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# Cereals and oilseed production in Finland under different socioeconomic scenarios until 2050: an analysis with models of two different scales

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*Abstract*

*We will use Finland as example of a small, developed country with difficult climatic conditions for agricultural production to show how changes in global diets, international trade and global population growth will influence local production. In order to do so we will use two very different models, a global spatially explicit land use model, adapted for the simulation of Finnish agriculture and a national farm sector model. By using a global model we can cover the complexity of global changes such as international trade or population growth, while the farm-sector model can simulate closely national characteristics, like national subsidies or intra-national trade. We investigate how Finnish cereals and oilseed production develop under different socio-economic conditions. Additionally we test how agricultural production of oilseeds can profit from yield increase and national subsidies. We found that cereal production will persist, but that oilseed production will cease if no additional measures are taken.*

Keywords: Finnish Agriculture, SSPs, Global modelling, National farm sector model

JEL codes: A11

## 1. Introduction

Finland is the world's northernmost agricultural country, where farming is only possible as a result of the warming effect of the Gulf Stream. The growing season (defined by days where the average daily temperature exceeds 5 degrees) varies from less than 100 days in the North to 180 days in the South compared to central Europe where the growing season lasts 280 days. Due to this short growing season the yield levels of the field crops are considerable lower in Finland than in central Europe and the harsh winters additionally reduce productivity as they restrict cultivation of winter cereals (Marttila et al., 2005). This is reflected in low yield levels (the reference yield in Finland is the lowest among EU-15) and high production costs (Ministry of Agriculture and Forestry, 2006). The return on investment in the agricultural business has been negative on average for the period 2000-2013 (Niemi & Ahlstedt, 2014). The Gross Value Added of agriculture accounted 2.9% of the national Gross Value Added in 2010 and the the number of people employed in agriculture was 78,000, only 3.1% out of the total employment in 2012 (Niemi & Ahlstedt, 2014).

Despite the unfavorable climatic conditions and the economically small importance of agricultural production, the Finnish agricultural policy is to maintain an inhabited country side and a certain level of food security, aiming for self-sufficient food production in most important, traditional production lines, especially livestock and cereals production (Marttila et al., 2005; Ministry of Agriculture and Forestry, 2006). From this point of view it has been considered problematic that only 30% of protein supplement feed is domestically produced.

The competitive disadvantage due to natural conditions is compensated through the Common Agricultural Policy as well as through national measures (Niemi&Ahlstedt, 2014). In the cereals strategy of 2012 of the Finnish Cereals committee (a high level broad based group of cereals and oilseed industry and other stakeholders) a desired production amount of 200.000 tons for the year 2020 was announced, with an explicit target of reaching a level of 2 tons of oilseed per ha.

Additionally to the strains which are already pulling on the agricultural production in Finland, global markets will have an increasing influence on the national production in the coming years. While subsidies in nominal terms will remain at current levels even after the new CAP takes place in 2015, their real value will decrease, meaning that a larger part of the agricultural revenue must come from direct farm profit. This means in turn that farms will be more dependent on international markets, where major price fluctuations have become every-day business over the last years. International markets will also be impacted by global population growth, changes in global diet, where an increasingly meat-based diet (Pingali, 2007), will require an increase in global protein production, changes in bioenergy production (Popp et al., 2014) and eventually changes in tariffs and other trade-barriers resulting from successful discussions in the Doha Development Round.

In this study we concentrate on cereals and oilseed production since they are the most important tradable crops cultivated in Finland. Cereals produced in Finland are spring barley, spring oat, wheat and rye, they utilized an agricultural area of 1100.000 ha in 2013. Turnip and oilseed rape production (termed as oilseeds in this paper) covered an area of 53.000 ha in the same year (Finnish Cereal Committee, 2014). However the area under oilseeds exceeded 150.000 ha in 2010, following a year 2009 when cereals prices drastically decreased from very high levels of 2008. Large fluctuations in oilseed areas and their responsiveness to cereals prices suggest that oilseed is not a main crop but one of the viable complements for cereal farms in their crop rotation in Southern Finland. When the viable and profitable alternative crops to spring cereals are few, expected high prices of oilseeds, or low prices of cereals, seem to incentivize farmers for a temporary increase in oilseed production.

In Finland turnip rape is the most important cultivated oilseed crop, since its short growing season is suitable for many regions in Finland, whereas oilseed rape is mainly grown in the South, where growing seasons are longer. 15-25% of the Finnish cereal production is exported, depending on the realized yield level. From the domestic use half is used as feed and the rest for foodstuff. Of the oilseeds produced everything is used domestically, either as food oil or rapeseed meal for feeding (Finnish Cereal Committee, 2014).

In addition to its importance as feed protein source, oilseeds deliver important ecosystem services. When using rapeseed in crop rotation, the soil quality increases through root penetration which can prevent subsoil compaction and improves the soil-structure (Peltonen-Sainio et al., 2011). Oilseeds in crop rotations are also break crops, where they have the potential to suppress weed growth (Zoschke and Quadranti, 2002), which in turn might reduce the need for herbicides and to break disease cycles in cereal monocultures (Kirkegaard et al., 2008; Smith et al., 2004).

In order to understand how international markets affect national agricultural production, which depends to a high degree on national subsidies and intra-national differences, it is not sufficient to use a global model, which has to use generalized and aggregate economic information on single countries or even aggregates of nations. On the other hand it also not adequate to use a single-country model only to capture the dynamics of the changes influencing the country from outside the border, since national models have to rely on aggregated rest of the world assumptions which cannot cover the complexity of global changes. In our study we therefore use the global agro-economic model MAgPIE and the national sector model DREMFIA to analyze the impact of future socioeconomic changes on agricultural production in Finland. We link these models by transmitting commodity specific, European agricultural production costs from the global model MAgPIE to the national model DREMFIA. Linking global economic models to national economic models in order to utilize the most relevant features of each for understanding a complex topic has been done before. Adams et al., 2000 couple a multiregional General Equilibrium model (GTAP) to a single-country model to analyze the effect of trade liberalization on the Chinese economy. Mensbrugghe et al., 2006 and Robilliard et al., 2008 combine GCE-model results with micro-simulation results to analyze the impacts of trade liberalization on poverty in Brazil and Indonesia, respectively.

In this study we go one step further than just linking models of different scales and analyzing the results of the national model, we also compare the model results of the national model DREMFIA to an adapted version of the spatially explicit global agro-economic model MAgPIE where agricultural production patterns in the Finland are simulated at a high resolution of 0.5°and thus closely specified. The resulting development paths of cereals and oilseed production, especially their shifts due to changed demand and global prices, are compared.

With this paper we therefore aim to answer three main questions. Firstly, how will Finnish production of cereals and oilseed develop under the different Socio-economic scenarios? What are the underlying drivers and mechanisms affecting the simulated development paths in the models, and what are the main new insights they thus provide for farmers and policy makers? Thirdly, to what extent can additional measures, such as investment in yield increase and per ha subsidies support oilseed production in the future? Finally, we conclude on the role of oilseeds as one alternative and complement to cereals production in the long-term land use and farming system in Finland. These considerations are likely to be interesting and relevant from the entire Northern European viewpoint, since climate change is expected to increase the relative importance of northern European agriculture in food security.

## 2. Methods

### *2.1. Dremfia*

Dremfia (dynamic multi-regional sector model for Finnish agriculture) is a dynamic recursive model for simulating agricultural production and markets in Finland from 1995 up to 2050 (Lehtonen, 2001; Lehtonen et al., 2010). The model is based on spatial price equilibrium under maximisation on producer and consumer surplus, i.e. the underlying hypothesis in the model is that in competitive markets, producers engage in profit maximising behaviour and consumers engage in utility maximising behaviour. Each region specialises in products and production lines that yield the greatest relative profitability, taking into account the profitability of production in other regions and consumer demand. Use of different production resources, including farmland, in different regions is optimised in order to maximise sectoral welfare, taking into account differences in resource quality, technology, costs of production inputs and transportation costs. The Dremfia model consists of two main parts: (1) a technology diffusion model that determines sector-level investments in different production technologies; (2) an optimisation routine simulating annual production decisions (within the limits of fixed factors) and price changes, i.e. supply and demand reactions, by maximising producer and consumer surplus subject to regional product balance and resource (land and capital) constraints. In part (1), production activities include a number of different animals, hectares under different crops and set-aside, feed diet composition, chemical and manure fertiliser use and the resulting crop yield level. Products and intermediate products may be transported between the regions at certain transportation costs. In part (2), Technical change and investments, which imply evolution of farm size distribution and production capital in different regions, are modelled as a process of technology diffusion. In a dynamic recursive model, parts (1) and (2) interact each year so that prices from the market-simulating optimisation model enter the technology diffusion model, representing sector-level investments in each region, and changes in animal production capacities of different techniques enter the market model in the following year. Foreign trade activities are included in Dremfia through Armington assumption. Imported and domestic products are imperfect substitutes, i.e. endogenous prices of domestic and imported products are dependent. This means that the demand functions of domestic and imported products are coupled through substitution elasticities. Exogenously given EU prices influence domestic prices (e.g. exogenously given European prices from MagPie model), but domestic prices may be different from EU prices. Four main areas are included in the model: Southern Finland, Central Finland, Ostrobothnia (the western part of Fin- land) and Northern Finland. Production in these areas is further divided into sub-regions on the basis of the support areas. In total, there are 17 different production regions. This allows a regionally disaggregated, exact description of policy measures and production technology.

### 2.2. MAgPIE

MAgPIE (Model of Agricultural Production and its Impact on the Environment) is a global, spatially explicit, economic land-use model solving in a recursive-dynamic mode (Lotze-Campen et al., 2008). The model distinguishes ten world regions on the demand and uses input data of 0.5 degree resolution on the supply side. Due to computational constraints all model inputs on the supply side are aggregated to clusters for the optimization process based on a k-means clustering algorithm (Dietrich et al., 2013). With income and population projections (see scenario section) as exogenous inputs, required demand is projected in the future and produced by 15 food crops, 5 livestock products, fiber, and fodder as intermediate input. Feed requirements for the livestock production activities consist of a mixture of pasture, fodder, and food crops. The livestock-specific requirements depend on biological needs for maintenance and growth but also temperature effects and the use of extra energy for grazing (Wirsenius, 2000). The model simulates time steps of 10 years and uses in each period the optimal land-use pattern from the previous period as initial condition. On the biophysical side, the model is linked to the grid-based dynamic vegetation model LPJmL which simulates crop yields depending on climatic conditions on a 0.5 degree resolution. In addition to crop yields, LPJmL transfers water inputs, like water availability and requirements per cell and crop, to MAgPIE, while land availability is data based (Krause et al., 2013). The objective function of MAgPIE minimizes global costs, which involves production costs for the agricultural commodities, technological change costs, land expansion costs and trade and transport costs. Production costs are derived from the GTAP database (Narayanan and Walmsley, 2008) and include factor costs for labour, capital, and intermediate inputs. Investments in technological change allow MAgPIE to increase crop yields in a particular region. The endogenous implementation of technological change (TC) is based on a surrogate measure for agricultural land use intensity (Dietrich et al., 2014). Expansion of cropland is the alternative to increase the production level. The expansion involves land-conversion costs for every unit of crop-land, which account for the preparation of new land and basic infrastructure investments (Krause et al., 2013). Land conversion costs are based on country-level marginal access costs generated by the Global Timber Model (GTM) (Sohngen et al., 2009).

### 2.3. Adapting the global model MAgPIE to Finland

As stated above due to computational reasons and the complexity of the MAgPIE model it is not possible to simulate the globe on a 0.5° grid cell level, instead grid cells with similar information are aggregated for the optimization process to 200 to 1000 clusters, depending on the complexity of the model settings (Dietrich et al., 2013). Information from the clustered cells are distributed to single cells using adequate distribution algorithms after the optimization process. While this approach is effective and sufficient for analyzing global land-use patterns (Dietrich et al., 2013)., results would be inadequate for analyzing a relatively small area such as agricultural land in Finland. We therefore adapted MAgPIE in such a way that Finland could be simulated at 0.5° and that grid cells in the rest of the world were aggregated to clusters. This resulted in 256 grid cells for Finland and 500 cell aggregates for the rest of the world. In this way we were able to simulate both, a spatially explicit land-use pattern for Finland, as well as the complex interaction between the ten world regions.

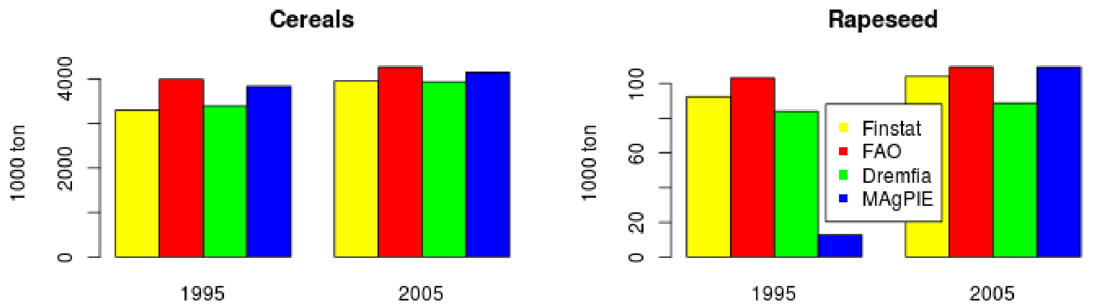


*Figure 1: Comparing observed data and model results for cereal and oilseed production in Finland. MAgPIE results and FAO data are 10-year averages, Finstat data and DREMFIA results are years averages for 1995 and 10 year averages for 2005. Source: Tike 2012, FAO, own calculations (using MAgPIE and Dremfia models).*

In order to justify the use of the global model MAgPIE for such a small region we validated our simulation of cereal and oilseed production with data from the FAO, as well as with data from Statistics Finland and compared them to outputs of DREMFIA model (*Figure 1*). While production amounts of cereals in 1995 and 2005 were almost identical to FAO data, rapeseed yields were too low. This can be explained by the relatively less favourable climatic conditions for rapeseed in Finland, the specific cultivars, which are not accounted for in the biophysical model providing potential yields to MAgPIE, and the fact that national subsidies, which support current production levels, are not accounted for in MAgPIE since the production costs per ha are identical in Europe. We therefore took the effort of calibrating the rapeseed production to the 2005 production level measured by the FAO.

We also compared the resulting land-use patterns for cereal and oilseed production to spatially explicit data from Portmann et al., 2010 for the year 1995. Here again, the land use pattern of cereal production fits almost perfectly to the data, while the area for oilseeds is too small (see

*Figure 10*). This implementation also made it possible to tackle explicitly yields and costs of Finnish agricultural production. The costs of production and thus subsidies could be manipulated by changing the factor requirements per ha for the Finnish grid cells.

### *2.4. Coupling MAgPIE and DREMFIA*

European average prices of cereals, oilseeds and different livestock products from MAgPIE, specific to each SSP scenario were simulated, were included directly as exogenous EU prices into Dremfia. Since MAgPIE is a partial equilibrium model, prices used are not the result of the interaction of supply and demand, but rather the marginal of production. This shadowprice indicates the costs of producing one additional unit of commodity. Since we can assume that there is a constant mark up on the producer prices, the shadow price can be interpreted as market price. Based on European prices from MAgPIE, national prices in Dremfia become affected through the Armington–based demand system where imported products are imperfect substitutes to the domestic ones. Hence there is competition between different production regions and the EU markets.

In Dremfia, substitution elasticities of the Armington demand system have been calibrated ex-post so that 1995-2012 prices in Dremfia follow closely the observed national commodity prices, on the average (Lehtonen et al., 2010; Lethonen et al., 1998).

### *2.5. Comparing DREMFIA and MAgPIE*

In the following we are looking at advantages and disadvantages of the two modeling approaches considered in this paper, The spatially explicit model MAgPIE is more exact in terms of covering the different production regions and their crop growing conditions than Dremfia, since Finland is divided in 256 production units with different crop-specific yield levels in this study, while in Dremfia, which aims for exact national level agricultural policy analysis follows support-zone classification. In fact the disaggregation of Dremfia is well suited in analyzing the economically most important product groups such as dairy meats, and cereals. However, Dremfia is not ideal from the point of view of some individual crops such as oilseeds. Since Dremfia misses the crop yields and production conditions of the best oilseed growing regions when aggregating i.e. all the support region “A” municipalities, many of them cultivating only little oilseeds, into one aggregate.

Since , MAgPie simulates production globally, taking into account trade between the 10 world region, production decisions are taken on the basis of relative costs (cost minimisation) and comparative adavantage. Dremfia, on the other hand, incorporates international trade by using the the persistent differences in especially meat and milk prices between Finland and the rest of the world. Finnish consumers in Dremfia pay a premium on the processed domestic milk products compared to the EU average, reflecting the 25-30% higher milk producer prices in Finland shown by the EU price statistics 2000-2012. The level of milk prices also affects feeding and therefore the prices of cereals and oilseed used as feed.

While in MAgPIE demand for the world regions is exogenously given and cannot be influenced by changes in commodity prices, Dremfia has a flexible demand with own- and cross-price elasticities and production reacts to changes in prices in and outside of the country.

Lifestock production is endogenously implemented in MAgPIE, this means the amount of livestock demand influences the necessary feed production. But feed efficiencies are identical in the single world regions. Peculiarities of the Finnish Livestock Production system can therefore no be accounted for. But Dremfia is exact and accurate on the realized animal specific feed use, validated to national data sources of feeding (www.proagria.fi) and aggregate food and feed balance tables provided by the national statistics. Most importantly, the use of crushed oilseeds as dairy feed are closely taken into account. This is done by taking into account the positive effect of crushed oilseed feed on dairy milk yields, compared to soybean, and by implementing imports of crushed oilseeds.

## 3. Socioeconomic Pathways and Model Scenarios

### *3.1. Socioeconomic Pathways*

In order to be able to consider how the Finnish oilseed production would develop under the conditions of different future worlds, we use the Socio-economic Pathways (SSPs). The SSPs have been developed by the communities of integrated assessment and climate change modelers in order to be able to explore the long-term consequences of anthropogenic climate change and possible response options (Moss et al., 2010; van Vuuren et al., 2012). The data for these scenarios have been made publicly available by the International Institute for Applied Systems Analysis (IIASA). They allow for the identification of a set of global narratives which cover the most relevant and most plausible global futures. The SSP scenarios are spanned in a two dimensional space, with one axis depicting the challenges for adaptation through caused by climate change on the other hand the challenges for mitigating climate change (see *Figure 2*)

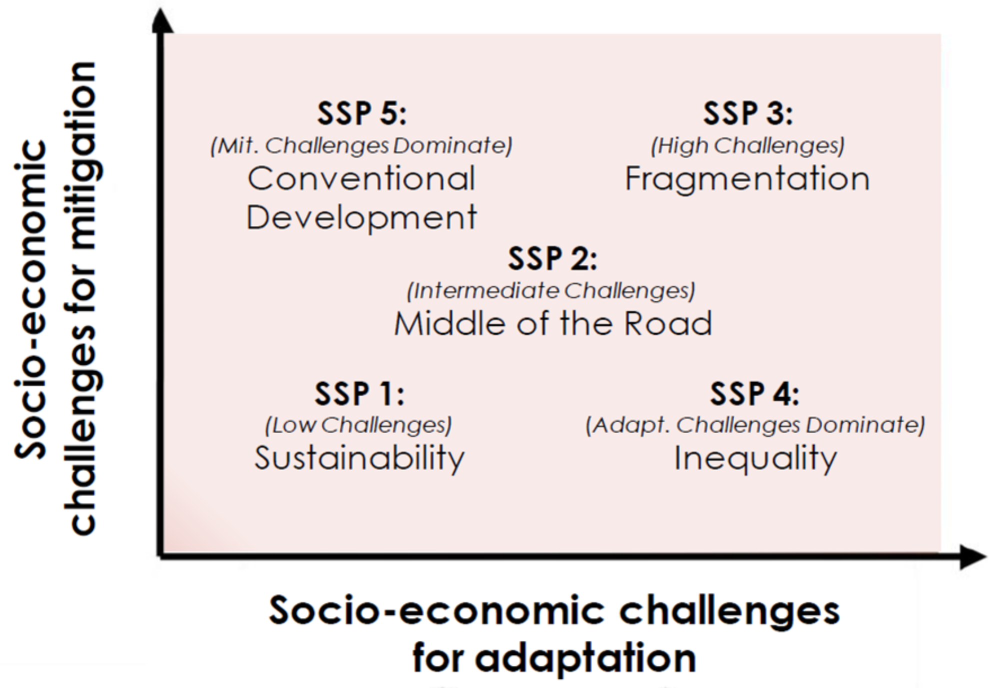


*Figure 2: Socioeconomic Pathways.*

Average seed yields per hectare of Brassica oilseed crops in Finland, mainly summer turnip rape (Brassica rapa L. var. oleifera subvar. annua), which covers 0.93-0.99 of the total oil crop cultivation area depending on year, have fallen dramatically during the last 15 years. This downward trend is contrary to those in other temperate regions, where rapeseed yields have increased or levelled off after reaching a relatively high level. The 5-year moving averages for Finland show that seed yield started to diminish gradually after reaching its highest level of over 1700 kg/ha in the early 1990s. By 2005 it had fallen to 1270 kg/ha (Peltonen-Sainio et al., 2007). The present study evaluated the possible reasons for the recorded collapse in Finnish turnip rape yields. All the statistical analyses were based on large, previously produced, datasets from multi-location Agrifood Research Finland (MTT) Official Variety Tests, Finnish Food Safety Authority (EVIRA) Seed Testing datasets and the Information Centre of the Ministry of Agriculture and Forestry in Finland (TIKE) national production datasets. Results from MTT trials indicated that the latest turnip rape cultivars were more sensitive to elevated temperatures at late seed set and during seed fill - and such temperatures often occurred during the years of greatest yield reduction. When taking into account how commonly sown these cultivars were at national level during the last 10 years, increased sensitivity contributed to up to two thirds of the recorded yield reduction. Even though the growing area of turnip rape has slightly exceeded 100 000 ha, after long being 60000-70000 ha, by extending cultivation to more northern areas of Finland, such changes do not explain the yield collapse according to data from TIKE. Furthermore, lower national yields do not stem from larger, but rather are associated with narrower within year variation in seed yield. Additional empirical work is needed to understand the causes of increased temperature sensitivity in modern cultivars (e.g. possible linkage to drought, diseases and/or drastically increased seed energy content). Furthermore, a national survey is essential for a thorough and up-to-date picture of the prevalence of pests and diseases in turnip rape and their contribution to reduced yields (Peltonen-Sainio et al., 2007).

In our study we will use the SSPs which develop along the diagonal of the scenario space. These three SSPs include the two extreme scenarios, one with a world which is least able to adapt and mitigate to climate change (SSP 3) and one which is best suited to do so (SSP1), as well as a middle of the road scenario (SSP 2). SSP 1 is a world which makes good progress towards sustainability. The elements responsible for this are a rapid development of low-income countries, reduction of inequality, rapid technological development and a high level of awareness regarding environmental degradation. In this world, trade barriers are massively reduced and meat consumption in developed countries decreases. Due to the positive economic development in poor countries, the fertility rate declines and the global population grows relatively slowly. Although the labor markets are open, the migration incentives are reduced due to the increasing relative wellbeing of the people in the less developed countries.

In the middle of the road scenario (SSP 2) some of the historical trends of the last decades continue, but progress is made towards improving the situation of the very poor, resource and energy intensity and slowly decreasing fossil fuel dependency. Trade barriers in the different markets are removed very slowly. Population growth is moderate, with higher growth in low-income countries. SSP 3 is characterized as a fragmented world which is characterized by extreme poverty and pockets of moderate wealth. In this scenario trade barriers remain as they are and population growth is high as a result of education and economic trends. Environmental awareness is very weak, and even in developed countries the trend to more meat consumption continues.

### *3.2. Implementation of SSPs*

The SSPs provide through their storylines indications which have to be translated into model input. Population scenarios in the SSPs translate therefore in the context of agricultural modelling into demand for crop and livestock products, while the development of GDP in the different world regions can be understood as influencing dietary habits such as meat consumption and amount of calories consumed per person. The exogenously given food demand for cereals and oilseeds is derived from scenario information on kcal consumption per capita and on the population Based on historic time series the amount of kcal per capita changes with the per capita GDP and decreases after a certain point has been reached (Valin et al., 2014). The food demand for oilseed and cereals depends on the livestock share of the diets as well. If less meat and other livestock products are consumed in a scenario, demand of all the vegetal parts in human diets, including oilseed, increase proportionally and vice versa.

*Table 1: Main characteristics of Dremfia and MAgPIE in comparison.*

| | **DREMFIA** | **MAgPIE** |
|---|---|---|
| Crops | 16 Finnish crops;<br>cereals specified in: spring wheat, winter wheat, rye, barley, maltbarley, oats, mixedgrain | 18 global crop groups, Temperate cereals summarized in one group |
| Spatial resolution | 18 sub-regions | For Finland 0.5° , corresponding to 256 clusters<br>- The rest of the world: 500 clusters |
| Yields | Calibrated on Finnish statistics | Based on a spatially explicit global crop model (LPJmL) |
| Endogenous TC | Yes | Yes |
| International trade | Armington specification, exogenously given European border prices | Endogenous between the 10 world regions |
| National trade | Between the 4 main-regions | Non existent |
| National/ European Subsidies | Subsidies derived from data and directly implemented | Indirectly implemented through GTAP Factor costs |
| Demand | Flexible demand with cross and -own price elasticities (in a certain range) | Exogenously given for the world regions (dependent on scenario specific population, income) |

The direct drivers for agricultural production in Finland are on the one hand the European demand for the different food crops, which are predefined as parameters in the SSPs (and derived from population and GDP), and on the other hand the demand for feed, which depends on the livestock production, and the exports and imports of food- and feed crops, which are variables and only indirectly influenced through the SSP indications. The direct drivers of Finnish agricultural production for the year 2050, their extent and their relation to the SSPs are summarized in *Table 1*.

Since the SSPs are storylines developed for global scenarios, the implementation of the SSP indications into the global model MAgPIE follows the logic presented in *Table 2* For the national sector model an interpretation of the global storylines and a translation into the national context was necessary. Two main indications of the SSPs are influencing the agricultural production in Finland. On the one hand the Finnish population, influencing the demand and on the other hand the international trade. The population scenarios of Finland are directly implemented into Dremfia, but trade is only indirectly taken into account through the prices of agricultural products on the border determining the market price and thereby influencing demand for domestic products and exports. Prices of agricultural products are not part of the SSP database, but they are an outcome of the global model MAgPIE. Therefore agricultural production prices for Europe, for all commodities and for the three different SSPs are transferred to the national sector model Dremfia. These prices do entail the important SSP indications for global and European population and GDP and for globalization and are therefore a valid representation of the SSP storylines.*Table 3* compares how the two different models take the SSP indications into account.

*Table 2: SSP indications, model switches and translations into the SSPsS relevant for the Finnish production of oilseeds and cereals.*

| *SSP Indications* | *Model switches* | *Model switches - SSP 1* | *Model switches - SSP 2* | *Model switches- SSP 3* | *Influence on* |
|---|---|---|---|---|---|
| | | | | | |
| *Global Population* | Global demand for food- and feed crops | Low | Medium | High | *European trade and production* |
| *European population* | European demand for food- and feed crops | Medium | Medium | Low | *European trade and production* |
| *Globalization* | Trade liberalization | High | Medium | Low | *European exports and imports* |
| *European GDP* | Share of livestock products in the diet in Europe | Medium | Medium | High | *European feed production, European feed demand* |

| | | | | | |
|---|---|---|---|---|---|
| | Kcal per capita per day consumed in Europe | Low | Medium | High | *European food – and feed production and trade* |

*Table 3: The way in which the SSPs influence the dynamic of the two models.*

| *SSP Indications* | **DREMFIA** | | **MAgPIE** | |
|---|---|---|---|---|
| | *Model switches* | *Influence on* | *Model switches* | *Influence on* |
| *Population* | Finnish population, the relative change follows closely European average development | Finnish food- and feed crop demand | Population for the 10 world regions | Global and European demand |
| *Globalization* | European production prices from MAgPIE | Domestic prices | Trade liberalization | Exports, imports of food and feed crops and, livestock |
| *GDP* | Share livestock in human diets gradually approach and fully reach European livestock shares 2050 | National food and feed crop demand | Regional livestock share | Global and regional food and feed crop demand |

### 3.3. *Scenarios*

In our study we aim to evaluate how global circumstances influence local production, but we also want to analyze how and if additional policy driven measures can increase Finnish agricultural oilseed production. We investigate therefore two possible measures, first, how improving agricultural conditions leading to an increase in oilseed yields can influences the Finnish oilseed and cereals production and second how increasing national subsidies for oilseed production might enhance the local production.

In the last decades the oilseed yields have increased in most countries of the world. One country which couldn't keep up with this trend was Finland. According to (Peltonen-Sainio et al., 2007) this is due to three reasons. First, due to its rather difficult climate conditions and its short growing season, Finland depends on spring turnip rape, instead on the more productive canola rape, which is mostly grown in the countries with better climatic conditions. Second, the modern rape crop cultivar grown in Finland seems to be very temperature sensitive, together with the high temperature conditions of the last ten years, this has caused a large part of the yield reduction. And third, there have been increased infections caused by pathogens, which have decreased production. The authors of the study conclude therefore, that the Finnish oilseed production can be improved by postponing the time of sowing, which shortens the exposures of the seedlings to high temperatures, due to a shorter growing season. It is also proposed that canola rape cultivars which are less temperature sensitive, could substitute current cultivars in Finnish oilseed production. To implement these measures and maybe others, such as improving disease resistance of the cultivars, will be costly, as the farmers have to change their cropping system and eventually to buy new and more expensive crops. Farm level calculations of MTT Agrifood estimate that with an increase of costs per ha of 10%, yields will eventually improve by 30% until 2050. In fact, yield data of recent years suggest that the canola rape seem to produce nearly 30% higher yields already, compared to turnip rape, in Southern Finland. We therefore define a scenario for our study where we assume that a gradual increase of costs up to 10% until 2050 will lead to an increase in oilseed yields until 2050 of 30% (see *Table 4*).

*Table 4: Defining the three scenarios.*

| Scenario | Absolute national subsidy | Increase in national subsidy | Rapeseed yield increase | | Both |
|---|---|---|---|---|---|
| | Euro per ha | Euro per ha | Yield increase in ton per ha (%) | Production cost increase per ha(%) | |
| 2000 | 46 | 0 | 0 | 0 | Both measures |
| 2010 | 46 | 0 | 0 | 0 | Both measures |
| 2020 | 72 | 26 | 5 | 2,5 | Both measures |
| 2030 | 98 | 52 | 15 | 6,125 | Both measures |
| 2040 | 124 | 78 | 25 | 7,625 | Both measures |
| 2050 | 150 | 104 | 30 | 10 | Both measures |

After the CAP-reform 2014/2015, 30% of the direct payments will be linked to provision of sustainable farming, one of the measures suggested is crop diversifying/rotation. There will be payments per hectare for respecting agricultural practices beneficial for the climate and the environment (30% of the national envelope will go to this). Under this conditions we assume that LFA and European subsidies will stay constant but that national subsidies for oilseed will increase, since oilseed is very environmental friendly, preventing soil erosion through deep roots, having a smaller demand for fertilizers than, e.g. cereals, and since oilseed production is supported by different stakeholders such as the “Finnish Cereals committee”, discussed in the introduction. Predicting the development of subsidies is very difficult, since this depends on the political as well on the economical circumstances of a country, but starting from an average subsidy level of 46 Euro per ha for oilseed production in 2010 we define in this study a scenario where additional national subsidies will lead to a generous area support for the production of oilseed of 150 Euro per ha in 2050.

# 4. Results

## *4.1. MAgPIE producer prices as input to DREMFIA*

In order to simulate how global changes influence the Finnish production of oilseeds in the sector model Dremfia we use the MAgPIE generated European producer prices in the different SSPs (see Section 2.4), which we use as base to calculate the relative price change. The price levels in the model are obtained by multiplying the baseline price, assuming no changes in population, food diet, and other drivers prevalent in SSPs, based on OECD-FAO Outlook prices for 2012-2021, with the calculated indices are based on MAgPIE prices. The prices passed from MAgPIE to Dremfia are on the one hand the prices for oilseeds and cereals and on the other hand the prices for agricultural commodities influencing the cereals and oilseed prices such as milk, beef, poultry, pork and eggs.

To be able to understand the prices of agricultural products in the different SSPs, it is important to show how the SSP indications influence the production, including demand and exports, for cereals and oilseeds used as feed and food in the EU, according to the MAgPIE simulations. In SSP1, a high population growth in Europe resulting from an opening world, as well as medium calorie consumption and low meat consumption due to a conscious behavior of people lead to medium food demand and a low feed demand for cereals and oilseeds. The modest population growth requires less exports, although markets are open and would allow for it. While population in the SSP3 world in Europe is lower, a high amount of calories consumed per capita leads to a food demand which is approximately equal for cereals and oilseeds to SSP1. Feed demand in contrast is much higher in SSP3 due to the high per capita demand for livestock products. Since global population is also much higher in SSP3 than in SSP1, the European exports of oilseeds and cereals in SSP3 exceed the exports in SSP1 and SSP2 (see *Table 5*).The relative price development in the scenarios SSP1-3 are shown in *Table 6*,
*Table **7***. The first remarkable feature is a sudden decrease of prices from 2020 to 2030 in all scenarios and for cereals and oilseeds. This decrease of agricultural prices can be explained by

the exogenously given demand trajectory for bioenergy, where first generation bioenergy (rapeseed in Europe) is substituted by second generation bioenergy such as woody grasses (*Table 8*) (Popp et al., 2014). This release of pressure on resources such as land, leads to a decrease for all agricultural commodity prices, but of course the price fall for oilseed is steepest where oilseed prices decrease e.g. by 50% in the SSP1 scenario.

*Table 5: Direct drivers, influenced by the parameters in the SSPs, for the Finnish oilseed and cereals production in 2050 in Mio ton DM. The drivers are defined for Europe.*

| *SSP Indications* | *Type* | *Driver* | *Driver - SSP1* | *Driver - SSP2* | *Driver - SSP3* |
|---|---|---|---|---|---|
| Population and GDP | Parameter | *Food demand cereals* | 194,7 | 206,1 | 184,2 |
| Population and GDP | Parameter | *Food demand oilseeds* | 8,7 | 9,2 | 8,2 |
| Population and GDP | Variable | *Feed demand cereals* | 117,7 | 159,7 | 213,1 |
| Population and GDP | Variable | *Feed demand oilseeds* | 0.8 | 1,2 | 1,6 |
| Globalization, population and GDP | Variable | *Exports cereals* | 58,4 | 26,3 | 125,5 |
| Globalization, population and GDP | Variable | *Exports oilseeds* | 0 | 2,9 | 7,3 |

*Table 6: Relative agricultural output price indices of cereals based on MAgPIE production prices in Europe in the SSP scenarios. OECD-FAO 2012-2021, 2020 price = 1.*

| Cereals | SSP1 | SSP2 | SSP3 |
|---|---|---|---|
| 2030 | 0.78 | 0.82 | 0.87 |
| 2040 | 0.73 | 0.75 | 0.89 |
| 2050 | 0.79 | 0.69 | 0.89 |

*Table 7: Relative agricultural output price indices of oilseeds based on MAgPIE production prices in Europe in the SSP1 scenario. OECD-FAO 2012-2021, 2020 price = 1.*

| Oilseeds | SSP1 | SSP2 | SSP3 |
|---|---|---|---|
| 2030 | 0.49 | 0.57 | 0.65 |

| | | | |
|---|---|---|---|
| 2040 | 0.45 | 0.52 | 0.65 |
| 2050 | 0.42 | 0.48 | 0.64 |

While decreasing prices of cereals in the SSP1 and SSP2 scenarios can be attributed to decreasing production and therefore to a release of pressure on factor requirements, prices in SSP3 for cereals stay approximately constant although production increases (left, *Figure 3*). This can be explained by the endogenously implemented technical change in MAgPIE, which leads, as consequence of investments into research and development, to an increase in yield without the necessity to increases factor inputs. This comparison of production and yields showing the Total Factor Productivity can be seen in *Figure 3* (right hand side).

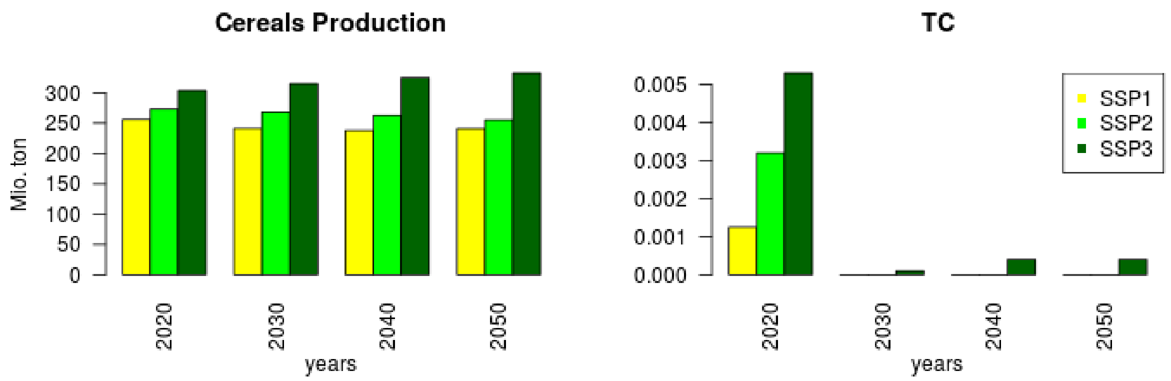


*Figure 3: Development of production of cereals in Europe (left) and endogenous technical change (TC) (right), MAgPIE simulations.*

The increasing production as well as the consequentially constant prices in SSP3 can be attributed to the high feed demand as well as to the high exports due to the global population pressure. In SSP1 prices can decrease most, since people in Europe waste little (low demand of calorie per capita), eat relatively little meat and global population requires only a small amount of international exports. In the middle of the road scenario SSP2, prices are in between.

### *4.2. Future changes of cereal and oilseed production in Finland*

According to MAgPIE simulations, production of cereals will stay around 4 Mio. tons in Finland over the coming decades, which is the level observed in 2005 (see *Figure 4*) and increase most in the SSP3 scenario in the year 2050 to 4.6 Mio ton compared to 4 Mio tons in SSP1. In Dremfia production of cereals decreases after 2020 in all scenarios, but is also highest in the SSP3 scenario from 2030-2050, where in SSP3 in 2050 production is 2.8 Mio tons compared to 1.9 in SSP1 (see *Figure 4*). Since the cereal production is hardly influenced by the policy scenarios targeting oilseed production, results showing the cereal production under the different scenarios are not shown in this paper. In 2020 the oilseed production in the default scenario is close to the observed level of production from 2005 (see *Figure 1*) in DREMFIA and in MAgPIE and decreases after 2020 to almost zero, respectively zero in MAgPIE and Dremfia in all SSPs (see *Figure 5*).

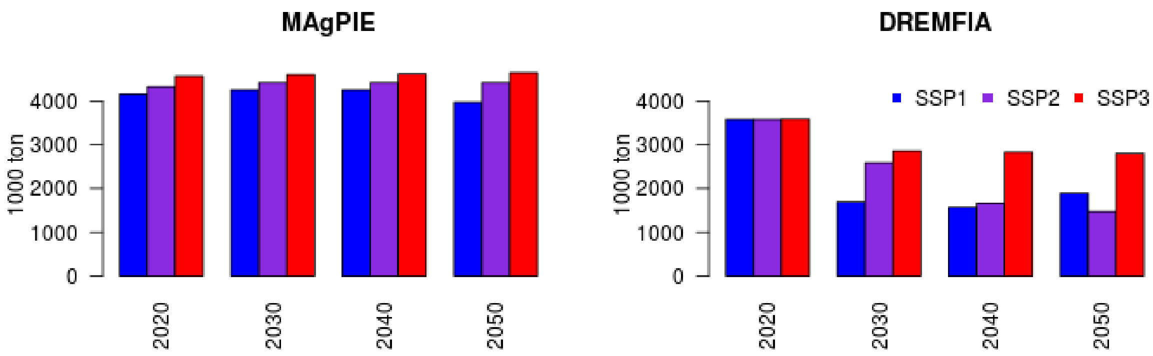


*Figure 4: Comparing cereal production in Finland for the three SSPs and the two different models for the default case.*

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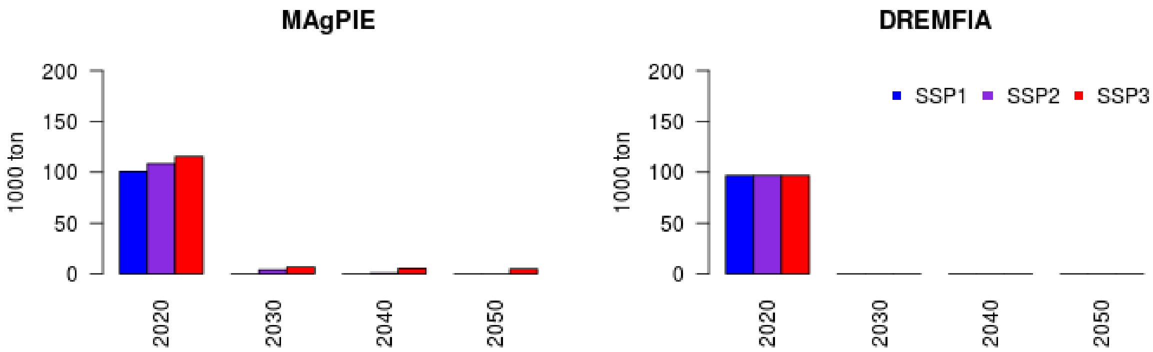


*Figure 5: Comparing oilseed production in Finland for the three SSPs and the two different models for the default case.*

When the Finnish government would start subsidizing the per ha oilseed production beginning in 2020 with additional 26 Euro per ha and increasing rates afterwards, it would affect the production slightly in MAgPIE. However, the oilseed subsidies would have no effect on oilseed production in scenarios SSP1-2, according to DREMFIA model simulations (*Figure*

6). There is also no effect of the subsidy in the SSP3 scenario up to 2040, except in 2050 where a sudden production increase up to approximately 80 tons occurs.

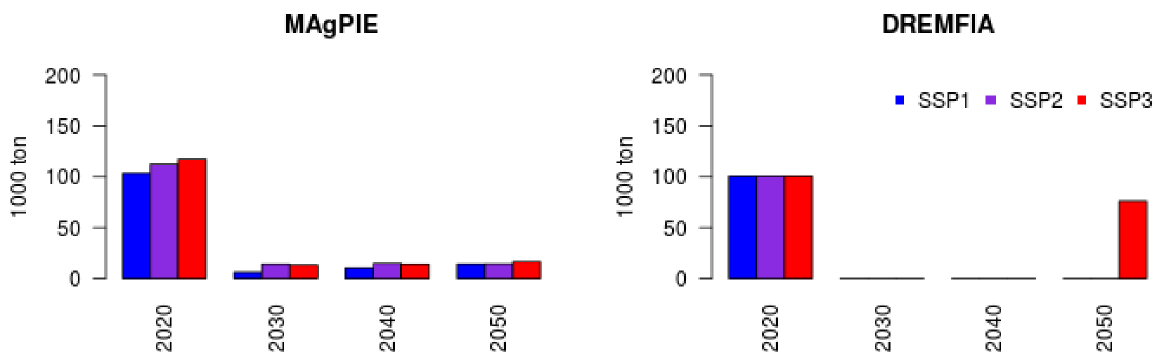


*Figure 6: Comparing oilseed production in Finland for the three SSPs and the two different models for the scenario with national subsidies*

When farmers invest in increasing oilseeds yields, starting in 2020 and reaching 30% more yield compared to 2020 in 2050, the production significantly increases in MAgPIE. Here it also can be seen that such a measure is especially effective in SSP3. In Dremfia the increase in yields has  again no effect on the production (see *Figure 7*).

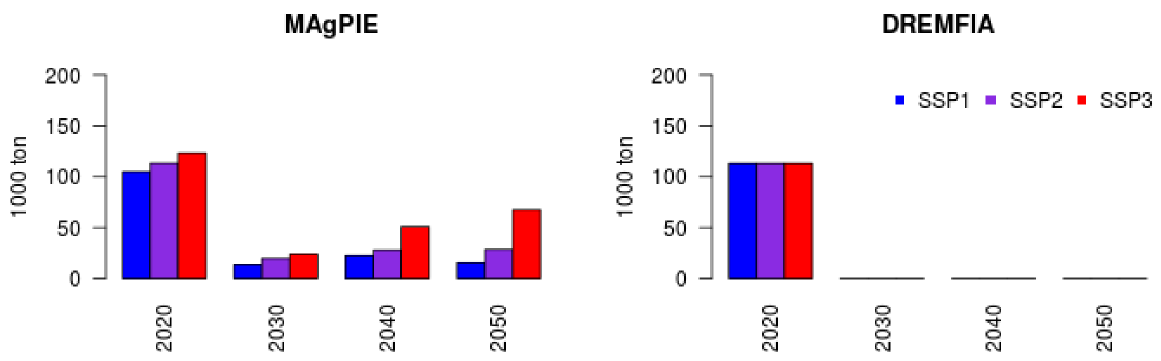


*Figure 7: Comparing oilseed production in Finland for the three SSPs and the two different models for the scenario with 30% yield increase for oilseeds.*

When both measures, the yield increase and the national subsidy are combined, this will lead to an increase in oilseed production in all SSPs in MAgPIE and to an increase in production in SSP2 and SSP3 in Dremgia. In Dremfia the production in SSP3 is even 90 percent higher than in the year 2020 (see *Figure 8*).

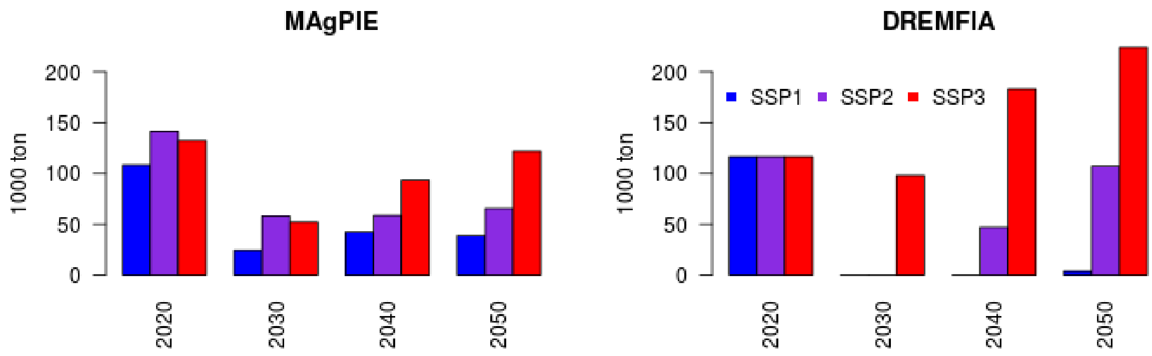


*Figure 8: Comparing oilseed production in Finland for the three SSPs and the two different models for both, the national subsidies, as well as the oilseeds yield increase.*

## 5. Discussion

### *5.1. The default case*

For all scenarios as well as for cereals and oilseeds it can be clearly seen that if there is any production at all, than the production is highest in SSP3. This is due to the SSP3 feature of a large global population which rises the pressure on agricultural production and therefore leads to higher exports and due to the higher per capita demand for livestock products which leads to more demand for feed crops.

The seemingly sudden decrease of oilseed production in 2030 compared to 2020 in all scenarios can be explained by the change of source for bionenergy production. The increasing demand for bioenergy in MAgPIE is fulfilled by first generation bioenergy until 2020, which consist in Europe mainly of oilseeds, and is then substituted by second generation bioenergy such as woody grass starting from 2030 (Table 1) (Popp et al., 2014). Since the change from high demand for oilseeds resulting from first generation bioenergy demand to lower demand also translates into European oilseed prices, the production of oilseeds in Dremfia also decreases in the default scenario after 2020.

The decreasing demand for oilseeds for bioenergy also influences the pressure on agricultural ressources such as land, consequentially the prices for cereals fall after 2020 (see *Table 6*,

*Table 7*). Since Dremfia is very sensitive to outside market prices, the production of cereals in Finland decreases and import increases. When looking at MAgPIE results this effect of decreasing European prices on Finnish production cannot be seen. This is due to the fact that there is no trade between Finland and the rest of Europe. If prices decrease in Europe they also decrease in Finland and low prices would rather lead to an additional production due to a competition of Europe with the other world regions. But in MAgPIE the potentially possible area for cereal growth is reached, the difference in production between the different SSPs results from different yields in Finland

### *5.2. Scenarios*

Nevertheless, the simulated production level of oilseeds (appr. 240.000 tons) and the necessary land area (if reaching 2ton/ha) simulated by the Dremfia model in 2050 in the SSP3 scenario, assuming both 30% yield increase and the 104 eur/ha additional subsidy for oilseeds, are close to the upper bound previously estimated for Finnish oilseeds area by (Peltonen-Sainio et al., 2007). They estimated that an area of 120.000 ha is well suited for oilseeds, while even more land allocated for oilseeds is likely to imply significant yield losses. In the Dremfia model such a soil type condition is not directly accounted for (but only implicitly through the region specific yield expectations based on historical yield levels). It is explicitly required, for crop rotational reasons, that oilseed areas should not exceed 20% of the area under cereals since these crops are cultivated in rotation.

However the actual reason for the sudden increase of oilseed production in SSP3 under both oilseed subsidy and yield increase assumptions, is driven by the increase in European exports and the increase in feed demand for oilseeds. Most of this demand is currently covered by imports of low priced crushed oilseeds. These imports are currently hard to be outcompeted by domestic production. The low priced imports of crushed oilseeds thus affect the oilseed producer prices in Finland which have been occasionally significantly lower than the EU average prices. The increase of oilseed production close to the maximum levels, i.e. the quantity covering well the domestic food oil consumption, and the domestic crushed oilseed demand of dairy cows, in 2050 in the SSP3 scenario is explained by the following reasons. First, the feed demand of oilseeds in dairy production in 2050 is significantly larger than in SSP1-2 due to higher demand and prices of dairy products (and partly beef prices as well). Second, both the oilseed prices and the cereals prices are clearly higher in SSP3 than in SSP1-2 when both cereals and oilseed prices are low. High cereals prices combined with still relatively high milk prices imply larger demand of oilseed feed for dairy cows, since more milk and higher milk yields per cow are demanded. Hence it seems that yield increase and the increased national subsidies are sufficient to maintain and increase oilseed production in Finland only under those conditions, i.e. sustained high demand of milk and meat, combined with higher cereals and oilseed prices.

While MAgPIE does not take into account the significant imports of crushed oilseed and its use in the feeding of dairy cows, it is understandable that MAgPIE results do not show more than 120.000 tons of oilseed production in SSP3, even under yield increase and national subsidies. However the MAgPIE results are likely to be more realistic in the sense that some oilseed production may sustain the best productive grid cells in the SSP1-2 scenarios, at least if aided by increasing yields and subsidies. In fact the higher regional resolution (256 grid cells in contrast to the 18 production regions, of variable size, in Dremfia) is probably the main value added here compared to the Dremfia model. In fact the closer look at the MAgPIE results could point to areas where oilseed production could be most likely be sustained, and even expanded in favourable market and productivity developments.

Our analysis shows that increasing oilseed production in Finland is possible only if livestock and oilseed prices remain high enough simultaneously with a 30% yield increase, and a possible increase of oilseed subsidies coupled to production. In such conditions the domestic oilseed production becomes competitive.

There are some synergies between cereals and oilseeds cultivation, which, under high prices of both crops, could benefit true cereal-oilseed-rotations. Oilseeds as a break crop (pre-crop) for cereals could decrease plant disease pressure. In high disease pressure conditions such benefits could arise. However in these simulations presented above no real climate change with most likely increasing pest pressure was assumed. Hence the synergies between oilseeds and cereals were very small when current relatively low pest pressure was assumed.

## 6. Conclusion

This study shows that when developing policies in order to sustain local production of oilseed and cereals, it is important not only to consider the efficiency of different measures, but also the circumstances under which these policy measure will take effect. By using the different worlds developed in the SSP storylines, we could show that the impact of the overall conditions such as trade, population growth and the lifestyle of the people play a decisive role for the production of local oilseed, while cereals production is relatively less affected.

This is because cereals is a less demanding crop than oilseeds, in terms of production conditions, such as quality of the soil (pH value, soil structure etc.), temperature sum, crop protection. Some close to average (3.5-3.7 tons/ha in Finland for e.g. barley and oats) yields of cereals can be reached with relatively little effort and investment in most soils and most parts of the country. Consequently, the model results are likely to be right in terms of showing stable developments of cereals cultivation and while oilseed cultivation requires sustained high demand and prices of livestock products and preferably also increased yields and/or production coupled subsidies to sustain, or even increasing, production.

However, in the SSP1 scenario also cereal, not only oilseed, production decreases significantly, due to decreasing demand and prices of feed cereals globally and in the EU markets. In the SSP1 scenario global supply of cereals and oilseeds have lower marginal costs than in other scenarios since production can be increased in relatively favored production areas, due to effective adaptation to climate change challenges, and due to more liberal trade than in other scenarios.

In such scenarios with a significantly reduced demand of livestock products and feed crops, especially oilseed production in the relatively disadvantaged Northern European areas such as Finland seems to be in a weak position. Significant reductions in cereals production could be compensated by the expansion of grassland areas, since moderate reductions of meat and milk prices would not lead, according to Dremfia model results, to any significant decrease in livestock production. This is in fact partly compensated for through the reduction of demand due to the decreased feed prices. Anyway the results show that oilseed production is relatively more affected by price, demand and subsidy changes.

Already earlier and today, oilseed production areas are largely volatile over years in Finland, and the role of oilseed production has remained marginal in crop rotation, except in most southern parts of Finland. According to our analysis, there is a reason to find also other means for more diverse crop rotations in Finnish agriculture, and not to rely too much on the productivity potential of oilseeds, even if it looks reachable and despite the identification of its key role in northern agriculture in earlier literature. Various benefits of more diverse crop rotations, including environmental benefits such as reduced nutrient leaching and enhanced biodiversity, can also be reached via cereals-grassland-set-aside rotations. They may be also less risky for farmers, though not providing much potential for increased revenues in favourable market conditions. Realisation of future prices, lifestyles and demand conditions is highly uncertain. Nevertheless, proper strategic choices in Northern European concerning agriculture and farming systems seem to require more explicit accounting for alternative future state of the world.

Our main message to Finnish and other northern European agricultural stakeholders and policy makers is as follow. It takes a lot of effort to increase oilseed production in Finland. Even with combined measures can only in SSP3 the production be sustained at current levels. Finnish policy makers should therefore consider how much effort and resources should be spent into oilseed based development strategy of crop production (cereals-oilseeds rotations) and domestic feed protein supply under all circumstances. At least it should be recognized that oilseed based strategy is risky, because any significant decrease in European livestock production may lead to a concentration of European production to the most productive regions and hence to a collapse of marginal costs and market prices of oilseeds.

This study and its results show that it pays off to adjust global models such as MAgPIE for analyzing agricultural developments in individual countries such as Finland, which however is one of the least favoured agricultural production regions in Europe, in terms of production conditions. Applying global models in national or regional analysis seems to require adjustment and calibration efforts to make the modelling feasible and appropriate for the regional scale research questions. Some issues could still be improved to reach more exact representation of regional agriculture in a global model. This is best achieved in cooperation with an existing country/ regional scale sector model since many of the validation issues, also from the economic point of view, have been at least partly solved already. This type of joint application and development of both modelling approaches seem to be appropriate and promising in this respect.

Further work is likely to be needed, since the role of Northern European agriculture is predicted to be increasing rather than decreasing because of climate change and global market changes, leading to higher real prices and increased feasibility of some crops in Northern Europe. To what extent and under which conditions the role of Northern agriculture could increase is a topic well-suited for an approach presented in this paper. Embedding climate change, e.g. gradually increasing pest pressure, yield potential, and nutrient and crop protection requirements, in the both models together with the global socio-economic scenarios, could open up even more interesting results for farmers, food industry and other stakeholders.

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# Appendix

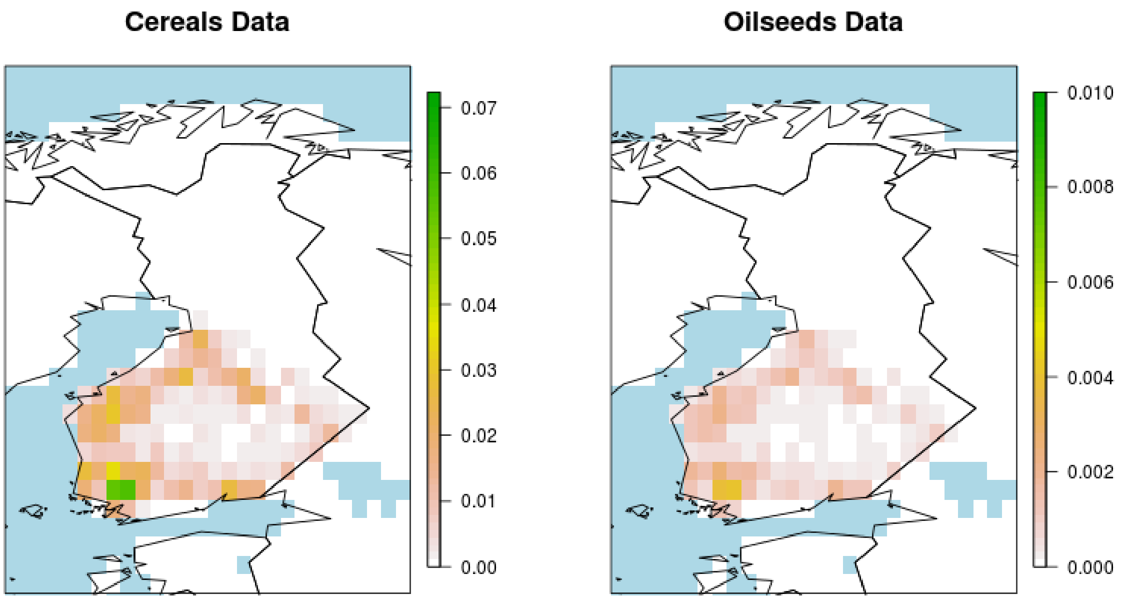


*Figure 9: Data for agricultural crop pattern in mio. ha per 0.5° grid cell in 1995, source Portmann et al. (2010).*

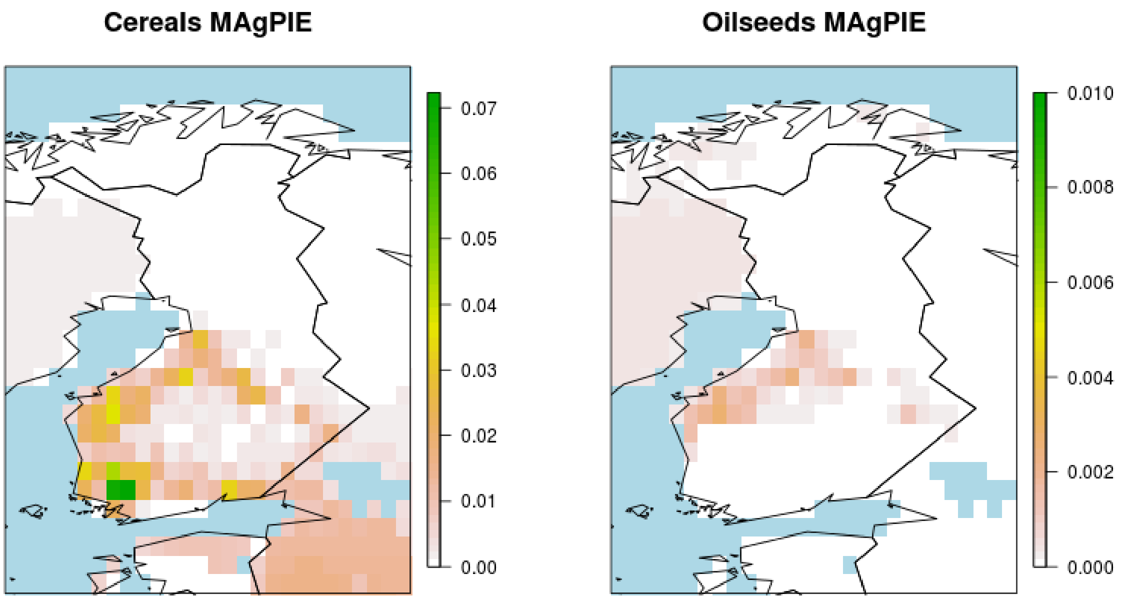


*Figure 10: Simulation results for agricultural crop pattern in mio. ha per 0.5° grid cell in 1995, source own calculations with MAgPIE.*

*Table 8: Demand for bioenergy implemented in Europe for all three SSPs.*

| year | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Bioenergy demand in Mio ton | 11,5 | 9,0 | 1,8 | 0 | 0 |