black mold

Like-minded nogoodniks seeking out and publishing political work as they see fit.

Winter
2024

Early in 2022 we were contacted by a friend of a friend of a colleague of a neighbor named Will. Will works on a market garden in the American Midwest and spends what little free time he has researching technical systems from agriculture to industrial production and how they would need to adapt to fit an ecological communist society. What follows is one of his lengthy letters to us at black mold published here under the name *Agriculture, Industry and Communist Society*. It is conversational in tone, and, to us, one of the most impressive and all-encompassing pieces of writing we have ever come across.

Enjoy,

the black mold editorial team

AGRICULTURE, INDUSTRY AND COMMUNIST SOCIETY

To black mold,

I didn't really talk much about food systems in the email I sent you a couple months ago, and I am trying to develop an agricultural system, so I guess I'll start there. The most developed part of that aspect of the project consists of the area of agriculture I'm directly involved in day to day, which is annual vegetable and fruit production, and to a lesser extent perennial crops like berries and asparagus. That's a major focus partly because that's what I know the best, but it's also one of the most inherently complex areas of agriculture because you're dealing with a very large variety of crops and they tend to have higher soil quality, nutrient and water requirements. Most of these plants also don't lend themselves well to mechanization, and those that are well suited to mechanical harvesting tend to only be worth growing that way in very specific areas with just the right soil and environmental conditions. They also vary in how long they can be stored, the conditions they need to be stored in vary widely, many of them are highly perishable or are only useful as food at specific stages of ripeness that are fleeting, like tomatoes.

I. MODELLING THE MARKET GARDEN

The methods I'm focusing on come from the market gardening tradition, which I think is a good tradition, but that means the systems I'm working on are very limited in scope. Where I am at least in the US, these systems, or later variations on them, are very much dominant in the industry, and the local organic area of production is where you see methods being used that are the closest to historical market gardening methods of growing. This particular style of gardening reached its height of development during the mid 1800s to early 1900s due to the readily available horse manure from the cities and the need to make extremely compact vegetable production systems to utilize expensive growing lands close to the rapidly developing cities of Europe and the US, though I'm sure systems very much like these existed throughout the rest of the world as well at the time. These were predominantly bed systems that were designed to be as space efficient as possible with paths between beds that are extremely narrow, sometimes so narrow you can barely work in them, with very tight successions of crops in each bed that had to fit into the narrow planting and harvesting time frames typical of temperate environments.

There were also a lot of interesting trellising systems developed around this time that were incorporated into these gardens, sometimes including espaliered fruit trees trained along curved brickwork systems derived from the walled gardens of the wealthy. To retain more of the heat absorbed during the day by these brick walls they began enclosing them on the sunny side with glass, even including coal fired heating systems built into the walls. This eventually led to actual glass greenhouses that were coal heated or utilizing elaborate steam heating systems. This was also the period when a lot of the familiar heirloom varieties were developed, or the foundations for plant breeds that became widespread later on. Varieties started being developed specifically for these heated greenhouses or for complicated early forcing systems for crops like melons. Kropotkin's writing is full of descriptions of growing systems like this, that were really cutting edge at the time. By the late 1800s these systems were beginning to be perfected, and combined with improved breeding methods, they were doing some very impressive things considering the limited technology they were working with at the time. Of course, once horsepower became replaced by the internal combustion engine, all of this soon changed, the cheap supply of manure dried up and vegetable production shifted towards the large scale systems made possible by tractor power, and post WW1, by the Haber-Bosch process that allowed for large scale ammonia synthesis.

The modern variants of these systems, that are typical of the current state of organic market gardens like the one I work at, are highly simplified compared to the historical systems. To reduce the labor required for weeding, and to warm the beds for earlier crops, black plastic "mulch" is laid down by tractors after the rows are formed and plants are transplanted into holes in this plastic. This isn't possible for all crops, those that require direct seeding like carrots must be grown in exposed beds, but it's general practice for the majority of bed systems that you will find in market gardens throughout the US. When this system is used, you are basically forced to use drip irrigation, which is placed over the top of the beds beneath the plastic. These drip irrigation lines need to be set up every year because if they are left out during winter the water in them will freeze and destroy them. These systems constantly leak in random places and need to be repaired and are very prone to getting holes cut in them when doing hand weeding. They tend to use one standard width of 30 inches for these beds, because that's the size almost all of the machinery is made for, and it's narrow enough to step over them in the field and to reach to the center of the beds when working in them. This allows for a field to be subdivided into 4-foot wide sections by using 18-inch wide walkways. The beds are generally at least 50 feet long, but often are 120 feet in length in the larger gardens because this allows a square one-hectare plot to contain two fields of beds with enough space between them for vehicles to maneuver.

Every year in the spring we reform these beds with a tractor, lay out the plastic mulch and set up irrigation lines, then in the fall this plastic must be taken back off by hand, which inevitably tears into a thousand tiny pieces that get lost in the field, the irrigation lines taken down and stored, then the field is plowed with a tractor and a cover crop is planted. Whatever beneficial effects this cover crop might supply in terms of organic matter contribution is surely negated by the constant plowing that's necessary to maintain this style of gardening, which burns up the organic matter by exposing it to oxygen. We almost exclusively fertilize these beds using nothing but chicken manure, because it is extremely concentrated so less needs to be moved in terms of weight, and it is cheap to buy from confined animal feeding operations, compost being deemed uneconomical to use because of the large quantities required and the labor involved in placing it in the beds. This chicken manure is simply scattered on top of the beds, not incorporated into the soil as should be done, so a large amount of the nitrogen is lost to the air because it is rapidly volatilized into ammonia gas. Most of the nitrogen that remains will not be available to the crop, because it takes time for it to break down in the soil, so when these beds are plowed down at the end of the year this nitrogen is scattered throughout the field, inevitably feeding the weeds that quickly overtake the walkways that are conveniently too narrow to effectively be mowed.

The only way around this situation is essentially to use a permanent bed system, that is set up once and never plowed down, so that the organic fertilizers that are added remain in the soil for crops in the following years and organic matter can remain in the beds and not be mixed into the rest of the soil in the field. Applying a plastic mulch over this then becomes rather impractical, because it must be buried on either side of the bed with soil and that requires reforming the bed itself. This limits you to basically having an exposed surface that will need to be weeded using hand tools, or if it gets out of control, by hand with a knife. This is essentially how these systems had always been done, weeding being assumed to be an inherent feature of vegetable and fruit gardening. Drip irrigation can then be abandoned in this system and replaced with sprinkler irrigation systems that use more water but are the only practical way to irrigate in an open field setting, though drip irrigation remains the only practical option when growing inside a greenhouse or where water is scarce.

To effectively manage weeds in a system like this, a wire hoe must be used until the crop develops enough to form a complete canopy over the soil, and this is pulled across the entire surface of all the beds regularly to kill weeds while they are still in the seedling stage. Once the crop forms a canopy, the weeds are effectively kept under control with only periodic maintenance. Now systems may differ in terms of what soil amendments are added to these beds and how they are incorporated, but I do think this is the general structure that's required if you are trying to establish a system of vegetable growing that's based on the market gardening bed systems. A good example of this kind of system being used would be Conner Crickmore's garden, though he has the advantage of working in well-draining sandy soils that are easier to work by hand.

Open field systems such as these can be very productive, especially in places with fairly regular mild weather and long cool seasons like in regions near the coast or by large lakes. Once you move into the interior of a continent, where I am, or into higher latitudes or altitudes, the weather becomes more extreme and unpredictable, there is less rainfall and you are working in harsher conditions unfavorable for vegetable and fruit production. Season extension systems become more important in areas like this to have a reliable crop at all, and many crops may only be possible by using these methods. The open field may still give enough yields year to year to make them worth maintaining, but the range of crops that will perform well in them will be more restricted. Working under cover brings with it its own set of problems, crop rotation becomes more difficult to achieve due to limited space, salt build up becomes an issue because rain isn't reaching the soil and leaching the salts out, a good understanding of ventilation is essential for temperature control and to prevent stagnant air that promotes fungal disease, and drainage systems need to be well thought out to move water away from the structure because rainfall is diverted to the perimeter of a greenhouse. Even in a location that allows nothing but open field systems to be used, a market garden style system still needs at a minimum some sort of greenhouse to serve as a propagation house for seed starting and to raise seedlings to be used in transplanting.

A hoophouse is the most common kind of greenhouse used in a market gardening system, it's a simple structure made of galvanized steel piping that form arches that are usually spaced four feet apart to form a half cylinder, though a pointed roof made from gothic arches is also common, especially in areas with higher snow loads. Several of these placed side by side to form a larger structure, with gutters to remove the water that collects between the ridges gives you what's called a gutter connected system, and if the structure is to be heated at all this is a far superior structure. Any stationary greenhouse should really be a gutter connected greenhouse and the only reason you would use a hoophouse is if you lack the capital to construct a gutter connected greenhouse. The only real exception to this is the sort of moveable hoophouses that Eliot Coleman experiments with, because they can overcome many of the inherent disadvantages of the stationary hoophouse and they allow for many interesting crop rotation systems that aren't possible otherwise. I won't go into the details of those systems here, but they play a large role in the systems I'm trying to develop and although they are still highly experimental, I think they are worth pursuing further.

Now that's just a very general overview of the sort of system I am actively trying to understand and work with. There are all kinds of interesting alternative systems that people are working on, and I am sure these can have advantages over the one I am trying to develop. Without working with those systems though, I can't really have any informed opinions on them, especially if they are systems designed for tropical environments, which are inherently very different from those in temperate environments that I live in. I do think that any temperate vegetable gardening system meant to be used for commercial production should be directly compared to a market gardening system to assess its feasibility and possible advantages, because that is the system it would be competing with in the market. Home or very small-scale gardening is a totally different kind of system, and there are all kinds of reasons that labor productivity or yield per area of land would not be prioritized when designing a system like that. Even large-scale systems that are meant to operate independently of a market or at a greatly reduced level of technical complexity have totally different design requirements and I can see all kinds of possible reasons other kinds of growing systems may have real advantages on a societal level. A large amount of world agricultural production is still oxen or water buffalo powered, because it is a system that fundamentally works, and that will continue working regardless of any later developments.

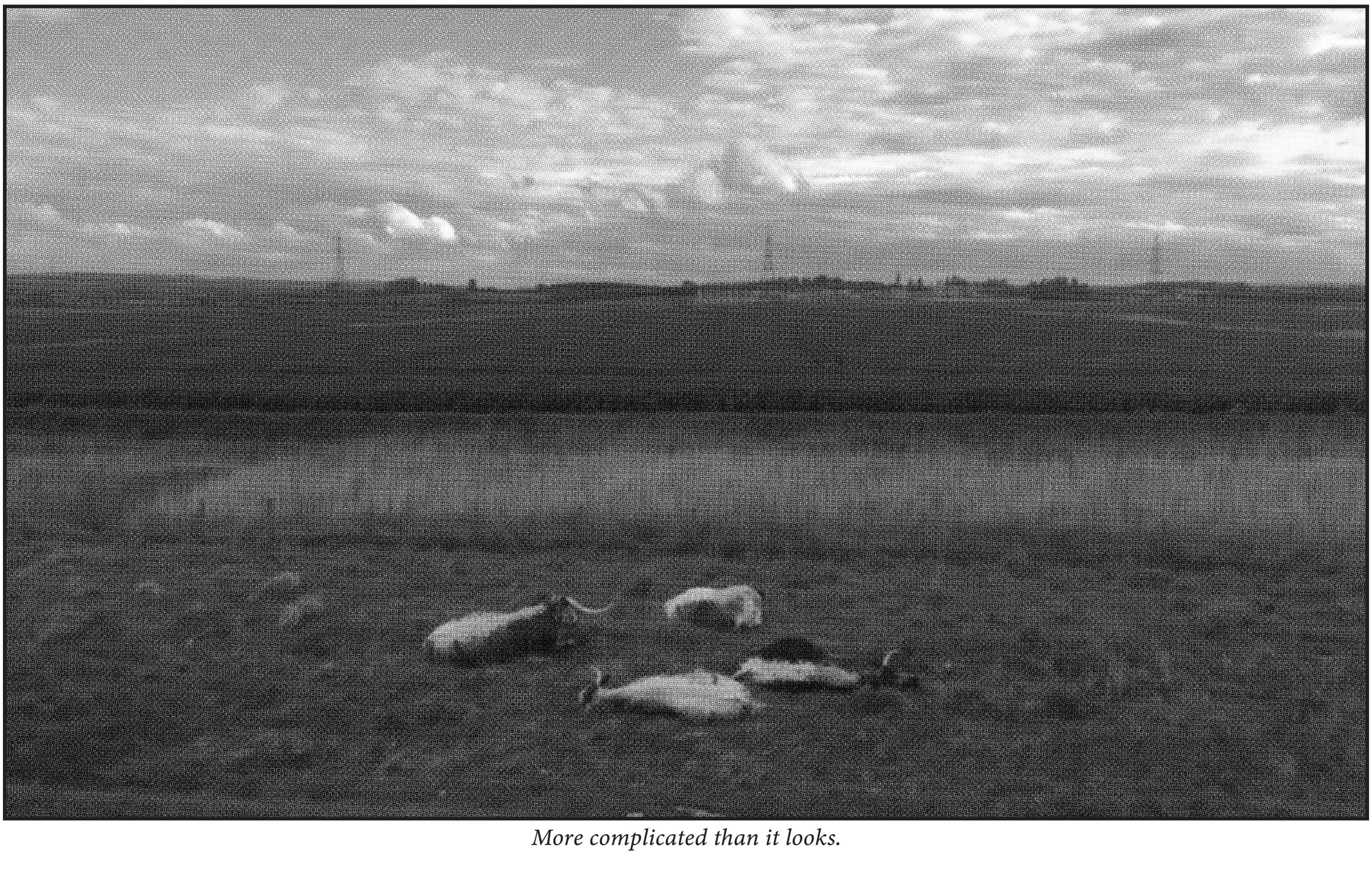
II. SOIL CHEMISTRY

Annual vegetable and fruit production is, however, only one small part of a much larger agricultural system, and in an organic based system it relies on other cropping systems for its primary physical inputs to maintain fertility, like sources of biomass for producing compost or concentrated sources of plant nutrients like manure. If these inputs are moved off of other fields to sustain the more resource intensive system of gardening, that puts pressure on these larger less complex systems in terms of maintaining organic matter and soil nutrient levels in the soil. Organic matter and nitrogen can be regenerated in these fields through biosynthetic processes, but there are still limits to the rate these processes occur that are influenced by environmental conditions like air temperature, soil properties, or precipitation patterns. All soil nutrients other than nitrogen, most importantly phosphorus and potassium, must in some way be returned to those fields to maintain an equilibrium that allows their soils to remain fertile. There is a lot that can be done as far as nutrient recycling goes, there are sewage systems that can effectively recycle wastewater back into the water supply and retrieve a lot of these nutrients, but the entire stormwater system would need to be fundamentally redesigned for this to be practical. It would be very difficult on a societal level to avoid some degree of phosphate and potassium mining to maintain soil fertility overall, but it could surely be greatly reduced.

When phosphorus and potassium are added to soils, they become bound to soil solids by electromagnetic forces, and this combined with their limited solubility in water compared to nitrogen means that only a small fraction of the available phosphorus and potassium is accessible to plants during a growing season. As these nutrients are taken up by plants, the concentration of dissolved nutrients drops, and this changes the chemical equilibrium allowing for more of the nutrients that are bound to soil particles to dissolve into the water and become accessible. The rate of this process is also influenced by factors other than plant uptake, like temperature, chemical weathering processes, microbial and mycelial interactions, and soil pH, and isn't completely understood. Due to this complex process, it takes phosphorus about 20 years to fully cycle through the system once added and potassium requires about 10 years, so maintaining the levels of these nutrients in a soil profile is much different than maintaining nitrogen levels. This is a bit different in areas with high rainfall levels and sandy soils, like much of Florida, there the soil has much less capacity to hold onto nutrients and rates of nutrient leaching are much higher due to more water flowing through, so added phosphorus and potassium have a much shorter cycle time, though they are also absorbed more quickly due to more rapid growth possible at higher temperatures.

Organic sources of nitrogen will release about 50% of their nitrogen content to plants in a growing season and about 25% in the following year, and this is mostly limited by the rate of decomposition processes that are driven by microbial activity. Microbial processes are strongly influenced by temperature and available water, and it's for this reason that organic systems are much harder to develop in temperate regions than in tropical regions, because of generally lower temperatures with more seasonality and lower levels of precipitation. Once the carbon compounds the nitrogen is bound to are broken down, it becomes immediately available to plants due to its high solubility, though it then becomes prone to leaching out of the rootzone and entering the groundwater. Due to these underlying differences in solubility and how they interact with the cation exchange capacity of soil solids, nitrogen fertilization rates are established based on the expected nitrogen requirements of the next crop to be planted, while phosphorus and potassium sources are applied with the goal of building up their levels in the soil gradually to a specific parts per million range and then maintaining them within this range.

Once these potassium and phosphorus levels are adequate, you can begin applying them at the expected crop removal rates to keep their levels in a state of equilibrium. This underlying strategy remains the same regardless of the source of these nutrients, but it becomes much more complex when the sources of these nutrients are organisms or the byproducts of organisms. These are of course not the only nutrients that need to be accounted for, but it's easier to supply the rest of the plant nutrients because they are needed in much smaller quantities, and the same basic principles described previously also apply to these micronutrients. One of the main problems with trying to achieve this with chemical fertilizers is that without sufficient organic matter in the soil to act as substrate for microbial life you get a reduced crop response for a given application rate. They also tend to be highly soluble forms of these minerals, to maximize plant availability, though they will be quickly bound to soil solids anyway. Their solubility makes them prone to leaching and moving below the rootzone and into groundwater or being carried along the soil surface by runoff. Through either pathway they can migrate into surface water and phosphorus and nitrogen, in particular, will lead to eutrophication of surface water by increasing available nutrients leading to algal blooms and



More complicated than it looks.

anoxic conditions, destroying freshwater ecological systems and potentially contaminating drinking water, or at least making it more difficult for treatment plants to purify it.

To maintain soil carbon, you need rest periods where biomass can be generated to allow it to accumulate, and this reduces the area available for row crops. These rest periods could just be allowing a field to go fallow, but often some kind of short-term cover crop is planted to make use of gaps in the crop rotation. This is better than nothing, but if you want to maintain very high levels of soil carbon, you'll plant some kind of perennial crop or mixture of them, especially deep-rooted legumes like alfalfa or red clover that can send roots deep down into the subsoil and can bring nutrients there back up to the surface. This also has the effect of giving the chemical processes I was describing time to transfer soil nutrients into this biomass where they are retained and gradually released as decomposition progresses. Obviously, soil disturbance in the form of plowing or digging will burn up this soil carbon, so this should be minimized, but if you want to exclude or reduce the use of herbicides in row crop farming, it's going to be hard to do that without some degree of soil disturbance. Most no till methods rely heavily on herbicide application, though there are people trying to develop things like roller crimpers to get around this problem. Herbicide termination of a cover crop or previous planting will make it much easier to preserve soil carbon levels, but you are then accelerating the evolutionary rate of herbicide resistant trait development in weed populations, with obvious long term negative consequences.

These physical processes must be taken into account when trying to design any agricultural system that prioritizes long term sustainability, and they can only be fully accounted for by viewing agriculture as a whole from a systems theory perspective. For this reason, something like annual vegetable and fruit production can't be considered in isolation from the systems that generate the inputs that are required for their continued operation, they are properly one interconnected system and system interactions need to be well understood if the entire system is to be kept in a state of homeostasis. At the same time, there is not one possible stable state this system can exist in, there may be an infinite number of possible system configurations for a specific environment that can reach a homeostatic state. Soil nutrient cycling is just one component of this, the spread and buildup of plant diseases, pest and weed populations, biotic interactions of the system with the local ecology, along with many other considerations need to be all simultaneously regulated and kept in balance by management decisions. The very act of imposing on an area of land an alternative stable state and maintaining that state itself has ecological consequences, because niche space is being occupied by domesticate populations and is no longer available to the local biota.

III. THEORIZING A COMMUNAL AGRICULTURAL INFORMATION SYSTEM

What's needed is a general theory that can be applied to any such system that can allow us to develop an understanding of the fundamental underlying processes at work and a method of data collection that will allow us to compare our models to the actual behavior of the system so that errors in our theoretical understanding can be identified and our general theory can be continuously developed. Data collection may only be possible within a specific system of agriculture, but our goal is to use a particular system to tease out the fundamental processes that are at work within all possible systems in general. This constitutes the mathematical and computer modeling aspect of the project. I want to put together a general overview of the mathematical models that have been developed and how they can be combined to construct a representation of these physical systems. Abstractions of this kind aren't sufficient, but they can be powerful tools to guide our decisions and to allow us to consider features of the system that may not be apparent from our day to day surface level observations. We can't know the relative merits of specific agricultural methodologies without physically performing them, and even then, we are only trying to establish how they behave in specific regional contexts.

This regional nature of the systems we are dealing with does not prevent, however, a general understanding of how the environmental conditions of a geographical area influence the behavior of agricultural systems. Data collected from specific areas simply informs a still higher level of this general theoretical system of agriculture, that incorporates the discipline of biogeography into itself and grounds the entire theory in material reality by constructing a spatial representation of the physical world. This constitutes another major aspect of the project, using the theoretical framework of the Hutchinsonian niche space combined with the concept of the discrete global grid to organize data collected throughout the world into a unified geographic information system that can incorporate all agricultural systems into the ecological modeling systems currently being assembled by biogeographers. Actually constructing this would be a worldwide effort on a massive scale, that would be well beyond the abilities of any small group of people to accomplish. I just want to draw attention to the fact that these systems are being actively developed and at least on a conceptual level this is an important ecological theory that should inform our understanding of agricultural systems generally. Even with very rudimentary and incomplete datasets this theory has important applications to agricultural planning and would be essential for constructing a global scale representation of the environmental system.

I'd like to at least briefly describe this theory and what an information system like this would consist of, because it's what allows vector space representations of environmental conditions to be applied to all of agriculture and ecology. This information system contains within it, a representation of the entire surface of the earth, anchoring the entire modeling system in physical space and allowing all of the other vector space modeling systems to include within them information about their spatial position. This system allows these vector space representations to not merely describe the interactions between systems and balance their inputs and outputs, by including geospatial data they can be transformed into a true spatio-temporal model of the entire logistics system. By doing so, all of the data gathered from all operations can be brought together into one interconnected modeling system that can be updated in real time, unifying the entire vector space representation system. This shared and well-defined spatial coordinate system is essential for developing a mathematical model of an economy that can go beyond simple system scaling and proportionality optimization. By establishing the relative positions of system elements, graph theory based representations of the economy can incorporate distance measurements that allow for more nuanced system descriptions such as representing supply chains as multicommodity flow networks.

To establish this shared geographic coordinate system, the surface of Earth is divided into a grid of non-overlapping regions, where each region is called a cell and each cell is represented as a point in a nearly spherical coordinate plane. Any polygon that tiles the plane can form the grid, but typically grid squares made by subdividing longitude and latitude lines are used so that cell boundaries correspond to a standard geographic coordinate system such as WGS84 that is used by GPS. This system has several drawbacks, the cells become smaller and more distorted in shape as you approach the poles, so they don't have equal areas, creating an irregular grid tiling. To overcome these problems, many alternative global grid systems have been developed that tile the plane using other shapes like triangles or hexagons to create a more regular tiling where the grid cells have equal or at least more equal areas.

Regardless of the particular method used for space partitioning, the overall goal is to create what is called a discrete global grid, or DGG, so that any location in physical geographic space can be correlated with a specific region in a mathematical model of geographic space. This forms a mathematical foundation for a geospatial database that can describe the location or distribution of objects in space, the physical characteristics of a region of geographic space and how these change over time. The discrete global grid essentially defines the geographic coordinate plane by partitioning the physical world into regions, these regions are abstracted as discrete points in a coordinate plane and are identified by some kind of geocode system, such as an alphanumeric code. This coordinate in space can then be correlated with attributes, like local physical conditions or the presence or absence of an object by using a spatial indexing system.

In Hutchinsonian ecological niche theory, or at least the way the theory is applied when constructing ecological niche models, the physical space this discrete global grid system is representing is called geographical space, or G-space, and this corresponds to the actual coordinate plane itself. Any species, including all agriculturally significant species, can occupy a specific area in geographical space called its biogeographic range, biogeography just being a branch of biology that tries to understand where things live and what factors influence where things can live. One aspect of the environment that influences where things can live are abiotic environmental variables, the material conditions of an area that aren't biologically determined but are due to geographic variation in climate or geological formations, so things like latitudinal temperature gradients, precipitation levels and seasonal variations in precipitation patterns, the topology of the landscape, or light intensity and its seasonal variation.

Abiotic environmental factors like these are thought of as dimensions of a mathematical vector space, with a species possessing a physiological range of tolerances to these conditions that limits where the species can live within this space. The set of positions within this vector space that fall within the tolerance range of the species is described as a hypervolume in n-dimensional space. By taking local measurements of these abiotic environmental variables and correlating them with grid cells in geographical space using a spatial index, these grid cells become points in this n-dimensional vector space. If the biogeographic range of a species is mapped out, the grid cells can include presence absence data for the species, they are given a value of 1 if they are included in the biogeographic range and a value of 0 if they are not. The grid cells where the species is present, as points in this n-dimensional hyperspace, are points within this hypervolume and can approximate the abiotic tolerance range of the species or populations within a species.

Those grid cells where the species is present as seen on a map of geographical space, represent the realized niche of that species, that area of niche space where the species actually lives. It's important to understand in Hutchinsonian ecological niche theory, the niche is something sort of possessed by the species, which is different from niche concepts like the Eltonian niche where a niche is conceived of as an ecological role that might be occupied by several species. Returning to the n-dimensional hyperspace, all of the grid cells occupying points inside of this hypervolume, including those where the species is absent, can then be projected back onto geographical space and this produces a map of where the species could live given its abiotic tolerance range, if it could get there and biotic interactions it requires to live there are present, and this is called its fundamental niche, the area where it can live.

In this theoretical framework, an ecological community results from the overlapping of different species' biogeographic ranges, which is possible because their fundamental niches overlap and their historical dispersal allowed them to occupy the same area. By studying trophic interactions within these communities, you can then develop an understanding of the biotic interactions each species requires to be able to persist in an area, or how biotic interactions may restrict biogeographic ranges. Biotic interactions are much more difficult to quantify and represent as dimensions in a vector space, so these are often just completely ignored in ecological niche modeling, but trying to find ways of incorporating biotic interactions into these models by using mathematical models from population and community ecology is an active area of research. A model that just includes abiotic factors is still very useful, these describe plant distributions and rate of growth quite well and this has obvious implications for the possible distribution of agricultural crops. In that context, overlapping crop niche spaces in a locality form the basis for possible crop rotation sequences.

I've attached three different papers (*EDITOR'S NOTE: These papers are available via request from blackmoldpress@proton.me*), that I really encourage you to read, that describe these ideas in more depth than I can do here. "Hutchinson's Duality: The Once and Future Niche" is an excellent introduction to the basic ideas of Hutchinsonian ecological theory and describes some of its potential applications. "Niches and Distributional Areas: Concepts, Methods, and Assumptions" is a paper on ecological niche modeling and gives a very good overview of the fundamental ideas involved as well as an especially clear visualization of the sort of map projections I described earlier. "Agriculture Biogeography: An Emerging Discipline in Search of a Conceptual Framework" provides an overview of the potential applications of biogeographical theory to agriculture specifically and is one of the only texts I've found that argues for incorporating these ideas into agroecological theory. These are really central ideas in modern ecological theory and they have far reaching influence in a wide variety of other fields.

I first learned about Hutchinsonian niche theory through paleontology because it's very important for palaeoecological reconstructions, a field that is unfortunately often overlooked by modern ecology creating significant theoretical blind spots. Evolutionary theory is of course intimately linked to the fossil record and its study, and ecological thought needs to be informed by the study of palaeoecology, otherwise it only has access to what is essentially just a snapshot of evolutionary history. For example, we only know mass extinctions are even possible as a result of palaeontological investigations of the fossil record, this information provides us vital information about the potential causes of mass extinctions in the past. Background extinction rates are derived directly from the fossil record and can be compared to current rates of extinction, that is fundamentally how we know that we are currently causing a mass extinction event to develop, not at some point in the future as a result of climate change, but in the present. Climate change is not the only source of ecological destabilization we need to be concerned with, even if that was not a factor, we would still be creating the conditions for a mass extinction level event at present as a result of our interactions in general with the global ecological system.

To add rapid climate change to this situation dramatically increases the likelihood of this mass extinction becoming exponentially more severe than it would otherwise be. To get an idea of how bad a mass extinction event can become, consider that during the end Permian mass extinction event about 95% of marine species and 75% of terrestrial species were driven to extinction. So, it might be a good idea to take theories from paleontology into account as well as mainstream ecological thought when we are evaluating the sustainability of productive systems. It almost certainly won't become quite as bad as that, the end Permian involved part of the mantle literally breaking through the crust and raising CO_2 levels up to about 8000 ppm, nearly ending all life on earth, but if methane clathrates do end up becoming destabilized, it could get pretty bad. Hutchinsonian niche modeling is used a lot in paleontology to reconstruct ancient ecosystems, but it also is directly relevant to the modern climate crisis because it can be used to predict how different simulated future climate scenarios might affect the ecosystem or species ranges as well as future crop distributions and yields.

This description of biogeography and the Hutchinsonian niche space provides the theoretical background for the next aspect of the project, the division of geographical space into ecoregions to make sense of the spatial distribution of agricultural production, using the US as an example because that's the region I'm most familiar with. Obviously, this same sort of thing would need to be done globally to create a global representation of all agricultural regions. The EPA has divided Canada, the US and Mexico into geographical regions using a hierarchical system of classification consisting of four levels of resolution, where each division is meant to identify areas with relatively similar environmental conditions and ecosystems. This was based on a system devised by Omernik that builds on the traditional classification scheme of biomes based on plant communities by incorporating other geographical elements as well, such as an area's geology, landforms, soil types, climate and land use patterns. The Level III ecoregions correspond closely with the primary agricultural lands of the US, partly because land use patterns are a factor determining the ecoregion divisions, and these are each further subdivided into Level IV ecoregions that show local variations within these areas.

Thirty-seven of these ecoregions represent the majority of agricultural growing lands of the US and these can be somewhat arbitrarily grouped into seven major divisions that I'm calling, The Western US, The Southwestern US, The Northern Great Plains, The Southern Great Plains, The Great Lakes Region, The Mississippi River, and The Southeastern US. What I'm mostly working on right now is trying to assemble maps of these ecoregions that contain state and county divisions and trying to combine this with the available county level agricultural data so I can map out the distribution of the major crop types throughout the country. There is unfortunately a surprising lack of this information, but I'd like to at least get a general idea of what information is available. What I'd like to do is then use this information to model agricultural communities in each of these areas with agricultural systems and crop rotations that are somewhat realistic for the region. At first, these just consist of drawings representing reasonable proportions of subsystems and an arrangement that is convenient for moving objects from place to place, while being somewhat walkable. Eventually, I want to create mathematical models of these subsystems that are linked together to model system interactions. I can then get a better idea of how communities located in different parts of the country would need to interact to provide themselves with a relatively complete supply of agricultural crops and how that would fluctuate seasonally.

Another major part of this whole project is identifying what these crops are, and what a complete list of the agricultural crops that can be grown in the US would look like. So, I am trying to organize all of the cultivated plants by their common and species names and then group these together by their taxonomic family and genus. Whatever phylogenetic information I can find is then included to describe these groups as clades along with any information about when these species or intraspecies breeding groups diverged. This is then combined with information about common pests and fungal and bacterial disease susceptibility to try to see if these correspond to phylogenetic groups. What I'd then like to do is include information on historical varieties, when they were developed and from what lineages and include phylogenetic analyses of current varieties, though this information often doesn't exist yet. These are again grouped into agricultural categories like cereal and pseudocereal grains, oilseed crops, pulses, annual vegetables, nut trees, fruit trees, etc., according to the specific agricultural systems they are a part of along with information about the mechanical systems that are used to grow, harvest and store them. Alongside this, domesticated animals and cultivated mushrooms and other fungi are treated in a similar way, though these would be described in their own separate system descriptions.

IV. CONSTRUCTING THE COMMUNE

I'll try to include in this a photograph of the sort of thing I mean, this is an old drawing (*EDITOR'S NOTE: See pages 14-15 for basic commune layout)*, but it gives at least an idea of what I'm talking about. This represents the smallest system I consider practical, where you can adequately contain all the fundamental systems of cultivation in one integrated system. This assumes a totally flat land, something like what you might find in Iowa, with access to groundwater, good soils and a climate that can support most varieties of vegetables and fruit. The bold lines represent roads, it's divided into four quadrants, each a full section measuring one mile by one mile, so the entire system is contained in four square miles. The layout itself is arbitrary, it's just a geometric pattern that is convenient to organize it with the best possible pathing. A real landscape might contain areas unsuitable for cultivation, but this represents a best-case scenario, where the entire area is arable and continuous. This was made to get a general feel for the relative proportions of each system, using realistic practical scales of cultivation for each of the fundamental systems, and to get an idea of the population density that's reasonable in such a system. Just to be clear, this is in no way a proposal for something to be built, though if it was built it probably would work pretty well. It is an abstract model of a fully integrated agricultural system with a contained community and it serves as a beginning point from which abstract mathematical models can be constructed so I can daisy chain mathematical descriptions of subsystems together to formally represent their interactions.

Ley farming: the cow eats, it poops, it moves onto another field...everyone's happy.

So, this entire thing has been drawn to scale, each system it contains has been scaled so that it fits within the system of land surveying that was adopted in many of the growing lands here, called the public land surveying system. This is so they can fit inside of the established road networks and the property divisions as they exist in most of the country. This is where you get your fundamental property divisions, the full section containing 640 acres, the quarter section of 160 acres, 40-acre plots are these divided into four, 10-acre plots are these divided into four again, and then finally another quartering gives you your one hectare plots of 2.5 acres. A hectare measures 330 feet on each side, for reference each grid square in this drawing represents a quarter hectare, 165 feet by 165 feet. These are divisions of survey townships containing 36 square miles measuring 6 miles by 6 miles. The land didn't start out that way, that was something that was done to it.
I don't know how well you'll be able to make all this out, but in the center, you have a circle of squares that represents a housing area loosely based on the euroblock system, able to comfortably house about 1000 people. Each square sits on a hectare of land and each housing unit contains four L shaped buildings, that each contain four two story connected houses, with paths between them leading to a central courtyard. In their corners, there are unoccupied buildings for community spaces, things like libraries or community sewing rooms, corner shops, that sort of thing. These houses have complete floorplans made for them and are all totally identical, they represent what I see as the practical size limit of a family home. They contain four bedrooms, one on ground level, each with en suite bathrooms to give some degree of basic privacy so that they can be initially used as coliving housing while the entire community is being built up. Eventually, I want to make detailed drawings of their framing systems and from this give a full account of the actual lumber and construction materials along with all of the objects they contain inside. This is so I can get a general idea of the requirements for domestic production and the raw material supply for housing.

This is about the 50th iteration of the commune map and stopped there because I couldn't manage to improve on it. There are still some problems with it, the ground level living room is a bit cramped, but that's about as developed as it's going to get because I am sick of working on it. Technically, this floorplan is from several years later and is slightly larger than the agricultural community drawing shows, but the blocks still end up being pretty close to a hectare in size once the road network is added in. There are a lot of reasons a euroblock system works well in agricultural contexts like this that I won't go into here, but it provides natural light and access to fresh air well for a high population density while keeping road networks very efficient and is compact enough that it is very walkable. A standard euroblock system is very different and could also be used, normally the ground floor contains shops and there are two or three levels of apartments above this for housing. A drawback of that system is a rather excessive reliance on stairs, elevators only make sense in taller buildings with more levels, so it's a bit cruel to the disabled. Modern building codes also make these systems illegal to construct these days, but they still remain widespread in many older European cities, Barcelona would be a good example of this style of construction being incorporated into a planned grid system. There are of course many other alternative housing systems that could be used, but something had to be chosen for the purposes of modeling.

The pinwheel looking things are blocks of vegetable and fruit plots that have moving greenhouse systems that roll on castors along metal pipes, in this case they can cover four different fields, though 3 could also be used. There are four one-hectare fields in each with a space in the middle to place compost and mulches. Each hectare field contains 32 plots, each plot is about 30 ft by 60 ft in size and is made up of several beds. Half of these pinwheels use the bog standard bed width of 30 inches with 18-inch pathways that's typical in market gardens and works well for most of the smaller fruits and vegetables. The other half uses a wider 42-inch bed system still with 18-inch paths, this is because the standard bed width is too small to effectively space tomato plants in a lean and lower trellising system. 30-inch beds are also too small to provide space for many of the larger plants like melons or the larger brassicas. The moveable greenhouses cover 7 of the narrow beds or 6 of the wider beds using the same sized structure. The same trellising system is needed for cucumbers, another very important greenhouse crop, and it would allow for some of the more obscure crops like true cantaloupes to be grown under cover, otherwise impossible to grow because they require too long of a growing period in most places. I've never seen this multiple bed width system done, it's almost impossible on the scale most of these gardens operate on, but it would solve many of the fundamental problems with this growing system. One of these pinwheels would be considered an extremely large market garden by most people's standards, a single hectare is typical.

Normally a stationary hoophouse would be used for this that's a bit larger, 30 by 96 ft is typical. The main problem with this is that crop rotations end up being far too short, because a small number of crops are very valuable and people want to use their protected cover space for these. Soil borne diseases like fusarium or verticillium wilt end up building up in this way and all of the disease reducing benefits of the greenhouse like keeping rainwater off the leaves to protect against fungal disease are lost. Being able to move it from plot to plot extends its benefits over multiple plots, giving you a much longer cool season in the spring and fall that's extremely important for places, like here, that are far from water so have more rapidly changing weather. In the spring especially this is a huge advantage, because the rate of plant and insect pest development is temperature driven, so these become decoupled and you don't get cabbage looper damage on the brassicas. It gives you the ability to build in much more varied and longer rotations, but the winter phase is where it really changes what you can do, because you don't sacrifice space in the fall for establishing the winter hardy plants, they can just be covered immediately before the threat of frost. This is essentially like having a massive cellar that can preserve that plot of crops, except the plants themselves are living and continuing to grow. Certain root crops like carrots, parsnips and beets grown in this way through winter will also develop much higher sugar levels because plant sugars function as energy storage to be used for growth in the spring.

These pinwheels are spread out away from each other to reduce disease and pest spread, and to help maintain isolation distances for plant breeding work. This system is large enough that you can effectively maintain a relatively high number of varieties of each species while still having large enough breeding populations to select from. The breeding system is loosely based on the metapopulation theory of Richard Levins, where individuals are being periodically exchanged between communities to keep genetic diversity high. This entire system is effectively a massive plant breeding facility, varietal trials are conducted to see how they respond to local conditions and then the most promising populations are developed over generations into locally adapted cultivars. This entire process is directly incorporated into the cropping system itself so that it can be performed at scale. In this system and at this scale, the crops will essentially self-select for phenotypic traits that develop well in the locality, and this is important because phenotypic trait expression is highly influenced by environmental conditions, a phenomenon well known to plant geneticists but not to farmers. The diversity of cropping types and systems isn't just done to provide the full range of what the area can produce to the local population, it's also so that the entire range of possible crops can be systematically bred, including specific populations for use in season extension systems.

By calculating the area between the temperature curve over the season and the base temperature of the species (below which development slows to nothing, essentially an integral), growing degree day measurements can be taken at specific developmental stages for every variety. Technically there is also a maximum temperature, usually taken to be 86F, above which the growth rate does not actually increase, and when this is accounted for in the calculation it's called a modified growing degree day system. This allows the temperature dependent nature of plant developmental rates to be better accounted for, because plant development is a thermodynamically driven process, and is a better method than days to maturity for estimating harvest dates and windows. A similar measure can be used to model the heat gain and retention of a greenhouse, or even the heating or cooling requirements of any sort of structure. This helps with the timing and design of the complex and tight crop rotation sequences in the moving season extension system. When the same method is applied to insect development you can estimate pest emergence dates as well, so that mitigation can begin before the populations become large enough to be obvious, because by that time it is too late to intervene, things have already spiraled out of control.

All of this can be derived directly from weather data, and historical weather data can then be used in a probabilistic model to estimate the probability of specific harvest dates of each crop as the season progresses, accounting for the conditions the plant has experienced so far. This information can also be used to plan out in advance complex staggered harvesting sequences, even between season extension systems and the unprotected main crop for each species. More accurate data can be obtained through direct air temperature measurements in the field as well as within the greenhouse systems themselves, with data logging temperature sensors recording information throughout the growing season. This data can be compared to what the greenhouse heat gain and retention models would predict for the actually experienced weather conditions to further refine these thermodynamic models. This modeling system has obvious applications for scheduling local food processing operations and food transport between regions, even before the food itself is harvested.

Using previous seasons yield data and the nutrient content of crops and their residues, the nutrient removal rates can be estimated for each bed in this system. This information is combined with estimates of residual nitrogen and other minerals from previous fertilizer applications to estimate the required fertilizer application rate. Periodically the beds would also need to have soil tests performed to check macronutrient and micronutrient levels that might need to be adjusted. By solving matrix equations that represent nutrient contents of various manure, amendment, and compost mixtures, and mixing these together in the central square in the center of the pinwheels, the specific nutrient ratios required for each crop can be applied to the beds, keeping the nutrient content of the soils in perfect balance. I'd also like to be able to work biochar into the subsoils during an initial double digging process when first forming the beds, so that drainage through clay layers or plough pan can be increased, and the biochar can absorb nitrates that leach beyond the crop root zone allowing longer rooted crops to then periodically bring these back to the surface. Once the soil composition has been adjusted, these bed systems are pretty much maintained in the same manner that it sounds like you are using in your no dig system.

I'll try to attach an excel file (*EDITOR'S NOTE: Excel file available upon request to blackmoldpress@proton.me)* that has a very rudimentary fertilizer calculation system so you can see how that works. There are many more things that need to be built into this calculator, but it shows the basic guts of the system and is a good example of how even a simple vector space representation can be used to regulate complex systems of this kind. I've labeled the inputs in green, and you can play around with the ratios of different compost application rates and fertilizers there or change the crop removal rates and residual nitrogen levels to see how balancing these systems can be done. The nutrient values of various organic fertilizers that you see in this model are, by the way, actual nutrient values taken from the literature or available products and the prices given are actual market prices. When you see negative values for the required fertilizer mixture quantities, it means that there is no way to mix the fertilizing mixtures in a way that will provide the crop with the right proportions of nutrients. When that happens, the ratios of nutrients in the fertilizer mixtures need to be adjusted so that they are more heavily weighted towards the respective nutrient they are meant to supply to the system.

The yellow areas show the vectors that are being used to represent the nutrient ratios present in these fertilizer mixtures. Matrix equations are solved to determine the ratios of these mixtures required and then it calculates a scalar value that multiplies the vector components in such a way that the weight required of each can be found. The size of the bed itself can also be adjusted, it uses this information to calculate the growing area in terms of acres, because that is the typical way that fertilizer application rates are calculated, and this is fed into the entire model to determine the required nutrient inputs for the crop. It also calculates the price of each input, and this can be replaced with a labor time value. The information it provides can then be multiplied by the number of beds in a plot planted to that crop to calculate the amounts of amendments that will be required for a plot to maintain nutrient levels over a growing season. The basic idea here is that compost mixtures can then be made based on these values and concentrated nutrient sources can then be mixed into this compost, to prevent nitrogen volatilization losses, and then this enriched compost is applied evenly over the surface of the beds.

In the center of these pinwheel clusters, there is a ring of four rectangles, each rectangle is 5 acres in size and contains four blocks of open field bed systems, with each bed 120 feet in length. These are essentially the same as the previous system, just larger without any season extension, though I suppose you could put some low tunnels in there for winter onions. These are main season crops that grow best in a bed system, but don't require protection to produce reliably. Many of these are best grown using transplants, so they surround two very large 200 ft by 500 ft gutter connected greenhouses, 20 bays each, with areas containing benches and automatic misting systems that serve as heated propagation houses that also serve the moveable greenhouse rotations. In the summer, these can be used for curing onions or garlic for storage. Some areas of these greenhouses would contain hydroponic systems for growing salad greens, especially summer lettuce that would otherwise get too bitter and bolt in the heat. This is only really useful for shallow rooted plants like small greens, almost anything else requires too much inert media or water capacity to provide rooting space that's hard to maintain at scale in a system like this. It's worth doing for salad greens though, especially because it makes them easier to harvest and keeps the dirt off them so they're easier to wash. This could be combined with an aquaponics style reservoir system containing live fish, salad greens are about the only thing that could be adequately fertilized by a system like that, but it would probably be simpler to just use a standard organic hydroponics setup.

A gutter connected greenhouse like this is much more efficient to heat in the winter than any other kind, they are also tall enough that heat can rise to the top in summer and they hold heat absorbed during the day better throughout the night. The length of the bays is limited to about 200 feet for reasons of ventilation, but bays can be added to the sides without much of a problem, and they become better at all these things as they get bigger. Their temperature swings more gradually than a stationary hoophouse, and you don't have the water and weed infiltration problems along the sides like in a hoophouse. The entire floor space is also useable, in a hoophouse the curved pipes along the sides restrict movement by limiting available height, so it can't be used well as a walkway, and if beds are placed there to better utilize the space, they are inconvenient to tend unless their width is reduced by half. These really become much more useful beyond the scale of this system, if you can use combined heat and power to generate electricity and do district heating, waste heat from power generation or industrial processes can be used to heat these through the winter. They are also essential for any sort of nursery operation where you're doing garden plant propagation or large-scale rooting of hardwood cuttings. One interesting heating system for these would heat water in a boiler by running the exhaust gasses from a charcoal kiln, that produces biochar for the fields, through a heat exchanger, so they can be heated by wood. The Jean Pain style large forest brushwood composting systems with anaerobic digesters in the center could even be used for supplemental heat, especially for a simple seed starting greenhouse.

Bordering this central cluster of larger bed systems and gutter connected greenhouses, along one corner, is a quarter circle arc of five one-hectare fields, one in each quadrant for a total of 20 fields. These are for crops that don't fit into the normal annual crop rotations because they require multi year rotation cycles, specifically strawberries and garlic. Strawberries, in particular, are extremely hard to grow reliably in an organic system like this, they're susceptible to fungal disease and once that builds up in the soil it's very hard to get rid of without dangerous soil fumigation. For this reason, they're given a ten-year rotation cycle, though they occupy three full years of this and bear fruit in their second and third year. That leaves a seven-year period where you can get two garlic crops in with a three-year space between them, preferably with a perennial legume cover crop like white clover, and a year of cover crops before and after the strawberries that will build up as much organic matter as possible and reduce weed pressure. A mustard cover crop done in the spring before planting the strawberries in early summer will provide some protection from fungal wilt disease if well macerated and turned into the soil. The long cover cropping period is necessary because both crops require extremely high organic matter in the soil for water retention and drainage. Since there are 20 fields in all, four one-hectare fields of strawberries bear fruit every year along with four one-hectare fields of garlic, or ten acres of each.

There are also a couple one-hectare plots in each of those large bed system clusters with a road running through them that have 100-foot long beds for perennial berries and asparagus with center to center bed spacings of 10 feet. These are spaced far apart to reduce disease spread, especially because they contain raspberries, blackberries and boysenberries that can infect each other with otherwise unnoticeable dormant viruses. They can also include things like grapes, blueberries, gooseberries, black or red currants or elderberries, and all of these are usually given the same 10-foot bed spacing, so they can be incorporated into a very long crop rotation sequence interrupted periodically with flower beds to allow any disease buildup to dissipate. There are eight of these plots in all, or 20 acres total, though a good chunk of this would be taken up by the flower beds. You're not really limited to this space for them, the orchards where the fruit trees are located can also house berry bushes and canes, but it'd be nice for some of them to be near the intensive gardens. The insect populations in these crops are totally different from what you'll find among the annual crops, assassin bugs, in particular, like the blackberries where I am and they'll host a lot of other predatory insects, especially if flower beds are included that the parasitoid wasps like. In our asparagus patch, the fleabane daisy takes over the whole plot in early fall each year and the air just swarms with various predatory flies, lacewings, and a wide variety of hymenopterans. Wildflowers like this can be intentionally incorporated to provide nectar sources throughout the year near the annual plots.

Surrounding this central area of intensive vegetable and fruit bed systems, there is a ring of ten-acre plots, twenty-eight in all. In this drawing, eight of these are occupied by dry lots for pigs with deep straw bedding and rotational cover crop pastures, each with twelve sows and a boar. Each year there is a spring and fall farrowing period, each sow has about 8 piglets per farrowing season, so each 10-acre plot houses about 100 pigs twice a year, or about 1600 pigs total per year. This is about the population size that would be required for a single purebred pig breed to be maintained long-term. Near each pair of pig plots are windrow composting systems, four one-hectare sized plots for rotational pastures for chickens and turkeys and a good sized orchard providing apple pomace for supplemental feed for the hogs. Plum curculio, a weevil that is a common orchard pest, will lay eggs in unripe apples, causing them to drop early, a phenomenon called June drop. If hogs are allowed into the orchard during this time, they will eat these apples and prevent the larvae from developing into adults, helping to control their population. After apple harvest, they can also be fed on windfall apples by letting them in again in the fall, or collecting the fruit that's fallen and bringing them to the pens. They are also given whey from cheese making, along with damaged fruit and vegetables that can't be stored and scraps generated from the food processing systems. Their manure and straw bedding are collected and used in vermicomposting systems or as a nitrogen source for the composting windrows.

I'm not going to be able to go into the details of managing or planning out an orchard, it's been about ten years since I tried studying it. I have a lot of orchard systems drawn out somewhere around here, but I'm not going to try finding them. I have no idea how useful they are but it's a fascinating subject. That kind of stuff is highly specialized and very regionally specific, in general you want to be near water to have any sort of consistent yield, especially for many stone fruits. That's why, at least in the US, you see most tree fruit production happening near the great lakes and along the East and West coasts. Apples and other pome fruit trees can grow reliably in much more varied climates, but you still need to match specific varieties with your location and conditions and the insect pests and diseases will vary regionally. Perennial plants are a lot harder in many ways than annuals, disease or insect damage can destroy many years of work and pruning requires a lot of experience and forethought to do well. You don't experience the entire developmental cycle over a single season, so it takes years to gain experience and there's a long time delay before you can even see the results of your actions. I do include tree nut production in the orchard category as well as grapes, I think it's stupid to pretend grapes are their own thing. If you would like a fairly comprehensive take on fruit producing orchard systems that at least attempts to incorporate ecological thought, Michael Phillips' "The Holistic Orchard" is an absolutely beautiful text and I remember being very impressed with what he'd put together there. If I was to plant and manage an orchard, I'd pretty much just be testing his methods and have a wide range of experimental varietal trials to determine how well each variety grows in an area and how they handle disease and pest issues.

The other twenty 10-acre fields contain field crops that are best grown in rows using mechanized harvesting and are impractical in bed systems but aren't needed in huge amounts. These are mostly fresh vegetable row crops like potatoes, sweet potatoes, green beans, fresh peas or sweet corn, that sort of thing. They could also be used for crops like squash, melons, or determinate tomatoes to give more space so that more varieties can be grown, or for specialty dry bean and other pulse row crops. Ideally, these would have highly diverse rotations with periodic breaks to help build up organic matter and allow nutrient cycling to catch up with removal rates. These rest periods could easily incorporate pastured poultry into the rotation to provide extra fertilizer and help control insect populations. For instance, blue hubbard squash attracts squash bugs particularly well and if included into a chicken pasture in spring, can divert some of them away from the squash fields where they will be eaten by the chickens. These fields can also be used as test plots to trial varieties used in larger scale row cropping systems, or simply to provide space for variety trials for the vegetable and fruit breeding projects in general.

There is a circular gap on the inner side of this ring of ten-acre fields, this is just permanent pasture with white clover being periodically reseeded to provide a nectar source for bees and extra pasture space that various kinds of poultry can be rotated through. Along this entire inner circle near the annual beds, you'd place perimeter strips of trap crops like sunflowers and sorghum combined with insectary plants like buckwheat and the same would be good to do on the outer edge of the 10-acre plots. These attract insects like stink bugs to them and the flowers feed parasitoid wasps in large numbers that will prey on them forming a swarm of predatory insects that act as a barrier that any insects moving from other fields into the intensive bed systems must pass through. If this is done on the outer edge of the 10-acre plots, two concentric rings are formed that act as lines of defense protecting the entire system from traveling insect pests. The specific mixtures of plants used in this can be adjusted depending on the particular insects you're having problems with. These also provide the larger scale field crops with an extra level of protection against insect damage. This can be augmented by adding similar diversity strips between the fields that can target common insect pests of each crop type.

Surrounding these, along the outer corners of the entire system, are four groups of five 40-acre plots that are dedicated to dairy pastures incorporated into a ley farming system. Half of these fields are covered with perennial pastures with a mixture of grasses, forbs and legumes; two plots in each quadrant are active pastures with grazing animals. These are divided into eight 10-acre paddocks in a conventional rotational grazing system. One plot is planted to pasture each year and left to grow for a year, to allow time for pasture establishment. One plot has pastured pigs on it, to allow the McClean County System of Swine Sanitation to be used for farrowing pigs that was developed in the 1920s that greatly decreases the death rate of piglets due to parasites that can build up in the soil. This allows fresh pasture to always be available for farrowing that hasn't had any pigs on it in the last twenty years, and since it will be broken up for field crops the following year, the damage pigs cause to the pasture doesn't matter. Pigs actively root and destroy pasture lands, but in this case it's beneficial and provides manure to the pasture that will help it break down after it gets turned under. This is then planted to a corn silage, soybean, corn silage, dry pea, oats rotation, followed by five years of alfalfa before being planted again to pasture.

In this way, supplemental feed needed for dairying can be incorporated directly into the pasture rotation without disrupting the position of barns and milking parlors that are located in the empty L shaped space at the inner corners of these fields. The manure and bedding generated from housing the dairy animals can then be collected and used in the vermicomposting system to provide worm castings for the vegetable beds. In this system, two of these corners are occupied by dairy cows, one has dairy sheep and another dairy goats, allowing for almost all varieties of cheese to be able to be produced on site. In the dairy cow rotations, wool sheep can be added so that sheep follow the cows in the rotation, which can be useful for disrupting parasite cycles by providing dead ends by exploiting the fact that many intestinal parasites are species specific. This is about as small as you can get a system of this kind, it would be much better for quarter sections to be used instead, that surround this entire farming system, with the 40-acre plots occupied entirely by wool producing livestock, but that would increase the total size of the system to nine square miles rather than four square miles and this is meant to represent the smallest feasible fully integrated agricultural system. This large expanse of fields that surround the vegetable and fruit growing areas is necessary just to generate the biomass that's required to maintain the organic carbon content in the intensive bed system.

There is no inherent reason animals need to be used in a system like this, the entire system is fundamentally plant based after all, but these fields would still be needed just to provide composted plant matter to the rest of the system, and not much is really lost by feeding these plants to animals. By having animals in the system, useful bacteria are maintained that have symbiotic relationships with these species, and the nutrients in the plants are conveniently concentrated, which makes it much easier to hit specific nutrient ratios in the very complex fertilization system being used. The decomposition process is also accelerated, and it would allow for the mass cultivation of dung loving mushrooms, like button mushrooms or the portabella and cremini mushrooms, that are just variations of this species, that require animal manure to grow, or at least are conventionally grown using such substrates. I'm including as many types of domesticated animals as possible in this system mostly for the sake of completeness, so that it can provide as many ingredients used in traditional cooking as possible. The same basic system could though be modified in various ways to omit elements, but I'm not sure there would be much of a benefit to be gained by doing this. It would at least be much more difficult in some ways to accommodate the needs of some annual crops that need very rich soil to thrive, though it would also simplify other complex aspects of this system by eliminating them.

I haven't really discussed mushroom cultivation much, and won't go into much detail about it here, that subject is complex enough that it would require its own 50-page long text to describe adequately. It should be noted however that this growing system mass produces all of the fundamental substrates required for the large-scale production of all of the major mushrooms that lend themselves to indoor cultivation. The spent substrate can be broken down in the windrow composting systems to provide very nice mushroom compost with its own desirable properties. In areas with the right climate, outdoor mushroom cultivation can also be done and at an even higher level of sophistication and complexity, even mushrooms that require symbiotic relationships with tree roots, like chanterelles, along with truffles, can be inoculated into tree roots grown in greenhouse systems before being planted and all this can be directly incorporated into a system such as this. I have a long history of experimental indoor mushroom cultivation and have studied commercial systems of cultivation and culturing techniques in depth, it is a longstanding interest of mine that predates my study of plant cultivation, but it is well outside the subject at hand, so I won't go into that further here.

This drawing omits row crops like cereal grain, oil seeds, dry pulses and fiber crops, that would be grown in very large fields, anywhere between 40-acre and 160-acre quarter sections. Ideally these would be located along the periphery of a system like this, but this drawing assumes that in an early stage of development it would be too difficult to control uninterrupted expanses of land large enough to directly incorporate these into the rest of the system. These instead exist as isolated clusters distributed throughout the local area, operated either by individual families or much smaller communities than exist in the clustered village system I'm describing. These row crops are incorporated into an integrated crop livestock rotation using a ley farming system similar to the one I described before, where the row crop rotation is periodically interrupted by perennial pasture. These can accommodate any sort of grazing system into them, including dairy if they contain small scale cheese making facilities or are close enough to the clustered villages for milk trucks to transfer milk to creameries located there. They would be more suited, however, to wool production, grass fed meat production, and pastured poultry or pastured pig systems.

They would have local grain bins or smaller storage facilities for temporary storage of their harvests that are then brought by trucks into larger long-term storage systems like small grain elevators located in the clustered villages. These clustered villages operate the milling and processing facilities that are required for each crop type, and act as distribution points where raw materials and intermediate products are transferred between localities. To overcome the highly centralized slaughterhouse system that currently dominates all meat production and to comply with food regulations, these clustered villages would need to operate what are called mobile slaughter units, specialized refrigerated semi trucks that can drive to a farm, perform slaughtering onsite and then bring back whole or half carcasses, or slaughtered and processed birds. The clustered villages would need local butcher shops, where the carcasses can be hung and cured, butchered, and then flash frozen with blast freezers to minimize the size of ice crystals in the meat to maximize its quality when thawed. Directly incorporated into this system are the charcuterie operations that produce dry cured meats like hams, bacon, salami, etc., along with any other prepared meat products like fresh sausage, jerky, pastrami, corned beef, etc. This also provides a ready supply of bones for stock production and eventually bone meal as well as blood meal for supplemental crop fertilization, animal hides for tanning operations and leatherworking, and all other animal derived raw materials.

Ley farming systems of this kind aren't encountered much in the literature, but they have a lot of potential advantages that are often underestimated. No till or minimal tillage systems can greatly reduce a lot of the fundamental problems with row crops cultivated by conventional tillage practices, they can increase soil organic matter levels and retain more moisture in dryland row crop farming by leaving crop residues on the surface of the soil. Without long-term rests, however, the rates at which nutrients are being removed from the fields is problematic and annual crops that are produced by these systems lack the extensive root systems that perennial plants are able to develop over multiple years of growth. If very high levels of organic matter are going to be maintained in a row cropping system throughout the entire soil profile, I have a hard time imagining this being accomplished without multiple year rest periods of perennial plant growth taking place. If organic matter and nutrients are being removed from these fields to maintain soil qualities in other more complex systems, as they are in the system I'm suggesting, these rest periods become even more important to balance the organic matter levels in the row crop system, which is why I'm assuming a ley farming system wherever that is feasible.

Ley farming allows perennial polycultures to be incorporated into grain production in a way that makes physical sense, the duration and relative proportions of pasture and row crop rotations can also be adjusted as needed to suit the requirements of each locality. They have many other potential advantages, they can have beneficial effects in maintaining groundwater quality, limiting insect pest populations and reducing the spread of weeds in row cropping systems. There is a very good paper that was recently published that I really encourage you to read called, "Role of Ley Pastures in Tomorrow's Cropping Systems. A Review," that goes into a lot of detail on this kind of system and is one of the very few in depth papers that discuss this sort of thing. There was also a very nice agroecological modeling paper called "Ten Years for Agroecology in Europe" that is the only agroecological proposal I know of that incorporates a system like the one I am most interested in. I'm not really taking any of my ideas from these papers, I only recently found them, but they are very good resources if you'd like more information about ley farming and some of the implications this would have if it was applied on a national or international scale. It's certainly not the only good system, but it's a useful idea that should be explored more than it is, and it has a long and interesting history.

There is a fundamental problem that must be solved by any proposal for an alternative system of agriculture, how grain production is going to be accomplished on the large scales that are required to provide a stable supply of wheat, rice, corn, oats, barley, rye, beans, peas, lentils, broad beans, chickpeas, etc., that today and for all of human agricultural history constitute the fundamental staple crops, along with high calorie vegetable root row crops, that provide the vast majority of calories and protein to people in every region of the world. Often the answer given is, especially by people influenced by permaculture, because these cropping systems must be grown as monocrops to allow them to be mechanically planted and harvested, they must be entirely removed from the human diet or grown exclusively in complex polycultures that will require planting and harvesting to be done by hand. They will insist that perennial crops can replace the role annual row crops, or even annual crops in general, play in the human diet and so allow these to be phased out completely or relegated to a small percentage of food consumption. I'm not entirely convinced that imposing a false dichotomy of monoculture vs polyculture, or annual vs perennial that can't be clearly defined onto all of human agricultural production and then restricting food production systems so they conform to this arbitrary requirement is the best way of designing a food supply.

Monoculture is a problematic term usually defined as growing one type of crop on an area of land. It could refer to a row of cabbages as well as entire landscapes of genetically identical continuous corn operations, I understand why it's used but the reality is much more nuanced. There are cropping systems where monoculture may be the best option and I think row crop rotations, done in a responsible way, are one of those situations. There are systems of grain cultivation that may include other plants in them, I know there are people growing old rice varieties like Carolina Gold that claim that they are using historical polyculture systems that provide better quality and yields than would be possible otherwise. There are also systems of strip cropping where different row crops are grown side by side so that they can be harvested by combines but aren't as susceptible to insect damage. Those sorts of alternative systems should be looked into and might have advantages, I don't know enough about them to really say, but I don't think this attitude of monocultures are always bad and polycultures are always better is especially helpful. A cropping system needs to be considered based on its own potential advantages and disadvantages using actual experimental data, and as far as I can tell we don't have that data.

If polyculture systems have been developed that make sense in an area, and they often do make good sense especially in more tropical areas, then by all means utilize those systems. It would be very interesting to see what could be done along those lines, and where knowledge has been preserved from systems of that kind that have been developed in the past, I think that knowledge is important to preserve and draw from. It is naïve, however, as advocates of permaculture often do, to pretend that "food forests" can replace all of human agriculture or are in all cases more labor efficient and space efficient than any other system. We also need systems that can operate outside of forested environments, they are not some kind of ideal ecosystem type that all biomes are just hoping to attain someday, forests exist in environments with enough water and with climates that are suitable for trees to grow. We need systems of cropping capable of producing every plant that humans actively cultivate, our goal shouldn't be to arbitrarily remove plant species from human agriculture. That being said, there are all kinds of interesting agroforestry practices that can incorporate food production into a forested area, it's specifically the system proposed by permaculture and its underlying philosophy I have a problem with. The systems that they are usually suggesting as good design are impractical and sometimes actively ecologically harmful, they contain bad ecological theory, they use words from ecology like guilds and change their meaning, and they overstate the advantages of their system and misrepresent all other systems.

Agroforestry is beyond the scope of what I'm talking about in this, or have enough knowledge of to talk about in depth, but there are contexts where it can be used as the primary food production system in a region, and I think those are very important to develop. It also has applications for forested regions that aren't well suited for primary growing lands where you still want some local food production to take place. Silvopasture systems, where you are combining grazing areas with tree production, or alley cropping where you grow food crops on small scales between rows of trees in a plantation are both interesting ways of doing this. Agroforestry is properly an entire category of agricultural production, along with forestry more generally, and both of those are just as important to me as the sorts of growing systems I'm talking about here. I'm especially interested in coppicing and hedgerow management, for instance. So, just to be clear, I'm not at all claiming those are competing agricultural systems and that any of this is inherently better. A lot of people in permaculture, and other esoteric branches of alternative agriculture, often do approach things in that way. They will literally claim their methods can take any environment, including deserts and grasslands, and transform it into a lush forest garden. Anyway, back to the agricultural collective that is to transform human productive capacities and pave the way for our glorious communist society of the future!

Between the large bed system clusters, there are four rectangles at the North, South, East and West with roads running through them. This is space left empty for workshops, wash pack facilities, refrigeration and freezing facilities and food processing buildings. A large amount of the work involved in any sort of food system isn't just growing the food itself, it's post-harvest handling and then processing it into finished meals. You need to be able to cool the food down immediately once it comes in from the fields and provide the right temperature and humidity conditions for it to store well until it can be shipped out or processed. For some crops, this can be done by immediately immersing them in cold water baths or dripping cold water over them before they are put into cold storage. For crops that can't handle getting wet, you'll generally use forced air cooling, where you have a refrigerated cold room with fans that circulate air through holes in the crates or boxes the plants were sorted into. They are then moved into walk-in refrigerators and palletized, and you'll need multiple large walk-in refrigerator systems with different temperature and humidity conditions to properly store the full range of crops. These refrigerated rooms also need to be set up so that everything can easily be moved around using pallet jacks, doorways need to be flush with the ground and pathing needs to be wide enough to easily maneuver. The cold chain system also needs to have built into it a loading bay to allow refrigerated trucks to be easily loaded and unloaded.

This can be done using simple cellars for some things, you're basically making an artificial cave that will give you something close to the right conditions and then adjusting the humidity and dropping the temperature to where it needs to be. Monolithic domes made of reinforced concrete using foam insulation that are covered in a water impermeable layer of bentonite clay and earth-bermed would be especially good for this, they're strong and cheap to build and will last a long time, as long as a good drainage system is used to prevent water from building up around the concrete. These would mostly be useful for bulk storage of crops that can store for months at a time at relatively high temperatures where you only need to periodically go through them to control the rot. They can also provide the conditions needed for the storage of wine or beer, for large scale vegetable fermentation, for mushroom cultivation, for curing meat, and can serve as cheese caves. For crops that need temperatures just above freezing or those that can only store for very short periods of time, you'd need conventional large refrigeration rooms, preferably an entire block of them connected with a common cooled hallway to prevent losing cooled air when loading and unloading. These systems become much more energy efficient as they increase in size and are one of the reasons vegetable and fruit production needs to be done at the sort of scale I'm describing to make any real sense for producing for exchange.

V. CULINARY LABOR AND COMMUNIST CUISINE

I come to all this, first of all, as a cook, and someone who sees the accumulated cooking traditions of the world's cultures as a great treasure, something that has been painstakingly developed over generations that must be actively preserved. These traditions are a precarious thing that's never been properly recorded, often handed down from one person to another and that chain can be broken at any time and the information lost forever. It's important information, not just because the food is good, it has built into it seasonally compatible ingredient combinations that also tend to be very nutritionally balanced. The ingredients a tradition selects from are also those that can be produced largely from their specific ecological region and the underlying structure of the meals tends to be quite labor efficient in the context of agricultural systems with a low level of technological complexity, because their history often goes back before large-scale food transport and mechanized agriculture existed. Turning food into something that is merely bought and sold, a commodity on the market like any other, not only limits it to the mediocre slop that can be churned out quickly with as little labor as possible, it erodes away into nothing what should be considered one of the central achievements of human culture. Food is more than just food, it's a relationship we have with other species, with each other, with history. It's the center entire civilizations revolve around and were built from, it is fundamental to cultural identity and often the last remnant of cultural heritage to disappear in a diaspora population. It is an act of caring for another person, of giving, it is an act of kindness and hospitality, it is as close to a sense of the sacred as I get.

In the field of gastronomy, there is no separation between cookery and cultivation, these are one united collection of accumulated human cultural traditions. The organisms we cultivate are natural objects, but they are natural objects that have been transformed by their interaction with us, their appearance and properties are the physical manifestation of human imagination and desires. Crop varieties themselves, along with all domesticates, are just as much a part of this cultural heritage and must be preserved and developed just like the systems of cookery that we have inherited. A tomato is not equivalent to any other tomato, it has bred into its flavors and textures, and these aren't permanent features, they are ephemeral qualities. A cook is limited by the quality of their ingredients first, everything else is secondary, the freshness and the care of its cultivation matter, not just to the cook, they matter to the quality of what they are transformed into. You cannot make a food system that can be considered truly developed unless you can achieve that level of quality, which is an incredibly hard thing to achieve. It takes a great deal of care and coordination on a societal level to make a system that's capable of that. That is the system that I am trying to develop and think I am approaching, one that can provide the whole of humanity with food that is at the absolute limit of what's possible in terms of quality.

You cannot achieve that under capitalism, these traditions are kept alive in the liminal spaces outside its reach, in the home kitchen, or in the garden of an obsessed collector of cultivars, or in the outer reaches of human society that have managed to hold on to them. Communism allows these traditions to regain their proper place in human society, as a daily celebration of human imagination and skill. If that was all communism could offer me, that alone would be enough for me to be a communist. If the system I have developed were ever implemented, a system I can see as if it was right in front of me, I can see the gardens and fields, I can smell the meals and taste them, you would be tapping into the most fundamental drive a human being has. This system can provide people not just with what they need to live, but to live well. I think it could provide much more than that, and I still believe people could construct that world if they were really dedicated to bringing it into being, even within this nightmare world they've woken up into. They've just had all of their hopes and dreams beaten out of them for so long they can't even conceive of any other sort of existence.

This requires a very complex logistics system to coordinate everything well enough to prevent food waste. There is a constant threat of losing huge amounts of labor that has gone into planting, weeding and harvesting these things and any decline in quality at any stage not only reduces the quality of what these are made into, it greatly increases the labor involved in food preparation. What has been stored, when it was stored, where it is, how much there is of it, where it's going or what it will be made into and how much is needed when, all of this needs to be immediately available to everyone involved in the system and needs to be able to be accounted for at all times in a clear and easily understandable way. This combined with the inherently unpredictable nature of food production requires an extremely complex logistics system to be in place to handle this complexity and be able to effectively maneuver in this system, so that the food processing system can immediately respond in the right way to constant fluctuations happening in the food storage system. Furthermore, everyone involved in this system needs to be fed daily from the output of this system, and that entire internal food distribution system needs to be planned out ahead of time in a way that provides tasty meals with balanced nutrition to the entire local population. That system needs to, at the same time, be flexible enough that it can utilize ingredients that might be overwhelming the food storage and food processing systems and serve to bring the entire system into balance.

One part of this logistics system I'm trying to develop consists of taking Marx's labor theory of value equations that describe the production process and combining them with an algebraic structure, specifically an algebra over a field, that represents flows of raw materials and their transformations as a series of individual batch processes. Data taken from each individual process within the system, the labor time in a shift combined with mass or unit measurements of its corresponding input and output, is converted into average local flow rates in a discrete system that accounts for the fact that these processes have a regular duration. From the initial mass of a harvest, it automatically calculates an estimate of the labor time and number of shifts required to send it through the system, so that a sequence of labor processes can be planned out and coordinated in advance. The outputs of this raw ingredient representation system become inputs to the food processing calculation system that can draw ingredients it needs out of the larger agricultural production network. Food preparation processes, whether for freezing, canning or cooking, are then modeled in the same way and these outputs become inputs to the batch processes that cooking or food preservation processes consist of. This system can even account for how different durations of shifts or number of workers involved influence the flow rates within the system.

This is a generalized modeling system that is just applied linear algebra and it can work with any batch process and it can also be adapted to certain continuous processes, though complex continuous processes would need to be modeled using differential equations in a system dynamics style. The same basic algebraic structure is what linear programming is based on, and if you wanted to, this entire calculation system can be fed directly into a linear programming planning system to balance the proportions of different elements in the system. It can also be fed into a dynamic representation of the sort Beer is suggesting and used for modeling and from those models simulations can be created. There are other applications of this, it's the basis for all flow network analysis, and Odum, an early ecologist and student of Hutchinson, had done some interesting things along these lines where he was trying to represent complex systems from an energetic perspective. Towards the end of his life, he was making a cybernetic modeling framework that described energy flows through ecosystems and economic systems as electronic circuits, though I don't have copies of his books that describe this so I'm not sure about the details or how useful it would be.

The other side of this logistics system is an attempt to create a unified recipe collection that brings together all of the English language cookbooks into one systematic database. Any source of recipes can be used of course, but I cook from books a lot, so I'm using those. Different versions of the same basic foods are grouped together and then a sort of taxonomic classification system is imposed on them to organize all of traditional cooking into one comprehensive system. For now, I'm just trying to focus on the cooking of what I guess I'd call Southwest Asia and related systems of cookery, because a good term doesn't really exist for it. This combines the cooking of the Maghreb, the Levant, Turkey, Greece, the Balkans, Iran and the Caucuses into a vast system that connects regional variations on similar foods together. Eventually I want to do the same for the cooking of Mexico, Central America, South America and the Caribbean because this is another highly developed system of cookery with related cuisines over a large geographic area with local variations. Unfortunately, most of what's been published on those countries has never been translated into English, so that would need to be done first and I can't speak Spanish. Korean and Indian are also cooking styles that would be especially useful for temperate regions, but the ultimate goal is to include all of the world cooking systems.

Each recipe has a unique tag, created by the region or book category, book and page number that eventually will be linked to scanned copies of each recipe. Each is associated with a list of all the ingredients and their ratios are converted from imperial units into grams along with the yield, then this is stored in an indexing system as a vector with ingredients and their quantities as components. In this way, any recipe can be scaled for a specific yield and it creates a searchable database, where a list of available ingredients can be put in and it will output the set of all recipes that can be made from them. If you are largely depending on local fresh produce production, this food is highly seasonal, but its production is also cyclical. This allows each locality to perform meal planning in advance, knowing from previous years what is generally available and when. If there is a glut of one kind of food, this database gives a comprehensive account of what can be produced from that food and what else is required to do this.

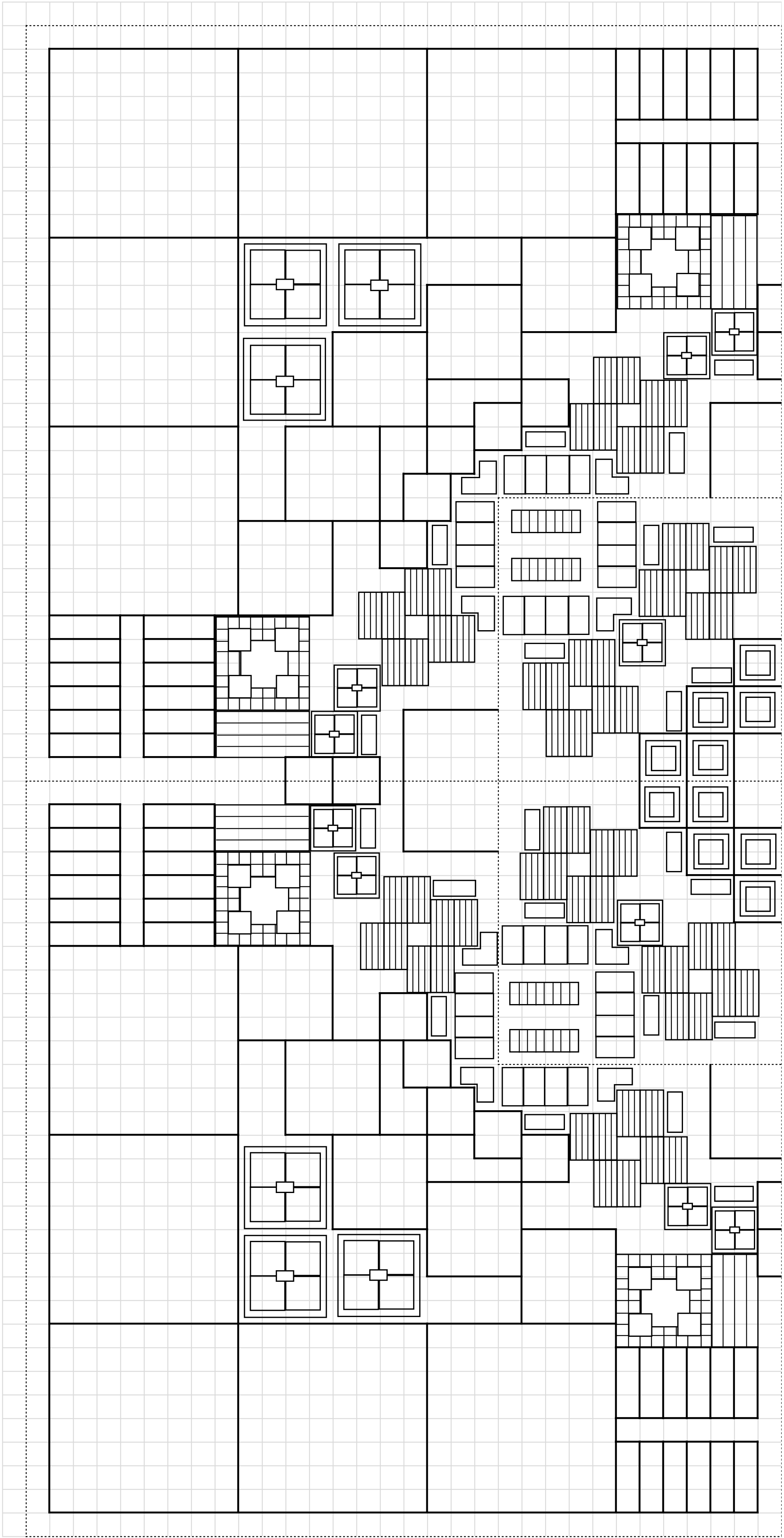
This database is incorporated directly into the entire food processing system, so it can automatically bring in data about the time required for ingredient production and food preparation and when combined with measurements taken while cooking, it can estimate total labor time required. In addition to this, nutritional data can be built in using a similar vector representation and fed directly into the system, automatically calculating the nutrition of recipes or combinations of recipes for meal planning purposes. It would also be very useful for home meal planning, because prices of ingredients can easily be built into this system and would allow people on strict budgets for food to get the most nutrition out of what they cook, without sacrificing quality. I'll try to remember to attach a cookbook index and classification system of the sort I mean, but it's going to be pretty fucking rough. I need to go back through everything I've done so far to get further with it because the format was gradually changed, but it works well enough for me to find recipes to use.

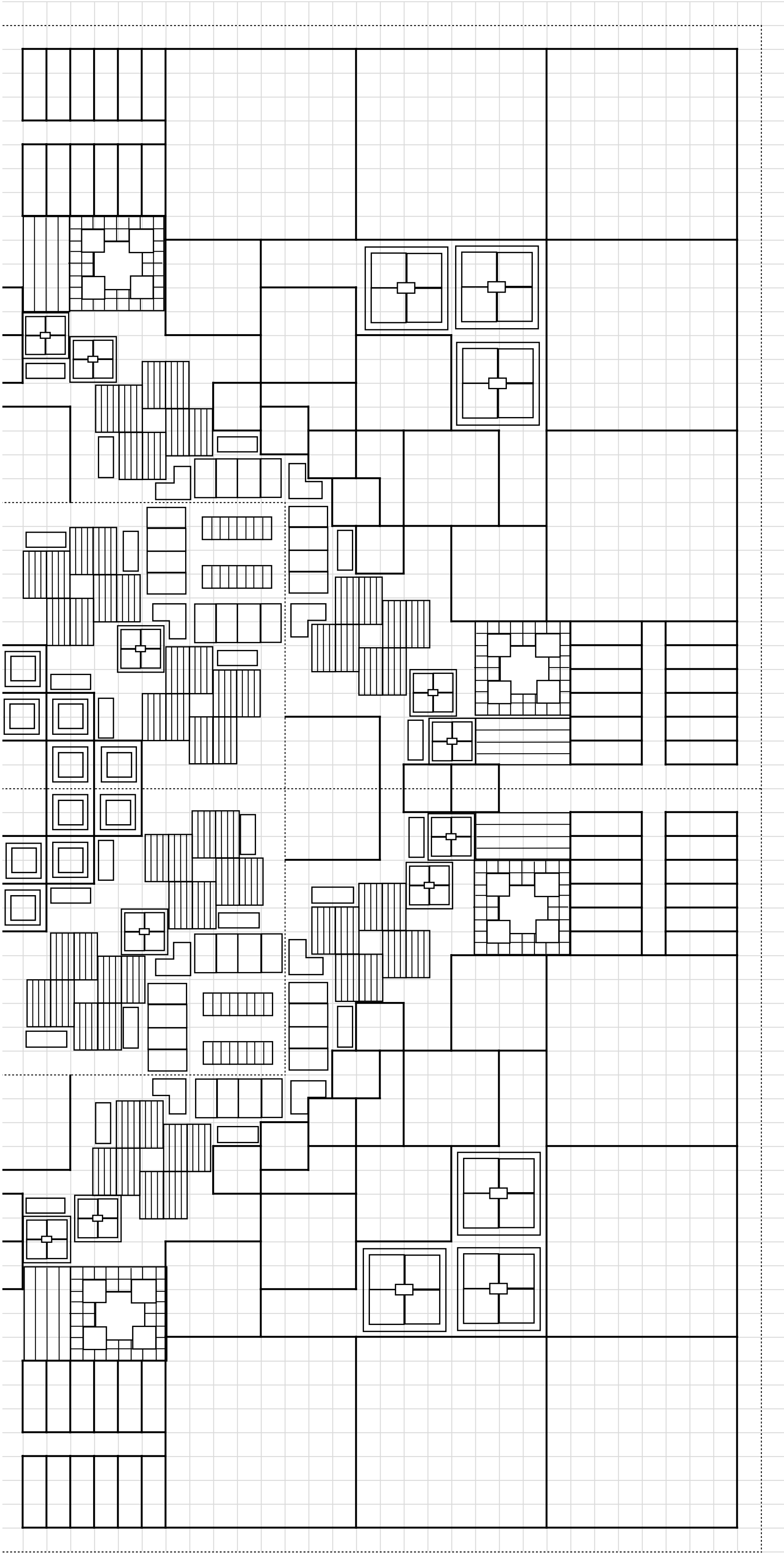
This entire calculation and planning system is then combined with an inventory system to estimate current inventory based on what processes have been done recently, then inventory is periodically checked. This can also be used to predict future inventory based on the plan that's being created and estimates of expected harvest dates and previous yields. That's basically the logistics system that I'm trying to construct so I can plan out all of the food preservation and soup cooking I do at work, because those petty bourgeois fucks think they can just decide on a whim each morning what I'm supposed to do and we never have what I need to do anything. Soon those far-right libertarians will have their entire system running on Marxism. That system contains within it all of the information that's required to set up a labor time accounting system, that can run alongside the capitalist money-based accounting system that's needed for operating the system as a business within capitalism. If a cooperative existed at a national scale, like the sort of cooperative system Marx was advocating for, you could organize a separate economic structure within it that could perform internal circulation of products all using a single mathematical system, because they're fundamentally the same system just with minor system behavior altering differences.

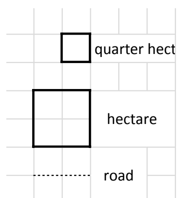
This is all just one part of a much larger mathematical modeling system I'm trying to develop, where these local models are then combined into a national and international distribution network. Using rough descriptions of possible

THE AGRO-ECOLOGICAL COMMUNE

The commune at a viable scale



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local agricultural communities, like the system I was showing you as an example, the full range of agricultural subsystems and the technical systems needed to operate them is gradually developed in more and more detail. From systems like that, and mathematical representations that have been developed for modeling those sorts of systems, I can slowly construct an integrated mathematical representation that can be used to model all possible agricultural systems. The technical systems they contain give me a clearer idea of what sorts of industrial systems are required to supply systems like this with raw materials and machinery coming from other parts of the economic system, so a mathematical framework can be established for describing an entire supply chain that can function independently of the rest of the economy. I think building up an interlinked map of such bare bone descriptions of the productive processes that constitute the ultimate foundation of an economic system are necessary if we want to have a clearer idea of how a new mode of production might be brought about, either within existing society or in general.

VI. OFF FARM TECHNICAL SYSTEMS - FROM INDUSTRY TO ENERGY PRODUCTION

Now that brings me to another aspect of all this, how technological systems in general are enmeshed with agricultural production and how I think about technology as a whole. All agricultural practices are in a sense technical systems themselves, and the kinds of food systems people might support have built into them certain assumptions about the technical systems they think are desirable or possible to sustain. Food systems also are a fundamental element of production that in many ways influences the extent to which technical systems can be implemented and sustained in a society. These kinds of systems, and the means of production more generally, obviously play a very central role in the Marxist conception of society, social relations revolving around them and interacting with them reverberate through the entire structure of society. I think a lot of Marx's ideas about technology are some of the most interesting ideas in Marxism, he was a studious student of technology indeed, and his theories on the subject are the most comprehensive view of technology I've ever seen. He's often portrayed, falsely I think, as having an almost unhealthy infatuation with technology or of being a technological determinist, where technical systems are relentlessly driving society forward independent of human will.

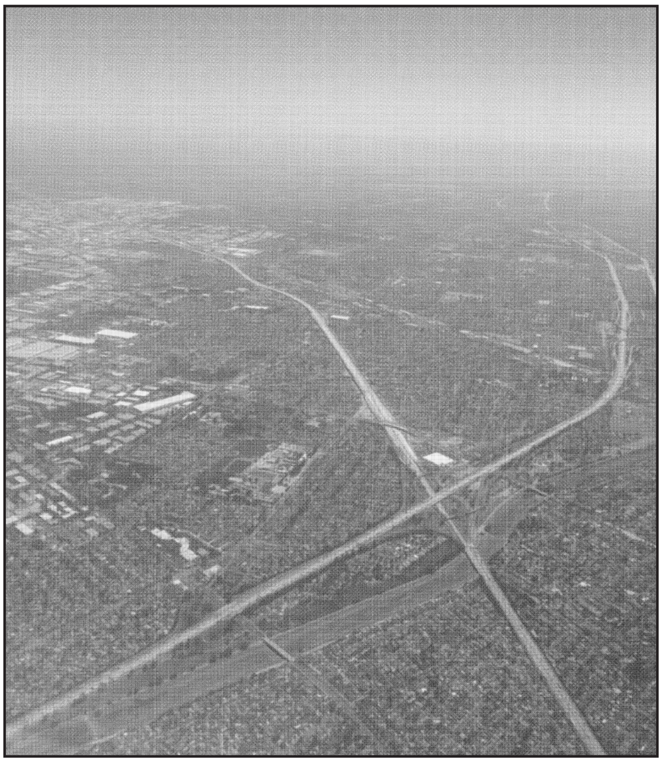
The Marxists want the working class to gain control of these means of production, but they don't generally seem to show much interest in them, I don't think most of them would know what to do with them if they did have control of them. Technology appears to them as a great jumbled mass, and they see the great harm it does, and they see its great untapped potential, but its complexity raises an obstacle to their understanding. The kind of broad view of how the capitalist economic system functions that Marxism offers I think is very powerful and important, but it's necessarily abstract and meant to give a detailed theory of the fundamental underlying forces at work in our society. The ultimate goal of Marxism is establishing an alternative to that system, and I think it provides a well thought out outline of what that alternative would be like that I'm completely on board with. We need a lot more, though, than the theoretical system Marxism offers to actually construct that world and organize it in a way that can provide us with a system that can facilitate the kind of free human development and flourishing that to me is the absolute core of Marxism.

How technical systems that have been developed are to be used to provide us all with the free time that will allow us to pursue our interests and enjoy each other's company should be a central aim of this project of collective emancipation. That is the highest social goal they can be put towards, not how do we maximize the number of products that we obtain from a certain quantity of labor time. Are the products we are producing things that serve to achieve this goal, or are they so much superfluous baggage that merely drains our energies and occupies our time without satisfying our true desires? In our society, technology is not being directed towards these ends, it is being directed towards facilitating a cycle of senseless growth that leads to our collective destruction. In the society we are trying to develop, technology needs to be able to be utilized in such a way that it can achieve its intended purpose and then stop expanding so it doesn't needlessly consume all of the limited resources available to us.

If we are to achieve this, we need a well thought out theory of technical systems that describes what they can really do, what their fundamental limits are, and what we can know about their inherent structure. For some reason, this is being almost completely ignored by the Marxists. It is also being ignored by everyone else, but it actually matters if the Marxists are ignoring it, because they are the only ones who have a clear theory of the social relations that perpetuate this vicious cycle of accumulation that not only might plunge us into a global catastrophic breakdown, it is currently doing so. They need to stop moping about just because a wrongheaded authoritarian faction of them who managed to gain local power ended up losing it because their leadership wasn't up to the task at hand.

I first came to the writings of Marx when I was 13, and at the time I was very much immersed in the work of Michael Faraday and James Clerk Maxwell, along with the entire scientific culture of the 19th century. Their work was what led directly to modern physics and Einstein's theory of relativity, who first introduced me to the idea of socialism. The way those people wrote and thought, was like nothing I had ever seen before, and I learned through them the true potential of what a human being was capable of becoming. That was a time in the history of science that had a fanaticism and a passion that has never been equaled since, the things they achieved, considering how rudimentary the equipment they were working with was, is absolutely incredible. When I came to Marx, I could see immediately that he was coming directly out of that same culture, that had as its central mission taking human understanding to its absolute limits, and here was someone directing that perspective at the entire social structure, and it was beautiful.

At the time, I didn't realize that there was any other idea about how a communist society was to be established other than a labor voucher system, it made perfect sense and seemed to flow directly out of his labor theory of value from the beginning of Capital. I just thought, well of course, that's the most reasonable way to measure the value of a commodity and we could just use that directly as the way of distributing the products of labor. It wasn't



You ever just take a step back and wonder- how we're gonna change all this?

until years later, when I started talking to other Marxists, that I realized their entire focus was on these obscure historical disputes that didn't have anything to do with what I'd been reading. The whole idea of using labor time as the basis of a new economic system was conspicuously absent, this had been replaced by ideas about the collective ownership of the means of production that were so vague they seemed to be utterly meaningless.

Any specific ideas as to how this was to be implemented was considered to be impossible to determine in advance, because apparently Marx just forgot to elaborate on it, and we were to just figure it all out, at a moments notice, once society had collapsed to a point revolution was achievable, because it all had to be compatible with the material conditions at the time and anything else was just strictly utopian. That's an extraordinarily destructive idea that's taken hold in this community, to place arbitrary limits on our understanding without any investigation, in direct contradiction to the authority you are appealing to on the matter, and somehow these are to be the guiding light that shall lead humanity to its freedom from tyranny. It's the most ridiculous thing I've ever heard, these people make the liberals seem reasonable. What has happened to my movement, what has become of this meticulously detailed and compelling explanation of the origins of the fundamental problems of our society and the ways these can be addressed?

There are things we are able to know about the productive forces themselves that are relevant to the implementation of socialism, we don't need to stop at theories of how social relations might be changed so that they can be used for the benefit of everyone. I'd like to, as best I know how, describe the structure I see in the productive forces, how I think this structure can be described mathematically and how the relevant information needed to use this mathematical structure to help guide production on a societal level can be derived from the activity of production. I'll try to explain a bit how food systems relate to this whole network, and why they, along with agricultural systems generally, play such a central role in society. I also want to touch on the sustainability of technology, especially what an economic system without fossil fuel consumption might look like and how that might affect the potential technological sophistication of agriculture.

Capital is a special category of commodities, not just because it can produce other commodities when combined with labor, it can produce itself. Somewhere within that complex of capital, there is a self-replicating machine, that when acted on by labor can make an exact copy of itself. I want to cut away the fat from the whole system and find the beating heart of this monstrosity, understand its internal anatomy and the mechanisms that allow it to physically reproduce itself. I think the best way of doing that is by focusing on the means of subsistence and the processes involved in their production, because this is the branch of the machine that facilitates the reproduction of labor power, which is essential to the operation of the thing. A large portion of that is the food system, along with housing, and all the domestic goods in those houses, with textiles occupying a significant portion of that subset in terms of variety and technical complexity.

The idea of a food system is important because it attempts to go beyond agriculture proper and include in its analysis the entire chain of processes involved in the food supply, the primary production of organisms in agricultural systems, the infrastructure required to accomplish this and to initially store and move this food around, all of the food processing systems that transform the raw materials of food into the ingredients of cookery and finally the entire process of then making these into prepared meals. This concept is then often extended to so called agrifood systems, that add onto this complex system all the nonfood outputs of agricultural systems, such as natural fiber production and wood products, and their entire system of processing that transforms them into finished goods. Within this broad view, there is how these systems operate in the world now, how these systems have operated in the past, and combining these both together, you get the range of historically developed systems available to draw from. Then you have ideas of how these systems might operate in the future, both in terms of combinations of historical systems, and experimental systems that could be in their nascent stage of development or untried theoretically possible systems.

This is a useful way of thinking about the physical structure of capital from a systems theory perspective, because it identifies the areas of production that rely on biological processes, what technical systems exist to facilitate these processes and then transform organisms into products, what these products are, what the organisms are that we're relying on to do these things, and the physiological requirements they have. Systems that have organisms as their input or output are fundamentally more complex than those that don't, they are more unpredictable, they are more variable, the objects they contain are continuously changing over time, they are often ephemeral in the way food is and must be constantly regenerated and consumed. Although the scope of what's being considered is vast and the complexity of this network of processes is extremely high, there is nothing about these things that are fundamentally beyond our ability to understand them, even if our understanding will always be in some ways incomplete.

It is important to develop this understanding, particularly if we are trying to bring into being a new economic system for society. All economic activity is made possible by the agrifood system precisely because this is the area of economic activity that is most directly generating the means of subsistence, it allows a subset of the population to do something other than reproduce labor power. It is the foundation the rest of the economy is built upon, and the outputs of this system significantly impact the quality of life of a population in terms of food quality, the quality of housing and the quality of clothing. The agrifood system, as an abstract collection of technical systems, encompasses all possible ways of physically organizing that economic foundation, and the particular systems you select from that collection and implement sets off a chain reaction of industrial processes that become necessary to construct and maintain that system. The aggregate output of the system must provide for the basic needs of the people operating that system, in addition to, a surplus output that sustains all people that are part of the economy outside the agrifood system.

For any given agrifood system, there is an associated set of mechanical objects, building materials, electrical systems, synthetic chemicals, etc., that are the outputs of an associated industrial system. Together, these represent a sort of minimally complex economic system in the sense that you need at least this industrial system in place to supply inputs and replace parts that are being continuously used up by the operation of a particular agrifood system. This industrial system may be using outputs of the agrifood system for some of its inputs, but to some extent this industrial system is inherently extractive, requiring mineral extraction for its own source of raw materials. An agricultural system cannot be said to be sustainable if the industrial system that sustains it cannot be sustained. At the same time, this minimally complex economy must be efficient enough that the aggregate output generated by the aggregate input of labor hours can provide the means of subsistence to at least its entire population, or it ceases to constitute a food supply.

This minimal economic system is also deriving the energy it consumes from somewhere, and the source of energy used influences the specific technical systems that can be used. The growth and development of the modern industrial complex was made possible largely by a readily available supply of natural gas, petroleum and coal, and so most of the industrial systems we have to work with require these inputs to operate. If the goal is to design an agrifood system that is sustainable in any meaningful sense of that word, the associated industrial system must be able to operate without any of those inputs. It can't be emphasized enough how extreme of a design requirement that is, because many industrial processes are extremely energy intensive and a very large number of industrially important chemicals use petrochemicals as their feedstock. A drastic reduction in per capita energy availability would radically limit the kinds of agricultural systems that are actually feasible as well as reduce the labor efficiency of mineral extraction resulting in a severe decline in the labor available for all other economic activity.

One potential way of at least partially overcoming that problem would be to derive that energy from biomass, though that introduces into the system a whole new set of difficult to overcome problems. How difficult or easy that is to do will also vary significantly from region to region, especially if you try to go the bioenergy with carbon capture and storage, or BECCS, route that would require the right kinds of geological formations beneath the power plant to pump CO2 into. Carbon capture and storage, or CCS, would use up a sizable portion of the energy generated by the powerplant, but that might be worth it if it can turn the system into a carbon negative process. There are legitimate concerns about how feasible CCS is, if that can be done without significant leaking, what effect this might have on groundwater or the geological formations, but it is probably worth seriously considering. The big problem with this idea is if biomass is the primary energy source, you would need very extensive tree plantations and other biomass sources to feed it, and this would almost certainly have large scale negative effects on the ecosystem if implemented. A lot of this depends on the scale you are attempting to do all this on, the specific cultivation systems you are using, and the systems you are using to transport massive amounts of very heavy material long distances to these power plants.

One system that seems especially promising to me is George Olah's proposal of a methanol economy, where wood or other biomass would be gasified and converted into synthesis gas, or syngas, consisting of a mixture of hydrogen, carbon monoxide, and CO2, which is now mostly made with natural gas and coal. The syngas can then be converted into methanol fuel, that can be used as is or can then be made into dimethyl ether, a gaseous fuel similar to propane that is relatively easy to compress and can provide a low emissions fuel for diesel engines. The methanol itself can run internal combustion engines, or be used in methanol fuel cells, and though it has about half of the energy density of gasoline, it's a liquid fuel that would be a good replacement. The synthesis gas has an excess of CO2, so if more hydrogen was put into the reactors, it could be easily converted into more methanol. This allows electricity from intermittent renewable sources to drive the electrolysis process to create green hydrogen and pure oxygen and this can then be processed into easily storable liquid fuel as opposed to the rather difficult to use batteries or hydrogen storage systems. How useful this system really is depends a lot on how much energy things like solar or wind can actually provide in the long run, because if it is a lot, the scale of the biomass plantations required is less problematic.

In a similar way, syngas made from biomass can also be converted directly into methane to make synthetic natural gas, and this can be pumped directly into the existing natural gas pipeline system. There are a lot of reasons you might want to do this, that I won't go into here, but a major one is that natural gas is very good at generating power close to population centers because it has very low particulate emissions and a high Carnot efficiency. It's particularly good for combined heat and power, or CHP, applications that can provide district heating. CHP is very useful because you can utilize the waste heat of a power plant, which is typically a larger amount of energy than the energy of the electricity generated, and direct that heat in the form of hot water flowing through insulated underground pipes to supply residential or industrial heating needs. Additionally, waste heat from industrial operations can be recovered and reused by storing it in this hot water network using heat exchangers. If there was an excess of heat, this could be used for the production of food in greenhouses through the winter or even the cultivation of tropical plants in temperate climates.

If that system incorporates absorption or adsorption chillers, you get a combined cooling heat and power system, or CCHP, that can also supply cold water in a similar way for refrigeration and air conditioning. That would be especially useful for a rural community focusing heavily on food production, because you can have a direct supply of gaseous fuel from a pipeline that supplies a CCHP plant that provides cooling for the entire cold chain system needed for storing perishable food along with heat and electricity for the entire community. The CO2 released by the CCHP plant can then be separated and converted into methanol fuel using hydrogen produced using renewable electricity sources. A CHP or CCHP facility can operate by burning biomass directly, but it will have more harmful emissions than a methane fueled plant, which is problematic if it's located near densely populated areas, which it would need to be to supply these with heating or cooling.

This biomass fueled syngas process is also able to provide the raw materials for the full range of synthetic hydrocarbons that are currently made from oil and natural gas, allowing practically all of polymer synthesis to continue. Synthesis gas itself is extremely important for industrial chemical processes requiring hydrogen, that include the Haber-Bosch process of ammonia synthesis, so the same system can be used as a general method of converting biomass into hydrogen gas for these processes, if that can't be done easier using renewable electricity. For example, this would allow you to convert wood into the raw materials you'd need for making foam board insulation panels for houses, or for making wood into the formaldehyde-based glues required for plywood production. Some other important materials coming out of this synthetic pathway are polyethylene and polycarbonate plastic used in greenhouses, synthetic rubbers, a wide range of energetic materials, industrial lubricants, and many of the chemical building blocks of pharmaceutical drugs like acetic acid.

This has applications that reach far beyond polymer and hydrocarbon fuel synthesis as well, because synthesis gas can be used as a reducing gas for making direct reduced iron, or DRI, out of pelletized iron ore. This allows you to convert iron ore into metallic iron without melting it, bypassing the need for blast furnaces in primary steel production, and by doing so, eliminating the need for coke derived from coal in steel production. The DRI is compressed into hot briquetted iron, or HBI, that resemble charcoal briquettes, reducing its reactivity and allowing it to be effectively shipped out to steel mills, where it is converted into steel using electric arc furnaces, or EAF, that can derive their electricity from renewable electricity sources or from biomass driven power plants. This is the general process that most of the carbon neutral steel manufacturing proposals rely on, but it can also be extended to cupola systems that produce cast iron as well as ductile iron. DRI is what allows a steel mill to operate on a scale much smaller than an integrated steel mill without relying exclusively on the recycling of scrap metal. Since the basic oxygen furnace can be overcome, the necessary scale it imposes on the system isn't as much of a restriction and a more limited set of rolled steel products can be made, though it can also form the basis of a larger completely integrated system.

The cokeless cupola, developed in the 1970s, allows for the melting of iron without using coke as an input, instead using gaseous fuels like methane to melt the iron charge, which can use HBI as up to 30% of its composition along with scrap steel. In this system, the cupola performs the initial melting and then the molten iron is transferred to an EAF to superheat the metal to temperatures suitable for casting. The carbon content is provided by injecting graphite rather than coming from coke fuel, and depending on the amount injected and the chemical composition of the iron charge, this system can produce either gray iron, which is typical cast iron used for among other things the body of machine tools, or it can make ductile iron, which is a more malleable and ductile form of iron with a specific carbon nodule shape that is very important for making things like ductile iron pipe used in water supply networks or for components of heavy vehicles like tractors or mining machinery. This cupola-based foundry system, together with the rolled steel processes of the continuous casting system in a steelworks, form the ultimate basis for all of the raw steel and iron stock that enter into industrial steel and iron working operations and represent a significant portion of the entire metalworking industry.

Now, I'm sure there are a lot of other systems that are possible that could serve as the foundation of an industrial system that does away with fossil fuel inputs, but this at least gives you an idea of what such a system might look like that is constructed entirely out of already existing processes that are presently well established. There are a lot of other metals and alloying components that would need to be included, of course, that I'm not going to describe here, but these constitute a smaller share of the overall percentage of metal produced and many of these require a similar reduction process as for iron or, for example aluminum, can be effectively smelted using electrically driven processes. There are also all kinds of other especially energy intensive materials that are made on a large scale including cement production, ceramic materials and glass products, but as long as you can produce synthetic methane they don't impose any serious problems. This whole section of the industrial system, the energy and raw material supply system, form the sort of foundation of the foundation for the rest of the system.

As far as I can tell, no one has any clear idea of how well that system would actually operate or what the fundamental limitations of that system are, what mineral or water resource limits exist or how efficient any of these processes are from an energy or labor efficiency standpoint. Whatever data has been collected, is to a large extent artificially removed from our view, it is either behind paywalls or this knowledge is siloed by private business organizations and isn't available to the public. There is still a lot of literature published on this sort of thing, especially in the last few years. The 2022 paper, "On the History and Future of 100% Renewable Energy Systems Research" by C. Breyer et al gives a pretty good overview of modern academic perspectives on the subject and presents some of the modeling work that's been done. I'm not sure that I'm quite as optimistic as they are, but from what I understand about the sorts of options available to us, the basic system they are describing there seems pretty reasonable and realistic.

I think we do know enough about the kinds of systems that can operate without fossil fuel inputs to say that it's at least conceptually possible to have a food system with significant industrial inputs that is sustainable overall, even if a lot of the specific details about such a system are unclear. Based on a proposal for an alternative industrial system like what I've described, you can map out all the components that constitute this system as a flowchart and describe how these components are interacting with each other, and in this way describe the overall structure of such a system, at least on a sort of abstract level. At this level of abstraction, the system is sort of just hanging in midair, we are only concerned with the broad categories of technical systems and the flows of materials or energy moving between types of facilities in aggregate. We aren't concerned with where they are located, or how many of them there are, or how big they are, or at what rates things are moving from one to the other, or at what rates parts are being used up and replaced, just with what are the raw materials each type of facility requires to operate and what facilities are supplying these raw materials once these facilities have been set up and are operating.

A flowchart of this system is useful purely as a visual description of how the system is operating, what it's made up of and what's producing and consuming what, and so makes it easier for us to comprehend at a glance, though how comprehensible it would actually be I'm not sure because it would appear as an immense tangled ball of interactions. The real purpose of this mapping out of the system as a flowchart is that you can then represent the system as a mathematical structure, specifically as a graph by using the techniques of graph theory, which allows you to do all sorts of useful things with it. In this system, you can convert a flowchart of this kind into a graph, G, with each facility represented as a node or vertex contained within a set of vertices, V, and the interactions between vertices are represented as a set of links or edges, E, where in its simplest form the graph is an ordered pair notated as $G=(V,E)$. The simple version of this is that you would number the vertices of the graph and construct a matrix, called the adjacency matrix, where the rows from top to bottom are labeled 1,2,3,… and the columns from left to right are labeled 1,2,3,… and this forms a square diagonally symmetric matrix where the entries are 0 or 1, 0 indicating that the vertices aren't interacting, and 1 indicating that the vertices are interacting.

This is kind of the core idea behind the linear programming systems of Kantorovich and Leontief, but graph theory is an entire subdiscipline of discrete mathematics and there are many more things you can do with this. This sort of system is particularly useful for describing flow networks, with applications in things like the flow of electrons through an electrical circuit or the flow of water through a distribution network, and these sorts of calculations can become incredibly complex, often requiring iterative calculations that gradually approximate a solution. The system we are looking at is specifically a directed multigraph, directed because materials or forms of energy are moving from one facility to another, a multigraph because there can be multiple materials or forms of energy moving from one facility to another, in other words, the edges have a direction and vertices can have multiple edges linking them. Once you can describe a system like this in matrix notation, you can start applying mathematical notions that conceive of matrices as sets of vectors in a multidimensional coordinate space, called a vector space. You can then use the techniques of linear algebra that formalize the properties of vector spaces and the operations that can be performed on them to construct systems of equations that are the vector space equivalent of normal algebraic equations. For instance, you can solve for a variable that is a matrix in an optimization problem, like the fertilizer calculator I sent you does. Linear programming is just one particular method for doing this and is part of a much broader field of mathematical optimization techniques.

There are also hierarchical levels of analysis possible here, we are looking at the level of the overall system structure. A particular system with multiple instances of each facility at different scales that each have a position in geographical space and are interacting with each other becomes what's called a multicommodity flow network, we are taking our general system description and adding onto this mathematical structure more levels of information that makes the overall representation more complex and detailed. The overall system structure is treating this more complex system as an aggregate, as if all of the facilities of one type were one facility and describes how the system is behaving as a whole. If you did have more information, like how much electricity and methane gas are required to produce a certain amount steel, how much energy and steel are required for each type of rolled steel stock of a certain length, how much wood produces how much methane or electrical energy, etc., you could then use this information to give you a general idea of the relative proportions that would be reasonable for an overall system like this to have. If you had information about the scale at which each system becomes practical to implement and how the scale of facilities influences their overall efficiency, you could then use this model to get an idea of the minimal possible scale a system like this could have. This sort of model, like linear programming in general, is useful for the problem of scaling elements of a system relative to each other so that overall inputs and outputs are in balance.

This system also has a recursive structure, below the level of the higher system interactions, each facility is itself representable as a flowchart and graph, with all of its internal components interacting with each other. A more natural way of describing these process flows within a facility would be by using system dynamics models that apply models based on systems of differential equations that can describe how elements of the system are changing over time while they are interacting with each other. This is the mathematical technique you introduce when you're not dealing with relatively simple linear system interactions and need to account for complex interactions between parts that are occurring over time. These systems are typically nonlinear, often they will include the accumulation of stocks and variable flow rates between elements, they might display oscillatory behavior or complex feedback loops and can incorporate time delays. A lot of the language and concepts Beer is using when talking about complex systems and dynamic models is coming directly from this system dynamics perspective, which had essentially just been developed and was only able to be utilized once the computation power of computers was up to the task.

These kinds of mathematical representations are of course not limited to small scale systems, they can be applied at all scales, but at a large system wide scale you often don't have or can't have the relevant information about system parameters that allow any clear solution to be possible. Climate modeling systems that are used to forecast possible effects of global warming are a good example, they can simulate certain scenarios given particular paths humanity takes and this can be useful to guide behavior, compare possible proposed solutions, or describe possible outcomes, but they can't themselves predict future behavior. A specific industrial process at a specific place, however, is limited enough in scope that you can effectively measure the relevant parameters with enough accuracy that systems of differential equations can be used to construct an adequate representation of the system. These systems are also often complex enough that that is the only way to adequately describe the system.

It should be noted here that these are not in any way opposed systems of mathematical modeling. The kinds of differential equations that are used to model complex systems, even nonlinear systems of differential equations, tend to be the kinds of differential equations that can be solved, and they almost always can be solved or approximated because they can be reduced to linear algebra problems by applying this formalized treatment of matrices and vector spaces. Even problems of differential or integral calculus essentially consist of forcing principles of linear algebra onto nonlinear mathematical objects. Linear algebra is in a real sense the only mathematical subject we truly understand and our understanding of other areas of mathematics comes from applying these fundamental theorems and concepts from linear algebra to those other subjects. Ultimately, when talking about the mathematical representation of a system, or for that matter, all of the mathematical descriptions of the fundamental physical laws of nature, it's vector spaces all the way down.

So, with whatever new insights you've managed to glean from that, let's return to the only subject of any real interest to all true Marxists the world over, that of agricultural machinery and the agro-industrial complex we all know and love. We have our foundational, complex, industrial system conveniently hanging in the vacuum of space, surely being admired at a distance by God and his angels, who nod approvingly, interacting with itself at all hours of the day and night, capable of producing an exact copy of itself on a whim. Its internal interactions have been delineated by an adjacency matrix by God's only perfect creation, the subject of linear algebra. Its individual facilities have themselves been modeled dynamically by applied systems of differential equations that describe how the individual components that together constitute those facilities interact with each other to produce the overall system behavior. Now, for this system to be able to produce an exact copy of itself, as it is wont to do, it must include within itself the means of producing all of these individual components that constitute its facilities.

Imagine that you took all of the useful minerals contained in the earth, as they exist in geological formations right after you rip them out of the ground and made big piles of them in a big circle. There are a lot of these minerals, but they aren't infinitely many and some of them will be roughly interchangeable. The circle is big enough that you can set down our foundational industrial system inside of it and you put a really big building in the middle of it, big enough to contain all of the means of producing all of the individual components. The industrial system contains the facilities that refine all of these mined minerals into the raw inputs for the system, smelts the metallic ores and forms all the metals. The industrial system also contains a tree plantation that feeds an additional pile of wood together with a syngas generating wood gasification facility, where nature can be converted into a flammable gas, for its own good. This is a windy world, and a fleet of wind turbines spin in the distance, and these together with massive solar panel arrays and a glowing concentrating solar power tower with thermal storage, feed the system an intermittent stream of electrical energy.

You go into one of these facilities and take a component out of it and place it in the middle of the big building, and break it down into all of its individual parts. You then inspect each piece carefully and determine how it was made, what it's made out of, measure all of its features and draw up a blueprint that includes all of the processes and the machines that must perform them in order to replicate the part. Whatever machines you need are placed in the big building and the raw materials are brought in, the time to set the machine up is recorded, and the time to make the part, and the time to tear down and bring the machine back to its original condition, and the raw materials required and energy consumed to make the part. You do this with all the parts, adding more machines into the building as they are needed, then you form them all into a replica of the component, put that in the place of the original, and the original is dragged out several miles away and put on the ground. The blueprints are rolled up into scrolls and put in a big library of Alexandria type storehouses of all human technical knowledge.

You keep doing this with all of the components of the facility until, Ship of Theseus style, the entire facility is composed of replicas and the old facility is rebuilt several miles away. Do this with all the facilities until the entire foundational industrial system has been replaced and a replica of it is constructed several miles away. Inside the building is now all of the machinery required to replicate the foundational industrial system, and in the library is all of the technical information required to do so, along with all of the information needed to estimate the required materials, energy and labor time for producing any of the components. This isn't the only information obtained from performing this replication, you also now have all of the interactions between the surrounding foundational industrial system and this internal machine complex, which you can use to construct a graph of the system.

To complete the replication, you take each machine in the building and put it into the center of the building, break them down into their components and repeat the process, until no new machines need to be put into the building and the big building a few miles away contains all of the original and new machines. This gives the interactions between the components of the internal machine complex, that combined with the casting processes of the foundry, form the heart of the machine that facilitates the circulation of fixed capital through the system by physically reproducing it, and if fed raw materials, labor and energy, can reproduce itself. I think that in any technical system, you can extract out of it a machine complex of this kind, it can replicate itself and it can replicate any other sort of mechanical object by throwing it into its center and expanding the machine complex to include it.

In this sense, a food system can't be considered to be separate from this industrial foundation, a food system is this industrial foundation once it has been expanded to include the systems that are replicating its operators and designers. Now in the system I'm trying to develop, I'm assuming the industrial foundation that I have described earlier, but this same basic pattern holds no matter how simple that industrial foundation is, even if it's consisting of a network of stone tools forming each other. If a food system is to be physically constructed from scratch, the hard part of that project isn't the activity of farming or cooking, it's assembling the infrastructure required to build a tractor, build a refrigerator, or build a combine. If you're trying to design a food system, the industrial objects necessary to operate that system are as important as the specific methods of cultivation or fertilization, because they are one interrelated system.

In this simplified abstracted industrial system, there is one machine of each type, just enough to represent the fundamental structure of interactions between components of the system. If this industrial system can make a copy of itself, it can make copies of every component it is composed of, and with data from previous replication events we can know the raw materials, labor and energy required to accomplish this and project the series of processes necessary to increase the quantity of components by some magnitude forward in time. So, relative proportions of these system components can be altered, if needed, or the overall extent of the system itself can be expanded or contracted, by replicating individual components or removing components from the system and then scaling the rest of the components of the system based on internal system interactions so that, as a whole, a state of balanced production is achieved. This is what the linear programming methods of Kantorovich and Leontief are meant to accomplish, to scale the system components in such a way that they are in proportion to a given set of production goals.

In such an expansion or contraction of the industrial system or its subsystems, the system is subject to fundamental material constraints. Individual system components have a capacity or rate of production at the initial system state, before this change occurs, the whole purpose of this disproportionate growth or contraction is to alter the rate of production various system components are capable of. There is a finite pool of skilled laborers to draw from who are capable of performing these operations, workers can be trained to perform operations but this takes a certain amount of time, there is a finite pool of raw materials and energy available to immediately begin drawing from, there is a finite amount of mineral deposits we are aware of at any given time, a finite total pool of mineral deposits that are actually accessible, a finite area of land actively producing organisms at probabilistic rates, a finite area of land that is capable of producing any specific organism at probabilistic rates and a finite area of land available for cultivation without inducing global ecological destabilization. For long-term system stability, the overall industrial system must not continuously increase in size, it must be kept at a size well within the boundaries of these system constraints. These system component expansions and contractions are being performed mainly to alter the relative proportions of system components so that they better serve the immediate needs of the population. Overall system expansion is only performed to initially establish such a system and overall system contraction is only performed if the system has mistakenly overshot and has expanded beyond its system constraints.

VII. ECONOMIC PLANNING & LABOR-TIME ACCOUNTING

In the labor time accounting system Marx describes, commodity exchange is replaced by distribution according to labor time contributed, after all of the deductions have taken place that allow that system to make sense. The socially necessary labor time required to produce a product establishes a standard unit of account so that labor time contributed by an individual to society can then be taken back in a roughly equal measure as individual consumption. This is a nice feature because individual consumption is regulated in such a way that no one is taking from the stock of social products more in terms of labor time required than they are providing to the system. Withdrawals of products from the stock of social products give us a way of determining local and system wide consumption rates that should inform the requirements of the social productive processes. It doesn't seem like it would be too hard to just design the logistics system to adjust production and the transport of products to local warehouses in response to these signals. It's often insisted that this is not a market, but it sure seems an awful lot like a market, though it's a very weird market structure. Maybe there is some subtle definitional difference that I'm not appreciating, like that a market explicitly refers to commodity exchange, but I don't have any real problem with seeing this as some sort of market socialist system. It has marketlike elements at least with some degree of self-regulation and operates in a way analogous to a market system with price signals that can continuously adjust supply and demand, but overcomes the negative aspects of production for profit.

Now, there is a passage in the Critique of the Gotha Program just after the part where Marx is describing this system that says, "In spite of this advance, this equal right is still constantly encumbered by a bourgeois limitation. The right of the producers is proportional to the labor they supply; the equality consists in the fact that measurement is made with an equal standard, labor. But one man is superior to another physically or mentally and so supplies more labor in the same time, or can work for a longer time; and labor, to serve as a measure, must be defined by its duration or intensity, otherwise it ceases to be a standard of measurement. This equal right is an unequal right for unequal labor." Kliman, and a lot of other people I've read, interpret this to mean that in Marx's system, individual remuneration will be based on the labor hours contributed as well as their individual "intensity" of labor. I had always interpreted this passage to mean that the system isn't primarily trying to enforce absolute equality in society, that Marx accepts that in the lower stage of communism there will still be social inequality simply because people's abilities and needs are unequal. If Marx is suggesting what Kliman is saying, I think we can safely say, fuck trying to objectively measure every individual's intensity of labor because that seems fucking impossible. Moving on.

The Fundamental Principles of Communist Production and Distribution is a very interesting text, but it's light on details about how this system of labor time accounting gets tied in with a comprehensive system of economic planning. That's not exactly a fault of the text, I think there are a lot of ways a system like that could be planned that would all work. It succeeds I think in what it sets out to do, it very clearly and systematically explains the system Marx was putting forward for how a socialist mode of production would work, the history of the thought of economic planning that led up to how this ended up being implemented and why that had such a negative effect on the social structure of those societies. It fleshes out their conception of how this might work and why using labor as a unit of account is essential to implement immediately if you want to successfully establish the socialist mode of production.

The basic organizational structure they put forward, to the extent they provide this, is compelling and an interesting way to go about things. Their structure of guilds or productive associations is reminiscent of some of the syndicalist conceptions of organized production, but without the rather convoluted underlying economic system that you usually find in that tradition. They say that behind all this you have a system of economic planning, but I'm still not clear exactly on, in their conception of this system, how the rates consumer goods are being withdrawn from the system in each locality gets responded to by the productive system and coordinated, if this is done by planning periods or is being continuously adjusted. They kind of just fall back on, the producer and consumer associations will decide by communicating with each other, but there is clearly the idea that the flow of products through the system directly indicates demand rather than it being indicated through an arbitrary profit mechanism as in capitalism. I've only read the first edition, so maybe some of these things were more clearly addressed in the second edition and I'm not aware of that.

This system would be a lot easier to use for products that are truly reproducible and don't rapidly deteriorate, that can sit around for a while and be moved around as needed throughout the system. How the labor required for transport is accounted for seems complicated, it could either be added into the labor required for the product in aggregate or accounted for with the communist tax for infrastructure. You could also have regional variations in the cost of products that reflect local differences in transporting different products to different locations, which seems almost essential for the accounting system to account for the actual labor required for intermediate products used in productive processes. The final transportation cost, once the product has left the productive facility, is really what needs to be addressed, all of the other transportation costs can be adequately incorporated directly into the labor time accounting system that is suggested in the text, though this never seems to be directly addressed. If this cost is accounted for in aggregate, either by the labor cost itself or indirectly through the GSU system, labor that is being performed due to the spatial distribution of products throughout the world is being effectively obscured, the individual consumer does not see this cost tacked onto the labor time representation they are confronted with when the product appears before them on the shelf, or more precisely, they do see this value but only in aggregate, it is not directly tied to their individual position in geographic space.

It seems like this would be most problematic with food distribution, a globally aggregated labor time accounting for food is obviously not going to reflect the cost of getting each type of food to each locality. Accurately representing the actual labor cost required would require some sort of regional variation in labor cost for each particular region. Though long-distance transport of ingredients for cooking needs to be minimized, there are clearly plenty of reasons this would still be commonplace, so it seems likely that however this system works, labor costs aren't going to be identical for the same product type in all localities if the labor cost that appears on the shelf is to serve its fundamental purpose in this system of distribution, to indicate to the consumer in as transparent and clear a manner as possible, the socially necessary labor time required to reproduce this specific product of labor and to place it onto this shelf that appears before them.

Producing a pint of strawberries in January is not the same as producing a pint of strawberries in June in every region of the world, even if globally the aggregate socially required labor time were to somehow remain the same throughout the year because the cyclical production rates average out or can be forced to average out over the entire geographic expanse of the earth. If those strawberries need to be transported from a farm in Peru to appear on a shelf in Vermont in January, their embodied socially required labor time is fundamentally not the same as it would be on a shelf in Peru in January. It takes a great deal more labor time to accomplish this than would be represented in a globally aggregated system, the consumer must be informed, through the labor cost presented to them, that we can get you your strawberries in January, but this will be done at a cost that you will need to provide through an additional expenditure of labor power if our global system of labor time accounting is not to be thrown all out of whack by your incessant demands.

Now it needs to be made clear that this does not constitute a price policy such as shadow prices, this is simply a more nuanced representation of embodied labor time that represents labor costs as the sum of vector components, one is the average socially required labor time globally that a product requires for its reproduction, the other is the concrete labor time required to physically move this finished product from one location to another. This allows the labor cost to contain within it a spatial component, because the spatial distribution of products at any time in any society is fundamentally an aspect of product distribution that must be accounted for in any system that seeks to regulate how products are distributed on the basis of embodied labor time. Maybe this problem can be addressed by just excluding extreme cases from circulation, or it somehow isn't actually a problem, or this solution introduces new problems that are worse and that's not apparent to me. It seems like this is a system wide problem that needs to be dealt with in some way, and I don't see any clear solution to it other than a local spatial component being included in the labor cost representation.

Transport is not that big of a problem in the long run, our current freight transport system is incredibly badly designed when compared to what could be done with simple electrified rail, but it's still an important consideration especially for the long-distance transport of products. It becomes much more complicated once you are moving products that can rot, you don't have the same maneuverability where you can let a car sit in the yard to make up for slop in the scheduling system. Trains aren't just moving from point A to point B, they are moving node to node and being broken apart and reassembled, most of the time a car is just sitting not moving and the rate it can move through this system is not determined by the speed the trains move but by the rate of this sorting process. Movement of products through the system is not a minor consideration, it is a very important aspect of coordination, and that process needs to run smoothly if you want to be able to rapidly adjust process scheduling to local changes in the rates of consumption without excessive time delays. In the modern economy, this sorting problem is often sidestepped by shifting transport to trucks that can facilitate point to point transport, but that comes with a massive loss of efficiency in terms of energy, labor time and raw material consumption. That can be somewhat alleviated through local food production, but you will absolutely need to be able to move perishable food through this system to balance out stochastic variations in regional yields and to increase the local variety of food ingredients that are constrained by local environmental conditions, and that comes at a high social labor cost.

Now, there are other problems food introduces into this labor time accounting system besides the complexity of transporting perishable goods. Previously I described a labor time accounting system for food production that models all of food processing as a series of batch processes that culminates in either a shelf stable product or a prepared meal. There is no inherent difficulty there, the labor time can be effectively measured as with any other productive process. Within the domain of food preservation, transforming organisms into foods that don't rapidly degrade, this becomes relatively straight forward, these products can be effectively treated as reproducible because they are being made in a standardized way at scale. What is not freely reproducible is a freshly prepared meal, the products flowing from the cook's hand are as much non reproducible works as paintings, they are an individual interpretation of food categories continuously developed over generations, they are studies in the subjective experience obtained by the transformation of mixtures of organisms by the application of heat and knives. If you want to obtain an average socially required labor time for the product of cookery you are effectively averaging a set that contains one element, the labor time spent in preparation and the final cooking can only be expressed in any meaningful way as the concrete labor time embodied in the product of cookery, period.

No universal system presents itself as an obvious choice through which these processes are to be carried out. If you want to maximize the range of prepared meals, everyone must have access to a well-stocked kitchen to cook in, that much is clear. If you want well trained cooks in the collective kitchens, they need to learn at their mama's knee, that also is clear. Nothing can replace home cooking, the quality that is possible there through sheer obsession and dedication is a level of quality that a collective kitchen can only vainly aspire to. The home kitchen can't be done away with entirely or replaced with some kind of communal group kitchen, it also can't be the sole system of cooking, after a day's work people need the option available to them to buy a hot meal. Socialized cooking also plays a role in regulating the stockpiles of the ingredients used in cookery, the cook's task is to transform the ingredients overwhelming the food storage system into prepared meals. Due to the unpredictable nature of food production, this must be accomplished on the fly and must be able to be done for any given collection of ingredients in a way that satisfies the nutritional requirements of all the individuals in the community. That is why the cultural heritage of accumulated culinary techniques must be at the cook's fingertips and organized in the way suggested by the recipe indexing system, to develop the cook's repertoire so that it is capable of immediately transforming this ever shifting and fluctuating storehouse of ingredients into the meals that the workers bellies hunger for. There is no other way for this to be accomplished without large scale waste, there is no time to delay, the food will rot and waste away if it is not immediately converted into an object suitable for consumption.

Under capitalism, the "hospitality industry" is imagined to be part of the "service industry," though that is obviously not the case, cooking is fundamentally a productive process. Perhaps this is a historic relic of cooks being the servants of the wealthy, but they make a product out of products, this is not at all some sort of service being provided that has no identifiable product of labor. I can imagine it being suggested that perhaps the weird behavior of the food industry can be incorporated into the GSU, where all of the social activities that don't fit nicely into the labor theory of value get crammed into to ameliorate the problems they present to the labor accounting system that is to form the basis for the socialist mode of production. This doesn't seem like a reasonable solution, though it could be done. Very often a person's appetite is only properly satisfied by some obscure delicacy that isn't to be consumed constantly but periodically and these moments form in periods of pleasant retrospection the illusion that our lives are more than a continuous sequence of miseries. These only temporarily obtainable subjective experiences need to be made available on demand to the laboring masses, although they can never form the primary basis of a food supply, and so they need to be accounted for in terms of the labor cost associated with them. Such is the nature of human life, to be constantly presented with the potential for contentment and to have this opportunity snatched away by the limitations inherent in the productive processes present in any particular period of economic history.

This is the domain of the high quality kitchen with a regional focus, with its own specialties and a high variety. It can only be sustained in an area with a relatively high population density, its output can't be made on an immense scale because it requires a high labor input and at any given time there will be a relatively limited demand. Its ingredients may be expensive, but they don't need to be to attain a high quality, its purpose is merely to make available traditional foods that either can't be recreated in a home kitchen or to approach the quality of the skilled home cook at a larger scale. Its cost of production is relatively high, but that is unavoidable due to the nature of the processes involved and this will vary from kitchen to kitchen depending on the foods made. This is the highest level that socialized cooking can aspire to, to adequately represent all of the major world cuisine types in a single community would be a major accomplishment. Food waste would be hard to manage in these systems, something would need to be done with food that is prepared but never purchased. Included among this sort of establishment would be pubs, pizza shops, chocolate and candy shops, bakeries, donut shops, pastry shops, ice cream parlors, and all of the other various small food producers, and it would be neglectful to do entirely without them.

There are also institutional kitchens, where large amounts of food can be cooked at once and not necessarily at a low quality, but the potential variety of meals prepared is limited to the sorts of meals that lend themselves well to this style of cooking. With just a few smallish 40 gallon steam kettles and broiler pans, a handful of people can easily cook for a thousand people at a time and the labor cost of a meal can be driven down nearly to the cost of the ingredients and energy consumed. This is the style of cooking I do when I prepare soup, though my scale is limited due to a lack of capital and I'm doing it to freeze or make it into powder. Certain styles of cooking lend themselves to this technique rather well, Indian and Cajun cuisine come to mind. If done well, quality can be maintained at scale, but you are dropping the variety available at a given time, in a day only a few types of food are going to be prepared, though the meals could change each day. This would also be the sort of thing a basic cafeteria or buffet style establishment would be doing, though there, variety at one time is raised quite high, but it remains the same day to day. This has the advantage over a smaller kitchen of lowering the socially required labor time involved in cooking, and if this is prioritized over an ability to choose among many options, and it would justifiably be for many people, it can be an extremely efficient system of mass producing high quality nutritious food. It also allows you to draw a lot of a handful of particular ingredients out of the food storage system in a local area at once, and this is very useful for maintaining fresh stock of produce. A well designed food cooking system really needs both of these to properly function as an efficient system that can minimize food waste and provide the full range of variety together with low cost options, along with providing people with the ability to cook at home and develop their skills, in kitchens that are actually designed to be cooked in.

Let's return, for a moment, to the agricultural system as a whole. The best that can really be done from a planning perspective, is to create for each agricultural region a set of crops that

is as balanced as possible and to model each plot using the information available to create a probabilistic estimate of potential yields the region can be expected to produce. There is no way of predicting in that system exactly what will be obtained at the end of that process, there is an expectation that over the large scales involved the actual yields obtained across all regions will approximately correspond to these probabilistic estimates. There is a baked-in incentive to slightly overshoot the food supply and what we don't consume can be fed to the hogs, to reduce the likelihood of famine or the unpleasant situation of barren shelves. Once the seeds and transplants are in the ground, the output is set, and this can only be increased by the diligence of the cultivation process and the continuous battle with the rot. It is only after the fact that for a given piece of ground the system can be adjusted in light of new information, it is only after the harvest that regional variations in yield can be adjusted by regional transfers, although these harvests are in some sense continuously occurring. In addition, this is an inherently cyclical system, the goal is to arrive at a stable system that can be repeated year after year with minor refinements and though it displays fluctuations, these are within acceptable limits that permit the reproduction of human labor and the satisfaction of basic nutritional requirements.

I think a modeling system incorporating mathematical representations of the sorts of soil property balancing systems I described earlier, combined with crop growth models calibrated for local conditions would allow local farming communities to effectively plan their production and maintain the health of the soil about as well as that's possible to do on a scale as large as entire landscapes. Mathematical models already exist that are perfectly capable of doing that, and much more sophisticated mathematical modeling systems could be developed if needed.

There is a place for agricultural planning above that level of course. On a national and international level, those cropping systems need to be in the right proportions and planned out in a way that in aggregate they can meet the overall needs of society. Using those crop growth models and probabilistic models that can account for expected rates of extreme weather events can help test that system using simulations to see how they would perform as a whole in those cases and adjustments could be made to make them more resilient in certain ways. Once those proportions have been relatively well established there's not much need for that sort of thing unless adjustments need to be made based on the systems performance. You could use linear optimization to do things like plan the transport of food after harvests are known to distribute it through the system based on local consumption rates or something like that, but other than that, there's not a whole lot that a central planning agency would need to do here that the local community could not do itself. Once the system itself is set up, you're pretty much planting your shit and hoping for the best, like people have always done. The hard part is monitoring and modeling the surrounding ecosystem and finding ways to minimize the harm you are doing to local populations there just by using that land to produce crops and keep animals on it.

The food processing systems as well are perfectly capable of being modeled and regulated by the labor time accounting system and batch process representations I described, you have a lot of leeway in proportions of stocks of domesticates that can be mixed together to provide balanced meals. Just using the standard already developed traditional styles of cookery there is enough variety of recipes that a person could eat a different meal every day of their life without ever repeating one. The mechanical systems and energy flows through the system are what would be hardest to maintain and regulate in a system like this, you would gain a lot of systemic efficiency however by just spatially orienting everything in a way where cars can be mostly done away with and keeping the density of housing and productive establishments high so that the extent of infrastructure stays rather limited. Electric rail would make transport pretty damned efficient, especially compared to the system in place now and it could easily facilitate public transport and travel between communities if they were planned using the clustered village style I described in the model farming community. Problems are really going to be present where population densities like this can't be maintained due to resource constraints, a lack of rainfall and available ground and surface water in regions with large expanses of dryland agricultural systems or marginal pastures. If these are farmed, you're going to be limited to dispersed settlements and there is probably no real solution to that.

Regulating a system like this once it's in place, at least the food system portion, seems fairly straightforward. I don't know in extreme detail how that regulatory apparatus should be set up but I feel like it's at least possible and cybernetic styles of organization and dynamic modeling would help with that. What remains very unclear to me is what level of technical sophistication can be maintained in the long-term, how do you select from all of the possible systems of agriculture in a way that the rates of mineral and water extraction required are kept low enough that it can keep going for long periods of time. That seems at least as important a design criteria as seeking improvements in labor efficiency or system stability in the short term. Industrial systems producing agricultural machinery or infrastructure must be selected from to reduce the use of rare minerals and rely as much as possible on more abundant ones. Another part of that process involves designing equipment to be durable, easily repairable and its parts easily replaceable and recyclable. Another is developing an energy accounting system that can make transparent the embodied energy in every process and component of that system, not as the basis of transactions like in technocracy or for establishing prices, but just so it can be kept track of to determine ways energy use can be driven down. The same goes for all of the other economic processes built on top of that agro-industrial foundation, consumer goods need to be radically redesigned so a consistently high level of quality can be maintained across the board while emphasizing durability, repairability and recyclability in the design process.

How long is good enough to be considered sustainable is also unclear, a thousand years, ten thousand, forever? To what extent can we even know how many minerals can be extracted or how the variations present in mineral deposits will affect their end products. If we decide we want it to be able to continue going for a very long time and drop the mechanical systems required down very low, this is going to have very significant impacts on the rest of the system. Increasing labor time involved in food production puts fundamental restrictions on the service industry and the consumer goods system. The overall scale of the system required is influenced by the population level, what human population size are we comfortable with maintaining and how would that even be determined? A higher population size means a lower technical complexity for a given mineral extraction rate, how are these variables to be weighted? Regulation finds a stable state and maintains it, but just as in ecosystems, economic systems have an infinite number of possible stable states and once reached, these are difficult to shift back out of without a sufficient perturbation, capitalism being an unfortunate example of this. We do not even know what exactly will be left once this new mode of production can be established, capitalism has already exhausted in the blink of an eye much of what should have been the inheritance of future generations.

There is no way to calculate in a systematic way the social desirability of such tradeoffs. Maybe we can estimate according to some rubric the opportunity costs in a strictly comparative way of a set of known productive processes and their products, but there is no formula that will provide the technical solutions themselves that might exist that are hidden from our view. The physical structure of a product or system of mechanical replication flows from the design priorities of a designer, this is not some application of scientific understanding as is often pretended. It is a subjective evaluation drawn from a limited understanding that leads the design down one path that is iteratively explored while innumerable possible pathways go neglected. This process may take into consideration and incorporate material properties and mathematical descriptions of forces or interactions, but these are all secondary considerations to mold the physical world into a structure that will satisfy the initial design priorities. If we want to restrict the use of iron ore so it can last a thousand more years based on what we think we clearly have, state that and build the system in a way that can be done. If we are trying to stay within acceptable planetary boundaries that if crossed will rapidly destabilize the entire system, those need to be clearly defined and the system designed within it, we don't need some elaborate system of shadow prices that we hope will indirectly guide consumer choices to avoid planetary meltdown. As far as I can tell we don't even know what those boundaries are or how they could be determined.

I suppose in any sort of proposal suggesting a cybernetic system of social organization this is to be done by those higher level systems involved in future planning, but that seems about as unsatisfying as the council communists reassuring me, when the path to be taken becomes less clear, that the cascading system of workers councils will decide. Ultimately, agricultural systems need to be worked out at all levels of technological complexity, I don't know what the fundamental limitations to the system are, like mineral or water resources, population levels, energy availability, the extent of growing lands, the requirements of the biosphere as a whole to minimize our current mass extinction event, and I don't think anyone really does. Developing that understanding would get us closer to more realistic ideas about how food systems need to be, but we need a wide variety of design proposals that assume different levels of mechanization and industrial development.

Just to develop the infrastructure required for a food system with relatively high mineral and technical requirements, if that ends up being feasible, we need simpler systems that can be put in place first to sustain us in the meantime. The food system I described includes combine harvesting of grain on a large scale, because as far as I can tell removing that with as high of a population as we have today could have mass genocide inducing consequences. It assumes that a transition away from fossil fuels is possible that could be efficient enough energetically to accommodate cold chain systems, season extension structures, liquid and gaseous fueled engines, large mechanized vehicles and a complex system of cookery that can maintain a very high variety of foods. That would all be very nice to have, but it's entirely possible that raw material restrictions might be far more extreme than I realize that could make such a system unworkable. I'd love to see other approaches that assume an oxen driven system or how this might work entirely without combustion engines, but the kind of stuff I generally see done along those lines tend to be rather limited in imagination or amount to a return to homesteading or feudal society.

I'd really like to see more work done on economic planning systems that try to incorporate cybernetics into the fundamental principles framework. The only system I've seen that uses labor vouchers over a shadow price system is Cockshott's, and though it's actually rather good compared to the others, he's trying to do too much with simple linear programming methods and you can definitely see his Leninist background in his model. I just don't see the appeal of the shadow price approach, it's so unimaginative and fundamentally unworkable. It seems like it's coming from a perspective that can only conceive of an alternative to capitalism as an artificial recreation of its pricing mechanism where all economic information needs to be ambiguously mashed together and represented as a single set of exchange values. I do actually like Lange quite a bit, I'd really like to get around to reading his later book where he explicitly tries to incorporate cybernetics into an economic planning system and Kantorovich is also quite wonderful, I want to go through his appendix in detail to better understand what he is suggesting there, which I can mostly follow.

VIII. CONCLUSION

I wish I could tie these systems together better for you, I'm afraid I'm not acquainted enough with the literature of economic planning or cybernetics to do it any justice, but hopefully the agricultural system I described here sheds a bit of light on possible agroecology minded approaches to food systems that may be useful in such a system, though I feel like I've barely scratched the surface of what I'd like to say on the subject. I also don't have the mathematical sophistication to draw up a formal model that could adequately describe the sort of planning system I envision a socialist economy like this might have. I only know enough mathematics to be able to understand how particular branches can be used to model certain system components, there is unfortunately so little information available on these things. I will say that I don't think anything short of a true spatio-temporal model will do, I don't like these really simple vector space representations you see in parecon's formal model. These planning period systems are totally inadequate, you need continuous planning processes and dynamic system representations to get anywhere near what you need. Hopefully, eventually, I can find the time to study the higher mathematics required to understand these topics and describe the system I can imagine in more detail, something I'd really like to explore further.

One last thing, you guys have been reading a lot of the more recent ecological Marxist texts, which I should really get around to reading someday. I've only read a few essays by Foster and Moore, but I wonder if they went into the ideas of Lewontin and Levins at all in those books you read. The Capitalism and the Web of Life book seemed like he was lifting the whole cartesian rationalist foundation of ecological thought straight from Lewontin, which is kind of a recurring idea you see in him. Maybe that's just a coincidence because that's the only other place I've encountered that idea before and it's more common than I realize. I did manage to find this quote in an interview of Moore's which I think supports this idea. "It was with Bellamy Foster that I learned Richard Levin and Richard Lewontin on the Dialectical Biologist – and I still remember saying to Bellamy Foster in a seminar that this should be our methodological text, and he sort of laughed it off and didn't quite know what to do with that. He still celebrates them, but does nothing like what that dialectical imagination does."

The Dialectical Biologist is a wonderful book and Lewontin and Levins influenced me immensely. They were both extremely important theorists in evolutionary biology who, along with Gould, were very openly Marxists. I don't know if you'd want to do an episode on that book, it's just a collection of essays, but I did find a free version of it online, though it's full of errors and the equations are all garbled. It'd be worth reading, if only for your own benefit, most of it is pretty easy reading but a few of them are more technical essays on biology. At the very least you should consider watching some of Lewontin's lectures, especially his Massey lecture, Biology as Ideology, which is on youtube. There is also an excellent three part lecture series he did at the Santa Fe Institute on there, they are called What is Evolutionary Theory?, The Organism as Subject and Object of Evolution, and Does Culture Evolve?. There are a few videos with Levins on there but not a whole lot, one describes some of his work in Cuba helping them to develop ecological farming systems.

I hope that helps explain in more detail what I've been working on. Sorry for the delay, but there was quite a lot to go over. Properly explaining each subject requires some other subject to be explained until the entire thing grows out of control and I've still left out most of what I'd originally wanted to describe. This was going to continue on to include an overview of how these systems can be developed within capitalist society and what that developmental process might look like in its nascent stages. This was to include how rudimentary textile and heavy machinery infrastructure can be developed by reverse engineering things like the old Draper looms, early knitting machines, WW2 era machine tools and agricultural machinery of the 60s to 80s before computerized control began to be implemented. That will require another text at least as long as this one and be more difficult to write as my ideas on those subjects are less developed, but hopefully I can get something out to you eventually along those lines.

Hope that you are doing well too comrades, if you have any specific concerns or questions about the things written here let me know, I can go on in more in depth about any of these subjects. It is very nice to see any sort of interest in what I'm doing, I have been working completely alone on these things for two decades without any sort of outside input, any suggestions or criticisms would be much appreciated. I mostly just thought this information would be useful to you to help you develop your understanding, your discussions of Marxist literature that I no longer have the time to read have certainly been useful to me so I thought I should return the favor. The sort of stuff you are likely to find on this sort of thing is going to be in general very badly researched and impractical, almost no serious work is being done on it. It is good that you are looking to the agroecology literature, that is about the best of it, especially the work coming out of Latin America where the discipline seems to be centered these days.

Nearly everything coming from permaculture and biodynamics is going to be intellectual poison, anything valuable they might have to offer is simply being lifted from other more developed systems. The alternative agricultural movement is dominated by liberals and the far-right libertarians and they thoroughly infest it with their half-baked doctrines and pseudointellectual culture. These systems can only be developed into what they need to become by the socialists, but unfortunately this work has been almost completely neglected. I appreciate the work you are doing to raise awareness of these issues and encourage you to continue researching these things. There is a great deal to learn and connections to be made between very diverse disciplines. Continue in the struggle comrades, these ideas must be spread, the Lamp of Science must burn, alere flammam!

-Will

“The Marxists want the working class to gain control of the means of production, but they don’t generally seem to show much interest in them. I don’t think most Marxists would know what to do with the means of production if they did have control of them. Technology appears to them as a great jumbled mass, and they see the great harm it does, and they see its great untapped potential, but its complexity raises an obstacle to their understanding.”

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