlement dynamics. Since 1960, around 60% of all settlements in Iowa have been shrinking, with several of them losing more than half of their population. Decades of depopulation have left more than half the counties in Iowa almost empty, with densities of less than ten people per square kilometre, leading to a downward spiral where depopulation means unbearable living conditions for those who remain, leading to even more depopulation.

At the same time, however, the more counties become depopulated, the more operational they become for the corporate metabolism of the Corn Belt. Several counties that have lost half their populations have increased their productivity. For example, since the 1950s, Adams County has lost more than three-quarters of its farms and farmers but has been producing four times more corn. Such counties represent extreme examples of operational landscapes

Fig. 19

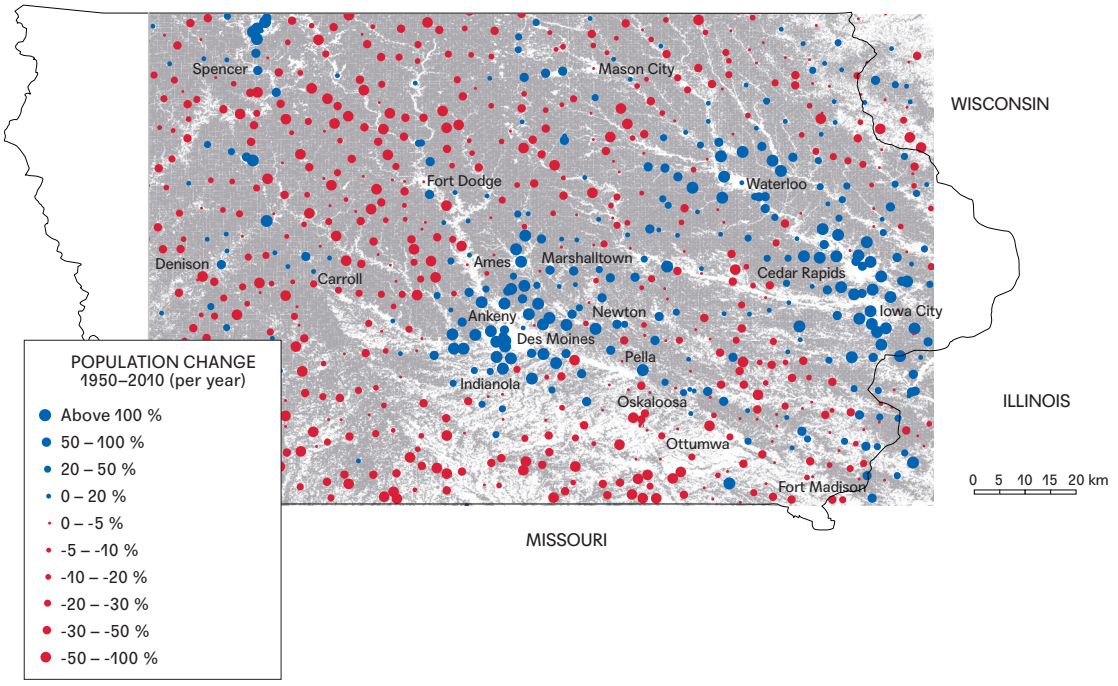
that are almost devoid of any social activity. They are dedicated almost completely to primary production, shaped by a lean, industrialised functionality where all operations are precisely prescribed, like parts of a horizontal factory.

The ongoing process of operationalisation, leading some of Iowa's counties in these extreme, almost ultimate stages of performativity, is interwoven with a dual process of centralisation and peripheralisation. This process has largely reshaped the initially decentralised pattern or settlement into a rather distinct set of depopulated but highly productive operational landscapes surrounding the four major agglomeration zones that continue to grow in terms of population and economic activity: the area around the capital of Des Moines, the agglomeration zones forming around Iowa City, Cedar Rapids, and Waterloo across the Iowa and Cedar rivers and of course around the city of Davenport on the Mississippi River, as well as the areas around Omaha and Sioux City on the border with Nevada. [Fig. 20] Major operations of agricultural corporations such as Pioneer (seed manufacturing) and John Deere (tractors) are concentrated around these agglomerations and along the corridors connecting them, reflecting through their spatial concentration also the market consolidation of agricultural manufacturing businesses that used to be much more dispersed across the less centralised settlement. Corporate agribusiness is shaping both agglomeration zones and the extended operational landscapes of Iowa.

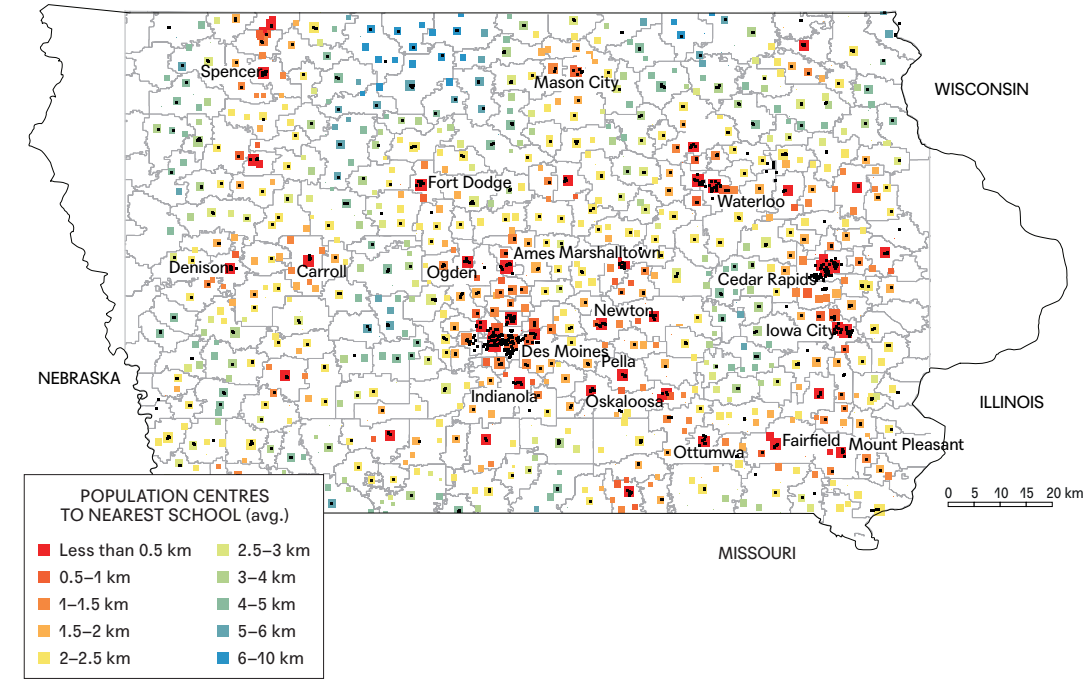
INHABITING AN OPERATIONAL LANDSCAPE

As farm employment has remained rather static (when not decreasing), the jobs created by the increasingly corporate agribusiness economy

F. 19 Lithography, perspective view of John D. Rivers' stock farm in Des Moines Township, Iowa, 1875. The town of Dallas is seen in the back, while farms dot the landscape. The mixed farming of cattle, pigs, and feed cultivation is supported by early mechanised means.



POPULATION CHANGE IN IOWA
Fig. 20



SCHOOL DISTRIBUTION IN IOWA
Fig. 21

Fig. 22

Fig. 23

F. 20 Per cent change in settlement population in Iowa, 1950–2012: population growth is limited to the central agglomeration of Des Moines and the corridors of the Cedar and Iowa rivers in the East, leading to a clustering of the population around the major cities and a hollowing out of the in-between farming zones.

F. 21 Distribution of schools and school districts in Iowa, and distance of settlement from the nearest school, 2015.

F. 22 Davis Avenue, looking south, Corning, Iowa.

F. 23 Music fair in Pocahontas county on a Saturday afternoon, Iowa.

suggest a growing penetration of wage labour relationships that concentrate around the major agglomeration zones and extend to the smaller towns of the depopulated Iowa counties. In fact, for counties such as Pocahontas, or Buena Vista, with populations in the range of 10,000 or 20,000, the operation of a biofuel refinery, a soybean mill, a seed production facility, or a meat processing plant is crucial for the employment of the thinning population, and especially for their fragile towns. For example, a medium-sized biofuel factory, such as the Valero plant next to Albert City (population 700), can employ around 100 people, a significant percentage of the workforce.

The combination of the sparsely populated counties and the growing significance of the operations of agribusinesses, as the sole employment opportunities has led to increased competition between the struggling counties to attract corporate investment and the relocation of plants, but also to a high precarity in the labour market. A striking example is the case of Cherokee county, one of the most depopulated counties in north-west Iowa, which has lost more than 50% of its population since the 1950s. Since 2014, Tyson Foods closed its meat processing plant near the city of Cherokee (population 4,900), laying off more than 450 people, and has since refused to allow any competitors to take over the plant, thus largely keeping the city hostage.[66] The “we are hiring” banners that are very often hanging at the entrance of seed processing facilities or biofuel and feed mills signify both the prevalence of this model and the underlying dependencies it creates. Within this context, the existence of (or proximity to) less precarious employers, such as medical services, and of course, city and state jobs (schools, postal service, etc.), can often prove a decisive factor for the prospects of Iowa’s small towns.

But the more the population retreats, the more difficult it becomes for cities and counties to sustain such functions, impacting the daily life of the local communities. The consolidation of school districts and the closing of schools offers a striking indicator in this respect, with Iowa losing more than 4,000 schools since the 1950s, making access to education increasingly challenging for those left behind. [Fig. 21] Equally decisive, both for the labour market and for the standard of living, has been the restructuring and rescaling of retail functions. Once concentrated along the main streets of the agricultural towns, most retail has consequently moved either closer to highway entrances or completely eradicated and replaced by shopping centres, positioned even further away in selected locations. Thus, walking along the few blocks that used to constitute the commercial centre of the main street, even in the central towns and county seats, is an uncanny experience, often accompanied by zero encounters with people, closed shops, and a relative surprise when a business is still running. [Fig. 22] Still, quite a few of the towns manage to concentrate basic retail (clothing, furniture, giftshops) and service options (accounting, real estate, insurance, banks) and recreational facilities, even movie theatres, while the occasional local pub, or bar, is often the only place that is still full of people.

Besides the few general supply stores and low-cost stores that often remain in the centre of towns, most everyday retail takes place along state roads and highway intersections. The diffusion of corporate retail chains adds a sense of genericity with McDonalds, Burger King, and Subway weakening the sense of any local character or the feeling of being in "the countryside." Especially the existence of large retailers, such as Walmart, is often considered an advantage, both for the jobs created and the shopping options they are believed to offer. They function as a magnet that can attract growth to surrounding communities. The penetration of corporate America can also be seen as an ironic reflection of the commodified relationships that characterise the food, feed, and fuel nexus: a Big Mac consumed in Corning, Iowa, could be very well conceived to contain some of the local landscape in it, but only after the corn harvested in one of its farms, concludes a long journey across the operational landscapes of the US agri-food system.

With the rescaling of production and retail, and the retreat of social infrastructures, living in Iowa's small-town communities has several negative elements of larger and denser agglomeration zones without any of their advantages. From a high dependency on the automobile to the penetration of generic corporate chains, the inhabitants of the depopulated counties of the Iowan operational landscapes have, in some respects, a quite similar experience to every other citizen of suburban America. But at the same time, they have to face a deficit of social infrastructures, retail, entertainment, and recreational options, and the lack of economic and cultural versatility of larger cities, further aggravated by environmental problems (such as water population), and the negative externalities of industrial agriculture (especially those associated with CAFOs, such as waste and odour).

Nevertheless, while these problems are often acknowledged, most inhabitants are rather conscious of what they see as a trade-off between the difficulties of inhabiting an increasingly operational landscape and the persistence of several elements of "rural" or "countryside" living. Indeed, stronger community bonds, the ability to better manage time, and a closer relationship to the land, contribute to the robustness of the local communities, while informal economies continue to thrive even under the pressure of ever more pervasive wage labour relations. In fact, the liveliness that the small Iowan towns are missing is to be found in the numerous smaller or larger town and county fairs and community festivals, which are quite common, especially during the summer months. From simple food and music fairs to more radiant specialised thematic events (often related to popular leisure activities, such as reconstructions of vintage agricultural machinery), these events reflect and strengthen community ties and animate the otherwise dormant landscapes. [Fig. 23]

The same community and family ties play an important role in the persistence of a complex web of multivariate, often informal economic activities that are directly interwoven with the seasonality and the diverse needs linked to farming. While farming activities are concentrated around specific periods of time—mostly during spring (planting) and fall (harvesting)—the maintenance and management of the farm and the model of the farmer/entrepreneur require a multitude of tasks that are often outsourced through family or community networks in the form of informal, part-time jobs. From accounting tasks to construction work and equipment installation and maintenance, the basic economic functions of agricultural production are diffused through various employment opportunities in local communities.

This exact condition offers a certain robustness to the socio-economic structure of the local communities. It could also be seen as the final frontier of ecological surplus for the capitalist mode of agricultural production, as these often-informal relations between agricultural production and social reproduction provide several degrees of elasticity for local communities to absorb the volatility of agricultural markets. They also allow high degrees of self-exploitation, not limited to the farms themselves, but diffused to the whole community within which they are embedded, thus absorbing economic pressures that allow profits to be accumulated elsewhere along the agricultural commodity chains. Revisiting Harriet Friedman, who highlighted this mechanism at the level of the family farm, perhaps it makes more sense to consider this elasticity at the level of the whole community within which it is positioned.[67] But as local communities are eroded through depopulation, even this last frontier for the appropriation of ecological surplus seems to be exhausted.

FRONTIERS OF EXHAUSTION

Operational landscapes are landscapes that depend highly on the appropriation of ecological surplus for the extraction of surplus value. As bundles of human and more-than-human natures are appropriated and eventually exhausted in the search for profit, operational landscapes are transformed by the continuous search for the next "frontier" of accumulation. The more these frontiers are exhausted, the more operational landscapes tend towards a complete commodification of all the relationships that construct them. And vice versa, high degrees of commodification signify the exhaustion of ecological surpluses, which are basically operational landscapes that have reached a "mature" or "saturated" state.

The Corn Belt can be undoubtedly characterised as an operational landscape that has reached such a state. A landscape where frontiers of ecological surpluses have been gradually exhausted. The initial appropriation of high-ecological surpluses was based on the extraction of the socio-natural work that was embedded into the mid-western soil. As this frontier was gradually exhausted, productivity gains started becoming more and more dependent upon a high-input metabolism that unfolded together with the mechanisation of the means of production. In turn, this high-input metabolism reflected the struggles to assemble frontiers of cheap energy that fuelled industrial farming and pushed chemical innovation in fertilisers and pesticides. Genetic engineering in crops signified an additional level in the exploitation of biochemical frontiers, which increasingly challenged the sensitive state of ecological systems.

Achieving a balance with nature has proven an elusive task. Since 2011, superbugs (such as the corn rootworm) have been observed to develop resistance to genetically modified crops and have actually evolved into stronger breeds as a result of the modified seeds.[68] Similarly, the emergence of superweeds able to resist herbicide treatment occurred even earlier, around 2005. Superweeds and superbugs

only confirm the downward spiral of environmental disruption that has accelerated in the past decades, only to amplify historically persistent problems of soil erosion and nitrogen pollution.[69] Soil erosion problems are as old as the mechanisation of agriculture in Iowa in the 1920s, and nitrate diffusion problems date back to the intensification of fertiliser application after the 1960s. Soil erosion is most prevalent in the west and southwest, where the terrain is hillier, since erosion is directly related to slope. While the negative effects of soil erosion are directly linked to the area of the farm, nitrogen pollution through extensive fertiliser use has extensive and multiscalar negative externalities.

Since the late 1970s, nitrogen from fertilisers leaking through the soil has entered Iowa's hydrological system as converted nitrates, which are poisonous to drink and cause oxygen depletion through eutrophication in aquatic ecosystems. Over the past decades, the intensification of nitrate pollution problems has forced water suppliers to install water treatment systems to remove nitrates, costing millions of dollars. Furthermore, polluted water from Iowa has made its way to the major water corridors of Missouri and Mississippi, and through them, to the Gulf of Mexico. This contributes to the recurrent emergence of a "dead zone" close to the Mississippi delta—a hypoxic zone leading to massive fish kills, biodiversity reduction, and the fishing industry's destruction.[70] Ironically, it is through the underground infrastructure of tilling that has been placed under the glacial depression of the Des Moines Lobe to improve draining that most of the nitrate-polluted water is leaking into the system. Equally ironic is that the Mississippi River carries the pollutants to the gulf yet is the main waterway through which nitrogen fertilisers are shipped north from the clustered processing plants in its mouth, around New Orleans, completing a destructive cycle.

Superbugs and superweeds, soil erosion, and nitrate pollution are all signs of an exhausted landscape, where attempts to increase productivity are releasing complex and often unpredictable sets of negative externalities. These negative externalities are often spatially or systemically offset and are unaccounted for in the costs of production. But as the ecological surplus contributed by the work of nature has been continuously exhausted, the family farm as a form of production, but also as a source of ecological surplus (through the self-exploitation of its members), has been also challenged. As the productive landscape of Iowa has been continuously depopulated, relationships of social reproduction have been largely commodified and disassociated from the reproduction of the productive elements of farming, a common pool that used to add to the robustness of the family farm model. It is not just nature that has been in a state of exhaustion in Iowa, but also several communities, especially in northern and southern areas.

As the operational landscapes of Iowa are deeply interwoven into globalised networks of production, they become elements of geopolitical struggles and capitalist power, revealing the indifference of capitalism's global search for profit to local ideologies, cultures, and political beliefs. The latest shocks in the soybean markets, inflicted by the growing trade tension between China and the United States, had a severe impact on Iowan soy exports, revealing the weak positionality of local farmers within the global agri-food dependency scheme. Spending several hours in front of their computers monitoring the prices of commodities, they have the illusion that they have agency in the global market. Yet, while they produce more than one-third of the global output they are mere subjects of commodity markets set by hedgers, traders, speculators, and political opportunists. Ultimately, they can only drive their produce to the closest grain elevator with reassurance that federal subsidies will cover their losses. Occupied with trying to decipher the right choices for the upcoming cycles of production, out of an increasing amount of information, they fail to realise that their choices are not real but prescribed within a corporate pallet of commodified product bundles and that perhaps they are the

last generation of farmers able to reproduce the model of the family farm. Not surprisingly, when asked if his children would continue the family farming business, Don replied that his son was planning to set up a business that would sell the last remaining foundation of the Corn Belt farm: the soil.[71]

ENDNOTES

1 Cronon, *Nature's Metropolis: Chicago and the Great West*, 385.
2 Conversation with Don Vogel in Corning, IA, 2 July 2018.
3 United States Department of Agriculture (USDA) *Quick Stats 2.0.*
4 Bureau of Agricultural Economics, "Generalized Types of Farming in the United States: Including a list of counties in type-of-farming regions and subregions."
5 In its latest phase, it has been the "green energy" transition that has been largely driving the intensification of production across the Corn Belt. Historic data from: United States Department of Agriculture (USDA), *Quick Stats 2.0.*
6 Banerjee, "Food, Feed, Fuel: Transforming the Competition for Grains."
7 While dairy production has a reasonable efficiency rate of calorie conversion (around 40%), for poultry and pork this goes down to 10% and for beef to a mere 3%. Direct energy consumption on the farm depends upon the mechanisation of cultivation processes (such as the use of tractors, harvesters, etc.), but also storage (drying grains in grain elevators), and indirect consumption depends upon energy embodied in the chemicals, fertilisers, pesticides, and seeds, which are used as inputs (especially nitrogen fertilisers that use natural gas as the main input). See: Banerjee, "Food, Feed, Fuel: Transforming the Competition for Grains; "Cassidy, "Redefining Agricultural Yields: From Tonnes to People Nourished per Hectare."
8 Harvey, *The Limits to Capital.*
9 For an initial framing of the concept of operational landscapes, see: Katsikis, "The 'Other' Horizontal Metropolis: Landscapes of Urban Interdependence,"; Katsikis, *From Hinterland to Hinterglobe.*
10 Smith, *Uneven Development: Nature, Capital, and the Production of Space.*
11 Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital.*
12 Brenner and Katsikis. "Operational Landscapes: Hinterlands of the Capitalocene."

13 Smith, *Uneven Development: Nature, Capital, and the Production of Space.*
14 Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital.*
15 Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital.*
16 Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital.*
17 Friedmann, "World Market, State, and Family Farm: Social bases of household production in the era of wage labour."
18 See for example: Denevan, "The Pristine Myth: The Landscape of the Americas in 1492."
19 The latest glacial advance that shaped much of the topography of the Corn Belt, the Wisconsin Episode, retreated fairly recently, around 12,000–14,000 years ago. For an overview of the history of Corn Belt landforms in Iowa see: Prior, *Landforms of Iowa*.
20 Veenstra, "Fifty Years of Agricultural Soil Change in Iowa."
21 For a discussion of first and second nature in relation to the Midwest see: Cronon, *Nature's Metropolis: Chicago and the Great West*; in relation to urbanisation processes see: Luke, "Urbanism as Cyborganicity: Tracking the Materialities of the Anthropocene."
22 For a discussion of this position see: Sauer, "A Geographic Sketch of Early Man in America."
23 Hudson, *Making the Corn Belt: A Geographical History of Middle-western Agriculture.*
24 Hart, "The Middle West."
25 Hudson, *Making the Corn Belt: A Geographical History of Middle-western Agriculture.*
26 Johnson, "Gridding a National Landscape."
27 Lefebvre, *The Production of Space.*
28 For a critical overview of the role of enclosures in processes of planetary urbanisation see: Sevilla-Buitrago, "Capitalist formations of enclosure: Space and the extinction of the commons"; In the context of extended urbanisation see: Nancy Couling (this volume) and Rodrigo Castriota (this volume).
29 Hart, "The Middle West."
30 Parcels of land were sold for $2 per acre for a minimum of 640 acres in East Coast markets. When most of the Midwest was being settled, after 1820, land law allowed acquiring a minimum of 80 acres for $1.25 per acre, in 1840 a minimum of 40 acres. For a detailed discussion see: Bogue, *From Prairie to Corn Belt: Farming on the Illinois and Iowa prairies in the nineteenth century.*
31 Shannon, *The Farmer's Last Frontier: Agriculture, 11860–1897*
32 Hudson, *Making the Corn Belt: A Geographical History of Middle-western Agriculture.*
33 Cronon, *Nature's Metropolis.*
34 Cronon, *Nature's Metropolis.*
35 Sinclair, *The Jungle.*
36 Schneirov, "Thoughts on Periodizing the Gilded Age: Capital Accumulation, Society, and Politics, 1873–1898."
37 Page and Walker, "From Settlement to Fordism: The Agro-industrial Revolution in the American Midwest."
38 Hart, *The Changing Scale of American Agriculture.*
39 For example, an early Ford tractor that cost around $600 when introduced in the early 1920s, would cost around $8 per acre if harvesting an 80-acre farm, but only $4 per acre if operated on a 160-acre farm. See: Cochrane, *The Development of American Agriculture: A Historical Analysis.*
40 In 1910, there were around 1.5 million horses on farms in Iowa and 1.4 million in Illinois, and every farm could have up to 7 or 8 horses. United States Department of Agriculture (USDA), *Quick Stats 2.0.*
41 Soybeans are legumes and capture and store nitrogen in the soil, which is in heavy demand by corn plants.
42 United States Department of Agriculture (USDA), *Quick Stats 2.0.*
43 United States Department of Agriculture (USDA), *Quick Stats 2.0.*
44 Cochrane, *The Development of American Agriculture: A Historical Analysis.*
45 For a general discussion on industrial livestock production see: Weis, *The Ecological Hoofprint: The Global Burden of Industrial Livestock.*
46 Clampitt, *Midwest Maize: How Corn Shaped the US Heartland*
47 Hudson, *Making the Corn Belt: A Geographical History of Middle-western Agriculture.*
48 True, *A History of Agricultural Experimentation and Research in the United States, 1607–1925: Including a History of the United States Department of Agriculture.*
49 Hart, *The Changing Scale of American Agriculture.*
50 Even after 2010, family owned and operated farms in the US, accounted for more than 95% of all farms, operated close to 90% of all farm area, and accounted for more than 85% of all agricultural production. United States Department of Agriculture (USDA), *Quick Stats 2.0.*
51 Duffy and Johanns, *Farmland Ownership and Tenure in Iowa, 2014.*
52 Hendrickson and Heffernan, "Concentration of Agricultural Markets."
53 Lang and Heasman, *Food Wars: The Global Battle for Mouths, Minds and Markets.*
54 Hendrickson and Heffernan, "Concentration of Agricultural Markets."
55 Andersen and Pardey, "The Rise and Fall of U.S. Farm Productivity Growth, 1910–2007."
56 Bronson and Knezevic, "Big Data in Food and Agriculture."
57 Corporations such as the tractor and combine manufactures, John Deere and New Holland, are establishing control centres that collect data, monitor the tractors and combines, and could be eventually used to command fleets of driverless farming machines. See: McBratney, "Future Directions of Precision Agriculture."
58 McMichael, "A Food Regime Genealogy."
59 McMichael, "A Food Regime Genealogy."
60 Carolyn, Effland, and Conklin. *The 20th Century Transformation of US Agriculture and Farm Policy.*
61 McMichael, "Global Development and the Corporate Food Regime."
62 Carolyn, Effland, and Conklin. *The 20th Century Transformation of US Agriculture and Farm Policy.*
63 Hart, *The Changing Scale of American Agriculture.*
64 United States Department of Agriculture (USDA), *Quick Stats 2.0.*
65 Johnson, "Gridding a National Landscape."

66 Article in *Des Moines Register*, 19/9/2018: https://eu.desmoines-register.com/story/money/business/2018/09/19/tyson-foods-cherokee-iowa-plant-iowa-food-group-moves-justin-robinson-pork-beef-chicken-pro-cessing/1356962002/.

67 Friedmann, "World Market, State, and Family Farm: Social Bases of Household Production in the Era of Wage Labour."

68 See for example the Iowa State University report from 2018: https://www.ent.iastate.edu/dept/faculty/gassmann/files/page/files/2018_ent_report.pdf.

69 Patel and Moore, *A History of the World in Seven Cheap Things: A Guide to Capitalism, Nature, and the Future of the Planet*.

70 Turner et al., *Corn Belt Landscapes and Hypoxia of the Gulf of Mexico.*

71 Soil trade for landscaping, greenhouses, and even the replenishment of soil erosion has become a growing practice.

BIBLIOGRAPHY

Alston, J., M. Andersen, and P. Pardey. "The Rise and Fall of U.S. Farm Productivity Growth, 1910–2007." *Staff Paper P15–02,* St. Paul: Department of Applied Economics, University of Minnesota, 2015.

Banerjee, Arindam. "Food, Feed, Fuel: Transforming the Competition for Grains." *Development and Change* 42, no. 2 (2011): 529–557.

Bogue, Allan G. *From Prairie to Corn Belt: Farming on the Illinois and Iowa Prairies in the Nineteenth Century*. Chicago: Ivan Dee, 1963.

Brenner, Neil, and Nikos Katsikis. "Operational Landscapes: Hinterlands of the Capitalocene" *Architectural Design* 90, no. 1 (2020): 22–31.

Bronson, Kelly, and Irena Knezevic. "Big Data in Food and Agriculture." *Big Data & Society 3,* no. 1 (2016).

Bureau of Agricultural Economics, "Generalized Types of Farming in the United States: Including a List of Counties in Type-of-Farming Regions and Subregions" in *Agriculture Information Bulletin* No. 3. USDA, 1949.

Cassidy, E. S., West, P. C., Gerber, J. S., & Foley, J. A., "Redefining Agricultural Yields: From tonnes to people nourished per hectare." *Environmental Research Letters,* 83, 2013.

Clampitt, Cynthia. *Midwest Maize: How Corn Shaped the US Heartland*. Champaigne: University of Illinois Press, 2015.

Cochrane, Willard W. *The Development of American Agriculture: A Historical Analysis*. Minneapolis: University of Minnesota Press.

Cronon, William. *Nature's Metropolis: Chicago and the Great West*. WW New York: Norton & Comapny, 2009.

Denevan, William M. "The Pristine Myth: the Landscape of the Americas in 1492." *Annals of the Association of American Geographers,* 82, no. 3 (1992): 369–385.

Dimitri, Carolyn, Anne Effland, and Neilson C. Conklin. *The 20th Century Transformation of US Agriculture and Farm Policy.* USDA Report No. 1476-2016-120949, 2005.

Duffy, Michael, and Ann M. Johanns. *Farmland Ownership and Tenure in Iowa 2014*. Extension and Outreach Publications, Iowa State University, 2014.

Friedmann, Harriet. "World Market, State, and Family Farm: Social Bases of Household Production in the Era of Wage Labor." *Comparative Studies in Society and History* 20, no. 4 (1978): 545–586.

Hart, John Fraser. "The Middle West." *Annals of the Association of American Geographers* 62, no. 2 (1972): 258–282.

———.*The Changing Scale of American Agriculture*. Charlottesville: University of Virginia Press, 2003.

Harvey, David. *The Limits to capital*. London: Verso Books, 2018 (1982).

Hendrickson, Mary, and William Heffernan. *Concentration of Agricultural Markets.* Columbia, Missouri: Department of Rural Sociology, University of Missouri, 2007.

Hudson, John C. *Making the Corn Belt: A Geographical History of Middle-western Agriculture.* Bloomington: Indiana University Press, 1994.

Johnson, Hildegard. "Gridding a National Landscape." In *The Making of American Landscape. New York*, edited by Michael P. Conzen. London: Routledge, 2010, 142–161.

Katsikis, Nikos. "The 'Other' Horizontal Metropolis: Landscapes of Urban Interdependence," in *The Horizontal Metropolis Between Urbanism and Urbanization*, edited by Paola Viganò, Chiara Cavalieri, and Martina Barcelloni Corte, Berlin: Springer, 2018, 23–45.

———.*From Hinterland to Hinterglobe*. Doctoral Dissertation, Harvard GSD, 2016.

Lang, Tim, and Michael Heasman. *Food Wars: The Global Battle for Mouths, Minds and Markets.* London: Routledge, 2015.

Lefebvre, Henri. *The Production of Space*. Blackwell: Oxford, 1991.

Luke, Timothy. "Urbanism as Cyborganicity: Tracking the Materialities of the Anthropocene." *New Geographies* 6 (2015): 38–51.

McBratney, Alex, et al. "Future Directions of Precision Agriculture." *Precision Agriculture* 6, no. 1 (2005): 7–23.

McMichael, Philip. "A Food Regime Genealogy." *The Journal of Peasant Studies* 36, no. 1 (2009): 139–169.

———."Global Development and the Corporate Food Regime." *New Directions in the Sociology of Global Development.* Emerald Group Publishing Limited, 2005, 265–299.

Moore, Jason W. *Capitalism in the Web of Life: Ecology and the Accumulation of Capital*. London: Verso Books, 2015.

Page, Brian, and Richard Walker. "From Settlement to Fordism: The Agro-industrial Revolution in the American Midwest." *Economic Geography* 67, no. 4 (1991): 281–315.

Patel, Raj, and Jason W. Moore. *A History of the World in Seven Cheap Things: A Guide to Capitalism, Nature, and the Future of the Planet.* Oakland: University of California Press, 2017. Prior, Jean Cutler. *Landforms of Iowa*. Iowa: University University of Iowa Press, 1991.

Sauer, Carl O. "A Geographic Sketch of Early Man in America." *Geographical Review* 34, no. 4 (1944): 529–573.

Schneirov, Richard. "Thoughts on Periodizing the Gilded Age: Capital Accumulation, Society, and Politics, 1873–1898." *The Journal of the Gilded Age and Progressive Era* 5, no. 3 (2006): 189–224.

Sevilla Buitrago, Alvaro. "Capitalist Formations of Enclosure: Space and the Extinction of the Commons." *Antipode* 47, 4 (2015): 999–1020.

Shannon, Fred A. *The Farmer's Last Frontier: Agriculture, 1860–1897.* Routledge, 2017.

Smith, Neil. *Uneven Development: Nature, Capital, and the Production of Space.* Athens, GA: University of Georgia Press, 2010.

Sinclair, Upton. *The Jungle.* Create Space Independent Publishing Platform, 2014 (1906).

True, Alfred Charles. *A History of Agricultural Experimentation and Research in the United States, 1607–1925: Including a History of the United States Department of Agriculture*. US Department of Agriculture, 1937.

United States Department of Agriculture (USDA), *Quick Stats 2.0.* U.S. Department of Agriculture, National Agricultural Statistics Service, Washington D.C. https://quickstats.nass.usda.gov/

Veenstra, Jessica. *Fifty Years of Agricultural Soil Change in Iowa*. Doctoral Dissertation, Iowa State University, 2010.

Weis, Tony. *The Ecological Hoofprint: The Global Burden of Industrial Livestock*. London: Zed., 2013.

IMAGE CREDITS

All photography from author unless otherwise stated.

All maps from Philippe Rekacewicz with author unless otherwise stated.

F. 1 Bureau of Agricultural Economics. "Generalized Types of farming in the United States: including a list of counties in type-of-farming regions and subregions." In: Elliot, F.F. (Ed.), *Agriculture Information Bulletin* No. 3. USDA, 1950.

F. 2 Cassidy, E. S., West, P. C., Gerber, J. S., & Foley, J. A. (2013). "Redefining agricultural yields: from tonnes to people nourished per hectare." *Environmental Research Letters, 8*(3), 34015.

F. 3 Bureau of Agricultural Economics, "Generalized Types of farming in the United States: including a list of counties in type-of-farming regions and subregions." *Agriculture Information Bulletin* No. 3. USDA, 1949.

F. 5 USDA National Agricultural Statistics Service, USDA-NASS, Washington, DC: USDA Cropland Data Layer, USDA 2017; Agricultural Atlas of the United States; USGS The National Map: National Boundaries Dataset, Geographic Names Information System, National Structures Dataset, and National Transportation Dataset; United States Environmental Protection Agency, ECHO Detailed Facility Report.

F. 6 USDA National Agricultural Statistics Service. NASS – Quick Stats, 2017.

F. 7 Atlas of Marion County, Iowa, 1901. Iowa University Libraries Digital Library

F. 8 Cao, P., Lu, C., and Yu, Z.: "Historical nitrogen fertilizer use in agricultural ecosystems of the contiguous United States during 1850–2015: application rate, timing, and fertilizer types." Earth Syst. Sci. Data, 10, 969–984,

F. 9 USDA National Agricultural Statistics Service NASS – Quick Stats, 2017.

F. 10 USDA National Agricultural Statistics Service NASS – Quick Stats, 2017.

F. 11 USDA National Agricultural Statistics Service, USDA-NASS, Washington, DC: USDA Cropland Data Layer, 2018.

F. 13 USDA National Agricultural Statistics Service, USDA-NASS, Washington, DC: USDA Cropland Data Layer, 2018; USGS The National Map: National Boundaries Dataset, National Transportation Dataset; United States Environmental Protection Agency, ECHO Detailed Facility Report; Iowa Geodata portal, State of Iowa Office of the Chief Information Officer; Iowa DOT open geodata portal, Iowa Department of Transportation.

F. 14 USDA National Agricultural Statistics Service, USDA-NASS, Washington, DC: USDA Cropland Data Layer, 2018; USGS The National Map: National Boundaries Dataset, National Transportation Dataset; United States Environmental Protection Agency, ECHO Detailed Facility Report; Iowa Geodata portal, State of Iowa Office of the Chief Information Officer; Iowa DOT open geodata portal, Iowa Department of Transportation.

F. 19 A. T. (Alfred Theodore), 1839–1900, Rumsey Collection

F. 20 U.S. Census Bureau, Population Division: County Population in Iowa by Year.

F. 21 Iowa Geodata portal, State of Iowa Office of the Chief Information Officer and Iowa Department of Education.