Production of nettle (Urtica dioica), environmental and economic valuation in conventional farming

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Maataloustuotanto ja sen osa-alueet kuten viljelykasvien monipuolistaminen, jatkuva kasvipeitteisyys sekä erilaiset maaperän parannuskeinot ovat kestävää kehitystä tukevia ja potentiaaliltaan merkittäviä toimia ilmastonmuutoksen hallinnassa. Kasvava ilmastonmuutokseen liittyvä keskustelu on osaltaan lisännyt kestävien materiaalien ja ratkaisujen kysyntää valmistavassa teollisuudessa.

Nokkonen (Urtica dioica) on todettu ekologisesti ja taloudellisesti arvokkaaksi kasviksi jolla on merkittävä kaupallinen potentiaali. Nokkosen monivuotisuus ja vaatimaton panoskäyttö, sekä monet mahdolliset käyttötarkoitukset kasvukauden aikana tekevät siitä viljelijöille kiinnostavan kasvin. Nokkonen on ollut historiallisesti teollisen mittakaavan viljelykasvi, mutta nykyinen tuotanto on marginaalista positiivisista ominaisuuksista huolimatta. Nokkosen kaupallista potentiaalia on viimeaikoina tutkittu monista eri näkökulmista ja käyttötarkoituksista, viljelijöiden vähyys on kuitenkin jättänyt tulokset hyödyntämättä laajemmassa mittakaavassa.

Tämä tutkimus on toteutettu perinteisin laskentatoimen menetelmin tarkoituksena löytää nokkosen viljelyn kannattavuusraja tavanomaisessa suomalaisessa maatalousympäristössä. Tuotantotiedot on kerätty eri kansainvälisistä kirjallisuuslähteistä tarkoituksena selvittää nokkosen viljelyn kannattavuustekijät ja laajentaa tarkastelua sen ympäristöllisiin hyötyihin. Vertailuksi, samanlainen arviointi toteutettiin tavanomaiselle viljelykiertosuunnitelmalle jossa kasvintuotantoon oli valittuna öljykasvi, vehnä sekä nurmikasvi.

Valitussa neljän vuoden asetelmassa nokkosen viljely osoittautuu kustannuksiltaan kalliimmaksi pääasiassa ensimmäisen vuoden vähäisen tuotoksen vuoksi. Nokkosen satovuosien alhainen panoskäyttö ja odotettu monivuotinen tuotos alentavat tuotantokustannuksia yli ajan. Nokkosen tuotantokustannus on 0,29 euroa kuivaa kiloa kohden ja kannattavuushinta sisältäen kansalliset tuet 0,16 euroa kuivaa kiloa kohden, samaa luokka vehnän kanssa. Nokkosen alhainen panoskäyttö ja suhteessa suuri kahdeksan tuhannen kilon kasvukausikohtainen tuotos viittaavat kannattavuuden parantumiseen verrattain alhaisin myyntihinnoin. Ympäristöllisesti arvioituna nokkosen viljely aikaansaa vuosittain noin 1,3 tonnin hiilinielun huolimatta konekäytöstä ja perinteisestä lannoitekäytöstä.

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Agricultural systems hold great potential in contributing greenhouse gas mitigation measures globally. Crop diversification, perennial vegetative cover and soil conservational measures are highlighted in order to develop agricultural production in a sustainable way. Increasing climate related public concern has created a demand for sustainable materials for manufacturing industries.

Nettle (Urtica dioica) has been proven to hold economic and ecological advantages and great commercial potential. Nettle is a perennial low input crop with multiple end uses within harvest offering an attractive crop for farmers. The crop has been historically used in industrial scale however, current nettle production in agricultural scale is marginal despite its positive characteristics. Research on nettle's commercial potential has been conducted in various industries. Lack of farmers has left results idle and commercial potential unachieved.

This study uses basic management accounting practices in order to find the break-even points and profitability of the production in Finnish conventional farming framework. The production information is gathered from various international projects and is used in order to assess the profitability of nettle production and expand the assessment to evaluate production's environmental benefits. For a comparison, similar assessment is performed for a conventional crop rotation consisting an oilseed crop, wheat and grass.

In the chosen 4-year setting, the nettle production proves more expensive majorly due to first year's economically non-viable production. Nettle's low input use during the yield years and predictable long term yield output is likely to reduce unit costs over time. Nettle's production cost of dry biomass is 0,29 euros per kilogram and break-even price after subsidies is 0,16 euros for a kilogram, similar to wheat. Nettle's low input use and relatively large, annual 8000kg fresh yields indicate the production could turn profitable with comparably low prices. Environmentally, after the first year nettle creates an annual 1,3 ton carbon sink despite conventional fertilizer use and machinery work done of field.

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Abbreviations

CO	Carbon Oxide	Hiilimonoksidi
CO2	Carbon Dioxide	Hiilidioksidi
DM	Dry Matter	Kuivasato
DMY	Dry Matter Yield	Kuivasato
EU	European Union	Euroopan Unioni
EU 27	EU member states (1.1.2007-30.6.2013)	Unionin jäsenmaat (1.1.2007-31.6.2013)
EU ETS	European Union Emissions Trading System	Euroopan unionin päästökauppajärjestelmä
GHG	Greenhouse gas	Kasvihuonekaasu
HC	Hydrocarbon	Hiilivety
IPCC	Intergovernmental Panel on Climate Change	Hallitustenvälinen ilmastonmuutospaneeli
KG	Kilogram	Kilogramma
kWh	Kilowatt per hour	Wattitunti
MJ	Mega Joule	Megajoule
Nox	Nitrogen Oxides	Typenoksidit
N2O	Nitrous Oxide	Dityppioksidi, typpioksiduuli, ilokaasu
PM	Particulate Matter	Hiukkasmassa
SOC	Soil Organic Carbon	Maaperän hiilitase
TYKO	Mathematical model for mahinery emission rates (VTT)	Ajoneuvojen päästölaskentamenetelmä (VTT)
UN	United Nations	Yhdistyneet kansakunnat
VTT	Technical research centre of Finland	Teknologian tutkimuskeskus

1. Introduction

Nettle (Urtica Dioica L) is a perennial low maintenance crop with all parts such as leaves, fibre, roots and seeds being usable and have been used by households as well as in industrial scale throughout the history in different purposes.

Land use causes various environmental impacts from which many are caused by agricultural production. The current focus on land use related greenhouse gas emissions, such as animal husbandry in agricultural production is shifting towards carbon cycles and storages, soil quality and soil net productivity. In production of goods relying heavily on raw materials, majority of environmental impacts have been found to origin from the cultivation phase (Mattila et al., 2012). In 2016 total emissions within European Union were estimated to be 4 423 Mt CO_2eq. The agricultural sector was responsible for around 12 percent of the total emissions, 6.5 Mt CO_2eq. Agriculture uses nearly 179 million hectares of land and accounts around 41 percent of the European territory in 2015 (Eurostat, Natural Resources Institute Finland, 2017). The ecological impact of the production and products could be partially reimbursed by re allocating and re assessing current farming practices.

This study uses nettle as a reference crop as different parts of the plant can be used for different purposes from the same harvest indicating efficient land use. The research interest from sustainability and material perspective is partially explained by nettle's agronomic characteristics such as efficiency in photosynthesis and low maintenance, partially explained by high competitiveness, ability to grow in marginal and poor soils as well as fewer diseases and pests ((Lehtomäki, Viinikainen & Rintala, 2008; Baltina et al., 2012). Nettle's environmental benefits are linked to its low input use and post-harvesting phase including processing and disposal. Environmental impact of the pre-consumer and post-consumer phase, especially in the textiles industry is remarkable and currently re-assessed similarly to food industry (see Ellen McArthur foundation, 2017). Based on the life cycle assessment carried out to nettle, majority of the environmental impacts were found from nitrogen fertilization application and CO_2 emissions from fossil fuels and highlight the significance of the cultivation phase in environmental assessment (Di Virgilio et al., 2015). Nettle's carbon sink abilities and low input use are here studied as additional revenue

Current economic conditions of conventional agricultural production seem unsustainable for farmers. Therefore, possible revenue derived from the environmental perspective rather than markets and prices can be viewed as possible future source of revenue or as a way improving profitability in a sustainable manner (Waldén et al., 2019).

The theoretical basis of the study is in agricultural production economics. As a supportive background theorem is the concept of ecological efficiency, which combines economic performance and positive ecological impacts measured by emission outflow from the production management and annual CO_2e and N_2O sequestration into soil. Ideally, the biomass yield and the rate of input use can be expressed in costs as well as by environmental profile of the output. Ecological efficiency has been promoted for businesses and industrial companies. However, the thoughts and applications are useful in this study as re-allocating resources in terms of environmental sustainability has found to increase profitability and creating business value commercially.

1.1 The aim of this study

The aim of this study is to show the possible economic potential of cultivating nettle in conventional farming and whether its production's environmental benefits can be quantified into comparable form.

The production of nettle requires significantly less work and inputs during its production cycle, which can last 5–10 years without significant decline in annual yields (Hakkarainen, 2004). This leads to an assumption that farming nettle could be environmentally and commercially beneficial option.

The study is formed from previous studies and production data, Finnish and international combined. The data is assembled to hypothetical orderly calculations to find the breakeven points for profitable production. Nettle's positive environmental impacts are assessed on the basis of its emission sink capabilities and the input use which are used in order to create a balance sheet for the emissions generated from the production. Similar emission assessment is calculated to an oilseed crop (rapeseed, *Brassica napus*), wheat (*Triticum*) and grass (Timothy grass, *Phleum pretense*) as a comparative crop rotation set to illustrate the average predictable emission points per field task per hectare.

The aim of this study is to provide comparable and predictable results that ideally show the causal connection within the framework and that can be perhaps implemented to alternative crops and settings.

Considering the environmental impact of primary production of consumer products, this information could be useful in order to increase the value creation on cultivation phase and improve risk management within the supply chains by valuating the production processes based on environmental performance. The type of data could help farmers to increase the value of production and participate into carbon markets similarly to other industries.

The study aims to answer the following questions. The main research question is:

> What is profitability of nettle production from the farmer's perspective?
>
> Followed by three additional questions:
>
> Can positive environmental impacts like emission sequestration abilities be converted into economic and commercial value for the farmer?
>
> Is it reasonable to assume that the method could be suitable to assess emission rates derived from machinery use?
>
> How does this conversion affect profitability of the production?

1.2 Proceeding and structure of the study

This study starts reviewing older literature and combines it with more recent field trials and reports. From the literature I have first collected the most fundamental parts of nettle's agronomic management and characteristics including review on historical perceive and commercial prospects. Simple immediate variable cost structure based on the production is illustrated to find breakeven points and profitability measures of production. This forms the principal for my study on economics of nettle production. In this study, profitability of nettle is assessed on the cost basis of input costs and hypothetical revenues. Nettle's profitability relies on hypothetical end use of output which will be briefly discussed among different pricing scenarios. Ideally, the whole plant is used in at least two (2) purposes without excluding one another.

Environmental impacts are assessed by estimating emissions from machinery use of nettle's production based on a specific agronomic management program, TTS-manager (Työtehoseura, 2019). The program determines each field task by the use of machinery giving task specific time estimates and overall rates of use per crop. Nettle's emission sequestration rate is used to study the carbon sink balance of the production based on the immediate CO_2e emissions that are caused by tractor work on field. The emission outflow is calculated using VTT's reference figures according to task specific fuel consumption estimates per hectare.

This measure illustrates nettle production's CO_2e outflow and carbon sequestration ratio per hectare based on the immediate work required in production. Additionally, emission rates of fertilizer inputs are included to the environmental assessment by their indirect and direct CO_2e value using manufacturer's references and emission assumptions by IPCC (2006). The carbon balance is examined via profitability perspective from a hypothetical situation where carbon markets cover agri-food systems, which participate in the carbon trade, acting as a carbon sink. Nettle's carbon sequestration rate is treated as a separate income flow.

Ideally, in the future current primary agri-food systems are included in carbon trade industry and the potential of the on-land carbon sequestration is commercialized. In addition, this would lead to improvements in the practices and resource use, to increase in farm profitability -and further neutralization of the negative environmental impacts of production (Waldén et al., 2019).

Both carbon balance and the gross margin are assessed to find break even points and profitability measures for the production.

2. Production and commercial use of nettle

Nettle is a nitrophilous perennial crop that thrives well in northern climate. Interest towards nettle has been consistent during the past decades due it’s commercial potential. However, lack of farmers, due current high costs of post-harvest processing and lack of technical efficiency in the retting wide commercial use has remained unachieved (Edom & Harwood, 2012; Suomela 2015; Hakkarainen, 2004). This section reviews nettle’s agronomic management, production characteristics and different intended purposes for the output.

2.1 Production and characteristics of nettle

Majority of literature recommend direct planting of nettle as separate seedlings. Direct sowing of seeds is possible and recommended to be done in the fall to for required frost treatment for following sprouting. Direct sowing has proven to create inconsistent growth in the first years when optimal harvests are reached in the third year (Vogl & Hartl, 2003; Seuri & Väisänen, 1995; Heeger, 1956). A hectare plot requires around 45 000–50 000 seedlings to ensure homogenous growth from the first year (Galambosi & Hakkarainen, 2002). The above ground biomass productivity was highest with planting density 60x60 cm (Jankauskiene et al., 2015).

In several field studies, planting nettle in rows and ridges is declared as the most efficient way of managing the production in both conventional and organic farming. Hedges have given positive results in replacing the use of pesticides when mechanical cultivation can be done between the plantations (Seuri & Väisänen, 1995; Galambosi, 1994). Nitrogen supports stem’s growth and boosts nettles weed suppressing abilities reducing naturally the need for weed management (see Appendix table 1). Phosphorus-nitrogen-kalium combination of inputs or solely used nitrogen is recommended in conventional and organic line of production (Leghne et al., 2002; Lehtomäki et al., 2008; Galambosi et al., 2002; Vogl et al., 2003, also Appendix table 1).

Literature on organic production of nettle recommends fast growing legume species such as crimson clover (*Trifolium incarnatum*) for nitrogen fixation (Vogl et al., 2003 & Lehne et al., 2002). Also composted household bio-waste and manure had positive impact on nettle’s dry matter fibre content (Lehne et al., 2002). In both above mentioned field trials the nettle was planted in rows and the fertilizer was placed in between.

Nettle has no known nor commercialized pesticides for its main pest small tortoiseshell (*Aglais urticae*), which must be evicted manually as early stage as possible. Nettle’s primary plant disease *Puccinia caricis* can infect the entire area and can be determined by yellow colored plants from an early summer forward. The disease can be controlled by cutting the infected plants and preventing sowing near wetlands where the disease usually contaminates (Seuri et al., 1995, 11).

Harvesting and post-harvesting methods

The post-harvest processing of nettle has been the major obstacle in commercializing nettle fibre use. High water content of the biomass sets requirements for drying which is often highly energy consuming and therefore expensive. Additionally, lower fibre content in relation to stem biomass in comparison to other fibre plants relates to cost-effectiveness of the post-harvest procedure (Bodros & Baley, 2008; Suomela, 2015; Harwood & Edom, 2012).

An interesting insight for economical processing of stem fibre plants was done moving the harvest to early spring instead of more common August. The dry line method by Pasila (2004) shows northern climates optimal relative humidity between March and May reducing the need for drying of stems prior processing. Pasila's study with hemp and flax resulted in 10% moisture content when harvested in the spring in comparison to autumn harvest and 30 –35 % in flax stems and 50–70% in hemp (Pasila, 2004, 1–14). Nettle's fibres are attached on the outer edges of the stem unlike bast fibres such as linseed flax (*Linum usitatissimum*) and hemp (*Cannabis sativa*) (Suomela, 2015, 26; Saastamoinen et al., 2011, 89). Similarly to hemp and flax the impact of winter frost would detach long fibres from the stem facilitating further extraction of the fibre making retting more economically viable. The process will however most likely damage the long fibres making the process more suitable for the production of composites rather than textiles (Pasila, personal communication, June 8th, 2016; Suomela, personal communication, February 6th, 2019).

Many informal sources, such as online recipes and blogs suggest collecting nettle in early spring when intended in human consumption. When investigated for food processing nettle's microbe density has found to increase significantly towards the end of production period supporting that the first harvest should be used for human consumption purposes and second harvest could be dedicated for solely fibre purposes. Additionally, nettle's microbe density is lower in upper parts than lower and the upper stalk of the stem has higher fibre percentage than lower parts (Moilanen, 2006; Bacci et al., 2013). Higher fibre percentage in upper parts in respect to lower woody stem part supports the suggestion to use the first harvest for human consumption.

Nettle has naturally high microbe content which tends to increase towards the end of summer. Timing the harvest and collecting only upper parts can reduce microbes but still exceed permissible levels. Steam sterilization equipment used for spices was found unsuitable due exceeding heat and inconsistent results. Positive results were found assembling larger steam engine to simple 40 m^2 batch dryer, combining microbe reduction process to biomass drying. The steam was directed to biomass and brief (20 second) treatment with 70 degree (Celcius) steam continued with 2 – 3 minute 50+ degree steam reduced the microbe content to 0,002 – 0,02%, well below permissible levels. The study was conducted with intention to find processing solution on site to reduce the need and costs regarding pre-consumer processing and logistics (Moilanen, 2006).

Leaf biomass & combined production

When assessing production of nettle it is reasonable to measure the leaf biomass separately as it is commonly used to foods and supplements. The leaf harvest can be predicted calculating general leaf area index which can be used for production planning. Leaf area index measures the leave area of vegetation relative to the land (m^2m^2). Based on the literature the nettle's leaf area related to fresh or dry weight can be reliably estimated with a linear regression model. These results can be used in estimating the leaf yield of the production as well as land use efficiency based on the leaf area (Sabouri & Hassanpour, 2015). Unfortunately the differences in leaf area indices between wild nettle and fibre nettle clones have not been studied (Rolf, 2018).

In Finland commercial nettle production utilizes the leaf biomass and the stems are not used for fibre purposes (Veijola, personal communication, November 23rd, 2016). In Germany contracted farmers utilize the stem for fibre and textiles but the leaves are left unused (Beckhaus, personal communication, January 17th, 2019). Despite the lack of practice the leaves can be harvested separately from stems before or after drying the complete biomass (Pasila, personal communication, June 8th, 2016; Veijola, personal communication, November 23rd, 2016).

Yields

The production of nettle in agri-food setting has been studied in Austria (Vogl et al., 2003), Finland (Galambosi et al., 2002; Seuri & Väisänen, 1995), Germany (Nebel et al., 2002, Lehne et al., 2002), Lithuania (Jankauskiene et al., 2016) and Italy (Bacci et al., 2009; di Virgilio, 2013). Yields vary between 6–15 tons per hectare depending on fertilization and agronomic practices, soil and the clones of nettle. Nettle produces high biomass annually and the stem length correlates positively with fibre content. Different nettle clones have different fibre content and the percentage can vary from the wild nettle's 3–5% fibre content up to 17 – 20% in cloned fibre nettle.

The yields in Finnish field trials amounted 13 tons of stem biomass per hectare, after drying totaled 3.4 tons of dry matter (DM) (Galambosi et al., 2002). In earlier Finnish studies the harvests averaged at 5.8 tons per hectare in the first harvest and in the second at 6.8 tons of fresh biomass per hectare (Seuri & Väisänen, 1995; Galambosi, 1994). It is reasonable to presume that the harvested total biomass consists of both stems and leaves. Majority of the literature suggest homogenous and high yields during the first four to even ten years with or without a decreasing trend (Butkute et al., 2015; Vogl et al., 2003; Harwood & Edom, 2012; Galambosi, et al., 2002; Hakkarainen, 2004).

2.2 Commercial and circular uses for nettle

Historical use of nettle can be traced back hundreds of years throughout Europe, Asia and East Asia. Industrial use in the United Kingdom was solely in textiles as in Germany during the 1st and 2nd World War. In Germany, the use consisted of leaves for food until the fibre was replaced by lower cost cotton. Most known uses of nettle have been in the textiles and fibre use, herbal medicine and household food consumption (Suomela, 2015; Harwood & Edom, 2012; Edom, 2005; Galambosi, 2017, 113). Various commercial prospects of nettle illustrates the multi-purpose potential as well as collects different studies to serve wider audience. Ideally, the complete plant is utilized for different purposes increasing land use efficiency and reducing unit costs. Various end uses can create higher income and reduce risk.

In this chapter I review nettle's commercial prospects and use within farming systems.

Fibre and properties for textiles industry

Due nettle fibre's similarity to other bast fibres the historical use has been difficult to determine and investigate. Suominen's research (2015) on identification methods and structural characteristics of nettle fibre show's that nettle has been used in fine garments in Finland more widely than expected. Similarly she points out that in Denmark and Norway archeological findings on textiles show that garments assumed to be cotton and linen have in fact been nettle textiles. Etymological use of the word nettle describing different cloths in Germanic languages suggests wider use of the fibre than expected. Nettle fibre is fine and has been found from lavish garments that were intended for weddings and funerals (Suomela, personal communication, December 14th, 2017). A wide use of bast fibres and especially different nettle varieties has been traced in Japan which has a long history with and many varieties of plant fibres. In Japan, nettle was used mostly by rural, poor population since wild nettles were accessible for everyone and cloth made from its fibre was strong and durable (Edom, 2005).

Fibre content varies between (European) nettle clones from 5% fibre content in wild nettle up to 17 – 20% in cloned fibre nettle varieties (Bacci et al., 2013, Beckhaus, personal communication, January 22nd, 2019). Fibre yields vary depending on agronomic characteristics. Field trials in Austria found the fibre yields range from 335 – 411 kg ha^{-1} in first year to 743 to 1016 kg ha^{-1} second year (Bacci et al., 2013), 300–450kg of pure fibre per hectare in Germany (Lehne et al., 2002) or 9% of the 3.2 – 4.4 t ha^{-1} DMY in Finnish field trials (Galambosi, 2002).

Fibre qualities and characteristics

Nettle's fibre is characterized close to flax, however the fibre is finer creating more versatile cloth when finished (Harwood & Edom, 2012). Tensile properties and mechanical performance of nettle fibre is comparable to flax and higher than ramie (Asian nettle, *Boehmeria nivea*) which is similar bast fibre plant used in textiles and belongs to the genus *Urtica.* Regardless of characteristic similarities nettle fibre's weight is twice lower than cotton, hemp or flax (Bodros & Baley, 2008; Baltina et al., 2012, see details for characteristics from tables 2 and 3, Appendix).

Nettle fibre has mold resistant qualities and after bio technical soak (retting) processing mold wasn't able grow on the fibre. Testing did not specify the variance of mold species and further investigation on the matter is recommended (Hakkarainen, 2004). Nettle's antifungal properties have been studied also from transgenic resistance perspective (Does et al., 1999) and mold resistance at the University of Clausthal Zellerfeld by Ziegler and Ziegmann in composites (Beckhaus, personal communication, January 22nd, 2019).

Fibres can be extracted by chemical extraction, water retting, manually or by microbiological or enzymatic methods resulting different qualities of fibre. Nettle fibres are long, breaking the stems prior to biotechnical soak ruined majority of fibres in a study conducted in Finland (Hakkarainen, 2004). Microbiological retting (anaerobic plus aerobic bacteria) proved to produce higher quality fibres than water retting (Bacci et al., 2010). Finding environmentally sustainable solutions for retting process is crucial ensuring textile products over all sustainability through-out its life cycle (Di Virgilio et al., 2014; Kääriäinen, personal communication, May 3rd, 2016; Zekovic, 2017).

European nettle fibre spins best with support fibre from silk, viscose or wool with a ratio of 70% of nettle and 30% additional fibre, depending on the intended purpose. In the U.K. Nettle textile intended for upholstery purposes was mixed with wool and was awarded due its biodegradability and fire repellent qualities. 'G star' company used nettle mixed with cotton in a specific collection, besides that larger international companies are not known using the fibre (STING project, 2009; Hakkarainen, 2004; Suomela, 2015).

Raw fibre, woven textiles and products made of nettle yarn are available at commercial internet web platforms such as Etsy (2019), Amazon (2019) and Alibaba (2019). Majority of the textiles are woven from Himalayan nettle or 'allo' (*Girardinia diversifolia*) and are made mostly entirely in Nepal. Textiles from this origin are brownish and coarse, mostly due limited technical processes and resemble textiles made from hemp. Some companies in Europe sell more refined nettle textiles, however only NFC GMBH Nettle Fibre Company (2019) in Germany sells European nettle yarn produced by contracted farmers (Beckhaus, personal communication, January 22nd, 2019). An Italian company Maeko sells fine textiles made of nettle, however the fibre they use originates from China and is most likely ramie (Vismara, personal communication, January 18th, 2019).

Nettle as food

Interest towards different potential uses of nettle includes medicinal use and consumption as food. Several studies have been conducted regarding its health potential and value for human consumption in many countries like in Finland and Austria (Galambosi, 2002 and Vogl, 2003) as well as in Italy and Mediterranean, Iran and India (Amarellou et al., 2012; Butkute et al., 2015; di Vigrilio, 2013; Jan et al., 2017).

Nettle is often compared to spinach due its usability and characteristics. In Finland nettle has been used in soups and mixed with bread for additional nutritional value (Galambosi, 2004). Nettle's leaves are rich in minerals and micronutrients as well as iron and vitamin C. High amount of Vitamin C (see Appendix table 4 and 6) prevents nitrates from forming into harmful nitrite compounds. Nitrite levels can be reduced by boiling nettles prior to use. Nitrate concentration in the stem biomass can be nine (9) times higher than on leaves (Jan et al., 2017; Seuri & Väisänen, 1995; Nurmela, 1984, Weiss, 1992 & 1993). High composition of minerals (such as Mg, Fe, Ca, Zn, Mn and K) and Vitamins K, C and A can be a positive contribution for dietary enhancement but nettle's high composition of lead (see Appendix table 4 and 6) requires further investigation as similar levels are not found or mentioned elsewhere in literature (see nettle's nutritional value illustrated in Appendix, table 5).

In Finland dried nettle is marketed for human and animal consumption as a special dietary supplement and prices for human consumption vary between 166 – 178 euros per kilogram of dried nettle. For animals the price was between 93 euros per kilogram for horses and 56 euros per kilogram for dogs (Helsinki Wildfoods, 2019; Nokkoskauppa, 2019; Chia de Garcia, 2019) in online contents. In Amazon (2019), internationally popular platform 1 pound (lb) of Bulgarian dried nettle cost $25.38 or about $56 (49 euros) for a kilogram. The majority of the Finnish nettle supplements are collected wild nettle except the products from 'Nokkoskauppa' which farms nettle.

Medicinal and cosmetic use

Ethnographically nettle has been used in different soaks to prevent hair loss, dandruff and various skin problems such as acne and irritation. Nettles bioactive compounds have been seen preventing infection, stimulate wound healing and regulating inflammatory symptoms, and its prospects as wound dressing purposes are currently studied in Maastricht (see Maatsricht University , 2019). Nettle roots have been found to prevent prostatic hyperplasia and both roots and seeds are found to have antimicrobial and antioxidant properties.

Nettle's therapeutic benefits are attributed to its phenolic compounds however, the root extracts were poor in phenolics and contained chemicals such as fatty acids, scopoletin, sterols, isolectins and polysaccharides. Nettles anti-inflammatory, antimicrobial, diuretic, anthelmintic and hepatoprotective qualities have been tested and all aerial parts have been studied to medical purposes (Jan et al., 2017).

Nettles antifungal properties have been investigated separately from both material and medicinal perspectives (Jan et al., 2017; Broekaert et al., 1989).

Nettle as a farm input

Nettle has been studied as an animal feed component, where especially poultry and horses are mentioned frequently for example by Heeger in 1956 (Seuri et al., 1995) and Marghitas in 1990. Adding nettle in different ratios to feed has proven to increase the feed utilization and overall consumption with pigs in early and mature growth phases as well as with poultry and geese. Additional nettle in poultry feed refined the color and quality of meat, where additional nettle increased the feed intake of geese.

A comparative trial on pig feed was set in Poland to investigate the growth rate difference by additional antibiotics and herbal mix that consisted nettle, garlic (*Allium sativum*) and couch grass root (*Elytrigia repens, Agropyrum)*. The control group with additional herbal input in conventional component feed had 6 % better daily growth both in growing period and in fattening period. Use of antibiotics provided an additional 5% increase in the first growing period but not in the second. Additional herbal mixes in pig feed consisting nettle in the ratio of 1–50% increased the feed utilization ratio and overall consumption in all age groups based on studies done in Germany (Galambosi, 2004).

Nettle water, which is prepared by soaking different amounts of nettle in water from one to two weeks and then diluted has been researched from natural pesticide perspective in Hungary, Yugoslavia and Germany. Nettle water's impact was tested on different plant lice such as rose aphid (*Macrosiphum rosae*) and red spider mites (*Tetranychus urticae*). In the study conducted in Yugoslavia (Sekulovic et al., 1996) the liquid was found to have a toxic impact on the insects. In Hungary consistent use of nettle water on prunes (*Purunus domestica)* and red currant (*Ribes rubrum)* decreased the amount of abelgid populations such as red currant aphid (*Cryptomyzus ribis*) and the *Aphis spiraephaga* population in plants. Dead insects were found absent on observed plants therefore study suggests the nettle water's affect was evictive, not toxic. Similar results were found in Finland when studying the impact of nettle water to common cabbage's (*Brassica oleracea)* pests. Usage of nettle water reduced cabbage butterfly's (*Pieris brassicae*) egg laying on cabbage leaves. Nettle water did not stop the larvae consuming the leaves, the reducing impact was based on restraining laying eggs on the plants and therefore diminishing the overall amount of pests (Galambosi, 2004). In Spain nettle slurry is commonly used in organic farming as a fertilizer and pesticide and nettle slurry products are marketed commercially (Garmendia et al., 2018).

Planting nettle to over fertilized soils has been suggested in literature in addition to improve soil health, however, this may set constraints to the intended end use due possible change in nutritional composition.

2.3 Nettle as a carbon sink

Carbon is an essential basis of agricultural production where it enters the farm system from the atmosphere via plant photosynthesis, is fixed in the soil and exits as crops. Conceptually, including carbon sequestration and vegetative above ground carbon fixation (i.e. photosynthesis) within agri-food systems to future carbon markets is essential ensuring the control of greenhouse gas emissions and utilizing their full potential participating into climate actions. Technically all farming is carbon farming where CO^2 transfers from the atmosphere to plants which stabilize it in the soil and fixate it into above ground biomass. For sustainable agricultural production, neutralizing activity in arable land could decrease farming's over all environmental impact.

Nettle's carbon sink properties within dry matter yield have been researched and carbon stock in stems of nettle was found on average at 3719kg ha $^{-1}$. The difference between high fibre content nettle clones and wild nettle plants was significant in terms of carbon concentration per dry matter yield. The carbon stock of fibre nettle clones in above ground biomass was between 4882–5389 kg ha^{-1}, in comparison to wild stinging nettle, slightly over 2000 kg ha^{-1}. Fibre nettle clones proved to consume significantly larger quantities of atmospheric CO_2 (t ha^{-1}) in relation to biomass than mature forests (Butkute et al., 2015). According to the study, hemp and fibre nettle clones could be promising candidates contributing to the reduction of atmospheric GHG emissions. Nettle's carbon stock has been examined from the stems and shives, a residue from extracting the fibre also in Finland from the potential bio energy perspective suggesting the plant itself can act as a carbon sink where shives as well as the stem straw, an agricultural waste material concentrates carbon richly creating high heating value of the biomass. This residue material for example can be used as a farm input in energy production and wouldn't rule out commercial use of the leaves nor fibre. Nettle's atmospheric CO_2 emission consumption was quantified by fibre nettle clones 18,8 tons per ha^{-1} and the wild stinging nettle 7,7 tons CO_2 per ha^{-1} (Butkute et al., 2015).

Nettle's carbon sink characteristics are utilized in this study by assembling carbon sequestration rates into a hectare-based carbon balance in relation to the immediate emission points of the production. Determining these emission points helps to improve climate mitigation practices within the agri-food chain and possibly reduce costs both financially and environmentally. Next, I will review the theoretical basis of this study and how the additional environmental variables are assembled to conventional agricultural accounting practices.

3. Economic analysis of nettle production

Previous sections illustrated the agronomic principals of nettle production and its commercial prospects as a crop. From the literature review I move to theoretical principles of agricultural production economics and further to cost accounting and different factors of revenue. I approach them from a management accounting point of view and illustrate how these calculations can be used to investigate farm level productivity and its association to positive environmental measures. These sections provide background information for my empirical section where we form the economics of nettle production, the effects of input use and different factors on profitability at the farm level.

3.1 Production economics

Production economics illustrate the economic process that leads to output from using the available resources and means of production. Resources can be divided into non-current assets such as land and improvements, buildings, machinery and equipment and current assets such as crops and supplies as well as cash. Farm management controls the proportions in which these inputs are used to achieve goals within the economic and biological environment within the available technology. The farm manager (i.e. management) is primarily responsible in choosing how the farm resources are allocated to ensure the best possible economic result (James & Eberle, 2000). Theoretically, the economic optimum is chosen from the combination of production possibilities on the basis of input and output prices.

Theoretically all production possibilities are presented as $\mathbf{T}=\{(\mathbf{x},\mathbf{y}):\mathbf{x}\ \textbf{can produce}\ \mathbf{y}\}$ (1)

Where $\mathbf{x}=(x^{1},…..,x^{n})$ represents the inputs as a vector of a non-negative inputs and $\mathbf{y}=(y^{1},….,ym)$ is the output vector of m non-negative output values. **T** consists of all possible input-output combinations that can be executed (Sipiläinen & Ryhänen, 2012).

In this study, I will not use theoretical modelling of production possibilities. However, it is important to highlight the systemic nature of agricultural production and the environment in which the farmers make their decisions and what drives them. Theoretical modelling is useful in order to understand the production possibilities set within the given set of resources and to compare different lines of production within that set.

Agricultural production is a portfolio of physical production processes, where the relationship between revenues and costs determine farm's profitability and the outcome relies on the implemented technological process that creates the most beneficial outcome. Production technology is the technology set that represents all possible production combinations with the available resources. The term technology does not refer to any specific machinery or equipment but to any available line of production that is possible to obtain within the farm context. The assessed production technology in this study includes the available land, usable machinery and other inputs used in the production where the chosen production combinations are the conventional crop rotation and production of nettle.

As shown in figure 3.1 below the farm income is dictated by different factors, some of which are external and cannot be influenced by the farmer and some internal and under farmer's command. Prices of inputs and outputs are mainly external to the farm but productivity of the production process is to a large extent an internal factor.

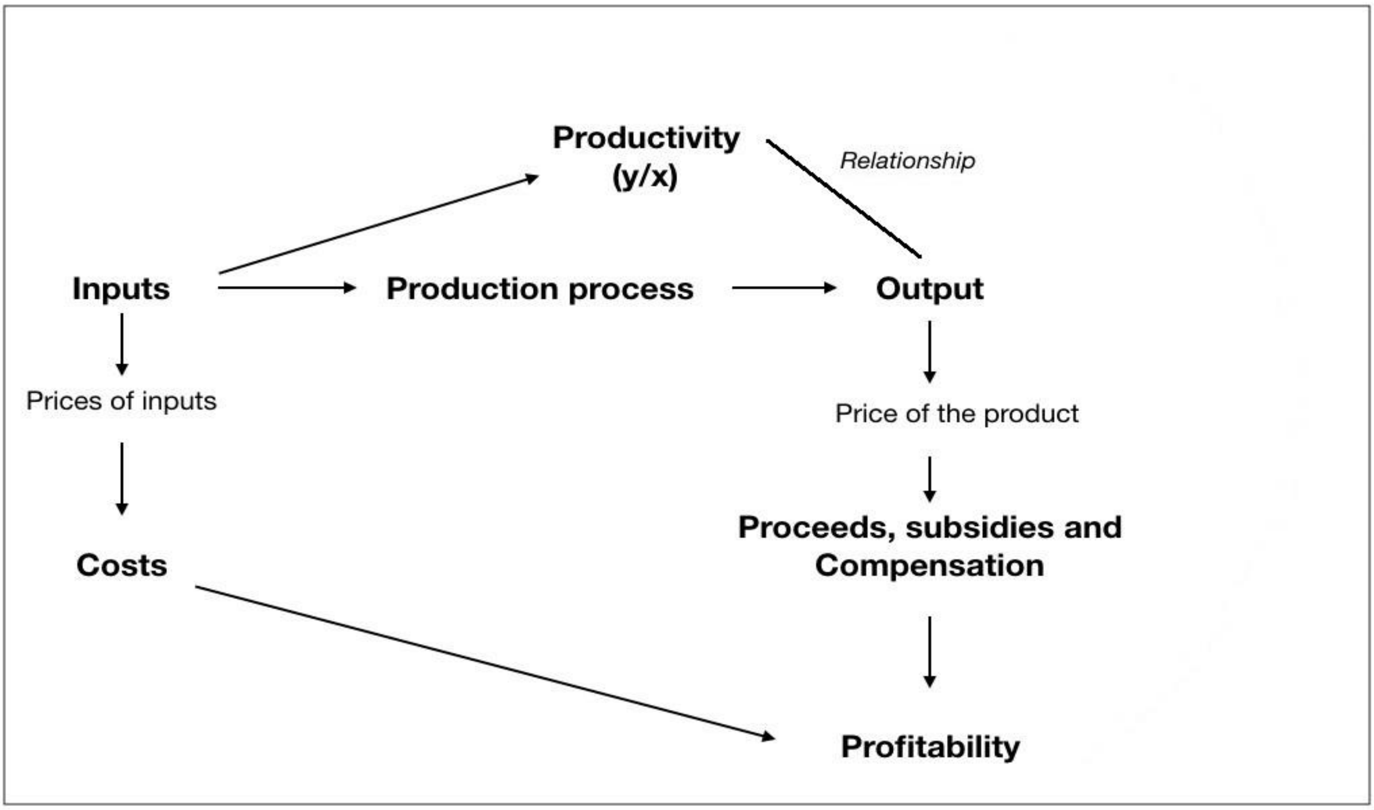


Figure 3.1. Agricultural production process and determination of profitability (Ryhänen & Sipiläinen, 2012, 86 retelled and translated from original by writer).

Most farms have multiple profit units (i.e. lines of production) contributing to the revenue. One of the most common partial productivity measure is yield per input unit, primarily generated by using the farm resources, i.e. physical inputs such as land, seeds, fertilizers and pesticides or fuel in machinery (James & Eberle 2000, 105, 108). Depending on the model the yield per hectare comparisons between farms can measure productivity in biological and physical terms as well as give information about farms management and efficiency when input data is available. The farm's productivity per profit unit increases when a greater output or- higher yields are achieved without affecting the amount of used inputs, i.e., increasing technical efficiency (i.e. management practices).

Marginal revenue illustrates the change in revenue by unit when the input is marginally increased. If the output increases proportionally in higher rate than inputs productivity increases. In relation, by improving utilization of inputs farmer can decrease costs or increase revenue (Ryhänen & Sipiläinen 2018, 85).

Farm revenue is obtained as a combination of revenue from agricultural subsidies and compensation schemes as well as sold produce (Sipiläinen & Ryhänen, 2012, 207). Farmers cannot influence market prices of outputs or inputs. Therefore, high productivity and optimal allocation of available resources are the main means to affect farm's profitability both in crop production and animal husbandry. The value of the produce depends on the crop, demand, quality and other factors. Specialized crops such as spices and organic products may generate lower biomass per hectare but this is compensated by higher output prices (James & Eberle, 2000).

In conventional agricultural economics, economies of size often reflects the assumption where larger size is associated with better profitability. The distribution of "fixed" costs to a larger quantity of output decreases the unit costs relatively by increased farm size. The advantage of bigger size capitalizes in the long term and is measured by cost elasticity or economies of size. In economies of size the larger output becomes cheaper to produce by unit over time (Kay et al. 2016, 163– 65). This has led to the structural change in agriculture internationally, where small family farms have often been replaced by large scale farms either operated by enterprises, private farmers or co-ops. Kay et al. (2016, 165) argue that machinery and equipment in smaller farms should perform multiple tasks and duties across profit units. Similarly, a farmer must cover multiple tasks and the machinery must be adequate to perform many different purposes. Further, Kay et al. argue that multiple tasks may increase personal stress and create inefficiency in management and utilization machinery. In contrast, it is argued that large scale units enable each worker to specialize on certain tasks and increase efficiency within the process. This study does not aim to assess the virtues of one farm type over another. However, understanding of different operating environments is important and where large-scale size farms can produce high volumes smaller enterprises have ability to adapt and specialize in a way that large necessarily cannot (Kay et al. 2016, 165).

The outcome of economic activity is primarily measured by generated profit. However, in the short term it's possible to have periods of low or even non-existent profit, if the activity is bound to turn profitable during a reasonable period in the future. For nettle, first years expected commercially non-viable output could be reimbursed by future's consistent relatively high yields. Management practices determine the efficiency of this process. Different origins of costs must be recognized and traced in order to increase capacity utilization and gain optimal results.

Next, I will review the basic elements of management accounting, cost accounting and different cost factors.

3.2 Management accounting and gross margin calculations

Economic decision making means a specific process where a plan is chosen over another based on economic factors. Internal accounting or management accounting means utilizing all available accounting information to create as informed picture of the company as possible and to plan for foresight prospects. The accounting information can be retrospective, assess present performance or target future opportunities (Neilimo & Uusi-Rauva 2005, 36; Haverila et al. 2009, 163).

The aim of cost accounting and management accounting is to explain how the company's revenues were comprised. Principally, input costs are the factors that created the revenue and can be determined and examined with analytical profit calculation methods.

Costs

The production function, the relationship between inputs and output, is the basis of cost planning. The cost of producing something in a given unit of time equals the product by the quantities of the needed inputs and their prices. Determining costs is based on operative functionality and is the first phase of planning. Different cost items must be traced reliably and the most important factors for the production to be carried out, such as raw materials and necessary amount of labor and have the higher order priority (Scheider 1952, 79, 139). Principal accounting practices are operated on a cost basis where cost is derived from the inputs use and input prices. In reverse, revenues are extrapolated from the produce when multiplied by the selling price. Revenues and costs are determined by relation with one another within the production process (see Appendix, formulas 2 and 3).

Costs are commonly divided into (1) fixed that remain stagnant regardless of the capacity use or (2) variable costs which change with production. When assessing costs, duration of the process is crucial as all costs are variable in the long run, including fixed costs. In agronomy, interest on operating capital is an example of duration of costs. Operating capital is the amount of funds that are tied to the process for its duration, usually 6 months. The interest rate represents the time cost of money, the compensation for fixing the current funds to the given process for the time period. When allocating costs to different profit units, the time cost of money is relevant for reliable results. An alternative for a farmer could be selling all the means of production and finding a different occupation.

Different types of calculations are used for different purposes and the most relevant for this study are cost accounting and gross margin calculations that show the pattern and structure of the production within the profit unit (i.e. line of production). The gross margin method is a simplified procedure that is based on the cost and divisions of costs into variable and fixed. Gross margin method shows at which rate the sales must be a) to cover the most immediate variable costs and b) to cover all – also fixed – costs. (Haverila et al. 2009, 166–170). Next, I will review these calculations and how they're effective.

Gross margin calculations

In agronomy, one of the most commonly used practice to control and plan production processes is the use of gross margin calculations. The method illustrates partial profitability of the farm entity showing generated gross margin when variable costs are deducted from revenues and final profit after deducting the fixed costs from the gross margin. Gross margins and cost accounting give information about the cost structure of a single profit unit and can be seen as partial productivity information regarding the farm's portfolio of profit units.

The first phase of the method is to recognize the variable input costs that are necessary in the production process. These inputs are seeds, fertilizers, pesticides and immediate running costs of machinery necessary for production. The sum of these costs is gathered into working capital percentage which shows the amount of capital that is tied to the immediate costs of production. The interest on working capital is obtained by multiplying the sum by the time factor and interest rate. Fixed costs represent the set of all farm resources that are used as means of production and cannot be offset in a short period of time. These resources cause costs inevitably whether they are used or not. The only way to avoid these costs is to sell the resources (Sipiläinen & Ryhänen, 2012, 112). These costs are the family labor input, interest on land and improvements, buildings, machinery and equipment. The recognition of costs is crucial when examining profitability of different production lines as fixed costs tend to overlap with different profit units.

In order to assess profitability of production the calculations need market information regarding the price of the output. Reliable information about nettle's market price is not available. Therefore, we carry on with cost-based calculation and the target price is set according to the break-even price. Due to the European Union Common Agricultural Policy (CAP) the Union subsidizes agricultural production. In countries with high production costs, such as Finland the subsidies form a large part of the revenue (Appendix, table 7; revenues, first section). Next, I will review some valuation methods and how the economic value of the environmental variables may be examined.

Environmental framework

The limits of land resources and increased demand for biomass originated materials and fuels has put pressure to increase the area of arable land for cultivation. When market mechanisms cause the utilization of land to serve the demand the result is indirect land use. The most significant share of environmental impacts of products is caused by land use change in order to meet the market demand for biomass products such as food, feed, fuel and other raw materials such as fibre (Mattila et al., 2011, 29).

Environmental costs and revenues

The cost based environmental impact assessment can be divided into direct and indirect where direct costs are immediate emissions from production. Indirect costs are emissions from the production of inputs which are used within the production, in this study the production of fertilizers. These indirect costs are environmental costs that appear elsewhere.

In agriculture large share of indirect and direct environmental costs originate from the use of fertilizers and pesticides. Systemically the consumption of inputs is declared as indirect energy consumption of the agricultural production. The major share of energy consumption of the process is caused from the manufacture of the inputs and reducing the input use affects the overall energy consumption by reducing the demand and decreasing the manufacture of these inputs (Ahokas, 2011, 13). Additionally, reducing inputs and increasing yield by enhanced agronomic management such as crop rotation and bio waste originating or recycled fertilizers can save resources and reduce immediate costs on the farm. In this study, the primary calculations are carried out using the immediate variables from the production plan such as tractor work and fuel consumption as well as conventional fertilizers.

By definition, environmental costs are related to the deterioration of natural resources due to economic activities. The costs can be caused by the activities of economic units or costs of the units independently whether they have actually caused the environmental impacts or not (OECD Glossary of statistical terms, 2019). These costs represent all expenditures that incur in order to prevent, remove or contain environmental contamination or distress. These expenses can be set to cover product design, manufacture, logistics and strategic foresight. Cost benefit analysis is used in environmental economics to study the utility ratio of reducing emissions and increasing positive or controlling environmental impacts. Carbon pricing is the result of these analyses when the price of carbon represents the compensation for the society of the environmental loss that’s caused by emissions and therefore represents the cost of emissions. In this study the price of carbon is used to monetize the positive environmental impacts of the production by using the ratio of quantified direct emissions caused by production and produced output’s carbon sink.

Environmental revenues

Adoption of agricultural practices like cover crops, agroforestry and introducing hedges have a significant potential in increasing carbon sequestration within agri-food systems. The technical potential of carbon sequestration within these systems in EU-27 is estimated to be 1566 million tons of CO_2-equivalent annually, corresponding 37% of all EU CO_2 equivalent emissions in 2007 (Aertsens et al., 2013). The environmental benefits can and perhaps should be studied from a revenue perspective. In this study, the valuation of positive environmental impacts is based on nettle’s carbon sequestration abilities (see figure 3.2, p. 22).

Due to the systemic nature of agriculture the effectiveness of carbon sequestration is dependent on soil characteristics and the amount and intensity of used inputs. Excessive use of fertilizers such as nitrogen may offset the positive effect through higher nitrous oxide (N_2O) emissions. Introducing nitrogen fixative crops was found to increase the carbon (C) accumulation, which, however, is progressively offset by higher N_2O emissions caused by nitrogen fertilizers over time (Lugato et al., 2018). Agrochemicals indirectly account 49% of the total energy consumption (3900kWh/ha) of conventional barley production (Ahokas et al., 2013, 7). The energy share of agrochemicals can be converted into CO_2-equivalents and so valuated by the emission to give the input an environmental value. From a farmer's perspective (soil) carbon sequestration is an additional environmental policy scheme that may increase bureaucracy and lacks realism. Soil carbon sequestration requires long term commitment which has proven to be problematic in the United States due to scattered landownership (In 2012 nearly 40% of farmland was operated by renting tenants) (Amundson & Biardeau, 2018).

The European Union emissions trading system (EU ETS) is the main market-based instrument for reducing emissions within the Union. The system allows companies to buy and sell emission allowances at the emission market offering a flexible and cost-effective way to allocate cuts of emissions. The value of carbon depends on many economic factors and price has varied from \$1 per tCO_2e to \$30 per tCO_2e (Waldén et al., 2019; EEX, 2016). These markets can hypothetically offer a price that allows us to examine the price for carbon sequestration as additional value creation within agricultural production. Environmental impacts of carbon sequestration in nettle production can be monetarily valued by using the carbon emission market pricing. This valuation method is hypothetical as carbon markets do not currently cover agri-food systems.

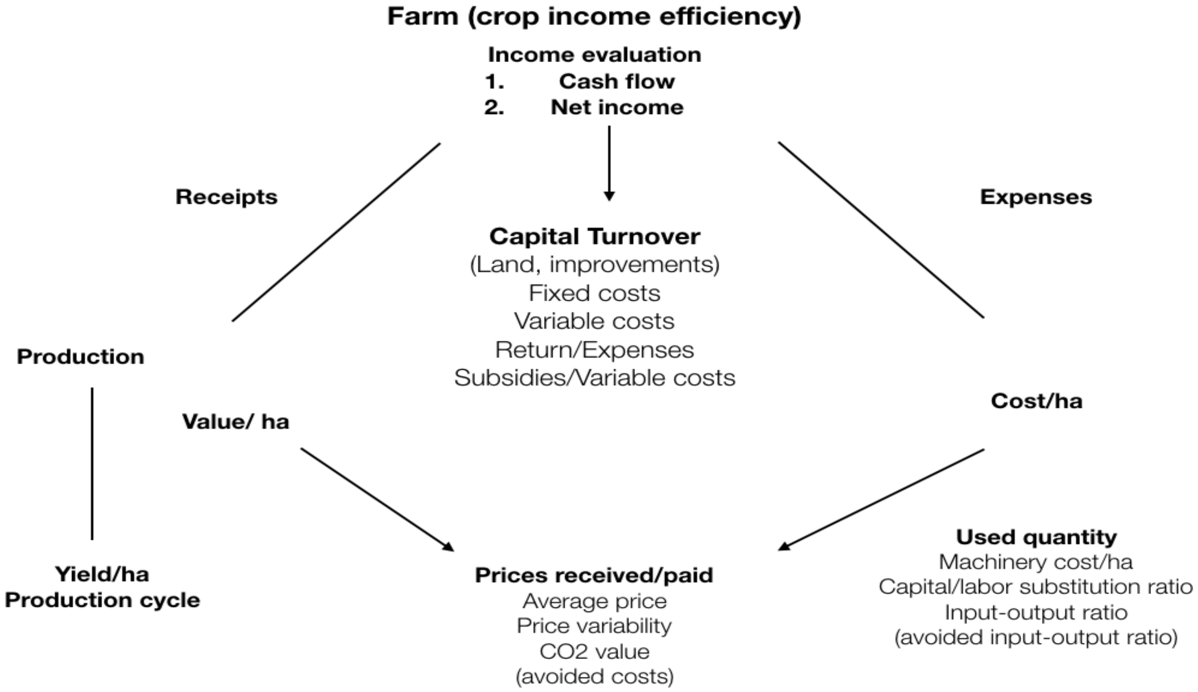


Figure 3.2. A graph based on James & Eberle (2000, 10).

Additionally, nettle's environmental benefit can be examined from the avoided cost perspective, where 'saved' inputs create revenue for the production. In this case, the revenue is formed in the opportunity cost basis, where avoided costs of alternative production are benefits of the current production - in this case nettle.

As a reference in this study the alternative crops are conventionally produced cereals and grass silage. Production costs and emissions generated from the farming activity are assessed from this basis.

Pricing the output

A company's pricing process is a multi-dimensional litigation, however the primary aim is to set a price that will cover the expenses and ensure profitability. A company must recognize its costs and constraints and set the price so that operations are secured. Cost based methods concentrate on covering the immediate production costs and market-based methods rely on the information of median market prices and therefore on competitors. Cost effective pricing is in principal based on actual costs but remarks the target profit of the company within the process (Neilimo & Uusi-Rauva, 2005, 185). In this study, we are assessing a specialty product that has currently limited but existing market. The following methods offer a starting point for forming the empirical calculations for profitability of nettle production.

Basic microeconomic theory approaches pricing from consumer perspective and from private enterprise point of view. For consumer the price is tied to the amount of utility the buyer is going to get from the purchase. This relationship determines how the consumer is to distribute personal wealth between the available goods. The theory assumes free market conditions, where prices affect the demand of the product so that higher prices decrease demand and lower prices increase it (Haverila et al., 2009, 183–184).

Industries, such as agriculture, belong to the economic sector where producers are price receivers and cannot influence current prices. Likewise, in industries that are tight in competition or otherwise regulated by price information about costs and expenses are used to determine profitability. Company's cost-effectiveness can be examined by subtracting assumed (or real) costs from the available market price data in order to verify profitability.

Gross margin-based pricing is calculated through variable costs caused by production and a separate profit margin which together form the target price for the product. Determining variable costs correctly and creating sufficient revenue to cover fixed costs sets additional requirements for the method. Full costing pricing includes fixed costs into the process (Neilimo & Uusi-Rauva, 2005, 185; Haverila et al., 2009, 186).

Agricultural production units are highly capitalized entities and farms hold large investments for running processes. Return on investment method is based on immediate variable costs but ensures that expected return for capital is targeted correctly (Haverila et al., 2009, 188). Gross margin calculations offer detailed information about the production process and method allows to include the required fixed factors into the price estimate to ensure sufficient price coverage for the product.

The value of the nettle output is difficult to assess without an extensive market research for relevant stakeholders. With a review to online selling platforms, the majority of nettle products were dietary supplements, cosmetics and textiles of different kinds. Prices of specialty food supplements do not tend to give reasonable price information to support farmers production decisions, as the market price is not likely to remain as high if the supply increases.

Crop characteristics can be taken into account when developing pricing mechanisms beyond production cost basis. The fibre content of wild nettle is remarkably lower than cloned variances which is the reason why pricing of the output could be related to the fibre content of the stem biomass. Most common nettles found in Finland amounted to 5 – 7% fibre content when cloned fibre nettle variations amounted up to 17%. Due nettles lower fibre content in comparison to flax and fibre hemp the farmer should receive higher compensation for the stem harvest (Lehne et al., 2002). In Finland, the production's break-even price for a kilogram of dry nettle was 0,29 euros, when annual yield of dry biomass was 4000 kg/ha. The production price of spinned nettle thread amounted to 27,80 euros (Hakkarainen, 2004, 17). For a comparison, production cost of fibre flax was 0,14 euros per kilogram (Valkonen, 2010). A suggestive price for the fibre could be illustrated by creating a ratio from the production cost and the percentage of fibre in the clone.

The expected leaf output can be theoretically predicted using the linear regression model. This method could be applied in estimating a hypothetical price for nettle's leaf output and compare the leaf yield per hectare to production costs. However, in this study I have chosen to concentrate on the immediate variable costs of the production and create suggestive prices based on the gross margin method, which should also cover fixed costs regardless of the end use. Ideally, multiple end uses would distribute the costs for example between stems and leaves separately.

3.3 Profitability

Economic performance is commonly assessed from accounting information using measures on liquidity, solidity and profitability (Haverila et al., 2009, 149). Several indicators for profitability will be used in this study. Profitability measures the performance of the physical production process and integrates it to prices through costs and revenues. This measure can be affected by factors such as quantity and prices inputs and biological characteristics such as soil fertility and weather. Expressed by accounting terms, a line of agricultural production represents a profit center of an enterprise which is responsible for a certain amount of revenues as well as expenses. Expenses may overlap with profit centers as some centers may act as inputs (or partial inputs) contributing to overall profit without creating revenue on their own (Kay et al., 2016, 334).

Generating profit is a principal aim for most economic activities and can be measured by the ratio of return to costs of these activities. Profit simply means the economic gain that is left after all the costs of the process are deducted from revenues. Agricultural productivity is measured by physical output in relation to physical inputs. Profitability is the crucial measure for farm performance, it eases access to financing and backs up plans for the future (Haverila et al., 2009, 150). Profitability can be improved by reducing unit costs, improving management and use of resources, and increasing value of the output.

A profit increase is often predicted to go in hand with increased productivity. However, high cost of inputs and low market prices of output and low soil quality have great effect on the margin. Higher yields do not necessarily increase profitability and growth in profitability can be achieved by re-allocating resources and finding new pathways for value creation.

The conventional profitability approach by van Loggerenberg and Cucchiaro (1981) (see figure 3.3) shows profit solely as an outcome between revenues and costs ignoring the possible drivers behind the generation of the prices and quantities.

Figure 3.3. Components of profitability, a conventional approach (van Loggerenberg & Cucchiaro, 1981).

Van Loggerenberg and Cucchiaro (1981) expanded the approach towards more systemic view where the relationships between the components and their ratio affect profitability that models the quality of the economic activities (see figure 3.4 below).

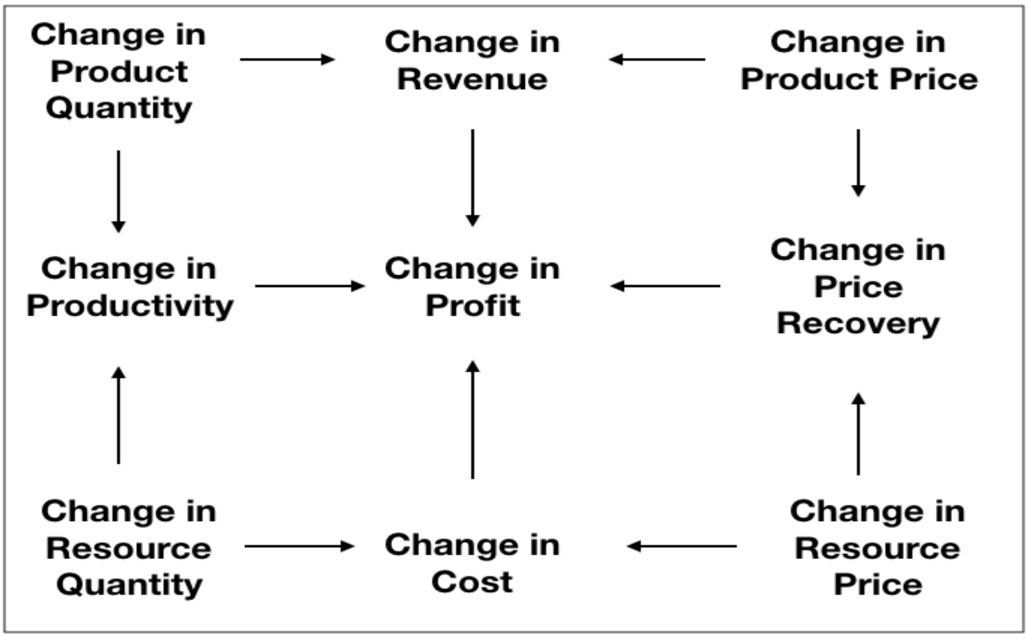


Figure 3.4. Multiple components of profitability (van Loggerenberg & Cucchiaro, 1981).

In the farm context, the variables presented in the left (the change in product quantity, the change in productivity and the change in resource quantity) are (in short term) bound by productivity that determines the physical set of production possibilities. Economical (short term) factors are presented on the right.

Due to the stagnant nature of input prices the technological set and allocation of resources are vital in finding the best possible outcome. Environmental indicators and variables represent the framework in which the profitability measures take place.

In this study, I will concentrate on the economic factors and investigate how selection of crops within the conventional agricultural framework will affect the profitability. Environmental performance is studied based on generated emissions by hectare.

4. Methods and data

This study is a deductive case study with quantitative characteristics. The deductive character is derived from the study's premises, in this case factors of production. In a deductive study the correctness of the variables determines the validity of the outcome, not the outcome itself (Halonen, 2009). This means that if the premises, data and characterization are correct, so is the outcome. The data of this study are formally numeric but due to its limits it cannot be representative as a statistical average.

The study is a case study which aims to describe a single event, situation or illustrate a case in part of a systemic matter or as a phenomenon (Ylitalo, 2015; Hirsjärvi et al., 2004, 126; Uusitalo, 1999, 76 – 77). The data represents production activities of nettle that takes place in Finland – or in comparable environments. Variables are suggestive for similar climates and production environments within the theoretical and analytical framework with similar crops and production scenarios. Similarly, the model to assess emission rates is assembled using Finnish references for the input use. The method is ideally extendable to other environments - with certain reservations.

This is a study about production costs and characteristics of nettle in the conventional farming framework. The data are gathered combining production data from previous research articles and assembled according to relevance to Finnish standard gross margin templates applied in 'TuottoPuntari' (ProAgria, 2019).

The setting makes the following assumptions;

> The gross margin is assembled in a hypothetical situation where a farmer is planning to start nettle production.
>
> There is no reliable market price for nettle output. Therefore, the price is set based on costs and environmental variables
>
> European Union Emission Trading System is expanded to cover agri-food systems by carbon sequestration conducted at arable land such that we apply expected prices of CO_2 equivalent emission permits as the environmental cost of emissions.

4.1 Data

The information and data about nettle were collected from the scientific literature and accessible databases. The data was collected and selected based on the relevance and reliability. Majority of the references are selected from authors that are academically focused on nettle with the intention to highlight the prospects of the crop for future reference and use. The framework of this study is constructed using academic literature, governmental reports and internationally acclaimed publications. Personal communications have been conducted in addition to clarify the assumptions regarding the most current markets for nettle and to predict its commercial prospects. The setting of this study is assembled from previous trial projects of nettle production. The combination of different projects and trials was selected to integrate the most relevant production data and environmental measures.

The data on nettle yields and agronomic management are from Finnish field trials by Galambosi et al. (2002). They combine Finnish agricultural characteristics and calculation methods. The data are collected from trials that were intended to fit conventional agricultural production. The results were compared to similar alternative nettle projects in Italy (Bacci et al., 2009), Germany (Organic production approach, Lehne et al., 2002) and Lithuania (Jankauskiene et al., 2016; Butkute et al., 2015) where findings are in line with each other suggesting universal similarity in characteristics of nettle's production. The variance in yield formation can be partially explained by natural constraints and soil characteristics. Nettle's input use is set according to literature (see Appendix table 1 for different levels of fertilizers and table 11 for nettle's chosen input level in this study). The level of nitrogen is set to 100 kg N/ha to ensure high potential biomass output but to preserve environmental effects at a reasonable level. Machinery is chosen on the basis of grass production technique as similar machinery has been used in Finnish field trials.

The machinery costs for each crop are derived using ProAgria's average variable (28,52 €/ hour) and fixed (16,93€/ hour). Variable costs (Variable) are standard costs that include labor and fuel cost and fixed costs (Fixed) include cost of maintenance and annual depreciation. The cost of dryer is derived from wheat drying machinery. The drying of nettle biomass can be conducted with a simple level dryer for hay. The cost of drying the nettle biomass was adjusted from drying cost of wheat (28% moisture content) setting the price accordingly by nettle's higher, approximate 50% moisture content (Veijola, personal communication, November 23rd, 2016). The cost of drying the biomass is hypothetical but includes the drying cost in the gross margin assessment.

The above ground carbon sequestration values are selected from field trials conducted in Lithuania, which has relatively comparable agronomic climate to (southern) Finland.

The assessment of environmental performance is carried out by modeling the N_2O and CO_2e emissions based on immediate variable input use of machinery and fertilizers. The immediate emission outflow from machinery use per hectare was calculated according to the performance per task using Technical Research Centre of Finland's (VTT) emission outflow estimates of CO_2e outflow g/l of fuel. The measures were adjusted accordingly to an average 90,5 kW capacity tractor. The fuel consumption estimate per task was assembled from Finnish averages by Ahokas et al. (2013). The model (see picture 9, Appendix) uses specific fuel assumptions (see specification table 8, Appendix) which are used to calculate the average rates of emissions. The same values are used to form and deliver all required official emission rates of Finland to the EU, United Nations (UN) and governmental statistics and are in line with international calculations guide provided by IPCC.

The indirect emissions from fertilizers are from Yara's online website and chosen due the current best available technology in terms of CO2e emission reduction at manufacture stage and the product's commonness in Nordic agricultural environment. The direct emissions from nitrogen fertilizer use is included accordingly to IPCC estimates (2006) suggesting every 100 kg of nitrogen applied to soil one (1) kilogram can be expected to be emitted as N_2O. An emission of 1 kg of N_2O equates to 1,57 kg gas, the impact of N_2O kilogram is equivalent to around 470 kg CO_2 (Jensen et al. 2011). Soil characteristics, management practices such as tillage and particularly climate conditions such as temperature and humidity affect the rate of N_2O emissions. These variables are not included as the aim of this study is to illustrate a robust estimate using desktop references. Both indirect and direct emissions were included in order to see the share of actual emissions from fertilizer use on the farm level.

4.2 Methods

The agronomic data was assembled into gross margin calculations and priced based on production factor averages provided by ProAgria – a Finnish rural consultancy organization. Variable costs of nettle production were derived from the literature and costs of chemical fertilizers and used machinery were adapted quantitatively to fit the agronomic management. Variable costs and quantities regarding seeds, chemical fertilizer and costs of machinery were adapted from Finnish standards also provided by ProAgria. In this study the calculations are assembled with the base assumption of an average larger scale farm with hundred (100) hectares of arable land and adequate machinery with an annual minimum of 600 h/year use rate.

The calculations proceeded in two phases. The first phase assembles nettle's production characteristics and input use according to gross margin based on Tuottopuntari (ProAgria,2019). All calculations were formed based on one (1) hectare of arable land per crop setting so that nettle occupies one hectare and the rotation set another, with different crops each year.

In the second phase two different sets of nettle's agronomic management estimates were done using TTS-manager program. The first calculation for nettle consisted of 1st year set up work under the assumption that the farmer would sow seeds directly into the soil (in the previous autumn) and fertilize later (in the following spring). The second 'n-year' set assumed a lighter, perennial agronomic management in order to assess the following years management requirement. Similar proceedings were done for the comparative setting, a four (4) year hypothetical crop rotation plan for annual spring oil crop, annual wheat and perennial grass (2 years).

The TTS-program's average default width and speed of machinery fit for the basis assumption of a large scale conventional farm. Machinery's declared default performance does not reflect reality on the field so the calculations were adjusted to present the actual utilized capacity giving the actual emission outflow per hectare (See formulas 5 and 6, Appendix) (Ahokas et al., 2013; Stolarski et al., 2018, 772). The actual capacity was assumed to be 70% on tractors and 75% on harvesters. The work requirement was calculated separately for all crops using the same capacities and fuel consumption estimates. The program gives precise duration estimate for the work performance per task. Both variable and fixed machinery costs were adjusted accordingly to estimated duration of each task by using the duration as a multiplier.

The CO_2e and N_2O outflow per hectare was derived based on using VTT's average emission rates (table 10, Appendix) for each of the individual crop's estimated field task's fuel consumption separately. The adjusted capacity and therefore fuel consumption gives more reliable emission outflow per field task (Ahokas et al., 2013). The fuel consumption was adjusted with duration similarly to costs in order to create a precise emission value per task. The fertilizer's emission value were calculated by indirect CO_2e emission from fertilizer manufacture provided by manufacturer and direct emission from applied nitrogen as soil N_2O emission accordingly to IPCC (2006). Additionally, the generated emissions are compared to hypothetical carbon sequestration of each crop in order to assess the possible carbon sink and complete emission balance of production.

5. Results

Based on the TTS-Manager estimates, nettle requires slightly over 7 hours of active machine work on field during the first year and around 4 hours in the following years. The task duration estimates for crops in rotation were in line with the ProAgria standard average work duration and cost estimates.

Nettle's estimated work load and derived emission outflow is illustrated in the table 5.1 below. Table 5.2 presents the TTS-manager estimates for each crop in a conventional crop rotation. The tasks (work) are set in order they are intended to take place in the production schedule.

Required machinery work by each task is indicated by capacity (kW); 128,6, 95,6 and 66 depending on a task. The fuel consumption of the machinery was estimated by using a multiplier (Multiplier), a value created by the ratio of VTT's average power per machine and a ratio of declared capacity (kW) and actual capacity (Capacity).

Table 5.1. Summary of nettle's machinery costs and emissions by TTS-manager estimates.

Nettle	**Work**	**km_h**	**ha**	**min/ha**	**h/v**	**%**	**kW**	**Capacity**	**Multiplier**	**Fuel l/ha**	**CO2e (F)**	**N2O (F)**	**Variable**	**Fixed**
1	Ploughing	6	1	84,5	1,41	0,20	128,6	90	1,16	25,1	112221,018	1,877582	40,2132	23,8713
2	S-spring harrov	8	1	21,5	0,72	0,10	95,6	60,2	0,91	5,4	9585,60342	0,160378	20,5344	12,1896
3	Sowing	8	1	35,2	0,59	0,08	128,6	90	1,45	7,6	17755,6191	0,297071	16,8268	9,9887
4	Field roller	7	1	24,7	0,41	0,06	95,6	60,2	1,03	4,5	5179,62561	0,086661	11,6932	6,9413
5	Pneumatic fert	6	1	14,1	0,23	0,03	66	33	0,37	2,9	673,547335	0,011269	6,5596	3,8939
6	Mowing	8	1	24,7	0,41	0,06	95,6	60,2	0,40	15,1	6800,82047	0,113785	11,6932	6,9413
7	Collection	8	1	31,2	0,52	0,07	66	33	0,32	3	1338,45219	0,022394	14,8304	8,8036
8	Transport	15	1	43,6	0,73	0,10	66	33	0,22	3	1290,64429	0,021594	20,8196	12,3589
9	Mowing (2)	8	1	24,7	0,41	0,06	95,6	60,2	1,19	15,1	20135,3393	0,336887	11,6932	6,9413
10	Collection (2)	8	1	31,2	0,52	0,07	66	33	0,43	3	1809,06925	0,030268	14,8304	8,8036
11	Transport (2)	15	1	43,6	0,73	0,10	66	33	2,80	3	16679,9369	0,279074	20,8196	12,3589
12	Collection (2)	8	1	31,2	0,52	0,07	66	33	0,37	3	1579,75061	0,026431	14,8304	8,8036
99	**Total**			410,2	7,2	1				**90,7**	195049,427	**3,263393**	**205,344**	**121,896**
1000	**Kg**										**195,049427**			
Nettle n-year	**Work**	**km_h**	**ha**	**min/ha**	**h/v**	**%**	**kW**	**Capacity**	**Multiplier**	**Fuel l/ha**	**CO2e (F)**	**N2O (F)**	**Variable**	**Fixed**
1	Pneumatic fert	6	1	14,1	0,23	0,06	66	33	0,43	2,9	775,494344	0,012975	6,5596	3,8939
2	Mowing	8	1	24,7	0,41	0,10	95,6	60,2	0,78	15,1	13130,9503	0,219695	11,6932	6,9413
3	Collection	8	1	31,2	0,52	0,13	66	33	0,43	3	1813,74989	0,030346	14,8304	8,8036
4	Transport	15	1	43,6	0,73	0,18	66	33	0,43	3	2546,22581	0,042601	20,8196	12,3589
5	Mowing (2)	8	1	24,7	0,41	0,10	95,6	60,2	0,78	15,1	13130,9503	0,219695	11,6932	6,9413
6	Collection (2)	8	1	31,2	0,52	0,13	66	33	0,43	3	1813,74989	0,030346	14,8304	8,8036
7	Transport (2)	15	1	43,6	0,73	0,18	66	33	0,43	3	2546,22581	0,042601	20,8196	12,3589
8	Collection (2)	8	1	31,2	0,52	0,13	66	33	0,43	3	1813,74989	0,030346	14,8304	8,8036
99	**Total**			244,3	4,1	1				**48,1**	37571,0962	**0,628606**	**116,0764**	**68,9051**
1000	**Kg**										**37,5710962**			

Table 5.2. Summary of costs and emissions of conventional crop rotation plan by TTS-manager estimates.

Spring oil crop		Work	km_h	ha	min/ha	h/v	%	kW	Capacity	Multiplier	Fuel l/ha	CO2e (F)	N2O (F)	Variable	Fixed
	0	Ploughing	6	1	84,5	1,41	0,301927	128,6	90	1,16	25,1	112221,018	1,877582	40,2132	23,8713
	1	S-spring harrowing (2x)	8	1	21,5	0,72	0,154176	95,6	60,2	0,78	5,4	8246,34706	0,137971	20,5344	12,1896
	2	Sowing	8	1	35,2	0,59	0,126338	128,6	90	1,16	7,6	14218,2771	0,237888	16,8268	9,9887
	3	field roller	7	1	24,7	0,41	0,087794	95,6	60,2	0,78	4,5	3913,1971	0,065472	11,6932	6,9413
	4	Pesticides	8	1	12,2	0,2	0,042827	95,6	47,8	0,62	1,8	606,274439	0,010144	5,704	3,386
	5	Harvesting	4	1	46,4	0,77	0,164882	164	123	1,59	15,1	50386,2045	0,843017	21,9604	13,0361
	6	Transport	15	1	4,4	0,07	0,014989	66	33	0,43	3	244,158639	0,004085	1,9964	1,1851
	7	Warm air drying		1	30	0,5	0,107066					0	0		
	99	**Total**			258,9	4,67	1				**62,5**	189835,477	**3,176158**	**118,9284**	**70,5981**
	1000	**Kg**										**189,835477**			
Wheat		**Work**	**km_h**	**ha**	**min/ha**	**h/v**	**%**	**kW**	**Capacity**	**Multiplier**	**Fuel l/ha**	**CO2e (F)**	**N2O (F)**	**Variable**	**Fixed**
	0	**Ploughing**	6	1	84,5	1,41	0,220313	128,6	90	1,16	25,1	112221,018	1,877582	40,2132	23,8713
	1	S-spring harrowing (2x)	8	1	21,5	0,72	0,1125	95,6	60,2	0,78	5,4	8246,34706	0,137971	20,5344	12,1896
	2	Sowing	8	1	35,2	0,59	0,092188	128,6	90	1,16	7,6	14218,2771	0,237888	16,8268	9,9887
	3	Herbicides	8	1	12,2	0,2	0,03	95,6	47,8	0,62	1,8	606,274439	0,010144	5,704	3,386
	4	Pneumatic fertilizing	6	1	14,1	0,23	0,04	66	33	0,43	2,9	775,494344	0,012975	6,5596	3,8939
	5	Pesticides	8	1	12,2	0,2	0,03	95,6	47,8	0,62	1,8	606,274439	0,010144	5,704	3,386
	6	Harvesting	4	1	47,9	0,8	0,13	164	123	1,59	15,1	52349,3034	0,875862	22,816	13,544
	7	Transport	15	1	4,4	0,07	0,01	66	33	0,43	3	244,158639	0,004085	1,9964	1,1851
	8	Warm air drying		1	30	0,5	0,08					0	0	14,26	8,465
	10	Collecting of straw	8	1	31,4	0,39	0,06	66	33	0,43	3	1360,31242	0,02276	11,1228	6,6027
	15	Collecting of straw	15	1	23,3	0,29	0,05	66	33	0,43	3	1011,51436	0,016924	8,2708	4,9097
	16	Storage of hay (crane)		**1**	79,7	1	0,16					0			
	99	**Total**			396,4	6,4	1				**68,7**	191638,974	**3,206332**	**154,008**	**91,422**
	1000	**Kg**										**191,638974**			
Hay/grass		**Work**	**km_h**	**ha**	**min/ha**	**h/v**	**%**	**kW**	**Capacity**	**Multiplier**	**Fuel l/ha**	**CO2e (F)**	**N2O (F)**	**Variable**	**Fixed**
	1	Ploughing	6	1	96,5	0,4	0,046404	128,6	90	1,16	25,1	31630,2	0,53	11,41	6,77
	2	S-spring harrowing (2x)	8	1	33,5	0,28	0,032483	95,6	60,2	0,78	5,4	3129,9	0,05	7,99	4,74
	3	Sowing	9	1	50,9	0,21	0,024362	128,6	90	1,16	7,6	5071,6	0,08	5,99	3,56
	4	Pneumatic fertilizer	6	1	14,1	0,23	0,026682	66	33	0,43	2,9	756,1	0,01	6,56	3,89
	5	Herbicides	8	1	12,2	0,2	0,023202	95,6	47,8	0,62	1,8	591,1	0,01	5,70	3,39
	6	Mowing	8	1	24,7	0,41	0,047564	95,6	60,2	0,78	15,1	12811,8	0,22	11,69	6,94
	7	Plumpling (x3)	8	1	24,5	1,22	0,141531	66	33	0,43	3	4151,2	0,07	34,79	20,65
	8	Plumping	6	1	16,8	0,28	0,032483	66	33	0,43	3	952,0	0,02	7,99	4,74
	9	Collection of hay	8	1	31,2	0,52	0,060325	66	33	0,43	3	1768,6	0,03	14,83	8,80
	15	Transport	15	1	43,6	0,73	0,084687	66	33	0,43	3	2482,6	0,04	20,82	12,36
	16	Collection of scattered hay (by hand, 2		1	234,8	3,91	0,453596					0,0	0,00		
	20	Fertilizer	6	1	14,1	0,23	0,026682	66	33	0,43	2,9	756,2	0,01	6,56	3,89
	99	**Total**			596,9	8,62	1				**69,9**	63345,1	**1,074272**	**134,3292**	**79,7403**
	1000	**Kg**										**63,3**			
Hay/grass 2nd year															
		Work	**km_h**	**ha**	**min/ha**	**h/v**	**%**	**kW**	**Capacity**	**Multiplier**	**Fuel l/ha**	**CO2e (F)**	**N2O (F)**	**Variable**	**Fixed**
	1	Pneumatic fertilizer	6	1	298,4	0,23	0,029754	66	33	0,85	2,9	1551,0	0,02595	6,56	3,89
	2	Herbicides	8	1	319,1	0,2	0,025873	95,6	47,8	1,24	1,8	1212,5	0,020287	5,70	3,39
	3	Mowing	8	1	339,8	0,41	0,05304	95,6	60,2	1,24	15,1	20852,5	0,348885	11,69	6,94
	4	Plumpling (x3)	8	1	360,4	1,22	0,157827	66	33	0,85	3	8510,7	0,142393	34,79	20,65
	5	Plumping	6	1	381,1	0,28	0,036223	66	33	0,85	3	1953,3	0,03268	7,99	4,74
	6	Collection of hay	8	1	401,7	0,52	0,06727	66	33	0,85	3	3627,5	0,060692	14,83	8,80
	7	Transport	15	1	422,4	0,73	0,094437	66	33	0,85	3	5092,5	0,085202	20,82	12,36
	8	Collection of scattered hay (by hand, 2		1	443,1	3,91	0,505821			0,00		0,0	0		
	9	Fertilizer	6	1	463,7	0,23	0,029754	66	33	0,85	2,9	1551,0	0,02595	6,56	3,89
	99	**Total**			3429,8	7,73	1				**34,7**	42799,9031	**0,71609**	**108,9464**	**64,6726**
	1000	**Kg**										**42,7999031**			

The hourly time estimate (h/v) represents proportionally the time requirement per field task and was used as multiplier in emission and cost calculations. Fixed and variable machinery costs were adjusted to each task based on the exact estimated duration of the task. Similar rationale was used in calculating the direct CO_2e and N_2O emissions generated from the machinery use.

Production costs

Significant amount of agricultural production costs come from fixed costs such as cost of land, machinery and facilities (see table 3.1 on page 17 and table 5.3). Variable machinery costs for crop production vary accordingly to task. Ploughing and extensive seed bed preparation work accounts for a proportionally large share of general machinery costs. Variable cost of machinery (Variable) used in this study, 28,52 euros per hour (ProAgria 2019) consists all costs of usage such as labor (16euros/hour), fuel (0,73 euros/litre) and motor oil. Fixed cost (16,93) includes maintenance, depreciation and insurances accordingly to annual minimum 600h use. With nettle and grass the cost of foundation work and for example seeds realizes only on the first year and could be distributed to future years.

Table 5.3. Variable and fixed costs of crops.

			1st	2nd	3rd	4th
Costs	**Crop rotation plan**		Oilseed crop **1**	Wheat **2**	Grass **3**	Grass **3**
	Yield	Kg/ha	2500	4000	5000	5000
	Price (revenue)	€/Kg	0,34	0,16	0,12	0,12
Variable	Fertilizer Yaramila Y2 **1** & **2,** Y3 **3**	Kg/ha	560	440	450	450
	Yaramila NK2 **3**	Kg/ha			390	390
	Fertilizer cost	€/kg	207	163	315	315
	Herbicides	€/kg			14	14
	Machinery	€/ha	164,5	182,5	134,3	91,6
	Seeds	€/ha	50,0	84,0	171	
	Drying	€/Kg	35,0	56,0		
	0,014	€/kg				
	Preservents & wrapping				31	31,0
	Working capital	0,5	210,7	214,8	310,2	203,3
	Interest	0,03	6,3	6,4	9,3	6,1
Fixed	Machinery	€/ha	70,6	91,4	79,7	64,7
	Dryer		48,0	48,0		
	Facilities	Kg/ha	129,0	141,0	181	181
	Land interest	€/ha	250	250	250	250
	Improvements	€/ha	166	166	166	166
	Total costs	€/ha	1126,4	1188,4	1337,4	1105,3
	Production cost		**0,45**	**0,30**	**0,27**	**0,22**
			1st	2nd	3rd	4th
Costs	**Nettle production**		Nettle	Nettle	Nettle	Nettle
	Yield	Kg/ha		4000	4000	4000
Variable	Fertilizer Yaramila Y2	Kg/ha	450	450	450	450
	Cost	€/Kg	210,6	210,6	210,6	210,6
	Machinery	€/ha	205,344	116,1	116,1	116,1
	Seeds	€/ha	229,5			
	Drying					
	0,025	€/kg		100	100	100
	Working capital	0,5	322,7	163,3	163,3	163,3
	Interest	0,03	9,7	4,9	4,9	4,9
Fixed	Machinery	€/ha	121,9	68,9	68,9	68,9
	Dryer	Kg/ha	48,0	48,0	48,0	48,0
	Facilities	Kg/ha	181,0	181,0	181,0	181,0
	Land interest	€/ha	250	250	250	250
	Improvements	€/ha	166	166	166	166
	Total costs	€/ha	1422,0	1145,5	1145,5	1145,5
	Production cost		**1422,0**	**0,29**	**0,29**	**0,29**

Accordingly to estimates, nettle's production cost is on the first year 1381 euros as the first year of production is assumed not to produce any output accordingly to literature references (Hakkarainen et al. 2002).

National subsidies for crop production are illustrated in table 5.4 below. Total revenue depends on production area (from AB to C4).

Table 5.4. Agricultural subsidies and payments (ProAgria. 2019).

Revenue/ha		Gross margin		
Direct payment (EU)[1]		122	1	123,7
Greening (EU)[2]		74,9	1	74,9
Natural Constraints (EU)[3]		212	1	212
Environmental payment (EU)[4]		112	1	112
National support (FI)[5]		0-55	1	0/55
Organic production (EU) [6]		0/160	1	0/160
Total revenue (areas[5])	**(AB)**		522,6	
	(C1)		515,99	
	(C2)	10	525,99	
	(C2p)	20	535,99	
			545,99	
	(C3)	30		
	(C4)	55	570,99	

1) Direct payments in AB-areas 123,70 and C-areas 110,6€/ha, additional changes may occur	110,6 €/ha, Additional changes may occur
2) Greening is predicted; AB-areas 74,9 and C-areas 65,39€/ha, additional changes may occur	65,39 €/ha, additional changes may occur
3) National constraints; AB-areas 212 and C-areas 237€/ha (+additional 60€ increase for livestock farms)	237 €/ha (+ additional 60€ increase for livestock farms)
4) Environmental payment; AB-areas 112 and C-areas 103€/ha (estimate)	103 €/ha (estimate)
5) National support additional payment/ha based on area	
6) Organic production payment 160€/ha not included this setting	
7) YaraMila NK2, reference based on literature recommendations, soil characteristics may affect choice of product	
8) Manure slurry price is set to 0€ due the cost of spreading the manure is close equivalent to the nutrient content.	

Nettle's first year unit- production cost is exactly the sum of variable and fixed costs as it is not reasonable to assume commercially viable output in the first year. Similarly, the unit production costs were calculated for conventional crops.

Environmental performance

Environmental performance of the production was assessed based on CO2e emission outflow of the work done on field and the emissions generated from fertilizing. The fertilizer emission amounts from indirect manufacture CO_2e emission and direct N_2O emission from application of nitrogen on field. The machinery's CO_2e and N_2O emission outflow is expressed by grams per litre of fuel. In the table

5.5 the difference of the conventional crop rotation plan and alternative nettle in terms of generated emissions and assumed biomass carbon sequestration.

Table 5.5. Emission estimates and annual carbon balance per hectare.

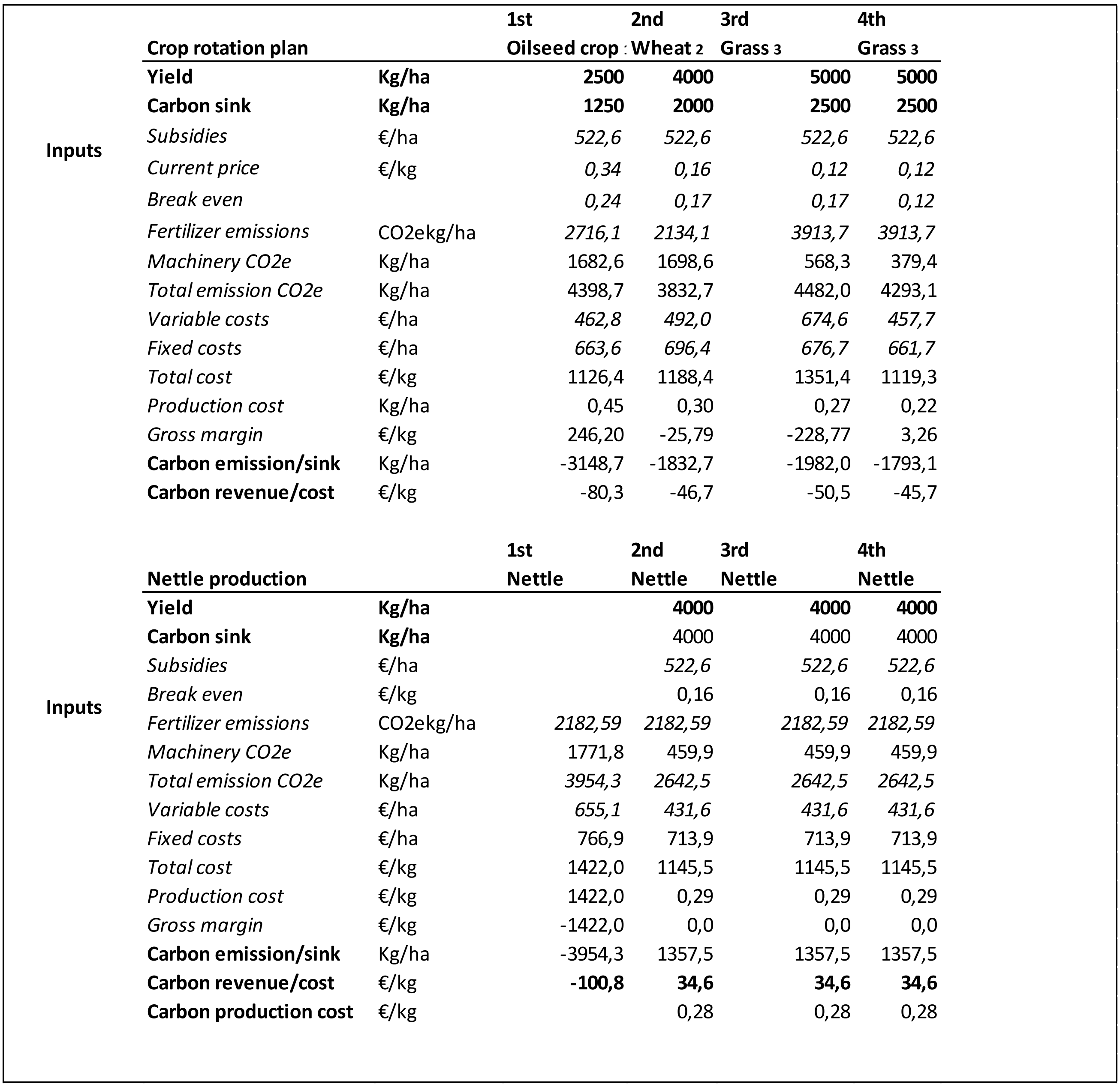
			1st	2nd	3rd	4th
	Crop rotation plan		**Oilseed crop [1]**	**Wheat [2]**	**Grass [3]**	**Grass [3]**
Inputs	Carbon sink	Kg/ha	1250	2000	2500	2500
	Fertilizer Yaramila Y2 [1] & [2], Y3 [3]	*Kg/ha*	*560*	*440*	*450*	*450*
	Yaramila NK2 [3]	*Kg/ha*			*390*	*390*
	Indirect Fertilizer CO2e/ha	Kg/ha	2016	1584	3024	3024
	Machinery CO2e	Kg/ha	189,8	191,6	63,3	42,8
	Machinery N2O converted to CO2e	Kg/ha	1492,8	1507,0	504,9	336,6
	Fertilizer N content	*Kg*	*149,0*	*117,0*	*189,3*	*189,3*
	Direct N fertilizer emission	*Kg/ha*	*1,5*	*1,2*	*1,9*	*1,9*
	Direct N generated CO2e	Kg/ha	700,1	550,1	889,7	889,7
	Total CO2e	Kg/ha	4398,7	3832,7	4482,0	4293,1
	Annual carbon balance		-3148,7	-1832,7	-1982,0	-1793,1
Total CO2e	**17 006,5**					
			1st	**2nd**	**3rd**	**4th**
	Nettle production		**Nettle**	**Nettle**	**Nettle**	**Nettle**
Inputs	**Carbon sink**	Kg/ha		4000	4000	4000
	Fertilizer Yaramila Y2	*Kg/ha*	*450*	*450*	*450*	*450*
	Indirect Fertilizer CO2e	Kg/ha	1620	1620	1620	1620
	Machinery CO2e	Kg/ha	238,0	164,5	164,5	164,5
	Machinery N2O converted to CO2e	Kg/ha	1533,8	295,4	295,4	295,4
	N content	*Kg/ha*	*119,7*	*119,7*	*119,7*	*119,7*
	DirectN Fertilizer emission	*Kg*	*1,2*	*1,2*	*1,2*	*1,2*
	Direct N generated CO2e	Kg/ha	562,6	562,6	562,6	562,6
	Total CO2e	Kg/ha	3954,3	2642,5	2642,5	2642,5
	Annual carbon balance		-3954,3	1357,5	1357,5	1357,5
Total CO2e	**11881,9**					
Emission change CO2e Kg/ha -5124,6						

Environmental performance

Carbon sink of the crops is calculated based on rough assumption of 50% carbon content of the complete above ground biomass yield (Ahokas, 1983; Regina, 2018). Nettle's carbon sequestration rate cover's the direct emissions caused by production and created an additional annual 1,3 ton carbon sink. Respectively, conventional rotation's carbon sequestration is not sufficient to cover emissions generated from the production when measured with above ground biomass.

Significant share of production's CO_2-e emissions are generated from the N_2O emissions. IPCC suggests 1kg of N_2O emissions stands equivalent of 470kg of CO_2 emissions (Jensen et al., 2011; IPCC, 2006). Generation rate of N_2O emissions depends on soil moisture, microbial activity and temperature, therefore in this study the highest available value, 1kg of N2O emissions per 100 kilograms of nitrogen was chosen due the theoretical setting.

Table 5.6.Crops costs and emissions.



			1st	2nd	3rd	4th
	Crop rotation plan		**Oilseed crop**	**Wheat**[2]	**Grass**[3]	**Grass**[3]
	Yield	**Kg/ha**	**2500**	**4000**	**5000**	**5000**
	Carbon sink	**Kg/ha**	**1250**	**2000**	**2500**	**2500**
Inputs	*Subsidies*	€/ha	*522,6*	*522,6*	*522,6*	*522,6*
	Current price	€/kg	*0,34*	*0,16*	*0,12*	*0,12*
	Break even		*0,24*	*0,17*	*0,17*	*0,12*
	Fertilizer emissions	CO2ekg/ha	*2716,1*	*2134,1*	*3913,7*	*3913,7*
	Machinery CO2e	Kg/ha	1682,6	1698,6	568,3	379,4
	Total emission CO2e	Kg/ha	4398,7	3832,7	4482,0	4293,1
	Variable costs	€/ha	*462,8*	*492,0*	*674,6*	*457,7*
	Fixed costs	€/ha	*663,6*	*696,4*	*676,7*	*661,7*
	Total cost	€/kg	1126,4	1188,4	1351,4	1119,3
	Production cost	Kg/ha	0,45	0,30	0,27	0,22
	Gross margin	€/kg	246,20	-25,79	-228,77	3,26
	Carbon emission/sink	Kg/ha	-3148,7	-1832,7	-1982,0	-1793,1
	Carbon revenue/cost	€/kg	-80,3	-46,7	-50,5	-45,7

			1st	2nd	3rd	4th
	Nettle production		**Nettle**	**Nettle**	**Nettle**	**Nettle**
	Yield	**Kg/ha**		**4000**	**4000**	**4000**
	Carbon sink	**Kg/ha**		4000	4000	4000
	Subsidies	€/ha		*522,6*	*522,6*	*522,6*
Inputs	*Break even*	€/kg		0,16	0,16	0,16
	Fertilizer emissions	CO2ekg/ha	*2182,59*	*2182,59*	*2182,59*	*2182,59*
	Machinery CO2e	Kg/ha	1771,8	459,9	459,9	459,9
	Total emission CO2e	Kg/ha	*3954,3*	*2642,5*	*2642,5*	*2642,5*
	Variable costs	€/ha	*655,1*	*431,6*	*431,6*	*431,6*
	Fixed costs	€/ha	766,9	713,9	713,9	713,9
	Total cost	€/kg	1422,0	1145,5	1145,5	1145,5
	Production cost	€/kg	1422,0	0,29	0,29	0,29
	Gross margin	€/kg	-1422,0	0,0	0,0	0,0
	Carbon emission/sink	Kg/ha	-3954,3	1357,5	1357,5	1357,5
	Carbon revenue/cost	€/kg	**-100,8**	**34,6**	**34,6**	**34,6**
	Carbon production cost	€/kg		0,28	0,28	0,28

The production's environmental profile is assessed from a hypothetical setting where farmland is included in European emission trading system. The current price (25,50 € per CO2e ton) for secondary market emission allowances is derived online from EEX (Online content revised 25.5.2019).

During the first year without output nettle production creates estimated 4 tons of CO2e emissions by agronomic practices. Using the EEX price this creates an additional 100€ cost per hectare in the first year, after which nettle's carbon sink creates annual 34 euro revenue per hectare, decreasing the production cost of nettle slightly. For conventional rotation, carbon pricing creates additional cost for every crop, ranging between 75–45 euros per hectare.

Pricing the output

One aim of this study was to find a break-even price for production of nettle, at which farmer could cover the costs of production. The production cost of each estimated crop was shown in the previous table 5.6. The break-even cost includes the national subsidy payments.

Nettle’s break-even cost per kilogram with subsidies is 0,16 euros per kilogram, when measured by dry biomass, 4000kg. This price would be approximately half, if calculated with fresh produce which would make sense when the aim is to utilize the leaf yield fresh. The break-even cost was similarly calculated to conventional rotation. Nettle’s production cost is slightly lower than wheat and similarly higher than grass. Oilseed crop’s current price is significantly higher than break-even point and it is the only clearly profitable crop in the setting. Nettle production could turn profitable with relatively low price’s especially if the whole crop is utilized.

6. Discussion

Significant share of production costs in all reference crops come from fixed costs such as land, annual fixed costs of land, machinery and facilities. Ploughing accounts significant share of fuel consumption and emissions in relation to other tasks. Farm level selection of crops and adequate machinery should be in line to distribute the costs to multiple profit units (i.e. lines of production, crops).

Interestingly, based on the Finnish Natural Resources Institute Finland the average cereal crop farm's CO_2e emissions caused by energy use per hectare are significantly lower in comparison to this study's results. The approximate 20% energy share of the total CO_2e emissions per hectare amount around 600kg of CO_2e in organic farming and around 500kg of CO_2e in conventional. Luke's estimate does not specify whether the energy use includes fertilizers indirect or direct emissions.

Table 6.1. Average greenhouse gas emissions (Natural Resources Institute Finland, 2019).

	Cereal Farms	Cereal Farms
Greenhouse gas emissions	Organic	Conventional
Ton CO2 ekc per arable land	2016	2016
Farms represented	240	13 300
Farms in sample	5>n>10	150>n>160
Arable land	183	61
Livestock units	1	0
Economic size, SO euro	102.858	32.002
GHG emissions from agriculture	0,95	0,83
Methane emissions from enteric fermentation	0,00	0,00
Methane emissions from manure management	0,00	0,00
Nitrous oxide emissions from manure management	0,00	0,00
Nitrous oxide emissions from soils	0,79	0,73
Carbon dioxide from liming	0,16	0,09
GHG emissions from land use	1,74	1,52
Carbon dioxide emissions from organic soils	1,74	1,52
Carbon dioxide emissions from energy use	0,21	0,20
Total Emissions per Hectare	2,89	2,55

Luke's energy consumption estimate is close to the machinery emission estimates of this study. Thus, fertilizers additional share is presumably not included in the LUKE estimate. Estimation of the emission outflow based on machinery use for specific crops could be a useful tool when assessing agriculture's and each produce's environmental performance. Further, when the average carbon sequestration rate of the above ground biomass is known, the estimation methods could be applied to create farm specific carbon balances.

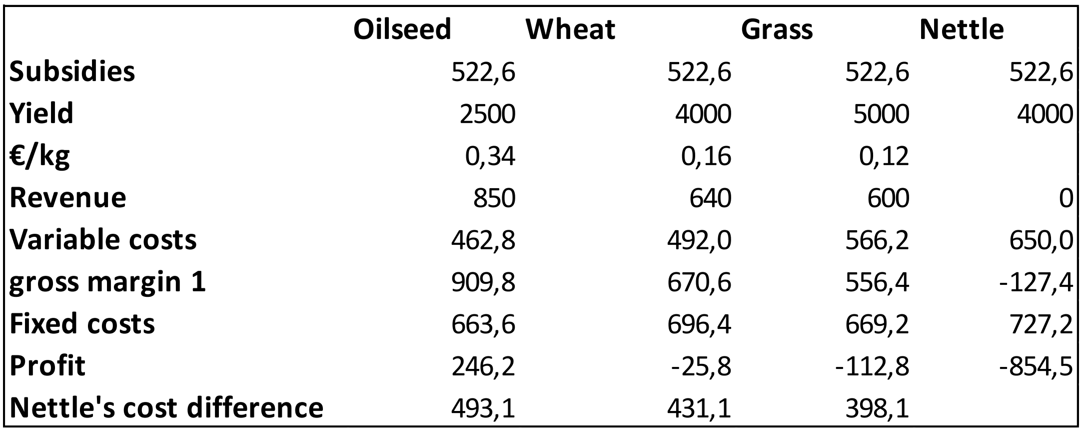
The fibre content of nettle correlates significantly with the stem length (Lehne et al., 2002). This correlation could be tested against nettle's carbon sequestration rate and used further as a tool in the valuation of output. The correlation coefficients between aboveground biomass growth and carbon sequestration (i.e. efficiency in photosynthesis) could offer similarly usable variables for further carbon sequestration modelling.

Conceptually, the carbon revenue has increased farmers profitability in comparison to monocultures in sub-Saharan agro-forestry context (Waldén et al., 2019). Modelling crop specific emission outflows could clarify actual emission points of agricultural production and help to assess both societal and environmental impact of the production of raw materials as well as to evaluate environmental performance of specific products.

The assessment of nettle's (or any alternative crops) environmental performance can be based on the opportunity cost which evaluates the amount of saved resources (i.e. inputs, emissions) when production of one is chosen instead another.

Choosing nettle over the conventional crop rotation saves around 1,3 tons of CO2e emissions per hectare however, costs around 400 euros more than conventional crop-plan in the current 4-year setting (see table 5.2 below).

Table 6.2 Cost differences between crops.



	Oilseed	Wheat	Grass	Nettle
Subsidies	522,6	522,6	522,6	522,6
Yield	2500	4000	5000	4000
€/kg	0,34	0,16	0,12	
Revenue	850	640	600	0
Variable costs	462,8	492,0	566,2	650,0
gross margin 1	909,8	670,6	556,4	-127,4
Fixed costs	663,6	696,4	669,2	727,2
Profit	246,2	-25,8	-112,8	-854,5
Nettle's cost difference	493,1	431,1	398,1	

Nettle's high variable and fixed costs are explained by the first non-commercially productive year. In the table 6.2 the costs of nettle (and 2-year grass production) are annualized so that the first years cost are included. The annual production costs are likely to reduce over time as nettle can be assumed to produce sufficient yields for as long as ten years without a decline, distributing the 1st year's set up costs further (Hakkarainen, 2004).

In the case of nettle, low environmental impact in this study's comparison to selected crop-portfolio show the commercial potential of the perennial fibre crop that could be used to replace imported fibres in textiles and composites (Akgul, 2013). The low environmental impact is commercially valuable characteristic and the link between costs and low environmental impact could encourage farmers to adopt nettle and other environmentally viable crops due lower costs and perhaps higher profitability. Waldén et al. (2019) see carbon modelling within the agricultural production as a way to hypothetically improve agronomic management practices both by promoting sustainable production and improved profitability.

Specific CO_2e measures of raw material production are commercially viable information to manufacturing companies that are increasingly required to provide data on the environmental performance of their products and services. Emission savings data derived from the cultivation phase could offer economically valuable commodity enabling farmers to sell ‘carbon neutral’ materials and processes.

7. Conclusion

Nettle has great environmental and commercial prospects in diversification of current portfolio of agricultural crops. Nettle’s low input use and cost structure indicate that farmers with adequate machinery could adopt he crop with relatively low costs and access the market without significant risk. The commercial potential of nettle relies on the amount of available output, as subsidies are likely to cover the production costs after the first year, farmers could start producing nettle while market is still evolving.

TTS-Manager program performed well for estimating work requirements and specific values per task enabling further modelling. The modelling estimates do not reflect reality, and actual work requirement of the production is likely to vary. However, the program’s results give numeric data of the production process and enabled to quantify the specific emission points of the production.

As nettle does not have comparable market price to other conventional agricultural commodities, assessing profitability of production based on environmental performance show’s that hypothetical carbon price could improve nettle’s profitability, however not entirely cover the total costs of production.

Calculating environmental performance generated quantitative data regarding different phases of agricultural production. The significant share of fuel consumption and emission outflow of ploughing and harrowing shows how management practices may impact to emissions and costs generated from production. On the farm level, the differences may seem insignificant or small, but on societal level less intensive cultivation practices could sum up significant savings on emissions.

This study excluded many factors that may affect the farm’s environmental performance. However, recognizing some emission points can help farmers to brand and characterize the value of their output more specifically and contribute to emission mitigation in a commercially viable way.

Different methods for pricing of outputs in the basis of environmental performance could be interesting aspects for further investigation. Also vast amount of statistical farm-level production data could offer an interesting opportunity for further emission modelling.

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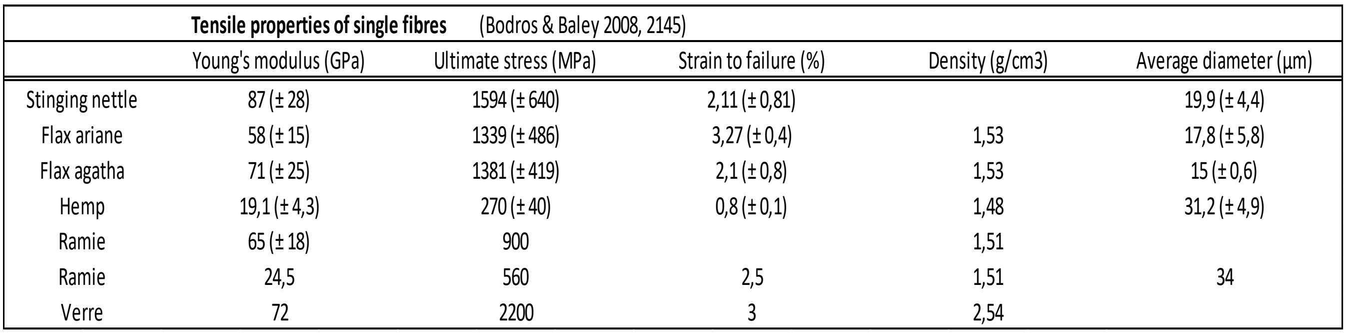
Appendices

Table 1. Nettle's fertilization (for organic production see also Vogl and Hartl 2003).

	Amount	Type	Impact	Source	Additional	Price estimate
	3 - 22 mM	Nitrate - N	No impact on biomass	Fetene et al. 1993		
	3 - 22 mM	Nitrate - N	Stem length 2x, leaf area 2x	Rosnitschek-Schimmel 1982		
	3 - 22 mM	Ammonium - N	No impact on stem length, leaf area 2x	Rosnitschek-Schimmel 1982		
	3 - 15 mM	Nitrate - N	No impact on biomass			
			Biomass higher than with 1 or 22 mM			
	200Kg N/ha		400 g DMY/m2	Weiss 1992		
	440Kg N/ha		650 g/m2 DMY (1990)			
			600 g/m2 DMY (1991)			
	40Kg N/ha or 200kg processed chicken manure (=96Kg N/ha)		25 - 35% increase in DMY	Galambosi 1991, 1994		
	16:16:16, N-P-K (Chemical nitrogen)	200 Kg/ha		Jankauskiene & Gruzdeviene 2016	Application in early May	
	40Kg N*ha*a (Crimson clover), 100Kg K*ha*a (stonemeal)	Crimson clover & stone meal nitrogen fixation	300kg pure yield/ha	Lehne, Schmidtke & Rauber 2002	1st. Trial - All applied in may, compared to control (no fertilization), measured at ripeness	
	100Kg N/ha*ha*a	Organic compost	350 kg pure fibre/ha		2nd Trial - Yearly average fibre yields from 150kg to 460 kg/ha	
	70 + 30 kg N*ha*a	Liquid and solid manure	500 kg pure fibre yield/ha		Stem dry matter of fibre content (%) ranged from 25 - 40	
	120 - 150 kg N/ha	Chemical nitrogen	highest stem biomass (440g/m) by NPK (125-50-312)	Galambosi, Hakkarainen & Vilpunen 2002		
	60 - 80 kg N/ha	Chemical nitrogen	With 150 - 180kg K2O/ha and 40-50kg P2O5/ha	Dreyer & Mussing 2000		

Table 2. Tensile properties of nettle fibre (Bodros & Baley 2008, 2145).



	Tensile properties of single fibres	(Bodros & Baley 2008, 2145)			
	Young's modulus (GPa)	Ultimate stress (MPa)	Strain to failure (%)	Density (g/cm3)	Average diameter (µm)
Stinging nettle	87 (± 28)	1594 (± 640)	2,11 (± 0,81)		19,9 (± 4,4)
Flax ariane	58 (± 15)	1339 (± 486)	3,27 (± 0,4)	1,53	17,8 (± 5,8)
Flax agatha	71 (± 25)	1381 (± 419)	2,1 (± 0,8)	1,53	15 (± 0,6)
Hemp	19,1 (± 4,3)	270 (± 40)	0,8 (± 0,1)	1,48	31,2 (± 4,9)
Ramie	65 (± 18)	900		1,51	
Ramie	24,5	560	2,5	1,51	34
Verre	72	2200	3	2,54	

Table 3. Nettle fibre characteristics (Baltina et al. 2012; Bacci et al. 2009).

	Nettle fibre characteristics		
Weight	0.72 g/cm3	Cotton, Hemp, Flax (1.5 - 1.54g/cm3)	
Chemical composition	Cellulose 79 - 83.5%	Hemicellulose 7.2 - 12.5%	Lingin 3.5 - 4.4%
Average fibre length	43 - 58mm	Finer fibres on the top	

Table 4. Nutritional comparison of nettle and spinach by some vitamins and minerals (Galambosi 2004; Lahtinen 1988). Translated from original by writer.

100g of edible parts		**Nokkonen/Nettle**	**Pinaatti/Spinach**
Vesi	Water	82g	93g
Tuhka	Ash	2.6g	2.0g
Typpi	Nitrogen	1.0g	0.32g
Kalium	Potassium	670mg	470mg
Kalsium	Calcium	590mg	88mg
Magnesium	Magnesium	86mg	59mg
Fosfori	Phosphorus	92mg	30mg
Rikki	Sulphur	120mg	32mg
Rauta	Iron	4.4mg	1.3mg
Mangaani	Manganese	3.1mg	1.7mg
Sinkki	Zinc	1.7mg	0.91mg
Kupari	Copper	270 µg	110µg
Molybdeeni	Molybdenum	<10µg	<10µg
Koboltti	Cobalt	3 µg	1µg
Nikkeli	Nickel	50µg	20µg
Kromi	Chromium	18µg	2µg
Fluori	Fluoride	140µg	49µg
Seleeni	Selenium	<0.2µg	<0.2µg
Arseeni	Arsenic	2µg	2 µg
Elohopea	Mercury	0.5µg	0.4 µg
Kadmium	Cadmium	1µg	15µg
Lyijy	Lead	110 µg	11µg
C-vitamiini	Vitamin C	130mg	60mg
B2-vitamiini	Vitamin B2	20mg	60mg
K-vitamiini	Vitamin K	0.04mg	0.24mg

Table 5. Nutritional value of nettle (Jan et al., 2017; USDA, 2013).

Constituents	Unit	Amount (per 100g)
Water	g	87,67
Energy	kcal	42
Protein	g	2,71
Total lipid (fat)	g	0,11
Carbohydrate, by differece	g	7,49
Fiber, total dietary	g	6,9
Sugars, total	g	0,25
Minerals		
Calcium, Ca	mg	481
Iron, Fe	mg	1,64
Magnesium, Mg	mg	57
Phosphorus, P	mg	71
Potassium, K	mg	334
Sodium, Na	mg	4
Zinc, Zn	mg	0,34
Vitamis		
Thiamin	mg	0,008
Riboflavin	mg	0,160
Niacin	mg	0,388
Vitain B-6	mg	0,103
Folate, DFE	µg	14
Vitamin A, RAE	µg	101
Vitamin A, IU	IU	2011
Vitamin K (phylloquinone)	µg	498,6

Khan et al. 2016; USDA National Nutrient Database for Standard Reference, release 26 full report 2013)

Table 6. Nutritional value of nettle for human consumption per 100g of edible content (Galambosi, 2004; KELA1993) Translated from original by writer).

Ravintoaine	**Nutrient**	**Content**	**Ravintoaine**	**Nutrient**	**Content**
Energia	Energy	149^1 kJ	Tiamiini (B1)	Thiamin	0.20mg
		36 kcal	Riboflaviini(B2)	Riboflavin	0.15mg
Vesi	Water	83g	Niasiiniekv.		1.7mg
Proteiini	Protein	5,9g	Niasiini	Niacin	0.80mg
Rasva	Fat	0,7g	Pyridoksiini (B6)	Pyridoxin	0.22^3mg
Rasvahapot	**Fatty acids:**		B12-vitamiini	Vitamin B12	0 µg
Tyydyttyneet	Saturated:	0,09g	Foolihappo	Folic acid	220^3µg
Palmitiinihappo	Palmitic acid	0,07g	Pantoteenihappo	Pantothenic acid	0.30^3mg
Steariinihappo	Stearic acid	+ g	Biotiini	Biotin	1.6^3µg
			C-vitamiini	Vitamin C	175mg
Kertatyydyttymättömät	**Single unsaturated**	0,04g	Tuhka	Ash	2.6g
			Natrium	Sodium	1.0mg
Monityydyttymättömät	**Polyunsaturated**	0,43g	Kalium	Potassium	67 µg
Linolihappo	Linoleic acid	0,07g	Kalsium	Calcium	590mg
Linoleenihappo	Linolenic acid	0,31g	Magnesium	Magnesium	86mg
Kolesteroli	Cholesterol	- mg	Fosfori	Phosphorus	92mg
Hiilihydraatti	Carbohydrate	1.3g	Rikki	Sulphur	120mg
Tärkkelys	Starch	0g	Pii	Silicon	120mg
Glukoosi	Glucose	0,6g	Mangaani	Manganese	3.1mg
Fruktoosi	Fructose	0,5g	Sinkki	Zinc	1.7mg
Laktoosi	Lactose	0g	Kupari	Copper	270µg
Maltoosi	Maltose	0g	*Molybdeeni*	*Molybdenum*	*<10µg*
Sakkaroosi	Saccharose	0,2g	Koboltti	Cobalt	3µg
			Nikkeli	Nickel	50 µg
Ravintokuitu	Fibre	4,1g	Kromi	Chromium	18 µg
Polysakkaridit:	**Polysaccharide**		Fluori	Fluoride	140µg
Vesiliukoinen	Water-soluble	1,4g	Jodi	Iodine	<1µg
Veteen liukenematon	Water- insoluble	0,8g	Seleeni	Selenium	(<0.2)µg
Selluloosa	Cellulose	1,7g	Arseeni	Arsenic	2 µg
Lingiini	Lignin	0,2g	Strontium	Strontium	1.4mg
			Rubidium	Rubidium	0.32mg
A-Vitamiini (RE)	Vitamin A	358 ^5 µg	Alumiini	Aluminium	6.2mg
Retinoli	Retinol	0 ^5 µg	Boori	Boron	0.65mg
ß-karoteeni	ß-carotene	2150 ^5 µg	Bromi	Bromine	2.0mg
D-vitamiini	Vitamin D	0 µg	Elohopea	Mercury	0.5µg
E-vitamiini (α-TE)	Vitamin E	1,68mg	Kadmium	Cadmium	1 µg
α - tokoferoli	α - tokoferol	1,64mg	Lyijy	Lead	110µg

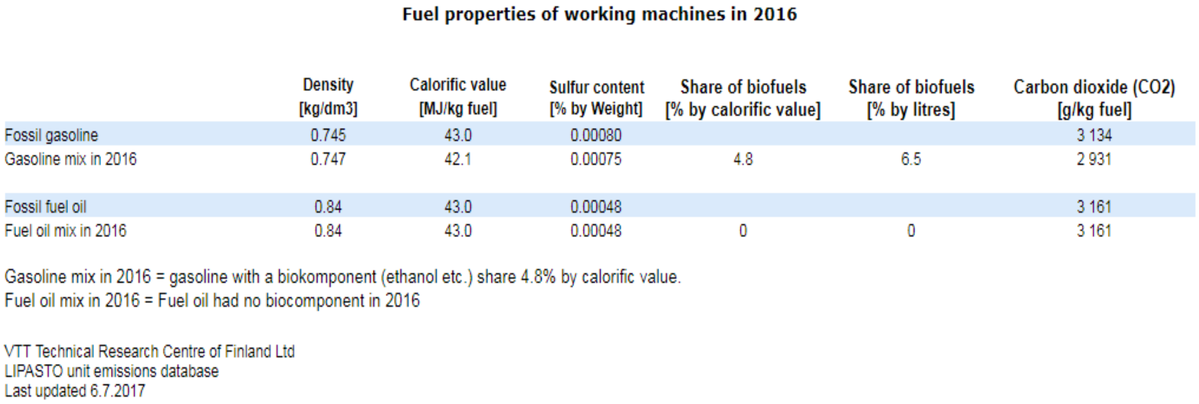
Table 7. Standard gross margin template for 2nd class barley by TuottoPuntari (ProAgria 2019).

Gross margin- 2nd class barley (2018)	**Unit**	**Unit Price**	**Quantity**	**€/ha**
Revenue/ha				
Barley output	kg	0,14	4000	560
Direct payment (EU) 1	ha	122	1	122
Greening (EU) 2	ha	74	1	74
Natural Constraints (EU)3	ha	212	1	212
Environmental payment (EU)4	ha	72	1	72
National support (FI)5	ha	0-55	1	0/55
Organic production (EU)6	ha	0/160	1	0/160
Total revenue (areas)*	**(AB)**			966
	(C1)			1010,6
	(C2)	10		1020,6
	(C2p)	20		1030,6
	(C3)	30		1040,6
	(C4)	55		1065,6
Variable costs/ha				
Seeds (own)	kg	0,28	164	45,92
Seeds (purchased)	kg	0,44	41	18,04
Fertilizer (1)7	kg	0,37	0	0
Fertilizer (2)	kg	0,38	380	144,4
Manure (slurry)8	tn	0	0	0
Liming	tn	42	0,25	10,5
Pesticide (1) 7	ha	26	1	26
Pesticide (2)	ha	26	1	26
Tractor	h	8,7	5	43,5
Harvester	h	10,6	1	10,6
Drying	kg	0,014	4000	56
Logistics	kg	0,015	3836	57,54
Organic Certification	ha	8,9	0/8,6	0/8,9
Working capital (amount)	€	0,5		
Working capital (interest)	€	0,05		
Total variable costs				**438,5**
Gross margin A (AB)				**527,5**
(Without payments)				121,5
Labor	h	16	10	160
Gross margin B (AB)				**367,5**
(Without payments)				-38,5

Fixed costs				
Tractor	h	13	5	64
Harvester	h	137	1	137
Dryer	ha	48	1	48
Other equipment	ha	1	104	104
Total cost of machinery				**353**
Drying facility	ha	1	111	11
Machine shed	ha	41	1	41
Total cost of facilities				**52**
Gross margin C				-37,5
Cost of land- interest	ha	0,05	5000	250
Improvements	ha	166	1	166
Total fixed cost				821
Profit				**-453,5**
		Total		**€/kg**
Production cost		**1259,5**		**0,314875**

1) Direct payments in AB-areas 123,70 and C-areas 110,6 €/ha, Additional changes may occur
2) Greening is predicted; AB-areas 74,9 and C-areas 65,39 €/ha, additional changes may occur
3) National constraints; AB-areas 212 and C-areas 237 €/ha (+ additional 60€ increase for livestock farms)
4) Environmental payment; AB-areas 112 and C-areas 103 €/ha (estimate)
5) National support additional payment/ha based on area
6) Greening support not applicable for organic hectares. This study assumes the farm is conventional
7) (1) YaraMila Y2 (2) YaraMila Y3, references for clay soil (50mg K/l, 10mg P/l) incl. Freight rate
8) Manure slurry price is set to 0€ due the cost of spreading the manure is close equivalent to the nutrient content.
9) European emission allowances, 19.2.2019
* Greening not included

Table 8. Specification of fuel properties in working machines (VTT, LIPASTO Unit emissions database, 2019).



Fuel properties of working machines in 2016

	Density [kg/dm3]	Calorific value [MJ/kg fuel]	Sulfur content [% by Weight]	Share of biofuels [% by calorific value]	Share of biofuels [% by litres]	Carbon dioxide (CO2) [g/kg fuel]
Fossil gasoline	0.745	43.0	0.00080			3 134
Gasoline mix in 2016	0.747	42.1	0.00075	4.8	6.5	2 931
Fossil fuel oil	0.84	43.0	0.00048			3 161
Fuel oil mix in 2016	0.84	43.0	0.00048	0	0	3 161

Gasoline mix in 2016 = gasoline with a biokomponent (ethanol etc.) share 4.8% by calorific value.
Fuel oil mix in 2016 = Fuel oil had no biocomponent in 2016

VTT Technical Research Centre of Finland Ltd
LIPASTO unit emissions database
Last updated 6.7.2017

Picture 9. Mathematical model for emission rates, retelled from original by writer (VTT, LIPASTO Unit emissions database, 2019).

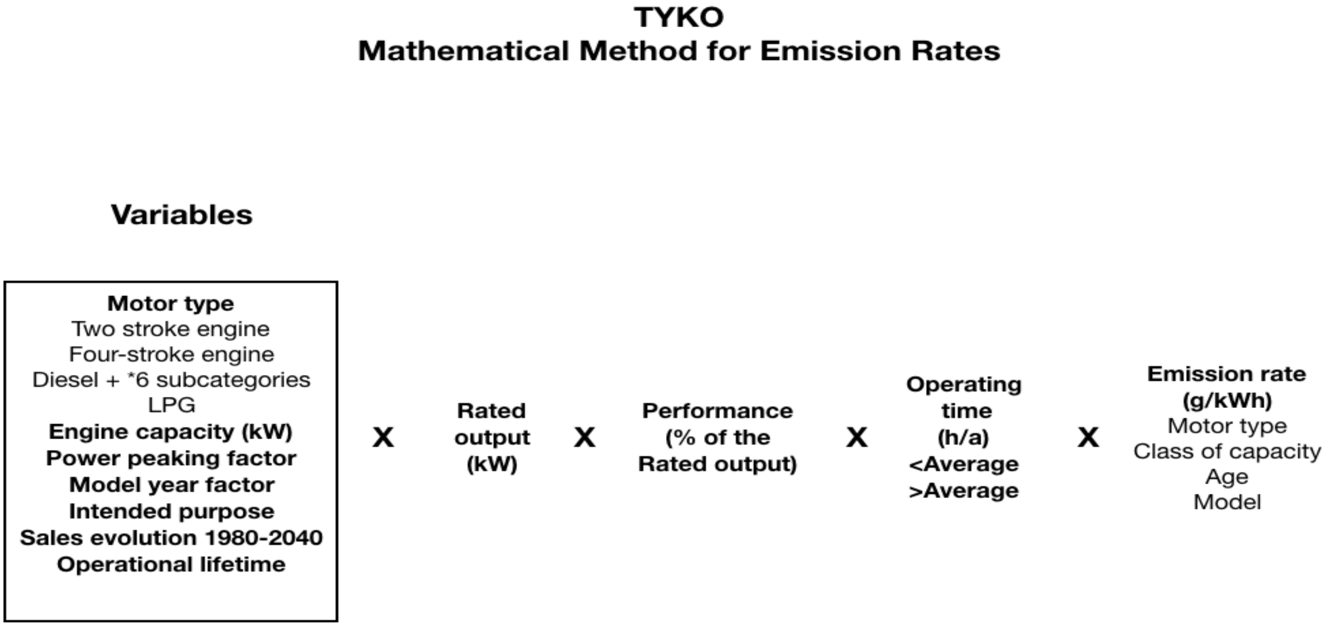


Table 10. VTT Average emission rates and energy use of working machines per fuel use in Finland 2016 (VTT's LIPASTO Unit emissions database, 2019).

Average emissions and energy use of working machines per fuel in Finland in 2016

			Emissions [g/fuel litre]								
Drivable machines, diesel	**Average power [kW]**	**Average load factor**	**CO**	**HC**	**NOx**	**PM**	**CH4**	**N2O**	**SO2**	**CO2**	**CO2e**
Cranes	99	0,26	14	3,4	20	1,2	0,16	0,048	0,0081	2655	2673
Other lifts, diesel	33	0,30	16	4,3	21	1,6	0,15	0,042	0,0081	2656	2672
Forklifts, diesel	88	0,30	13	2,9	16	0,75	0,16	0,043	0,0081	2655	2672
Bulldozers	112	0,40	14	3,4	21	1,2	0,16	0,050	0,0081	2655	2674
Graders	149	0,37	11	2,9	19	1,0	0,16	0,051	0,0081	2655	2675
Rollers	45	0,30	15	3,1	17	1,1	0,15	0,042	0,0081	2656	2672
Wheel loaders	94	0,33	13	3,0	17	0,94	0,16	0,046	0,0081	2655	2673
Backhoe loaders	74	0,33	17	3,6	20	1,1	0,16	0,044	0,0081	2655	2672
Miniexcavators	22	0,40	19	7,8	29	3,0	0,15	0,040	0,0081	2656	2672
Excavators, skid steer	104	0,31	13	2,3	13	0,62	0,16	0,043	0,0081	2656	2672
Excavators, rubber tire	88	0,32	14	2,5	14	0,68	0,16	0,042	0,0081	2656	2672
Farm tractors	77	0,31	15	3,1	18	1,1	0,16	0,046	0,0081	2706	2723
Tractors in industry	67	0,29	21	4,7	26	1,8	0,17	0,042	0,0081	2658	2675
Maintenance tractors	62	0,28	14	2,3	13	0,72	0,16	0,042	0,0081	2729	2746
Other tractors	58	0,27	16	6,2	33	2,4	0,14	0,067	0,0081	2655	2679
Combines	89	0,57	14	2,8	16	0,82	0,16	0,044	0,0081	2655	2673
Harvesters	149	0,40	5,7	0,72	3,9	0,082	0,15	0,042	0,0081	2657	2674
Forwarders (forest tractors)	105	0,30	7,9	0,94	6,0	0,20	0,15	0,042	0,0081	2657	2673
Dumpers	153	0,30	12	2,7	16	0,70	0,16	0,045	0,0081	2655	2672
Sid steer loaders	50	0,25	14	2,9	16	1,0	0,16	0,043	0,0081	2656	2672
Telehandlers	78	0,28	15	2,9	16	0,84	0,16	0,043	0,0081	2655	2672
Lawn tractor, diesel	12	0,30	20	8,7	32	3,5	0,15	0,040	0,0081	2657	2672
Other drivable machines, diesel	89	0,36	12	2,3	13	0,56	0,16	0,042	0,0081	2656	2672

Table 11. Nettle gross margin sheet, based on ProAgria (2019).

Production cost- nettle (2018)	**Unit**	**Unit Price**	**Quantity**	**€/ha**
Revenue/ha				
Grass output	kg/dm		4000	0
Direct payment (EU)[1]	ha	122	1	123,7
Greening (EU)[2]	ha	74,9	1	74,9
Natural Constraints (EU)[3]	ha	212	1	212
Environmental payment (EU)[4]	ha	112	1	112
National support (FI)[5]	ha	0-55	1	0/55
Organic production (EU) [6]	ha	0/160	1	0/160
Total revenue (areas [5])	**(AB)**			522,6
	(C1)			515,99
	(C2)	10		525,99
	(C2p)	20		535,99
	(C3)	30		545,99
	(C4)	55		570,99
Variable costs/ha				
Seeds (own)	kg			0
Seeds (purchased)[6]	kg			229,5
Fertilizer (1) [8]	kg	0,52	450	210,6
Manure slurry [7]	tn	0	0	0
Tractor fuel	h	8,7	4,29	37,323
Drying				
	€/kg	0,025		100
Organic Certification	ha	8,9	0/8,6	0/8,9
Working capital (amount 50%)	€	0,5		
Working capital (interest)	€	0,05		0
Total variable costs				**577,423**
Gross margin A (AB)				**-54,823**
(Without payments)				-577,423
Labor	h	16	7,2	**115,2**
Gross margin B (AB)				**-170,02**
(Without payments)				-692,623
Fixed costs				
Tractor	h	16,93	7,2	121,896
Harvester	ha			0
Total cost of machinery				**121,896**
Facilities		1	140	140
Dryer	ha	48	1	48
Total cost of facilities				**188**
Gross margin C				-479,919
Cost of land- interest	ha	0,05	5000	250
Improvements	ha	166	1	166
Total fixed cost	ha			725,896
Profit				**-895,92**
		Total costs		**€/kg**
Production cost		**1303,319**		**0,32583**
With 2 harvests				**0,086578**

1) Direct payments in AB-areas 123,70 and C-areas	110,6 €/ha, Additional changes may occur
2) Greening is predicted; AB-areas 74,9 and C-areas	65,39 €/ha, additional changes may occur
3) National constraints; AB-areas 212 and C-areas	237 €/ha (+ additional 60€ increase for livestock farms)
4) Environmental payment; AB-areas 112 and C-area	103 €/ha (estimate)
5) National support additional payment/ha based on area	
6) Organic production payment 160€/ha not included this setting	
7) YaraMila NK2, reference based on literature recommendations, soil characteristics may affect choice of product	
8) Manure slurry price is set to 0€ due the cost of spreading the manure is close equivalent to the nutrient content.	

Table 12. CO2e emissions for fertilizers (Niemelä, 2016, 19-20; Yara, 2019).

	Yara Mila Y 3	**700**	**kg**	**533,75**	**CO2e kg**	**0,7625**	**CO2e/kg**
	N Nitrate	Ammonium	P	S	K	# + Mg, Mn, Zn & B	
%	0,096	0,127	0,03	0,06	0,06		
Kg	67,2	88,9	21	42	42		
CO2e	215,04	284,48	14,91		19,32		
	Yara Mila NK 2	**700**	**kg**	**529,83**	**CO2e kg**	**0,7569**	**CO2e /kg**
	N Nitrate	Ammonium	P	S	K	# + Mg, Mn, Zn & B	
%	0,1	0,12	0	0,03	0,115		
Kg	70	84	0	21	80,5		
CO2e	224	268,8	0		37,03		
CO2e/ N kg*	3,2						
CO2e/ P kg	0,71						
CO2e/ K kg	0,46						
*Yara CO2e values for N are lower from EU average 7,8kg/ CO2e to a kg/ N							