TAMPERE UNIVERSITY OF APPLIED SCIENCES

DESIGNING A SMALL SCALE BIONINTENSIVE VEGETABLE FARM IN FINLAND

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ABSTRACT

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Designing a small scale biointensive vegetable farm in Finland

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This thesis aims to design a small scale biointensive vegetable farm in Suurpelto, Finland. Encompassed in this design are calculations estimating the potential crop production and revenue of the site.

Introductory literature gives an understanding of Finland’s vegetable production and imports, institutional recommendations and legislation and an introduction to small scale biointensive farming with case examples.

The literature review of the text gives a theoretical insight to some factors effecting and influencing farming and ecosystems, European agricultural industry standards and the key elements to small scale biointensive farming.

The design of the Suurpelto site in Finland encompasses: site analysis, the design process, the materials and budget required, the crop selection and crop season and the production and revenue numbers that have been calculated.

The results of this thesis indicate that small scale biointensive farming is feasible in Finland. The budgeted cost of construction (20100 euro) compared to projected yields (4950kg) and revenue (44676 euro) show a return on investment in the first year of production. Further refinements to the design could see results closer to peer dater which indicates crop revenue to feasibly reach ≈ 83000 euro per crop acre.

Key words: biointensive, vegetable, farming, Finland, design.

CONTENTS

ABBREVIATIONS

CO_2	Carbon dioxide
DTM	Days to maturity
EU	European Union
FAO	Food and agriculture organisation of the United Nations
GMO’s	Genetically modified organisms
HF	Heavy feeder
LF	Light Feeder
PPP’s	Plant protection products
SOC	Soil organic carbon
SOM	Soil organic matter
USDA	United States department of agriculture
UN	United Nations

1 INTRODUCTION

1.1 Aim

To design a small scale biointensive farm in Finland and ascertain the feasibility of such a project in regard to projected yields and potential revenue created from such an enterprise.

1.2 Vegetable production in Finland and local initiatives

In 2013 Finland's domestic vegetable production accounted for approximately 265 million kg of the 384 million kg being utilised by the local population. Such figures indicate an additional 119 million kg was imported which accounted approximately 30% of utilised fresh vegetables. When comparing this percentage to recent years (2007-2013) this was the largest recorded figure. (Tike, 2014)

Finland realises the importance of having a local food supply and has actually put into policy the "Local food programme". Local food in this context is considered to be "products produced from raw materials of the region for consumption within the same region" (Ministry of Agriculture and Forestry, 2013). The aims and objectives of the programme can be summarised as follows (Ministry of Agriculture and Forestry, 2013):

- Increase the production units and diversity of local food to meet the demand of the market and increase market value and proportion of local food
- Improve market access and prospects for success of small scale local produces through favourable legislation and guidance
- Increase the proportion of local food in "public procurement" through better "procurement skills" and better screening criteria
- "Improved opportunities in primary production"
- Increasing the awareness and importance of local food producers in the market and educate on why such producers should be appreciated

1.3 UN predictions of feeding the world

A paper published by the UN (United Nations) in 2013, "Wake up before it's too late", proposed some key findings surrounding the topic of agriculture. The paper suggested that there needs to be a shift away from conventional agriculture or industrial agriculture to a new approach that takes agroecology as a central focus. Having systems that rely heavily on inputs such as fossil fuels, fertilizers and pest protection chemicals is suggested to be increasingly inefficient. Such inputs are stated to have adverse effects on soil health and life within the soil, soil carbon content, hydrological systems, biodiversity and plant resilience to pest pressures. It is suggested that there needs to be a central focus on the following issues (United Nations, 2013):

- increasing in soil carbon content
- better integration and partnerships between crop and livestock production (holistic management)
- greater integration of trees and wild vegetation into food production systems (agroforestry and agroecology)
- a reduction in livestock production greenhouse gas emissions
- organic and inorganic fertilizer usage optimisation
- waste reduction and more efficient systems
- a change in dietary patterns to orientate towards a more climate friendly/appropriate diet
- reform of international trade regarding food and agriculture products

For modern day food production, it is suggested that there not just be a slight change to the system yet a total overhaul. The notion that the farmer is only a food producer is simply a one dimensional view that lacks to consider the broader impacts the farmer has on the entire system. The farmer is imperative to: biodiversity, food security, food quality and health of the population, carbon sequestration, habitat availability for wildlife, a healthy hydrological system, managing the agroecology system and soil health. This approach moves away from the destructive nature of conventional agriculture to a more sustainable regenerative approach that would improve efficiency of farms even on a small scale. (United Nations, 2013)

1.4 Biointensive small scale farming

Biointensive small scale farming, or biointensive market gardening as it is commonly known, is a farming production technique characterised by concentrated plantings of vegetables in permanent raised beds. The emphasis of the production is to maximise yields whilst trying to maintain or improve soil ecology. The scale of the land in relation to the words "small-scale" refers to enterprises that consist of a single to a few crop acres. The associated revenue generated from the selling of produce often uses the scale "per crop acre". (Fortier, 2014)

Biointensive farming is often confused with biodynamics, a technique defined by the late Rudolf Steiner. Biointensive farming like biodynamics is concerned with soil preservation and aims to even improve the quality and the life within it. Where biointensive farming differs is that it does not follow strict preparations of cow horn manure and does not necessarily have to involve the partnership of animals and plants in one system. The biointensive farming method is extremely relevant in today's context where there are growing populations with an increase in demand for land and food, so growing more in a small space is very relevant in today's context. (Demeter, 2017; Fortier, 2014)

1.5 Case examples

Case examples of farms that use biointesive farming techniques include: Neversink Farm (Claryville New York), Singing Frogs (Sebastopol, CA, USA), Four Seasons Farm (Harbourside, ME, USA), Les Jardins de la grelinette (Saint Armound, QC, Canada), Le ferme des quatre temps (Hemingford, QC, Canada), Ridgedale permaculture (Sunne, Sweden) and Lilliklobb permaculture (Espoo, Finland). Such farms are great examples showing how biointensive farming is not just beneficial for the environment but also feasible to be profitable. Les Jardins de la grelinette, a farm by Jean-Martin Fortier and his wife, is a very good model of how small scale biointensive farming is profitable without the aid of farm subsidies. Furthermore, Jean-Martins farm is also a great case example of cold climate growing, which is relevant in this context, to show that it is feasible to make a good income off a small farm. (Fortier, 2014; Hartman, 2017; Kaiser & Kaiser, 2016; Stone, 2016)

2 Literature Review

2.1 Carbon cycle and the mitigation potential of farming

Carbon dioxide has received much publicity over recent decades as it is thought to be a main contributor (along with other greenhouse gases) behind recent changes in our climate (United Nations, 2014). Carbon dioxide is released into the atmosphere via combustion, decomposition and respiration and is absorbed via photosynthesis in terrestrial and aquatic plants and organisms and mixing of the oceans via wind and wave action. (United Nations, 2014)

In terrestrial ecosystems atmospheric carbon, produced from combustion, respiration and decomposition, in combination with water, is synthesized by autotrophs to produce glucose and oxygen (equation 1). Glucose can then be used within and is also resynthesized to form other molecules such as proteins. Plants also release products of photosynthesis as exudates to the soil which feed fungi, bacteria and other organisms to form the basis of life within the soil. The organisms within the soil respire and release carbon into the atmosphere in the form of carbon dioxide. Likewise plants and animals respire further increasing atmospheric carbon dioxide. Carbon is also fed into the soil via organic matter which consists of leaves, dead plants and animals and excrete.: Soils are huge carbon storage zones for the planet and if not managed properly much of the carbon will be released into the atmosphere having adverse effects not just on the soil but also on the climate. (Kaiser & Kaiser, 2016; United Nations, 2014)

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

EQUATION 1: Photosynthesis reaction, the prime energy source plants. (Timberlake & Timberlake, 2011)

A paper published in 2012 called “EU low-carbon roadmap: Potential and costs for non-CO2 emissions” has analysed the mitigation potential of sectors including: industry (non-emissions trading schemes), wastewater treatment, waste processing, energy production, air-conditioning and refrigeration and agriculture. Conclusions reached by this paper stated that agriculture has the greatest mitigation potential for carbon dioxide equivalent emissions versus cost inputs. Interestingly enough, agricultures mitigation potential in relation to cost inputs has been estimated to be ten times greater than that of the energy sector. (Hogland-Isaksson, et al., 2012)

2.2 Soil

From soil science pioneers of the previous centuries (including Vasily Dokuchaev, Elaine Ingham and Hans Jenny just to name a few) there has been a move away from describing soil as some kind of object, towards describing it as more of a system that has a process of formation that is dependent on its environment and the inputs that are associated with that environment (Jenny, 1994).The composition of soil (although varying in proportions between different locations) in general is recognised as containing minerals, water, air and a small amount of organic matter (USDA, 1999).

Soil organic matter (SOM) is a critical component of soil that affects its physical, chemical and biological properties (Schulte & Schulte, 2012). SOM consists of: living organisms, fresh residues, root exudates, particulate organic matter, lignin, and humus (Ingham, et al., 1999). These components that make up SOM are particularly rich in carbon and this proportion is referred to soil organic carbon (SOC). Due to its relationship with SOM, SOC is often used as a way in which to measure organic matter in soil. The amount of SOC present is a combination of contributing natural processes that include: the rate of photosynthesis of terrestrial plant life, the rate of decomposition within the soil, respiration of living organisms, erosion and leaching. Photosynthesis and litter deposition will add to the carbon present in soil and respiration, erosion and leaching will decrease it. So in order for there to be an increase in SOC levels, inputs would have to be greater than losses. (Schulte & Schulte, 2012)

Agriculture losses of SOC have been associated with miss management practices (such over cultivation and bare soil exposure) which not only effect the soils productive capacity but also may be having adverse effects on the climate and other ecosystems and cycles. (United Nations, 2014)

2.3 Agriculture Industry Standards in Europe

2.3.1 Conventional

The principles of conventional farming, also referred to as industrial farming, involves the tillage of land for cultivation purposes, the usage of synthetic fertilizers and pest protection products (PPP) and the selection of high yielding varieties of crops for maximum output (The Organic Center, 2007). Such produce can contain certain levels of chemical residues from PPP's however is regulated in Europe. Currently there are 1,359 active substances that are centralised on the European Commission's PPP database and of those 545 are approved for consumption. Herbicides, fungicides and insecticides are all categorised under PPP's (European Commission, 2016).

Conventional farming accounts for the vast majority of producers in the European Union with a total area spanning at least 90% of all cultivated lands (European Union, 2017)

2.3.2 Organic

As defined by the European commission: "Organic production respects natural systems and cycles. Biological and mechanical production processes and land-related production should be used to achieve sustainability, without having recourse to genetically modified organisms (GMO's) (European commission, 2008)."

Organic farms account for approximately 5% of farms in the European Union. The organic label sets a standard for the consumer to understand that they are not receiving GMO crops and the conditions which the crops were grown under are of a more stringent nature than that of conventional agriculture. One key point to realise with organic is that synthetic PPP's may actually be used in the production of those crops if there is not organic alternative available. The list of approved PPP's for organic food production is only 27 items as stated in Annex II of European regulation 889/2008. (Commission regulation (EC) 889/2008, 2008; European Union, 2017).

2.3.3 Bio-dynamic (Demeter)

Demeter is the biodynamic standard that was created by Rudolf Steiner in order to regard the farm as a living organism. The inputs and outputs need to be balanced in order to achieve an operation that is as close to self-sustaining as possible. There are very strict regulations regarding fertilizers, pesticides, soil preparation, imports and exports from the farm. (Demeter, 2017)

Strict soil preparations using cow horn manure and growing plants in unison with animals make this model difficult to manage as the enterprise contains many areas that are not to be outsourced. These regulations coupled with a very short growing season in Finland make this model difficult to reach a stage of business profitability, due to the labour required to manage such an in-depth operation. (Fortier, 2014)

2.4 Pest management in Finland

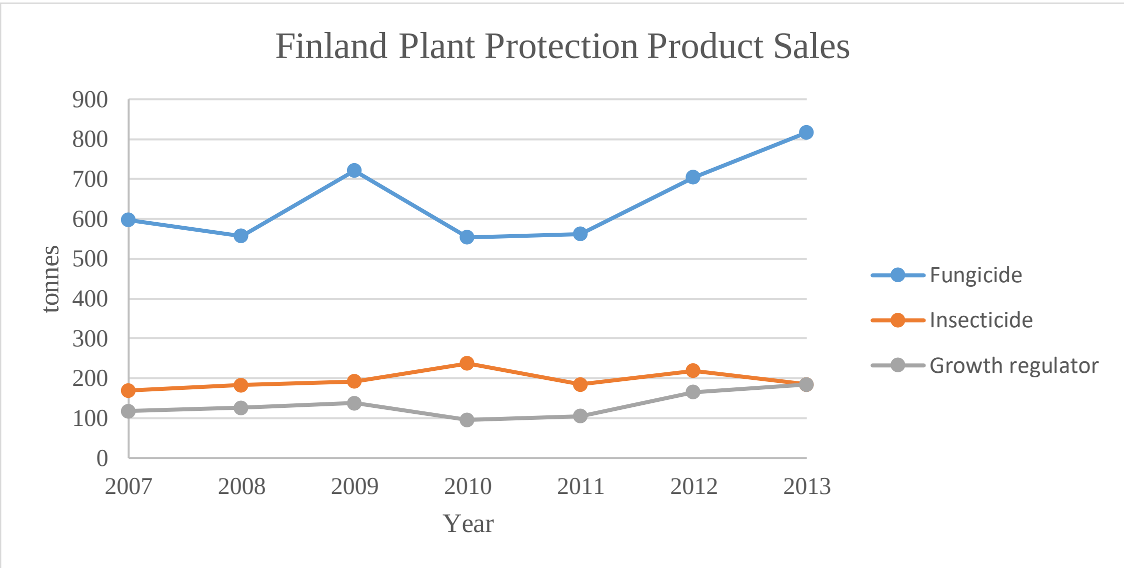

FIGURE 1: Represents the sales of fungicides, insecticides and growth regulators to farms by tonnage for the years 2007 to 2013. Here it is evident that insecticides consumption has remained relatively stable, plant growth regulators have seen an increase in usage by nearly double (over the surveyed time) and fungicides have also increased in usage by approximately 200 tonnes. (Tike, 2014)

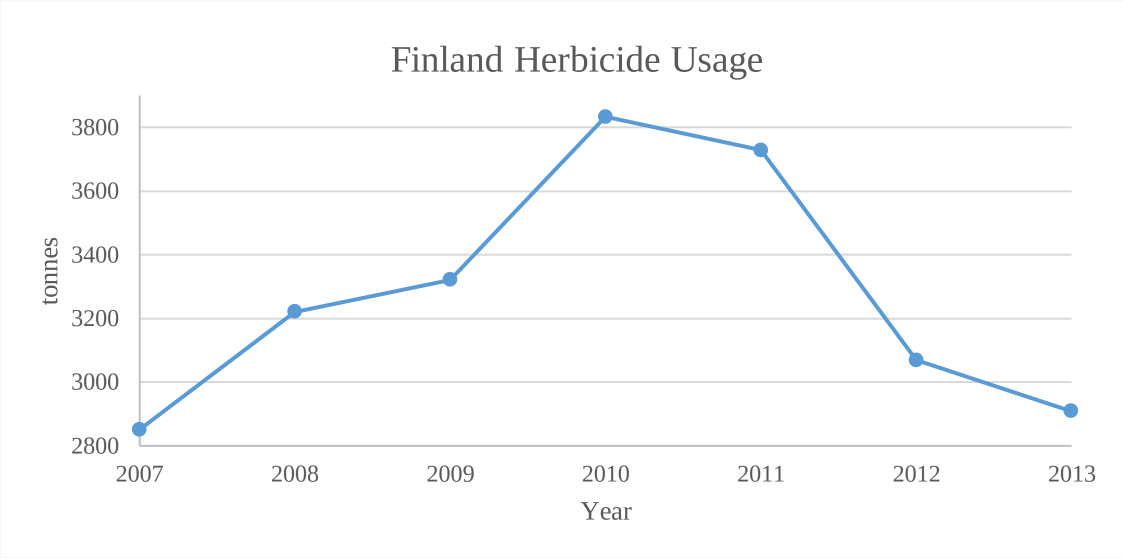

FIGURE 2: Represents the sales of herbicides to farms in Finland by tonnage, from the years 2007 to 2013. Although usage increased consistently from 2007 to 2010, 2011 to 2013 saw a decreasing trend which returned levels back towards 2007 usage. (Tike, 2014)

2.5 Biodiversity

Biodiversity is defined as the variation among living organisms and the ecological systems that they are present within (Greip & Manley, 2012). The health and further the resilience of a system positively correlates to the biodiversity present within that system (Greip & Manley, 2012). The importance of biodiversity has not been stressed enough during the period of the "Green revolution" which has seen large-scale monoculture depleting topsoil's of nutrients and relying heavily on inputs, mainly fossil fuel based. Such practices have seen a decrease in: the variety of crops grown, soil organic matter, soil organisms present and habitat for beneficial insects and predators. Such practices have further had to rely on pest management strategies involving chemicals in many instances, harmful to much life present within the soil, causing populations of soil organisms to die off additionally creating greater problems due to imbalances within the soil biota. (Ingham, et al., 1999; United Nations, 2013)

In Finland similar problems have arisen in biodiversity with the move away from diversified agriculture to conventional, intensive agriculture. Such practices have seen drastic changes in the farmland bird populations(due to loss of habitat) to such great extents that there were approximately half the population present in 2012 compared to 1979. (Finnish Environmental Administration, 2013)

2.6 Key elements to small scale biointensive farming

Biointensive farming's key objectives are to be as productive as possible over each square metre of the growing space whilst taking into account soil ecology. To design a whole enterprise requires understanding of the different scales encompassed within it (figure 6). The scales range from the spacing's of individual crops, to the permanent raised beds the crops are produced in, to the field blocks that harbour the permanent raised beds and to the entire enterprise that harbours the field blocks and infrastructure to form the whole. Understanding scale and the important use of standardisation make biointensive farming a great food model, not to just increase yields per acre but provide a large and diverse range of food for the local market within a relatively small space.

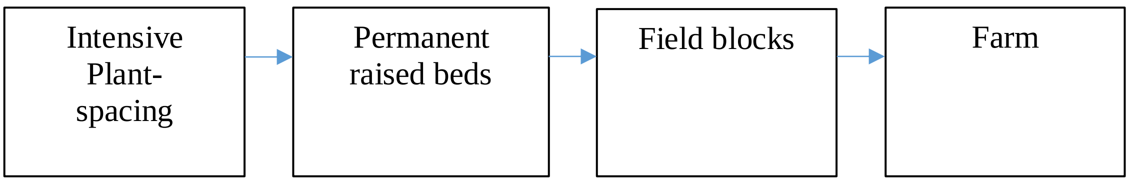

FIGURE 3: A block diagram simplifying the different macro scales present in small scale biointensive horticulture production from the smallest on the left to the largest on the right.(Benjamin MacNab, 2017)

2.6.1 Permanent raised beds

Permanent raised beds are a key to biointensive farming and are characterised by a specific width of 0.75m and have walkways either side (figure 7). This width of the bed is an industry standard that most tools are designed upon. The size proves very workable for manual field harvesting as the bed are able to be straddled to ensure minimal disturbance and compaction to the soil. The length of the bed does not have such a standard but numerous farms operate on specific lengths to plan materials required, estimate yields, and plan crop rotations. Additionally, many products related to market gardening come in specific sizes such as greenhouses, insect and bird netting, irrigation etc. For this reason, it is important to analyse products that are planned to be used when designing a plot. (Hartman, 2017; Stone, 2016)

The construction of permanent raised beds in biointensive farming can vary between differ operations but in general will lead to the same result of a raised bed that is permanent and not seasonally cultivated. Large amounts of compost, preferably with a high carbon to nitrogen ratio, are added to the beds in the initial construction. The compost helps provide an even surface to plant in and doubles as a slow release fertilizer that aids in rhizosphere development and reduces plant protection product usage by encouraging phytochemical production by the plant. (Fortier, 2014; Hartman, 2017; Kaiser & Kaiser, 2016; Stone, 2016; The Organic centre, 2007)

When choosing to do permanent raised beds instead of cultivating the beds on a seasonal basis there are many advantages such as: increased drainage, increase in SOM, earlier crop production, decreased soil compaction and hardpan, higher yields, increased soil ecology, reduced need for a tractor and an increase in work efficiency (Fortier, 2014).

2.6.2 Field blocks

Having a standard size allocation for permanent raised beds is beneficial for planning and by further upscaling that standardisation model into groups or blocks enables a plot to be manged on a more macro-scale. Such an example as to why field blocks are helpful is if a biointensive farm contained a total of 80 permanent raised beds with a diversity of crops growing. To make a farm simpler and more efficient, those 80 permanent raised beds could be divided into groups of 8, which would now create 10 smaller plots (figure 4). By grouping beds, similar crops can be grown in the same area and cared for in the same manor to optimize efficiency and work flow. To ensure diversity is kept, zones or blocks can contain different intensity nutrient feeding crop types and can be rotated accordingly to not exhaust the soil of nutrients. (Fortier, 2014)

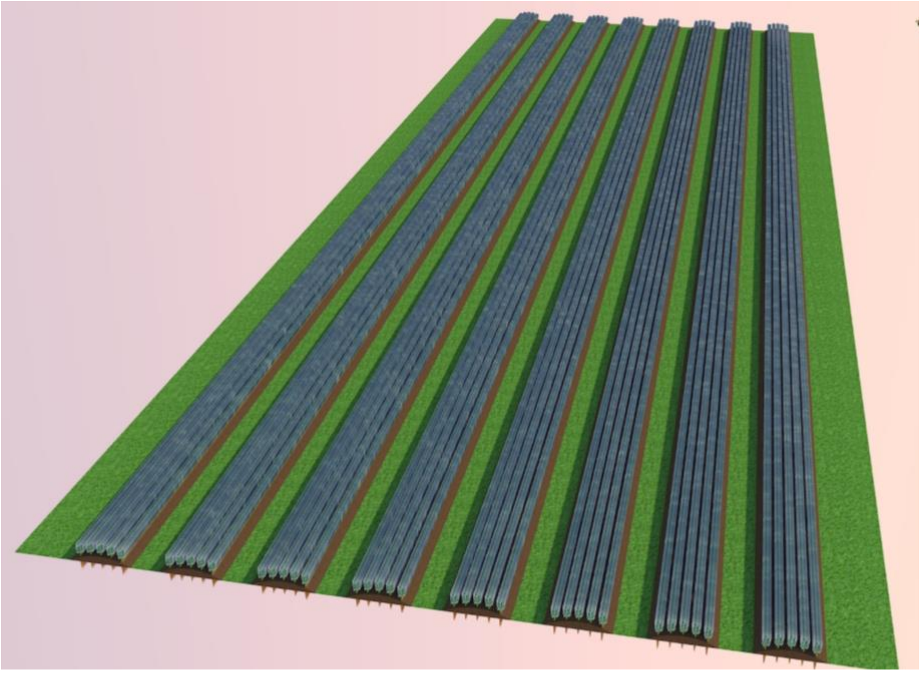

FIGURE 4: displays three dimensional model of a field block area of approximately $300m^2$ that would consist of 8 grow beds of 0.75m in width by 30m in length. In between these beds there is a walkway that measures 0.35m, approximately the width of a shoe, and at the outer edges of the field block there is a double width walkway to allow bigger tools to enter such as a wheel barrow. (Benjamin MacNab, 2017)

2.6.3 Crop protection using hedgerows and fencing

To inexpensively create better conditions for plant production, the incorporation of wind breaks to fields helps limit wind exposure and decreases soil erosion and soil moisture loss on a site. Low lying shrubs surrounding field blocks can help protect crops without having too much shading effect whilst providing habitats for pollinators and beneficial insects. An example would be shrubs such as: lavender, rosemary or berry bushes. Windbreaks can also be constructed of posts and synthetic fabric and such structures have the same effect as natural windbreaks. An advantage of synthetic windbreaks is that they are effective immediately (compared to natural ones) and can be used simultaneously while natural ones establish. (Fortier, 2014; Kuhns, 2012)

Perimeter fencing is a necessity to protect crops when there are pest animals present. Animals such: rabbits, hares, deer and moose can cause widespread crop destruction in a relatively short period. The construction of a perimeter fence should be high enough that large pest animals cannot jump over it and strong enough that it cannot be pushed over. For smaller animals a fence construction should include a finer grade mesh in the bottom section (above and below ground) to prevent intrusion. (Fortier, 2014)

2.6.4 Infrastructure, utilities and tools

Having the right infrastructure present to streamline farm operations is essential for efficiency in production on a biointensive farm. Infrastructure that is necessary for an operation includes: irrigation, an indoor area for seedling production, post-harvest and tool storage facilities, adequate space to store compost, cold storage and road access to the site. (Hartman, 2017)

Utilities that are needed onsite of a biointensive farm are pressurised water (well water or mains pressure) for irrigation and electricity (either grid power or generator) for powering cold storage and other items needing electricity.

Individual tool requirements will vary between biointensive farms however operations will need basic tools for: site preparation, seeding and seedling production, field production and maintenance, harvesting, post-harvest and storing and transporting goods. Many tools are on the market that have been designed specifically for biointensive farming which help streamline work-flow whilst being affordable.

2.6.5 Crop Selection and Planting Techniques

Annual crops are the main types that are used in biointensive farming. Crop selection and understanding how to produce those crop successfully is essential when constructing a biointensive farm operation. Having crop knowledge of: days to maturity (DTM), Nutrient requirements, planting techniques, planting densities and possible pest pressures allow for better planning for successful crop production. (Stone, 2016)

Knowing the DTM of crops is key in estimating harvest times, succession plantings and yields. Crops with a short DTM can provide more regular harvests and consistent revenue for the farmer. Crops that have a long DTM provide less frequent harvests and less consistent revenue.

Direct seeding is a planting technique that transfers seeds directly into the ground. It is very quick (when using a seeding tool and not placing by hand) allowing a relatively large area to be planted in a short period of time. Disadvantages to this technique can be: spotty germination, increased weed pressure, longer DTM (compared to transplanting) and decreased yield over the season when comparing seeded to transplanted crops. (Stone, 2016)

Transplants are plants that are generally started indoors from seed in a seedling flat (a celled container divided into many compartments that allow the growing of many plants from seed in an very confined space compared to that of starting the seeds in the field) before being planted outdoors (Fortier, 2014). Advantages of this technique include: only the strongest seedlings are transplanted into the field, exudates always being fed to the soil, reduced time in the field, bare soil exposure is kept to a minimum, weed are shaded out quicker so they have less time to grow and greater yields per grow bed per year. The disadvantage to transplanting is an increase in labour required and the need for a protected grow space. If facilities are not present to raise seedlings, an initial investment would be required which would increase start-up costs. (Fortier, 2014)

Interplanting is a technique that involves planting complimentary crops in the same area to in effect “Double up production” (Stone, 2016). Such a technique allows for more production in a smaller area to generate higher yields per bed over the growing season. A specific example of interplanting would be pairing a crop with a long DTM (broccoli), with a crop that has a short DTM (lettuce). By interplanting lettuce seedlings with a newly planted broccoli crop (which has a large spacing in between plants) a partial yield of lettuce can be attained whilst the broccoli crop is being established. Such planting not only provides greater yields per bed but also decreases bare soil exposure. (Kaiser & Kaiser, 2016)

Succession planting is technique used very often in biointensive farming which entails having two or more crops succeeding one another. It not only gives the farmer greater yields per crop season but allows far less land to be utilised for the same yields (compared to if only one crop was planted). Succession planting gives the farmer the ability to plan for a more consistent supply of vegetables to the consumer and delivers the farm continuous cash flow. Using the technique requires pre-planning to ensure success and needs knowledge of many factors such as: crop DTM and growing requirements, changing climate conditions and day light length through the growing season. (Stone, 2016)

Maximising yields and trying to achieve a steady supply of produce to the market during the growing season does not necessarily correlate to planting or seeding more. Certain crops can actually produce multiple times before being replanted. Some examples of such crops include: cut and come again greens (spinach, rocket, kale and mesclun salad), most herb varieties, beans and peas, broccoli, cucumbers, indeterminate tomatoes and zucchini's. Such crops are keystones to biointensive farms productivity and ability to produce a steady, diverse flow of vegetable varieties for the consumer over the growing season. (Hartman, 2017)

2.6.6 Crop-Season planning

Planning for the crop-season is imperative as it creates a guide how to reach harvest projections and revenues desired by an operation. Having a detailed list of the selected crops and their requirements and the goals in production with those selected crops, allows for a crop plan to be constructed. A crop plan is best planned in weeks for the crop season to get a total overview of the seasons planting and harvesting schedule. Following the crop plan a seeding plan can be constructed for transplants that are to be planted during the crop season.

3 Methods and Materials

3.1 Site analysis and location planning

When analysing site specifics for a prospective biointensive farm important issues that need to be considered are: previous and current land use, zoning, soil conditions, the climatic and geographical location specifics, the orientation and obstructions present on the site in terms of light availability, ease of access (both to the site and market streams) and infrastructure and utilities present. Having a good understanding and knowledge of a site will help in designing and planning phases which should lead to the successful construction and operation of a biointensive farm (figure 5). (Fortier, 2014; Kaiser & Kaiser, 2016; Stone, 2016; Hartman, 2017)

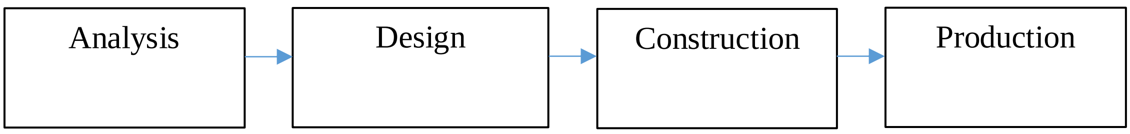

FIGURE 5: Displays a block diagram of the process from site analysis to production (Benjamin MacNab, 2017)

3.1.1 Land usage and zoning

Having knowledge of current and previous land usage of a site is essential to ascertain whether or not a site is suitable for a farming. If a site has previously been used as farm, then this gives some indication that the land may be suitable for future farming operations as compared to if the land was a municipal waste site. Furthermore, the area in consideration should be studied for how it is zoned by the municipal, as planning laws may prevent a site being used for agricultural purposes. Thus, contacting the local municipal is essential in the planning stages of a farm.

3.1.2 Soil conditions

Understanding the medium in which a biointensive vegetable farm will grow its crops in is essential to planning how productive a site could be. Therefore, having soil tested is imperative for successful plant growth by analysing specific factors such as: pH, mineral and nutrient content, biological activity and organic matter. Furthermore, a soil test can help in determining whether or not a site is safe for usage as substances such as heavy metals can be tested. Such testing can ensure the grower and the consumer alike that the food produced within a site is not exposed to toxic chemicals. When soil is being sampled for lab analysis, it can also be observed and noted how the grade of the soil is. If the soil is fine with little rocks it will be easily cultivated and if it is full of rocks it would be far harder to cultivate thus making for difficult working conditions. (Fortier, 2014)

3.1.3 Infrastructure and utilities

Accessing whether a site has electricity, a pressurised water supply, buildings for utilisation and road access are important factors when determining the usability of a prospective site for a biointensive farm. The less infrastructure and utilities that are present the higher the initial investment required would be. (Hartman, 2017)

3.1.4 Environmental and Geographical factors

Researching and understanding the environmental and geographical factors that effect a location are imperative in designing and constructing a successful small-scale biointensive farm. Such factors include: climate, light conditions, plot orientation and slope.

Climatic conditions may present challenges for growers and extremes in temperature, precipitation and wind can have drastic effects on the development of plants. Understanding regional climate trends provides information vital for all areas including: planning and design, site construction and eventual production on a biointensive farm.

Optimal temperature ranges vary between crops, however, most crops will be extremely inhibited in the rate they photosynthesize below 5℃ as enzymes catalysing the reaction will be extremely inhibited below this temperature. Using 5℃ as a baseline for seasonal crop planning is suggested to estimate crop-season length and corresponding yields. (Finnish Meteorological Institute, 2017; Timberlake & Timberlake, 2011)

Water is necessary for plant development and understanding the precipitaion trends of a region can aid in more efficient irrigation shedules. Conversely, percipitation can have debilitatiing effects in large downpoors such as: crop loss, top soil erosion and flooding. Understanding the seasonal differences in precipitation can preapare farms for better resource management and crop and field protection from large precipitation events.

Wind is necessary for clean air circulating around plants for healthy plant growth. However, excess winds can cause topsoil moisture loss and erosion and stress plants in turn stunting growth or causing crop loss. Understanding regional winds and preparing fields for protection against high wind events (using windbreaks and hedgerows) will create more stable conditions for crop production and limit topsoil moisture loss and erosion. (Fortier, 2014; Kuhns, 2012; Finnish Meteorological Institute, 2017; Timberlake & Timberlake, 2011)

Plot aspect (orientation) is critical for plant growth as if facing the wrong direction crops will not be able to photosynthesize efficiently. In the northern hemisphere a plot ideally would face south to receive the maximum amount of direct sunlight. Additionally, obstructions located to the South of a plot will cause shading will inhibit photosynthesis. Using this concept, an example of a plot orientated to the south but in shade for the majority of the day would not be a suitable site. (Fortier, 2014)

The slope of a site can have many effects on its suitability to be used for a biointensive farm. Too steep, a slope will be prone to erosion and will be hard to work. If flat, a site will be more prone to flooding and will not circulate air well. Taking these factors into account a slope with slight drop (approximately five degrees) would be ideal for drainage, air circulation and light distribution. (Fortier, 2014)

3.2 Selected site for a biointensive farm design

Suurpelto is a suburb within the Greater Helsinki region in the city of Espoo and was the location chosen for the design of a small scale biointensive vegetable farm. The suburb is west of the Helsinki central business district but in relatively close proximity (under 10 km) (figure 6). The particular piece of land chosen (figure 7) comprises of $\approx 8000m^2$ and is currently operational as farmland. Due to its locality, Suurpelto has access to the greatest concentration of people in a region of Finland which coupled with agriculture policy of the “Local food programme” strengthens the chances of a this proposed project succeeding. (Ministry of Agriculture and Forestry, 2013;Helsinki region, 2016)

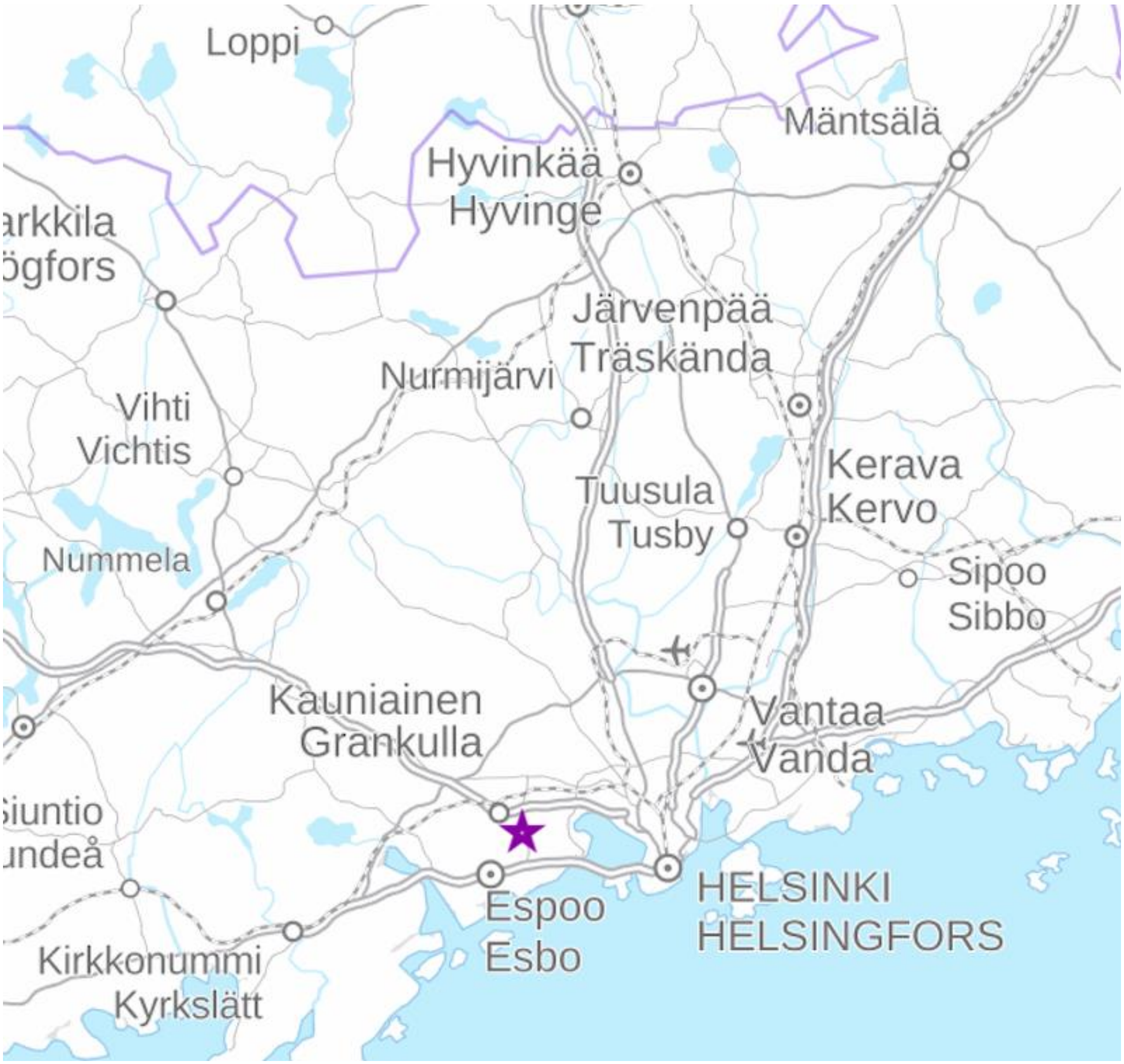

FIGURE 6: displays the background map of the Helsinki region. The proposed site in Suurpelto, Espoo is marked with a star on the map. (National Land Survey of Finland, 2017)

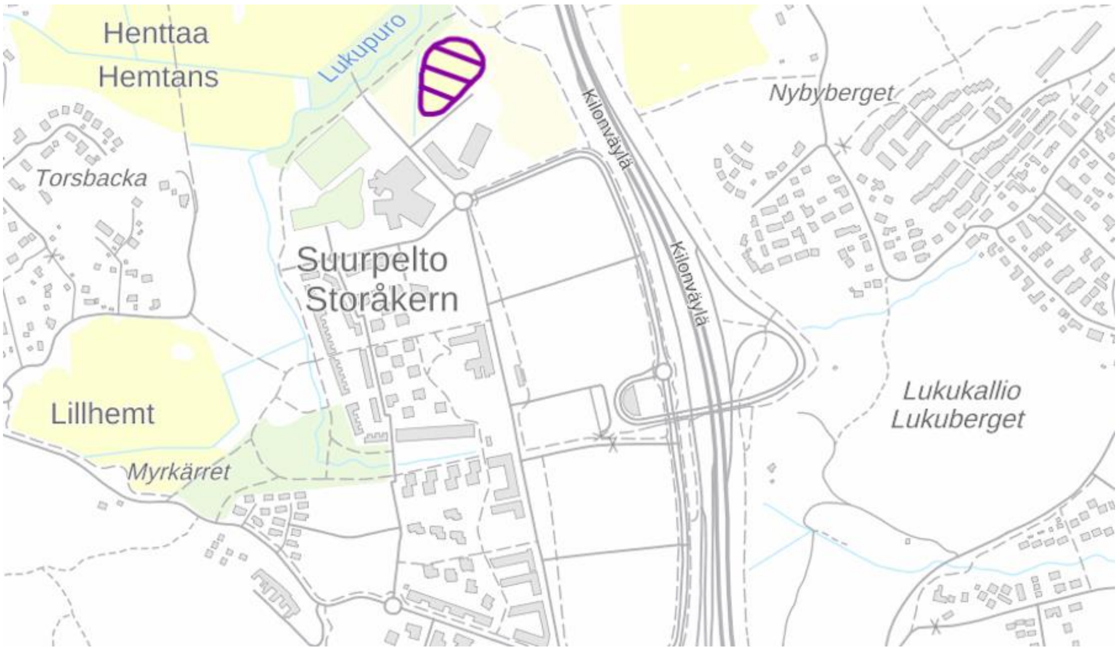

FIGURE 7: Displays the background map of Suurpelto. The proposed site in Suurpelto, Espoo is marked on the map in purple. (National Land Survey of Finland, 2017)

An assessment of the Suurpelto site indicated the soil has been mechanically cultivated and is of a relatively fine grade free from large rocks. The soil composition and productive capacity are unknown so certain factors such as: pH, mineral and nutrient content, biological activity, organic matter and potential toxicity would need to be further analysed by a laboratory. The onsite utilities include electricity and mains water but infrastructure is not present indicating an investment would be required to: rear seedlings, process and store crops once harvested and house onsite tools and materials. The plot aspect is not obvious, there is however a slight drop from the north-east to the south-west. The exposure of the plot to sunlight to the south east is not hampered but the plot may be shaded to the southwest in the early and late season. In relation to market access and clientele, Suurpelto (figure 6) is in Finland's densest population region, which gives the farm the greatest prospect of succeeding in terms of access to potential customers. (Ministry of Agriculture and Forestry, 2013; Fortier, 2014; Helsinki region, 2016)

Climate analysis from the Finnish Meteorological Institute indicates that the thermal growing season for the Suurpelto site in 2017 was from the beginning of May until mid-October, a growing season of just over 20 weeks. However, the average thermal growing season according the Institute from 1981-2010 was actually over 25 weeks (figure 8). (Finnish Meteorological Institute, 2017)

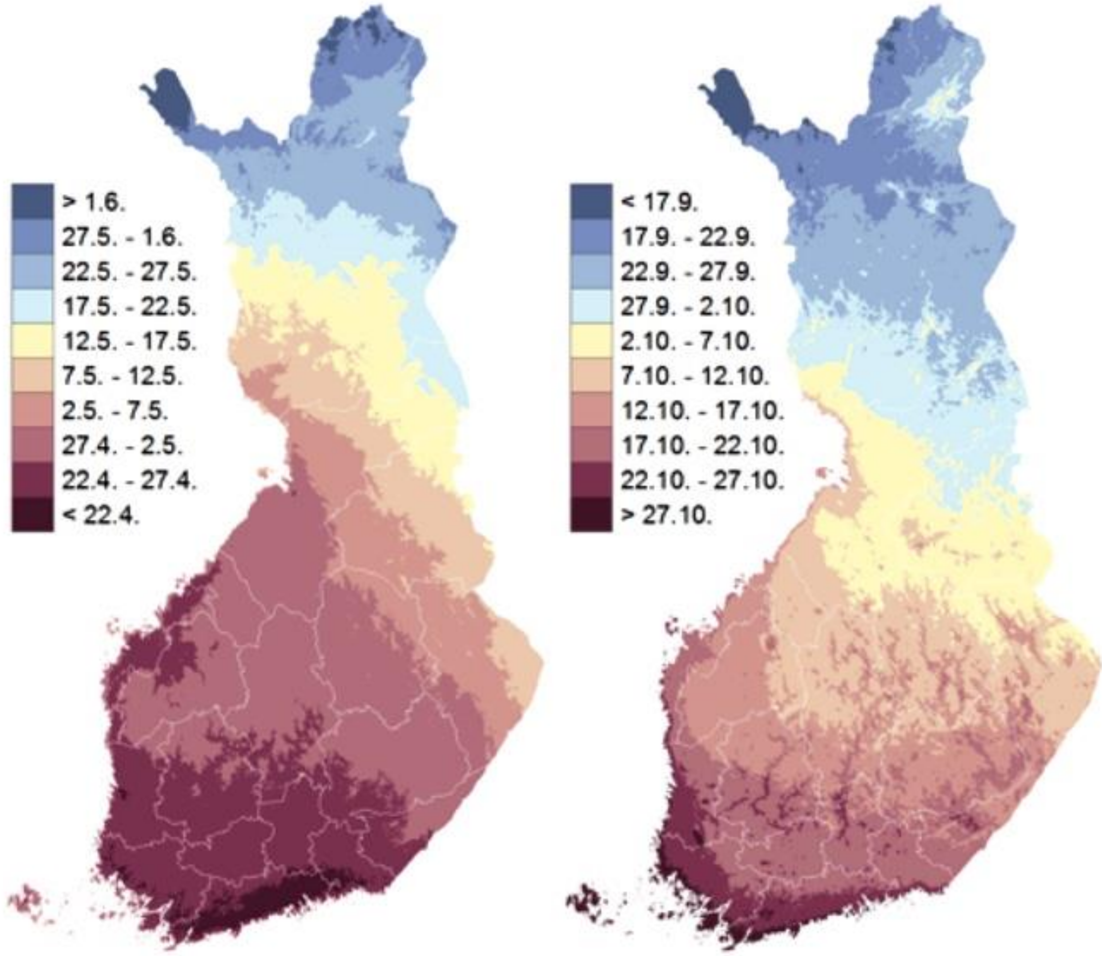

FIGURE 8: Average thermal growing season in Finland from 1981-2010. Image on the left constitutes the 30 year average beginning of the thermal growing season and the image on the right displays the average end. (Finnish Meteorological Institute, 2017)

Precipitation averages from 1981-2010 for Helsinki (figure 9), for the thermal growing season (May to October), indicate the driest part of the season to be in the beginning. Precipitation then becomes more frequent throughout the season with August being the wettest month of the year on average. Such trends indicate that additional crop irrigation may be required in the beginning of the season with less need in the latter thermal growing season.

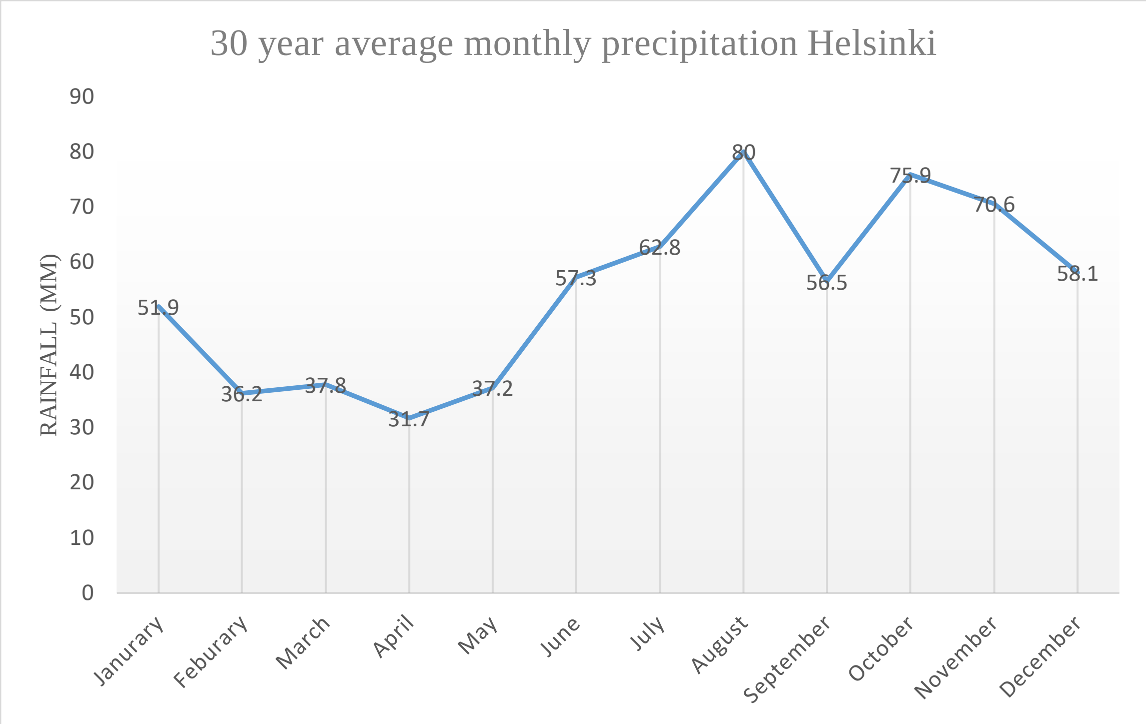

FIGURE 9: represents the average monthly precipitation figures for Helsinki from the years 1981 until 2010. (Finnish Meteorological Institute, 2017)

4 Suurpelto site design and budget

The design for the biointensive farm was based on a grid like structure encompassing field blocks of permanent raised beds and a central operations area containing: compost piles, tools, a greenhouse for seedling production, a post-harvest area for processing and packing and on-site refrigeration for storage of perishables. The grid shape of the design (figure 10) allows for minimal space usage as the field blocks can be placed close together in an organised method. (Fortier, 2014)

The permanent raised beds follow the industry standard 0.76m and 30 metres long. The length was devised as it associated with many pest protection covers, season extension tools and greenhouses often being constructed to lengths of 30m.

The field blocks for the Suurpelto site harbour 8 permanent raised beds, which run parallel with the fall of the land from the north-east of the site to south-west. By orientating the beds in this manner water can easily drain during the spring, ensuring the permanent raised beds do not become water logged. The field blocks were designed to be surrounded initially by synthetic windbreaks to the north-west, north-east and south-west. Over-time hedge rows consisting of perennial shrubs would be planted and could grow up and replace synthetic wind breaks add diversity and providing habitat for wildlife and beneficial insects. Walkways of two metres are in between the field blocks for ease of access around the farm and could be used for a small utility vehicle. A continual fence surrounds the entire operation to deter pest animals such as deer, moose and rabbits (figure 10).

The central location of the infrastructure was designed to streamline the operations for the Suurpelto site. This area is also easily accessible by vehicle to ensure deliveries to and from the farm would be quick and efficient. Having the utilities located in this area also ensure that all of the infrastructure can be managed efficiently and effectively and any breakdowns can be easily noticed.

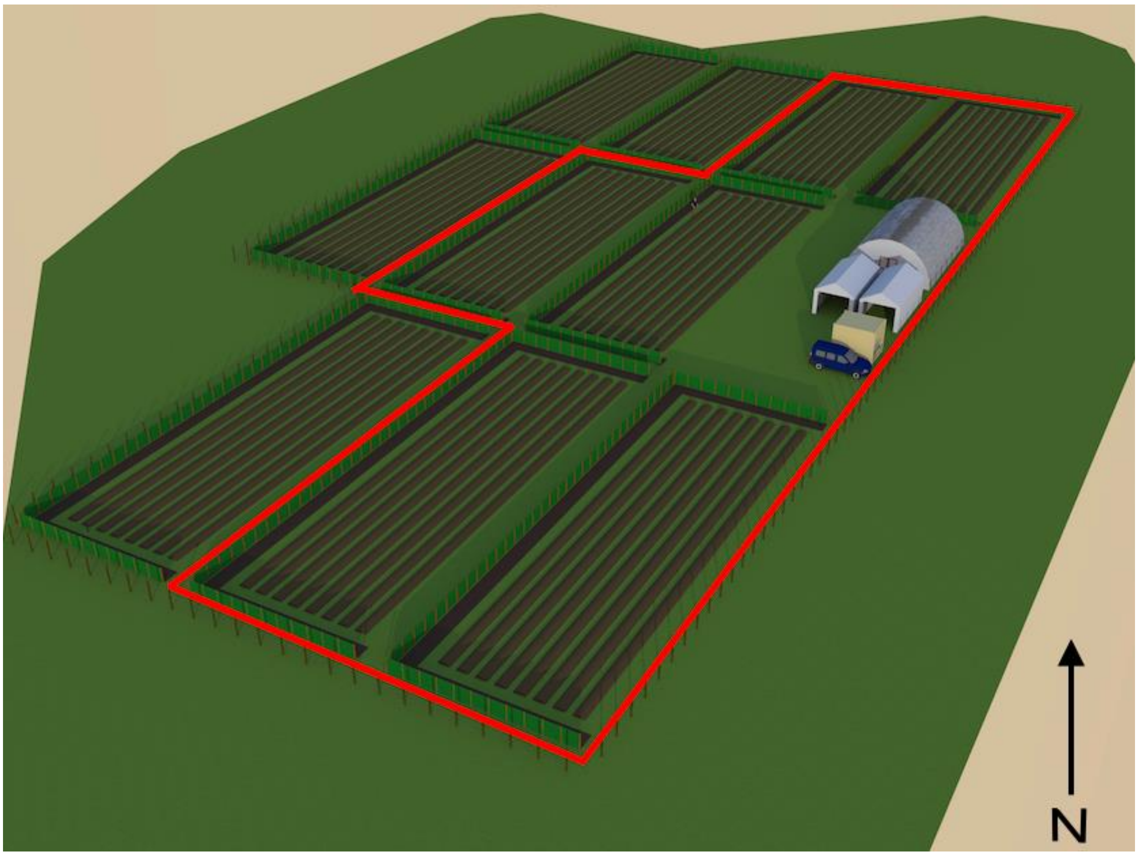

FIGURE 10: a visual representation of the design for the proposed Suurpelto site. The boundary present in this figure defines the area for the first season of production, $\approx 3400m^2$. The total area once utilised would equal $\approx 5000m^2$. (Benjamin MacNab, 2017)

TABLE 1: displays the Suurpelto site start up costings. The values calculated for these start -up costs are based on some material of: Curtis Stone, Jean-Martin Fortier and Ben Hartman and other market research that was conducted by the author Benjamin MacNab. (Fortier, 2014; Stone, 2016; Hartman, 2017)

Item	Cost (euro)
Heated Greenhouse 7x10m	7000
Compost for site 105m^2	3000
Seed	500
Containers for harvest and storage	500
Post-harvest area and equipment	2000
Tools (Wheel barrow, weeders, shovels, forks	500
Pest protection covers	500
Irrigation	2000
Silage tarpaulins	1000
Transplant trays and equipment	500
Refrigeration (rented)	1200
Harvest and tool cart	200
total	20100

4.1 Suurpelto site season production

For the Suurpelto site, field production was planned based on climatic analysis of the region which estimated that outdoor vegetable production to be possible from May until the first weeks of October. Crop selection (table 2) and field production was designed to primarily be based on greens (which have a short DTM and demand a high price) such as: mesclun salad, baby spinach, cos lettuce, kale and rocket and would be available on a weekly basis. A Regular production of carrots, beetroots, radishes, zucchini and herbs was incorporated to create a more diverse range of produce however all items would not necessarily be available every week. Secondary production of crops with longer DTM such as broccoli, cauliflower, bok choy, spring onions, cabbage, garlic, onions, beans and peas was integrated to add even more diversity but would be irregular due to seasonal influences. (Finnish Meteorological Institute, 2017)

Vegetable production for the site was designed to primarily involve transplants (where possible to reduce the time in the field) and some direct seeding where crops were not ideally suited to be transplanted (table 2). The seasons production plan is displayed in detail in Appendices 1, 2, and 3.

TABLE 2: Describes the different crops, planting methods, nutrient requirement (HF=heavy feeder LF=light feeder) days in the field and expected harvest quantities per 30m permanent raised bed. Values displayed in this table have been formulated using a conservative estimate from the materials of: Curtis Stone, Jean-Martin Fortier and Ben Hartman. (Fortier, 2014; Stone, 2016; Hartman, 2017)

Transplant/Nutrient Requirement/Days in ground/Expected yield per bed kg	Direct seed/Nutrient Requirement/DTM /Expected yield per bed kg
Spinach/LF/45/35kg	Carrots/LF/90/100kg
Kale/LF/90/60kg	Coriander/LF/60/20kg
Rocket/LF/45/35kg	Beans/LF/80/45kg
Mesclun salad varieties/LF/45/25kg	Garlic/HF/90/500 units
Head lettuce/LF/40/250 heads or 25kg	Onions/HF/100/150kg
Basil/LF/40/20kg	Radishes/LF/30/60kg or 300 bunches
Broccoli/HF/70/60kg	
Beetroot/LF/60/60kg	
Cauliflower/HF/90/100kg	
Zucchini HF/70/100kg	
Spring onions/HF/60/60kg	
Parsley/LF/60/20kg	
Cabbage/HF/90/110kg	
Peas LF/90/35kg	
Dill LF/60/20kg	
Bok choy/HF/50/70kg	

4.2 Predicted harvest volumes and revenue

Predicted harvest volumes and the coinciding revenue created by the sale of that produce to the market, are imperative figures when it comes to assessing the financial viability of an enterprise. Although financial gain isn't the only value that is created, such data is valuable for institutions that may be financing a project if an individual does not possess the needed funds.

Based on the crop plan for the Suurpelto site (appendix 3) and the predicted harvest quantities per 30m permanent raised bed (table 2), it was calculated that 4950kg of processed produce (appendix 5) would be able to be produced off ≈3400 m^2 of land. This estimated figure largely comprised of rocket (355 kg), spinach (390 kg), head lettuce (350 kg), carrot (360 kg), cauliflower (400 kg), radish (420 kg) and zucchini (400 kg).

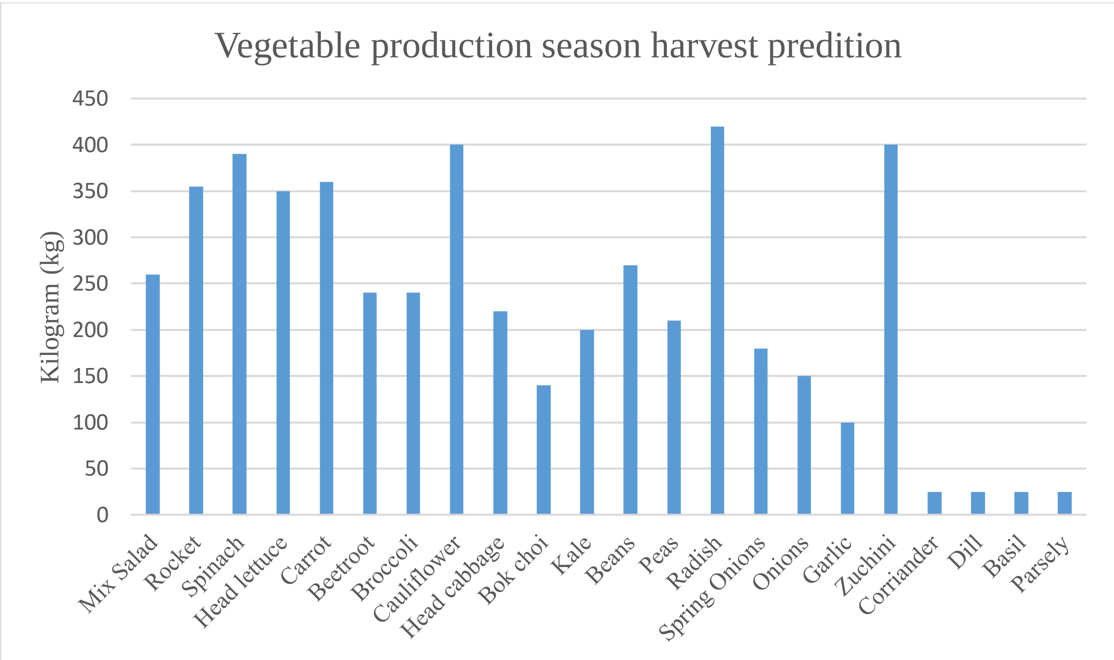

FIGURE 11: Represents the predicted vegetable harvest volumes in kg for the proposed Suurpelto site.

The predicted revenue created from the Suurpelto biointensive site was (calculated by multiplying the predicted harvest figures (appendix 5) and the market value per unit (kg) (appendix 6) 44676 euro. The main revenue producers included: mixed salad (5200 euro), rocket (7100 euro), spinach (7800 euro) and head lettuce (5250 euro) with the other crops producing the remaining 43%.

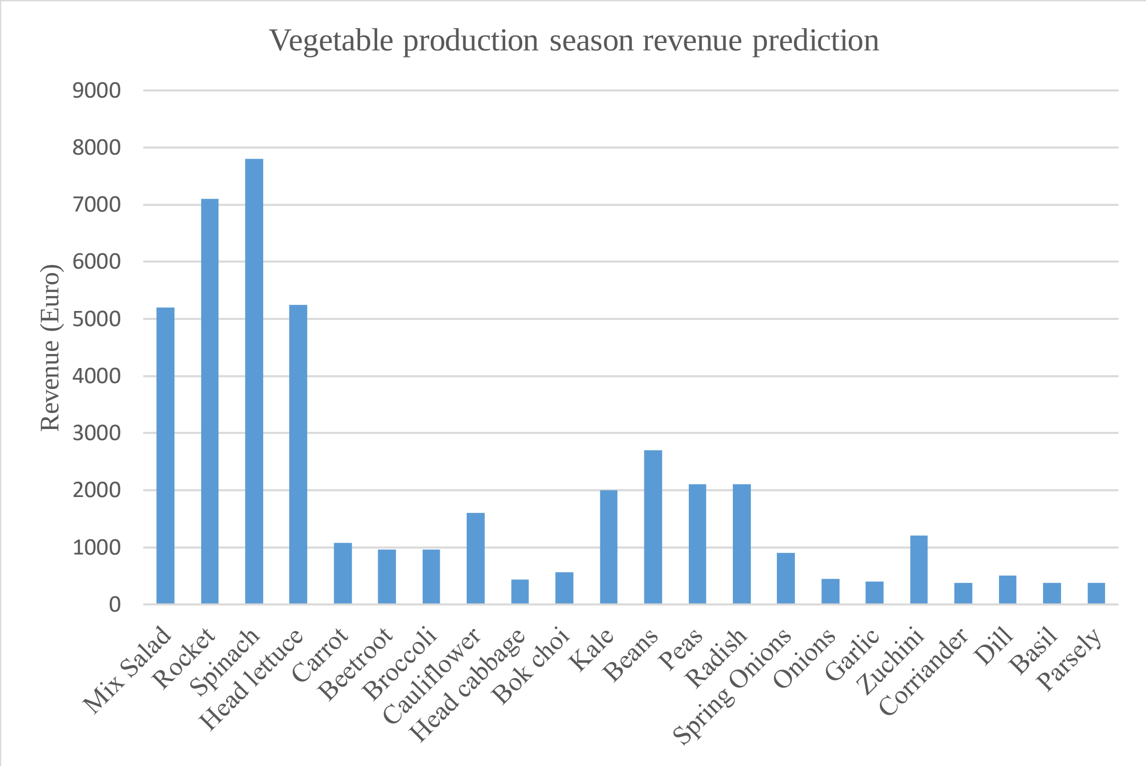

FIGURE 12: Represents the revenue prediction of the proposed Suurpelto crop plan.

5 Discussion

Food in the modern day is a necessity for humanity to exist and with aid of the "Green revolution" in agriculture has seen a huge population increase that has more than doubled in the last sixty years (The World Bank, 2016). This in conjunction with globalisation has seen agricultural products shipped all over the world for consumption, giving humanity the ability to access a greater range of products as a whole. Further, industrial agriculture has tried to compartmentalise itself from nature with the aid of high yielding hybridised crop varieties, inorganic fertilisers, pest protection chemicals and mechanised monoculture production techniques. In contrast to this, biointensive small scale farming has created a food model that is extremely profitable (without the addition of subsidies) that still takes into account soil ecology. Such a model is not based on industrial scale mechanisation or monoculture, however is more focused on polyculture and local food production and distribution that creates significant value both directly and indirectly. Additionally, the United Nations even published a paper "Wake up before it's too late" emphasising the importance in shifting away from industrial agriculture techniques to an approach that takes agroecology as a centrepiece. On a local level the Finnish Ministry of Agriculture and Forestry has legislated the importance of local food production and consumption by creating the "Local food program". Such initiatives even further support the case for biointensive agriculture to become a more common food production model. (Ministry of Agriculture and Forestry, 2013; United Nations, 2013, The World Bank, 2016; The World Bank, 2014; United Nations, 2009)

The direct value created from small scale biointensive farming includes: local job creation, local revenue creation, increased food security (of nutrient dense food) and decrease in start-up costs (compared to industrial mechanised monoculture farming). By biointensively farming on a local scale, local food is produced efficiently and cost effectively, as the start-up costs in relation to the potential revenue able to be created are quite low. Such an example can be seen when comparing the start-up costs to revenue creation of the Suurpelto site design (initial investment (table 1) is less than half of that of the projected revenue (figure 12) created in the first season of growing). This projected revenue for the Suurpelto site, when comparing to other biointensive growers, is actually quite low though. Other farmers such as Curtis Stone, Jean-Martin Fortier, Ben Hartman and Paul and Elisabeth Kaiser report the ability to create revenue of approximately ≈ 83000 euro per crop acre of which 50% is profit. (Fortier, 2014; Kaiser & Kaiser, 2016; Stone, 2016; Hartman, 2017)

The indirect value created from small scale biointensive farming includes: an increase in biodiversity and habitat, an increase in biota health (compared to conventional agriculture), increased carbon sequestration and a decrease in nutrient losses (via erosion and leaching). Although biodiversity does not directly have a monetary value currently, biointensive small scale farming with its diversity in crops inadvertently creates one, as a system with a more diverse environment is a more resilient one. Crop resilience means survival and survival means yields, which in turn creates revenue. In the Suurpelto site design, the addition of perennial hedge rows also increases biodiversity. The perennial hedge rows also provides habitat for wildlife and beneficial insects and protects the soil from erosion via wind. Biointensive farming and its emphasis on soil ecology also builds SOM and in turn SOC. By using planting techniques such as succession planting, soil always has a supply of exudates that result from the reaction of photosynthesis from crops always present in the ground. When analysing the mitigation potential of carbon dioxide in relation to cost, agriculture by far has the greatest potential and further emphasises the importance of such food systems. (Greip and Manly, 2012; Hogland-Isaksson, et al., 2012; Kaiser & Kaiser, 2016)

The issues faced with small scale biointensive farming is that this is not an institutional idea or teaching. Much of the information presented in this thesis is not taught in universities or encouraged as a mainstream food production system by agricultural ministries, it is produced by individuals who are part of a grass-roots movement. All of these individuals involved do not necessarily follow the same beliefs system either (such as no till) so it would be difficult to regulate, however the language used by experts in the field has a general consensus. Such a consensus is only relevant to those interested in the idea however many are lured into the topic by the results such systems can produce when comparing revenue to land size (≈ 83000 euro per crop acre). Further, with biointensive farming's profitability proven, this model could be used by institutions to move away from the idea of agriculture subsidies (which almost all farms in Finland receive). (Fortier, 2014; Hartman, 2017; Kaiser & Kaiser, 2016; Tike, 2014; Stone, 2016;)

6 Conclusion

The results of the design of a biointensive small scale vegetable farm in Finland show that such an operation is feasible. By comparing setup costs (20100 euro) to estimated yields (4950kg) and revenue (44676 euro), it is evident that there would be a total return on investment after the first growing season. Even with Finland's cool climate and short length of the thermal growing season (figure 8), viability is further supported by similar enterprises existing in cold climates. Such farms (Green city acres, Les Jardins de la grelinette, Le ferme des quatre temps, Ridgedale permaculture etc.) produce far larger revenues (per crop acre) than that mentioned in the results of this thesis (figure 12). (Fortier, 2014; Perkins, 2017; Stone, 2016)

Through analysing external data from other enterprises, the design and crop plan produced for this thesis could be refined to include heated and non-heated greenhouses for crop production to extend the growing season. Further, by incorporating heat loving crops such as: tomatoes, cucumbers and peppers into such greenhouses (which demand a high value and heated greenhouses) further revenue could be created but would require a larger capital investment. Microgreen production could also be included to increase and diversify revenue as they quick and easy to produce, takes little space and require only small investment (if a seedling greenhouse is already present in an operation). (Fortier, 2014; Kaiser and Kaiser, 2016; Stone, 2016; Hartman, 2017)

When analysing farm data from a worldwide perspective, small scale biointensive farming may not just be a viable food model for Finland, but many other countries and regions. A survey of 460 million farms in 111 countries has revealed that 72% of all farm holdings were less than $10000m^2$. This does note state that all of those were vegetable farms, however many could be and biointensive farming could be a technique used to help such operations increase productivity and ecology. (FAO, 2015)

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8 Appendices

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Appendix 1: Transplant Seeding density for Suurpelto site (Fortier, 2014; Stone, 2016; Hartman, 2017)

Crop	Amount of Seedling trays per 30m biointensive growbed
Spinach	10 x 128 cell trays (4-6 seeds per cell)
Kale	5 x 72 cell trays (1 seed per cell)
Rocket	13 x 128 cell trays (1 seed per cell)
Mesclun salad	13 x 128 cell trays (1 seed per cell)
Head lettuce	4 x 72 cell trays (1 seed per cell)
Beetroots	8 x 128 cell trays (4-6 seeds per cell)
Carrots	N/A
Radishes	N/A
Coriander	N/A
Parsley	8 x 128 cell trays (1 seed per cell)
Basil	3 x 128 cell trays (1 seed per cell)
Dill	8 x 128 cell trays (2-3 seeds per cell)
Broccoli	2 x 72 cell trays (1 seed per cell)
cauliflower	2 x 72 cell trays (1 seed per cell)
cabbage	2 x 72 cell trays (1 seed per cell)
Spring onions	13 x 128 cell trays (2-3 seeds per cell)
garlic	N/A
onions	N/A
Beans	N/A
Peas	10 x 128 cell trays (1 seed per cell)
Bok choy	4 x 72 cell trays (1 seed per cell)
Zucchini	1 x 72 cell trays (1 seed per cell)

Appendix 1: Transplant time in seedling trays before field planting (Fortier, 2014; Stone, 2016; Hartman, 2017)

Crop	Seeding time before field planting
Spinach	3 weeks
Kale	5 weeks
Rocket	2 weeks
Mesclun salad	2 weeks
Head lettuce	3 weeks
Beetroots	5 weeks
Carrots	Direct seed
Radishes	Direct seed
Coriander	Direct seed
Parsley	6 weeks
Basil	4 weeks
Dill	5 weeks
Broccoli	5 weeks
cauliflower	5 weeks
cabbage	5 weeks
Spring onions	6 weeks
garlic	Direct seed
onions	Direct seed
Beans	Direct seed
Peas	5 weeks
Bok choy	5 weeks
Zucchini	2 weeks

Appendix 1. Weekly Seeding schedule for transplant crops and the amounts to be seeded for the Suurpelto site crop plan. This table is used in conjunction with table 8 defines the amount of seedling flats to be seeded per 30m biointensive growbed. Here one unit represents one 30 metre growbed (Benjamin MacNab 2017)

Week	Mix Salad	Rocket	Spinach	Head lettuce	Beetroot	Kale	Zuchini	Radish	Dill	Basil	Parsely	Broccoli	Cauliflower	Head cabbage	Bok choi	Peas	Spring Onions
13																	1
14					1	1						1	1	0.5	0.5		
15											0.5					3	
16			3	2					0.5								
17	2	2	1	1			1	1		0.5		1	1	0.5	0.5		
18	1	1		1													
19			1	2	1						0.5						
20	1	1		1			1	1	0.5			1	1	0.5	0.5		
21				1		1				0.5							
22			1	1													
23	1	1			1		1	1				1	1	0.5	0.5		1
24						1											
25			1	1				1								3	
26	1	1					1				0.5						
27			1	1					0.5								1
28	1	1	1	1	1					0.5							
29	1	1															
30																	
31			2	1				1									
32	1	1	1														
33	1	1															
34								1									

Appendix 2: Plant Spacing's for selected crops on Suurpelto site (Fortier, 2014; Stone, 2016; Hartman, 2017)

Crop	Planting density
Spinach	4 rows/10cm spacing
Kale	3 rows/30cm spacing
Rocket	5 rows/10cm spacing
Mesclun salad	5 rows/10cm spacing
Head lettuce	3 rows 30cm spacing
Beetroots	3 rows/10cm spacing
Carrots	5 rows/3 cm spacing
Radishes	5 rows/5cm spacing
Coriander	5 rows/5cm spacing
Parsley	4 rows/15cm spacing
Basil	3 rows/30 cm spacing
Dill	3 rows/10 cm spacing
Broccoli	2 rows/45cm spacing
cauliflower	2 rows/45cm spacing
cabbage	2 rows/45cm spacing
Spring onions	5 rows/10cm spacing
garlic	4 rows/30cm spacing
onions	3 rows/30cm spacing
Beans	2 rows/5cm spacing
Peas	2 rows/5cm spacing
Bok choy	3 rows/30cm spacing
Zucchini	1 row/ 60cm spacing

Appendix 3: Field block 1 crop plan. (P) is for planting and (H) is for harvest

Week	Grow bed 1	Grow bed 2	Grow bed 3	Grow bed 4	Grow bed 5	Grow bed 6	Grow bed 7	Grow bed 8
19	Mesclun (P)	Rocket(P)	Spinach (P)	Spinach (P)				
20					Mesclun (P)	Rocket(P)	Spinach (P)	Lettuce(P)
21								
22								
23	Mesclun (H)	Rocket (H)	Spinach (H)	Spinach (H)				
24					Mesclun (H)	Rocket (H)	Spinach (H)	
25	Mesclun (H)	Rocket(H)	Spinach(H)	Spinach(H) Radish (P)				
26					Mesclun (H)	Rocket (H)	Spinach (H)	Lettuce(H) Kale (P)
27								
28					Mesclun(H) Beans (P) 30% Carrot (P)	Rocket (H) Beans (P) 30% Carrot (P)	Spinach (H) Beans (P) 30% Carrot (P)	
29	Peas (P) 30% Carrot(P)	Peas (P) 30% Carrot(P)	Peas (P) 30% Carrot(P)	RADISH (H) Kale(P)				
30								
31								
32								
33								Kale (H)
34								Kale (H)
35					Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Kale (H)
36	30% Carrot (H)	30% Carrot (H)	30% Carrot (H)	Kale (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Kale (H)
37	30% Carrot (H)	30% Carrot (H)	30% Carrot (H)	Kale (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Kale (H)
38	Peas (H) 30% Carrot(H)	Peas (H) 30% Carrot(H)	Peas (P) 30% Carrot(H)	Kale (H)				
39	Peas (H)	Peas (H)	Peas (H)	Kale (H)				
40	Peas (H)	Peas (H)	Peas (H)	Kale (H)				
41	Garlic (P)	Garlic (P)	Garlic (P)	Garlic (P)	Garlic (P)	Garlic (P)	Garlic (P)	Garlic (P)

3(2)

Appendix 3: Field block 2 crop plan. (P) is for planting and (H) is for harvest

Week	Grow bed 1	Grow bed 2	Grow bed 3	Grow bed 4	Grow bed 5	Grow bed 6	Grow bed 7	Grow bed 8
19	Peas (P) 30% Carrot(P)	Peas (P) 30% Carrot(P)	Peas (P) 30% Carrot(P)	Kale (P)				
20								
21								
22								
23					Beans (P) 30% Carrot (P)	Beans (P) 30% Carrot (P)	Beans (P) 30% Carrot (P)	Kale (P)
24								
25								
26	30% Carrot (H)	30% Carrot (H)	30% Carrot (H)	Kale (H)				
27	30% Carrot (H)	30% Carrot (H)	30% Carrot (H)	Kale (H)				
28	Peas (H) 30% Carrot(P)	Peas (H) 30% Carrot(H)	Peas (P) 30% Carrot(H)	Kale (H)				
29	Peas (H)	Peas (H)	Peas (H)	Kale (H)				
30	Peas (H) Mesclun (P)	Peas (H) Rocket(P)	Peas (H) Spinach (P)	Kale (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Kale (H)
31				Lettuce (P)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Kale (H)
32					Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Beans (H) 30% Carrot (H)	Kale (H)
33								Kale (H)
34	Mesclun (H)	Rocket (H)	Spinach (H)					Kale (H)
35					Mesclun (P)	Rocket(P)	Spinach (P)	Kale (H)
36	Mesclun (H)	Rocket(H)	Spinach(H)					
37				Lettuce (H)				
38								
39					Mesclun (H)	Rocket (H)	Spinach (H)	
40								
41					Mesclun (H)	Rocket(H)	Spinach(H)	

Appendix 3: Field block 3 crop plan. (P) is for planting and (H) is for harvest

Week	Grow bed 1	Grow bed 2	Grow bed 3	Grow bed 4	Grow bed 5	Grow bed 6	Grow bed 7	Grow bed 8
19	Broccoli (P) 50% Lettuce(P)	Cauliflower (P) 50% Lettuce (P)	50% Cabbage (P) 50% Bok choi (P)	Zuchini (P)				
20								
21								
22					Broccoli (P) 50% Lettuce(P)	Cauliflower (P) 50% Lettuce (P)	50% Cabbage (P) 50% Bok choi (P)	Zuchini (P)
23								
24								
25	50% Lettuce (H)	50% Lettuce (H)		Zuchini (H)				
26			50% Bok choi (H)	Zuchini (H)				
27				Zuchini (H)				
28				Zuchini (H)	50% Lettuce (H)	50% Lettuce (H)		Zuchini (H)
29	Broccoli (H)						50% Bok choi (H)	Zuchini (H)
30								Zuchini (H)
31	Mesclun (P)	Cauliflower (H) Rocket (P)	50 % Cabbage (H) Spinach(P)	Radish (P)				Zuchini (H)
32					Broccoli (H)			
33								
34				Radish (H)	Mesclun (P)	Cauliflower (H) Rocket (P)	50%Cabbage (H) Spinach (P)	Spinach (P)
35	Mesclun (H)	Rocket (H)	Spinach (H)					
36								
37	Mesclun (H)	Rocket(H)	Spinach(H)					
38					Mesclun (H)	Rocket (H)	Spinach (H)	
39								
40					Mesclun (H)	Rocket(H)	Spinach(H)	Lettuce (H)
41								

3(4)

Appendix 3: Field block 4 crop plan. (P) is for planting and (H) is for harvest.

Week	Grow bed 1	Grow bed 2	Grow bed 3	Grow bed 4	Grow bed 5	Grow bed 6	Grow bed 7	Grow bed 8
19	Mesclun (P)	Rocket(P)	Spinach (P)	Lettuce (P)				
20								
21								
22					Mesclun (P)	Rocket(P)	Spinach (P)	Lettuce (P)
23	Mesclun (H)	Rocket (H)	Spinach (H)					
24								
25	Mesclun (H) Broccoli (P) 50% Lettuce(P)	Rocket (H) Cauliflower (P) 50% Lettuce (P)	Spinach (H) 50% Cabbage (P) 50% Bok choi (P)	Lettuce (H) Zuchini (P)				
26					Mesclun (H)	Rocket (H)	Spinach (H)	
27								
28					Mesclun (H) Broccoli (P) 50% Lettuce(P)	Rocket (H) Cauliflower (P) 50% Lettuce (P)	Spinach (H) 50% Cabbage (P) 50% Bok choi (P)	Lettuce (H) Zuchini (P)
29								
30								
31	50% Lettuce (H)	50% Lettuce (H)		Zuchini (H)				
32			50% Bok choi (H)	Zuchini (H)				
33				Zuchini (H)				
34				Zuchini (H)	50% Lettuce (H)	50% Lettuce (H)		Zuchini (H)
35	Broccoli (H)						50% Bok choi (H)	Zuchini (H)
36								Zuchini (H)
37		Cauliflower (H)	50% Cabbage (H)					Zuchini (H)
38					Broccoli (H)			
39								
40						Cauliflower (H)	50% Cabbage (H)	
41								

Appendix 3: Field block 5 crop plan. (P) is for planting and (H) is for harvest (Benjamin MacNab 2017)

Week	Grow bed 1	Grow bed 2	Grow bed 3	Grow bed 4	Grow bed 5	Grow bed 6	Grow bed 7	Grow bed 8
19								
20								
21					50% Corrianderi (P) 50% Dill (P)	50% Basil (P) 50% Parsely (P)		
22								
23								
24				Lettuce (P)				
25	Mesclun (P)	Rocket(P)	Spinach (P)				50% Corrianderi (P) 50% Dill (P)	50% Basil (P) 50% Parsely (P)
26								
27					50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)		
28	Mesclun (H)	Rocket (H)			50% Corriander (H) 50% Dill (H) Mesclun (P)	50% Basil (H) 50% Parsely (H) Rocket(P)		
29			Spinach (H)					
30	Mesclun (H)	Rocket (H)		Lettuce (H)				
31			Spinach(H)				50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)
32	Mesclun (H) 50% Corrianderi (P) 50% Dill (P)	Rocket(H) 50% Basil (P) 50% Parsely (P)	Lettuce (P)		Mesclun (H)	Rocket (H)	50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)
33							50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)
34					Mesclun (H)	Rocket(H)	50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)
35								
36								
37								
38	50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)	Lettuce (H)					
39	50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)						
40	50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)						
41	50% Corriander (H) 50% Dill (H)	50% Basil (H) 50% Parsely (H)						

Appendix 3: Field block 6 crop plan. (P) is for planting and (H) is for harvest (Benjamin MacNab 2017)

Week	Grow bed 1	Grow bed 2	Grow bed 3	Grow bed 4	Grow bed 5	Grow bed 6	Grow bed 7	Grow bed 8
19		Radish (P)	Onion (P)	Spring Onion (P)	Garlic (P)			Beetroot (P)
20								
21							Lettuce (P)	
22						Radish (P)		
23		Radish (H) Lettuce (P)						
24	Beetroot (P)			Spring Onion (H)				Beetroot (H)
25				Spring Onion (H)				Beetroot (H)
26				Spring Onion (H)		Radish (H)		Beetroot (H)
27						Spinach (P)	Lettuce (H) Radish (P)	
28				Beetroot (P)				
29	Beetroot (H)	Lettuce (H) Spring Onion (P)						Lettuce (P)
30	Beetroot (H)							
31	Beetroot (H)					Spinach (H)	Radish (H)	
32								
33	Spring Onion (P)		Onion (H) Beetroot (P)	Beetroot (H)	Garlic (H)	Spinach(H) Radish (P)	Lettuce (P)	
34		Spring Onion (H)		Beetroot (H)				
35		Spring Onion (H)		Beetroot (H)				Lettuce (H)
36		Spring Onion (H) Radish (P)						
37						Radish (H)		
38	Spring Onion (H)		Beetroot (H)					
39	Spring Onion (H)		Beetroot (H)				Lettuce (H)	
40	Spring Onion (H)	Radish (H)	Beetroot (H)					
41								

4(1)

Appendix 4: Weekly harvest and produce availability based on the crop plan of Appendix 1 (Benjamin MacNab 2017)

Week	Mix Salad	Rocket	Spinach	Head lettuce	Carrot	Beetroot	Kale	Zuchini	Radish	Corriander	Dill	Basil	Parsely	Broccoli	Cauliflower	Head cabbage	Bok choi	Beans	Peas	Spring Onions	Onions	Garlic
23																						
24																						
25																						
26																						
27																						
28																						
29																						
30																						
31																						
32																						
33																						
34																						
35																						
36																						
37																						
38																						
39																						
40																						
41																						

Appendix 5: Field production volumes (kg) in processed produce (not total produced biomass) and revenue created from the sale of that produce based on the values per kilo of Appendix 4 (Benjamin MacNab 2017)

Week	Mix Salad	Rocket	Spinach	Head lettuce	Carrot	Beetroot	Broccoli	Cauliflower	Head cabbage	Bok choi	Kale	Beans	Peas	Radish	Spring Onions	Onions	Garlic	Zuchini	Corriander	Dill	Basil	Parsely
23	30	40	60											60								
24	15	20	20			15									20							
25	20	30	45	50		15									20			25				
26	25	35	35	25	30	30				35	10			60	20			25				
27				25	30						10							25	2.5	2.5	2.5	2.5
28	15	20	20	50	30						10		35					50	2.5	2.5	2.5	2.5
29	15	20	20	25		15	60			35	10		35	60				25				
30	10	15		25	30	15					20	45	35					25				
31			35	25	30	30		100	55		10	45		60				50	2.5	2.5	2.5	2.5
32	20	20	0		30		60			35	10	45						25	2.5	2.5	2.5	2.5
33			15			15					20					150	100	25	2.5	2.5	2.5	2.5
34	25	35	20	25		15		100	55		20			60	20			50	2.5	2.5	2.5	2.5
35	15	20	20	25	30	30	60			35	10	45			20			25				
36	10	15	15	0	60						20	45			20			25				
37	10	15	15	25	60			100	55		20	45	35	60				25				
38	15	20	20	25	30	15	60				10		35		20				2.5	2.5	2.5	2.5
39	15	20	20	25		15					10		35		20				2.5	2.5	2.5	2.5
40	10	15	15	25		30		100	55		10			60	20				2.5	2.5	2.5	2.5
41	10	15	15																2.5	2.5	2.5	2.5
total kg	260	355	390	375	360	240	240	400	220	140	200	270	210	420	180	150	40	400	25.0	25.0	25.0	25.0
revenue	5200	7100	7800	5626	1080	960	960	1600	440	560	2000	2700	2100	2100	900	450	400	1200	375	375	375	375

Appendix 6: Unit costing per kg based off a market analysis of retail outlets and larger distributors (Benjamin MacNab 2017)

Crop	kilogram price (Euro)
Spinach	20
Kale	20
Rocket	20
Mesclun salad	20
Head lettuce	15
Beetroots	4
Carrots	3
Radishes	5
Corriander	15
Parsely	15
Basil	15
Dill	20
Broccoli	4
cauliflower	4
cabbage	2
Spring onions	5
garlic	10
onions	3
Beans	10
Peas	10