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DEVELOPING THE AGRICULTURAL DEPARTMENT OF FRANTSILA HERBFARM AS A PART OF THE COMPANY SUSTAINABILITY STRATEGY

Bachelor's thesis

Climate Smart Agriculture

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Smart Organic Farming Tiivistelmä
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Työn nimi Frantsilan Luomuyrttitila Oy:n viljelyosaston kehityssuunnitelma osana yrityksen kestävyysohjelmaa
Ohjaaja Tiiti Kämäri

Kestävyysohjelman tavoitteiden saavuttaminen on tärkeä päämäärä Frantsilan Luomuyrttitila Oy:lle. Omistajatahdon ja Ruokaviraston valvomien luomuohjeiden lisäksi ne muodostavat rungon kehityssuunnitelmalle, korostaen siirtymistä kohti uudistavaa luomuviljelyä.

Monimutkaisuutensa vuoksi uudistavan viljelyn ja sen vaikutusten määrittelemiseksi luotiin taulukot, joilla tavoitteista ja toimenpiteistä saatiin kokonaiskuvat käyttökelpoisen suunnitelman pohjaksi.

Luomuviljelyohjeet määrittävät pakollisen lähtökohdan ja rajoitteet toimenpiteille, maaperän ja ympäristön määritellessä vaaditut tavoitteet. Tutkimuslöydökset paljastavat, että suorakylvömenetelmän harjoittaminen ilman mittavaa maanmuokkausta on yhteydessä lähes kaikkiin tavoitteisiin, mutta saattaa aiheuttaa hankaluuksia koskien satomäärää ja koneistoa. Kun suorakylvö yhdistetään jo sovellettujen luomuehtojen noudattamisen lisäksi muihin toimenpiteisiin, kuten tehostettuun katekasvustoon, monimuotoisten ja funktionaalisten monivuotisten kasvien käyttöön yksivuotisten lisäksi, paljaan maaperän minimointiin, sekä korkean biomassan ja syvät juuret omaavien kasvien käyttöön, saatetaan lisätä ja kiihdyttää hiilensidontaa, parantaa maaperän mikrobiaktiivisuutta ja maaperän rakennetta, sekä parantaa satoa ja luonnon monimuotoisuutta maanpinnan ylä- ja alapuolella.

Kehittämällä tavoitteellisia työskentelytapoja sekä uusimalla koneistoa voidaan lisätä kestävyyttä tilan toiminnoissa sekä toimipaikassa. Tärkeimpien sertifiointikriteerien saavuttaminen voi lisätä markkina-arvoa ja toimia esimerkkinä muille yrityksille ja viljelijöille.

Avainsanat Uudistava viljely, kestävä maatalous, lääkekasvit, hiilensidonta, maaperäeliöstö.
Sivut 44 sivua

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Smart Organic Farming		Abstract
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Reaching the objectives of the company sustainability strategy is an important goal for Frantsilan Luomuyrttitila Oy. Along with the owner demand and the set standards for organic agriculture, they form the framework for the development plan, highlighting the importance of transition towards regenerative organic agriculture.

Due to the complexity of defining both the criteria and the impacts of methodology in regenerative organic agriculture, tables were established to summarize the objectives and activities to reach a general view for establishing an applicable plan to reach the goals.

Organic agriculture regulations set the mandatory baseline and limitations to the actions, and the soil and the environment determine the required objectives. The findings of the research reveal that practicing no-till agriculture is linked to nearly all objectives, but may cause difficulties regarding yield and machinery. Combined with other activities, for example practices such as intensified cover cropping, using diversified and functional perennials among annual crops, keeping bare soil to a minimum and using high-biomass plants with long roots, along with the organic agriculture practices already applied, may increase and accelerate carbon sequestration, improve soil microbial activity and soil structure, and increase yields and biodiversity above and below ground.

By developing goal-oriented work methods and by renewing the machinery, sustainability can be increased in the farm activities and facilities. Reaching the goals of the most important certification criteria can increase marketing value and set an example for other companies and agricultural entrepreneurs.

Keywords	Regenerative farming, sustainable agriculture, medicinal plants, carbon sequestration, soil biota.
Pages	44 pages

Content

Figures, tables and equations

1 Introduction

The thesis functions as a development plan for Frantsila Herbfarm (Frantsilan Luomuyrttitila Oy). The founders of Frantsila, Virpi Raipala-Cormier and James Cormier started farming Virpi´s mother´s family farm organically in the beginning of 1980´s and producing herbs for holistic wellness and educating people in wellness in alignment with nature. As the next generation of Frantsila, Jupiter and Valo Cormier, are beginning to take charge of the company, the agricultural department is again under development – to sustain the position as the vanguard of agricultural sustainability in Finland. (Frantsilan Luomuyrttitila Oy, personal communication, 30.8.2023)

The company sustainability strategy states that ecologically sustainable businesses can be successful and show impressive sustainable growth. Frantsila aims to inspire, share knowledge and enrich ecosystems instead of degrading them, as well as produce products for physical, mental and spiritual wellbeing, starting from the fields of Frantsila, in the form of the healing force of the plants.

Along with organic agriculture, the next generation wants to take sustainability on the farm even further, towards regenerative agriculture, as well as farm as many herbs as possible for the future product lines. The aim is to enrich the soil, the ecosystems and the biodiversity on the fields, maximize carbon sequestration and maximize the nutritional value in the plants. It is also considered important to find ways to measure carbon sequestration, soil quality and its impact on the active substances in the plants. Reaching a full qualification for the EcoCert Cosmos certificate annually is an important target for the company.

The objective of the development plan is to find solutions on **how to reach the goals of the company sustainability strategy in the agricultural department**. For this purpose a range of scientific literature is analyzed and utilized to establish a science based project plan to integrate a more sustainable approach. The focus is on regenerative agriculture, without excluding agroforestry, permaculture and other applicable measures to increase or examine sustainability.

2 Frantsila Herbfarm (Frantsilan Luomuyrttitila)

2.1 Current state of agriculture

Frantsilan Luomuyrttitila has been farming organically since 1981. Many different methods of farming have been tried out during this period, but currently all agricultural practices are certified organic agriculture and applying to the European Union organic agriculture regulations. (Frantsilan Luomuyrttitila Oy, personal communication)

Frantsila is known for growing its own medicinal herbs for the natural cosmetics, herbal extracts and herbal infusions that are manufactured in Frantsila´s own factory. Currently there are approximately 30 herbs grown on the fields and some collected from natural resources in areas that are certifed organic. The main herbs grown are nettle (*Urtica dioica*), common yarrow (*Achillea millefolia*), common marigold (*Calendula officinalis*), purple coneflower (*Echinacea purpurea*), chamomile (*Matricaria chamomilla*), mints (*Mentha x dalmatica*; *Mentha x piperita*), St. John´s wort (*Hypericum perforatum*), narrowleaf plantain (*Plantago lanceolata*), common self-heal (*Prunella vulgaris*) and lemon balm (*Melissa officinalis*). Carrot (*Daucus carota*) and beetroot (*Beta vulgaris*) leaves are also grown in large amounts for green powders that are made on the farm. (Frantsilan Luomuyrttitila Oy, personal communication)

To achieve the minimum requirements for organic subsidies, the farm also produces oats (*Avena sativa*) on a minimum of 30 % of the fields, legumes on a minimum of 30 % of the fields (as main crops or cover crops, small seeded legumes should be at least 15 % of the mix and 3 kg/ha), and at least 50 % of the fields should include plants that promote soil fertility. These can include grasses and leguminous grasses, and they can be added as main crops, cover crops or nitrogen-fixing plants. It is also important to remember that at least 33 % of the fields should be covered with living plants during the period of 31.10.-15.3. (not including permanent grass fields). This sets certain boundaries to what can be done on the herb fields which are defined as ‘*herbs under 5 years*’ and it doesn´t qualify as year-round coverage despite being fully covered. (Frantsilan Luomuyrttitila Oy, personal communication; Ruokavirasto, 15.9.2022; Ruokavirasto, 18.4.2023)

The company is currently undergoing major changes as the founders of the company are passing the company and the farm to their two sons. The fields will be divided into three separate parts: one for each owner and one for the use of the company. This transition will most likely leave four parcels (Figure 1) for the company with a total of 7,04 ha: Pihlajavainio (3,28 ha, Riihivainio I (1,96 ha), Riihivainio II (0,07 ha, apple orchard) and Iitanvainio (1,73 ha). These four parcels are the main focus of this project plan. During the season of 2024 all of the herbs will be grown on Pihlajavainio, and some perennial herbs are collected from Iitanvainio and Riihivainio II, and also other parcels before the roots are ploughed into the fields. The current herb parcel on Pihlajavainio is 0,78 ha, but more will be tilled and covered. (Frantsilan Luomuyrttitila Oy, personal communication)

Figure 1. Frantsilan Luomuyrttitila Oy parcels.

As the oats that are grown on the farm are currently sold to a nearby farmer directly from the fields, and oats are also bought from other farmers for the use of Paras Ystävä oat bags, it is worth investigating whether Frantsilan Luomuyrttitila Oy could use the oat yields from its own fields, and conducting the necessary calculations to determine which method is more profitable, when the Frantsila oats are grown, harvested and dried by subcontractors. (Frantsilan Luomuyrttitila Oy, personal communication)

2.1.1 Farming methods implemented

Frantsilan Luomuyrttitila Oy uses basic methods of organic cultivation on the parcels. The oat fields are deep ploughed, harrowed and sown, mainly during springtime. Under the oat fields, clover-grass or lucerne-grass mixtures are used as cover crops to promote year-round coverage and next year´s leguminous grasses. The farm uses crop rotations effectively and oats are mainly grown once or twice before returning to grass. (Frantsilan Luomuyrttitila Oy, personal communication)

The herb fields have been part of the main crop rotations, which at times has meant that they have been collected far from the drying facility between Pihlajavainio and Riihivainio (Figure 1). Driving or walking far from the facility is time consuming and requires fueled transportation to bring the yield to the dryer. This also extends the time that the herbs are in the collecting sacks which may affect the quality of the herbs. (Frantsilan Luomuyrttitila Oy, personal communication)

The herbs are grown on each parcel for 4-5 years at a time. The herb fields are fertilized with dry manure and deep ploughed before adding a new parcel after nitrogen-fixing crops, and the fields are then harrowed and tilled with a rotary tiller. Currently the herbs are grown in agricultural plastic mulch, as seen in Figure 2, which is not a sustainable option despite its easy and profitable use. The research on farmer opinions about strawberry mulches conducted by Goldberger et al. (2019) stated that plastic mulch has significant environmental impacts, such as accumulating on landfills, causing harm to wildlife and releasing micro- and nanoparticles into soil and the surrounding water systems. However, the company personnel have found that the black plastic has advantages as well, keeping the sensitive plants covered during the cold winters for several years, heating the soil underneath in the springtime to promote their growth, keeping weeds from spreading, as well as keeping moisture underneath during hot summers. Irrigation is only required for two to three weeks after the seedlings are planted. The seedlings are first grown in peat pots in the company greenhouse from mid April forward, using fossil fuel heating when required. They are then planted in the plastic covers in the beginning of June, and covered with soil to keep the peat from drying. Last time the Pihlajavainio fields were fertilized using manure was in the fall of 2022. Lime was added to the fields in the spring of 2024. (Frantsilan Luomuyrttitila Oy, personal communication)

Figure 2. The agricultural plastic mulch.

The agricultural department is not limited to farming and drying only, but the facilities and processes include storing and processing dry herbs, as well as book-keeping from agricultural functions to processed herbal mixes. (Frantsilan Luomuyrttitila Oy, personal communication)

2.1.2 Machinery

At the moment, contractors are used for almost all of the field work. Frantsilan Luomuyrttitila Oy owns a tractor, a harvester, a rotary tiller, an agricultural plastic mulch layer machine and two tractor trailers. The herbs are mainly harvested by hand with a knife or by plucking (apart from nettle), and dried in four different dryers, of which the oldest herb dryer is approximately 40 years old (9,6 kWh, 14 stock units), another one is an old pill dryer (18 kWh, approximately 10 units), one is a two compartment silo run by fossil fuel, and one is a year-old Bucher 140K condenser dryer that runs on an air-source heat pump (3,1 kWh, 28 units). Compared to the older machinery, the Bucher dryer produces much better quality and stores twice as much produce compared to the oldest herb dryer. The dryers are in daily use approximately from the beginning of June until the end of September, which builds into 4 months give or take. (Frantsilan Luomuyrttitila Oy, personal communication)

The facilities in the agricultural department are heated with a ground heating system which was proven to be insufficient from the beginning, and the ground circuit too shallow to create heat in the coldest winter months, which causes severe need for electrical heating. As electricity is not created on-farm, this adds to the expenditure. It is, however, generated by wind power to promote sustainability. Not only is the facility cold in the winter (0 °C, if not heated with extra electricity consuming heaters), it also gets hot during summer (up to 30 °C), which affects the stock quality and compromises working conditions for the employees. (Frantsilan Luomuyrttitila Oy, personal communication)

2.1.3 Soil samples and the water systems

All of the parcels were examined during 2023. Broad soil fertility tests (NIR analysis) were made for Pihlajavainio and Aimonmoisio in the spring of 2023, and all of the fields were tested for their pH and nutrient content in the fall of 2023. It is important to note that the fields have had lime fertilization in the spring of 2024 which most likely has affected the nutrient content. For the development plan, it is best to only consider the analyses of Pihlajavainio, Riihivainio and Iitanvainio. (Frantsilan Luomuyrttitila Oy, personal communication)

The Finnish NIR-analysis, sampled by Frantsilan Luomuyrttitila Oy (personal communication) on 20.5.2023, and analyzed by Eurofins Viljavuuspalvelu Oy (2021), is a soil fertility analysis which defines the amount of each soil fertility factor, such as the utilizable main nutrients, soil type and structure, and the biomass of microbes, as well as their activity and the relation of bacteria and fungi. This analysis contains a suggestion for fertilization and the addition of organic material. Prior to year 2023, Pihlajavainio parcel has been used for clover and timothy based green manure production. It was ploughed 15.5.2023 and harrowed 23.5.2023. The analysis for Pihlajavainio reveals that the silty clay soil is high in nitrogen (N) and utilizable sulphur (S), fairly high in sodium (Na), good in utilizable potassium (K), fairly low in utilizable phosphorus (P) and low in utilizable calcium (Ca) as well as total Ca, and utilizable magnesium (Mg). The utilizable P value in the analysis is 3,3 kg P/ha, while the target value is 5,0-8,3 kg P/ha. The total value of P is within target value. The utilizable Mg came out as 135 kg Mg/ha, while the target value is 195-305 kg Mg/ha. The Mg stock in soil is fairly high, with the value of 455 kg Mg/ha.

The NIR-analysis of Pihlajavainio also reveals that the organic carbon (C) in the topsoil is 1,51 %, while the total C value is less than 1,6 %. The soil contains 1,8 % organic material, which brings the ratio between organic carbon and organic material high. The microbial biomass is fairly high, but both microbial activity and the fungi/bacteria (F:B) ratio are low.

Acidity (pH) of the Pihlajavainio soil is 5.2, which, according to the analysis, is fairly low. The analysis also reveals that the soil aggregation is extremely low, but the risk for the soil silting is well managed and the risk for wind erosion is extremely well managed. In the NIR analysis, liming was recommended on Pihlajavainio parcel with an addition of 1235 kg/ha. (Frantsilan Luomuyrttitila Oy, personal communication)

The basic soil analysis, which is every five years minimum, reveals the need for different nutrients, but also the pH of the soil. The analyses are categorised from 1 to 5 (very poor to very good). The last samples were taken in the fall of 2023, after harvest season. The analysis from Pihlajavainio shows an increase in pH, going up to 6,2, which shows a major difference to the sample taken the previous spring. The parcel is poor on sulphur (S). Riihivainio had similar samples, but Iitanvainio had a slightly lower pH of 6,0, and it was poor on phosphorus (P). Liming was recommended on all parcels. (Frantsilan Luomuyrttitila Oy, personal communication)

0,78 ha of the total area of 3,28 ha was used for growing herbs in the season of 2023, and 1,83 ha was used to grow oats, with timothy and red clover as cover crops (15:5 ratio). The herb crops yielded around 500 kg of dry matter. In the soil analyses, liming was recommended, and the following winter the fields were enriched with 5 000 kg/ha of Nordkalk Magnesium, apart from the current herb parcel and the natural meadows. The Ca content of the lime was 1050 kg/ha, and Mg 350 kg Mg/ha (Nordkalk, 2024).

Despite the fact that Frantsila farm is not located in direct proximity to large water systems, apart from one parcel, the field ditches eventually lead towards the Mahnalanselkä-Kirkkojärvi lake area. The lakes are relatively eutrophic and oxygen deficiency occurs each summer, but the phosphorus and chlorophyl contents have declined between 1990 and 2014. The proximity of agricultural lands and populated areas may affect the lake condition. (Järvi-Meri Wiki, 2024)

2.1.4 Limiting factors

Whatever is grown on the lands of Frantsila herbfarm, the future methodology is greatly influenced by the regulations on organic agriculture, the hectares after dividing the farm in three, the boreal climate and the openness of the area, causing occasional strong winds and heat stress. The farm is also focused on growing plants only, which calls for the need for external fertilizers as manure is not produced on-farm. (Frantsilan Luomuyrttitila Oy, personal communication)

Ruokavirasto (2022), the Finnish Food Authority, functions as regulating body in organic agriculture in Finland. The ground rules for organic agriculture are to use efficient crop rotations where fertilization is based on using nitrogen-fixing plants on at least 30 % of the field area, having a winter coverage of at least 33 % and growing grain or potatoes on a minimum of 30 % each year. The last requirement has other options as well, as one can also grow twice as much other produce, for example herbs or vegetables. The minimum total field capacity is 5 ha, unless one produces ‘horticultural plants’, where the minimum field capacity is only 1 ha. As Frantsila is also growing grain, and the total area is 22,33 ha, the herbs are listed as “herbs under 5 years” on field level agriculture. It should be examined whether the herbal area could be transformed into a vegetable garden, as the dividing takes place. The challenge in listing the herbs as “herbs under 5 years” is that the regulations don´t consider the area covered through winter, despite it having a full vegetative coverage in between the plastic mulch, and within most of the plastic as well. The minimum of 5 year crop rotation plan needs to include leguminous plants, 50 % fertility enhancing plants annually (leguminous plants and grasses grown together for green manure, pasture or silage and hay) and crop plants. The field capacity will change the dynamics of the herbfarm, as the total area will decrease and counting the minimum requirements on a smaller scale will become more difficult. (Frantsilan Luomuyrttitila Oy, personal communication)

The surrounding farms practice conventional agriculture, which may have an effect on Frantsila fields, if the chemical runoff crosses the border through water systems or with the wind. As Frantsila uses external contractors for most of the field work, it is important to take into consideration that some of the contractors farm conventionally, which requires a careful machinery cleansing before working on Frantsila fields. (Frantsilan Luomuyrttitila Oy, personal communication)

Frantsilan Luomuyrttitila Oy is located in Kyröspohja, Pirkanmaa, Finland, within the Southern boreal zone. According to Ilmasto-opas.fi (2022), the average temperature in Pirkanmaa is +3-5 °C annually, and the average rainfall is 600-700 mm annually. In Pirkanmaa, the average monthly temperatures typically vary from -6 °C in February to +17 °C in July. Higher temperatures are typically experienced for 15-17 days during summer. Drought is typically experienced in February and April, and July is typically the month with the most rainfall. The area is typically snow covered 3-4 months of the year. Spring typically starts mid March, and summer starts mid May. As fall starts by the end of September, the growing season is relatively short, 170-190 days (5,5-6 months) annually, during which the accumulated thermal unit is approximately 1300 °C. The average rainfall during growing season is 350-400 mm, but it can vary from 200 to 600 mm, depending on the growing season. It is estimated that temperatures will rise further and rainfall will increase in Pirkanmaa area. On the farm it has been noticed that climatic stressors, such as drought and rain, last longer periods of time (Frantsilan Luomuyrttitila Oy, personal communication)

As seen in Figures 1 and 3, the herb fields are placed in an open area. This exposes the plants to extreme weather conditions, such as strong winds and heat. The heat causes drought in the silty clay soil, and the strong winds have the potential to cause soil erosion and stress for the most sensitive plants. (Frantsilan Luomuyrttitila Oy, personal communication)

Figure 3. The herb field, facing south.

2.2 Sustainability strategy

2.2.1 Objectives

Frantsilan Luomuyrttitila Oy has developed a sustainability strategy with an ethical guidance. This guidance emphasizes ecological production and activities, including following the environmental legislation and guidance, actively promoting and protecting biodiversity, minimizing the carbon footprint and farming sustainably and regeneratively, as well as following the regulations of organic agriculture. Recycling and composting everything possible within production and social facilities is highly encouraged. The strategy also promotes finding ways to reduce negative impacts and increasing positive impacts on nature. All activities of the company should aim to generate social and environmental wellbeing. In agriculture, this means taking steps towards regenerative organic agriculture, increasing carbon sequestration and promoting ways to protect biodiversity. (Frantsilan Luomuyrttitila Oy, personal communication)

Sustainability is a broad concept, and not all factors of it are related to agriculture directly. The Sustainable Development Goals, also known as The 2030 Agenda for Sustainable Development, initiated by the United Nations and adopted by all member states in 2015, functions as a guideline for what to strive for when it comes to sustainability. The objective of the 17 goals is to not only maintain a satisfactory life on Earth, but to improve its quality for all living beings. All functions and approaches in the company aim for Responsible Consumption and Production. Frantsila takes pride in promoting responsible and sustainable business operations, especially in the agricultural department, which is the flagship of the company. The agricultural department is one of the main focuses in the company when it comes to Climate Action, which has lead to the need for this development plan. It is noticeable that Frantsilan Luomuyrttitila Oy does not produce foodstuff in large amounts, and the herbs produced are mainly utilized as different kinds of extracts and infusions. Therefore the sustainable development goal of Zero Hunger does not affect the company in that sense. However, certain articles under the goal do play a major role in the agricultural department, such as '*sustainable agriculture that helps maintain ecosystems, strengthens capacity to adapt to climate change and extreme weather, progressively improving land and soil quality*, as well as *maintaining the genetic diversity of plants'*. *Improving water quality* (goal of Clean Water and Sanitation) is a side effect of sustainable agriculture and responsible manufacturing, although a long-term process which requires actions from multiple farmers in the area. As the energy prices have increased in the past years due to the global instability (Nieminen, 2023), Affordable and Clean Energy is definitely a challenge. However, changes could be made by changing the purchased wind power to a self-reliant solar power system. Climate action is also directly related to Life on Land, as agricultural measures have an *effect on ecosystems below and above ground, as well as on freshwater ecosystems*. It is an important goal for the company to not only preserve, but also to *create abundance in the ecosystems and the biodiversity on and around the farm*, and to promote these actions in marketing. Along with the development of the cosmetics and food industry, Frantsila is also aiming to develop under the Industry, Innovation and Infrastructure goal, leading a small family owned company towards more professional approaches, by bringing in new, sustainable technology and work methods, and conducting research, development and cooperation under its activities. (United Nations, 2024; Frantsilan Luomuyrttitila Oy, personal communication)

The goal of promoting Good Health and Well-being is, and has been, one of the major objectives of the company from the beginning. This would also include the article of *reducing illnesses from hazardous chemicals and air, water and soil pollution and contamination*, by producing responsibly manufactured natural cosmetics as well as promoting work safety in the company. Frantsilan Luomuyrttitila Oy has also produced Quality Education, educating people about natural wellbeing since the very beginning, both by keeping courses and having an intensive internship and volunteer program, teaching different stakeholders about organic and sustainable agriculture as well. Frantsila has enhanced the reputation of the municipality of Hämeenkyrö and in that sense been a part of building a Sustainable community, partially by *providing possibilities for the students* in the nearby vocational schools, as well as broadening the possibilities to educational institutions all over the country and beyond, but also by providing services that attract guests from all over the world (the café and restaurant Frantsilan Kehäkukka, and the course and wellness center Frantsilan Hyvän Olon Keskus, run by two other companies). The company still works closely together with the *municipality, organizations and institutions, as well as the educational system*, especially in the agricultural department and taking part in events, creating Partnerships for the Goals. As the ideology of Frantsilan Luomuyrttitila Oy is based on health and wellness, it is noticeable that the company aims to offer a *good work environment* for its employees as well. As the goal of Decent Work and Economic Growth states, Frantsila offers its employees possibilities to *develop* themselves through work and to work towards *innovations* that benefit the company. *Economic growth* is obviously an important objective for any functioning business, without forgetting about the *health, safety and wellbeing of the individuals* working for the company. This said, Reduced inequalities is obviously a self-evident factor in the company. *Transparency* – one of the sectors within the goal of Peace, Justice and Strong Institutions – creates trust in the business that aims for sustainability. (United Nations, 2024; Frantsilan Luomuyrttitila Oy, personal communication)

Rhodes (2015) points out that farm practices should be regenerative, and not only sustainable, in order to remain sustainable in the longer term. According to Cambridge Dictionary (2024), the literal meaning of sustainable is to be "*able to be maintained or continued*", which in the current state of agriculture would imply to maintaining the degenerated agricultural lands as they are, as a minimum requirement. Permaculture examines agricultural practices through harmonious natural designs. Regenerative agriculture is targeted to function through regenerative practices at a soil level (Schreefel et al., 2020). Rhodes also defines the word regenerative as something that is 100 % recycled, recyclable, and improving the environmental conditions at all stages.

Measuring the actions has become an important part of the company strategy. Obviously sales are measured on a monthly, quartal and annual basis, but the annual outcomes in manufacturing and agriculture are shared in an annual meeting, where the whole company is gathered to hear about the achievements and development of the company. Also personnel wellbeing is measured twice a year with an anonymous survey to see which areas require improvements. Measuring and examining the sustainability of the company has been on focus, and in the agricultural department this means measuring the *agricultural impacts on soil, climate and biodiversity*. (Frantsilan Luomuyrttitila Oy, personal communication)

2.2.2 Cosmos certificate

As reaching the Cosmos organic certificate is an important objective for the brand, it was important to take a look at what it means in the agricultural department. Cosmos Standard is run by an international non-profit certification body that sets standards for natural and organic cosmetics, as well as raw materials used in manufacturing. According to the newest Cosmos Certificate Standard Criteria (Version 4.1 from March 1st 2024) the main rules are the following: '*promoting the use of products from organic agriculture, and respecting biodiversity*; *using natural resources responsibly, and respecting the environment*; *using processing and manufacturing that are clean and respectful of human health and the environment*; and *integrating and developing the concept of green chemistry'*. In the standard it is stated that the European standards of organic agriculture are satisfactory when it comes to agro-ingredients. However, this clearly calls for more actions towards sustainability from the agricultural department of Frantsila, such as developing the field areas in ways that promote sustainability and biodiversity on a higher level, and considering changes in the machinery and sources of energy on-farm. (Cosmos Standard, 1.3.2024; Cosmos Standard, 25.3.2024)

The criteria points out that a Quality Control System must be formed in manufacturing, which would, along with the basic organic requirements, require manufacturing processes at all stages, as well as testing and analysing ingredients and products. Packaging criteria includes a listing of renewable materials, which may not be possible to fulfill, due to the use of plastic sacks that do not collect moisture when frozen – all herbs are frozen for two weeks in -21°C to avoid pest infestation in the storage facility. The packaging, however, may be justified. (Cosmos Standard, 1.3.2024)

An environmental management plan, along with a waste management plan, should be conducted throughout the manufacturing process. Recycling is required for as many wastes as possible. Cosmos standard also sets clear instructions for cleaning products in the manufacturing facilities, promoting certified biodegradable, plant based products. Some of these criteria is already met, but improvements are necessary to reach the full criteria, also in the agricultural department. (Cosmos Standard, 1.3.2024)

2.2.3 Measuring sustainability

For a company aiming at sustainable agriculture, it is also important to measure the effects of the implemented practices. Finding ways to measure carbon sequestration on-farm is considered an important objective in the company sustainability strategy. Other indicators of soil and environmental health include presence of the most important pollinators (especially the endangered ones), occurrence of pests and predator insects, and soil microbes and soil microbial activity. According to several supporters of regenerative agriculture, healthy soil is also claimed to produce healthy, nutritious plants with plentiful plant active compounds, which the company also wishes to measure. (Frantsilan Luomuyrttitila, personal communication; Regenerative Food & Farming, 2024; Regenerative Organic Alliance, 2024)

3 Defining methodology

As it is important for the company´s sustainability strategy to define the techniques used and effects of regenerative organic agriculture, I began my research by searching for information on regenerative agriculture and its definitions, following a dive into scientific research on the impacts of these actions.

3.1 Regenerative agriculture defined

Beginning to define regenerative agriculture, the most relevant defining actors and organizations were taken into account. As Giller et al. (2021) summarized, the term ‘regenerative’ was first associated with the terms ‘agriculture’ and ‘farming’ by Gabel in 1979, but Robert Rodale from the Rodale Institute (RI) was the first person to give a definition to ‘regenerative agriculture’ in 1983. For decades regenerative agriculture was barely mentioned, until interest in it increased rapidly after year 2015.

Rodale Institute is still the leading actor in promoting, not only *regenerative agriculture* and *organic agriculture*, but *regenerative organic agriculture*, which is based on certified organic agriculture, but goes beyond organic and sustainable. According to Rodale Institute, regenerative organic agriculture has the potential to improve resources instead of just maintaining them. Soil health is considered a priority, as it affects plant and human wellbeing, and the whole planet. Along with soil health, Rodale Institute emphasizes animal welfare and worker fairness, and points out that regenerative organic agriculture aims to create harmony with nature through farm systems. (Rodale Institute, 2024)

In 2018 Rodale Institute introduced a regenerative organic certification which is monitored by the Regenerative Organic Alliance. Soil health, social fairness and animal welfare set the foundation for the standard. (Rodale Institute, 2024). The Regenerative Organic Alliance (2024), founded by the Rodale Institute, Dr. Brennan´s and Patagonia, defines regenerative organic agriculture as follows:

- vegetative cover: land should be covered year-round with live vegetation, mulch or crop residues, and a diversity of cover crops should be used, with nitrogen-fixing plants included for carbon sequestration, returning nutrients to soil, pest control, erosion prevention and decreasing weeds
- crop rotation: crop rotations should be used to improve soil health, optimize soil nutrients and battle against pests and weeds
- minimal soil disturbance: the soil should face minimal disturbance to maintain its biology and structure, water preservation capability, prevent erosion and carbon loss
- rotational grazing: ruminants should be grass-fed and grass-finished through rotational grazing that fertilizes the soil, letting the soil rest between grazing cycles
- compost: compost is added to boost soil health and carbon sequestration, and to improve the soil functions
- no synthetic fertilizers or pesticides: synthetic fertilizers or pesticides should never be used – the same goals are achieved through composting and rotations

Regenerative Organic Alliance (ROA, 2024) has set a framework for Regenerative Organic Certification (version 4.1 was published June 27th, 2023), which includes a set of practices that are followed according to which level the farm aims for or aims to keep (bronze, silver or gold). The base requirement for any activity is an organic certification issued by the local certifying body, and a Regenerative Organic System Plan (ROSP).

Baltic Sea Action Group (BSAG, 2024) is a Finnish foundation that promotes regenerative agriculture along with sea protection. BSAG has develop its own criteria for regenerative farming and a learning pathway for farmers. The criteria are the following:

- continuous development of competencies and operations
- purposefully improving and maintaining soil health
- biodiversity above and below ground is systematically reinforced
- a diverse crop rotation
- all-year-round, living vegetation cover is maximised
- minimised tillage
- nutrient use is based on plant seeds and relies on organic fertilizers and biological nitrogen fixation
- the use of plant protection products is minimised

The learning pathway consists of three levels: committed, active and advanced. These levels define how intensively the farmer implements the regenerative farming measures. BSAG has set three principles of regenerative farming: maximising assimilation, maximising soil microbial activity, and minimising soil disturbance. (Baltic Sea Action Group, 2024)

A UK based organization, Regenerative Food and Farming (RFF, 2024) promotes the following techniques to be used in regenerative agriculture:

- reducing tillage and keeping bare soil to a minimum
- diversifying grown plants
- using animals in rotations whenever beneficial
- rewilding
- stimulating life in the soil
- avoiding chemicals such as synthetic fertilizer, pesticides, herbicides, and fungicides, as well as using manure extensively
- using perennials, trees, and wildflowers among crops
- maintaining living roots all the time
- never overgraze fields
- reduce soil loss

RFF states that regenerative agriculture produces benefits such as a greater security of food which is also healthier, capturing and storing carbon, management against floods and drought, abundant wildlife and improved animal welfare. (Regenerative Food and Farming, 2024)

Karl Ritz (2024), an emeritus professor of soil ecology at the University of Nottingham, wrote an article about The Groundswell 5 Principles of Regenerative Agriculture (GW), giving the following definition for regenerative agriculture:

- diversity: broad rotations, rotation leys and companion cropping
- protection of soil surface: over-winter cover crops
- maintaining living roots: maintain mycorrhiza
- minimizing soil disturbance: improves water infiltration, no-till agriculture, maintain soil integrity
- integrating livestock: long recovery periods on pastures to minimize soil disturbance, use mob grazing and mimic nature

Table 1. was generated to gather the information for comparison. As can be seen, some of the criteria are similar between different organizations, but some differ slightly. Many of the criteria can be labeled as *promoting soil health*, which is already the main criteria for Rodale Institute, ROA and BSAG. ROA does not promote animal welfare directly on their definition of regenerative organic agriculture, but it is a major part of the standard criteria.

Table 1. Summarized criteria for regenerative agriculture by 5 organizations.

	RI	ROA	BSAG	RFF	GW
Soil health	■	■	■		
Animal welfare	■				
Worker/social fairness	■	■			
All-year vegetative cover		■	■		
Plant diversity		■	■	■	
Nitrogen-fixing cover crops		■	■		
Crop rotation		■	■		
Minimal soil disturbance/tillage		■	■	■	
Rotational grazing		■			
Grass-fed ruminants		■			
Compost to boost soil health		■			
No synthetic chemicals		■			
Continuous development			■		
Biodiversity above and below ground			■	■	
Organic fertilizers			■		
Avoid chemicals			■	■	
Bare soil to a minimum				■	
Adding animals into the rotation				■	
Rewilding				■	
Adding trees, perennials, wildflowers				■	
Maintain a living root in the soil at all times				■	
Never overgraze				■	
Reduce soil loss				■	■
Rotation fallows					■
Companion crops					■
Maintain mycorrhiza					■
No-till					■
Long recovery periods after grazing					■
Mob grazing					■
Mimic nature					■

Although the definitions of regenerative agriculture sound idealistic, many of the actors and organizations lack the scientific proof behind the measures. Khangura et al. (2023) report that farmers may have different reasoning for transitioning to regenerative agriculture, such as low operating costs, possibility to increase soil organic carbon and improve soil health, produce more nutritious food, and a willingness to increase sustainability.

3.2 Research on regenerative agriculture

Looking into scientific articles on regenerative agriculture, the complexity of defining it and proving that the criteria would function as sustainable measures, as it is claimed by different organizations, makes it challenging to put together a development plan based on this method. The review by Schreefel et al. (2020) focuses on 28 scientific articles, specifically focused on defining regenerative agriculture, to generate a proposal for a provisional definition. After categorizing the objectives and activities from these articles, they came into the conclusion that regenerative agriculture is specifically focused on environmental issues, with an emphasis on soil. The main objective supported by more than half of the authors was to *enhance and improve soil health*, with the second emphasis on *optimizing resource management*. The other core objectives were to *alleviate climate change* and to *improve water quality and availability*. The main activities mentioned were to *include grazing animals* to build soil, shifting to *multi-cropping* (especially *perennials*), preferring *animal manure* and *natural pest control*, *minimizing tillage*, and other soil conservation practices, including *windbreaks*, *silvopasture* and *managed grazing*. The objectives and activities affect positively on food security, regulating and supporting ecosystem services. *Socio-economic benefits* were also mentioned, but they are lacking a framework for implementation. The review points out that according to some authors regenerative activities are organic, but not all organic activities are regenerative. This statement, however, may not apply to all organic agriculture standards, which include strict regulations on land use and plants that are grown.

Khangura et al. (2023) state that regenerative agriculture aims for utilizing natural processes, for example by capturing soil carbon through photosynthesis using plants with high biomass, improving symbiotic interactions between soil microbes and plants, enhancing water retention and soil structure using biological systems, and including livestock to positively impact ecosystem services. They also point out three main expectations of regenerative agriculture: *regeneration of the agricultural ecosystem*, *improvement in landscape functions*, and *profitable farming*.

Giller et al. (2021) did not paint a very positive picture of regenerative agriculture, at least from an agronomic point of view, stating that agroforestry would be one of the best – if not one of the few – practices leading to continuous carbon sequestration, and that otherwise regenerative agriculture as a whole can be based on several different – and even controversial – practices. Elevitch et al. (2018) have come up with agroforestry standards for regenerative agriculture, with examples on how to adopt agroforestry on a field level. They have established the standards based on scientifically proven benefits related to the claimed objectives of regenerative agriculture, such as enriching the soil and enhancing water quality, enhancing and conserving biodiversity and ecosystem services, as well as sequestering carbon. Agroforestry practices and their impacts are specified in section 3.3 Other applicable farming methods to increase sustainability.

Khangura et al. (2023) have conducted a comprehensive review about the impacts of regenerative practices. Searching through scientific studies, they noted that despite the lack of studies conducted on regenerative agriculture, individual practices affecting soil carbon and soil biology have been studied in a large scale. The use of nitrogen-fixing cover crops is already a well known practice and a major part of organic agriculture. Their symbiotic relationship with the soil microbes called rhizobia form the first step in the nitrogen (N) cycle, providing the main crops the needed main nutrient, which impacts positively on yield. Using nitrogen-fixing plants in crop rotations has potential for improving soil structure and increasing the concentration of labile C. Combined with no-till farming these practices improve soil fertility and increase carbon levels. What comes to other benefits, Khangura et al. mention in the review that there is a lot of critique on study methods regarding regenerative agriculture practices, despite many of them being similar to those of climate smart agriculture, found to increase yields and profitability, and reduce greenhouse gas emissions.

3.2.1 Carbon sequestration

In the review of Khangura et al. (2023) they mentioned a phrase by Dr. Rattan Lal from The Ohio State University: "*Any system in which the input of biomass-C exceeds the loss (due to decomposition, erosion, etc.) will result in soil organic carbon sequestration.*" It is known that extensive tillage practiced in intensive agriculture causes carbon dioxide (CO_2) fluxes to the atmosphere and water, causing deterioration in soil, among other harmful impacts. Carbon is best captured into the soil through photosynthesis of plants with high biomass. Carbon sequestration depends on the residue quality (C:N ratio), as N is required for soil organic carbon sequestration. McLennon et al. (2021) mention that agricultural activities cause approximately 30 % of total greenhouse gas emissions. Khangura et al. estimate that greenhouse gas emissions could be reduced in the UK within 30 years by 14-27 % through regenerative agriculture practices.

In their review, McLennon et al. (2021) state that cover crops can be used to increase soil organic carbon. To further examine the reasoning behind the claim, as well as the impact of other regenerative agriculture practices on carbon sequestration, the review by Khangura et al. (2023) is taken under examination. In the studies they reviewed, they found the highest potential for C sequestration in the combination of cover crops, compost and no-till farming. Changing no-till to reduced tillage also increases soil organic carbon, depending on climate and soil type. Significant increases were also found in combining crop rotation, using compost and no-till, or no-till and stubble retention, which also had a positive impact on yield while the soil organic carbon increased 2-5 %. Combining no-till and crop rotation, significant C sequestration increases were found after five years of practicing the combination. Transitioning from conventional to regenerative agriculture, using cover crops and avoiding chemicals, a significant difference in C stocks could also be found. According to the studies reviewed by Khangura et al., no changes in soil organic C were found in soils deeper than 30 cm, but the following practices can be associated with increased carbon sequestration: adding perennial plants, plant diversity (with up to 6-8 % increase in soil organic C), cover crops, crop rotation and all-year vegetative cover, reduced or no-till farming, using compost as fertilizer and avoiding chemicals, stubble retention, adding animals for rotational grazing, as well as maintaining biodiversity above and below ground.

Using cover crops on at least 30 % of field parcels through summer season, soil organic carbon is increased significantly, especially in clay soils, through soil improvements, and mineralizable N and C, with the influence of years of practice as well as environmental features. Combined with no-till practices, the impact is more visible. Khangura et al. state that by increasing carbon sequestration in agriculture through cover cropping, farmers can reduce greenhouse gas emissions up to 10 % if adopted widely, and therefore mitigate the consequences of global warming. Some pastures may sequester up to 32 tonnes of CO_2 per ha annually, stored in the hyphae of the mycorrhizal fungi. (Khangura et al., 2023)

Several scientific studies Khangura et al. (2023) have reviewed suggest that despite the evidence of no-till farming (or conservation tillage) has shown its potential in carbon sequestration and greenhouse gas mitigation, as well as increasing yields, this factor is largely dependent on agronomic and environmental variables. Conservation tillage works best on arid regions and may potentially have a negative impact on soil organic carbon and yield in colder climates, according to the review Khangura et al. conducted on the study by Sun et al. (2022). However, this would require more long-term studies. For farmers to adopt new practices, there often needs to be more evidence on benefits and profitability. It is also noticeable that according to the review Khangura et al. conducted on a study by Lal et al. (2020), no-till agriculture has reduced global warming potential working on acidic soils, and the effects of both reduced and no-till practices are clearer after 6 to 10 years, peaking at 15 to 20 years. Khangura et al. also stated, that according to a study by Sun et al. (2022), in humid areas these practices increase soil organic carbon, but have no effect on yield.

Khangura et al. (2023) remind that increased soil organic C stock and concentration in the topsoil promotes resilience to harmful weather conditions and supports biological activity. The effect of minimal or zero tillage depends on rainfall, soil depth, crop yield, stubble retention and rate of decomposition. They propose a critical threshold of 2 % of soil organic C as an indicator for sustainable production particularly in temperate regions, which may be applied to southern boreal climates as well. However, soils with as low as 1 % of soil organic C contain considerable amounts of nutrients, that may be sufficient if accessibility to plants is achieved. It is important to improve soil organic C to achieve a suitable environment for soil microbes and plants, as well as sufficient nutrient cycling.

3.2.2 Nutrient cycling

As previously mentioned, nitrogen-fixing cover crops function as important nitrogen sources for the main crops. They convert N from the atmosphere into plant-available N, by the rhizobia bacteria in the root system. These plants also increase nutrient cycling, simultaneously increasing soil health. Decomposing a diversity of plants decreases nutrient loss and environmental contamination. With minimal soil disturbance and compost, it is possible to reach a higher content of N and P. (McLennon et al., 2021)

Several studies have been conducted on different practices affecting soil nutrient cycling. Khangura et al. (2023) have summarized the impacts of regenerative agriculture practices. Nutrient cycling is strongly linked to adding perennials and plant diversity, using nitrogen-fixing cover crops and crop rotation, practicing minimal or no tillage, using compost and organic fertilizers and maintaining biodiversity above and below ground. Using cover crops, crop rotation, organic fertilizers and compost increases soil fertility by increasing soil microbial biomass, soil C, and soil N. Using a diversity of plants with nitrogen-fixers C cycling efficiency can be improved. When reduced or zero tillage are practiced, soil microbes, especially mycorrhizal fungi enhance nutrient cycling in the soil. Zero tillage also increases soil chemical properties, soil chemical fertility (N, P and K), likely increases non-symbiotic nitrogen fixation through aggregate stability, and nutrient value of microbial biomass through increased nutrient cycling and fluxes. Combined with liming, zero tillage increases N content in the Mediterranean climate. Along with nitrogen-fixing plants as cover crops, mycorrhizal fungi improve nutrient uptake through their hyphae. Crop rotation and stubble retention promote non-symbiotic nitrogen fixation. Depending on a variety of environmental factors, maintaining biodiversity by using compost and organic fertilizer aid in nitrogen mineralization and a majority of nutrients in the soil organic matter become available through mineralization. Using perennial plants, cover crops, crop rotation and no-till boosts nutrient cycling. Using cover crops during summer N concentration is increased, and crop rotation increases N significantly. Khangura et al. also state that by using diverse plants, nitrogen-fixing, cover crops, organic fertilizers, compost and no-till, N_2O emissions can be reduced in longer term. Soil biodiversity is essential for the breakdown of organic matter, nutrient cycling and soil fertilization, as well as nutrient bioactivity.

According to Khangura et al. (2023), soil microbes convert inorganic nutrients into a form that is available for the plants, and mycorrhizal fungi are known for cycling C, N and P, as well as enhancing the availability of P (up to 75 %) and contributing to Zn uptake in cereals. Microbes are also responsible for converting K and S available to plants, as well as regulating C, N and nutrient cycling, which biotic and abiotic factors, such as precipitation, are influenced by. Long roots with a high biomass aid P uptake and P is made available for plants by root exudates. 80-90 % of soil metabolism is generated by soil biodiversity, and in temperate grasslands, 1-5 % of soil C and N is stored in living microbial biomass. Microbes are also known to release inorganic forms of N, P and S into the soil.

According to Holland et al. (2018), liming has several impacts on soil macronutrients through mineralization of elements that are organic bound, biological and biochemical activity, chemical adsorption, precipitation reactions and nutrient uptake by plants. The impact varies, depending on soil type and existing soil minerals. Liming may increase organic P mineralization and therefore make phosphorus available to plants. The optimal pH for increasing P uptake in plants is 5.5-6.5. Liming can also increase K adsorption. S can be both mineralized and immobilized through increase in pH. Liming may also increase risk of heavy metal leaching.

3.2.3 Soil microbial activity

Mycorrhizal fungi are responsible for mining and transporting nutrients and water to their host, in exchange for the carbohydrates the plants feed to the fungi. Using compost and minimal soil disturbance helps establish mycorrhizal communities and agroecosystem services associated with them. Together with liming, zero tillage has the potential of increasing mycorrhizal colonisation. Intensive fertilization may harm soil microbes, and especially mycorrhizal diversity and abundance. Therefore, avoiding chemical inputs to soil may be helpful. Mycorrhizal fungi have been shown to improve tolerance to drought in plants by increasing water potential through root adjustments, such as increased number of hyphae. Plant growth promoting rhizobacteria also increase drought tolerance. (Khangura et al., 2023)

Promoting microbial biomass by different management practices is critical for soil health. Using different combinations of plant species may manipulate the microbial composition to achieve the desired microbial functions. Crop rotation and compost enhance the effect even further. Minimal to zero soil disturbance and stubble retention produce higher microbial biomass. Stubble retention also increases soil diversity and function, and aids in returning nutrients to the soil through slow decomposition. Combined with crop rotation, the physiological diversity increases as well. Adding perennials and cover crops, together with zero tillage and crop rotation boosts microbial activity. Combining crop rotation with cover crops, compost and organic fertilizers, as well as zero tillage, soil quality is either maintained or improved, due to microbial regulating. (Khangura et al., 2023)

Plant diversity along with nitrogen-fixing plants impact positively on microbial abundance, activity and diversity. Designed into functional groups, diverse plants increase microbial biomass, higher soil organic C and microbial necromass, contributing to nearly half of the soil organic C in agricultural lands. This activity is stimulated by temperature and soil pH. Building soil organic matter may take several years, but by using cover crops biomass is increased. It also increases enzyme activity and glomalin, which works as a carbon storage and is produced in the walls of the hyphal cell of mycorrhizal fungi. Enzyme activity can also be increased using zero tillage. In the rhizosphere, the root exudates shape microbial communities, and soil microbiome can be strengthened by combining cover cropping with other practices. Hormonal signalling between plants and microbes increases the bioavailability of soil nutrients and therefore improves plant growth under biotic and abiotic stress through different microbial mechanisms, for example producing antimicrobial compounds, such as volatile organic compounds. These mechanisms have been reported in numerous scientific publications. (Khangura et al., 2023)

McLennon et al. (2021) state as well, that using minimal tillage and compost enhances microbial respiration, and mowing crushing the green manure into the field improves soil physical, chemical and microbial activities.

3.2.4 Soil structure

According to McLennon et al. (2021), certain regenerative agriculture practices improve soil structure and increase soil water retention. Khangura et al. (2023) explain how microbes are required to bind soil particles together in order to form soil aggregates, either directly by fungal hyphae or indirectly with glomalin or mucilage and polysaccharides produced by fungi and bacteria. A good soil structure by these aggregates works as an indicator of a healthy soil. The microbes receive carbon compounds for the binding component from the sugars the plants are producing. The soil particles that the aggregates are formed of are sand, silt and clay, and fungi are responsible for forming large aggregates. Earthworms, however, play a big role in forming water stable aggregates and water retention.

Khangura et al. (2023) explain how tillage destroys the aggregate structure, affecting soil physical properties through oxidation. Decreased soil organic C caused by CO_2 fluxes affects aggregate stability and reduces soil water retention. They suggest summer cover crops for increasing soil aggregate stability, and combining zero tillage, stubble retention and N fertilizer to improve soil aggregate formation. They also suggest stubble retention to reduce soil erosion and water run-off, and to increase water infiltration. By increasing soil organic C, fertility and nutrient availability, as well as soil structure, aeration, water infiltration and water retention can be improved. Increasing soil organic matter by 1 %, moisture is increased by 1,5 %. Nitrogen-fixing cover crops may improve soil structure as well. McLennon et al. (2021) state that increased soil organic matter, soil microorganisms and biological activities improve soil structure. Mycorrhizal fungi increase water use efficiency through a variety of mechanisms. 1 g of added C increases water by 50 %, due to mycorrhizal activity. Therefore soil biodiversity should be maintained by increasing decomposing plant diversity. Growing cover crops during harvest season, they have a positive effect on soil temperature, aggregate stability and water content.

3.2.5 Avoiding chemicals

Khangura et al. (2023) suggest that by mimicking nature and boosting biodiversity through the use of companion crops, crop rotation, and by avoiding chemicals, herbicide use can be reduced. By maintaining mycorrhiza, as well as other beneficial microorganisms and soil fauna, the field contains integrated biological pest and disease suppressors that restore the ecological balance through a variety of mechanisms, for example competition, hyperparatisism and antibiosis. Mycorrhizal fungi use their hyphae network in transmitting defence signals to plants, manipulating them to become more resilient. Weed control can be approached with physical, genetic, biological and chemical resources, but it is important to remember that the same pathogens may affect both weeds and crop plants. Despite stubble retention and cover crops having several positive effects, they may also infect the following crops with pests and diseases.

3.2.6 Animal husbandry

Grazing animals have multiple positive effects on a field level. Overall, they increase carbon sequestration and soil organic carbon significantly through rotational grazing, but they can also provide other co-benefits, such as improving soil structure and adding to the income stream. They also provide manure for compost. (Khangura et al., 2023; McLennon et al., 2021)

3.2.7 Yield

While regenerative agriculture practices may lead to lower yields on the grain fields at first, the positive outcomes are often seen within 6-10 years from the beginning of regenerative practices, as the topsoil regenerates into a more functional and abundant growth surface. The negative effect is most likely lesser in the herb fields, as they are weeded by hand, but, as the farm is obliged to follow the regulations of organic agriculture, intense weed growth on grain fields may become a threat in regards of subsidies in the beginning of transition, if weed harrowing is not practiced. (Khangura et al., 2023; Ruokavirasto, 2022)

According to McLennon et al. (2021), regenerative agriculture increases profitability. They state that increased crop diversity through cover cropping increases crop productivity, and that regenerative agriculture is beneficial especially in small farming systems. They also mention the profitability of the increase in daily weight of livestock using cover crops.

In their comprehensive review, Khangura et al. (2023) mentioned a variety of effects on yield, using the practices of regenerative agriculture. They claim that in some colder areas, using minimal or zero tillage alone there may be a negative impact on yield. Also using cover crops was found to decrease wheat yield by 10 % and proven to have a negative effect in areas with low rainfall. However, cover crops, compost and reduced tillage together may improve yield in some climates and soil types. They also came to the conclusion, that using crop rotations and diverse crops as a way to increase yield, it may have potential to improve crop yield through soil nutrients and biological control. With no-till practices barley yields have shown to increase, but the effect on yield varies with crop variety. Maintaining biodiversity above and below ground has positive effects on both crop and livestock yields. Stock can be increased 6-8 % with plant diversity, and nitrogen-fixing plants impact positively on yields.

3.2.8 Nutritional quality

Regenerative agriculture is known for its claim of higher nutritional value in foods. Despite the fact that poor nutritional value in food is related to depleting micro- and macronutrients, there are no studies proving that regenerative agriculture, as such, would improve the nutritional density of food. However, soil quality and fertility have an impact on nutritional values, and soil type may play a significant role as well. (Khangura et al., 2023)

Oliveira et al. (2022) conducted a research on volatile profile in mint (Mentha x gracilis Sole), comparing the methods of permaculture, organic agriculture and conventional agriculture. In the *conventional* method synthetic fertilizers and pesticides were used and soil was extensively cultivated. In *organic* agriculture natural fertilizers and biopesticides were used, and synthetic fertilizers were restricted, while ecological interactions and physical methods were also used to prevent and control insects and micro-organisms. Diversified cultivation was used. The *permaculture* method used only natural fertilizers and ecological interactions for pest and disease control. The crops were grown using diversification and preservation of natural cover, including agroforestry. The results showed that the permaculture method generated increased oxygenated terpenes, with a possibility for improved flavor and more functional compounds. There were no relevant changes between organic and conventional agriculture.

Also a research conducted by Montgomery et al. (2022) shows that regenerative practices, such as using zero tillage, growing cover crops and utilizing diverse rotations, result in higher soil organic matter levels, and soil health scores, as well as levels of certain vitamins, minerals, and phytochemicals, compared to conventional agriculture, even when the conventional farm practiced no-till method.

3.3 Other applicable farming methods to increase sustainability

Elevitch et al. (2018) have defined standards for nine agroforestry practices, with evidence based benefits. Out of the nine practices *alley cropping*, *riparian buffers* and *windbreaks* are easily applicable in organic agriculture, as long as the perennials used are accepted as *permanent garden plants* (e.g. apple, black currant etc.) in the organic regulations

(Ruokavirasto, 2023). In alley cropping the permanent plants are placed on the field in rows, allowing field level agriculture in the alleys in between. This practice has several benefits, such as reducing soil erosion and runoff by water, improving nutrient use efficiency, sequestering carbon, and increasing biodiversity. Riparian buffers stand for strips of variable vegetation in between fields and waterbodies and they function as blockages for runoff and soil erosion, improving water quality, and in increasing biodiversity. Windbreaks are taller vegetative barriers around the fields that help reduce wind erosion and create a different microclimate on a field level. By blocking strong winds on the plants, windbreaks also help improve growth and yield, and they increase water availability by reducing evaporation. By choosing perennials that can be utilized by the company, agroforestry practices also increase yields. Several organizations have set agroforestry certifications and standards with a baseline on organic production, but they are only applied abroad as such. However, the criteria prefer plants from multiple layers (e.g. trees, shrubs, perennials) and varieties (e.g. different varieties of apples) on each agroforestry parcel, with a higher density.

McLennon et al. (2021) propose integrated permaculture as one holistic approach for reducing or eliminating dependence on external inputs, and for restoring and maintaining natural systems similar to regenerative agriculture. Permaculture approaches the agricultural system from a holistic and local perspective, taking into account various ecological functionalities that promote diversity and resilience, as well as the farm´s relation to human health and well-being through interactions, innovations and adaptive management systems. They also propose applying modern digital technologies, which, on a larger scale, may be helpful to identify problems, such as water management issues.

The Finnish Food Authority (Ruokavirasto, 2024) has set up engagement terms for environmental compensation, which the farm is already putting into practice. Along with the basic subsidy terms, as well as basic fertility testing every five years, parcel notes and a climate and environmental plan, the farmer must commit to two of the following procedures annually:

- climate and environmental education
- multiyear diversity strips
- soil monitoring
- organic nutrients
- pollinator plants
- precision farming procedures
- plant pest and plant disease monitoring and recognition apps

Although quite limited, these terms are designed to encourage farmers to engage in sustainable measures. In Frantsila Herbfarm it is simplest to implement the *climate and environmental education*, *multiyear diversity strips*, *soil monitoring*, and *monitoring of pests and diseases*. Pollinator plants would be a good choice for the ideology of Frantsila, but the list of plants is limited to those that require either a specialized land use (e.g. orchard) or a more specialized crop production (e.g. buckwheat or hemp), and the need for these plants in the production is minimal.

Added to the previous procedures, it is possible to also choose procedures from the following list and receive a compensation for each activity:

- soil improving and rehabilitating plants
- nutrient fixing plants
- advancing circular economy
- buffer zones
- grasses on peat fields
- water drainage management
- alternative plant protection for vegetables
- bird fields

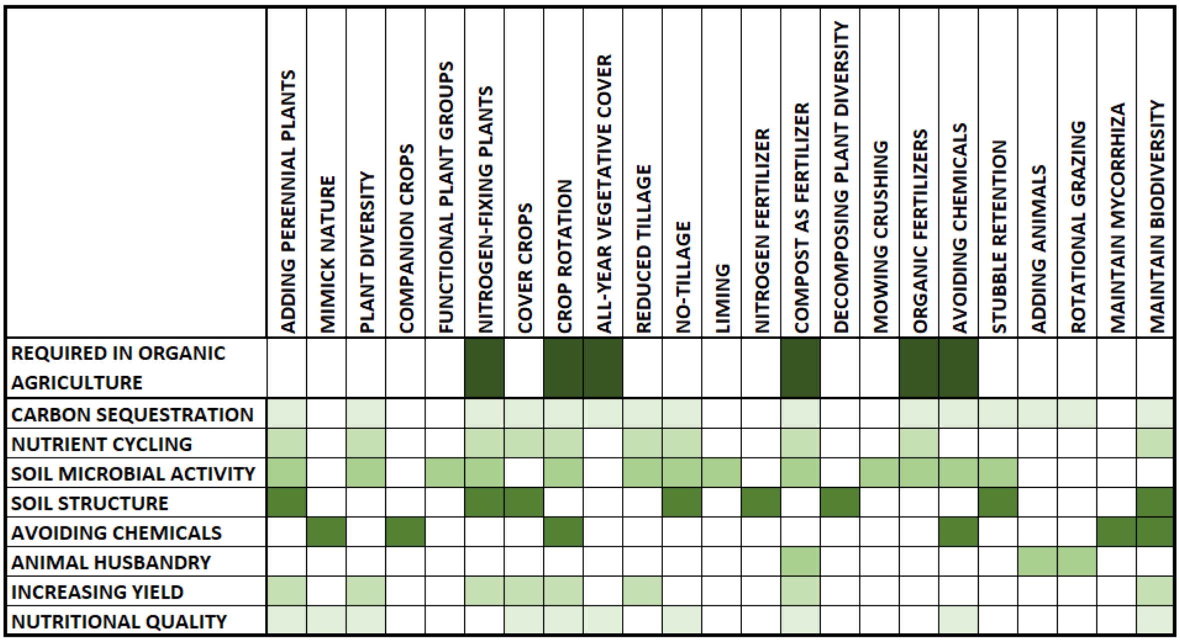
Apart from *grasses on peat fields*, the methods are all applicable in Frantsila farm, but not necessarily current to proceed with.

Changing the agricultural plastic mulch into something more sustainable may be another approach to reduce detrimental impacts on nature. During the following two seasons, an experiment is conducted to come up with solutions on replacing the plastic mulch. This, however, comes with several variables related to, for example, weed growth, soil precipitation, heating and winter coverage, as well as durability underneath perennial herbs. (Frantsilan Luomuyrttitila Oy, personal communication)

3.4 Summarizing methodology

To reach a better understanding of the impact of different regenerative practices, Table 2 was established to summarize the studied benefits associated with them. The requirements of organic agriculture were added as an indicator of which practices are already applied. Despite the fact that Frantsila farm does not practice animal husbandry, animals are an important factor when it comes to carbon sequestration and fertilizing. Dry manure will most likely be utilized in fertilizing, but it is worth examining whether animals could be grazed on the parcels that will be used for herbal production the following year.

Table 2. Applicable regenerative agriculture practices and their impacts.



3.5 Methods to measure sustainability on farm

Although not required, it is possible to carry out extensive fertility tests on the fields annually to measure carbon sequestration and microbial activity. For the overall carbon footprints there are tables that farms can utilize, and for example a company called BioCode (2024) offers services to keep track of the carbon footprint for each product that the company is producing – from primary production to manufacturing and all the way to the delivery system. However, taking into consideration that Frantsilan Luomuyrttitila Oy is a very specialized agricultural company, counting the carbon footprint in primary production may require a more extensive research prior to adding the information to the calculators (Frantsilan Luomuyrttitila Oy, personal communication). Seinäjoki University of Applied Sciences has built a carbon footprint calculator for the food industry called IKE (Manninen et al., 2023), which could be used to calculate the overall carbon footprint of the company apart from the agricultural activities. The calculator counts the carbon footprint of basic raw material, packaging material, waste and side streams, energy use, and logistics. It is still unclear how the overall calculation would function with the specialized herbal production.

It may be worthwile to contact Baltic Sea Action Group about collaboration in the Carbon Action research (BSAG, 2024), which may provide important information about the condition of the fields and the future changes.

Insect calculation and soil organism research can be arranged as annual projects for students in universities of applied sciences. This will provide constant information on the effects of changes in the agricultural practices. Soil organisms can be gathered for calculation using a simplified version of pitfall traps and/or Berlese/Tullgren funnels (Fioratti et al., 2023). The research would require a careful implementation plan which can be utilized as an annual project.

4 Purpose and objectives of the development work

4.1 Utilisation of the development plan

This development plan will be used as a guideline for the agricultural department of Frantsilan Luomuyrttitila Oy, in order to develop the farm into a more sustainable direction, and to increase carbon sequestration in the agricultural lands.

Although further research on the variety of effects of regenerative agricultural practices is required, Khangura et al. (2023) suggest combining different practices to promote carbon sequestration in soil and to improve soil quality. It is important to keep in mind that different variables, such as climate, soil, crop variety and utilizable machinery, influence the impact of methodology, and that direct impacts may be different from long-term impacts. Therefore the plan conducted should be followed as an experiment, and all appearing effects monitored.

4.2 Applying the methodology

4.2.1 Changes in the field parcels

As Frantsilan Luomuyrttitila Oy is an organic certified farm, all certification requirements will be applied to the company parcels as well. The plan is to create a self-rotating microclimate of its own inside the Pihlajavainio parcel, that produces all possible herbs for the use of the company, simulating the ideal regenerative organic farming practices. According to Rhodes (2015), it is easier to create a stable regenerative system at a smaller scale, but larger systems can be created by connecting the smaller units. Therefore it is easier to begin the transition process towards regenerative agriculture on Pihlajavainio parcel.

At the moment Pihlajavainio is divided into four sub parcels: one with the herb growing area (A, B and C in Figure 4, 0,78 ha in total), 2023 oat field (1,83 ha), and the two natural meadows (0,06 ha and 0,61 ha). Due to the plants being planted on the herb area on three different years (2021-2023), it gets difficult to trace individual batches if herbage from different years are harvested simultaneously. By dividing the sub parcels using diverse trees, shrubs and perennials based on agroforestry principles, the batches are easier to separate from one another. The dividing method is called alley cropping, and the perennial plants could include trees and shrubs that are utilizable in the herbal production and suitable for organic production, such as black currants (*Ribes nigrum*), apples (*Malus*), sea buckthorn (*Hippophaë rhamnoides),* hops (*Humulus lupulus*), lavender (*Lavandula angustifolia*) and rhubarb (*Rheum rhabarbarum*). This will increase the stock of self-reliant yield and increase carbon sequestration in the meantime. The herbage of the trees and shrubs that end up on the ground in the fall, serve as organic fertilizer, mimicking the nature. Due to the fact that Pihlajavainio parcel is in an open area experiencing strong winds and heat stressors, and conventional agriculture is practiced southwest and northwest from the parcel, it would be beneficial to plant common hazel (*Corylus avellana*) and roses (*Rosa* spp.) on the sides of the field to function as windbreaks. These plants function as a thick shield against environmental stressors and would create a microclimate inside the parcel. Roses are also utilized in the company manufacturing.

Another major dividing action is to add more sub parcels on both sides of the forest area in the middle of the field (Figure 4). This would create a six-year self-rotating system, such as demonstrated in Table 3, of approximately 1,58 ha, where the required crop rotation can be utilized, and all of the herb crops are close to the processing facility and greenhouses visible at the top of Figure 4. It is possible to keep one or two sub parcels creating green manure at all times, using nitrogen-fixing plants as cover crops for hay, ones with high biomass whenever possible. As the nitrogen-fixing plants red clover (*Trifolium pratense*) and lucerne (*Medigago sativa*) can be utilized in production, they should be the main interest when choosing the species. As there is a slight slope on Pihlajavainio parcel, facing southeast, placing the herb mulches sideways will collect rainfall and increase water availability to the plants.

Figure 4. Pihlajavainio sub parcels.

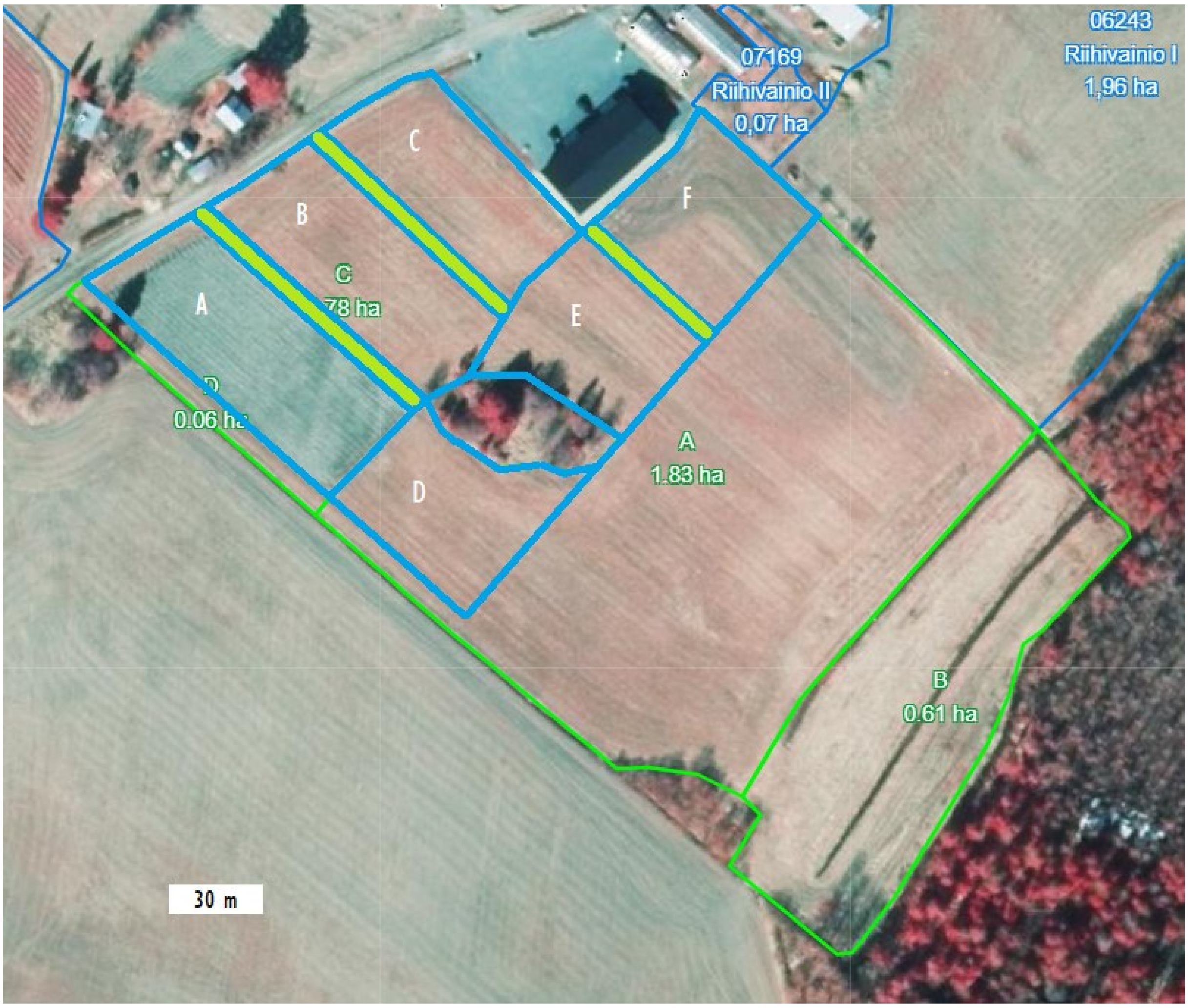


Table 3. Herb field crop rotation.

PARCEL	2024	2025	2026	2027	2028
A	herbs	grass + red clover	grass + red clover	herbs	herbs
B	herbs	herbs	herbs	grass + red clover	grass + red clover
C	herbs	herbs	herbs	grass + red clover	grass + red clover
D	herbs	grass + red clover	grass + red clover	herbs	herbs
E	grass + red clover	herbs	herbs	herbs	herbs
F	grass + red clover	herbs	herbs	herbs	herbs

4.2.2 Organic agriculture criteria

In order for Frantsilan Luomuyrttitila Oy to maintain the organic status, it is important to make sure that the fields meet the requirements of certified organic agriculture before the division takes place (Table 4). By dividing the parcels in the estimated uses (herbs/crops/meadows/orchard) and sizes (ha), it is made possible to count the requirements for crops and nitrogen-fixing leguminous plants (30 % each), required winter coverage (33 %) and fertility enhancing crops (minimum of 50 % of crop rotation). With the crop field rotation in Table 5 (the fields available for growing grain crops and green manure), the requirements should be met. However, the crop rotation in the herbal area may not meet all of the requirements, if it is considered as one parcel or an entirety of its own. The size of the herbal areas may also affect the total calculations. To reach the environmental compensation through The Finnish Food Authority, it is beneficial to keep monitoring the soils of Pihlajavainio and Aimonmoisio parcels, as well as to acquire more practical information through the climate and environmental education.

Table 4. Parcels after division.

Pihlajavainio herbs	1,58
Pihlajavainio crops	1,03
Pihlajavainio meadows	0,67
Riihivainio I crops	1,96
Riihivainio II orchard	0,07
Iitanvainio A crops	1,36
Iitanvainio B herbs	0,37
	7,04

N-grass on herb fields	0,5
Requirement for crops/N-grass	2,112
Required for winter coverage	2,3232
Crop fields without herbs	4,35

Table 5. Crop field rotation.

PARCEL	**2024**	**2025**	**2026**	**2027**	**2028**	**FERTILITY**
Pihlaja	N-grass	oat	oat + N-grass	N-grass	oat	1+0+1+1+0
Riihi I	oat + N-grass	N-grass	oat	oat + N-grass	N-grass	1+1+0+1+1
Iita A	oat	oat + N-grass	N-grass	oat	oat + N-grass	0+1+1+0+1
oats	3,32	2,39	2,99	3,32	2,39	
N-grass	2,99	3,32	2,39	2,99	3,32	
coverage	4,42	4,42	4,42	4,42	4,42	

4.2.3 Implementation of regenerative agriculture

As regenerative organic agriculture is one of the most important requirements to implement in the agricultural department, it was mandatory for the implementation plan to be generated using a scientific evidence base.

Certain practices are already implemented in organic agriculture, such as nitrogen-fixing plants, crop rotation, partial all-year vegetative cover, as well as avoiding chemicals by using compost and organic fertilizers instead. Crop rotation decreases the need for chemical pesticides, herbicides and fungicides.

Carbon sequestration, which mitigates greenhouse gases and therefore has an impact on global warming, is an important objective to consider. In the soil analysis of Pihlajavainio it was stated that the current soil organic carbon in the topsoil measures at 1,51 %, while the goal for soil organic carbon is at 2 %. The fields have been ploughed prior to crops for several decades, possibly causing CO_2 fluxes to the atmosphere and to the nearby waterbodies. High biomass plants, such as mints (*Mentha* spp.), nettle (*Urtica dioica*), angelica (*Angelica archangelica*), plantago (*Plantago lanceolata*), and perennials such as trees and shrubs can be beneficial in capturing C due to the high biomass. Red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*) offer a great solution for applying nitrogen into the soil, but manure can also be used prior to establishing herb fields. The studies conducted on regenerative practices and reviewed by Khangura et al. (2023) and McLennon et al. (2021) reveal that no-till has a beneficial effect on carbon sequestration, especially when combined with other practices such as cover cropping, crop rotation, stubble retention, and using compost or crushed vegetative cover as fertilizer. These studies also show significant results after 5 years of practicing no-till and crop rotation. However, zero tillage may be impossible to implement without the appropriate machinery, and reduced tillage may only be applicable on smaller areas such as the herb parcels, and even then the impact may be affected by climate and soil type. One of the contractors may be able to implement shallow ploughing or cultivating on the crop fields prior to sowing, but the impact on carbon sequestration at this level of tillage is unknown, since the deeper tillage destroys the aggregate structure, affecting the important mycorrhizal fungi and other soil microbes that are responsible for several nutrient cycling activities and overall soil health. The liming implemented in February 2024 may, however, have a positive effect on increasing the mycorrhiza, if the fields are cultivated using minimal tillage in the future.

A good soil structure aided by aggregates reduces soil erosion and water run-off, and improves water infiltration. The fields should be left untouched, unless mandatory to improve yield, and they should be sowed right after cultivation to decrease the exposure to bare soil which is harmful for the soil biodiversity.

Several studies suggest that regenerative practices increase soil nutrient cycling, while soil biodiversity is responsible for total soil metabolism 80-90 %. The main nutrients N and P, as well as soil organic C can be increased by using cover crops, crop rotation, compost and organic fertilizers, which may be beneficial activities especially on the P deficient parcels Iitanvainio and Pihlajavainio. Mycorrhizal fungi play an important role in converting nutrients available to plants, which leads back to the importance of minimal or no tillage. Other microbes are also responsible for converting K and S into plant available form, and supporting the microbial activity may aid in the S deficiency in Pihlajavainio and Riihivainio parcels. Perennial plants, such as trees and shrubs, also boost nutrient cycling, and have been found beneficial in generating improved nutritional quality in herbs, as well as higher yields through diversified plants. Plants with long roots and high biomass increase P uptake, leading red clover (*Trifolium pratense*) to continue proving its worth.

Increasing microbial activity and abundance requires similar practices as mentioned above, and whereas chemicals are found harmful to the biodiversity, choosing a functional diversity of plants may have a variety of positive effects on the microbiome. Therefore getting more acquainted with companion planting may improve the microbial diversity and their positive impact on plant health. Pathogens are also avoided by crop rotation with a sufficient timespan, which may be several years long. The five to six year crop rotation on the herb fields may be satisfactory when it comes to eliminating harmful pathogens. Intense weed growth after adopting no-till may be reduced by using diversified cover crops that prevent the weeds from growing.

Adopting animal husbandry is unlikely at Frantsilan Luomuyrttitila Oy, due to the encouragement towards vegetarian diet by the original ideology of the company, but keeping ducks on the herb parcel grass fields, using rotational grazing with a mobile enclosure may significantly improve the soil for the upcoming crops, as well as function in pest control. However, the presence of foxes poses a risk for the animals, and the animals would require daily attention. (Frantsilan Luomuyrttitila Oy, personal communication)

The studies present strong evidence that zero tillage is one of the most important practices for increasing soil health and soil organic carbon, if not the most important, and it may be especially beneficial used in a large scale. Adopting practices such as intensified cover cropping, using diversified and functional perennials among annual crops, keeping the bare soil to a minimum and using high-biomass plants with long roots, along with the organic agriculture practices already applied, may increase and accelerate carbon sequestration, improve soil microbial activity and soil structure, and increase yields and biodiversity above and below ground.

4.2.4 Cosmos certification

Reaching the qualification for the Cosmos certification annually is important for the company. Despite the organic produce, lack of certain actions may affect the result of the audit. A comprehensive plan of action at the farm level, with a written quality control system that is actualized on a larger scale, as well as an environmental management plan with improved recycling systems and cleaning products, would serve as an impressive and valuable addition to the farming and processing system. Plastic is a mandatory packaging material on the farm due to its ability to reduce harmful impacts on the herbs, such as moisture or pests. Therefore its use should be negotiable. Improving the energy efficiency of the machinery use and heating in the facilities reduce environmental harm. Recycling system on the farm could be further improved by improving the composting system and by increasing the recycling bins with at least plastic recycling.

4.2.5 Machinery improvements

Machinery improvements are necessary to increase sustainability in the longer term. The drying machinery is the first subject of alteration, as it affects both expenditure and product quality. Not only the value of the drying is affected using different machinery, but the quality of produce is much higher using the Bucher dryer, based on the comparison made in the season 2023 when the first Bucher dryer was taken into use. The herbs are dried with a better air flow, which prevents them from sticking together and fermenting during the drying process. The laboratory tests of the foodstuffs in the future may be able to tell if this has an impact on the microbe levels of the herbs. (Frantsilan Luomuyrttitila Oy, personal communication)

As seen in Table 6, even without taking into consideration the increase in yield units fitting into the dryers, replacing the old dryers with another Bucher 140K dryer, the machine would pay itself off within 8,5 years, taking into account the savings in electricity use. As the Bucher dryer has a larger capacity in drying units, replacing both of the old dryers with a new Bucher would yield as many as 88 drying units more annually compared to the current situation. As the drying units can not be monetized due to differences in weight, value and utilizable percentage of the herbs, it is impossible to calculate the savings. However, the differences in annual expenditures per drying unit are remarkable, as the use of the old pill dryer can cost up to 10,17 € per unit annually, while the Bucher dryer can cost as low as 0,63 € per unit annually.

Table 6. Annual expenditure of drying machinery.

DRYING MACHINE	UNITS INSIDE	AVERAGE DRYING TIME (days)	DAILY USE (h)	ANNUAL USE (days)	ANNUALLY DRIED UNITS	kWh	ENERGY PRICE (€/kWh)	ANNUAL EXPENDITURE	ANNUAL EXPENDITURE PER UNIT
Old herb dryer	14	5	10	110	308	9,6	0,113 €	1 193,28 €	3,87 €
Old pill dryer	10	5	10	110	220	18	0,113 €	2 237,40 €	10,17 €
Bucher herb dryer	28	5	10	110	616	3,1	0,113 €	385,33 €	0,63 €
Difference between Bucher and others together					**88**			**3 045,35 €**	**13,42 €**
Bucher price estimated								**25 000 €**	
Replacing the old dryers with a Bucher (years of compensation in electricity usage)								**8,21**	

According to Rhodes (2015), in order for a system to be regenerative, it should not rely on fossil fuels. They also point out that solar power is only sustainable if it generates more energy in its lifespan than its manufacturing has utilized, which refers to the high energy input of certain manufacturing processes. Frantsilan Luomuyrttitila Oy (personal communication) has received an offer on new heating and cooling systems for the storage and processing facility, as well as an offer for a solar power system to replace the purchased wind power. If the solar power system is installed, it is possible to replace the fossil fuel operated heating system in the greenhouse into an electric one. The providing company counted the savings on the heating system to be approximately 6400 € annually, which would mean that with an approximate price of 22 000 € (VAT. 0 %) the new heating system would pay itself back in less than 3,5 years. The solar power system was planned to be installed partially on the roof and partially on the southeast wall of the facility, so that it would function during winter as well. This would provide savings in both drying expenses during harvest season, as well as slightly in the heating expenses during the months when the solar power system is still able to capture sunlight. The offer on the 74 panel 30,34 kWp total solar power system is 22 000 € (VAT. 0 %). By utilizing the Hehku Energia Oy (2024) solar power calculator, and taking into consideration the year 2023 energy consumption of 46 156 kWh, the solar powers would most likely be able to provide more than half of the annual energy consumption in the facility, close to 26 000 kWh. With the energy price of 11,3 c per kWh, the savings are close to 3 000 € annually, having the system paying for itself within 7,5 years. According to Glover & Tynan (2023), the lifespan of solar panels may be up to 30 years, with the average breaking even point being at 6 ot 10 years.

After the solar panels are installed, it is possible to renew the greenhouse heating system, using two electric PolarTherm Remko Elkomat 40 heaters (total price approximately 5 000 €). Currently the greenhouse is heated with an oil heater which creates an estimated expenditure of 2 500-3 000 € annually (based on a three year medium divided into two systems requiring oil to function). Surely, the total expenditure in the facilities will already experience an impressive reduction once the drying system is renewed, with the savings being approximately 2 660 € annually. (Frantsilan Luomuyrttitila Oy, personal communication)

When it comes to field action, the main interest regarding the transition towards regenerative agriculture is in tillage. The herb fields can be tilled with the rotary tiller to avoid deep ploughing, if the agricultural plastic mulch is dug up by shovel prior to milling. The larger agricultural areas focused on grain and grasses would require machinery that the current contractors do not have, such as a direct seed drill and perhaps precision weed harrows. Despite the largest possibilities in carbon sequestration existing in these larger parcels, the transition to a more sustainable direction will require more extensive research and planning, as well as nearby affiliates that are open for cooperation. (Frantsilan Luomuyrttitila Oy, personal communication)

4.2.6 Measuring the impact

The impact of regenerative practices can be simply examined through annual NIR analyses, which show the differences in soil organic carbon, pH, microbial biomass and activity, as well as different nutrient contents. Experimenting with different mulching practices may present valuable information and possibly a new, renewable and recyclable mulch for the fields. An experiment of growing nitrogen-fixing cover crops with annual crops such as marigold (*Calendula officinalis*) could present an opportunity for another experiment. Measuring the biomass of herbage produced on the renewed production system would serve as an indicator of the practices´ impact on yield. Biodiversity can be examined using a standard implementation for calculating pollinators or soil fauna.

4.3 Proposed schedule

The proposed plan of action is summarized and scheduled in Table 7. Scheduling in quarter year targets shows seasonal requirements, such as those related to agricultural periods (sowing and planting) or seasonal requirements (heating system).

Table 7. Planned schedule in quarters.

PROPOSED ACTION	2024	2025	2026	2028
Reduced tillage on crop fields	Q2			
Improving the drying machinery	Q2			
Adding sub parcels on Pihlajavainio	Q2			
Alley cropping	Q2	Q2	Q2	
Measuring carbon sequestration	Q2	Q2	Q2	
Bare soil to minimum	Q2	Q2	Q2	Q2
High-biomass plants with long roots	Q2	Q2	Q2	Q2
Measuring soil fauna	Q2-Q3	Q2-Q3	Q2-Q3	
Mulching experiment	Q2-Q4	Q2-4		
Cover crop experiment	Q3	Q3		
Measuring pollinators	Q3	Q3	Q3	
Intensifying cover crops	Q3			
Minimal tillage on herb field	Q3			
Improving composting	Q3			
Cosmos: plan of action	Q4			
Increasing recycling	Q4			
New heating system	Q4			
Diverse and functional perennials		Q2		
Zero tillage on crop fields		Q2		
New energy source		Q2		
New greenhouse heating		Q2		
Adding windbreaks		Q2	Q2	Q2
New mulch into use			Q2	Q2

5 Planning and realisation of the project

5.1 Planning

The need for the development plan arose from a deep demand to transfer the owner demand into action. Minor suggestions for changes towards sustainability had come up beforehand, but they needed to be aligned with the overall agricultural system. Converting the plan into a thesis was agreed upon due to the convenience of it. A thesis agreement was signed and the data management plan was run through the owners of the company to confirm which company data can be utilized in the thesis.

5.2 Implementation

It was necessary to first define the requirements of the company, as well as the owner demand. Only then it was possible to clarify what regenerative agriculture is, as it was one of the most important requirements of the owners in the agricultural department. The definitions of different organizations were the baseline for defining the topic, but adding the criteria into a table made it clear that there is no clear definition of what regenerative agriculture actually is. This required an intensive research through the scientific articles on HAMK Finna. The following search words and combinations are the most remarkable examples of what was used to find the information needed for the main research: ‘regenerative agriculture’, ‘carbon sequestration’, ‘permaculture’, ‘agroforestry’, ‘soil health nutritive, ‘organic agriculture’, ‘nutritive value regenerative’, ‘boreal agriculture’, ‘carbon sequestration “agriculture” temperate’, and ‘organic regenerative agriculture’.

After recognizing the requirements of the company, the current state of the farm and the criteria of the certifying bodies were defined. These, for the most part, set the limitations to which activities should, could and could not be carried out. After this a search through the scientific articles began, and the main topics were covered in bullet points, from where the definitions and impacts of regenerative practices were then categorized into a table and summarized. The plan of action was then carried out, taking into account the requirements that would meet the criteria of the certifying bodies, and the evidence based methodology to reach the main objectives of regenerative organic agriculture.

The machinery calculations were conducted using readily available information, to point out how machinery improvements reduce expenditures in the long term, despite high purchase value. Taking into account the demand for higher quality produce and sustainable energy use, the recommendations to renew the drying and heating machinery, as well as energy sources, are proven valid.

6 Conclusions and reflection

As a term and as a definition regenerative agriculture is still complex, unclear and in many ways controversial. In itself it is not regarded as a method of organic agriculture, and it is important to note that the regulations of organic agriculture in the European Union may complicate the application of specific methods of regenerative agriculture. As a practice, it has several different definitions which are interpreted in various ways, depending on the defining actor or organization. Although increasingly adopted, the scientific studies regarding regenerative agriculture are minimal. The vast amount of studies on separate regenerative practices reviewed by Khangura et al. (2023) establish an understanding of how regenerative agriculture may, in fact, increase carbon sequestration, biodiversity and nutritional quality in harvested crops. Machinery improvements are necessary to reduce dependence on fossil fuels and external energy sources, but also to improve the quality of stock.

Scheduling a plan for meeting the requirements of a company as complex as Frantsilan Luomuyrttitila Oy that functions on a farm-to-factory basis, as well as the owner demand with a modern insight into agriculture that, on the farm, has been similar for several decades, serves a challenge. Although organic agriculture is regarded as a high value sustainable agricultural practice, regenerative organic agriculture goes beyond sustainable, and aims to recreate what has been lost.

Through the suggested measures it is possible to reach a higher value harvest, with a higher value in products and marketing. Continuing to embody the role of a vanguard in sustainability sets an example for other companies and agricultural entrepreneurs to follow and collaborate with.

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