Ca' Foscari
University
of Venice

Master's Degree programme
in Environmental Humanities

Final Thesis

To harvest: promises and perspectives about modern agriculture

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Academic Year
2021 / 2022

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Abstract

Modern agriculture is but the latest stage of development of a human practice that has been brought forward by the entangled collaboration of multiple factors, such as the technical developments of the 20th century, the beginning of the Green Revolution, and the stabilization of the capitalistic systems. The ecological consequences of modernization have posed serious threats to local ecosystems, and its development has arisen at the expense of biodiversity, air quality, and the relationship between humans and microbes. This could be read as a significant acceleration of a trend lasting more than 10’000 years, since the beginning of agriculture itself.

Going back through the history of the practice of agriculture up to the last centuries, the present essay will try to define the contemporary situation, and highlight the problems and key issues related to the topic at a global level.

Expanding on the fragile but crucial relationship between humans and microorganisms, today threatened as a direct consequence of the exploitation of agriculture, the role of microbes in the management of natural resources will be taken into consideration by studying models of their functioning.

Introduction

What connections does the practice of agriculture possess with the daily lives of humans in the 21st century? What does this practice represent nowadays and where does it come from? Why is it important to talk about it in light of the current ecological crises?

It has become increasingly clear that it is impossible to think of history as an exclusively human product; other stories besides that of our species claim space and centrality in historical, economic, and social discourses, and, at the same time, the understanding of the biological and ecological world cannot be achieved without taking into account human history. The ecological crises that are characterizing our time appear as useful clues to better understand the reality of our societies. There is a temporal gap between each historical moment and its full understanding, which usually takes place in a more-or-less-near posterity. In this gap, we mature the awareness that we need in order to interact with the new present[1]. Time makes the task of an unbiased and detached interpretation of certain passages of the history of human evolution easier. In theatrical terms, the anthropocentric understanding of history and evolution sees the human being as the main character in the play; the intent of the present work is closer to the *site-specific* approach, in which the scene is not performed inside the theater, but it takes place outside of the walls of the building, in a natural scenario that substitutes artificial scenography. The idea behind the *site-specific* practice is to make a theater out of any space, while respecting and building on the conditions it poses. While in a theater all stage conditions can be realized and satisfied according to the specific needs of the hosted show, a street is a living place, which can not be shaped at will, and which dictates the conditions that must be understood and respected in order to carry out the show; a show that thus becomes a practice of listening and welcoming of conditions that extend beyond the mere need of the show itself. It's an exercise of *mediation*.

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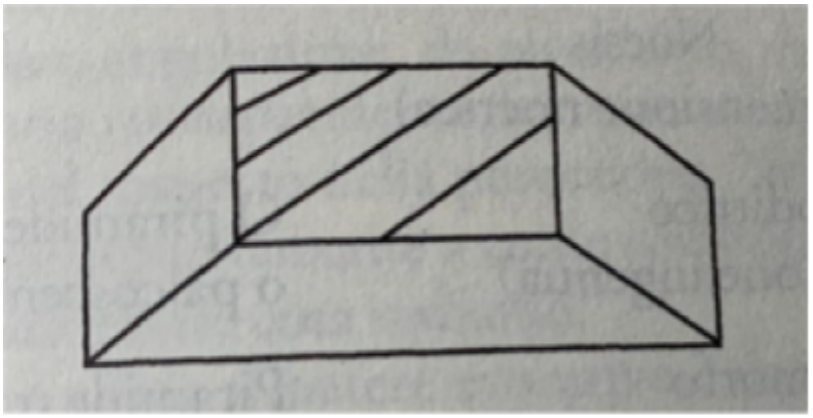
[1] M. S. Swaminathan, was an Indian agronomist born in 1925, director of the International Agriculture Research Institute (IARI), and many other companies involved in leading the Green Revolution in India. He was directly trained by Norman Borlaug and in India he's considered the father of the revolution. Mr. Swaminathan is also the founder of M.S. Swaminathan Research Foundation#. Throughout his career, he was a promoter of the idea of an *Evergreen revolution*. A revolution that follows the GR and implements its potential of a "prosperity in production", sustainable oriented. The image of *evergreen* arouses the image of the evergreen leaves of some plants that thanks to a balanced ecosystem they can survive all year long, like evergreen plants; through the repetition of a balanced cycle, it is guaranteed the perennial conditions for the plant to live. But evergreen plants are not the only plant that inhabits the Earth, other plants are not evergreen; there is a cyclicity. So, will this future evergreen revolution, the revolution for sustainability and ecosystems, be aligned with a real restoration of ecosystemic balance or just another benefit for specialized sectors? Will sustainability work? We are up to seeing it, but we will just acknowledge it in the next decades.

Agriculture can be seen from at least two different viewpoints. On the one hand, it is an economical and technological system; on the other hand, though, agriculture also exists in the form of smaller or larger actions performed by human beings for the biological purpose of self-sustainment. From this last perspective, the human approach to food production does not inherently differ from that of other species, in that in both cases living creatures interact with their surroundings and shape their habitat in a manner that allows them to meet their self-sustaining needs. The knowledge we have achieved in all related fields allows to draw a comparison between agriculture and the self-sustaining practices of other species, in order to gain perspective on our ways and move small steps outside of the given conceptual tropes. Complexity is the main problem to be reckoned with when adopting this approach; it is already inscribed into everything, but it becomes a perceived characteristic only in the moment of its understanding. I will propose an example to investigate it:



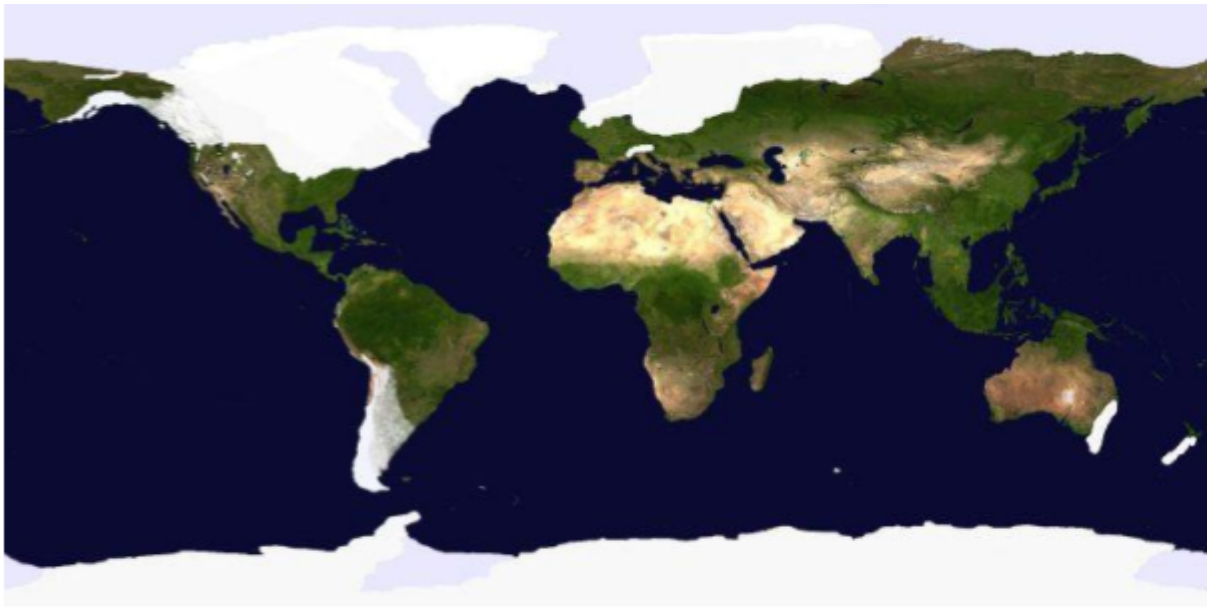
The exercise is taken from Scalvi, M. (2003) Arte di ascoltare e mondi possibili, Come si esce dalle cornici di cui siamo parte. Bruno Mondadori, Milano

What do you observe? It can be a full or empty image, or even just a set of lines without logic. It can be a room, a theatre stage, either a solid figure or a truncated pyramid. How did we manage to transition from seeing one kind of image to seeing the other? Once we experienced the multimodality of the picture, we lost the so-called *naive vision*, the vision that links this picture with only one possible representation. It won't be easy to go back and watch it just as random lines, or an empty room. The two perceptions cancel each other out and in order to switch from one to the other the observer must change their interpretation of the perceptual world. Likewise, in overcoming the *naive vision* we abandon the singularity of a single viewpoint and embrace the interdisciplinary approach that characterizes Environmental Humanities.

Chapter 1
Overground. Agrostories of a practice

Back on the '-cenes'[2] of the Earth: development of agriculture

During the geologic era of the Pleistocene from 3 billion to 12'000 years ago, Earth was in a period of deep glaciation. Temperatures and climatic conditions have fluctuated many times in order to follow conditions of ecosystemic balance. The ice caps took possession of the main islands mainly in the northern hemisphere of the globe and, less extensively, also in the southern hemisphere. Within this period, 22'000 years ago conditions reached the glacial maximum where temperatures forced the inhabitants from the territories of modern Europe to extreme Siberia to retreat to inland places at lower latitudes as in the modern French-Cantabrian area, in the Balkans, north of the Black Sea and the Caspian Sea, in south-eastern Siberia and on the Pacific coast of North America[3].



USGS website (february 2023)

Around 12'000 years ago the last North American ice sheet collapsed, and the process of glaciation started to reverse, leaving the great lakes on the border between the United States and Canada as footprints. The melting of the ice sheets caused a rise in sea level of hundreds of meters, with millions of kilometers of coasts submerged by water. With the increase in

[2] The expression '-cenes' is used here to refer to the geological times of the Earth's development, to create a more entangled history of the development of the practice of agriculture, trying to adopt a more holistic point of view where more than human subjects are included

[3] https://www.preistoriaonline.it/le-fasi-dellultimo-periodo-glaciale

temperatures and precipitation, the surface of the planet experienced a decrease of ice caps, allowing the accessibility of new territories rich in nutrients and characterized by great fertility. The conditions of many living species changed and their evolution and progression were made possible by such environmental modification. Temperature raised and climatic conditions unveiled new natural ecosystems. The blow of natural environments previously buried under the ice, the gradual flourishing of wild plants, and the spreading of vegetable species around all territories after the deep and cold glaciation, proved to be a magic stroke for every living species. The ability of animal and vegetable living species to use natural resources allows them to survive and proliferate, and genetically expand[4], gradually changing their way of living.

The historical period we are living in today and the manifested consequences of our practices should give the impulse for a moment of deep reflection on our ways of interacting with the environment. It is important to question our way of being as a species among others and heed the world around us, opening up our sight. Through the history of agriculture, we can explore the historical perspective of one of the main practices that accompany our life on the planet, trying to grab the key role of interconnectedness.

Agriculture is one of the most important *ecosystem services*[5] the environment offers to our species, it is directly linked with the population size in modern societies, and also with the economical and political spheres through global trade and the extraction of raw materials. Through workforce and progress, it is also bonded with the natural cyclings of the nutrients in the biosphere. When a plant grows, it absorbs from the environment elements like carbon, oxygen, nitrogen, potassium, phosphate and more, moving them from the *abiotic* environment (non-living) to the *biotic* one (the ensemble of the living community in its environment). When plants absorb these nutrients they release through *photosynthesis* oxygen, carbohydrates, fats, and proteins, as molecules in the environment (atmosphere) or as the biomass (body of the plant). Plants close their cycle giving back to the environment

[4] "Evolution doesn't care about hunger or suffering, only how many DNA helixes it can replicate" Harari Yuval N., *From Animals into Gods: A Brief History of Humankind*,, first published in Hebrew in Israel, Kinneret, Zmora-Bitan, Dvir (2011)

[5] An ecosystem service is the contribution of ecosystem function and structure to human well-being. Ecosystem services can be classified into four different categories: *regulation*, *provisioning*, *cultural*, and *habitat*. In the first case, the benefits obtained from the regulation of ecosystem processes are involved; these are automatic processes generated by the biogeochemical cycles of the natural system, such as purifying water, and nutrient restoration… The *provisioning* service (like agriculture) instead represents the benefits obtained by the products extracted from the environment like goods, and materials; in this case, an action of humans is needed, it is not an automatic natural process. *Cultural services* are non-material benefits that people obtain by experiencing ecosystems in a recreational way. Finally, *habitat* services represent the importance of ecosystems in offering natural spaces for all the species to live and reside in.

nutrients to supply their levy, by the falling of leaves or the death of the plant itself. Animals and fungi, instead, gain their energy from the process of *respiration*, opposite but complementary to the one of photosynthesis. In this case, the nutrients from the biotic environment come back to the abiotic through the organic matter of animals or through the work of microbes that practice the decomposition of waste. Photosynthesis and respiration are the two sides of the carbon cycle, which is the chemical base of life on Earth. The balanced functioning of this cycle is what guarantees, among others, the fertility of the soil.

During the Neolithic Age, around 10'000 years ago, nomadic communities of little groups of humans were living by gatherings of tiny amounts of products of the earth or by hunting other animals. Through evolution, they started to organize themselves in settled larger communities and gather products systematically. Agriculture is therefore meant as a "set of techniques with which natural products are systematically taken, and the set of tools with which the conditions for their rebirth are set. Systematic collecting (collection) and systematic reintegration (cultivation) are the two sides of each agricultural system"[6]. Systematic extraction of natural resources in the long term affects the natural cycling of Earth.
Between 12'000 and 10'000 years ago, during the glaciation melting, humankind discovered new ways of dealing with the environment. The practice of domestication of seeds and food (later on defined as agriculture) has triggered many societies to shift from nomadic hunter-gathering to sedentary communities, at same time in different regions of the world[7]. Around 10'000 ya, before the transition to agriculture, between five and eight million hunter-gatherers were living on Earth, as opposed to the one or two million that were left in the first century b.C. Nowadays more or less 25 percent of the whole landmass is dedicated to agriculture. Before the Industrial Revolution, agriculture was not so extensively spread; it was present as a practice in part of Asia, from Japan to Korea, part of China, the whole of India, part of the Middle East and North Africa, the whole of Europe, and part of the north and south America[8]. The majority of the human world population was concentrated in those areas, while in the nearby territories less dense populations of mountaineers, nomads, shepherds, and fishermen could be found. What is the historical process that leads agriculture to the construction of modern societies?

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[6] Malanima P., *Uomini, risorse, tecniche nell'economia europea dal X al XIX secolo,* Bruno Mondadori, Milano (2003). All translations are to be considered as made by the author of the present essay when not otherwise specified.
[7] Ibidem
[8] Ibidem

From agriculture to agroecosystems: domestication

Agriculture is a practice that was neither discovered nor invented. It is a spontaneous evolution of a process that nomadic communities were not really aware of, in that they didn't know about the effect and consequences of this new practice. Nonetheless, agriculture evolved, gradually. Hunter-gatherers were already used to feed on products gathered from the soil, but the transition to agriculture represents a different set of conditions and seems to have arisen as a kind of insurance against lean times for nomadic communities. As a regular practice, agriculture and breeding showed up in a spontaneous way only in certain regions of the world, like territories of modern Iran, Iraq, and Meso-America. These practices spread in different places and at different times and in different ways, mainly through the learning of techniques from nearby communities or through the invasion of agricultural populations.

According to anthropologist Jared Dimond several factors have helped to favor the lifestyle of farmers over that of hunters. First, the growing decrease of natural resources, and the different mass extinctions that happened after the end of glaciation, that many animal species did not survive due to rising temperatures and habitat conditions changes; at the same time, some species of seeds and vegetation increased in number, released by the melting of ice. The big climatic changes at the end of the Pleistocene in the Middle East expanded the diffusion, for instance, of wild cereals easy to collect in large quantities. Also, the increase of technological advancement in the collection, processing, and storage of food implemented this practice through time; in the Fertile Crescent the technology necessary for the practice of agriculture was not available before 11'000 b.C.; farmers would not know what to do with bigger quantities of food without tools to process and manage those quantities. Eventually, the communities of hunter-gatherers who converted to agricultural practices overtook in numbers those who did not. Hunter-gathers only survived as such, without contamination, in areas where ecological or geographical barriers would protect and isolate them. The last argument Dimond took into account is the cause-and-effect bond between population density growth and food production growth. He defines that as an *autocatalytic* process, a process where at least one product from a reaction is one of the reactants used in the process, a kind of feedback loop. The two processes of the cycle, production and hoarding of food and population growth, have triggered each other, making the reaction process faster and faster[9].

According to this proposal, around 11'000 years ago, part of the human population started to shift to a sedentary lifestyle. This turn had several consequences that modified mainly the

[9] Diamond J., Guns, Germs, and Steel. The Fates of Human Societies, W.W. Norton & Company, New York - London (1997)

social organization of communities. According to Dimond, sedentarism contributes to the *growth of population* density because, for instance, it allows for a decrease in the gap between the birth of children. In nomadism, a community has to wait for the newborn to be able to walk alone and not be carried by others. A nomadic lifestyle has to be light and agile. Thanks to the new lifestyle communities were able to give birth more frequently and meet the increasing need for a workforce for the new activities the gathering now entailed. Sedentarism also allowed the accumulation of alimentary resources and generated the possibility of developing social infrastructures dedicated to managing the *food surplus*. Hunter-gatherers were mainly egalitarian societies, organized in tribes, and all the people were involved in hunting and gathering food, without surplus and no need of managing it, working as a closed cycle. We can therefore refer to agriculture as a part of the history of evolution or "a revolution in the ability to turn to its own profit the variation and abundance of nature"[10].

The agricultural practice evolved in different parts of the world. The Fertile Crescent in the Middle East has been the first place where agriculture has been systematically practiced, around 6'000 b.C. In Central America, instead, the first domestication of seeds happened not before 3'500 b.C., and the first settled communities around 1'500 b.C[11]. Different timing for different environments. In the Fertile Crescent, agriculture ensured local communities more resources as compared to hunting and gathering. Different choices for different environments. In every place, communities were discovering how to deal with the environment around them. Sedentary life turned the human lifestyle into a new symbiotic relationship with the environment.

In the Fertile Crescent, the climate is mainly Mediterranean, with short, mild, and rainy winters and long, hot, and dry summers. To adapt to this kind of environment, species of vegetation need genetic traits that allow them to survive the dry season and rapidly grow during the rainy season. This kind of plant is called an *annual plant*. The *annual plants* carry different advantages. They are already abundant and productive in the natural environment, which suggests that they were already known by nomadic populations before the agricultural period. Their abundance is due to their hermaphrodite conditions, in that they can pollinate and reproduce in an autonomous way. Finally, they focus mainly on the seeds rather than on the production of stem and body, since their diffusion and survival is based on the

[10] Edmud Russel, *Evolutionary History: Uniting History and Biology to Understand Life on Earth.* Cambridge University Press, 2011

[11] Diamond J., Guns, Germs, and Steel. The Fates of Human Societies, W.W. Norton & Company, New York - London (1997)

consumption of seeds from organisms. These characteristics make those plants very suitable for sedentary communities[12].

The overall climatic conditions, the presence of native species, and the environmental benefits are the key elements in understanding why agriculture developed in certain regions at different timing and why not everywhere the benefits of shifting to farming were more convenient than hunting. It is estimated that there are around 200 '000 species of plants, but thousands of them are just not edible since they are woody, with no edible fruits or unusable roots. Just a few thousand can be actually eaten; a few hundred have actually been domesticated and, among these, just some have nutrients that are apt for feeding an organism. Overall, twelve species make up more than 80 percent of the annual harvest of the land[13]. If Central America, with different climatic conditions, is not able to provide the natural growth of native species of edible plants, the benefits for communities stay greater in being nomadic and following animals and spontaneous plants. Agriculture in these places will therefore only develop as an imported practice.

Techniques for working the fields changed during the millennia but still, nowadays, more than 90 percent of the food that feeds humanity is coming from a few varieties of plants such as wheat, rice, corn, potatoes, millet, and barley[14]. With agriculture, plants and humans entered into a different mutual benefit relationship, since the consumption of plants allowed the plants to proliferate, and eating them allowed humans to live and increase their population number. In choosing each other, plants and animals implemented a technique of *domestication*.

A plant is domesticated when multiple changes have made it useful for another species. The two created a bond of reliance. The journey from native species, the ones which naturally are present and grow in a given environment, to domesticated ones is something that characterizes a big section of human modern history. By interacting with something we modify its behavior, and we become an active part of its environment. The more we interact, the more this modification has an impact. Three characteristics of plants represent specific adaptations to specific environments: germination, growth rate, and disease resistance[15]. Only

[12] Ibidem
[13] Ibidem
[14] Harari Yuval N., *From Animals into Gods: A Brief History of Humankind* (also published as *SAPIENS*), first published in Hebrew in Israel, Kinneret, Zmora-Bitan, Dvir (2011)
[15] With intensive sowing competition to survive increase. This has been the reason for the selection of bigger and bigger seeds. The bigger is the seed, the more chances to survive the others it has. Diamond J., Guns, Germs, and Steel. *The Fates of Human Societies*, W.W. Norton & Company, New York - London (1997)

a balanced combination of the functioning of these three elements can assure a significant and proper cycle of benefits for the other species that interact with plants. Alternatively, the balanced combination of these three is the result of improved techniques that allow a species to gain enough benefits to continue investing energy in doing so. Anyway, it is not just a matter of techniques, but also of the different latitudes where earth's environments are placed, creating nested ecosystems. The same plant, with the same technique in a completely different environment, has not the same process, and not the same effects. The variety of latitudes is not exchangeable.

Domestication also happens when the growth rate of the plant is so efficient that it easily goes beyond the boundaries of its area of origin; it is always easier to domesticate a plant in its territory of origin. Starting from the Fertile Crescent (about 8'000 b.C.) different centrifugal forces pushed the practice of agriculture towards other areas of the Near East. It reached Greece, Cyprus and the Indian subcontinent before 6'500 b.C; Egypt right after 6'000 b.C; central Europe before 5'400 b.C; South of Spain before 5'200 b.C; and Great Britain around 3'500 b.C.[16] Humans selected plants according to their needs, shifting the existing bond they had with wild animals and spontaneous plants during hunter-gatherer times, to one ruled by the dynamic of domestication.

At the beginning of the domestication journey, communities of farmers started to inhabit the lands and cultivate different types of plants, more or less with the same ecological footprint that hunter-gatherers were having before. From this moment on, millennia of techniques of agriculture have been more or less the same. The fertility of the soil, sustained by the cycle of nutrients, and the relationship between plants and animals define the identity of agroecosystems, systems of nested ecosystems involved in the organization of agricultural practice.

According to the different strategies used to allow the reintegration of elements in the cycling of nutrients, agricultural systems can be grouped into three different typologies of agro-ecosystems: *discontinuous agriculture* (system of "swidden"), *hydraulic agriculture* (intensive system with irrigation), *arid farming* (fallow land system)[17].

Discontinuous agriculture is not so common nowadays, but it is still present in tropical regions with low population density. In this agro-ecosystem cultivation happens for many years in a row (3, 4, 5, or more) on the same soil. As a consequence of exploitation, fertility

[16] Ibidem

[17] Malanima P., *Uomini, risorse, tecniche nell'economia europea dal X al XIX secolo,* Bruno Mondadori, Milano (2003)

reduces, and production decreases. At this point, the cultivated soils are abandoned and the soil fertility has time (20-30 years) to restore the cycle. The new soil for agriculture is found in the forest, through deforestation, mainly by wildfires, of woods or brushwood. Deforestation by wildfires is an elementary form of fertilization, as it allows the penetration of ash's minerals into the soil. This agroecosystem can work in thinly populated areas and with significant availability of soil. This system was present in Europe since the beginning of the Medieval Age (476-1492 a.C.), and it was later on substituted by more productive systems.

Hydraulic agriculture has been for millennia the most widespread system of agriculture, from Mesopotamia and Ancient Egypt to modern times. In this kind of agriculture, the fertilization of soil happens through the continuous irrigation of a complex and capillary hydraulic net. River water is way more complete with nutrients, minerals, and salts than rainwater. The biggest productions of this technique are mainly cereals, like rice, which produces five times more than wheat, both in terms of growth and of calories. Hydraulic agriculture has been present in central and south America since the beginning of the XVI century. In those economies, maiz and potatoes provided high land productivity. In the whole globe, there are natural water spots historically exploited for agricultural needs, throughout different civilizations and times, like the Basin of Indus, together with the Basin of Aral, between Uzbekistan and Kazakhstan; Valle Padana in the northern territories of Italy; Nilus and its delta in the north-east of the African continent; Aquifer of Ogalalla, under the soil of High Plains in the US[18]. Hydraulic agriculture was also used in Europe and provided many benefits in terms of production for the continent since the time of the Middle Ages. Notwithstanding, the agroecosystem mainly spread in Europe was *arid farming,* with a fallow land system. On a global scale, this form of agriculture represented a minority. In Europe, the water system was not big enough to allow abundant and constant irrigation, and neither were the lands so massive to allow the abandonment of soils for years. The fallow system expects that part of the land is periodically left uncultivated, to guarantee the restoration of the natural cycle and ensure that the cultures rotate in order to allow the whole land to periodically regenerate. Both the fallow and irrigation systems were naturally helping in the fertility of the soil, fertilization was part of the cycling. In arid farming, animals are also necessary not only for the energy they provide but also for the manure they produce, used as a natural fertilizer for

[18] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

the soil. The coexistence of agriculture and breeding is thus essential for the functioning of this agroecosystem.

Beyond the given borders

The gradual process of increasing food production into bigger, organized communities and the rise of modern societies, are crucial in the historical analysis of the practice of agriculture. It is important to highlight the fact that capitalistic relationships with the environment and the management of food began to take shape within the period of colonialism when the biggest act of grabbing soil and resources started to take place. The ability to manage lands and environments started to give rise to a tendency towards massive extraction of resources, in order to sustain the collateral system of economy, logistics, and politics that was generated from it. Among the effects of the colonial project of looking for resources to trade, a big cost has been felt in the extirpation of local indigenous communities that cared for the land and territories for centuries or millennia, according to beliefs of respect and collaboration within natural systems.

In the last five centuries, the structure and functioning of colonialist corporations radically changed several times until the creation of Nation States, but the baseline stayed the same: accumulation of *wealth.* In the project of colonization, the East India Company (Honorable East India Company) was the very first international corporation ruling on natural resources, and on their management and trade. The power of the East India Company was growing bigger than the one of any single merchant, as it worked by centralizing power. The mission of looking for new lands has always been supported by governments and political power, to follow economic and political interests. From being just a way for human beings to manage resources, the economy of multinationals (as the first East Indian Company) became the dominant economy ruling the world, dominating the economy of nature. The logic of extraction and free trade managed by those companies and brought forward by current international corporations is based on the idea of *separation*: the detachment of actions of multinationals from their environmental impact, as well as the separation of resources from their ecosystems and their subsequent trade, without any consideration for the functioning of the cyclings of nature.

Until the Industrial Revolution, the practice of agriculture stayed more or less the same, with the same dynamics explored so far: a small-scale local practice with a low ecological impact, mainly affected by the project of colonial expansion in new territories overseas. However, the

boost in food production happened later on, involving a large portion of the 19th century in different ways, mainly by plowing uncultivated areas of the nearby lands, draining the wetlands, subtracting soil from the sea, or by the process of work mechanization. Since the European colonization of overseas lands in the 17th century, the extension of croplands increased overall, reaching lands and territories and exploiting them even when they were not ecologically suitable for agricultural practices. The practice of turning to cultivation wastelands like steppes, grasslands, and forests was a common trend. Most of the time these were political and economical bets, but they also represented a main strategy for increasing production. The ambition of the "Great Plains"[19] in the US at the beginning of 1900, or the program of "Virgin Lands" between 1941 and 1955 in Russia, and the exploitation of the Punjab region since 1968 represent just the more recent capital campaigns of soil conversion. The expansion of croplands by turning different habitats into places for agriculture has been massively fostered by the new technological techniques of the 20th century, which allowed the possibility to exploit the already existing fields and stop deforestation and wasteland conversion. The direct consequences of both cropland expansion and technologies, most of the time, have represented huge threats to natural ecosystems.

Up until the last centuries of the last millennium, the basic techniques of agriculture remained more or less the same as in the previous millennia: agricultural workers were gaining workforce from animal and human labor; manure was the main fertilizer and it was not common to find crop's specialization; microbes and harmful organisms were taken under control through the crop rotation or fallow; more or less between 70 or 90 percent of the population was working the fields, characterized by less technology and a high workforce.
With the turn of the 20th century, at the beginning of the domain of capitalism, new techniques mainly related to fertilization and crop breeding were introduced, following the flow of technical innovations already brought forward by irrigation and mechanization. Around the end of the century, less than 10 percent of the population was involved in the workforce job in agriculture; chemicals were used to control pests and massive quantities of fossil fuel substituted the human and animal workforce. All these new approaches and this new asset of agriculture can be grouped as a «contemporary agro-industrial revolution», the biggest revolution in the history of agriculture, from the moment of the rising of agriculture itself. At the end of the 20th century, one-third of the natural surface was dedicated to

[19] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

domesticated plants - cultivation and grazing lands - double the amount of the beginning of the century. Something around 35/40 percent of the whole production of earth soil was dedicated to human needs, against the 2/3 percent of the 18th century; in a few centuries, numbers exponentially soared[20]. The phenomenon of the Great Acceleration was impacting, among many other fields, also agriculture techniques[21]. The main characteristic of modern agricultural management is the massive production and crop exploitation through monoculture and fertilizers; everything is made possible by the development of contemporary technology and scientific knowledge.

About the Green Revolution

In the framework of the 19th century, human societies experienced a large-scale revolution comparable, so far, only to the one of agriculture: the Industrial Revolution.

The Industrial Revolution shaped a path of history that accelerated the rate of producing life and generated an exponential growth in economical, social, technological, and cultural transformation. A shift from agrarian and manufacturing societies to industrial ones will accompany the latest developmental processes of agriculture itself.

In order to understand the dynamics of the Industrial revolution, the indicators of economic historian Joel Mokyr will be followed. Mokyr grouped the scholars of the Industrial revolution into four different schools[22]. *Technological school* underlines the importance of inventors, engineers, and machines overall; *Organizative school* stresses the changes in the organization of work, in particular the birth of the production system of the factory; *Macroeconomics school* measures statistics regarding national income and economic growth; *Social school*, explores the impact of industrialization on social classes and other social structures. All of the schools identified by Mokyr focus on only the human species to explain the origins of the Industrial revolution. In his book, "History and Evolution" historian Edmund Russel proposes a fifth one, the *Environmental school*. It highlights the fact that the Industrial Revolution accelerated the use and consumption of natural resources and it was made possible mainly due to their exploitation. Some scholars of this school, like Harold Perkin, consider the Industrial Revolution as a glorious triumph of humanity on the

[20] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)
[21] Hylland Eriksen T., *Overheating. An Anthropology of Accelerated Change,* Pluto Press, Londra (2016)
[22] Russell E., *Evolutionary History. Uniting History and Biology to Understand Life on Earth*, Cambridge University press, New York (2011)

constraints of nature, a "human revolution towards access to the means that support the life of control of the ecological environment, the ability to escape the tyranny and cheapness of nature"[23]. Others instead, considered the industrial revolution as a complete ecological disaster (J. McNeill).[24] The Industrial Revolution impacted many layers of society, and made room for the Green Revolution to happen, the latest revolution in the field of agriculture. The impact of the Industrial Revolution was being felt outside the field of technologies and was going to affect also the quality of life, instilling the feeling of rapid progress and development. Several scholars started to draw attention to the the topic of exponential growth of population, such as the British economist Thomas Robert Malthus in 1789 with "An Essay on the Principle of Population"; Paul Ehrlich's 1968 "Population Bomb", and the Club of Rome's 1972 "Limit to Growth" were pointing to the same issue. What is going to happen in the following centuries in the framework of population growth and how are we going to deal with it? Why is this linked with agriculture and the Green Revolution?

The main techniques practiced in the field of agriculture of the 19th century were irrigation, natural fertilization of the soil, and human workforce. Agriculture was working thanks to the functioning of this set of parameters. With the inputs of the Industrial Revolution, the industrialization of the agricultural system and the mechanization of the practices of sowing, harvesting, and crop management experienced an important change, but it is just with the apport of the genetic modification of seed crops and the use of chemical fertilizers that we assist to a profound speed up of the means of production. The *Green Revolution* marked a period of new techniques and tools in the field of agriculture, a revolution of the middle of the 20th century inspired by positivistic ideas and perspectives, that aimed to defeat the world's hunger through science and technology. The Green Revolution is conceptually rooted in the western world, but its main systemic effect was reached when the tools of revolution were exported to developing countries, supporting their development. It was a silent revolution, slow in its manifestation, that began with the discovery of the possibility of genetically modifying the seeds, and the possibility offered by technology and scientific research to genetically program the seed on the basis of the demand for production, and continued with the export of a tested idea outside the environmental boundaries of its

[23] Idibem

[24] According to the environmental school, and following the proposal of Edmund Russel, we could observe how, by introducing other different components to the story, the perspective completely changes. In order to do so, the role of cotton in the Industrial revolution will be called into question. The cotton industry ends up replacing and overcoming the wool one, which by 1750 was one of Britain's oldest industries and the major source of wealth for the nation. This effect was produced by the 'domestic system', a vast network of local people working from their homes when they were not otherwise engaged in the agricultural sector.

theorization, treating the Earth as a unique and same ecosystem, lacking consideration for ecological diversity. From a systemic point of view, the whole trajectory of the Green Revolution has been an attempt to solve a problem, followed by another attempt to solve a different problem. First it was hunger, nowadays it is unsustainability. We are in the same process of problem-solving, looking for new technologies/strategies to do that.

With the latest development of modern technologies introduced by the Green Revolution, like fertilizers and crop breeding, agriculture became a system of nested systems that drastically impacted humanity on a very large scale. The seeds of this revolution were sowed at the beginning of the 19th century, generating a series of unforeseen feedback loops that only nowadays we can properly understand. At the same time, the contribution offered by the revolution to the development of the human species has been very effective. We rode a wave of prosperity and productivity, both natural and technological. Humankind's way of learning is programmed on experimentation and mistakes. We do experiment with our possibilities of actions within the environment we live in, and we do so because we are far from having all the knowledge needed in order not to make any mistakes. The Green Revolution has been a combination of different processes, with the aim of defeating hunger.

Irrigation

The practice of irrigation of the Nile flood in ancient Egypt is a good starting point to introduce the topic. The river Nile used to naturally flood once a year. During this period the water was nourishing the vegetation in the territories nearby, and growing crops in the surroundings. The flooding of the river is the result of the annual monsoon that causes huge rainfall on the Ethiopian highlands and is then driven directly into the Nile river through other smaller rivers. This period of the year was named by the Egyptians as ‘Akhet’, the season of the flood, and the soils in the surrounding areas of the river were nourished by this water only for the given time of the Nile’s esondation. While previously the floods of the river were expected in their spontaneous and cyclical manifestation, about 7000 years ago, ancient Egyptians began to develop the irrigation method of the *basin*. The land dedicated to cultivation was divided into large fields surrounded by dams and equipped with intake and exit channels. The tanks were flooded and then closed for about 45 days to saturate the soil with moisture and allow the deposit of silt; then the water was discharged into the lower fields or into the Nile. After the sowing began, the harvest followed about three or four months later.

From an ecosystemic point of view, one of the most significative threats to soil fertility is the process of *salinization*[25]. The salinity of the soil increases due to the rupture of the ecosystemic balance of the whole components of the biogeochemical cycles. The process can be triggered by different factors, such as massive surplus quantities of water from irrigation and not giving the soil enough time to absorb it; chemical fertilizers also are spread through water and in doing so they release chemical components on the ground, contaminating it; while the sea level is rising, the underground slops get contaminated by seawater, and in this way the salt is spread through the cultivation watered by underground flows. Salinization is a threat to agriculture cultivation, since it means that ecosystems are not cycling; modern and maximized irrigation systems are a biggest threat to ecosystems since they operate according to natural cyclings sensitive to external interferences, and massive irrigation did not take too much into account ecosystemic sensibility. Irrigation, from a spontaneous process of mutual benefit between the natural cycling and the services earned by human societies, has been subjected over time to a modernization which includes not only the management of natural resources but also institutional sets of agreements. According to FAO consultation (Bangkok 1996): "Irrigation modernization is a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reforms, with the objective to improve resource utilization (labour, water, economic, environmental) and water delivery service to farms."[26]

Mechanization

Crucial to the process of the Green Revolution was also the mechanization of large-scale agriculture, a process that involved the use of machinery for harvesting and planting; which drastically increased the production of fields. The easy substitution of labor force with machinery and technologies led to increased productivity for given processes. But often conditions of development for some mean underdevelopment for others; development for industrial production of machinery for agriculture means mechanizing the agricultural processes, while it means underdevelopment for small-scale farmers and people in rural areas who lose their job and fall into poverty. Small-scale farmers often went into debt as a result, with wealthier farmers quickly accessing more credit and more land.

Machines make farm work easier and faster, offering the possibility to relate less and less on human labor and to rely more on industrial offers; especially in a historical period where the

[25] National Integrated Drought Information System (november 2022)
[26] Food and Agriculture Organization (novembre 2022)

human labor force means high prices while fossil fuel offers low prices and high availability, like was the case at the beginning of 20 century. Would machinery have worked better than humans or animals? This was not taken for granted at the time of experimentation, but for sure it was thought they would have worked faster ensuring an increase in production.
The process of mechanization was better working for large-scale mono-crop farms, increasing therefore the productivity only of those farms, pushing out of the market the small-scale farms or biodiverse practices. Planting and harvesting only a single type of crop reduces equipment costs. It is also known that if the output increase, for the economy of scale, the overall costs of production will decrease; in this equation lays the attractive offer of mechanization, from an economic point of view.
At the beginning of the 19th century, Henry Ford in Michigan built the first steam-powered reapers. Until the steam-powered engines, the harvesting and sowing of fields happened through human-animal force; horses and cows were necessary to do the job and thus consuming a lot of wheat and grain that was taken off from the final production, which meant that humans started to have to face an important cost to sustain their lives. With the arrival of machinery that works with fossil fuel, capitalist investors saw the possibility to reduce a cost and to easily increase production. This technological revolution, together with irrigation, marks the path of the Green Revolution, which begins to appear now as a gradual combination of different factors from the modification of the environment, to the exploitation of fields, passing through the industrialization of work and improvement of production, but productivity success was not far-sighted, that is why we need an ecological and historical perspective that takes into account culture and agency.

Crops breeding

Cereals, like rice, wheat, corn, and barely are the most efficient production of agriculture based on intensive irrigation are. These crops became the typical seeds of *monoculture*, the agricultural practice developed in the frame of the Green Revolution, which substituted the practices used in the past to avoid the natural salinization of soil. Among all, this shift allowed the reduction of the practice of soil transition and expansion of cultivated lands through the exploiting of fields themselves. The idea of exploiting the already existing farmlands, without relating only to the hectares of cultivated land to produce food, has completely changed the approach of agriculture, at the expense of the functioning of the other

ecosystems. The development of technology in many countries around the world has been experienced as a technological achievement, "unprecedented in human history"[27].

In 1970, the Nobel Peace Prize has been awarded by the American agronomist Norman Borlaug (1914-2009) for his engagement with tackling hunger in America and Third World countries. "Peace is not where there is no war, peace is where there is no hunger" he claimed during the award ceremony[28]. Coming from a small family of farmers in the middle of Iowa, Bourlag got a degree in forestry, and a Ph.D. in plant pathology and got engaged by the Rockefeller Foundation through the CIMMYT (International Maize and Wheat Improvement Center) to move to Mexico where he studied and developed the so-called 'miracle seed'. Observing the reactions of different species of wheat, he noticed that the taller wheat grasses better compete for sunlight, growing faster, but tend to collapse under the weight of the extra grain. Through this observation, Borlaug worked to develop a semi-dwarf wheat seed, to improve the efficiency of production. This "miracle seed" would soon have changed world economies.

Thanks to the financial support of the Ford and Rockefeller foundation, FAO (Food and Agriculture Organization), and many other US Agencies the Green Revolution was able to spread his invention outside the Mexican border reaching the western coast of Asia and Africa. The Green Revolution appeared as a promising way to deal with world's hunger, being able to meet the need for food of the growing population of that period, just after WWII. By the time of 1968, eighteen countries in the world were sowing semi-dwarf seeds. The aim of making wheat production more efficient encountered the perfectibility of the new technologies of industrialization, and this encounter served the purpose of generating and accumulating a surplus of product. The time of the industry of monoculture was rising. Farmers from now on would have to buy the seeds, produced somewhere else, and not be able to use their own native seeds since those varieties responded very poorly to the improved practices of harvesting. Fertilizers began to be needed by the soil, which was weakened by the monoculture specialized system of poor nutrients. In the context of the Green Revolution, crops breeding is comparable with the other crops' incorporation of the past, such as the American maize, and potato exported to Eurasia and Africa after 1492; the banana plant in

[27] Shiva V., *The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics*, Zed Books (1991)

[28] Norman Burlag Nobel Price 1970 (november 2022)

Africa from Southeast Asia; or the introduction in the Mediterranean area of citrus fruit and sugar cane from the Arabs after 900 a.C.[29]

Fertilizers

The 'miracle seeds' of the Green Revolution were replacing the seeds heritage of small and local people, which acted to support the cycling of food production through centuries, without getting into commodities of private property. From small scale local farming systems, to a system controlled by agrochemical and seed corporations through agricultural research centers, the practice of agriculture has been standardized.

The system of monoculture worsens the problem of harmful organisms, due to the destruction of biodiversity which does lay in the non-specialization of cultures. Before the Green Revolution farmers around the world raised thousands of different wheat strains, each capable of surviving in local, smaller ecosystems. The revolution raised the need for chemicals, pesticides, and fertilizers due to the fact that monocultures destroy the functioning of ecosystems, attacking the biodiversity integrity of soils. For millennia the localized agricultural approach was indirectly supporting the act of natural repairing of ecological cycles and working in partnership with nature's processes. Nowadays farmers have become highly dependent on the import of chemicals for the functioning of the soil. Indeed, cropping systems based on biodiversity do have built-in protections against given pathogens present in the same environment. The same does not occur in cropping monoculture since the system based on a mono variety of seeds helps proliferate new pests and spread easily to the seeds that suffer and function the same, generating massive sickness. In biodiverse systems, the seeds that suffer from some pest will die while the rest of the vegetation can continue to grow; in a non-biodiverse system, the whole field of the same crop that contracts the disease will perish and could destroy all the production of the year. Trying to keep the environment more "sterile" and biodiversity poor, copying the functioning of the scientific laboratory, the place where the idea of the revolution actually took place, the natural environmental complexity took over and keeping away pests and controlling the new ones became central in the management of monoculture through the massive use of fertilizers.

This *'antibiotic'* approach is at the base of the capitalistic conceptualization of land and soil. The war on pests and bacteria started by the Green Revolution is inscribed in the spreading of

[29] Diamond J., *Guns, Germs, and Steel. The Fates of Human Societies*, W.W. Norton & Company, New York - London (1997)

an antibiotic mentality[30]. “But the ‘war’ with pests is unnecessary. The most effective pest control mechanism is built into the ecology of crops, partly by ensuring balanced pest-predator relationships through crop diversity and partly by building up resistance in plants. Organic manuring is now being shown to be critical to such a building up of resistance”[31]. Through the mechanisms of antibiotic resistance, by which pests and bacteria can develop a resistance to the antibiotic to survive it, the direct effect of fertilizers (antibiotics) was the creation of new pests, generating an infinite loop of need and co-dependence. Fertilizers also contribute to increasing the process of salinization of soils.

While researching for aggressive chemical weapons during the war, some of the industrial products showed lethal effects on insects and bacteria as well. These products are synthetic pesticides and differ significantly from the pre-war ones' organic pesticides. The latter derives from minerals already present in nature or from vegetable products, like arsenic, lead, zinc, and manganese... Synthetic pesticides are first synthesized in the laboratory and what distinguishes them is their enormous biological activity; they have massive power as poisons but also a great ability to easily integrate into life processes, diverting the course in a fatal way. The pesticides industry developed the so-called “systemic pesticides” which have the ability to permeate all the tissues of a plant or an animal and to make them toxic; they are also applied to seeds in order to increase their direct toxicity to fight pests. Despite all, between 1947 and 1960 the production of synthetic pesticides in the U.S. increased five times, from 56 billion to 290 billion for an amount of 250 billion dollars[32], and that was just the beginning.

“Anyone who can grow two cobs of wheat […] on a strip of land on which only one grew previously, will have done more, for humanity […] than the entire genius of politicians”
Gulliver's Travels

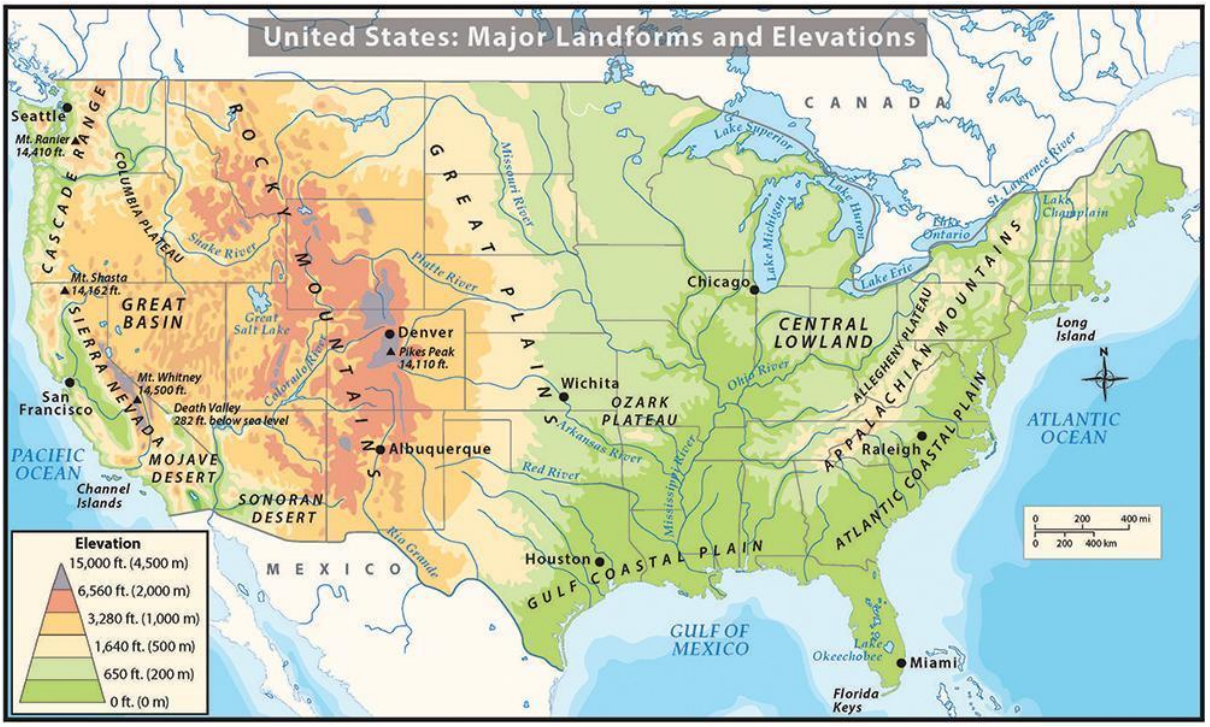
Case study: the Great Plains

I will present now a significant episode from the beginning of 1900 in the United States to better contextualize the Green Revolution.

At the dawn of the new century, North American society was rapidly transforming. The country as a whole was moving away from a rural agriculture-based lifestyle to an urban

[30] Raised with the discovery of Penicillin by Fleming in 1929
[31] Shiva V., *The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics*, Zed Books (1991)
[32] Carson R., *Silent Spring,* Houghton Mifflin Harcourt, Boston (1962)

industrial economy, on the wave of new industrialization process going on in Europe; less than fifty years before the turn of the century, five out of six Americans lived on a farm, by 1910, almost 50 percent of Americans resided in cities[33]. As the nation became increasingly industrialized, the economy came under greater control of large corporations, which were overseen by relatively few powerful executives.



The episode took place in the Great Plains of North America, a region that stretch from Canada to Southern Texas, from the Missouri River to the Rocky Mountains, a land of few trees, infrequent rains and constant winds; a broad expanse of flatland covered in prairie, steppes and grassland, houses of buffalos and native americans.

The coastal communities of north americans, independent from 1780, started to pioneer the inland of the country; from the beginning of 1821, Santa Fe Trail has been created, it was the first route through central North America, ran from the Missouri River to New Mexico. The central part of North America started gradually to be explored by the Americans homesteaders while native americans were confined into reservoirs and land started to be privately sold. In 1862 president Abraham Lyncoln signed the *Homestead Acts*[34]. This first

[33] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

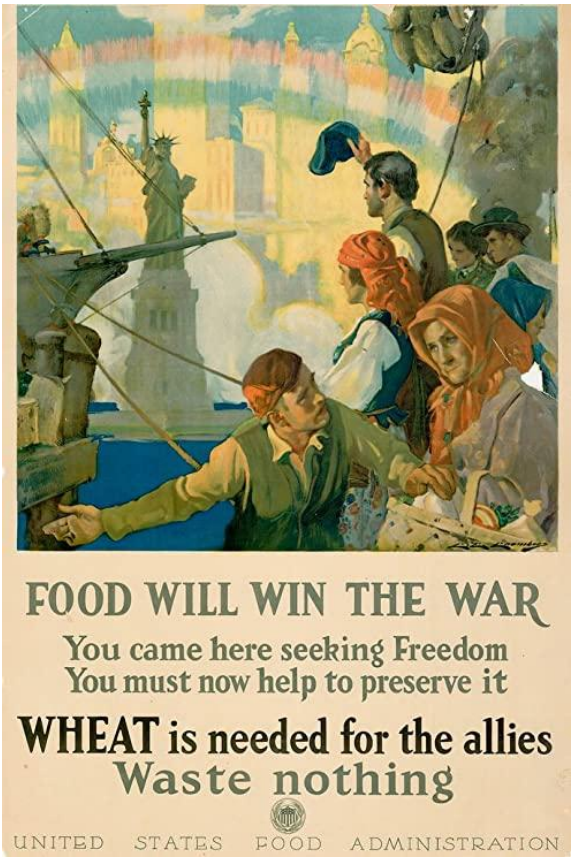
[34] Homestead Act was proposed by the Free Soil party, signed by Abraham Lincoln just after the end of American civilization, between the North and the South; divided in the intent since the Republican party of the north was siding for the abolition of the slavery in order to make room for bank and loans, while the south was still gaining benefits from the work of slaves and had any intention of renounce of it. Free Soil party was active from 1848 to 1852 and later on merged into Republican party after 1854.

Homestead Act demanded that the new lands opening up in the west were made available to *independent farmers* and not only to private slave owners, which had already colonized the south of the country in the business of cotton fields run by slavery. The Homestead Act allowed settlers to claim up to 160 acres (65 hectares) of land, proving that they lived on it for a period of five years to cultivate the land; it was open for women and immigrants as well. By the early 1900s, much of the prime low-lying alluvial land along rivers had been homesteaded, so the program was broadened by the *Enlarged Homestead Act*, passed in 1909. The new act served to enable dryland farming, it increased the number of acres for a homestead to 320 acres (130 he) given to farmers who accepted more marginal lands, especially in the Great Plains, places that present not easy ecological conditions for agriculture.

From this time on, massive campaigns of soil conversion and advertisement for the emigration to the Plains started to take place in the US. Farmers as well as citizens, and immigrants were coming from all over the country to benefit from the possibility of making a profit or just a better life.

"April 28th, 1908. Here I am, away out in that narrow strip of Oklahoma, between Kansas and the Panhandle of Texas. I wish you could see this wide, free, western country. With its real stretches of almost level prairie, covered with thick short buffalo grass. The marvelous glory of its sunrise and sunset, the brilliancy of its star-lit sky at night." [35]

[35] The Dust Bowl by Ken Burn documentary (2012)



In the settlements of the Great Plains the focus was almost exclusively on wheat, monoculture of wheat assured the biggest profit, especially during the year of WWI, when German blockades cut off access to Russian wheat, the US then entered the scene supporting with food its allies. Prices rose twice during the war period and in five years more than 11 million acres of virgin soil were plowed for the first time (twice the size of New Jersey), converted from grassland to wheat fields. When WWI ended the prices dropped but the plowing and planting only increased. Being a farmer in the Plains during the 20s was meaning making easy money, according to the vision of that time it was enough to "put seeds in the ground to have a crop"[36]. Being a farmer at that moment was like being a gambler, gambling that what they put into the ground was going to grow and produce. The Great Plains of the *Enlarged Homestead Act* were inhabited by communities of Scott-Irish kicked around the old confederacy, or by Germans from the Russian steppes, the Latinos from the south, a community of people that never owned anything. For them, those have been years of great prosperity, also thanks to the modern technologies and machinery, coming directly from the Industrial Revolution (gasoline tractors for instance). The support and discovery of carbon fossils have been a great incentive to mechanization. In the 20s there was a concerted movement in American society to turn agriculture into an industrial model, to make every farm into a factory. Production was turning massive.

The Federal Bureau of Soil proclaimed that "the soil is the one indestructible, immutable asset that a nation possesses. It is the one resource that cannot be exhausted, that cannot be used up"[37]. Awareness about previous climatic conditions of the Plains was common, severe drought had already occurred in the previous decades, but this was not enough not to be so

[36] The Dust Bowl by Ken Burn documentary (2012)
[37] Egan T., *The Worst Hard Time: The Untold Story of Those Who Survived the Great American Dust Bowl*, Mariner Books (2006)

confident about future prosperity. After twenty years of economic prosperity in 1929, the Great Depression arrived as an alley killer, impacting every area of American society, and just a few years later it also reached the Great Plains where it threatened the activities of the population. The price of bushels just drastically dropped and thousands of grain crops were being thrown away.

In addition to the depression, a few years later, in January 1932, one of the biggest dust clouds appeared in Texas. Dust clouds are a meteorological phenomenon common in arid and semi-arid regions, characterized by strong winds and massive sand transportation at high speed. Typically of the climatic conditions of the Plains, a period of dryness was affecting the area, and dust bowls started to repeatedly happen over the following ten years. All the people that moved there to live on agriculture suddenly became in extreme need of help and subsistence from the State due to severe drought affecting the area and the heavy economical depression affecting the country. The dust bowls of the Great Plains represent one of the biggest environmental catastrophes of the United States.

The territories of the Great Plains, previously transformed into agricultural land to exploit the apparent fertility of the soil, have been transformed into desert lands within ten years by the environmental conditions, destroying the whole economical and social structure built in previous decades, and making people dying of hunger in one of the most prosperous country of the so-called ‘First world’. In 1933 Franklin Delano Roosevelt was elected as the democratic president of the US. The situation of the country was a disaster and he

immediately enacted the New Deal (from 1933 to 1939), a series of aid programs, public work projects, financial reforms, and market regulations to support the needs of the American population. In March 1914, on the farm of his Norwegian grandparents who immigrated to Saude, Iowa, Norman Borlaug was born. The father of the Green Revolution was almost 24 years old when experienced the Great Depression in the farmland of central America, people were starving and the battle against hunger began to be his main personal struggle.

It is now the half of the twentieth century, a period of strong socio-political agitation, marked by the end of WWII in 1945. Starting from the post-war period begins a new cycle of economic growth and capital accumulation, in western countries. “This socio-political doctrine provides for the active intervention of the State in the economy through industrial plans and public expenditure in order to achieve an increase in consumption, full employment, and economic growth. This model spread parallel to the American hegemony, thanks to global infrastructure such as the World Bank and the International Monetary Fund" [38].

The story of the Great Plains is meaningful in this context because it highlights the promises of modernization and modern agriculture outside the conceptualization of the environmental assumptions. The period of so-called *glorious thirty* (1945-1975) represents a moment of promised economic and social prosperity, within a context of poor environmental consideration. By the 1950s, scientists had begun to point the finger at the dangerous impact of human intervention upon nature, since side effects started to show off, and different kinds of protests were rising. We can introduce the topic of the ecosystemic status led by the fable of Rachel Carson, in her book *Silent Spring; p*ublished in 1962, *Silent Spring* allowed Americans to understand what was happening within their government and how the actions and political decisions actually do have an impact on the status of the environment, and of humans lifestyle.

A Fable for Tomorrow from Rachel Carson [39]

“There was once a town in the heart of America where all life seemed to live in harmony with its surroundings. The town lay in the midst of a checkerboard of prosperous farms, with fields of grain and hillsides of orchards where, in spring, white clouds of bloom drifted above the green fields. In autumn, oak and maple, and birch set up a blaze of color that flamed and flickered across a backdrop of pines. Then foxes barked in the hills and deer silently crossed the fields, half hidden in the mists of

[38] Bergamo Nicola J., *Marxismo ed Ecologia. Origine e sviluppo di un dibattito globale*, Ombre Corte, Verona (2022)
[39] Carson R., *Silent Spring,* Houghton Mifflin Harcourt, Boston (1962)

the fall mornings.

Along the roads, laurel, viburnum, and alder, great ferns, and wildflowers delighted the traveler's eye through much of the year. Even in winter the roadsides were places of beauty, where countless birds came to feed on the berries and on the seed heads of the dried weeds rising above the snow. The countryside was, in fact, famous for the abundance and variety of its bird life, and when the flood of migrants was pouring through in spring and fall people traveled from great distances to observe them. Others came to fish the streams, which flowed clear and cold out of the hills and contained shady pools where trout lay. So it had been from the days many years ago when the first settlers raised their houses, sank their wells, and built their barns.

Then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town, the doctors had become more and more puzzled by new kinds of sickness appearing among their patients. There had been several sudden and unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours.

There was a strange stillness. The birds, for example, where had they gone? Many people spoke of them, puzzled and disturbed. The feeding stations in the backyards were deserted. The few birds seen anywhere were moribund; they trembled violently and could not fly. It was a spring without voices. On the mornings that had once throbbed with the dawn chorus of robins, catbirds, doves, jays, wrens, and scores of other bird voices there was now no sound; only silence lay over the fields and woods and marsh. On the farms, the hens brooded, but no chicks hatched. The farmers complained that they were unable to raise any pigs the litters were small and the young survived only a few days. The apple trees were coming into bloom but no bees droned among the blossoms, so there was no pollination and there would be no fruit. The roadsides, once so attractive, were now lined with browned and 249 withered vegetation as though swept by fire. These, too, were silent, deserted by all living things. Even the streams were now lifeless. Anglers no longer visited them, for all the fish had died. In the gutters under the eaves and between the shingles of the roofs, a white granular powder still showed a few patches; some weeks before it had fallen like snow upon the roofs and the lawns, the fields and streams. No witchcraft, no enemy action had silenced the rebirth of new life in this stricken world. The people had done it themselves.

This town does not actually exist, but it might easily have a thousand counterparts in America or elsewhere in the world. I know of no community that has experienced all the misfortunes I describe. Yet every one of these disasters has actually happened somewhere, and many real communities have already suffered a substantial number of them. A grim specter has crept upon us almost unnoticed, and this imagined tragedy may easily become a stark reality we all shall know…"

Chapter 2
Underground. Ecosystemic complexity

In this chapter, I will deal specifically with the intricate and complex system of relationships that exist at the ecosystemic level on our planet. Without including the contribution of this level it is not possible to close the circle of analysis and understanding of a model of subsistence such as agriculture. The interweaving and co-dependency of mechanisms that regulate the functioning of natural cycles are key paragraphs for a more holistic and inclusive understanding of the general mechanism of the functioning of human activities. In a perspective of openness and listening to the balance of the planet to better contextualize, not only historically, but also ecologically, the ways of humans live and relate to the planet and the environment that hosts them. The world of anthropomorphic management and the world of natural management are not separated but coexist in a dialectic of reciprocity, and it is through linking these points that we have the opportunity to rewrite our practices by tracing an interconnected path.

Gravitational force, sunlight, photolysis, and photosynthesis

Nymphs Filling the Cornucopia - Jan Brueghel the Elder (1568-1625)

In the introduction of his book *Photosynthesis* (1968), Isaac Asimov chose the metaphor of *cornucopia* to mean the neverending cycling of elements that allowed humans to proliferate as a species on the planet. Cornucopia represents the horn of plenty, a mythological symbol of abundance, for ancient mythology, it is the attribute of divinity dispensers of the goods of the earth. Asimov refers to this concept firstly to represent the perennial renewal of oxygen taken from the environment in the process of respiration and our attitude of giving this for granted, without questioning. But the process that makes this assurance unquestionable for us is the same that regulates also the reliability of many other natural phenomena that for millennia have been unquestioned, such as the oxygen in the air or soil prosperity. All living beings use oxygen to live, which is accurately replaced in the atmosphere by natural cyclings. Oxygen in the air doesn't get exhausted due to the cyclical processes of the ecosystems. The cyclings meant by Asimov is a circular movement where everything is restored at the same speed as it is demolished. The main point of the functioning of the ecosystem is therefore *restoration*. Living beings live through the intake of chemical elements that pass from the abiotic (non-living) to the biotic environment. This circular movement between biotic and abiotic environments is at the base of cycling, which allows ecosystems to function. Within these considerations, the metaphor of *cornucopia* sounds to Asimov like a misunderstanding about the natural disposition of elements living beings dispose of, but not completely wrong. If element restoration is ensured, then the cycle is balanced and can continue with few natural disturbances; otherwise, if the cycle gets interrupted then the balance is also lost, and it has to look for a new one. Photosynthesis is a process that produces and releases oxygen in the environment thanks to the range of light that reaches the atmosphere and does not get absorbed by the ozone layer. But the same atmosphere during its whole evolution passed through different status conditions, it has not always been like nowadays, it has been characterized by different atomic combinations of elements. Through a short analysis of these periods, I am going to introduce a few basic chemical processes necessary to understand the functioning of cyclings.

In the antechamber of the process of photosynthesis, known as the main regulatory process to keep the atmosphere at the chemical conditions to support and host organic life as we experience nowadays, there is actually another but fundamental chemical process called *photolysis*. Photolysis is the primary event of photosynthesis; it is the abiotic degradation of chemicals due to the radiant energy of light either directly or due to reactions initiated by other light-absorbing compounds. This has been the main regulatory process that worked

during the primary stage of Earth's atmospheric conditions (Atmosphere I)[40] when Earth was a sphere of gaseous elements such as hydrogen (H), helium (He), neon (Ne), and argon (Ar)… Some of the gasses that compose the atmosphere are noble gasses, which means that they do not create bonds with other elements (helium, neon, and argon), other molecules of gas instead create bonds and newly composed elements (hydrogen, oxygen). The main point is that in the period of Atmosphere I, the *gravitational force* of the planet was still not strong enough to retain the gasses in the area of the atmosphere, the bonds were just fragile and elements were just released into space. The gravitational force of the Earth is the key to allowing the creation of the solid and rocky planet we have in mind, made by elements combinations. Hydrogen is the most present element in the atmosphere and easily creates bonds with other elements, with oxygen for instance in the formation of the molecule of water (H2O). Since the molecule of water is heavier than just the two separated elements of oxygen, the weak gravitational force of the Earth, in constant reinforcing, was able to keep this bond, mainly in gaseous form, in the form of water vapor (H2O).

Another important component of the history of the planet is the *sunlight*. Planet Earth and Venus are the biggest planets of our galaxy placed so close to the Sun, and this allows their atmosphere to be reached by an important quantity of sunlight, the other planets are too far from the Sun to benefit from the sunlight effect. Sunlight is, therefore, together with gravitation force, an important component for the process of photolysis, it works through ultraviolet radiation affecting the chemical bond of H2O, which absorbs radiation, generating an increase of inner energy that causes the breakup of the bond and releasing oxygen and hydrogen in separate molecules; still not able to retain hydrogen but just retain oxygen (heavier than hydrogen), the gravitational attraction however in the lower atmosphere it became able to create new bonds with new elements, like for instance oxygen with methane generating carbon dioxide (CO2); or ammonia for nitrogen (N2). The process of photolysis, through the influence of sunlight and gravitational force, led to big changes in atmospheric conditions like a new set of combinations of elements (Atmosphere II): water (H2O), carbon dioxide (CO2), and nitrogen (N2), chemical conditions still not suitable for organic life.

The composition of the current atmospheric status (Atmosphere III), with conditions suitable for organic life, is mainly water vapor (H2O), nitrogen (N2), and oxygen (O2). What then has generated the transition from carbon dioxide to oxygen, to be the main gas present in the

[40] I will refer to the different stadiums as Atmosphere I, II, and III following the categorization and nomenclature provided by Isaac Asimov in its book Photosynthesis. Asimov I., *Photosynthesis*, Basic Books, New York (1968)

atmosphere? What happened to allow the increase in both senses of releasing more oxygen and subtracting carbon dioxide from the atmosphere? The answer is exactly the process of *photolysis*. When in Atmosphere II under the effect of photolysis hydrogen is released in space and not restrained by gravity and oxygen is free to create new bonds, a part of it also became a molecule of ozone (O3) by bonding with other molecules of oxygen, highly present due to the effect of photolysis. Ozone is able to absorb to a considerable extent ultraviolet radiations and to reflect back the other part, indeed 30 kilometers from the top of the soil there is an ozone layer that absorbs and reflects radiations, strongly crucial for our living on the planet. Sunlight and ultraviolet radiations can now reach the lower atmosphere only in a lighter and minor quantity, preventing damage to the living species but also photolysis to happen. Photolysis is a *self-regulated* process, it proceeds as long as there is oxygen to consume or radiation to break the bonds. Once one of the components of the process is missing, for any reason, from the formation of the ozone layer to the exhaustion of oxygen, the process stops. In this way, the atmosphere increases molecules of oxygen because the process of photolysis has been interrupted by the formation of the ozone layer, fundamental for the protection of life forms from ultraviolet solar radiation. But if photolysis helped in the increase of oxygen, how come instead the reduction of carbon dioxide? Is now the time of *photosynthesis*. Photosynthesis contributes to both the production of oxygen and the reduction of carbon dioxide. It is not a self-regulated process as photolysis was, it produces oxygen from the molecules of water through sunlight but does not release carbon into the atmosphere, it incorporates it into vegetable tissues, where it is later on reconverted in water and sugar by organic life, which gives back to elements to the cycle through the action of *metabolism* which allowing *restoration* of the cycle. The endless cornucopia of Mother Earth.

"Life is therefore the result of highly probable transformations that it is almost impossible that they are not realized once they have precise conditions. Seen from this perspective, life is not a 'miracle' at all." [41]

From algae to lichens: symbiosis

About 600 million years ago conditions on the planet were still not so hospitable for organic life, temperatures had dizzying oscillations and the landscape was rocky and dusty; the nutrients were sealed inside the rocks and minerals, and in the water, the climate was exceptionally dry. Nevertheless, life was not totally absent on Earth, since photosynthetic

[41] Asimov I., *Photosynthesis*, Basic Books, New York (1968)

bacteria, extremophiles, and fungal algae were living in the warm and shallow seas, and lagoons at that time life was an event almost entirely aquatic[42]; since those living forms came out to survive in the open air.

Green algae are a group of unicellular organisms able to photosynthesize, they are very easy cells similar to bacteria with some chlorophyll in them, "these were the ancestors of all land plants. The evolution of plants transformed the planet and its atmosphere and was one of the pivotal transitions in the history of life—a profound breakthrough in biological possibility. Today, plants make up eighty percent of the mass of all life on Earth and are the base of the food chains that support nearly all terrestrial organisms."[43] How did it happen that those photosynthetic organisms from water reached the land and initiated the reign of plants the way we know today?

"When it comes to piecing together origin stories it's difficult to find agreement among scholars. Evidence is usually sparse, and what fragments there are can often be mobilized to support different points of view. And yet, amid the slow-burning disputes that surround the early history of life, one piece of academic consensus stands out: It was only by striking up new *relationships* with fungi that algae were able to make it onto land"[44].

This relationship between fungi and algae is known as *mycorrhizal relationships,* a deep association dependent on mycorrhizal fungi. Those fungi are an important component of any kind of plant, even more than fruits or roots. Throughout this relationship, algae and aquatic plants started to track their path to land, beginning to co-evolve and structure their carbon vests declined in wood, leaves, roots, and fruits. Algae and fungi though belong to different reigns of living[45], and those reigns have created each other through time. The *reign of Plant* is the product of the encounter between the reign of Monere, Protists, and Fungi. "What we call 'plants' are in fact fungi that have evolved to farm algae, and algae that have evolved to farm fungi"[46]. Given the kind of relationship built between plants' roots and mycorrhizal fungi at the level of roots, in the soil, it is hard to say where it starts being a plant and where it ends

[42] The ozone layer allowed sunlight and ultraviolet radiations to reach gently the surface of water and life was an aquatic event due to the fact that water was helping to filter the ultraviolet radiation, aggressive for lifeforms.
[43] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)
[44] Ibidem
[45] Reigns of living are classified in five different categories: Monere, Protists, Fungi, Plants and Animals.
[46] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

being fungi. Algae and fungi become highly dependent on each other for their own survival, maturing a "long-lasting intimacy of strangers" in Lynn Margulis' words[47]. Primordial plants were not more than puddles of green tissue rootless with any other specialized structures, just 'favorable places' to allow bacteria and fungi to grow and live, which in their turn ensured water and nutrients from the ground to the green tissue of newborn plants. To support this relationship algae started to build relationships with these tiny roots (links) known as mycorrhiza. The term '*mycorrhiza'* was coined in 1885 by german biologist Albert Frank who was employed by the Ministry of Agriculture, Domains, and Forestry for the Kingdom of Prussia to promote the possibility of truffle cultivation. Deepening the soil looking for truffles Frank developed a good knowledge about the functioning of these relationships. Sprouts of plants are then in a relationship with air and light while fungi and roots with the underground. An example of this relationship are *lichens*.

by Ernst Haeckel

Through lichens, we just entered the domain of *ecology*. In 1866 Ernst Haeckel, a German artist and biologist engaged in studying and depicting lichens, coined the term *ecology*. Ecology describes the study of the relationships between organisms and their environments, the place where they live, and the relationships that they build. In the wake of the ideas of Alexander von Humboldt (1769-1859), a German naturalist and explorer, according to whom nature was interconnected and it is not possible to define and understand nature and organisms in isolation. A few years

[47] in Lovelock J., *Gaia. A New Look at Life On Earth,* Oxford University Press, Oxford UK (1979)

later in 1869 Swiss botanist Simon Schwendener published a paper advancing the *dual hypothesis* of lichens. According to this theory, the current idea of that moment was that lichens were a third separated entity from alga and fungi, Schwendener proposes that lichens are actually not a separate entity but rather a union of two different other things, the alga (today known as photobiont) and the fungus (or mycobiont) of the lichens. It did not have much success at the beginning, since the dominant theory of evolution of Charles Darwin (1809-1882) was claiming that evolution proceeds for division and separation, Schwendener was proposing instead to switch the perspective and adopt the idea of evolution through *merging*[48].

In 1877 Albert Frank, who coined the term 'mycorrhiza', also coined the term *'symbiosis'* to describe the specific practice of living benefit partnership between fungi and algae. New words were needed in the field of knowledge to precisely define the kind and different relationships nature was made of. Afterward until nowadays, the word *'symbiosis'* has been generalized and used to mean the full spectrum of the existing partnership relations, from parasitic to mutual benefit. "In the wake of the dual hypothesis, evolution could no longer be thought of solely in terms of competition and conflict. Lichens had become a typical case of inter-kingdom collaboration"[49].

[48] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)
[49] Ibidem

by Lunettes Roses

Lichens are massively spread on the planet's surface, mainly in the form of tiny layers of different colors from green to white. They cover rocks, buildings, animals, hills, plants… They act through a process known as *weathering*. First, they break up the surfaces while growing and then unfold acid and mineral compounds to dissolve and digest rocks, extrapolating chemical elements from biotic to the abiotic environment, serving nutrient cyclings to complete their restoration. Once they die, their decomposition contributes to the formation and regeneration of the living soil in the ecosystems.

Lichens are classified as organisms *extremophiles*, able to live in environments and conditions for humans and many living species out of conception such as volcanic springs, superheated hydrothermal vents, and kilometers under the ice in Antarctica, in these places extremophilic microbes live, apparently unfazed. They somehow enter a state of suspended animation, in total absence of water they reduce their photosynthetic activity to near zero and remain dormant for the rest of the time, resuming their normal activity when rehydrated.[50] They can preserve themselves until conditions are favorable to start living processes again. They are complex multicellular organisms and arise from symbiosis.[51] In order to have an actual symbiosis some relationship conditions have to be fulfilled. One criticism is that each

[50] "Members of the BIOMEX team harvested specimens of the hardy species Circinaria gyrosa from the arid highlands of central Spain and took them to a Mars simulation facility." see Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

[51] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

partner had to be able to do something that the other couldn't achieve on its own, "the identity of the partners didn't matter so much as their ecological fit"[52]. Looking from this viewpoint, the great resistance of lichens is a consequence of their symbiotic way of life, which allows them to survive due to their elasticity to collaborate. Therefore, any living species stands primarily but everything coexists through processes. Lichens formed the primary layer of ground for billions of years and they co-create the environment together with both biotic and abiotic partners.

The structure of fungi and molds is complex but relatively simple: they all consist of a body called *mycelium*, formed by very long filaments called *hyphae*, chains of cells visible only under the microscope. In some species and certain climatic conditions, the hyphae get tangled up to form the mushroom that we can see to the naked eye. The latter is called the *fruiting body*. In this area is formed the part of the fungus (*hymenophore*) which contains the fertile tissue (*hymenium*) in which the spores, the cells with which the fungi reproduce, form, and rip. Most fungi consist exclusively of *mycelium* (such as mold) and remain invisible to the naked eye. Mycelium is an ecological connective tissue and hyphae have the shape of pipes. In front of any crossroad, hyphae can take any direction they want at the same time. They branch out and move in any possible direction, by exploring the environment. Splits in two, or four but still linked to the same mycelium; is it one, or is it more than one? Is it hard to

[52] Ibidem

understand mycelial coordination since, like plants, fungi are *decentralized organisms.* There is no centralized center of control in their organism, decisions are taken everywhere and at any particular point of the whole body of the organism, a piece of mycelium can regenerate an entire pattern. Mycelium is also the structure that the fungi need in order to feed themselves; they are *heterotrophic* organisms, which means that they are not able to directly synthesize substances as carbon, transforming it from inorganic to organic to get the nutrients they need. They release in the environment special enzymes thanks to which they can digest and absorb the organic matter already synthesized in their plant partner. In order to do so, they have to be able to perfectly adapt their body on the surface to interact with, their body is multiform and every mycelium is different from another. Hyphae grow from the apexes and generate the body of the whole fungi. The growth of the mycelial reticulum is therefore an example of how life forms are in fact *processes* and not things; nature is an event that never stops. To say it with the words of William Beatson, the biologist that coined the term 'genetics': "We commonly think of animals and plants as matter, but they are really systems through which matter is continually passing." [53]

Microorganisms and humans: the antibiotic turn

At this point there is an important difference to underline between *soil* and *land*; the biggest part of Earth's land is dry matter, the *soil* is instead the product of the encounter between biotic and abiotic organisms. The material that created the dryland came directly from the volcanic eruption, from the core of the Earth to the surface where it condensed and started to be eroded by water flows and the power of ice sheets smashing the hardest rocks, allowing biotic organisms to start their "magic creative process"[54] that made those abiotic materials an actual organic soil. "Lichens, the land first cover, aided the process of disintegration by their acid secretions and made a lodging place for other life. Mosses took hold in the little pockets of simple soil—soil formed by crumpling bits of lichen, by the husks of minute insect life, by the debris of a fauna beginning its emergence from the sea"[55]. Soil is in constant change, it is made up of organic life and without it is just dust or land; it transforms itself in neverending processes.

The outermost and rocky part of the Earth is called the *lithosphere*, it floats on the glowing

[53] Ibidem
[54] Carson R., *Silent Spring,* Houghton Mifflin Harcourt, Boston (1962)
[55] Ibidem

rock as a “foam layer on a boiling soup”[56], and it is 120 kilometers deep. According to some scientists, also the lithosphere is actually in a constant process of moving and renewing. It is made up of new rocks that melt, and new magma that solidify. The organic *soil* that lies between the lithosphere and atmosphere is called the *pedosphere*; the “epidermis of the earth”[57], composed of mineral particles of organic matter, gasses, and microorganisms; this layer is no more than one meter deep, a fragile coating where life is generated, like the sea and the uterus. Just above the pedosphere, in the intersection with the atmosphere, and the hydrosphere stands the *biosphere*. The term *biosphere* has been coined by the Austrian geologist Edward Seuss (1831-1914)[58] to set up the concept, better known only during the development of the twentieth century, of the space inhabited by living species, from the deep oceans to the top of the mountains, from bacteria to big mammals.

The most important organisms that inhabit the soil are *microorganisms*, the smallest, from bacteria to fungi. Millions of bacteria can be found just in a little spoon of ground, the same that happens in humans’ guts[59]. All those biota have been living without human interference for more than 3 billion years, homo sapiens just appeared 4 million years ago. As we previously explored, humans haven’t been so advantaged technologically and in number, their interference with the other living forms on the Earth was minimal, they were just a species among others. Between 30'000 and 40’000 years ago they began to master new tools and techniques that made them able to improve social organizations and step ‘on other species' feet’ starting to be disproportionately influential in terms of coevolution. Up to 10’000 years ago, with the developed ability to tame other species this human capacity improved, starting to increase in numbers and evolving technologically. “In the twentieth century, the demographic entity, high-energy technologies, and a sophisticated division of labor with an associated exchange economy allowed man to transform ecosystems; individually and as a whole. Some have not suffered, for example, the cavities of the seabed. But in most of the biosphere, co-evolution with humans has initiated an "unnatural" process of separation, in which the possibility of surviving and reproducing was largely dependent on

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[56] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

[57] Ibidem

[58] Ibidem

[59] Bacteria are way more numerous than human beings and the knowledge about them has grown enormously in the last decades. At the beginning of the Green Revolution, it was minimal. At that time “in setting safe levels for a pesticide, the government takes into account not only its toxicity but also the economic benefits it provides” the principles that regulate the use of the soil were lacking knowledge and concerns about the components that make soil life and fertile, their existence was doubtful and their survival was just given for granted.”

compatibility with human intervention. In this new regime, living beings able to live in symbiosis with humans have prospered greatly"[60], those who better react to domestication resist, those who do not risk extinction.

For billions of years, microbes have been the most numerous species on the Earth, and they were involved in preserving the life cycles of the planet, determining climate, geology, and other life existences. In the last centuries, the balance between humans and microbes has been threatened; particularly since the discovery of Louis Pasteur (1822-1895) and many others in the field of microbiology.

As we already explored, the way in which microbes interact with biotic and abiotic organisms is *symbiotic*, it can happen that there is a double benefit from both species involved (*mutualistic*), or that the host organism is benefiting and the other is suffering from the relationship (*parasitic)*, or no benefit or negative at all (*commensalistic)*; we classify it according to the type of interaction is actually happens, according to the type of microbe that we are taking into account. All living beings are therefore symbiotic with others at a chemical (biotic) and a physical level (abiotic). These symbiotic interactions are at the base of the concept of *poiesis*, they generate life. How did we conceptualize *poiesis* so far? Let's have an aside on this topic, in order to have a light spot on how humanities conceptualize the concept of life.

Autopoiesis, or 'self-production' "is a concept introduced in the 1970s by the biologists Maturana and Varela to differentiate the living from the nonliving. An autopoietic system is a network of interrelated component-producing processes such that the components in interaction generate the same network that produced them"[61]. Later on, Niklas Luhmann (1988), a german philosopher and sociologist, tried out a 'theory transfer' extending the concept also to social science, meaning that both social and natural systems, actually do communicate to the extern through different kinds of communications and this makes them active in the process of *poiesis*, placing themselves in an open relationship of reciprocal interferences. Biologist and philosopher Donna Haraway challenged this way of thinking, shifting to the concept of *simpoiesis*, meaning "the systems that produce in a collective way, that have no spatial or temporal boundaries defined by their interior. Information and control are distributed through all components. Systems have evolved and can generate surprising changes" on the contrary "autopoietic systems are autonomous units that self-produce with

[60] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

[61] F. Geyer, Sociocybernetics, Editor(s): Neil J. Smelser, Paul B. Baltes, International Encyclopedia of the Social & Behavioral Sciences, Pergamon, (2001)

self-defined spatial and temporal boundaries that tend to contract control, homeostasis and predictability"[62].

Around the end of the twentieth century, Louis Pasteur played a central role in giving centrality to the role of microorganisms, many studies followed its intuitive initiation using information about microbes, especially in the medical field. The acknowledgment that some bacteria can act against others, changed radically the way of thinking. In the same period thus humans started to conceptualize and produce *antibiotics* to treat diseases, by the work of Alexander Fleming (1881-1955) they have been later on systematized . The war context has been a great trial for the diffusion of antibiotics: the protection of troops first, the extension of the protection of civil society then, and the later on the one of resources, sign the path for the integration of antibiotic mentality into different fields. Also, the concept at the base of fertilizers and pesticides and their use is actually antibiotic; it encourages and supports the growth of given plants, by eliminating competitors. As the effects of the multilevel antibiotic approach armies getting stronger, the human population could increase in number, and the production of goods and use of resources exponentially soared.

"If socialism could not defeat the louse, the louse would defeat socialism"[63]

Under the influence of typhus, the Soviet Union in 1923 began to organize its own health system, vaccination campaigns, and control of environmental diseases. Until the seventies, preventive antibiotic medicine contrasted the circulation of diseases in the countries.
During the nineteenth century extraordinary successes can be recorded in the fact of public health all around civil societies, populations that could resist environmental diseases were able to better survive and compete for life. Societies able to develop programs to improve public health had an advantage over those who did not. In 1948 was founded the WHO (World Health Organization) of the United Nations, which monitors and reports the progression of our relationship with microbes and diseases, according to which nowadays some illness are close to grubbing up and other infections have been greatly reduced throughout the years; we are winning the war on microbes. Ten years after the foundation of WHO, in 1958, American microbiologist Joshua Lederberg was awarded the Nobel Prize for medicine for the discovery of microbes' capacity for *lateral gene transfer.* Also known as

[62] Haraway D., *Staying with the Trouble- Making Kin in the Chthulucene,* Duke University Press, Durham North Carolina (2016)
[63] Lenin at Congress of Bolshevik party, in McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

HGT Horizontal Gene Transfer[64], is the process by which an organism incorporates genetic material from another organism without mating. Microorganisms can actually exchange genes between them, a bacteria can receive a trait from another bacteria, and this trait does not pass vertically in the genetic line (vertical transfer) but evolves horizontally through time (like the biggest part of human culture and social ability). Thanks to this capacity, microorganisms are also able to resist some antibiotics, spreading through all the individuals the trait to resist them. Indeed, around the 1970s began to be identified a class of microbes known as MDR (multiple-drug-resistant) performing *antibiotic resistance*, the ability to resist antibiotic effect.

If we investigate the official updated in 2022 website of the WHO under the voice of *antibiotic resistance* we read that, according to this organization: "Antibiotic resistance is rising to dangerously high levels in all parts of the world. New resistance mechanisms are emerging and spreading globally, threatening our ability to treat common infectious diseases. A growing list of infections – such as pneumonia, tuberculosis, blood poisoning, gonorrhea, and foodborne diseases – are *becoming harder*, and sometimes impossible, to treat as antibiotics, become less effective" and more "without urgent action, we are heading for a post-antibiotic era, in which common infections and minor injuries can once again kill"[65].

Also in the agricultural field, antibiotic resistance happens, and it is caused by the massive use of fertilizers, due to these pathogens beginning to recur, stronger and more resistant, humans have been forced to adapt in their turn, producing new pesticides, giving rise to new pathogens and so on. "The Green Revolution represents the antibiotic model over pathogens."[66]

I just tried so far to make light on two concepts: from one side the *symbiosis* of lichens as the way of nature to co-create environments and on the other, the *antibiotic* approach we developed so far in our interaction with microbes.

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[64] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

[65] Antibiotics erase competition, but nothing is created and nothing is destroyed, everything is just shared out. Antibiotics' mentality tries to fit the purpose of autopoiesis, supporting the continuation of the system by taking actions on the conditions that allow its reproduction. It is going to be an issue, concerning human and environmental health, with different degrees of attention. For more WHO website

[66] McNeill John R., *Something New Under the Sun: An Environmental History Of The Twentieth Century World,* W.W. Norton & Company, New York (2000)

From things to processes

"Stones lack the world, animals are poor of the world, only human beings are world-making"[67]

According to Greek philosophy, the *being* is the entity that is generated from a process. This process is an ongoing manifestation known as *physis* (*nature*), an endless dynamic of everything coming to existence, manifesting itself in the beings. The process of *physis* didn't run out just in what is coming to existance. The conceptualization of the *being* for the ancient Greeks stands both for the *ongoing manifestation*, the process of nature cycling, and all the *objects* generated each time from this process. The *process* and the *things*, generated by the process, are in western philosophy mainly two different things. But, for instance, if we try to identify the lichens in their final shape of lichens (product of the process) we find ourselves split into actually two different biological worlds (Fungi and Monere), if we look at the lichen as a single thing or an ensemble of different things that made it, we don't see the lichen itself, which is actually the *process* to which all its elements are taking part.

Crucial is to "step forward the narrative trope of the external environment (as *object*) to gain an environmental elaboration (as a *process*) co-create together by human and extra-human natures"[68] remarks the American environmental historian Jason Moore. The word 'ecology' (*oikologia*) has been borrowed from the ancient Greek botanist Theophrastus (371a.C-287a.C), a student of Aristotle. As a contraction of *"oikeios topos"* ("favorable place"). *Oikeios* is used to name the "best place", the "favorable place", in which plants better flourish, for instance. Looking at the relationship between plants and the environment, Theophrastus observes that "the nature of the plant may or may not find the nature of the place favorable. A plant seeks, so to speak, an environment where it may fulfill its purpose best. That place is the *oikeios*"[69]. Modern ecologists might call it *niche*.

"First come moisture and warmth: for every plant, like every animal, has a certain amount of moisture and warmth which essentially belong to it; and, if these fall short, age and decay, while, if they fail altogether, death and withering ensure"[70]

Ecology nowadays studies the relationship between organisms and their environments, as previously explored. Plants grow better and stronger in some places and weak and fragile in

[67] In 1930 philosopher Martin Heidegger (1889-1976) tried to define different ways of being in the world of different agents, living and nonliving (biotic and abiotic organisms).
Heidegger, Concetti fondamentali della metafisica. Mondo - finitezza - solitudine (1929/1930)
[68] Moore Jason W., *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*, PM Press, Oakland (2016)
[69] J. Donald Hughes, T*heophrastus as Ecologist*, Oxford University Press (1985)
[70] Ibidem

others, there are conditions that define their way of growing in terms of potential existence (life). This is how animals and plants are actants in the world, world-makers, generating the world around them. According to Bruno Latour "to have goals is one essential part of what it is to be an agent"[71]. The tendency for a plant to grow better, at full potential, according to the niche, or the *oikeios*, it's a struggle for resources and conditions, it's somehow agency. Plants and animals' way of realization is necessarily linked with all the other actants. The balance of gaining and losing, surviving and dying, represents the balance of the *physis*. In the functioning of the living environment, the goal is to keep the elements in balance in order to sustain life, not necessarily the life of human beings (that's our personal goal).

Ojibwa people are a tribe of Native Americans from the south region of modern Canada; in the grammar of their language, the word 'stone' appeared to be of a class normally applied to animate rather than inanimate entities. Eventually, stones can fall, can move into rivers, can produce a sound if they crash on each other, can break things, and can be rounded by the effect of water… they can do different things, in a different ontology. According to contemporary philosophers and anthropologists, the ontology of *animism* points to giving relevance and agency to all things, following the idea that "it is not that life is in stones. Rather stones are in life"[72].

Ecological systems

by Walter.L Kubiena

The relationship between organisms and their environment is really complex. By saying environment I include both interactions with the physical world, as stones, trees and lands and as well with members of the same or other species; environment includes the physical and chemical conditions as well as the biological or living components of an organism's surroundings. An ecological system, *ecosystem*, is therefore the organization of the communities of the abiotic and biotic environment, and their interactions. Moreover, the functioning of ecological systems is a gift that we receive from nature. If we had to perform all of what ecosystems do, it would

[71] Bruno Latour, *Agency at the time of Anthropocene*, Johns Hopkins University (2014)
[72] Tim Ingold, *Anthropology why it matter*s, Polity Press (2018)

probably cost too big effort to benefit from it. Ecosystems are a set of living and nonliving things working together and in order to function they need to have their *biodiversity* intact. Biodiversity is a very important part of an ecosystem because it makes it more resilient to never-ending change; ecosystems with high biodiversity are more resilient to *disturbances* than those with low biodiversity; disturbance is a natural discrete event that disrupts an ecosystem or a community. In a high-biodiversity system, losing one species among others is less likely that the ecosystem will collapse. The human impact on biodiversity has highly increased in the last centuries because affecting one ecosystem it also affected the neighboring ecosystems as well. This affection generates a so-called *cascade effect*. Deforestation induces desertification, removing trees from the surface of the planet is interfering also with the chemical combination of atmosphere; fertilizers on agricultural fields influence the status of seawater, and so on…

The characteristics of an ecosystem can be grouped into four categories: the *nesting of systems*, the *interdependence*, the *changing,* and the *cycling*.

Ecological systems are hierarchical and made of a *system of nested systems*; the borders of any layers are anyway assigned to ecosystems by humans for convenience, to facilitate analysis or manipulation. For instance, there is a sort of gradient of physical features between the marine environment and the land. The coast is the boundary, but the coast is itself a huge area where different individuals are living. Each level has its characteristics that do not appear in any of its component parts, it is only recognizable at the broader level, and some processes can be only defined and identified at a certain level of the ecosystem, they are not present at lower levels (*emergent properties)*. The very first level of the ecosystem is the *individual*, single or multi celled organisms of the same species in a given area, which are grouped in *population,* or different groups of individuals of the same species live in the same place at the same time. The following level is the *community* where the populations of all species in a precise area live and interact within an ecosystem. The nesting of these systems represents a community that is interacting with its physical environment through inputs and outputs of energy and materials. Ecology again is the study of the complex web of interactions between organisms and their environment at all levels of the organization, from individual to the whole biosphere.

The second characteristic of an ecological system is *interdependence*. Everything in it is connected in space and time. Even though there are several different ecosystems, ultimately

the planet Earth is one, embodying all the smaller subsystems through interconnection. The living and non-living components of ecological systems are interconnected and interdependent and all this produces enormous complexity because a change in any part ripples through the system similar to the effect of a rock tossed into a pod. An ecological system is a dynamic continuum and there is tremendous complexity reflected in many cause-and-effect interrelationships. In interconnected ecosystems, any effects or changes in one layer have an effect on other layers. For instance, one of the worst effects of chemical fertilizers on biogeochemical cycling is the *eutrophication of seawater,* probably in a distant place from the field watered with fertilizers. When chemical fertilizers are used in cultivation, they are spread on the whole field or delivered by irrigation, a part of it will get absorbed by the plants, and part is just released into the environment around the plant. Once chemicals are in the ground they simply continue their job, to fertilize, and when they pass into the water cycle raised fertilization also in the water, allowing the increment of primary producers (water plants in the marine environment) in the water and the consequent increase of organic matter to decomposes by macrobiotic communities. The process of decomposition of primary producers in the water requires a lot of oxygen that is taken from the molecules of water contributing to the eutrophication of seas, which is the formation of whole areas of oxygen-lack compounds of water, where life simply is simply not present.
The third ecosystemic characteristic is the *changing*, ecosystems are always changing, and they are dynamic. Changes in population abundance, species composition, and interspecific relationship change in time. Any change in any smaller ecological systems can add up to a significant impact on large-scale ecosystems. In conclusion, the *cycling* of an ecosystem is the movement and transition of matter and energy through *nutrient cycles*, following the steps of production, consumption, and decomposition.

We can properly understand nature as *physis,* as a process, and not just a set of things, through the analysis of the cycling of energy and matter in ecosystems. The matter follows processes that are cycled and closed. The organic matter moves across different trophic levels and then is transformed again and restored as initial organic matter. With the help of living beings like fungi and bacteria, and their ability to decompose, nutrient cycles can pursue their processes. An ecosystem survives thanks to the recycling of energy flow and matter, with a release of energy. When this cycling is complete, the path takes through all the major components of the Earth's system (atmosphere, hydrosphere, lithosphere, and biosphere), then is a *biogeochemical cycle* (or Global cycle). The function of biogeochemical cycling is

to move nutrients from the abiotic reserves to biotic reserves[73]; with nutrients, we mean chemical elements that are essential for life (water, phosphorus, carbon…). Biogeochemical cycles move nutrients across layers, they can involve gaseous elements, which make them *perfect* cycles, since the presence of gas means that the cycle passes through all four chemical compounds, including the atmosphere. The cycles that do not interact with gaseous molecules are *imperfect*, they do not pass through the atmosphere; since they involve earthbound elements those are slower processes, and a large portion of their supply may become unavailable for a long period of time, remaining stocked in the lithosphere. Both cycles, therefore, are driven by the flow of energy through the ecosystem, and both are tied to the water cycle. Water is the medium that moves elements and other materials through ecosystems, and without it, biogeochemical cycles would cease. The main difference between the two cycles is hence the *speed*. Cycles that can regenerate fastly (perfect cycles), and cycles that take longer since not passing from the atmosphere. The residency time of chemicals in the cycling is quite long for rocks, and earthbound elements, since the processes to move them require a lot of time (sedimentation and erosion); it is instead quite short in the atmosphere (photosynthesis and respiration); intermediate in the hydrosphere and biosphere where depends on the threat of each molecule. The speed, therefore, represents the condition of disposability of elements, a key subject in the environmental economy.

Nitrogen, Phosphorus and Carbon are elements present in the atmosphere and represent the very chemical core for the practice of agriculture. The environmental impact of modern agricultural systems can be understood also through the analysis of their cyclings.

The cycle of Nitrogen

Nitrogen (N) is a gas present in the atmosphere and its cycling among the compounds of elements is the second largest on the planet, second only to carbon. It is, therefore, *perfect* and fast to reintegrate the cycle, since it involves gaseous molecules of N. However, the structure of the molecule in its gaseous form is thus not usable for plants. The movement of Nitrogen from the atmosphere to the biosphere happens in two different ways: the first is the *atmospheric decomposition* (wetfall), such as rain, snow, clouds or fog droplets and drywall, aerosols, and particulates. Or from strong radiation and lightning, which provide a lot of

[73] *Abiotic* are nonliving cycles like rock cycle, water cycle, and other habitat; *Biotic* are living organisms, involving cycles like carbon and nitrogen.

energy needed to combine nitrogen with oxygen and hydrogen in water. The second way is *nitrogen fixation,* through the action of *nitrogen-fixing bacteria*, a group of bacteria specialized in the fixation of atmospheric nitrogen in compounds that can be absorbed by plants. Once nitrogen can be absorbed by plants then it starts to move inside the biosphere, across trophic levels as organic matter, returning to the cycle. The process of nitrogen fixation splits the two molecules of N and combines them with hydrogen to form ammonia NH3, the ammonia in the soil can be used directly from plants (*ammonification*). This community of bacteria, associated with some leguminous plants, is responsible for this fixation, they collaborate of course with environmental conditions, temperature, and moisture. This process is responsible for soil fertility.

The cycle of Phosphorus

Phosphorus (P) is a metal of the group of Nitrogen. Its cycling is *imperfect* since it does not involve gaseous molecules and atmospheric compounds. The lithosphere is the main reservoir of phosphorus, minerals, and rocks containing the chemical element, which is released by weathering, leaching, erosion, and mining to be used (for example as chemical fertilizer). The process regulating phosphorus availability from the primary production is its transition from inorganic to organic forms. Organic phosphates are taken up quickly by all forms of phytoplankton, which in turn are eaten by zooplankton and detritus-feeding organisms. Zooplankton may release as much phosphorus daily as it is stored in its biomass, returning it to the cycle. Part of the phosphate is deposited in shallow sediments and part in deep water. In the process of ocean upwelling, the movement of deep waters to the surface brings phosphates from the depths to shallow waters, where light is available to drive photosynthesis; the phosphates are then taken up by phytoplankton, while other phosphates continue to deposit in the sediments. Uplifting and weathering return the phosphorus to the cycle. Phosphorus is also highly stored in guano, the organic material of marine birds.

The Nitrogen and Phosphorus cycle have been greatly affected by human activity, especially for agricultural purposes, mainly in the removal of large amounts of phosphorus from the soil to make chemical fertilizers, which substituted the work of nitrogen fixation bacteria in the fixation of Nitrogen, overdosing it.

The cycle of Carbon

Carbon is the base of life on Earth, it is the most important element on the planet. It is stored in *reservoirs*, and it moves through a variety of processes like photosynthesis, decomposition, respiration, and mineralization. Carbon can be stored in a variety of places, including plants and animals, which is why they are considered *carbon life forms*. It is used by plants to build leaves and stems, which are then digested by animals and used for cellular growth. In the atmosphere, carbon is stored in the form of gasses, such as carbon dioxide. This makes the cycle of Carbon a perfect cycle, due to gaseous molecules. It is also stored in oceans, and captured by many types of marine organisms. Some organisms, such as clams or coral, use carbon to form shells and skeletons. Most of the carbon on the planet is contained within rocks, minerals, and other sediment buried beneath the surface of the planet. The amount of carbon in a specific reservoir can change over time as carbon moves from one reservoir to another. For example, some carbon in the atmosphere might be captured by plants to make food during photosynthesis. This carbon can then be ingested and stored in animals that eat the plants. When the animals die, they decompose, and their remains become sediment, trapping the stored carbon in layers that eventually turn into rock or minerals. Some of this sediment might form fossil fuels, such as coal, oil, or natural gas, which release carbon back into the atmosphere when the fuel is burned[74].

Fungi and Carbon: lifetime history

As we previously saw, according to Merlin Sheldrake "it was only by striking up new *relationships* with fungi that algae were able to make it into the land"[75] and became plants.
During the *Devonian* period about 300 and 400 million years ago, algae and fungi made it to the land and plants began to evolve. In the area of the Tropics, the first wood-producing plants spread around supported by their mycorrhizal fungal partner. Swampy rainforests were growing at a very fast rate, and in increasingly complex structures removing huge quantities of carbon dioxide from the atmosphere and using it to grow through the process of photosynthesis. One of the most important nutrients for plant growth is phosphorus, which is provided by the mycorrhizal partners, able to extract it from the soil and bring it within the

[74] John Grace, *Carbon Cycle*, Simon A Levin, Encyclopedia of Biodiversity (Second Edition), Academic Press, (2013)
[75] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

nutrient cycle. The following period of *Carboniferous*, 290 to 360 million years ago, represents in fact a different moment for the evolution of the planet. For millions of years, much of the plant matter generated during the Devonian period didn't actually decompose at the right rate. Layers of wood and dead matter were accumulating in the lithosphere through the soil storing so much carbon to cause a carbon dioxide crash in the atmosphere and the planet entered a period of global cooling. Plants triggered a climate crisis and they suffered firsthand the effects of that crisis, known as the *Carboniferous rainforest collapse.*

While trying to make space on the land, new forms of plants were continuing looking for solar radiations and growing in height, but in order to do so they needed a stronger structure to support their growth. Wood has been the technology developed for this problem. It is a hybrid material, mainly composed of *cellulose* and *lignin*, two of the more present polymerous on the planet. Lignin is way more resistant than cellulose due to its structural random molecular organization; only a few organisms on the planet can actually decompose it. One of these is the *White Rot Fungi (WRF)*, growing on the wood and able to decompose lignin due to their characteristic to match with the chemical structure despite their geometrical form[76]. Of the whole amount of rain forests that was growing and dying, a consistent part of it ended up in places where it was not possible for the WRF to partner with them. The reasons for this are dubious, it could have been due to the wet climatic conditions or the presence of water in the environment of rainforest, either the different speed of decomposing and growing of new matter, or WRF just didn't already develop this ability. This accumulation of non decomposed organic matter stored into the lithosphere, had become a carbon reservoir. Those carbon reservoirs are the one that sustains the development of human's *industrialization* based on fossil fuel.

Niche, carrying capacity and population growth

Let's take a step back to the concept of *niche*. We mentioned previously that niche/oikeios is the "favorite place" in which organisms live and grow, the sum of all abiotic and biotic resources that a species uses in its environment to feed. To find its own proper niche for a species, means to reduce competition for resources, helping to create a more stable biodiverse community[77]. Canadian-born ecologist Robert MacArthur, while researching his doctoral

[76] Lignin has a randomic and non-linear molecular structure, enzymes that decompose chemicals usually match with the form of the structure since it is mainly regular in other elements.

[77] *Fundamental niche* (the ideal situation in which an organism could have resources and conditions) and *realized niche* (the actual resources and situation that an organism figures out to survive) are the

thesis at Yale University in 1958, he was studying five species of warblers that live in coniferous forests in the northeastern United States. At that time there were so many different species of birds that lived and mated in such close quarters, many ornithologists thought that the birds occupy the exact same niche. Mac Arthur set out to measure exactly how and where each kind of warbler did its foraging, nesting, and mating. After many seasons he found that each species of warbler divided its time differences among the various parts of the tree, from the bottom to the top. These differences illustrated how the warblers partitioned their limiting resources, each finding its realized niche that allowed it to escape the fate of competitive exclusion. This phenomenon is now known as *resource partitioning*, similar species settle into separate niches that let them coexist. This operational way is an interspecies interaction in which species actually join forces in the fights for survival, species in a community manage to avoid competition altogether by forming downright tight relationships that benefit one, if not both, of the parties involved. Mutualism is a type of symbiosis relationship between organisms that link the two in a mutual benefit relationship to avoid competition; a prime example of mutualism is *mycorrhizae*, the fungal roots get tangled and essentially run each other's back for nutrition favors.

Since around the year 1650, the human population has been undergoing probably the longest period of exponential growth of any large animal in history ever. At that time there were about 500 million people on the planet, by 1850 the population had doubled to one billion, and it doubled again just 80 years after that, and so on until the eighth billion newborn of 2022. Ecology sized up two different ways of animal reproduction: this theory is known as *K or R selection*. Some organisms will reproduce in a way that aims for huge exponential growth (R-Selected species) while others are just content to hit the number of individuals that their habitat can support, or *carrying capacity*, and then stay around that level (K-Selected Species). R-Selected animals reproduce a lot during their lifetime; K-Selected animals instead only make a few babies in their lifetime and they invest in them very heavily[78]. Even though humans tend to reproduce on the K-selected side of the spectrum (pretty big mammals and usually have a few kids during our lifetimes), for the past few centuries our *population growth* curve has been looking like that of an R-selected species. The exponential increase of

way in which nature does conflict management; there is another way in nature to cope with life, different from the winner takes it all, but just a little bit (realized niche) for everyone in order to sustain life.

[78] K or R Selected Species is more like a spectrum. Some organisms, usually small ones, reproduce more on the R side and others, usually larger ones, on the K side. Most species are somewhere in the middle.

the human population has been allowed by the increase in the carrying capacity itself of human beings; humans figured out how to raise their own in an indefinite way, so far, by eliminating a series of obstacles (limiting factors) that would have made the population size level off at a lower level. Human population growth has been boosted around the seventeenth century, contemporary to the mechanization of the agricultural system. Those new agricultural practices, domestication of animals and crops, fertilization, irrigation and mechanization, and the ability to feed more people have been spread to much of the world by the mid-19th century, through the Green Revolution. Another decisive game changer for the human population size came in the form of medical advances, from the germ theory of 1700 to the antibiotics and vaccinations. With these two significant passages, humans started to live longer and childhood survival rates improved, more individuals signified hands and brain to work to raise the human carrying capacity itself; it also means to extend our ability to live in inhospitable places through the support of technologies (heating and cooling systems, transportation and communication…) As the human population increases, more ecological space has been taken up in order to expand and produce the resources that we need. Taking up more ecological space leaves less space for other species to the point of out-competing for the very basics of life, and as in the case of fossil fuels or water for instance, we humans could even start to compete within ourselves as a species.

Chapter 3
Entangleground. Ecological kins

Agriculture and wood: supporting infrastructure for energy accumulation

After having presented the historical development of the human practice of agriculture and the functioning of ecosystems, in this last chapter the intertwingled between humans and vegetable economy will be analyzed, trying to create a discourse that takes into account both subjects.

The human practice of agriculture is strongly connected with the humans practice of production of livelihood[79]. In the biological domain, living organisms can be of two categories, according to their attitude of getting energy from the environment to feed themselves: *heterotrophs* and *autotrophs,* organisms that differ in the modality to feed themselves. Autotrophic organisms are able to synthesize inorganic carbon and turn into organic, in this way heterotrophic organisms acquire energy and chemical compounds starting from these organic substances processed by autotrophic organisms, the primary producers for both organisms. Heterotrophs absorb nutrition from their surroundings, since they are not able to directly process inorganic chemicals, they need the collaboration of autotroph organisms like plants, that through photosynthesis are able to synthesize inorganic carbon and break down glucose producing organic matter. Primary producers, like plants and algae, (autotrophs) are the first level that organic the carbon molecules, creating biomass and make it available for all the organisms; in a second moment, plants as well as fungi, bacteria and animals (heterotrophs) make operative the production of biomass, consuming it. The heterotrophs therefore are not able to synthesize their own nutrients, but must take them in the form of carbohydrates, proteins and lipids from the other animals or vegetable tissues they eat. Heterotrophs are the majority of bacteria, animals, fungi and some parasitic plants totally free of chlorophyll; autotroph organisms are mainly plants.

[79] In this chapter I will refer to *food*, *livelihood* and *nutritions* to mean the source of energy for organic life, in the form of “nutrients” or chemical elements necessary to activate metabolic functions in the organism.

As mentioned in the second chapter, wood helped plants to get a more resistant structure to deal with the new set of conditions of a land environment; suppose we identify mainly in agriculture and farming the practices of humans' production of means of subsistence, in that case, we can read agriculture as a technology developed in order to support humans' life on the planet like *wood* has been for plants in the process of settling down on land environment. Agriculture therefore supported the development of humans under new climatic conditions (ending of glaciation of 11,000 years ago). In an ecosystemic narrative, *wood* and *agriculture* are different techniques developed by different organisms (autotrophs and heterotrophs) to process nutrients to get energy and food from their environment. We can train to read wood and agriculture not only as the *body* of an object (plants) or a *practice* of a species (humans), but also as the *process* of managing nutrients, allowing cyclings[80].

Processual, ecological thinking focuses on the *relationships* among beings, not on their own identity; it focuses among different layers and different spheres, following the biogeochemical cycles that among different compounds can complete the actual full course of a chemical molecule. As well as agriculture and farming, also human's economy works on cyclings, the trap is that it should work as a closed cycle, like biogeochemical cyclings do, by reintegrating "matter" into the cyclings and not generating "waste" or "surplus". Before digging the rupture into humans' economic cycles, let's leave some more space to interview how different heterotrophic organisms handle their relationship with autotrophs in the management of nutrients.

Heterotrophic relationships with autotrophs organisms

Fungi and plants

Fungi (heterotrophs) and plants (autotrophs) belong to the different food provisioning systems, and they both have a decentralized system of control. Decisions are taken everywhere and at every time in the body of an organism, there is not a centralized decisional system. They both live in very complex environments and relationships, learning different ways to deal with circumstances. The actions of the plants are moved by what happens in the system of fungi (and in the rest of the environment) and vice versa. Millions of different

[80] Processual thinking could be a key to stepping forward the historical dualisms that accompanied our perception of the world and nature so far, it is a training in seeing dynamically something that has been lately observed mainly statically. This is what the field of recent ecology and environmental studies are trying to propose, to raise and change the awareness of our being in the world as a part of the whole.

hyphal apices of fungi move and explore the underground soil, building multiple relationships with different species of plants. They have to find strong reservoirs of nutrients and hire them in order to increase and socialize with other microbes and bacteria, due to their heterotrophic condition. Information is entangled into a huge amount of hyphae apices, that at the same time interact with different plants extending for tens of meters. How does the information are managed in the dynamic of the relationship? How do plants and fungi keep their relationship going?

Dutch evolutionary biologist Toby Kiers[81], from Vrije Universiteit Amsterdam, studies this field entering into this complexity and unpredictability. From her research it emerged that neither fungi nor plants have total control over the relationship; they reach compromises, make agreements and implement dynamics of collaboration or, in market terminology, they make commercial strategies to trade nutrients. After a series of experiments, she concluded that plants prefer to provide fungi mainly with carbon taken from the atmosphere and fungi ensure more phosphorus back from the degradation of rocks; exchanges are somehow negotiated according to the disposability of resources. Kiers highlight the fact that these mutual rewards have guaranteed the stability of the plant-fungal associations. Of course, fungi is a very vast field, and not all fungi function the same, there are different symbiotic behaviors, in the spectrum of collaboration; they continuously adapt and swap according to what is happening around or inside them.

Here is where it becomes important to consider the fact of "*making choices"*. On the topic of *decisions*, Toby Kiers remarks: "There's a set of options, and somehow information has to be integrated and one of the options has to be chosen. I think that a lot of what we are doing is studying micro-scale decisions. […] Are there absolute decisions being made in every hyphal tip? Or is it all relative, in which case what happens would depend on what else is happening across the network" [82]. The hardest part in the study of mycorrhizal relationships is that they happen underground, into the first layer of the soil, hardly visible to the naked eye. Plants are thus the favorable way to look into the soil since mycorrhizal relationships express

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[81] Toby Kiers

[82] She and her team exposed a single mycorrhizal fungus to an unequal supply of phosphorus. One part of the mycelium had access to a big patch of phosphorus. Another part had access to a small patch. She was interested in how this would affect the fungus's trading decisions in different parts of the same network. Some recognizable patterns emerged. In parts of a mycelial network where phosphorus was scarce, the plant paid a higher "price," supplying more carbon to the fungus for every unit of phosphorus it received. Where phosphorus was more readily available, the fungus received a less favorable "exchange rate." The "price" of phosphorus seemed to be governed by the familiar dynamics of supply and demand. Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

themselves and their status through the shape, growing, smell, and taste of plants.
Plants and fungi do not inherit themselves genetically, it is not inscribed into the genetics of specific fungi that they can associate to specific plants, they keep different genetics but they do inherit the *tendency* to partner and associate. They can be more or less inclined to mate with others. Fungi, for instance, can influence the evolution and diffusion of a given species of plant, characterized by a tendency to mate. When the Laurentide ice sheet, covering the biggest part of Canada and the northern part of the United States, began to melt 11'000 years ago, it revealed millions of square kilometers of the land of North America and in those forests started to spread. In these forests, some species of plants - like beech, alder, pine, fir, and maple - were fastly moving, able to move more than a hundred meters every year[83]. Species of plants more inclined to partner with fungi had more possibility to expand. This ability of fungi and plants to shape and reshape their relationships have very important consequences that are of relevance also for humans and animals. Even for us humans, associations and partnerships with other organisms (from crops to animals and bacteria) have allowed our species to survive and proliferate.

Humans and plants

As well as other heterotrophic organisms, we do also need to gain energy for metabolic activities from the environment, using the one already processed by autotrophic organisms. Another interesting characteristic of heterotrophic organisms is moreover that they *consume* biomass to get energy, instead of autotrophs that *produce* the biomass they are going to consume to survive. Through the consumption of plants and other animals, we get the nutrients we need to live. Through the production of wood and vegetation, plants turn carbon into organic compounds, and from that, they do obtain energy for their life and provide it also for heterotrophs. If fungi entangle *mycorrhizal relationships* with plants to get nutriment, how do humans perform their relationship with nutrient reservoirs? It happens mainly through *agriculture* and *farming.*

Agriculture is the practice that regulates our relationship with the plants from which we derive energy to live. Mycorrhizal relationships collaborate by sustaining soil fertility for millennia, ensuring the healthiness of plants and soil, helping humans agricultural practices to be effective, and taking indirect care of the relationship between plants and fungi. The

[83] Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

practice of agriculture at the beginning of its development was gentle and tuned with the soil fertility. With the turn of the twentieth-century agricultural practices did radically change, starting to affect the soil in a very deep way, depriving it of its fullness of life, through the use of massive fertilizers, crops modification and monoculture structures. Modern agricultural practices have though been very effective: in the second half of the twentieth-century yields have doubled, the problem of hunger has been approached and many workplaces have been generated; also the use of fertilizers has increased by seven hundred times in order to increase the production of wealth. Pesticides and plowing gave their contribution to protect monoculture from threats of microbes.

However, altogether this set of new practices contribute to the degradation and loss of ecosystemic balance, as they undermine the status of mycorrhizal fungi, mainly substituting the function of the microbes of the soil. Their job is so variegate, researchers from Agroscope describe soil microorganisms as «ecosystems' engineers»[84]; they keep the soil together, increasing the volume of water that the soil can absorb, reducing the loss of nutrients. From the carbon stock in the soil, the biggest part is packaged in resistant organic compounds produced by mycorrhizal. Everything fungi do naturally indirectly help our purpose of growing plants, but our approach during the last centuries of modern agriculture has been of a type that moves against the support of our fungal neighbors, for many years *germs* and *microorganisms* have been considered as synonymous, especially in scientific literature, placing a veil of danger and alert on them. Some microbes do have negative and potentially dangerous effects, but a big variety of different species do actually a different job. We already explored how we ended up acting *antibiotically*, and this approach from western medicine has also reached agriculture, to increment the production in the fields. The practice of crop breeding and the massive use of fertilizers led the harvest to grow faster, according to the need of our internal markets and societies which present a characteristic, absent in the dynamics of the mycorrhizal market: *accumulation*.

Humans' peculiarity of accumulation

The concept of *primitive accumulation* has been described by Karl Marx (1818-1883) as a fundamental pre-history of capitalism. In primitive accumulation, the capital to increase it has to be created, it is the process that precedes the *capitalist accumulation* of capital. According

[84] quoted in Sheldrake M., *Entangled Life. How Fungi Make Our Worlds, Change Our Minds and Shape Our Futures,* Penguin Random House, New York (2020)

to this view the process of primitive accumulation is therefore the divorcing of the producers from the means of production, or the organisms from means of subsistence.

Between 1830 and 1870, European agricultural societies experienced a dramatic drop in the fertility of the soil, which became a significant ecological concern for societies, ending up in a massive action of guano import (phosphorus reservoir) from territories of Perù and South America, as natural fertilizer for agricultural lands. The fertility crisis represents the encounter of multiple factors, the shallow interests clash between landowners and farms, who were earning money on the free work of ecosystem services, and the failure of the recycling of dung due to the separation between the countryside and the city of that time. By analyzing this last factor, Karl Marx has been able to identify the causes of the loss of fertility and developed an ecological critique to capitalist agriculture through the concept of *metabolic rift*. The ecological concept of *metabolism* allowed Marx to express the functioning of humans' relationship with nature as a group of practices that from one side have conditions imposed by nature and from the other human capacity to influence this process.
By subtracting from the ecological cycling the organic waste of human societies, moving communities from the countryside to cities to invest in the field of industry, the soil altered its nutrient cycling, and the condition of fertility changed. The import of guano has partially solved the problem on a local level at the expense of native territories where it was taken off. Importing guano from South America and using it in the territories of the North Europe generated a cascade effect in the exponential new demand for other needs, as the logistic system to export the organic matter, the economic disponibility to buy it and the massive utilization of product available once at the time. All these new needs were generating a profit for many industries. The metabolism between nature and humans is therefore regulated by cycling, where a cycle is not a fixed condition of a treadmill, but more a frame of different conditions that have an intricate chain system in which each factor has specific consequences, in a context of more or less proximity, not only on an ecological level but also social and political.

"Large landed property reduces the agricultural population to an ever-decreasing minimum and confronts it with an ever-growing industrial population crammed together in large towns; in this way, it produces conditions that provoke an irreparable *rift* in the interdependent process of the social metabolism, a metabolism prescribed by the natural laws of life itself. The result of this is a squandering of the vitality of the soil, which is carried by trade far beyond the bounds of a single country. (Liebig.) […] Large-scale industry and industrially pursued large-scale agriculture have the same effect. If they are originally distinguished by the fact that the former lays waste and ruins the labor power and thus the natural power of man, whereas the latter does the same to the natural power

of the soil, they link up in the later course of development, since the industrial system applied to agriculture also enervates the workers there, while industry and trade for their part provide agriculture with the means of exhausting the soil." [85]

The success of the Green Revolution can be now read from a broader perspective that includes threats to ecological systems and economical and political implications, plus the awareness that agriculture is not just a practice of humans, it is part of the global metabolism which involves all the reign of livings. Agriculture is therefore the choice human societies make in front of a multiple set of conditions when it comes to getting energy for metabolic activities and life. Agriculture developed as a bottom-up practice but ended up being controlled by a top-down approach led by multinationals and profit-making industries.

While being consumers of biomass, humans began to produce part of the biomass to sustain their livelihood in the form of waste. As heterotrophic organisms, we have now the power of a geological force[86], producing huge amounts of biomass and organic matter, which stands outside the cycling mainly because it is not possible for the biogeochemical cyclings to reintegrate all this matter in an amount of time that is practical for our humans' societies. This is in line with the endless cycling of the capitalistic system which expresses itself through processes and innovations. The threat of this system is that it is built upon a knowledge that does not take into account the actual dynamics of relationships of the production of resources, but it takes those for granted. Nature as an external object will work, cyclings will continue, and upon this we will make our own decisions leaving behind the real eco-systemic awareness, the same that fungi and plants already sustain, not by actively thinking about it, but by just performing it.

Recent ecological crises place themselves in the human historical period of neoclassical economy, the current dominant economic theory, in academies and governments, according to which it was necessary to leave economic decisions to the politics of the *laissez faire,* or the free play, self-regulatory market forces. Neoclassical economy rose at the end of the nineteenth century in response to the classical economy, mainly formulated subsequently by Adam Smith (1723-1790), David Ricardo (1772-1823), and J. M. Keynes (1883-1946). The main difference between classical theory and *capitalism* lies in the fact that the economy in a capitalistic system is an end in itself. Everything produced and placed in the market generates

[85] (Marx 1981, pp. 949-50) quoted in Foster J.B., *Marx's Theory of Metabolic Rift,* Classical Foundations for Environmental Sociology, University of Chicago (1999)
[86] Chakrabarty D., *The Human Condition in the Anthropocene*, Yale University (2015)

a profit, which eventually will be reinvested in the production of the system itself. In a circular economic process there is no end outside of itself but its aim is to generate profits and allow the reproduction of the system itself. Capitalism is an economy where most of the means of production are privately owned, the production itself is driven and directed by multinationals, and income is distributed largely through the operation of markets. The development of capitalism was mainly fostered and benefitted by the spreading of industrialization during the 18th century. Even though capitalism as an economic and social system emerged much earlier, it is in relation to the impact of the ecological crisis on the nineteenth-century developments that needs to be addressed. The peculiarity of capitalism thus lies in *overproduction* and *overconsumption*, in order to expand the productive capacity of the system. Raw materials, processed by autotrophic organisms, are used by human societies; the extraction and production of resources to feed our species have been contaminated by a mentality of domination over those. The compromises and the mutual listening that characterized the relationship between fungi and plants are mainly absent in capitalistic systems. The massive production of food is done in order to feed humans, but it also feeds market dynamics, the massive extraction of materials is made up to support the infrastructures of our societies. Capital is the nutrient of capitalism, it feeds on capital.

According to Joseph Schumpeter (1883-1950), an influential economist of the early twentieth century, capitalism has occurred in two different phases. *Competitive* capitalism is characterized by companies of size not too large compared to the size of the market, and *trustworthy* capitalism instead with companies of increasingly large units. The difference between these two phases led to an interesting consideration about *competition* and *monopoly*. In the earliest competitive capitalism, at the stadium of primitive accumulation, the competition was actually taking place between all the companies involved in the production of the same product, in the second phase instead the competition, generated by most of the innovation, in terms of tools, products, knowledge or productive procedures, was between the biggest industries at the expense of smaller ones; the possibility of companies to grow radically, has cut out the smallest unities of the market. The shift described by Shumpeter as *creative destruction* (*Schöpferische Zerstörung*) is the "process of industrial change that incessantly revolutionizes the economic structure from the inside, constantly destroying the old one and always creating a new one"[87]. According to Schumpeter economic capitalist development, which is generated by innovative processes, evolves through an

[87] Joseph A. Schumpeter, *Capitalism, Socialism and Democracy*, Londra, Routledge, 1994

endless succession of cycles. As previously explored by Marx's formulation of *metabolic rift*, the economic cycle is the very way in which capitalist economy manifests its development. The issue generated by these imperfect cyclings concern the topic of waste and inegalitarian richness.

According to Jason Moore, environmental historian and historical geographer of Binghamton University, capitalism is also a *multispecies process*, a network of interactions and relationships. It regulates nowadays humans way to get from the environment the means of subsistence we need to live: it is therefore a *world ecology*[88]. The key point of modern ecological thought is not to think of capitalism *and* nature as different separated entities, but to bring them into the dialectic of complexity. Capitalism is inscribed into nature since "capitalism is not an economic system, but it's a way to organize nature"[89].
Moore describes capitalism as a *project* for the result of world practices where nature is meant as an external object to be mapped and used to serve the endless need of the capital system; and also as a *process* since it develops itself in the web of life and it is co-product by the simpoietic process of humans and nature. The theory developed by Moore of world ecology marks the dynamics of power between capital and nature struggling for a hard balance. The oikeios/niche of this system displays a massive need for *cheap* nature and work, that doesn't leave time for biogeochemical cycles to regulate and regenerate the elements that are needed in order to feed the system. Even though, Indian biologist Vandana Shiva remarks that "the capital of nature is the only real capital we have: everything else is a derivative of it"[90].

The theory of Great Acceleration proposes that in the last century human societies' entered a period of profound speed-up, due to various combinations of causes and effects[91]. The economic system has functioned so far on the expenses of matter accumulation to decompose (waste). The characteristic of human societies of accumulation is processed in the final production of waste and pollution. *Waste* is a concept that is not present in ecosystemic

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[88] Moore Jason W., *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*, PM Press, Oakland (2016)
[89] Ibidem
[90] Shiva V., *Dall'avidità alla cura. La Rivoluzione Necessaria per un'Economia Sostenibile*, EMI, Verona (2022)
[91] Hylland Eriksen T., *Overheating. An Anthropology of Accelerated Change,* Pluto Press, Londra (2016), The Great Acceleratio An Environmental History of the Anthropocene since 1945 J. R. McNeill, Peter Engelke

dynamics, since everything, with proper time, is going to be restored by the cycling of nutrients, nothing actually goes wasted. The concept of ‘waste’ is related to human livelihood since it refers to what is not going to be processed directly in an amount of time practical for human societies. Does our systems speed up so fast because we did not take into account the reverse step of consuming all the biomass produced in order to sustain our lives? Ecological timing and elements cycling have not been considered in the construction of the system, since the basements of capitalism have to ensure conditions of production, to feed the cycle of the capital itself, not the cycle of ecosystems. The timing of human societies and natural communities are not matching, since immediate profit is in contrast with ecosystemic cycles due to its need to properly reintegrate given living conditions in a given amount of time. If we would have included time for biological and biodiversity restoration, would we have progressed so far, so fast?

Scientific forestry and spectacular accumulation

Since the capitalistic system is a peculiarity only of the economy of the human species, what then happened in the specific relationship with the natural environment during the diffusion of capitalism? How did the relationship change for human societies?

In the agricultural system, primitive accumulation, followed by capital accumulation, is embodied in the practice of agribusiness plantation, which eradicated self-subsistence cultivation, generating a consequent competition between workers who have to compete with each other to keep and better do their job. From an economical point of view, the difference between these two approaches lies in the separation between *use-value culture*, giving value according to the use and consumption, and *exchange–value culture*, giving value according to the market. When agriculture was standardized by industrial format, the use-value started to disappear and exchange-value became the dominant form, and everything turned into a commodity. At the rise of the process of primitive accumulation, at the end of the twentieth century, landowners started to buy the land of peasants, and while single landowners started to buy and own more lands, the process of centralizing power was taking place. Farmers and families were forced to sell their lands to private businesses, and just found themselves keep working in the same field but under the control of others, without any more direct benefit from their work. The main value in the plantation was the product and the money. The

practice and products of cultivation started to be separated from the labor relations that produced it, in an aesthetic of fetichism of goods.

«Peasants! The sugar cane degenerates one; turns one into a beast, and kills! If we don't have land we cannot contemplate the future well-being of our children and families. Without land, there can be no health, no culture, no education, and no security for us, the marginal peasants. In all these districts one finds the plots of the majority threatened by the terrible Green Monster, which is the Great Cane, the God of the landlords» (Peasant broadsheet, southern Cauca Valley, 1972)

Prussia at the end of the seventeenth century (1600) assisted in the rise of the practice of *scientific forestry*, which tried to export the logic of the plantation also to other natural environments. Forests are a natural ecosystem used by humans, animals, plants, and other organisms for different reasons and purposes; they are complex ecology and common goods, open and accessible for everyone species, habitat, and specific ecological niche. During the pre-history of capitalism, in the phase of primitive accumulation, the State of Prussia began to think how to make forests profitable, from an economic point of view by selling their products. Forests are huge biodiverse habitats, which is why they are inhabited by many different species and represent a common good. In the practice of scientific forestry, just a few types of species of plants are in the area, to make them more profitable by creating a monoculture of trees. Trees, therefore, started to be considered as crops, something to harvest and sell in the market. The practices actually turn out to be profitable from an economic point of view for the State, and the discipline has been quickly exported also around Europe and US. The key point that made work scientific forestry lay in the fact that for the State, a bigger entity than a single farmer, was easier to calculate the profit and the economic value of each square meter of land cultivated by a single crop/tree[92]. Through the reduction of the complexity of the forest to only one species to control, the scientific calculation of profit became easier and manageable, creating a way to control nature and make it economically efficient. The first generations of 'scientific' forests were actually a success, but the following generations manifested serious problems in growth, due to the loss of all the biodiversity that was actually allowing the forest to grow prosperous[93].

[92] Scott, James C. "Nature and Space." *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*, Yale University Press (1998)

[93] Another side effect of the logic of capitalism, nourished by the need for a capitalistic system to reproduce itself, has been manifested around 1970 in the adoption of the USDA classification of soil. Developed by the United States Department of Agriculture and the National Cooperative Soil Survey provides an elaborate classification of soil types according to several parameters. https://www.nrcs.usda.gov/resources/guides-and-instructions/soil-taxonomy

In the wake of what has been investigated so far about accumulation, anthropologist Anna Tsing in her book "Friction" proposes the *spectacular accumulation* as another kind: «In speculative enterprises, profit must be imagined before it can be extracted; the possibility of economic performance must be conjured like a spirit to draw an audience of potential investors. […] Spectacular accumulation occurs when investors speculate on a product that may or may not exist. Investors are looking for the appearance of success»[94]. Spectacular accumulation is therefore a kind of investment that does not take into account the implication of products of investments, it is made on visions and dreams, individual and collective, and is projected right in the future. The spectacular accumulation as a complete separation and abstraction of the means of production, impacted the workers that became alienated from the object of their job, as well as the capitalists which focus became the assurance of capital, and also the consumers which experienced separation in the form of being not involved in the process of production of the product they consume.

According to the contexts, Nature has meant different things for humans. The complexity and interdependence of Nature gave rise to the concept of the *environment* for the field of ecology, as something interconnected to be considered as a whole, to protect or to exploit. The concept of the environment has been later on adopted by other fields to the point that in certain contexts Nature is meant as a *natural resource* or a *commodity* when it comes to dealing with her in relation to the Green Revolution or the market dynamics; and from this to the final alienation of *financial assets*, the furthest step of the commodification of the Nature. The ontological configuration of the world we live in depends on what relationships we have with other living beings, and these relationships do change by adopting different perspectives.

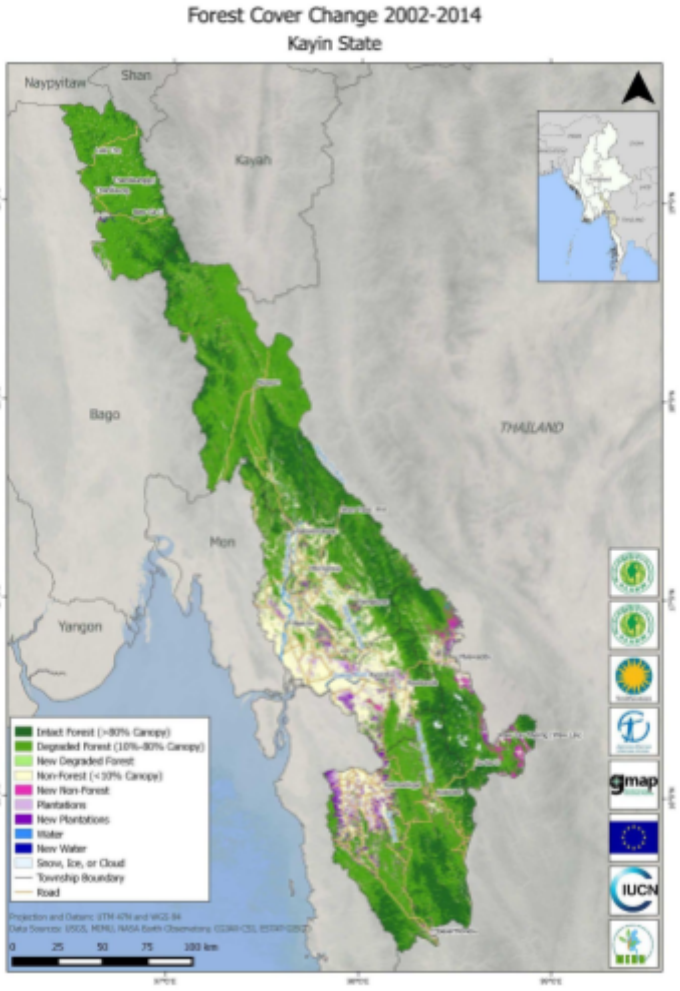
[94] Tsing, Anna Lowenhaupt. *Friction: An Ethnography of Global Connection*. Princeton University Press, (2005)

Case study: The Karen people and rotational farming

The Karen people are the largest tribe in the northern part of southwest Thailand, along the border with the southeast of Myanmar. The Karen State is inland territory and covered almost entirely by forest. It looks like a strip of mountainous land that separates the two giants around the Thai and the Burmese border. The region is characterized by the presence of the Dawna mountain range, which extends along the North-West/ South-East axis. Karen people live as a self-sufficient community based on practice of *rotation farming and forestry*. The relationship with the natural environment for the Karen people is at the base of their knowledge for centuries. Rotational farming is an agricultural practice that has been developed through centuries of life and practices in the forest. It helps to preserve the functioning of the forest, to maintain soil fertility and to store groundwater, which supports forest cover. The forest that covers the land in the Karen state is a typical rainforest, the most productive terrestrial biome, due to high temperature and moisture they have very productive growing seasons. The practice of rotational farming requires that of the whole territory of the forest only a few patches of land are under cultivation, while the rest is still a forest. After a few years of this asset cultivation, new patches of the forest are turned under cultivation leaving the previous patches fallow.

During the fallow period spontaneous vegetation quickly colonizes the patches, previously

dedicated to agriculture, and the forest can regenerate itself; proceeding by turning lands, not turning seeds but soil, this practice leaves space for the ecosystem of nutrients to spontaneously restore the cycle of the land. In order to create new available fields in the forest, the Karen use controlled fires to restore the land for vegetation, due to the big apport of ash from the fire the soil strengthens its fertility. The fire does not burn the whole vegetation of the patch, but the lower spontaneous herbage is left to grow also with the cultivation, to ensure the right environment for the harvest, and to protect the soil, and the structure of the forest will not be affected by the fire. Once the fire is gone the farmers can leave the current land to follow and move to the new patch just created for cultivation. While rotating lands, the rainforest continues to grow and the ecosystemic balance is restored. Thanks to this rotational system the Karen can assure the fertility of the soil and the outcome of the huge variety of cultures. In this way, there is always a young forest growing, and young forests have a great capacity to absorb carbon, hence helping the atmosphere to reduce the carbon dioxide in it. Rotational farming is also a food security area since some plants have edible roots kept in the ground and during the dry season they can be collected.



The Karen people have been living this way for centuries, developing a mutual relationship with the environment and healthy approach of managing the land, until 1957 when the Food and Agriculture Organization (FAO) of the United Nations condemned rotational farming as “primitive” and “culturally backward”, they proposed to governments to “solve” the issue by adapting shifting cultivation to modern agriculture so they can “emerge from their blind

alley"[95]. For decades FAO blamed rotational agriculture for deforestation, supporting the claims of the government of Thailand about the danger of fire, and indigenous people have been accused of using wildfire and being dangerous for the forest. As a consequence of this, in June 1981 Thailand announces the transformation of the forest Kaeng Krachan to the status of *National Park Kaeng Krachan*, and territories of the Karen people became protected reserves, making harder the activities of local self-sustaining; nowadays the National Park Kaeng Krachan is the biggest of the whole Thailand[96]. This governmental decision raised conflicts within the indigenous community. Since the forest became a National Park, all the buildings and construction inside of it have been declared illegal, and indigenous people were asked, or forced, to leave. The consequences of the government's decision of setting up a National Park are several: the eviction and displacement of indigenous communities, that were living inside the forest for centuries, to the outside of their native territory, and the consequent loss of their livelihood. The privatization of the forest into the Park led to losing traditions, practices, knowledge, and culture about the art of managing the environment and living in cooperation with it. Nonetheless, also violations of human rights have been perpetuated in regard to the indigenous people forced to move or killed for their disappointment[97]. Land expropriation led to the deterioration of the landscape and of the sense of place that only an active organic community who lives in it can represent. Even though covered by the intention of protecting a natural area, the National Park did actually serve the economic and political interest of governments to centralize power and generate income through activity of tourism and private exploitation of resources. From an indigenous perspective the land, the forest, and their management is something that belongs to the community that inhabits it; from a modern State point of view instead, forests and lands belong to the State, which has the right to decide how to manage them according to the knowledge they possess, at the time[98].

"The Karen forests are very important because most of our Karen people live in and live with forests and depend on what forests provide to them for everything. Because of the large forests remaining in our territory, we also have rich biodiversity and we also have rare species of wildlife. In our current territories, we can see clearly that forests managed by the indigenous and local communities are very effective because our way of life is so much attached to our forest and our land" (Saw Paul Sain Twa from Karen Environmental and Social Action Network)

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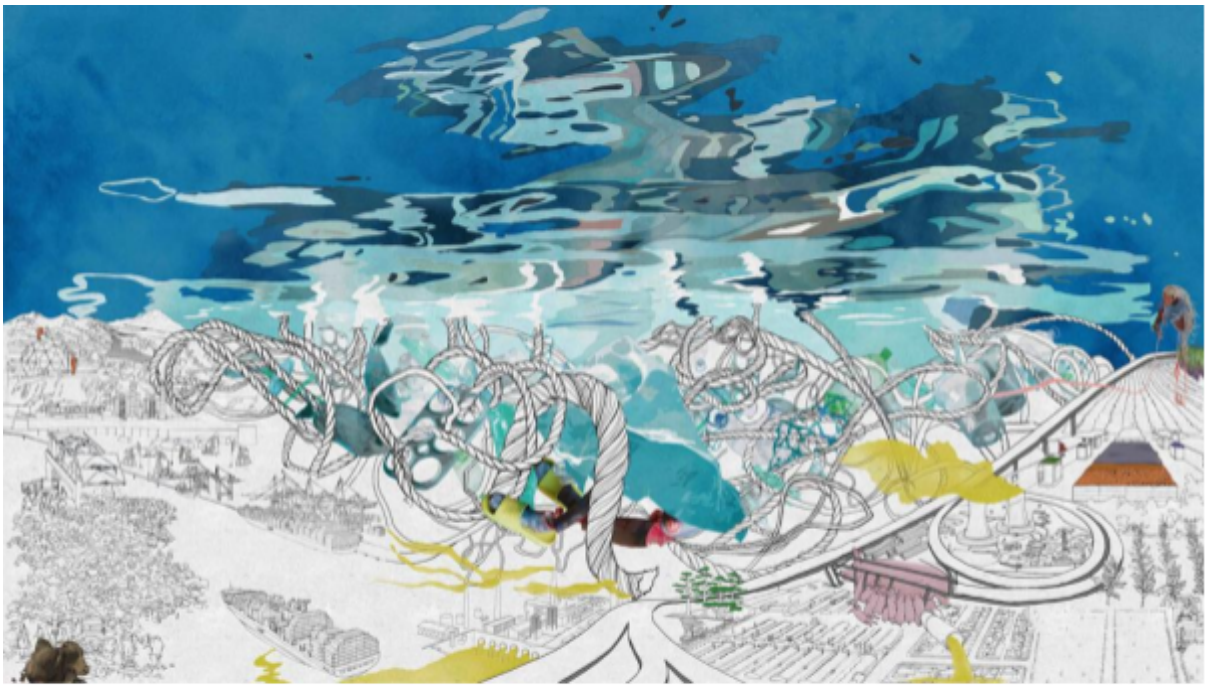
[95] Karen traditional rotational farming systems in northern Thailand
[96] EJAtlas
[97] Bangkok Post (january 2023)
[98] Between 1945 and 1975 forest cover in Thailand declined from 61% to 34% of the country's land area. During the 20th century, deforestation in Thailand was driven primarily by agricultural expansion, although teak deforestation happened as a direct result of logging.

Rainforests represent a natural biome that has been shared between communities and species, with different aims, and intentions. In the way of government and colonists, the approach has been led by the intention of maximizing the profit from the resource, the environment has been seen as a pure resource to use, not in the full awareness and understanding of its functioning. The approach of the local community instead showed a deep understanding of the functioning of the environment, as a tool to gain from it everything in order to sustain both existences, of human and forest community. The importance and restoration of the ecosystem have been given for granted in the approach of governments and colonies, while the forest is a living entity that needs care and understanding. While living inside the forest indigenous could develop a deeper and closer relationship with their environment, since it is their actual house. For governments and colonies that were living outside of it, far away from the places of the forest it came to be just a mere object, in the lack of practical experience of this place. What has been denied in fact to the indigenous community by the acts of the government, has not been a denial of their existence, but a denial of their livelihood. The indigenous have been moved from their natural communities, and governments started to provide them with food and new life conditions, as a demonstration of their human recognition, but placing them outside of the system of living that characterized their existence as a community so far, outside their system of practices. One place is not the same as another, even if survival conditions are assured. Of the global Earth's surface almost 22 percent is home of approximately 80 percent of the world's biological diversity, all those surfaces are sited among the land area used and inhabited by indigenous societies[99]. One of the reasons why biodiversity has been preserved in these territories can be found in indigenous *practices*. Exactly those practices that governments denied indigenous to act are the key to actually protecting the biodiversity, it is not just the presence of the indigenous community fed by the global and capitalistic system, but indigenous practices have to be performed. Time and space for those practices have to be allowed to protect the functioning of ecosystems and the protection of biodiversity. Not all agricultural systems are the same and we are living in a time where those practices have to be reinvented in order to listen to each other in terms of ensuring sustainability[100].

[99] Garnett, S.T., Burgess, N.D., Fa, J.E. *et al. A spatial overview of the global importance of Indigenous lands for conservation*, Nat Sustain **1**, 369–374 (2018)

[100] What is actually going on in the last decades is that FAO, recognized rotational farming as a Knowledge Intensive System to cope with Climate Change, it is precisely saying that "it is often misunderstood, and is considered to be a destructive farming technique which depletes soil nutrient content as it often involves the clearing of land by burning. When properly understood, it is an indigenous farming technique that takes into account local conditions such as climate, soil, and natural biodiversity". Recognizing indigenous practices is an act of real mutual listening and sharing

An entangled science



by Feral Atlas, Anna Tsing

The case of Karen people is just an example among many others of extirpation of practices of indigenous[101] community. The period of colonialism has opened the way to clean the environment from their inhabitants. The Indigenous of Mexico decreased from 15-20 million in 1520 to 2 million just at the beginning of 1600; In the United States and Canada, the indigenous decreased from 5 to 10 million in 1607 to just 500.000 in the nineteenth-century [102]. The development of the current economic system has disregard towards communities and traditions that for centuries or millennia have taken care of natural environments, in the mutual respect of a two-room practice. Modern capitalistic system has been foraged from scientific knowledge. The form of knowledge developed through the scientific method of collecting data, and experimental procedures; obtained through the rigorous, methodical, and verifiable study of the phenomena of nature, established during the Scientific Revolution in western countries between the 16th to 17th centuries. It gave rise to mechanistic science, reducing the understanding of living systems to fragmented parts. The strong specialization

pieces of knowledge that appear in different forms, which only by joining together can actually serve bigger intentions. https://www.fao.org/family-farming/detail/en/c/1032641/

[101] "The original inhabitants of an area that has subsequently been occupied by migrants". According to Macmillian Dictionary of Anthropology. It is thus synonymous with the term *native*, to which it is sometimes preferred where the latter has acquired pejorative connotations.

[102] Shiva V., *Dall'avidità alla cura. La Rivoluzione Necessaria per un'Economia Sostenibile*, EMI, Verona (2022)

of scientific knowledge resembles the tendency of the monoculture, typical in modern agriculture, to reduce the variables of the complexity of nature in order to better study and predict them; this way of thinking and studying phenomena has brought great possibilities to human communities, but as in the case of scientific forestry, nature thrives on biodiversity and complexity, and conceiving phenomena separately leaves spaces for unbridled interconnection, focusing on objects and not on processes. Ecosystems are based on biodiversity, on a more interconnected way also of thinking about them. In the process of specialization, scientific knowledge succeeded in isolating objects and fields of study in order to deepen the awareness and information about them; but in doing so it cut off the thin layers where everything is connected to something else. The form of knowledge we are aiming for, is more entangled into the roots of ecosystemic complexity. Observing the practices of indigenous we can identify their ability to stay in a *live* relationship with the environment, including themselves as a part of active ecosystems, in a position of mutual listening which really allows the prosperity of the environment and its species.

"They use the land and resources and develop the sensitivity to 'read' critical signs from the environment that something unusual is happening. If they were not connecting with the land, they would not be able to respond effectively to what they were observing"[103]

Non-capitalistic traditions are identified as a resource of knowledge that can help to face the modern climate crisis, especially in the field of agriculture due to their knowledge rooted into millennia of relationships and expertise developed by a direct and mutual listening of the environment around them. One of the reasons why biodiversity has been preserved in these territories so far can be found in indigenous practices of managing the environment. The knowledge of indigenous people it developed during millennia of life in the territories despite the external interventions; the territories that the indigenous was inhabiting amazed the colonists, and the preciousness, andcare devoted by the local people to the protection and coexistence within the territories entrusted to them, led the settlers to take personal advantage of it. Settlers do possess the means to conquer that, but not the right type of knowledge to follow up the environmental prosperity of what the indigenous peoples have achieved for millennia. According to Vadava Shiva, Indian philosopher and activist for environmental justice, "industrial agriculture based on fossil technologies and chemical products derived from fossil fuels are among the causes that most contribute to the ecological, social, and

[103] Berkes, F. *Indigenous Ways of Knowing and the Study of Environmental Change,* Journal of the Royal Society of New Zealand, 2009

health crises that we face nowadays" denouncing "the forced uprooting of indigenous and ecological technologies from agri-food systems, and the violent imposition of industrial technologies based on mechanistic reductionism, greed, and extractivism"[104].

"A group of blind people heard that a strange animal, called an elephant, had been brought to the city, but none of them knew about its configuration and shape. Out of curiosity, they said: "We must inspect it and know it by the touch of which we are capable". So they looked for it, and when they found it, they tried to try to figure out what it was. In the case of the first person, whose hand had fallen on his trunk, he said: "This being is like a big snake". To another whose hand reached into his ear, it looked like a fan. As for another person, whose hand was on his leg, he thought that the elephant was a pillar like a tree trunk. The blind man who put his hand on the side of the animal said that the elephant was like a wall. Another who was touching the tail had described it as a rope. The last one groped her fang, claiming that the elephant is what is hard, smooth and like a spear."[105]

This ancient Indian parable implies that someone's subjective experience may be true, but that experience is inherently limited by the fact that it does not explain other truths or a totality of truths. As we previously saw, according to different perspectives and situations Nature can be many different things, from environment to financial asset; probably we should recall to a more aggregate understanding of it. Nature can be a natural resource, it can also be a protected environment, it can also be left uncontrolled and undomesticated; multiple factors can intervene in it, but the cognitive accumulation of just one of its forms is misleading our relation to her. This is why human knowledge has to include different perspectives about the comprehension of nature, looking for different balance conditions. Scientific, indigenous, ecosystemic knowledge has to collaborate in looking for a better and sustainable modification of our practices, through different scales.

From domination to care

If we dig into the word *economy* we found an ancient greek word that was already found out in the previous chapter: *oikos (οἶκος)* this time in the sense of the «house», the complete sense of the word *economy* came to be therefore the «house administration». But what is «*house*»? House is the potential, ecological space in which every being on earth can survive[106]. Through economy we should thus take care of the house, by being aware of what the house actually is, and moreover of the strong interconnection existing in between all the

[104] Shiva V., *Dall'avidità alla cura. La Rivoluzione Necessaria per un'Economia Sostenibile*, EMI, Verona (2022)
[105] E. Bruce Goldstein, *Encyclopedia of Perception*, in *SAGE Publications* (2010)
[106] See the second chapter for *oikeios,* the "favorable place" used to formulate the word *ecology*.

different *houses* of all the different species and reigns inhabiting the Earth. The second part of the word *economy,* -nomia *(-νομία)* stands for «administration or management», but both these words do hold a detached feeling of mechanistic action. According to Cambridge Dictionary, «manage» or «administer» are terms related to actions of «control», «succeed», «being able», «manage»… neither of them is related anyhow with the action of «*care*». The *management* of the house or the *administration* of the house are not «the *care* of the house». The concept of *care* is essential in the storytelling about all the modern practices of dealing with the environment, from the economy to agriculture… it is essential, and it is completely absent. *To manage* and *to care* are two different actions and I will try to explore a little bit more the latter in order to apport new concepts to the modern narration of our practices.

The Law of Return

The first concept I would like to bond with the concept of *care* is the *Law of Return* formulated by Albert Howard. Albert Howard (1873-1947) has been an English ecologist born into agricultural lifestyle, raised on a farm in England, and educated at Cambridge, he served for a time (1899 -1902) as a mycologist in the Imperial Department of Agriculture for the West Indies, before returning to England. He then moved to India where for twenty-six years directed several agricultural research centers before permanently returning to England in 1931. In 1943, Howard published the book, *An Agricultural Testament*, in which he described the concept of *return*, according to which everything that is taken from the soil must be returned. The perpetuation of extraction of resources from the earth without giving back anything comparable, increases the rift. Giving back to the soil what is taken in the form of organic waste, or dead matter, completes the cycle of nutrients and it allows the functioning of the ecosystem the way we find it. The metabolic rift detected by Marx in the separation between city and countryside and the loss of organic matter given back to the soil that leads to the consequent crisis of fertility of the soil is actually a light spot on the *Law of Return*. The rupture of the ecological cycles for the renewing of nature actually generates scarcity, pollution, and waste but in ecology, everything is just processed. The same rottenness is a stadium of decompositions acted by fungi in the process of restoring elements in the right amount, at the right time. Everything decomposes, in different ways and at different speeds. Leaving thousands of hectares of waste of all kinds in decomposition in the dumps will make them decompose and reabsorbed by the ground and the air in an amount of time which is not favorable for our species. The waste left in the dumps is an act of

managing, while the art of decomposition of fungi is an act of *care* of giving the right time and the right room for something to happen across all the spots of being born, living and dying.

Apartheid and Ubuntu

The second concept related to the act of *care* is the *eco-apartheid*, the denial of being part, as humans and societies, of living ecological systems and cyclings. It is also the incapacity of understanding the complexity of biodiversity and its functions leading therefore to scarcity, the crisis of resources, and impoverishment of natural systems. *Apartheid* is an Afrikaans word, the language of Dutch settlers in South Africa, which precisely means: separation. Nowadays it refers, as a concept, to the rigid racial division between 1948 and 1993 of the black majority of local people of South Africa's territories from the European minority of the generations of colonizers. South African local populations as a culture, possess however a very powerful concept to express the opposite of separation, this concept is *ubuntu*[107]. In different traditions of African countries, the concept of ubuntu takes different meanings, and different nuances, but the core of its meaning is still «I am not without you», it is not possible to actually separate the beings from their interdependence. Due to the history of South Africa, the concept has been grabbed by people mainly as a human concept, used to internally and externally keep the fight for liberation from oppression and colonization. But *ubuntu* in itself stays for the status of the interconnectedness of all the living systems. «I am not without you» remarks that it is simply not possible to think outside of the web of life, in ecological or social identitarian terms. The case of South Africa concerning ubuntu is peculiar among others because is the only country in the world where the legal authorities claim that *ubuntu* is foundational to the constitutional order. The negotiators of the South African Interim Constitution of 1993 agreed that in order to address the divisions and strife of the apartheid era in South Africa, "there is a need for understanding but not for vengeance, a need for reparation but not for retaliation, a need for *ubuntu* but not for victimization"[108]. The Interim Constitution does not explain what ubuntu is, but according to the South African Constitutional Court, which was established to adjudicate in constitutional matters, the spirit of ubuntu is something that is "part of the deep cultural heritage of the majority of the population and it suffuses the whole constitutional order"[109].

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[107] Gade C.B.N, *What is Ubuntu? Different Interpretation among South Africans of African Descent*, Aarhus University (2019)
[108] Constitution of the Republic of South Africa, Act 200 of 1993: Epilogue after Section 251
[109] Port Elizabeth Municipality v Various Occupiers, 2004

In order to recognize and familiarize with the complexity of ecological systems in which we inscribe our practices, we must train our gaze to look beyond ourselves, beyond our *house*, into the *otherness*. Giving space, agency, and matter to others, in terms of humans, animals, plants, systems or words is a step in the process of care. Damage to others is damage to ourselves, and to care is giving the energy to regenerate our common house and the power to defend our common goods.

Microorganisms

The last bond of care presents itself through *microorganisms*. In the nineteenth century fungi and bacteria were classified as plants, the knowledge about their functioning was minimal and they had just been included in the biggest nearest reign. In more recent times knowledge and awareness about their identity raised in the next centuries unleashing endless possible interpretations. The most important thing microorganisms can remember us is that it is not possible to mean them as a fixed entity but as living processes, every biological system is actually a process[110]. Where the fungi begin and where the plant ends to be a plant is it not possible to say it, except through a top-down act of fixing a meaning, to make reality easier and more manageable. The boundaries are chosen for logistic purposes. Life exists in this intricate and complex system of edges. The main difference between complicated and complex systems is that with the former, one can usually predict outcomes by knowing the starting conditions. In a complex system instead, the same starting conditions can produce different outcomes, depending on interactions of the elements in the system. This is why the practice of care is so important nowadays as a method of taking all the passages into account and not focusing only on the outcomes.

"If you're new to farming and want to start a farm, start here. The New Farmers website offers a wealth of information and resources on how to start a farm, make a business plan, access land and capital, risk management, taxes, safety, and more"[111]

According to the USDA (United State Department of Agriculture) in order to start a farming project it is necessary to have knowledge about capital, risk management, and taxes… What about the soil? This approach to agriculture is focused on the products, on selling, and profits.

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[110] Dupré J., Guttinger S., *Viruses as living processes*, Studies in History and Philosophy of Biological and Biomedical Sciences, University of Exeter (2016)
[111] Official website US department of Agriculture

This is managing the resources and not taking care of them. These are starting conditions that once known can lead to a pre-fixed result. To manage is the practice to deal with complications, and to care is the practice to deal with complexity; it is a paradigmatic change.

Anthropologist Charis Boke proposes *care* as "a methodological mode of attention that can ground the sometimes frightening implication of the Anthropocene as an epoch. Care as a method helps shift the overwhelming largeness of the spheres - bio, -pedo, -litho toward more intimate and personal relationships with the Anthropocene as an emergent quality of the nature/culture world". The idea of care as a "methodological mode of attention"[112], or as a *practice,* is necessary when it comes to tackling ecological crises that are, like every crisis of the XX century, complex crises where none of the single parts of it can be faced alone, none of it can be addressed one at a time. The cat's cradle image from Donna Haraway is an appropriate metaphor for visualizing this issue, in order to create the next picture more strings at a time have to be pulled, pushed, and moved, simultaneously. Not through an act of managing compounds, but through an act of care in order to enhance conditions to be respected. The practice of care suffuses the concept of ubuntu of giving matter and attention to others in order to make them able to fit their purpose. *Care* is humans' mycorrhiza. What has been lost through the passing of centuries in human societies is the entangled bond of care that links our actions, in a spectrum of impact and consequences, in the web of life. A farmer working for USDA in the office of control for fertilizer logistics, does not have any bond with working the field, managings seeds, or knowing the soil, how can he care? In order to care it is important to have a direct bond, and in order to have a direct bond with the subject there must be a go through it; to have an experience with something we must experience proximity.

In November 2012 the Irish Food Safety Authority tested a batch of frozen burgers and discovered that instead of beef there was a mixture of horsemeat and pork. The products were sold by the supermarket chain Tesco. Tesco orders beef burgers from a French company, which company contracts out the order to a production plant in Luxembourg but the firm in Luxembourg does not actually have the meat and it orders it from the south of France; which in its turn doesn't have the meat needed to sell to Tesco chain and orders it to a Cypriot supplier who in last turn buys the meat from a Dutch distributor. From the Netherlands, instead of cattle, live horses are sent to a slaughterhouse in Romania. Finally from Romania,

[112] A property that manifests itself as the result of various system components working together, not as a property of any individual component. Charis Boke, *Care*, Punctum Books (2020)

butchered meat is sent back to France and back to Luxembourg where it is finally made into burgers, and then shipped to Tesco[113]. This is an example of how the human supply chain actually works in a capitalistic system. The example presented concerns the meat market, but the functioning of it is almost the same for other fields, from agriculture to the logistics of GMO seeds and chemical products, or to the textile industry and the chain of raw material and product processing. How far from the destination of use is the product that is generated by the work? A mycorrhiza is directly entangled with all the plants it is in relationship with, it can reach huge distances, but do not lose the bond. Humans' societies are entangled in rifts characterized by broken links to support growth and acceleration.

[113] The guardian website (January 2023)

Time for small practices

From the broad perspective of the development's history of agriculture to the analysis of the functioning of ecosystem models, through the intricate system of relationships that exist and characterize both topics, my speech begins to conclude by narrowing around the small practices. Why the small practices? The model of large-scale agriculture represents a way of hoarding the resources necessary for the life of human beings, the same that does a less extensive model such as the indigenous and non-capitalist practice, they both represent a model of action, the same that can be found in the daily and simple act of supply of resources on an individual scale, as a consumer. And it is as a consumer that I question my own work, as perfectly inserted within an economic model that represents the values in which I find myself least to believe. The practice of care as an act of restoration and ecosystem attention is an objective to be pursued, not only at a theoretical level but at a mechanical level as well.

In my kitchen, kefir is just a bunch of grains placed in a plastic jug, on the windowsill with a piece of paper on the top, to avoid oxygen. It is waiting over there and every two days I have to clean the curd from the yogurt, save the latter in a different bowl and feed the former with new milk, putting it back in the jug, on the windowsill; it takes about ten minutes of my daily lifetime. My friends Emma and Giacomo have sourdough, every week they take a piece of it and use it to make their own bread and feed with water the remaining dough, ready for next week; about 3 hours of their time, every week. A group of friends from my neighborhood have reassessed a vegetable garden from an old lady. They are five and have plenty of vegetables, olive trees, and chickens; they water, collect, and clean the garden, feeding the chickens every day, 2 hours each; 14 hours every week. One week has 168 hours. This is the time of our practices. It is the time we dedicate to practices that are nourishing living processes. Practices that are rewilding our time, stolen by productivism. Changing the practice of daily routine on the scale that is suitable with our choices and possibilities is making the time *we care for*, since "looking at temporality from the perspective of everyday experience shows that time is not an abstract category, nor just an atmosphere, but a lived, embodied, historically and socially situated experience"[114].
The time spans dedicated to living practices, also such as caring for a plant, playing an

[114] Adam, B. *Time*. Cambridge: Polity Press (2004) quoted in Puig de la Bellacasa, *Making time for soil: techno scientific futurity and the pace of care*. University of Leicester, UK (2015)

instrument, cooking, running, sewing, reading… are a non-qualitative time squeezed by productivism, where productivity "not only reduces what counts as *care* but also cuts the possibility of developing relations of care that fall out of its constricted targets. Productionism transforms care from a co-constructed interdependent relation into mere control of the object of care"[115]. Under a productivist logic, apparently, the time dedicated to care for the garden, kefir, making bread, or any personal pursuit sounds like a 'free' or 'wasted' time, or simply 'unproductive'[116]; in other words "from the perspective of productionism, time consecrated to the reproduction, maintenance, and repair of ecological life is wasted time. Against this, a politics of care exposes the importance of the work of care for creating livable and lively worlds"[117]. Giving kefir one week's hour, 3 hours to make bread, or 4 to care for the garden is subtracting time otherwise held by consumeristic practices. I have to decide which practice to practice.

I received my first grain of kefir as a *gift*. I was visiting my friends Emma and Giacomo on a cold November evening, they moved to the mountain after spending years in bigger cities. Every time I visit them I run into new and different ecological practices, and I ask questions and observe how they manage their life running through these little changes. Last year they were a lot into sourdough. It was so fascinating for me that I tried many times to ask Emma for a piece of dough to start my own practice, but she kept telling me: "You have to take care of it, it's not that easy. You cannot forget to feed it for one week, you will break the chain". She was not completely trusting me on this. Only once, she agreed to give me a small piece of dough and I forgot the jar in their house the same evening. She was right. I was fascinated by this, more than being ready to do it. My life and the management of my lifetime were way more frenetic than hers and easily I would leave behind small details in the bustle of city life. After this episode, I just kept eating their bread, without asking for more. I understood what she was telling me about, the amount of time dedicated to care, and the small practices which are composed, are timespans. I tried to figure out when and how I could have done it in my life's timetable, and keep doing it, and what I first saw was time missing, the ability of bread making missing, the ability to recognize the humidity of the dough as well, and so on…everything had still to be developed. The practice of care "takes time and involves

[115] Puig de la Bellacasa, *Making time for soil: techno scientific futurity and the pace of care*. University of Leicester, UK (2015)
[116] Adam, B. *Time*. Cambridge: Polity Press (2004) quoted in Puig de la Bellacasa, *Making time for soil: techno scientific futurity and the pace of care*. University of Leicester, UK (2015)
[117] Puig de la Bellacasa, Making time for soil: techno scientific futurity and the pace of care. University of Leicester, UK (2015)

making time of a particular kind. Time of care can be enjoyable and rewarding, but also tiresome, involving a lot of hovering and adjusting to the temporal exigencies of the cared-for"[118]. Winter came and on this new cold evening at their house, I saw a new jug on the shelf, and immediately asked Emma what it was. Here I met the kefir. Right at the time, I was trying to do a probiotic treatment through plenty of plastic jars of yogurt bought at the supermarket, every week. But Giacomo explained to me all about this new ailment and drew a picture of its story and characteristics that again fascinated me so hard just by hearing it, but I didn't ask for more. Before leaving the house, Emma gave me a little jar with a few grains of kefir in it. That was something I could have managed, something possible for me, a small trial of giving time to other things in my rushing life. I took it as a beautiful gift and a test, to make it possible. Now the small amount of kefir she gave me became a bigger jar and I have plenty of yogurts every week. I learned how to take care of it, and I'm still learning. They had this curd of kefir from their neighbor, an old lady from their village, she had it from her daughter, who had it, in turn, from her father-in-law, and so on… We dated this curd 40 years ago. Stringer figures are so made, lives connected between strangers, united by the same practice of giving time to affordable pro-life habits. I'm feeding my kefir with care, keeping it safe in its 40-year-old, every two days I take time to undo and do again the jug, I eat the yogurt, and I change my practices now ready to give it as a gift in my turn since the curd is growing and growing and because "care works better when is done again"[119]. What I would like to point out here asks for the explanation of anthropologist Anna Tsing about the 'gift economy' when talking about the Matsutake mushroom. The difference between the *gift economy* and the *commodity economy* lies in value-making. In the words of Tsing "just as in factories, workers are alienated from the things they make, so too, things are alienated from the people who make and exchange them. Things become stand-alone objects; they bear no relation to the personal networks in which they are made and deployed"[120]. The yogurt pods bought at the supermarket are stand-alone objects, enrolled by a capitalistic society for capital's needs. The curd of kefir is inscribed into a personal network of people and relations that made its value besides its economic and capitalistic connection. Same as Matsutake in Japanese culture, kefir is also involved in the same process of building relationships, where the gift became the extension of the person, a characteristic that is the definitional feature of value in a gift economy. Also, it is crucial not only the act of building relationships but even

[118] Ibidem
[119] Ibidem
[120] Tsing, A. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins.* Princeton University Press (2015)

more the maintenance of them. This maintaining of relations is a dedicated practice of care behind the act of giving. The quality of the bounty has to be accompanied by a thought of giving space to that relation, of linking what is being gifted with the person who is receiving it, they have to match. In this way, there is no patchy track, but a linked rhizome of goods and persons who are connected by an extensive *practice of care*. We can extend and expand the reach of what we are saying concerning Matsutake and kefir to other entities. If we extract the pattern we easily see that the act of care and giving works as a mycorrhiza of connections, allowing people to be in touch with their proximity, being in a healthy touch with the global.

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