Synecoculture Manual

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COMPLEX SYSTEMS DIGITAL CAMPUS

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Prologue

This manual is intended as a guide for advocates of synecoculture, who wish to apply this concept into practice at home or in their community. It covers the method of synecoculture farming in detail, including its guiding principle/philosophy, specific implementation methods and their management. It is my wish that readers find this manual as a useful reference to deepen the understanding of synecoculture in theory and in practical application. This edition is the most updated version as of 2016, and it reflects an extensive research and experimentation conducted in Japan and other parts of the world from 2008 to 2016. Synecoculture is a developing theory, and we expect it to evolve as new findings through on-going scientific research provide us with more data. Your personal experience with synecoculture in your own region will prove an invaluable resource in the evolution of synecoculture. To reach our ultimate goal of building a sustainable society for our next generation, I'd like to welcome you to join this movement, and will be looking forward to hearing your experience.

Sony Computer Science Laboratories, Inc. Tokyo, July 2016
Researcher Masatoshi Funabashi

1. General Remarks

1–1. Defining Synecoculture

Ecological optimum refers to a state where multiple species achieve their maximum growth while in competing symbiosis, to the extent possible in the given environmental conditions.
In contrast, conventional farming practices rely on physiological optimization, which generally changes the environmental conditions in order to optimize a single type of growth.

Synecoculture farming is an open-field crop cultivation method, which restricts the use of tillage/fertiliser/pesticide/herbicide. It requires nothing but seeds and seedlings to produce useful plants in **ecological optimum state**. This is accomplished through careful control of the ecosystem by exploiting the natural characteristics of the plant.

Synecoculture incorporates three essential components for occupational business farming: cultivation, application, and sales.
This manual was written on the assumption of practical implementation at home or in a community garden for local consumption. With that scope in mind, we will focus primarily on the cultivation aspect of synecoculture in this manual.

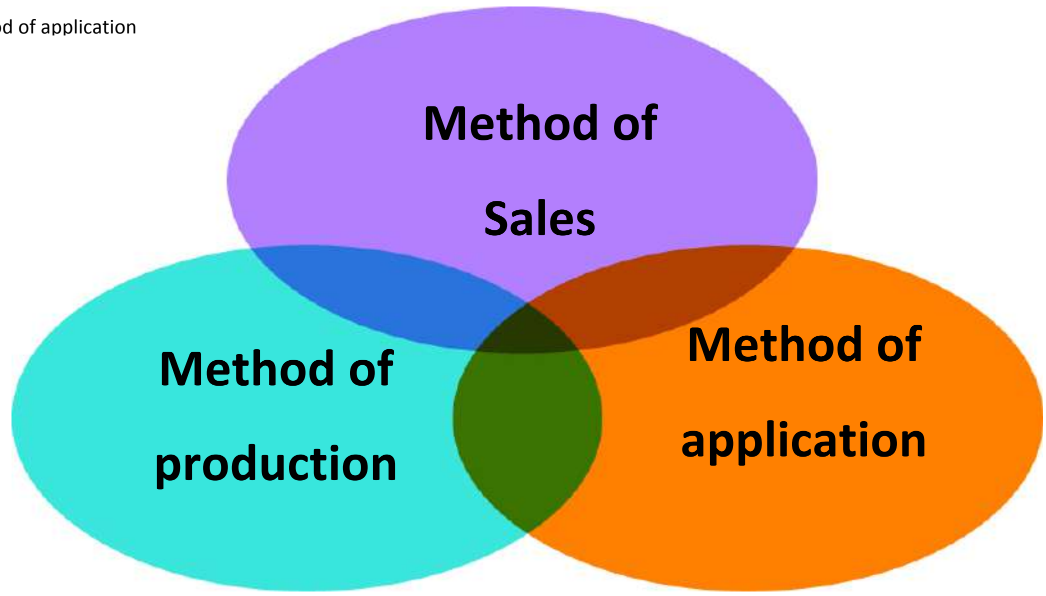
The application aspect of synecoculture consists of two steps:

1. Taking available resources from a synecological farm and its surrounding ecosystem.
2. Developing a product from these resources with additional economic value.

The produce of synecoculture includes not only the edible plants but also any food, essential resources, natural environment, scenic landscape, educational opportunity, and animal and insect groups attracted to synecoculture field.

The sales aspect of synecoculture involves the method of selling synecoculture produce through direct-sales model. It also touches on how to assess and quantify yield from the farm.
Synecoculture aims to establish distribution of its produce in an optimized ecological state/wild state, so it is necessary that the application method and the sales method be developed in accordance with regional guidelines.

Diagram: Three major synecoculture divisions: method of sales, method of production, method of application



1–2. Principles of Synecoculture

Synecoculture is a method of farming that creates an ecosystem which naturally cultivates edible produce. The most efficient way to build this ecosystem is to increase the diversity of species that colonize the area and to control the various inhabitants. In addition to species diversity, genetic diversity is also encouraged by a wide variety of breeds within the same species, and the diversity of the ecosystem is increased by a colonized vegetation that adapts to a variety of environmental conditions. The diversity of genes, species, and ecosystems is referred to as biodiversity.

Biodiversity and ecosystem functions work as a system that supplements each other. The rich and robust biodiversity improves ecosystem functions. In turn, improved ecosystem functions adjust the environmental conditions in an optimum range such as temperature, humidity, amount of sunlight, organic matter and chemical composition of the soil so that more life forms can live in the environment, allowing a richer biodiversity. This mechanism provides a variety of ecosystem services necessary for human life including food production.

Synecoculture aims to create sustainable food production and autonomous economic activity by using multi-faceted knowledge of ecology to comprehensively improve biodiversity, ecosystem functions, and ecosystem services.

One of the major differences between synecoculture and other farming methods is the restoration and development of the land through farming. Unlike other farming methods in which the natural environment is often harmfully exploited, synecoculture farming can have a restorative effect on the ecosystem. The most remarkable example of this was the introduction of synecoculture in an arid tropical region that was on the verge of desertification (see chapter 5).

Within any given **ecosystem,** there are the factors of plants and animals taking the resources necessary for survival, production and decomposition of organic matter, and the circulation of nutrients.

Ecosystem services can be divided up into 5 major services - "supply services" that create and supply things like food and water, "regulation services" in which things like climate are controlled, "cultural services" which provide benefits for recreation, mental, and cultural aspects, "infrastructure services" that are responsible for nutrient circulation and the supply of oxygen needed for photosynthesis, and "conservation services" which preserve diversity and protects the environment from unforeseen accidents.

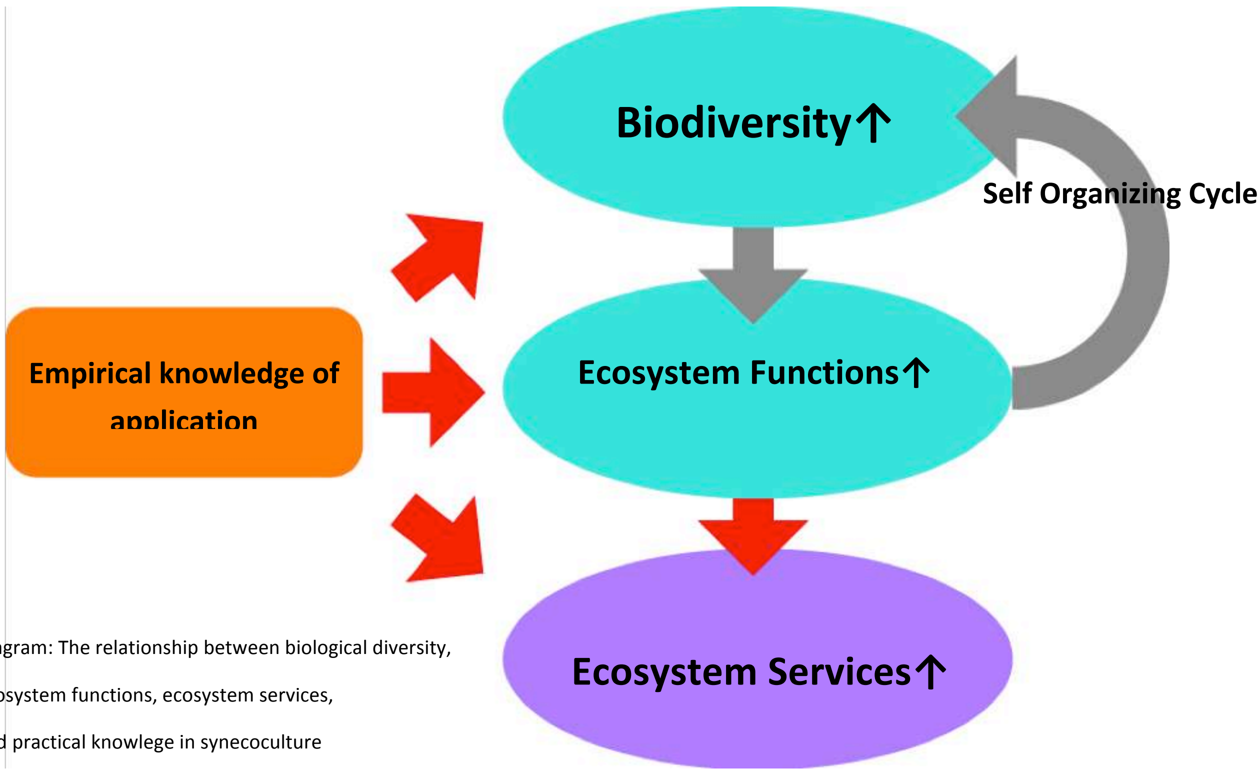


Diagram: The relationship between biological diversity, ecosystem functions, ecosystem services, and practical knowlege in synecoculture

The necessary conditions for establishing synecoculture are the ecological optimization of cultivated field, while sufficient conditions are the quantity and quality of valuable produce, and economic independence through sales. By meeting these conditions, synecoculture will be achieved as an occupation.

As one implements the synecoculture and starts to build the ecosystem, the biodiversity within a farm improves over time. It approches the target vegetation state in a manner similar to sigmoid-type growth. In the first half of the sigmoid, a healthy plant tissue provided by ecological optimum state that synecoculture aims for may not be reached, but it does create self-supporting consumption in home garden-like environments.
In the second half of the sigmoid, the saturation stage, biodiversity and ecosystem functionality are built to a sufficient level, and the environment in the farm asymptotically approaches ecological optimum. At this point, it meets necessary conditions to sell harvests as synecoculture produce. Synecoculture is fully realized upon reaching the next stage when an abundance of produce, with various product development, sustains autonomous economic activity as an professional occupation.

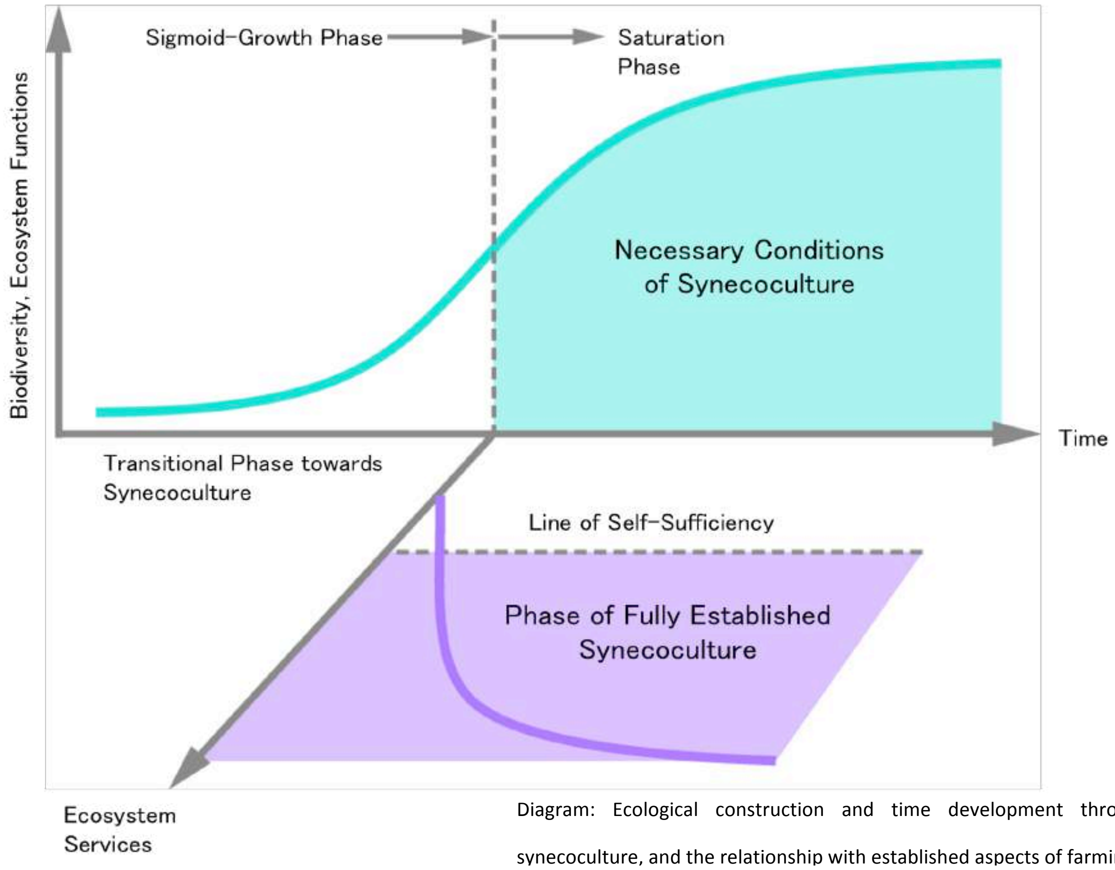


Diagram: Ecological construction and time development through synecoculture, and the relationship with established aspects of farming

In order to maintain sustainable productivity from the ecologically optimized vegetation of synecoculture without compromising ecosystem functionality, it is necessary to harvest from the saturation stage, not from the growth stage of the ecosystem construction. In practical assessment, if diversity of species in the synecoculture plantation exceeds that of the surrounding natural environment with equivalent vegetation stage, we can safely say it has fully entered the saturation stage. Since the settled species within the plantation are considered to be demonstrating ecosystem functionality as a part of on-farm ecological optimum, harboring species diversity beyond naturally saturated environment is sufficient for the judgement.
As a specific management method, we can promote symbiosis not by completely eliminating naturally occurring weeds, but by selectively utilizing them with useful plants we introduce to construct the ecosystem.

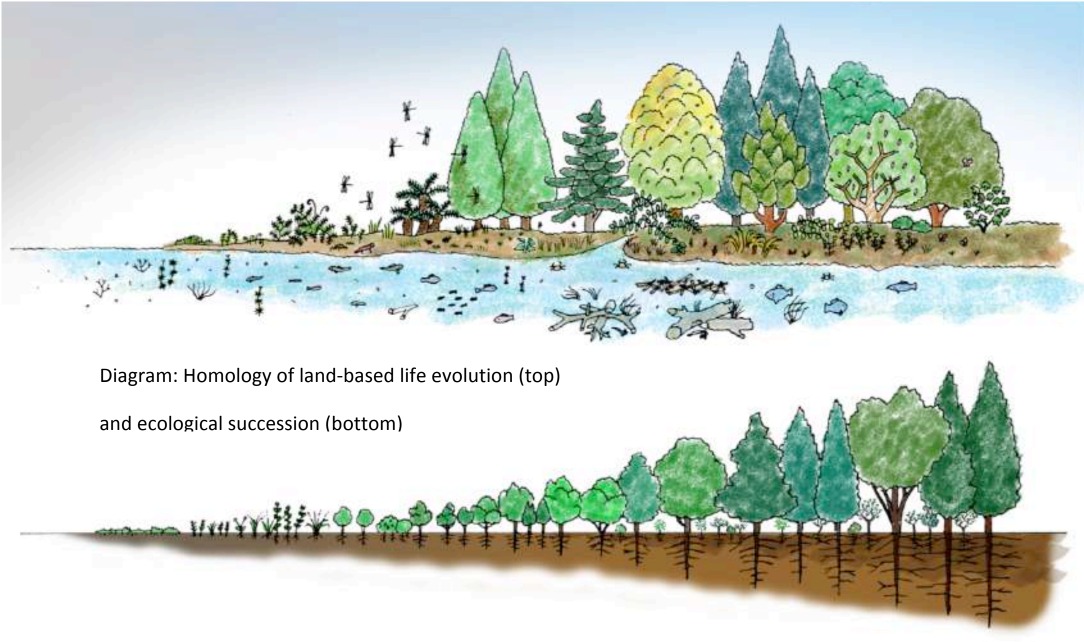


Diagram: Homology of land-based life evolution (top) and ecological succession (bottom)

The very reason synecoculture requires no-cultivation, no-fertilizer, and no pesticide/herbicide is because of the ecosystem functions we construct; simply leaving the farm untouched does not achieve synecoculture. Therefore, it is necessary to actively introduce useful plants into the ecosystem, and to plan every step towards biodiversity. Disturbance, ecological niche formation(optimum environment for growth) following the introduction of useful plants, and controling of food chain to regulate the fauna, all need to be incorporated into the plan to maximize its effect. As a result the methods necessary in conventional farming - plowing, fertilization, pesticides are replaced with disturbances in the form to promote biodiversity, formation of ecological niches, and a controlled food chain respectively.

In biology there is a recapitulation theory that states « ontogeny mimics phylogeny », but in synecoculture we manage the farm based on the view that states « ecological succession mimics evolution of land-based life». In order to develop a substrate devoid of life, start planting with the strong and low height annual plant, then the pernennial, the creeper plants, then gradually introduce low trees then on to high trees. This process will leads to an abundant forest. There is a homology in traits between ecological succession and evolutionary history of marine life that adapted, over incredibly long period, to live on a dry land that was inhabitable once.
In conventional farming methods, monocropping (making a single crop on a same land year after year) leads to the soil depletion. In synecoculture, varying degrees of growth rate among useful plants and naturally occuring plants prevents the soil depletion, and vegetation transforms itself to a new ecosystem.

Synecoculture could potentially create a huge number of different ecosystems because there is as much variety as there is the combination of natural vegetation and useful plants one introduces. It implies that we could achieve biodiversity on a scale that we have never seen in the biological history. Therefore, it is necessary to always be aware of and think about the big picture; what stage of succession your farm is positioned in an ecosystem, and where it is heading.

The core principle of synecoculture is based on the evlolutionary history of life on earth; primitive forms of life found their way on dry land, and over billions of years they evolved and created a complex system of topsoil that nurtures many forms of life. When constructing a synecocultural ecosystem, you can use this evolutionary history as a point of reference to assess the stages of your farm's ecological succession. As life evolved on land, plant species developed to grow tall with roots deep into the ground, and strengthened the adaptability to environmental changes. Many plant species of present time inherited these traits. Therefore, we can take advantage of these traits when transforming a deserted land with ecological succession into any stage through self-perpetuating climax community. To be more specific, your farm's vegetation should expand in succession that recapitulates the chronological order of plants evolution: starting from annual plant, perennial plant, creeper plant, low trees, and to high trees. This method makes smooth ecological succession possible, and you can also strategize the production schedule of useful plants that best suits for each stage of succession. In some cases, skipping or reversing the succession stage can be an effective strategy to promote biodiversity.

To increase the biodiversity in each vegetation stage and ecological succession, the following three species diversity indicators are useful in making evaluations.

α Diversity: species diversity at one vegetation stage. eg. species diversity of annual plants

β Diversity: species diversity that corresponds to the difference between two vegetation stages. eg. species diversity among annual plant and perennial plant that are independent from each other

γ Diversity: species diversity at all vegetation stages. eg. synecoculture farm and all the species diversity of the surrounding ecosystem.

Maximum biodiversity can be established by managing synecoculture farm so that these three indicators improve simultaneously. As a result, synecoculture is expected to restore and augument the biodiversity in both natural and urban environment. For example, if there are two ecosystems with the same number of γ Diversity of 500 species, one could have less α Diversity in a stage than others, and another could have a partially lower β Diversity in vegetation. Thus, it is essential to diversify vegetation from both micro and macro perspectives.

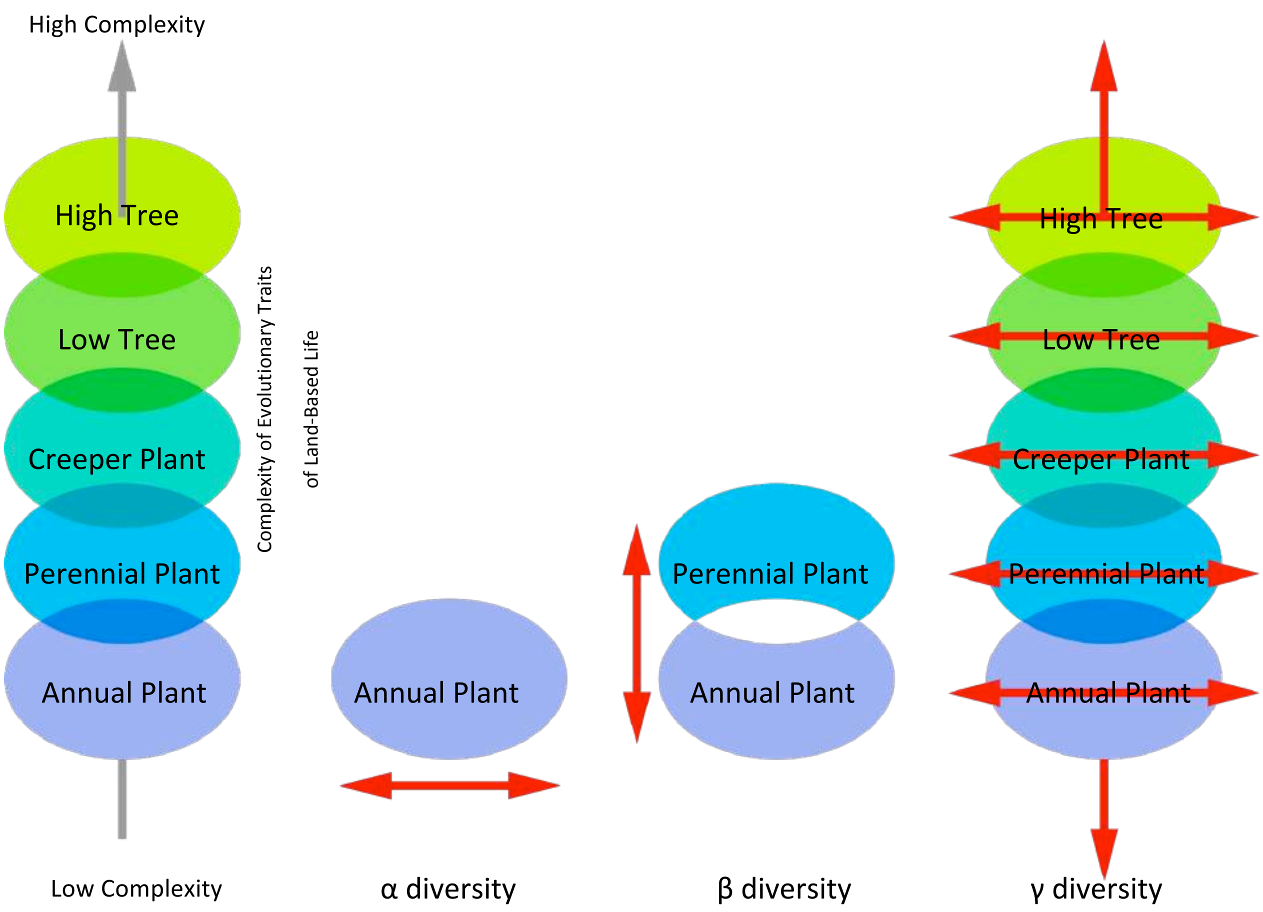


Diagram: Vegetation stages through synecoculture, and management model (axis layer struction) of αβγ diversity

Top image: Example of the butterflies observed in synecoculture farms. Through implementation in Japan, over 1000 species of insects and plant species have been observed in synecoculture farms and surrounding environment.

Bottom image: In synecoculture farms that are pesticide-free and highly biodiverse, a wide variety of natural predators coexists within the rich food chain, stabilizing the ecosystem.

1-3. Productivity

As productivity fluctuates corresponding to environmental conditions and the type of plant species, it is necessary to consider both diversity and adaptability to various conditions comprehensively. In regular farming methods, where a single crop is cultivated repeatedly in the same conditions, the average value of the yield is indicative of productivity. However for synecoculture, where farming is based on evolving conditions and the crop groups are constantly changing, that average value has no meaning within a pre-determined framework. It will be necessary to evaluate the net productivity as we adapt and diversify the vegetation strategy. For the production volume of each crop, the leafy vegetables grown at the surface of the ridge exhibit the highest yield. While for crops that take up a lot of area of the land in comparison to the cultivation period, such as Chinese cabbage, tend to have relatively low yield. For fruits and grains such as wheat and rice, the harvest period is predetermined, so it is not possible to reach a production volume of conventional farming methods for a single species. You can still cultivate some amount of grain as mulch by mixing in with other vegetables. This way, it is possible to grow grains with a normal plant tissue that is not bloated with fertilizer.

As for the track record of productivity, in the case of vegetables shipped from Ise synecoculture farm in Japan over four year period (2010-2014), it achieved five times the performance of conventional farming in revenue/maintenance cost ratio per one-tenth hectare.

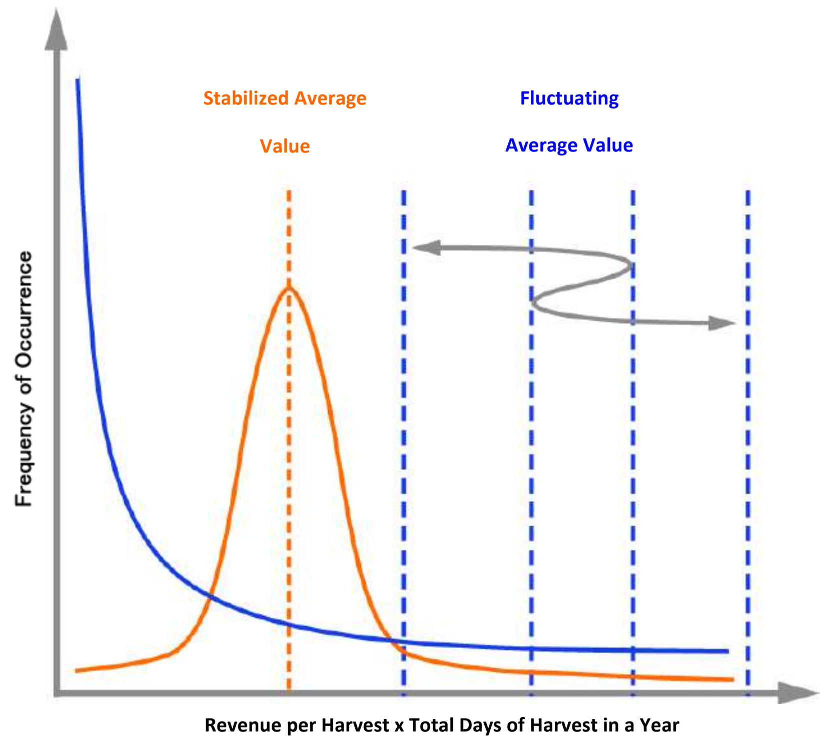


Diagram: Productivity in accordance with the normal distribution of conventional farming methods (orange), and the power law distribution of synecoculture farming (blue)

<Power Law Distribution Yield>

Although the yield produced through conventional farming creates a bell-shaped "normal distribution," the yield produced through synecoculture is based on the so-called “power law distribution” to create vegetation in a natural state. The power law distribution appears widely in natural phenomena like, for example the scale and frequency of earthquakes. As earthquakes of lesser magnitude occur more frequently than do earthquakes of greater magnitude, in synecoculture, small harvest of a variety of plants can be attained from many different environment, but large harvest from single species or environmental conditions is rarely observed. Since it fluctuates greatly in rare events, the average values of power law distribution should not be used as a predictive indicator. As synecoculture production could greatly increase through rare large harvests, it will be necessary to update the yield description according to the evaluations of each step. In order to stabilize the fluctuating production that is the cause of power law distribution, the synecoculture of various crops in the “portfolio” should be managed like an equity investment.

<Cost Calculation Supplement>

The income/maintenance cost ratio for synecoculture was calculated including the seed and seedling cost required for the initial construction. Additionally, with conventional farming the maintenance costs (seedling, fertilizer, pesticide, etc.) are added, and the initial investment costs of the tractor, etc. is huge, so the actual profitability of synecoculture practiced at Ise farm is over five times that of conventional farming.

1-4. Management Conditions

As a basic principle, synecoculture is a non-cultivation, non-fertilizer, and chemical-free farming method. Generally, humans can bring only seeds and seedlings into a synecoculture farm. Nitrogen, phosphorus acid, potassium, organic matter, and other trace elements are provided solely by the vegetation within the farm and the animals that are attracted from surrounding environment. Generally, aside from the initial soil improvement, soil enhancers and probiotics (soil microbes) as well as artificial mulch must not be introduced during the entire cultivation process. Even leaf mold and pest repellant materials used in other natural farming methods are in violation of this principle. What can be used is otherwise specified in a range that does not interfere with the soil formation in terms of the definition in synecoculture (see section 2-2-6.).

Management after the initial implementation is limited to three tasks: harvesting the crops, managing of the grass, and planting of seeds and seedlings. Grass management is carried out in accordance with the characteristics of each species of grass, however as a basic rule, annual grass stays and the perennial grass is removed.

In general, water should not be supplied by humans except for the following occasions: planting seedlings, after seed germination, and the times of severe drought. In these cases, using captured rainwater, water from a well or a river is more desirable than using tap water.

If you raise seedlings in a planter, it is permissible to use water and a minimum amount of fertilizer; however, residual fertilizer must be removed as much possible before planting in the synecoculture farm.

In this regard, seedlings sold in a hardware store can be introduced to synecoculture farm, as long as the harvesting of such crops takes place after a couple of weeks, because they are grown with negligible amount of inorganic chemical fertilizer just enough to keep them alive through shipping. The rain and the soil functions will immediately buffer this minimum amount of residuals. However, these seedlings are frail as they are raised in a short period with chemical fertilizers.

<The Difference between Annual Grass and Perennial Grass>

The roots of annual grass wither and decay in the soil, leaving pore spaces that are ideal for microbes. In contrast, roots of perennial grass keep growing without withering, and they tend to tighten the soil.

However, perennials do provide organic matter and contributes to the diversity of microbes; thus, they can be utilized to play a different role than the annual plants.

Image: In synecoculture farms a wide variety of flowers is also an important produce, as they attract pollinators.

1−5. Vegetation Conditions

The mixing of multiple vegetables, which are densely populated, is a primary rule. Annual weeds are allowed to the extent that vegetables do not lose out, and are utilized in the soil formation. It is ideal for the surface to be covered with plants throughout the year. In evaluating the vegetation stage, the following guidelines show the degree of superiority and inferiority. Items towards the top are the most desirable conditions for synecoculture while items near the bottom are less desirable.

In conventional farming methods, where single type of crop is planted in an interval, it ruins both the vegetation structure above ground and the soil structure underground, causing impaired ecosystem functions. The larger the surface area above and under ground that vegetation builds, the more biodiversity the soil can nurture.

Vegetables and fruit trees are densely mixed together, and vegetable mulch is formed with minimal amount of weeds.

▲

There are not many vegetables and fruit trees, however the field is covered by varieties of annual and perennial grass.

▲

The annual and perennial grasses are colonized and forming communities.

▲

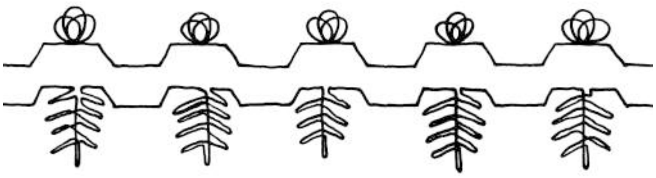
Vegetation is destroyed through cultivation, and the topsoil is exposed.

▲

Excessive use of chemical fertilizers and monoculture have depleted the land, and it is heading towards desertification.

▲

Organic matter is plowed deep into underground due to cultivation.



In comparison between conventional farming methods and synecoculture, the surface area produced by crops is substantially different for both above and under ground. As the vegetation structure becomes more complex, there will be a wider variety of coexisting organisms. Through the development of ecosystems, building the mechanism that contributes to productivity and risk management will be essential in synecoculture.

1-6. Harvesting Method

In synecoculture, harvesting is the primary method of management. Harvesting effectively thins the densely mixed vegetation and gives space and nutrition for next generation of vegetables. Start thinning with matured crops and vegetation that have reached high density. To minimize the labor cost, other management tasks should be conducted while harvesting. Empirically speaking, plains south of Kanto region in Japan do not have the agricultural off-seasons with synecoculture. You can harvest year-round by thinning, provided that proper vegetation strategy is in place, and environmental conditions such as sunlight and the means to protect from wind are sufficient. For professional farmers who require frequent harvesting, it may be necessary to have a countermeasure (e.g. an extra nursery space) in the transition period of March and September when yield decreases. We are currently running experiments in the northern limit where there is no agricultural off-season.

Image : Various states of mixture in synecoculture farms. There may be a countless variety of vegetation strategies depending on the environment and species composition.

1-7. Management Principle: "Space-Time Seed" (Multi-faceted use of time - space - variety)

In synecoculture, space is used efficiently in three dimensions to ensure constant harvest of multiple produce for prolonged period. Placement strategy and its management method should incorporate time, space, and produce types as an integrated system.

・Using Time: The defining characteristic of synecoculture is the multi-track usage of time (see section 2-2-8). Transition of vegetation and seedling planting are planned and managed so that you can continuously harvest one crop after another on a daily basis. To achieve this, you can shift the seedling planting period and/or diversify the environmental condition to create a difference in growth speed. You can also save some produce in the field until they can be harvested in a time when overall produce is low in quantity.

・ Using Space: To efficiently use the given space, utilize not just the ridge but all parts of the farm, and combine the plants with different shapes and physiological characteristics so they complement each other in three dimentions. The following are the examples of such an application: Creeper plants can be grown on the fences, passageways, areas around the farm, and on the tree trunks. Plant the crops that favor shade under the crops that favor sunlight. Plant crops with narrow vertical leaves, like green onion, in between the ones with wide horizontal leaves such as butterbur and burdock. Plant vegetables with different root length and spread patterns in a same space. Low branch of fruit tress can be trimmed to create a larger shade space, and then plant leafty vegetables there.

> Within one hectare of a synecoculture field, it is possible to introduce over 200 types of commercially available vegetables and fruits. If taking breeds into account, a diversity of over 1,000 types can be achieved. Adding herbs and edible wild plants can also double the diversity, although the distribution amount of these seedlings is low. This means that humans can help to expand the biodiversity beyond its natural state. In response to the environmental destruction caused by population growth, introducing useful plants expands the ecosystem, which is vital for both food production and conserving the environment.
>
> Though vegetables grown using conventional farming methods may have a harsh taste in some part, produce grown through synecoculture have a differently pure taste and can even be eaten raw. In particular a wide, diverse range of flowers becomes an important product as a food item. Asparagus, broccoli, mountanous udo plant, etc. grown under synecoculture have become popular produce items that many people preferably consume raw without boiling.

・ Using Variety: Not just vegetables, fruit trees, and herbs, but many useful plants such as edible wild plants will be mixed together. Even for the species with no growth record, if there is precedent of cultivation within the same climate zone, it may be introduced into the system. Additionally, separate parts of plants such as leaves, stems, shoots, buds, flowers, fruits, seeds, roots, etc., will be used as different products. In terms of application of the produce, you can develop variety of merchandise in a number of ways: vegetables can be sold raw or as seedlings, dried to make tea or spices, preserved to make pickles. You can even make and sell commodity items such as natural dye.

Image : An example of high-density polyculture where Chinese cabbage is planted in the center, and Japanese radish are sown on both sides in lines.

1-8. Cost

Aside from the initial construction materials, tree planting, seedling, and other maintenance fees, basically there is no need to purchase anything else. Heavy equipment such as tractors becomes unnecessary, and other farming tools are not needed. The only tools needed are scissors for harvesting, a shovel for seedling planting, and tools for cutting the grass (having one small-sized lawnmower would be convenient). The cost to purchase seedling, a part of maintenance fee, will gradually go down and will be replaced with homegrown seed from the farm. In an ideal situation, you want to keep cost of investment at 1/10th of the total revenue. For professional farmers with large field, the labor cost according to the scale is added to cover grass maintenance and harvesting throughout the year.

1-9. Search Method

When starting a new synecoculture field, initial "trial and error" is necessary to identify what kind of useful plants can be grown in the particular location. By planting a single type of vegetable in varying conditions of sunlight exposure, humidity, soil quality, density, mixing with other species and with different preexisting vegetation, possible growth environment for the produce will be discovered. Out of all the plants you introduce, a small percentage should be always allocated to trying a new plants even though they may have little prospect in a given environment. There are precedents of crops that did not take roots at all for the first few years, but flourished and became farm's primary revenue source as succession changed the environmental conditions over the years. By expanding the search field and not relying merely on past successes, the ability to respond flexibly to changes in the environment and ecosystems will increase.

> In making effective assessment about the ecosystem in implementing synecoculture at a high level, it is possible to engage a high level of information processing abilities, similar to that of the cognitive reaction of athletes and advanced medical diagnosis. What is necessary in the management of synecoculture is searching for useful plants that are suitable to the land, and the exchange of knowledge for comprehensive utilization. Currently a synecoculture support system that applies information and communication technology in the management process is being prepared for that reason.

Additionally, for vegetation that has yet to become useful, there have been many cases where it found new commercial value by applying multiple utilization methods, such as using different parts, the cooking method, the plantation and harvesting period, and other usages. Even for parts that are not commonly used, and for usage methods that go against common sense, it is widely possible to invent new practical and valuable usages, which increase the resources that can be leveraged in the future as part of the ecosystem service, and may also become an important product in other regions. Utilization methods can also be expanded by finding new uses for vegetables that are already in the market.

2. Detailed Exposition

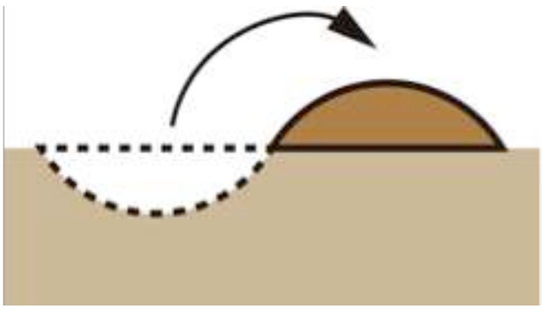
2-1. Initial Construction

2-1-1. Ridge Building

First, create a ridge of about 1 - 1.5m width. Do not plow the soil; just pile it into the ridge shape. If you want to raise long root vegetables, deep-plowed soil can make vegetables with good shape but it is not a necessary condition. The ridge width will need to be set at the largest size that allows for harvesting from both sides, so adjust according to the manager's arm's reach. If using tools such as a high twig spear for the harvest, allow for a width that makes for easy management. The purpose of making the ridge is as follows: creating different sunlight conditions for each crop; three dimensional usage of the lands to accommodate vegetables with different height; increasing arable surface area; improving drainage; promoting the formation of "briquette structure" in the soil (see section 2-2-3); separating the production area and passage area; making the overall management more convenient, etc.

If you make a ridge that runs from east to west, you can create two sections: south slope for vegetables that favor the sun, and north slope for vegetables that favor shade.

Having ridges is not a necessary condition, but it does improve convenience.



You can be flexible and change the shape of the ridge to match environmental conditions. For example, in a home garden, you may not need to make a ridge and leave it flat. On the other hand, in a dry location, you may want to dig a trench instead to create shades and moisture for the plants. You do want to take into account of the operational cost for grass management and harvest when designing a ridge. The passage between the ridges should be wide enough for people to pass through when harvesting. Choose a width that allows for ease of work. Use narrow passages if you want to increase the production area. With narrow passageways it's possible to reach the produce on both sides of the ridge while sitting. If necessary, the passageways can also be cultivated. Root crops are resistant to trampling and can grow in even hardened, tightened soil of the passageway.

2-1-2. Planting Trees

Along the center of the ridge, plant deciduous fruit trees and small shrubs at intervals of 1.5m. The purpose of planting fruit trees is outlined in the 4 points below, in order of priority.

<Why do vegetables grow well in the shade?>
Contrary to general common sense, non-fertilized vegetables grow better in the semi-shade than in facing the sun. The reason why is that the original breed of vegetables evolved in the mixed dense state with other vegetation, which optimized the capacitiy to photosynthesize in the conditions where trees provided half-shade.

(1) Creates semi-shade for vegetables
(2) Summons insects and birds that will promote pollination and provide micronutrients from feces and their dead bodies
(3) Forms mulch of leaf mold from fallen leaves
(4) Harvesting of fruit

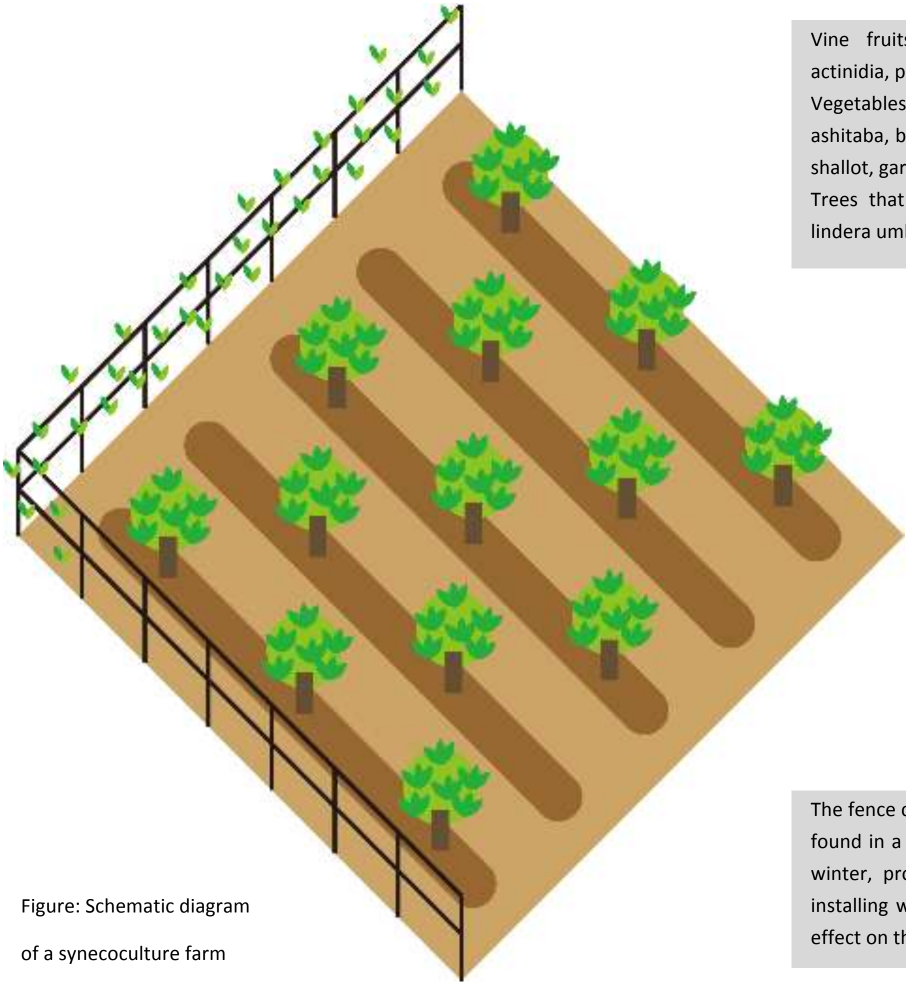
For the farm that focuses on vegetables, prune the fruit trees to a height within 2-3m. Larger trees should be placed along the edge of the farm so it does not interfere with management tasks on the field. However, fast-growing tall trees are extremely beneficial to the building of the ecosystem. One method is to plant them in the beginning, and after they've set the environment cut them down. The primary purpose of fruit trees is not to harvest but rather to create an environment suitable to the development of vegetable communities. Harvesting of fruit is considered to be a by-product.

For the farm that focuses on fruits, plant a variety of fruit trees in a mixed configuration and have them grow fully. You can grow vegetables as undergrowth of the orchard. To increase productivity, it will be necessary to come up with methods for efficient harvesting, such as setting up a net to collect the falling ripened fruit, and methods for extended sales, such as processing fruit into a paste and sell in a vacuum sealed packages. In synecoculture, it is recommended to introduce the seedlings of wild fruit trees and useful vine plants that are native to the region. It is also important to explore what type of fruit trees can be introduced by actually planting them even if there are no cultivation precedents. Grafted seedlings may result in sprouts from the rootstock, which would require pruning management.

Image: Feijoa, aralia elata in a dense mint area. This is an example of reducing management cost by using useful plants that remain superior even if left alone.

2-1-3. Perimeter Fence

Vine plants can be cultivated at the fence that surrounds the field. This will serve as windbreaks for the regions with seasonal strong wind. You can also utilize the space along the fence and walls as a nursery. Since such space has relatively high humidity in the field, it provides ideal conditions to grow seedlings in order to constantly supply the plants that are adapted to the given environment, which raises the productivity of the entire farm.



Vine fruits: kiwi fruit, arguta, yibin, grapes, actinidia, passion fruit, etc.
Vegetables that favor shade: edible wild plants, ashitaba, butterbur, mitsuba, zingiber mioga, leek, shallot, garlic, etc.
Trees that favor shade: zanthoxylum piperitum, lindera umbellata, etc.

The fence can be installed using low-cost materials found in a hardware store. Particularly during the winter, production volume can be increased by installing windbreaks. Wind condition also has an effect on the scattering of the seeds.

Figure: Schematic diagram of a synecoculture farm

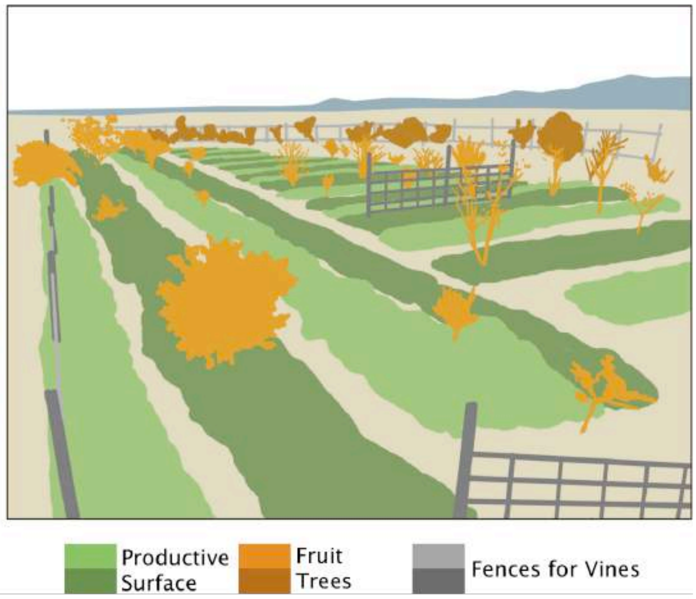


Figure: An example of the panoramic view of a synecoculture farm and its schematic diagram. (November 2010, Ise Synecoculture Farm)

2-2. Management

2-2-1.General Theory of Seeding

For professional farmers, the amount of seeding is determined by calculating backwards from the planned amount of harvest. For home gardens, the ease of grass management should be prioritized and the amount of seeding is determined accordingly. In general, leaf vegetables and root vegetables that can form living mulch, one small bag of seeds from a hardware store should cover a $1m^2$ space, but this may change depending on the types of produce and the number of seeds in a bag. In practice, you would not seed one bag over $1m^2$, but rather sow 4 bags of 4 different types of seed over $4m^2$ space to create diversity.

Mix a wide variety of seeds and sow them in a high density. The vegetables should cover the ground, effectively acting as living mulch, before grass forms a community. Regarding affinity among the plants (companion plants): though there is a variety of empirical knowledge in other farming methods, this information is based on the mixing of 2-3 different types at most. There isn't much information available for non-cultivation, non-fertilizer, and chemical-free methods. Dense mixing of various types of plants is a standard for synecoculture, and it is necessary to try different combinations without relying on precedents.

Seeds of fruit vegetables in summer season and large *Brassicaceae* vegetables are of a small amount within one bag, and cannot form vegetable mulch on their own.

Using the change in vegetation: for example, after one crop species (beans) have been harvested and withered, it can become the mulch for a different species that will emerge from the ground (potatoes).

Asteraceae vegetables: lettuce, salad lettuce, Korean lettuce, garland chrysanthemum, burdock, chicory, Jerusalem artichoke, etc.

You should consider not just spatial distribution when planting, but also the succession of vegetation over time.

Including an appropriate amount of insect repellant plants such as scallion and chives can help stabilize the insect population.

Until the suitable environment for target crops is established, start by planting vegetables that are resilient against insects and harsh environment, such as herbs and *Asteraceae* (daisy family). This will ensure the yield from the earlier stage of implementation.

Adding perennial vegetables such as chives, Italian parsley, and asparagus from the beginning can reduce grass management for the mid-to-long term, and contribute to the yield.

Depending on the rate of germination and harvest, perform over-seeding, seedling planting, and seedling transplanting within the farm.

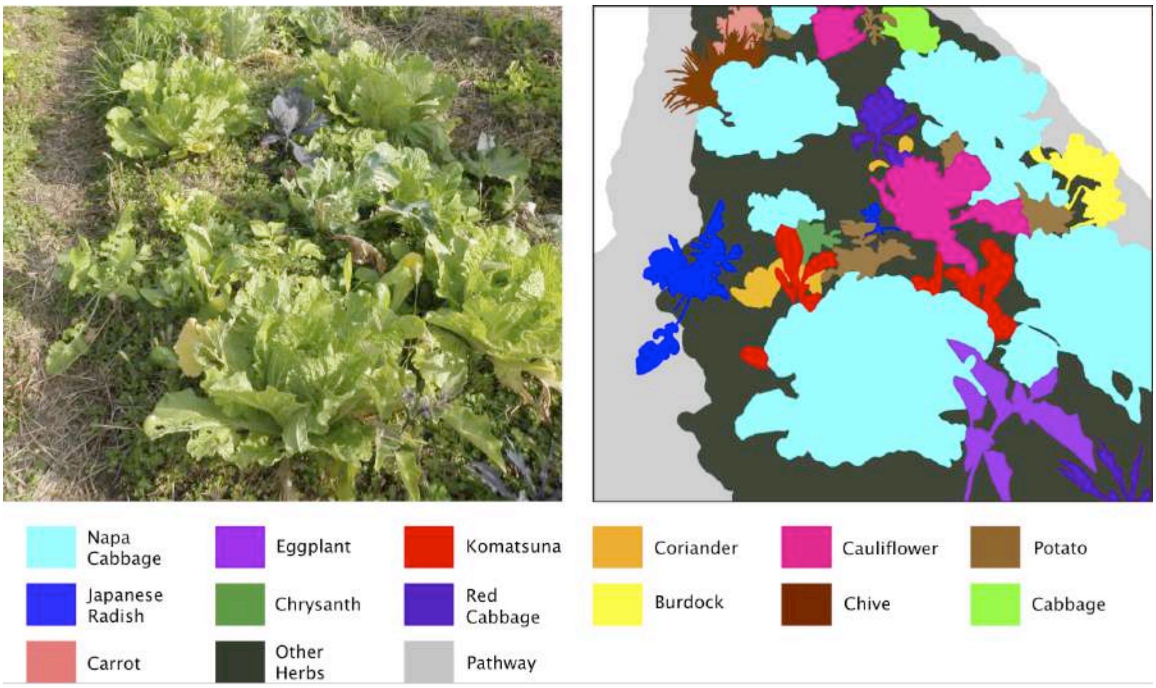


Figure : An example of the production surface of a synecoculture farm. 13 kinds of grown vegetables are found in a $4m^2$ area. (November 2010, Ise Synecoculture Farm)

2-2-2. Yearly Strategic Planning of Vegetation in Synecoculture

As a basic rule, vegetation strategy should be planned to eliminate any chance of low yield solely due to “shortage of seeds and seedlings”. In order to avoid this situation, type of vegetables, production space, necessary amount of seeds and seedlings should be determined in advance at the planning stage. As long as the quantity of seeds and seedlings are sufficient, the cause of low yield can be narrowed down to vegetation planning (arrangement, succession period), management methods, and climate. With this information you can implement a new strategy. The shortage of seeds and seedling does not give us any feedback information for next year’s strategy, and the whole year will be wasted.

In synecoculture, the seed and seedling cost at the initial implementation is higher than that of conventional farming (in case of the introduction of commercial seeds and seedlings). Though since there are no costs for fertilizer, pesticide, and machinery, the overall cost is lower. When planning the budget, It is important to think about not just the cost of seeds and seedlings but the overall cost.

Image : Mixing of wild mugwort and purple cabbage. The mugwort can be exchanged with a different vegetable, or can be used simply to construct the soil structure.

2-2-2-1. Production with a Focus on Annual Vegetables

The example of the spring and summer plans in 2012 for the Ise synecoculture farm:

Decide which crop you want to have as the primary produce for each month. Group A consists of such primary produce that you can expect a predictable harvest. This group needs to be managed and assigned to a specific location. Group B consists of the items that have potential to be primary produce, but you can not expect high yield yet since you have not experimented enough in your field. This group needs to be managed and assigned to a specific location as well. Group C consists of vegetables that do not need constant management, and can be dispersed widely and randomly as undergrowth. Group D consists of any other items that you are experimenting with, including vegetables with special characteristics.

Group A examples (parentheses shows the empirical knowledge at the Ise synecoculture farm over past few years):

Tomatoes (summer vegetable with reliable yield) cucumbers, potatoes, snap peas (reliable yield of beans), okra, shiso (tall, leafy item with reliable yield), chives (perennial with a stable yield), scallion (It is fall/winter vegetables but can be harvested in spring/summer as well), green onions, burdock, parsley, Italian parsley (reliable yield in the winter), shima shallot (year-round harvesting is possible), mountain udo (thinning of a shoot increases yield from spring to the beginning of summer), moloheiya (can be harvested until fall without losing to the summer grass), water spinach

Group B examples:

Eggplant (summer vegetable with an uncertain yield), bitter gourd, taro, sweet potato, bell pepper, green pepper, red pepper, zucchini, pumpkin, melon, watermelon, soybean (shipped as edamame bean), azuki beans, cowpeas, groundnuts (covers the ground but loses to strong grass)

Group C examples:

Carrots, turnips, radishes, lettuce and similar leafy vegetables, Japanese mustard spinach, mizuna, mibuna, bok choy

Group D examples:

Coriander (strong smells; with its peculiarity it won't sell out even if large quantities are made), saffron, asparagus, arugula, herbs

Once you have decided the primary produce from Groups A and C, determine the planting area of A and the sowing amount of C according to the planned yield (how many boxes of vegetable delivery you want to ship per month).
After planting of Groups A and C is done, you can experiment with Group B in an extra space. This experiment could be successful and produce additional yield but even if it fails you will still have enough of your primary produce.
Since March and September are transitional periods from winter vegetables to summer vegetables and vice versa, there is a risk that you run into vegetables shortage. To ensure the yield during this period, following 3 measures can be applied.

Synecoculture, which utilizes flowers and seeds, easily crosses *Brassicaceae* vegetables, creates hybrid species. *Brassicaceae*-hybrid vegetables do not have a name and are difficult to sell on the general market, but with their good flavor and tendency to have a high yield, they're valuable as a processed food ingredient. They are also suited as materials used in restaurant cuisine.

①Aside from the production area mentioned above, create an extra space where two months worth of vegetables can be grown without much management and plant seedlings there. In Ise synecoculture farm, an empty space nearby was mowed and utilized for this purpose. As long as you can save them for harvest in March and September, it does not have to produce high yield. You'll have more flexibility to respond to fluctuating yield if you manage three-tenth hectares at the same time, including this backup location, than focusing on managing one-tenth hectare.

②Harvest vegetables when they are in season, and then make preserved food through traditional methods, like pickling, to complement the low yield in March and September. *Brassicaceae*-hybrids and shallots are great for pickling.

③Besides conventional food products, you can make use of wild plants, seedlings and fresh flowers, such as butterbur sprout, butterbur seedlings, plum flowers, etc.

For Group A, diversifying the vegetation density can disperse the risk. For example, densely planted okra is resilient against strong winds such as typhoon, however it withers in November and there aren't many things that can take its place, making it difficult to transition to the next vegetation. By reducing the okra density, seedlings such as lettuce can be planted in between, for the purpose of succession after okra withers. Since there are advantages and disadvantages depending on the density, make sections with varying combination of densities. This is a specific example of the environmental conditions diversification in section 1-9 Search Method.

Image : As *Brassicaceae* hybrids develop a good flavor and have high productivity, they are a product that can be actively introduced in synecoculture.

2-2-2-2. Low Cost Production with Focus on Fruit and Perennials with Some Vegetables

In a subtropics temperate zone where the grass is strong, and if you want to take advantage of abandoned fields, reducing management costs becomes priority over the productivity per area. The strategy to achieve this is to have fruit trees, which can survive if left alone as opposed to the annual plants that requires frequent harvesting and shipping, be the primary crops for the farm and mix them with the vegetables by taking advantage of the soil environment made by naturally occurring, perennial plants. The soil structure provided by annual plants are considered by-product and are utilized secondarily as they form.

> Synecocluture farm can be designed in numerous ways to meet each farmer's objective. In contrast to conventional farming methods that use predetermined procedures and requires constant management effort, synecoculture methods are highly customizable that can sustain both high productivity farms with daily harvest and medium productivity farms with occasional harvest and mowing (lower maintenance cost). Depending on the objectives and budget, decide the cost and level of productivity you want to achieve, and design the vegetation accordingly. This flexibility allows synecoculture to be implemented even in an area that is considered unsuitable to practice conventional farming.

Example below shows the spring and summer plans for 2014-2015 for the Ise and Oiso synecoculture farms:

Group E consists of fruit tress that are strong against grass invasion and adapts well to wasteland. Group F consists of vegetables that can germinate on their own from seed form even among colonies of weed. Group G consists of vegetables that grows better when planted in seedling form instead of seed. Group H consists of vegetables that needs a little assistant as their seed does not germinate unless the grass is mowed and topsoil is partially removed to eliminate the inhibitory effect of past vegetation.

First, decide on the location for fruit trees in Group E and plant them in large quantity. Second, plant vegetables mainly from Group F among the trees. These two Groups will be the primary crops, and Group G and H can be introduced if you want to increase production volume or if you want to have better control of weed expansion.

Group E examples:

Persimmon: cultivar and native date-plums

Loquat: cultivar and native meliosma rigida

Cirtus fruits: sweet Chinese citron, oranges, kabosu, lemon, etc.

Plum, cherry tree types: plum, Nanko Ume (southern plum), nanking cherry, Japanese plum, cherry blossom, apple (two types or more make for better fruit bearing rate), angsana, etc.

Figs: western and Japanese figs, wild figs

Elaeagnus: silverberry, native autumn olive, etc.

Berry tree: blueberry, *Amelanchier canadensis*, wild *Vaccinium bracteatum*, etc.

Tree nuts: chestnuts, wild Japanese chestnuts, walnuts, hazelnuts, etc.

Other: feijoa, eucalyptus, etc.

Group F examples:

Apiaceae of carrot, parsley, Italian parsley

Asteraceae of lettuce (strong species of bitterness), chicory (strong allelopathic grass, does not lose to perennial plants), Jerusalem artichoke (occupies the community), burdock (grows even in hard ground)

Legumes: soybeans, kidney beans, peanuts, velvet beans (also strong against tall grass)

Potatoes: potatoes, taro (prefers wetlands), Jerusalem artichoke

Root crops: garlic (does not lose to grass even if buried), shallot, chives, burdock, carrot

Other mulch-types that crawl along the ground: strawberry types, herb types (mint in particular)

Predominately shade types: mitsuba, leek, *Zanthoxylum piperitum*, nandina

Group G examples:

Seeds with a high author rate even within grass: perilla, pepper, lettuce (cultivar), leek, tomatoes, cucumbers, cabbage, broccoli, artichokes

Things that becomes shrubs upon growth: tea plant, raspberry, kidney beans, velvet beans

Predominately shade types: butterbur, leek, ferns

Group H examples:

Lettuce (cultivar), Japanese mustard spinach, etc.

For potatoes and root vegetables, rather than leaving them be, moderately harvesting and disrupting them can increase the yield. They will be dug up during harvesting, so the perennial plant roots can be cut and controlled. For potatoes, if you thin out the above-ground portion of sprouts to leave a single stem from a root, the swelling of the potato can be observed.

Vegetables in Group F are the easiest to manage as these vegetables are capable of germinating on their own and propagate themselves. As there is no need to disturb the topsoil, this is the most useful for ecosystem construction. By keeping vegetables in Group F dominant, the management costs will be lowered while maintaining a certain degree of harvests. Even left untouched for long time, these vegetables will resurge after mowing the grass.

For Group G, there are advantage and disadvantage. The advantage is that you can manage and control them easily since they are planted in seedling form. The disadvantage is that if large quantities are planted continuously, the topsoil will deteriorate accordingly, and there are cases that the residual chemical fertilizer on the commercial seedling soil will accumulate over time. Whereas, items such as Japanese basil and artichoke are capable of reproducing themselves at the same location once they are planted, making them high value items. Many of F and G are biennial or have characteristic similar to biennials.

Many items in Group H are annual vegetables that are selectively bred to be commercially viable. They are modified to suit the conditions of conventional farming and the production outputs do increase thanks to the crop improvement; however, so do the management costs and destruction rate of the topsoil.

2-2-2-3. Home Garden

Synecoculture can be practiced for small-area such as home gardens with the object of self-sufficiency. There is a precedent of a small space of $4m^2$ with right choise of species and variety that produced year-round vegetables for a number of servings. We will show the grouping patterns as a hint for home gardening implementation.

Group I: Vegetables that you can expect to harvest from an early stage by thinning. They are grown by sowing the multiple types of seeds and letting them mix in high density.
Focus is yearly leafy vegetables such as lettuce, Japanese mustard spinach, radish, rucola, etc.

Group J: Vegetables that can build a suitable environment where continuous production is possible. These crops needs to be planted in bulk to some extent.
Brassicaceae vegetables such as cabbage, broccoli, Chinese cabbage, cauliflower, etc.
Fabaceae vegetables such as kidney beans, soybeans (green soybeans), peanuts, etc.
Apiaceae vegetables (perennial) such as parsley, Italian parsley, etc.

Group K: Root vegetables. They can be planted in the gaps among other vegetables, or in places where other produce does not grow easily. They increase efficiency and yield from your garden.
Carrots, radish, burdock, shima shallot, green onion, potatoes, taro, etc.

Group L: Vegetables that need careful management to prevent it from overly dominating other plants. It is useful to have in a small amount. Herbs, garlic, Japanese ginger, mountain udo, ashitaba, asparagus, butterbur, strawberry, *Zanthoxylum piperitum*, flowering plants, etc.

The characteristics of root vegetables can be utilized in combined strategies with other vegetable groups, such as arranging them in a line to block the invasion of other grasses, planting other seedlings in anticipation of the soil that will be dug up during the harvest, and sowing the seeds of lettuce and Japanese mustard spinach, which are easy to germinate after the disturbance.

2-2-3. Grass Management

Knowing the characteristics of each vegetable and grass allows you to perform efficient grass management in response to their characteristics ("control grass by using grass"). As long as the vegetables aren't losing out, do not remove the annual grass. Remove only the perennial grass that forms a community, and the annual grass that becomes too big. If using a lawnmower, cut the grass that grows taller than the height of the vegetables to reduce growth rate of the grass and create an environment that favors the vegetables. If germination has already occurred and it would be difficult to mow through the scattered vegetables, then remove the grass manually during harvest or while planting seedlings. It's best to pull out perennial grass from the roots; however, if they are large then cutting the part above ground repeatedly can shrink the underground root, which contributes to the formation of soil structure. Perennial grass may be allowed to grow on the non-ridge passage areas. Annual grass withers in the winter, forming **briquette structure** with pore space in the soil. Perennial grass tightens and hardens the soil without withering, but it can also enrich the soil environment and terrestrial ecosystem.

＜**Briquette Structure**＞
It describes the physical aspect of the soil structure. After the roots of annual grass spread underground and wither within the soil, they leave interconnected pore space similar to a briquette structure. This tightly knit structure strengthen the resilience of the soil and provides excellent ventilation and water permeability, making it strong against physical disturbance from wind and rain.

2-2-3-1. Three Basic Methods of Grass Management

① Mowing everything: In order to restart/reset the field where the grass dominates the vegetables, it is best to cut the grass and vegetables all at once to the ground level. The height of what remains can be anywhere between the ground level, slightly above the ground to 10 centimeters depending on your seed-planting strategy after the mowing.

② Mowing to the height of vegetables: If the vegetables and the grass are competiting and the grass is growing taller, cut the grass down to the vegetable height. Only the grass will be damaged and it will become easier for the vegetables to dominate.

③ Removing Large Grass: Individually remove the grass that stands out such as the perennials community or the annual grass roots that grow too big.

Methods ① and ② can be applied to surface. Thus, it is easy to take care of large area at one time. In some cases, it is not efficient to conduct these methods especially when the height of the vegetables varies greatly or when the newly sown seedlings are still around. You can use method ③ in this instance to mow individual parts although it takes more time to cover large area.

Image : Example of mixed vegetations in Honshu, where weeds are strong in the summer. These conditions require careful planning for fall/winter season since you have to balance between soil formation and productivity.

2-2-3-2. Soil Formation through Controlled Propagation of Grass

There is also a method of allowing weeds to grow thickly in summer so that the soil will be ready again for harvest from fall onward. Although it reduces the yield during summer, this strategy is effective because the weeds prepare the soil for higher productivity in the following seasons and labor costs can be reduced during the heat of summer. During this time, you can either leave the field alone completely or harvest the remaining vegetables and cultivate tall plants, like tomatoes in a bush. When the summer ends, use a lawn mower to cut down all the vegetable and the grass and sow seeds right on top. The mowed grass becomes mulch and serves as camouflage for the seeds against animals and insects. The growth rate of weed slows from fall, making it easier for vegetables to dominate. You can use this method of “mow everything and restart” until the vegetables become the dominant force, not just in summer but anytime when weeds are overpowering.

Image : Any produce outside the farm area, such as nuts and wild fruits, can be proactively utilized in synecoculture. It is essentially important to know comprehensively and take full advantage of the regional ecosystem when managing a synecoculture farm.

2-2-4. Production Deadline

The essence of synecoculture lies in the informational management of the dynamic ecosystem in order to maximize its productivity while reducing the cost. Therefore, it is very important to manage production schedules and set appropriate deadlines for each season. If the deadline is not met, you need to either scale down the current strategy or change it entirely. Otherwise you will end up reacting after the vegetation has changed. The deadline for each task varies depending on the climate conditions of the year. The following dates are based on the experiment in Honshu, Japan, mainly in the Kanto and Kinki regions (at north latitude 34-36 degrees).

When deadline is not met, it results in cost increase and reduction in yield due to excess weed invasion into vegetation area. Conversely, deadline should be set to hedge these risks.

Leek, arugula, shima shallot, mini-tomato, etc. can be undomesticated easily and adapt to a wild environment of synecoculture in a similar manner to weeds. Seeds from raw fruit such as watermelon and pumpkin are stronger than commercially distributed seedlings. Cucumbers grow well when sown near a tree at the end of May to the beginning of June. They thrive by tangling themselves up around the tree, in a way similar to their parent species in natural environment. Tomatoes in conventional farming often propagate self-sown seedling that can be pulled out and transplanted to synecoculture field, which creates long-lasting bushes of creepers from summer to winter.

・March: Deadline for spring seeding. From April, switch from seed to seedlings because the weed growth gains momentum around this time, and even the germinated seeds will lose to the emerging grass.

・Beginning of May ("Golden Week" holiday period in Japan): Many seedlings for summer fruits and vegetables start to appear in hardware stores. However the seedlings for summer vegetables grows better when planted later in the month with no-fertilizer condition, so this is simply a distribution deadline.

・1st Week of August: Mow the summer grass, sow the seeds of the root crops, and start preparing seedlings for fall and winter vegetable.

・1st Week of September: Mow the grass at the transition to fall, sow the seeds of fall and winter leafy vegetables, start preparing seedlings of winter vegetables.

・September 10th: Time limit for sowing fall leafy vegetables.

・September 15th: Decision deadline for the growth quality of fall vegetable seedlings. If the growth is bad, prepare to obtain new seedlings from a specialty shop or hardware store.

・September 30th: The last day for planting seedlings of fall vegetables.

・October: Observe the progress of fall vegetables, and begin sowing for the winter vegetables.

・Middle of October: Time to finish planting the winter vegetable seedlings. These plants are expected to grow until November.

・Next January: Construction work for the field, set up an anti-wind fences, cut the bamboo forest, prune and transplant the fruit trees, and plant the perennial grass seedlings. These activities should be performed in the middle of January so that seed sowing and harvest management from February onwards can be handled smoothly.

2-2-5. Grass Management, Seeding, and Planting of Seedlings in Summer Season

In the Honshu region (in this case, specifically in Kanto and Kinki regions), August and September are the crucial period for synecoculture practice. In synecoculture, where the ecosystem is proactively controlled through information rather than material resources, the timing to take the initiative is the most important. If the opportunity is missed, not only will it be a waste of effort, but it will also have an effect on the yearly scope of the yield until the next spring.

If a certain strategy didn't work, you should switch to the next strategy, and plan at least 4 to 5 steps in advance, so that the work itself is light and can be completed in the shortest amount of time possible.

2-2-5-1. Principle of Three Way Trade-Off -Example of Summer Strategy in Honshu, Japan

> In order to have vegetables be dominant as the grass changes from summer to fall, the period from the end of August to the first week of September is the most crucial. If you mow the summer grass during this period, the small seedlings should not lose to the fall grass.

During August and September, mowing grass, sowing seeds and planting seedlings are conducted, but it will be necessary to consider the balance and trade-off of following three aspects: 1. soil formation of briquette structure through summer grass, 2. benefits of early sowing of fall/winter vegetables, and 3. decomposition of mowed grass. These three points outlined below are concurrent and are in conflict with each other; therefore, it is important to make appropriate judgments of priority and timing, and address each point in balance.

(1) Have the grass grow as thickly as possible

In order for the grass roots to form the soil structure, the annual grass must be grown as thickly as possible. For this reason, the later the mowing of the grass, the better for soil formation.

(2) Have the seeds germinate as quickly as possible

In synecoculture, the growth rate of the vegetables is admittedly slow since we do not give any water and fertilizer (with the exception of watering right after planting seedlings and in case of aridity). The window of opportunity for the vegetables to grow densely into harvestable size is limited between the planting periods and mid-November when first frost occurs and the growth stops. In order to make this time line as long as possible, it is necessary to sow as early as possible: two to three weeks earlier than usual. This is directly in conflict with (1) because you cannot wait too long to mow the summer grass.

(3) Have the mowed grass decomposed as much as possible

Mowed grass is decomposed fairly quickly with the help of rain in August, creating natural humus by the beginning of September. This decomposition should take place at the location where vegetables grow to increase productivity. However, if (1) and (2) are given priority, the mowed grass needs to be pushed aside to a passageway before the decomposition takes place, in order for the seeds that are sowed in the middle of August to germinate. If you are sowing in the beginning of September, it is possible that decomposition takes place in time and you can leave the mowed grass on the ridge.

To balance these decisions could be difficult; in this case, you can simplify the decision process by pushing the mowed grass to a passageway from the beginning. This way, (3) are removed from consideration. In the beginning of August, have the mowed grass become humus at the top of the ridge, and proceed with the growth of the slow-growing root vegetables. Then in the beginning of September you can take priority to proceed with the leaf vegetables, by putting the mowed grass in the passageway that can be used later as dead grass mulch for seedling.

The mowed grass should be decomposed as much as possible, while when sowing the seeds, it will be necessary to move any non-decomposed grass. The mowed-grass mulch can be kept until it will be gradually decomposed in September and plant the seedlings. Even if it doesn't decompose you can simply push them aside just enough to make a space for the seedlings.

2-2-5-2. Example of the Relationship between Mowed Grass and Seeds and Seedlings

Plan a production schedule at the same time as you mow summer grass, so that a variety of vegetables are growing densely enough for continuous thinning harvest, through fall to the following spring season. Here are the examples:

・The end of July to August: Sow root vegetables such as carrots.

・Mid-August: Sow seeds of mustard family (*Brassicaceae*) such as cabbage, Chinese cabbage, and broccoli.

・First week of September: Sow all types of leafy vegetables. Daikon radish should be sown by September 15th.

・In general, you want to finish seeding as soon as possible; therefore, August is the optimum time for seeding fall/winter vegetables up until September 10th. For large vegetables that will contribute to the next round of yearly yield, finish sowing by the beginning of September.

・The end of August to the beginning of September: Sow leafy vegetables especially the ones that grow fast but are susceptible to mowing. Sowing these seeds at the end of summer grass mowing is critical for their success. Such vegetables include Japanese mustard spinach, radish, and any undergrowth vegetables that become living mulch.

・The beginning of August to the beginning of September: Sow root vegetables every time you mow grass. Sowing these vegetables frequently at intervals allows for continuous thinning harvest.

・Items such as green onion and chives can be harvested only from second year. Seedling of cabbage and broccoli may grow slow in the first year, but you can expect to harvest them in the following year. The objective is not to grow everything bigger but to differentiate the growth rate among the crops.

＜Difference in strategy between root vegetable and leaf vegetable＞

In general, you want to sow them in August, but there's a chance that the summer grass will come out again and bury crops. Therefore, use the slow-growing root vegetables (carrots, radish, Japanese shima shallot, etc.) after mowing the grass in August. This way there's no need to push aside the mowed grass as they are decomposed quickly, besides even if these root vegetables are mowed or buried, they will regain strength fairly quickly.

Depending on the characteristics of the seed, you can either choose manual broadcasting or sowing in a furrow and cover with the soil. Broadcasting is the simplest method with low workload, but it can be also harder for the seeds to germinate. If time permits, scratch the surface of the soil for better results. Leaving 10cm of surrounding grass prevents birds from eating the seeds and sprouts. You can expect a better rate of germination by sowing in a furrow, but this requires more labor.

Combine the cons and pros of broadcasting and sowing in a furrow, and plan a strategy to make best use of the space. In a narrow space, a furrow provides better germination rate. In a broader space, introducing seedlings can offset the downside of broadcasting such as the lower germination rate.

When broadcasting the seeds, leave the grass 10cm from of the ground when mowing, which will act as a deterrent, making it difficult for birds to eat the seeds.

If the mowed-grass mulch covers seeds too much, they will not germinate or turn into frail sprouts, so it is necessary to remove any excess into the passageway. They become passageway mulch or can also be used as the mulch when planting seedlings. Having mowed-grass mulch around the seedlings protects small seedlings and prevents grass from growing.

If the sown seeds are losing to weeds, trim them at the vegetable height. For example, mow all the grass to a height of 20cm from the bottom.

When sowing seeds in October, strip away the withered grass mulch then sow. In contrast, if you want to let the soil rest until next spring or if you do not want to manage the entire area, cover partial area with the withered grass mulch.

The mixture of vegetables in high density, the underlying principle of synecoculture, is performed starting from seed sowing. Seedlings are used as a supplement until the seed germinates, since it is harder to achieve high density only with the seedlings. Seedlings are particularly useful for large vegetables such as mustard family (*Brassicaceae*), because it is difficult to determine when to sow their seed in August: Summer grass imposes fierce competition against the seed sown in August. Therefore, large vegetables can be better managed by planting the seedlings toward the end of summer to avoid weed competition and reduce the labor in the heat. Seedlings for larger vegetables are also useful in a drought when moisture is not sufficient for the seed to sprout. You can either prepare seedlings on your own while sowing or order them from the seedling shop in advance to meet the deadline. In certain cases where too many vegetables are competing for a given space, you can transplant parts of them to less crowded areas in September.

If you do not want to run out of harvest in August, for example for the restaurant business, you should plant seedlings as early as possible to bridge the gaps.
Designating August as a break period allows the summer grass to grow, but at minimum you need to devise a strategy for fall and winter during this time.

In regards to grass mowing and seeding, it is essential to assess the circumstance accurately. This process cannot be standardized since each case, depending on what you want to focus, calls for different priorities. Some degree of empirical knowledge is required to make these decisions.

Image : Similar to established local variety, open pollinated radish seeds flew in by the wind grow remarkably fast.

2-2-5-3. Fall Vegetation Plan

To plant the seedling in fall season, you can simply push aside the mulch on the surface area, but more importantly, you need to create a vegetation plan for the following spring season. Here's an example of the transitional strategy: fava beans and kidney beans are planted in November to mix with other leafy vegetables (radish, bok choy, mibuna, etc) since they do not grow tall during winter and do not compete with leafy vegetables. As you harvest the leafy vegetables in winter, they start to withdraw their presence and in turn beans starts to dominate when spring arrives. After the spring, beans wither and become mulch, giving ways to potatoes and other leafy vegetables for the following season.

2-2-5-4. Irrigation

As a basic principle, you do not need to water the seeds. Simply let them germinate on their own. Use of cheesecloth is permitted only during the germination period. An exception to this principle is when dry weather persists following the sprouting of the seeds or planting seedlings. In this instance, you do need to water otherwise you will run the risk of ruining all of the crops. Having a sprinkler system as a temporary measure after the sowing of August and September can greatly reduce this risk. However, be mindful of excessive watering. When vegetables are excessively saturated with water, they will deviate physiologically from ecological optimum state and lose their original taste, a key characteristic of synecoculture produce. It is true that all plants need water to grow. If it does not rain much in the fall, the vegetables will remain small throughout the winter and they will stay small through following spring. For this reason, an appropriate amount of watering is acceptable. If using a sprinkler, use it on an as-needed basis during August and September and discontinue use thereafter.

> Even without irrigation, seeds are able to sense their own environment and determine the time that is suited for germination. On the contrary, when using artificial irrigation to force germination, the growth process becomes frail and it will be necessary to assist their lives afterwards. Throughout a long history of evolution, plants have been able to overcome multiple climate changes through spontaneous judgment and growth, so it is important to encourage environment adaptability of vegetables.

2-2-6. Alternatives to Fertilization (Method of Recovering Productivity)

The concept of human-provided fertilizer does not exist in synecoculture. All vegetations provide themselves the essential nutrients through photosynthesis, which is a direct interaction, and through indirect interaction with animal fauna. In an ecosystem in nature, plants produce organic matter by photosynthesis, and the animals disperse phosphorus, potassium, and other micronutrients. Any human-introduced materials into the ecosystem are considered foreign materials, and can be compared to an accidental introduction in nature such as landslides.

Phosphorus, potassium, and other micronutrients may become insufficient due to continued harvesting, however vegetation such as shrubbery and fruit trees will be introduced to encourage these supplies through diffusion from birds, insects, and other animal groups. As long as no chemicals or external fodder are used, livestock may also be introduced.

If it becomes necessary to restore the productivity of the soil by external means, only the following three methods can be applied during the initial soil amelioration stage. However, these methods do not comply with the basic principle of synecoculture that states “humans can introduce only seeds and seedlings.”

(1) Sprinkle seawater about once a year. Dilute with 1:100 ratio of seawater and water.

(2) Grind seaweed or fish leftovers and spread them over the surface (this is a direct way to restore soil nutrients that has run off into the ocean via underground water, caused by the conventional farming).

(3) Put grass and fallen leaves (humus) on the soil surface. Take them from a neighboring location that is not affected by pesticide.

These methods are acceptable for initial soil management especially when converting a housing site to an agricultural land, where the ground is leveled and the vegetation and organic matter in the topsoil are scarce. However, to be certified as synecoculture, it is necessary that the growth of the plants is completely free from external organic matters. To establish plants’ self-perpetuation to the standard of synecoculture, it is essential to maintain productivity without depending on the external supply.

Some vegetables (especially summer fruits and vegetables) such as eggplant and corn are selectively bred to grow well with the fertilizer. Therefore, their yield may decrease significantly in a non-fertilized field. In these cases, it is possible for the practitioner to utilize non-plow organic farming method and put on a fertilizer on the soil, however, the vegetables produced in this way is not cosidered as synecoculture produce.

Wild plants gather all nutrients needed for their growth by themselves. This results in unique geographic distribution of plants and environmental conditions, which is referred to as an ecological niche. The natural ecosystem does not turn into desert as long as there is sufficient rainfall and equitable species diversity: It self-organizes and maintains the diversity of ecological niche, as well as supports the sane metabolism of individual plant within. On the other hand, human-cultivated vegetables that are made with fertilizer and watering have significantly altered metabolite, which can be compared to the metabolic syndrome of humans.

The 3 alternate methods to fertilizer have its root in the material circulation between the ocean and the land, which was established in the course of evolution. These alternatives make use of this existing natural circulation and making it more efficient by shortening the route. Therefore, it makes the most economical sense to encourage birds, insects, and microbes to do the work for us rather paying the cost of these alternatives.

2-2-7. Harvest

In the high density of mixed vegetation, harvesting is done by thinning-out from the crops that grew large out of competition. Once the environmental conditions are established, daily harvesting is possible year-round. When cutting off the crops, it is better to leave the roots in the ground because they will protect the soil and encourage the vegetation to regenerate. Only certain cases, for example, if you are shipping the produce to a long distance, you can harvest the whole plant with the root intact so the vegetables stay fresh for longer period.

2-2-8. Sequence of Harvesting - Seedling Transplant - Overseeding

As you harvest or mow the large grass, these newly created spaces and exposed soil should be filled up either by transplanting new seedlings or by overseeding in order to maintain high density of edible plants and prevent grass from gaining ground. You can also utilize unused spaces in the field as nursery, such as by the fence/wall or in a shade with plenty of moisture, since this makes it easy to transfer seedlings within the farm. Once there is an open space in the nursery, sow more seeds. In this manner, harvesting, transplanting of seedlings, and sowing of seeds can be carried out in a sequence and at the same time.

In the diagram below, we show the schematic example of this sequence. After harvesting produce A, transplant the seedlings of a produce B from the nursery to where A was, and overseed with produce C in a nursery where seedling B was. Harvesting, transplanting, and overseeding are done in one set of action.

In the same manner, the harvesting of produce B – transplanting of produce C – overseeding of produce A, as well as harvesting of produce C - transplanting of produce A - overseeding of produce B are shown in parallel.

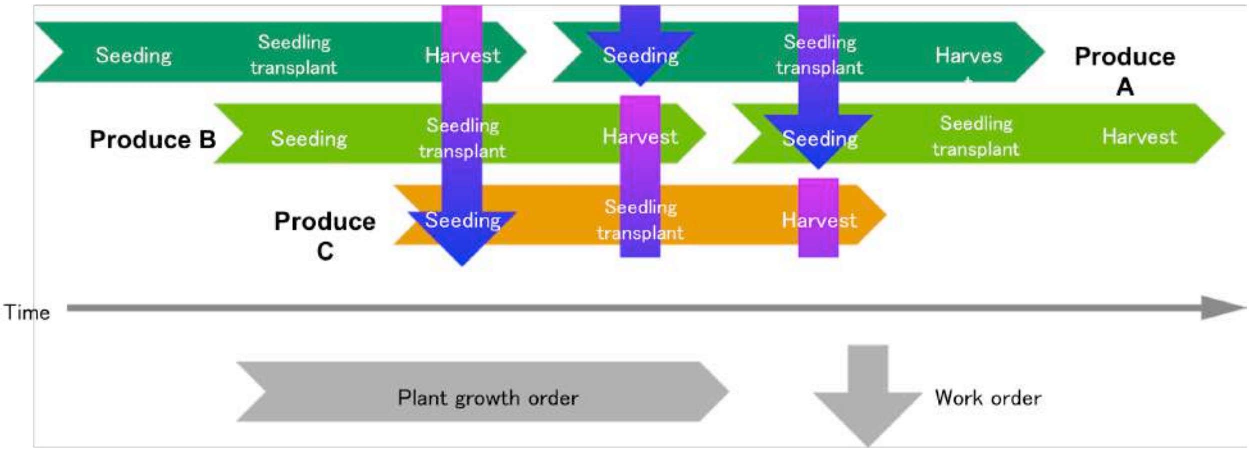


Diagram: Harvesting - Transplanting - Overseeding in a spatial and temporal combination

In reality, you do not need to strictly adhere to this sequence (harvesting-transplanting-overseeding) but rather be flexible to make a decision based on the situation. Sometimes, it is better to overseed instead of transplanting and vice versa. For example, after the initial sowing, you need to assess the rate of germination, and if the rate is low, you will proceed with overseeding.

In conventional farming, their basic principle is in the physiological optimization, and seeding, growing seedlings, and harvesting is done in a same location that is isolated from other crops (monocropping). In synecoculture farm, we optimize space and time of multiple crops simultaneously. The work sets (seeding, transplanting, harvesting) are performed with a time lag between the crops, and we spatially move around the plants to a place that is most suitable in a given situation.

2-2-9. Self-Seeding

Some proportion of the vegetables should not be harvested so they can fulfill their life, and leave until they bloom flowers and form seeds. Practically speaking, it is nearly impossible to harvest all the vegetables in a highly dense and mixed culture, therefore there will always be seeds left to some extent for later use. In order to increase the quality of open-pollinated seeds in synecoculture, you need to select the seeds that showed superior genetic and adaptive traits: For example, take the seeds from the crop that grew larger in a given environment rather than the ones that did not adopt well to the same conditions. This way you can ensure and ameliorate the yield of the strain for the long period of time. We have observed that the seedlings grown in a synecological farm are far more vigorous and resilient in a harsh environment than commercially distributed seedlings that are grown with chemical fertilizer. It suggests that those seedlings from synecoculture changed their metabolism and expanded their habitable environment where they can survive. In some cases, we also observed the extension of harvesting period as a part of adaptation.

We predict that the seeds obtained from synecological farm will be effective and useful when developing a new farm in a harsh and volatile environment.

2-2-10. Ridges

Unless it is physically destroyed by natural disaster, there is no need to add soil to the ridge because they will gain resilience against erosion with the help from the plants. Annuals contribute to this by creating briquette structure (compacted soil structure with abundant air holes) in the ground. The root of the perennials and trees also assist by holding the soil intact. In fact, this mechanism is exactly the same as how the mountain holds its shape over the years. In case the ridges in your farm keep collapsing, you may need to reevaluate the way the grass is managed.

Experimental reports from synecoculture practitioners in Honshu region confirm multiple resilience against harsh and intense weather conditions: While crops in conventional farm and green house suffer massive damage from disaster like typhoon and heavy snowfall, plants in synecoculture farm did not fall down against the wind and snow pressure, and their ridges did not erode from the torrent of rain. Synecoculture strategies naturally augment mitigation measures against climate change. Reduction of management and recovery cost in an event of natural disaster is one of the economic incentive synecoculture can provide for farmers. Besides increasing yield, reduction in cost is an important factor to keep agriculture as a viable business.

Image : Mixing with a focus on lettuce and chili pepper seedlings. Both are strong produce that can be harvested even while making the transition to synecoculture.

2-2-11. Seedling Strategies

Although you can purchase seedlings from a local shop or a hardware store, you can grow them at home when they are not available in an off-season. Homegrown seedlings are especially useful because it is possible to realize a longer span of harvest beyond the commercial distribution period.

For example, tomato seedlings are available at the store from April to May, but upon planting, most of the harvesting of these tomatoes will take place from July to August. On the other hand, if you grow your own tomato seedlings in a nursery it is possible to plant them until August. By planting the seedlings incrementally up to August, you can prolong the tomato harvest until around November. If we also utilize the unripe tomatoes, the harvest period can be extended until December in some cases.

In order to improve the efficiency of synecoculture production volume, it is useful to set a small green house or a room, where you can control physiological conditions to grow seedlings, as a backup supply system. This way, anytime you need to fill the space in the production area after harvesting, you always have a backup of seedlings. To increase the yield while eliminating the gap of crop transition, the farm and nursery should always be packed with produce and seedlings. Fluctuations in the natural environment can result in poor produce development, however it is possible to stabilize and keep efficiency of production by arranging the supply system of seedlings that can absorb the volatility.

Even for the cultivation and transplanting of seedlings, you must keep the non-fertilizer principle and should not introduce any external organic matter in synecoculture field. It is best to grow seedlings without fertilizer. As for hydroponic cultivation with indoor environment, it can be used in the nursery stage since the transplant does not require soil, and therefore it does not bring external organic matter into the field. However, without sufficient time of growth on site it will not become a healthy part of the vegetation in terms of plant metabolites. Hydroponic cultivation is suited for automated production of the seedlings of certain perennial vegetables, such as Italian parsley, that can take sufficiently long time to achieve ecologically optimal growth on site until harvest. For annual grass vegetables, the period from plantation to harvest is short, so there is the risk of their metabolites being influenced too much by liquid fertilizer.

Image : Rather than pulling out entire roots, cutting burdock part-way at the harvest regenerates another one in the same location. Unlike conventional product, you can eat burdock from synecoculture raw since it takes on clear taste without acridity.

3. Evaluation Method for Quality of Crop and Ecosystem

3-1.Relationship Between Crop Taste and Fertilizer

In traditional agriculture, the fertilizer heavily influences the taste of the produce. For example, organic fertilizers contain minerals, which add a characteristic mineral flavor to the vegetables. However, this is a taste derived from artificially applied fertilizer that is qualitatively different from an intrinsic taste of the crop.

As we continue to practice synecoculture, the soil will gradually be composed of only elements that are a part of the self-organized material circulation of the ecosystem, and be in a state where there is no artificial surplus. Promoting natural circulation stabilizes various unstable elements or makes them harmless, reduces adverse effects on neighboring ecosystems, and constantly reorganizes material composition and distribution in a way that globally promotes biodiversity. Soil developed under such process is what makes the spring water drinkable (for example in primeval forests in mountains, etc.), as the water passes through the elaborate soil structure, which we idiomatically call as "clear soil." Clear soil has already been formed in areas that have been left to nature, however, for areas where inorganic fertilizer was used as in modern farming methods, it will take several years to create clear soil. For areas with organic farming, we estimate that it will take at least 8 years if organic fertilizer was deeply mixed into the soil. Even during the transition from other farming methods to synecoculture, vegetables with vitality can be obtained. However, the metabolic state and consequently the taste will be influenced by the soil residue. Once clear soil is achieved through synecoculture, the taste of the vegetables will be of a different quality (**clear taste**) from organic ones.

In organic farming, there are many practices to plow organic fertilizer (decomposing organic matter) into the soil. If there is too much non-decomposed organic matter, the plowing level is too deep, or it exceeds the range of decomposition that microbes in the soil can achieve during a year, it will result in a decaying state that cannot be utilized as plant nutrition. Although using completely decomposed organic compost will not result in the decaying state in the soil, it will leach into the groundwater and pollute the water system. Additionally, there is a high risk of antibiotic contamination for the livestock waste of cows, pigs, birds, etc. In contrast to all these negative effects of human intervention, unmanaged, abandoned farmlands promote the recovery process of clear soil. Organic materials do not get too deeply underground in the natural state, with the sole exception of natural disasters. Such example is crude oil that is considered to have been transformed from organic matters over years deep in the ground.

Clear taste vegetables: carrots that take on the flavor of Japanese persimmon, cabbage with a sweet core, broccoli and asparagus that can be eaten raw to the stalk, etc.

3-2. Pest Outbreak

Pests refer to a large outbreak of insect species that have harmful effects for agriculture. Although many insect species are designated as pests in conventional farming methods, they do not multiply to the point of causing serious damage to production in synecoculture: They are controlled by the elaborate food chain in the plot and the surrounding environment. They can rather take on the tasks of essential ecosystem functions similar to other useful insects, such as pollination and stimulate vegetative regeneration. Synecoculture should be achieving a state where the vegetation is controlled in a manner that the benefits of insect fauna outweigh the losses, and where no single species will emerge as a dominant pest. This is common with the primeval forests of mountains, where little pest occurs under the dominance of single species as the degree of species mixing is high.

Plants take on the role of a "purification device" in the ecosystem, spitting out unnecessary materials from the soil. In the process of absorbing surplus components, the vegetation tends to be monotonous, and there's high risk of insects eating that vegetation to outbreak massively. In conventional farming methods, fertilization, single-species cultivation, plowing and pesticides destroy the food chain and create the background of a pest outbreak. Excess materials in the soil, such as leftover compost, are the ecological cause behind the loss of faunal balance expressed as a pest. Empirically, pest risk is reduced in soil that has been purified through the promotion of natural circulation. If there were a mass outbreak of a single insect species during the implementation process of synecoculture, it would be possible that the soil is at the stage where it needs to be purified. Rather than exterminating, we should facilitate the removal of the surplus materials by the insects. If there is damage due to external factors such as invasion of non-native species, we recommend diversifying the vegetation in order to further diversify the food chain to regain faunal equilibrium.

3–3. Soil Improvement

Soil improvement in synecoculture is carried out in the course of natural circulation and vegetation transition by using the plants and vegetables, without using any soil improvement materials.

However, for physical components that are independent from the biological and chemical disposition, they can be freely changed during the initial construction phase: For example, soil texture decides the capacity of organic matter retained by the topsoil in a given climate condition, which can be freely adjusted in the initial setup.

If dealing with hardened soil where the recovery of the natural circulation and vegetation transition processes is too slow, such as conversion from residential land, it is possible to freely enact initial soil improvement measures. However it will require a transition period to synecoculture until clear soil can be realized.

For example, soil improvement in the initial construction is possible through moving plant organic matter derived from nature, such as cut grass from the surroundings, and promoting decomposition using microbial materials. However cultivation through continuous and fixed usage of microbial and organic materials from external sources, is a violation of synecoculture principles.

Regarding chemical properties, it is possible to introduce adjusting method as long as it does not hinder natural circulation, and it will not be necessary to continually introduce external materials: For example, placing oyster shells on the surface during initial soil improvement will serve for pH adjustment.

If the vegetation is scarce, one method is to claw the surface first and then deliberately grow thick weeds, or plant fast-growing trees to construct the ecosystem regardless of its usage, however the most ideal method is to realize these functionality with useful plants.

> Examples of soil texture improvement: Overlay/mix into the field river sand and clay that does not contain organic material.
>
> ＜Example of Wasteland Soil Improvement＞
> For vegetation recovery in wastelands where vegetables do not grow, sow mainly *Asteraceae* vegetables such as lettuce and chicory, and mix in root vegetables in an appropriate level. *Asteraceae* vegetables can be raised even in pebble-filled wastelands. Wildflowers that can be used in tea, such as horsetail and chameleon plant, are also effective in soil improvement, and suppresses grass weeds. Strong woodland fruits such as persimmon, loquat, citrus fruits, blueberries; strong trees such as common figs, mulberry; shrubs and perennial plants such as mountain asparagus, ashitaba can also suppress weeds. Another method is to plant tall trees early, and then thin them out as other vegetation grows accordingly.
> If you are concerned about leftover fertilizer from conventional or organic farming used in the previous iteration, one method involves using wild oats and rye to suck in and expel, to purify the soil.

3-4. Plant Tissue Normalcy

In synecoculture, as a preliminary criterion before the crop taste and nutrients, the plant tissue normalcy is evaluated with respect to the ecological optimum state as a standard. The fresh allure of sane plant tissue is sometimes idiomatically referred to as vitality of plant. The most practical and simple method for determining plant tissue normalcy is the "**clear taste**" when eaten raw, which describes a particular quality of flavor common in synecoculture produce based on empirical expressions. However when determining the clear taste, it will be necessary to have comparative experience between synecoculture and conventional farming produce. It is possible to eat "clear taste" vegetables at the harvest experience lunch at the Ise Synecoculture Farm in Japan, sponsored by the Sakura Nature School.

There have been reports of heath improvements from those who consume produce that cleared the strict standards for synecoculture, even when consuming regular vegetable types. As a supportive evidence of health beneficial effect, compared to conventional produce, synecoculture produce is revealed to contain rich secondary metabolites, which is the largest source of medicinal ingredients.

> Though "**clear taste**" is a subjective expression, since it is a characteristic that is commonly and repeatedly experienced when eating raw vegetables from an ecological optimum state, evaluation is possible such as using food sensory analysis together with the assessment of the cultivation conditions.
> From consumers' health improvement cases, the positive relationship between the normalization of plant tissue and the normalization of human metabolism has been speculated.

3-5. Structure and Fluctuations

The concept for natural circulation in synecoculture is qualitatively divided into structure and fluctuations:
The structure is the establishment of the natural circulation, on which human shall not intervene. In contrast, the fluctuations are the variability within the structure, which vary in accordance to environmental conditions. Human intervention may be allowed as long as it remains in the variation range of the natural circulation.

3-5-1. Examples of Structure

Soil structure that is realized in a competing symbiotic state (ecological optimum state) of planting:
Plowing that destroys the soil structure is regarded as an intervention to the structure, and is not allowed. Even without plowing, removing all the weeds and exposing the topsoil means losing the roots that form the soil structure, so removing all weeds is considered to be an intervention to the structure. Regular installation of vinyl mulch acts as an obstruction to the soil structure formation, and is considered to be an intervention to the structure.

Traffic of Fauna, Material Circulation:
Starting with insects and birds, animals freely come in and go out of the synecoculture plantation. As trace elements are supplied through diffusion by these fauna, their traffic must not be disturbed. Additionally, an open-field environment that is not disconnected from rainwater and groundwater is necessary to establish material circulation.
Therefore, the use of agricultural chemicals such as pesticides, using a plastic greenhouse to completely shut out insects and rain, and an indoor environment that cuts off the connection with underground water does not constitute synecoculture.
However, using only the skeleton of the plastic greenhouse or the walls with no ceiling, or using fences to keep out mammalian pest such as wild boars, monkeys, deer, and other harmful beasts, is allowed as long as it doesn't inferfere with the coming and going of most other insects and animals.

3-5-2. Examples of Fluctuations

Amount of sunlight:

As there exists rock and tree shade even in a natural state, the changes in sunlight from the surrounding buildings and trees is within the range of fluctuation. However, no sunshine will result in no growth, and too much sunlight creates an environment that's advantageous for indigenous weeds. During germination, the use of cheesecloth, etc., to control the sunlight partially or short-term is acceptable.

Amount of water:

Since there exists seasonal and yearly changes in precipitation, artificial irrigation in response to reduced precipitation is within the range of fluctuation. However an excess of water leads to vegetable blistering and deviates from plant tissue normalcy.

Amount of seeds and seedlings and planting period:

As the amount of seeds in the natural state changes in accordance to the surrounding vegetation and seed bank, humans introducing seeds and seedlings for the purpose of controlling the vegetation strategy is within the range of fluctuation.

For the germination and establishment of plants, as there are fluctuations in the environmental conditions and individual differences in nature, time-selective planting of seeds and seedlings by humans as part of vegetation strategy is considered to be in the range of fluctuation.

From the point of view of ecological optimum in synecoculture, seeds and seedlings introduced by humans correspond to the initial condition setting to establish mixed vegetation toward ecological optimum.

The problem of invasive non-native species has been spreading along with modern agriculture. The non-native species introduced by humans largely influences the ecosystem, including the material circulation level, and is involved with the structure. However, the various mixes of useful plants that are enacted through synecoculture restrain the dominance of non-native species, create various material circulations similar to indigenous ecosystems, and we expect that will mitigate the adverse effects of alien species.

Naturally occurring vegetable organic matter on top of soil:

If the soil structure is formed, piling up naturally occurring vegetable organic matter such as mowed grass from the surroundings on top of the soil, or conversely removing mowed grass, these are considered to be within the range of fluctuation. It does not interfere with the maintainance of the soil structure nor causes the contamination of groundwater.

Other hyper-diluted amounts of active agents:

Naturally occurring active agents and natural pesticides that are hyper-diluted in homeopathic dose is practically out of concern of material cycle, however it will be necessary to make an objective assessment on that effect. It is best to not utilize any useless materials.

4. Application

4-1. Combining with Rice Cultivation

By conducting synecoculture in non-plowed, non-fertilized, pesticide-free rice paddies during the dry season, development of the soil can be achieved together with high diversity and high yield of total produce.

4-2. Introduction of Domestic Animals

A wide variety of domesticated animals can be introduced as a part of the fauna that coexists in a synecoculture farm. As with the vegetation, no artificial feed or chemicals shall be introduced, and that the domesticated animal be treated like a self-supporting wild animal as a part of the ecosystem.

Beekeeping can be carried out even in a small-scale, and has a high synergy rate with synecoculture. Various vegetables and tree flowers found in synecoculture farms become source-plants for nectar, and bees contribute to the pollination efficiency and augment nutritional value of the produce. It also increases the value of wildflowers as a nector source, such as white clover, Chinese milk vetch (*Astragalus*), and bushkiller (*Cayratia japonica*). The introduction of beekeeping raises the practical value of wildflowers and blossoming herbs as a part of ecosystem services, and has a significant effect on the vegetation strategy. Though the European honeybee has an established breeding method, they require constant care and may become weak due to the drug-free condition. The introduction of species native to the wild (such as the Japanese honeybee in Japan) is desirable. A synecoculture home garden and beekeeping set, even privately, can make great contributions to the regional biodiversity.

It is possible to grow birds such as domesticated chickens and pheasants, using the farm's wild grass and insect population as bait. The leftovers from synecoculture processed produce can also be used as bait in self-sufficient cycle. It would be necessary to keep them in a small hut to hide them from nighttime predators such as weasels, raccoon dogs, and cats.

It is also possible to raise sheep and goats based primarily on wild grass and herbs for feeding. As an application, they may be used as a part of grass management.
For large livestock such as pigs and cows, as they dig up and tread down the land, they are not suitable for synecoculture farms producing vegetables. However they may coexist as a byproduct in farms that focus on fruit trees and perennial plants as produce.
For producing with large livestock as a main product, it will be necessary to think in the direction of their natural habitat and behavior: Make entire use of primeval forests and forest edges grassland that can naturally serves plenty of feed, and enclosing it with a fence to create a wild animal ranch. Even with a monotonous tree plantation in mountain range, it is possible to create an environment for livestock by increasing the vegetation that will serve as feed, such as chestnuts and wild yams.

Fish species found in the waterways, rivers, lakes, and ocean waters surrounding the farm should generally also be utilized as produce.

4-3. Cooperation with Hospitals, Nursing Care Facilities

Creating a synecoculture farm next to hospitals and nursing facilities can support the health recovery of hospitalized patients and residents through fundamental eating habits.

4-4. Using Indigenous Plants

In conventional agriculture, indigenous plants (such as bamboo in Japan) are often considered as weeds and should be eliminated. Though in synecoculture, we consider that they are establishing an example of suitable ecosystem for that region. Your vegetation plan should be built taking advantage of those characteristics. For example, bamboo and bamboo grass can be found in many abandoned Japanese mountain forests. If left alone it drives away other vegetation with strong root. However a moderate existence rather increases the biodiversity, and the boundary of a bamboo grove can provide various conditions that promote the growth of other vegetation. As produce, there are other possible uses as well, such as tea, material resource, fishing equipment, etc.

4-5. Planter Cultivation

Planter cultivation that adheres to the principles of synecoculture. Using the topsoil that has already been formed in a natural state, such as from mountain forests, planter cultivation can be performed with no fertilizer and pesticide-free.

Unlike the natural state, as it's difficult to maintain the homeostasis of the soil environment such as soil temperature in a small scale, it's not yet possible to achieve a perfect natural circulation with a planter without interfering in the soil over the long term. However it is possible to create vegetables that are close to the ecological optimum state within a certain degree by applying the basic principles.

4-5-1. Planter Cultivation Method

A planter as large as possible should be prepared in order to maintain homeostasis of the soil to the greatest extent possible. Soil with a formed soil structure in a natural state should be introduced, such as that from mountain forests. Plant seeds and seedlings in this soil with a dense mixed state, and let them grow. Naturally originating vegetable organic matter may be placed on the soil, such as the powder of mowed grass.

Perform observation to see the effect of different soil quality for mountain soil, bamboo grove soil, perennial plant community soil, grassland soil, etc., whose formation being influenced by each different type of vegetation. Search for the application to planter cultivation according to the soil type.

Caution: You must obtain the permission of the landowner before collecting soil. There are many cases where soil collection is prohibited, such as in national parks, preservation area, etc.

4-6. Cooperation with Citizen Science

Currently, as the training for educational institutions, as a conservation research program, and as a part of corporate social responsibility (CSR), a lot of activity is taking place worldwide to document the biodiversity. Synecoculture farm can create and serve as a regional hot spot for biodiversity, and the documentation of the farm can also be used as high-profile data of regional biodiversity. Synecoculture field provides a great teaching aid for science and environmental classes starting from elementary and junior high schools. Currently, we are building information sharing network service for synecoculture practitioners that will include an interactive biodiversity database.

Within a synecoculture farm, there are examples of rare insect species being found, including threatened species in IUCN red list. Synecoculture farming is listed on Sony's CSR activity candidates.

Image : Examples of rare insects that have been observed in synecoculture farms. Through synecoculture, a high-value ecosystem can be built with biodiversity that can be greater than simple preservation.

4-7. Large-Scale Mechanization Model

Synecoculture is expected to mechanize and expand its scale in the future in order to efficiently manage vast abandoned farmland, or to increase the productivity in proportion to the smaller number of farmers and the greater level of economic and technological development of the industrialized countries. Provided the fundamental principle and definition of synecoculture are being observed, mechanization will be allowed only in a case when introduction of machinery and the technology augments the mananagement of a more complex ecosystem. For example, among the management tasks of synecoculture, planting of seeds and seedlings, grass management, and harvesting are the possible areas for mechanization. Large-scale synecoculture farms will require new combinations of vegetation, types and placement of crop, and method of harvesting for efficient management.

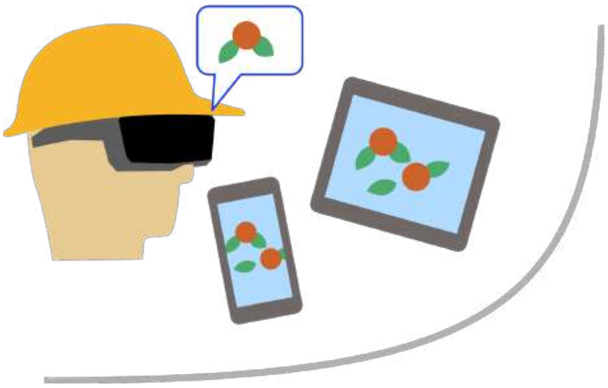
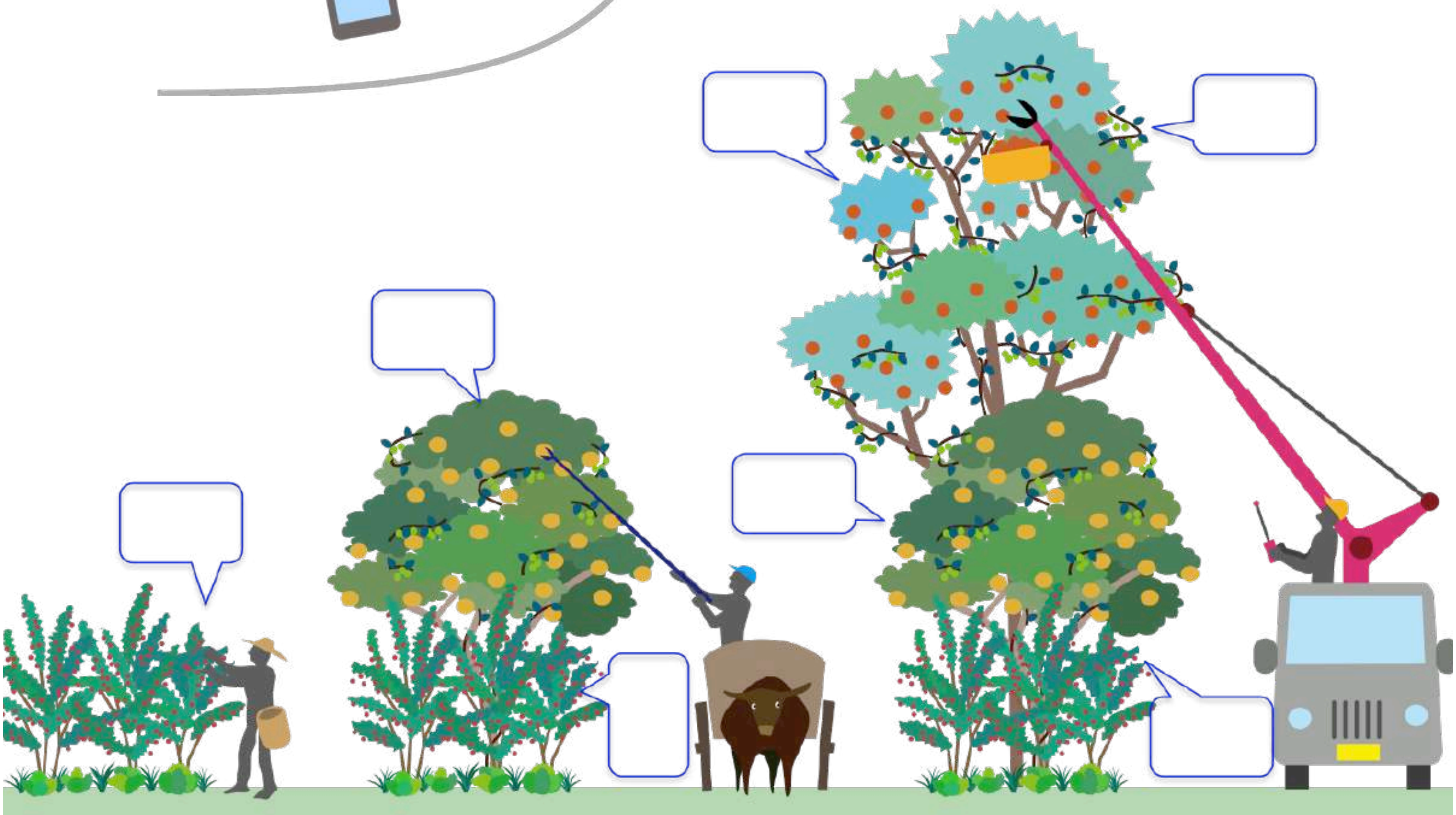


Figure: Schematic view of the augmentation of ecosystem through large-scale and mechanization of synecoculture. By using cart or wagon for livestock, machine technology such as vehicles and robot arms, virtual reality, etc., management of a more large-scale synecoculture farm with greater biodiversity is possible.



5. Synecoculture in Different Climate

5-1. General Remarks

The principle of synecoculture can be applied to all climate zones as long as temperature, precipitation, and sunlight are sufficiently present for growing plant. The specific strategy of implementation and the types of crop will vary depending on the climate and the vegetation of the particular region. In the following, we employ Köppen climate classification, which was determined by a relationship between temperature, precipitation and vegetation type, as a guide to illustrate the characteristics of the climate where synecoculture is being practiced.

5-2. Temperate Zone

5-2-1. Deciduous Forest Zone

Deciduous Forest Zone covers the area of many European and American major cities where modern civilizations were developed. A part of the subarctic zone is also included in this climate division. Vegetation is mainly composed of sparse deciduous forests and undergrowth, which makes weed management easier in practice, but some regions may need to take countermeasures against cold temperatures and insufficient sunlight during the winter months. For example, it would be essential to keep snow-hardy plants, root vegetables and the potato family stored underground, and mainstream productive fruit trees like apples, which can be harvested, kept in the storage facility until the following spring. To retain enough moisture in the soil, you can pile mowed grass or dead leaf matter on the surface. Growing the large crop root helps with cold resistance while some crops can survive through winter by staying as small buds. Making use of evergreen trees that are strong against the cold as a protective boundary against winter winds should also be considered, along with topography and geographical orientation of the farm. Overcoming the agricultural off-season during winter, which is longer in most cities than that of the Honshu region in Japan, is one of our main concerns and challenges in research. We speculate that a principal solution will be the scaling up to mass production that corresponds to the usually high economic level in these countries, with the use of the mechanization that would support the augmentation of the ecosystem.

> A climax forest of potential vegetation is an ecosystem with natural vegetation that has been developed with ecological optimum for several decades to over several hundred years. Concrete example has been academically conceptualized as Chinju-no-mori (the japanese forest of the village shrine) according to the ecologist Akira Miyawaki, and there are plantations all over Japan.
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> For implementation on the Pacific Ocean side of Japan, it becomes easy to make produce even in the winter with the use of forests and man-made structure to block the northern winds. It's also possible to create a windbreak by using evergreen fruit trees around the farm. Plum pine tree (*Podocarpus macrophyllus*) fences are traditionally used, but while they are highly effective in blocking the wind, they are slow to grow. Additionally, the plum pine garden trees that are commercially sold are generally male, so in order to grow fruit you will have to choose female trees.

5-2-2. Evergreen Forest Zone

In Japan, this zone includes from the Honshu region all the way south to the Kyushu region. Because of its plentiful rainfall, even a deserted field will be covered with tall weeds if left untouched. It would ultimately develop into a deep forest with a capacity to house an abundant variety of indigenous species, known as potential natural vegetation. This manual is based on the empirical knowledge of synecological farming primarily in this climate and vegetation zone.

5-3. Subtropics

This is the temperate climate zone that is closer to the tropics. In Japan it is commonly referred to as the region from southern Kyushu through the Nansei Islands, including Okinawa. As most of this region consists of small islands, the soil runoff from conventional fields such as sugar cane has the most direct effect on the marine ecosystem.

As a management strategy, it is essential to grow fruit trees and protect vegetables from intense sunrays. In the Nansei Islands, where many typhoons pass through, densely mixed fruit tree forests are crucial for protecting against strong winds. The plant tissue in a non-fertilized field becomes more robust, and the roots spread out more, which increases wind resistance.

As weeds are particularly strong in the subtropics, frequent grass management will be necessary to produce vegetables. Until vegetables dominate the surface, you need to take a countermeasure against weeds corresponding to their types and growth rate. There is also the method of letting the grass grow out intentionally to concentrate on soil formation at first.

If you take advantage of a warm and rainy climate and focus on producing subtropical fruit, this way you can lower costs and expand the production volume. It is also suited for producing seedlings, since the growth rate of fruit trees is high compared to Honshu. In Nansei Islands, abandoned farmlands are increasing due to depopulation and aging of the farmer. We are building a model for synecoculture farm to utilize these fields with focus on fruits trees that are suited for subtropical climate.

Subtropics are included in the temperate zone of the Köppen climate classification, and a number of varying definitions exist. This manual adopts common usage of the term subtropics as the southern Kyushu region to Nansei islands, based on the opinions from the inhabitants. Though it is classified as subtropics, the Nansei islands have exceptional precipitation in contrast to many of the world's subtropics that are predominantly arid regions.

To defend against the strong winds from typhoons that pass through the subtropics Nansei Islands every year, building an anti-wind fruit forest is an effective strategy. These forest will be composed a dense mixture of fast-growing fruit trees, such as papayas and bananas, since they bend easily and absorb wind impact. Raising fruit trees in a high density reduces yield, however as they support each other and increase their anti-wind effects, they can be placed as a nursery facing the wind from the shoreline. Conversely, the underside of the wind, enclosed by anti-wind fruit tree grove, productivity can be prioritized with high-value fruit trees like mango and island bananas, and creeper plants like guava, kiwi berry (*Actinidia rufa*), kiwi, etc.

Image : Examples of fruits that are cultivated in synecoculture farms in subtropical regions.

5-4. Arid Zone

Climate zone with high average temperature, low precipitation, dry like the desert, and little vegetation.

In contrast to the tropical, temperate, and continental zones that are a forest-forming climate where trees can inhabit, the arid zone is a non-forest climate, and forests will not develop even if left alone. This is a region that is subject to desertification.

There are two types of causes for desertification - natural factors like the lack of rainfall, and human activities like the agricultural practice such as overgrazing and over-logging leading to environmental destruction. Actually, many of the arid regions of the world are facing desertification due to human-induced factors. Once vegetation is lost in an arid region, precipitation will also be reduced, and the lost vegetation will not recover, expanding the vicious cycle.

In developed countries such as North America and Australia, groundwater is drying up and desertification is progressing due to large-scale monoculture farming. However even in regions where small-scale farming is the majority, such as Africa, India, and China, the use of modern farming methods is exacerbating the desertification process, expanding the regions under the risk. In arid zones where many developing countries are located, the frail ecosystem and socio-political instability are posing serious issues: Poverty and malnutrition prevail, and the loss of biodiversity is expanding at an alarming rate.

> Forests are nurtured by rain, and as the groundwater is cultivated, water vapor transpiration from the forest becomes rain again, making for circulation. The rain and groundwater system are tied together through the absorption and transpiration from surface plants. As rainfall, surface vegetation, and groundwater mutually exist and form a water circulation, deforestation crucially breaks this cycle. If there is not much precipitation or groundwater to be supplied externally, natural recovery will be impossible. This is called the regime shift of the ecosystem. As if building blocks that were once piled up are lost, it is not easy to reload to the original state. It is an irreversible destruction phenomenon that lies within the ecosystem dynamics as a mechanism of desertification.
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> In order to adapt to abnormal weather such as floods and droughts, we need to diversify the ecosystem with respect to the height of vegetation and depth of the root system. Covering the topsoil with perennial grass retains moisture. Place root crops and potatoes that will survive even if the surface dries out. Above ground, the multi-layer of herbs and trees can be placed in alternating order, which increase the efficiency of photosynthesis with perpendicular configuration of the whole vegetation community. Mixing in crops of differing height can also reduce damage of flooding. By stretching around the roots in a multi-layered way and in differing depth, underground water can be better retained and the rain capacity can be expanded, creating an ecosystem that is strong against droughts and absorbs floods.

Synecoculture farming has been implemented in Burkina Faso at the Sahel region in sub-Saharan Africa situated at the boundary of the arid zone and the tropics. From an initial success story, it is expected to make a great contribution to the recovery of both social and ecological systems.

The benefits of synecoculture farming in the arid zone, based on the implementation in Burkina Faso, are as follows.

1) Turnover speed similar to the tropics:
As the atmospheric temperature is high in the arid zone, if the vegetation is dense enough to hold the water in the topsoil, vigorous growth similar to the tropics can be observed.

2) Lack of competing vegetation (weed seeds) makes managing and mixing newly-introduced species easy:
In the arid region, the indigenous seed bank is not as robust as the other regions. Conversely, it is easy to manage vegetation that is predominantly covered with useful plants like vegetables.

3) Less risk of social conflict between synecoculture and conventional farming. Conventional farming is difficult to introduce in this region, and even if they do they can realize only a low level of physiological optimization:
It is not practical to implement conventional farming in this region since it poses a serious risk of environmental destruction. Lack of established conventional agriculture can be seen as an opportunity for new farmers because the market entry regulation is also non-existent. Standardization for agricultural product is rare, which means there is a ground for people to embrace huge variety of synecoculture produce, and they can be sold

directly on the local market. A lack of resources does not allow people to use expensive fertilizer and machinery, but in a way, this reduces the risk of introducing fertilizer and tillage machinery, which are both against the principle of synecoculture.

4) Job creation in a smallholder farm:
   Many members of society from this region are small-scale family farmers. Since labor skill required to work in the synecoculture farm are mostly manual labor, they can be employed immediately without much training. For small-scale farmers based on individual household economies as the main constituent, achieving low cost, high revenue leads to a large and direct economic impact.

To introduce synecological farming methods in arid regions as part of desert greening, the followings are the recommended strategies:

- Find the vegetation among robust creeper vines (e.g. kudzu legume, *Pueraria montana*) that could be used as a feed for livestock like cows. Use them as a pioneer plant when implementing synecoculture.
- Plant these creeper vines near the water source, and guide them to grow towards the desert. Once the tip of the extended end grows thick leaves and takes root, have the livestock feed on the leaves. Feces of the livestock will serve as natural manure and increase the productivity of the soil.
- If necessary water at the base of the vine plant. If there isn't much water, creating V-shape vegetation from the water source is effective at greening over a wide area.
- Create walls of creeper plants in intervals of a few tens of meters. In between these walls, plant a mixture of perennial plants, trees, and grass that are strong against dry weather and reinforce water retention of the soil. At this beginning stage, focus on building the environment and growing seedlings at minimum cost. After the ecosystem is established, gradually increase the elements of productivity.

Image : Examples of synecoculture farms in arid regions of the tropics. Even in a harsh environment where other farming methods face difficulty, synecoculture's farming method that is founded on the construction of the ecosystem, is proven to accomplish both agricultural productivity and ecological restoration. (Photo: July 2016 AFIDRA)

5-5. Tropics

Supported by high temperatures and precipitation, tropics features the most diverse inhabitation of plants, animals, and microbes on the planet. However, as the decomposition rate of organic matter is fast, the topsoil formation is thin and vulnerable to disturbances. At a glance it may seem like the most rich environment, but it's also an environment that requires meticulous care and maintenance.

Tropics are a region surrounding the equator. Temperature is consistently high and its fluctuation remains small in annual range. For the most part, it rains heavily but some regions do have a dry season. Lush vegetation of tropical plants forms a various degree of jungle depending on the precipitation. It is also a treasure trove of medicinal plant resources.

Tropical rainforests of Southeast Asia and the Amazon in South America typically provide the critical ecosystem that supports biodiversity of the earth. However, this function is being diminished severely due to rapid economic development and deforestation. Soil structure in tropics form quickly, but also is susceptible to external forces. This trait makes its soil highly vulnerable to logging and plowing, leading to rapid structural failure. Furthermore, the coastal ecosystems of the tropics and the subtropics are a home to coral reefs that nurtures 25% of all marine species on earth. The expansion of conventional farming in this region will contaminate the ground water and consequently affect the global marine ecosystem. Synecoculture in tropics hold important implication, as it allows the continuous formation and maintenance of soil structure while taking into account the circulation of land and sea.

6. Education, Certification System, Other

6-1. Synecoculture Farming Workshop

Takashi Otsuka in the Ise Synecoculture farm holds synecoculture farming workshops regularly in Ise City, Mie Prefecture, Japan. Please contact the Sakura Nature School for more information.

Contact for participation in synecoculture farming workshops: gmv2000@muse.ocn.ne.jp

6-2. Synecoculture Farming Certification System

Japanese word for synecoculture (協生農法) is a registered trademark of Sakura Nature School in Japan. Any economic activity using the name of 協生農法(synecoculture), such as sales of produce, must be authorized by the Sakura Nature School.

There is no regulation to implement synecoculture in home gardens, and sell produce without authorization as long as it does not use the name of 協生農法(synecoculture).

The term "synecoculture," as well as the original Japanese terminology (協生農法, kyousei nouhou) and its multilingual derivatives are copyrighted as an open source. The practice of synecoculture, including sales and research activities, is free to everyone, however, any uses that do not conform to the content presented in this manual or the academic definition are irrelevant to the results of synecological farming or synecoculture, and will be judged as a falsification regardless of the presence or absense of intent.

For the implementation in every region, for those who require authorization for synecoculture, a certificate will be issued following an appropriate field survey.

6-3. Disclaimer

For any kind of damage resulting in the implementation of synecoculture based on the information contained in this manual, all actions are the responsibility of the practitioner. We appreciate your consent and understanding as you apply these methods.

In Conclusion

The objective of the conventional agriculture has been to produce artificially enlarged “farmed vegetables” through the use of science and technology. This is ironic in the sense that the more effort that is dedicated to this pursuit, the further the plants travel away from a natural, healthy state. When I look at the current agriculture and their plant species, I can’t help seeing a resemblance to our own species and struggles with countless health issues such as lifestyle disease and metabolic syndrome. Additionally, as biodiversity on this planet is reducing at an alarming rate, human population is growing at an exponential rate, which could be compared to a large outbreak of pests in the ecosystem of monocultural farm.

In synecoculture, our objective is to return to the natural state of plants and animals as our primary food source, which we have relied on for our survival over millions of years. Furthermore, considering our exceptional ability to affect and modify natural environment in global scale, it is not an overstatement to say that we, the human species, hold the leading role to a truly sustainable society in harmony with nature where all living species can coexist. Such an endeavor depends, wholly on the success and sustatinability of our primary industries, starting with agricultural practices.

I believe that goal is attainable if we advocate for the cultivation and utilization of plants in their natural state rather than continually furthering research on element-wise pesticides and fertilizers. To this end, relying purely on research and academia will not be sufficient. Practical implementation and experience from the general public should be brought together, and our reponsibility to the environment must also be addressed as an integrated citizen science. Synecoculture aims to take on part of that responsibility in realizing a truly sustainable social ecological system.