Finland

Janne Rämö[1*], Heikki Lehtonen[1]

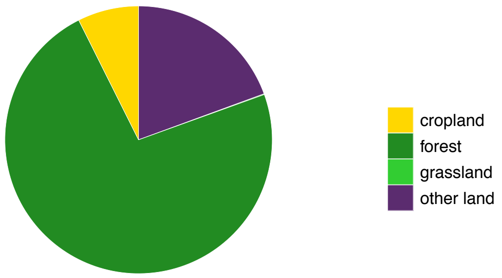
[1]Natural Resources Institute Finland, Helsinki, Finland.
[*]Corresponding author: janne.ramo@luke.fi

Land and food systems at a glance

A description of all units can be found at the end of this chapter

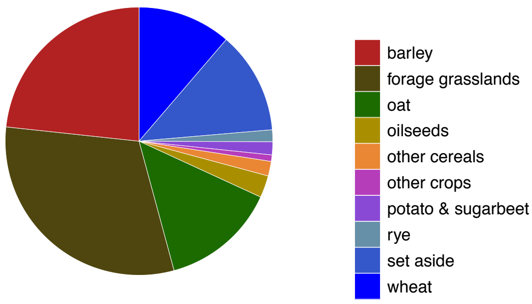
Land & Biodiversity

Fig. 1 | Area by land cover class in 2015



Source: Statistics Finland (2014)

Fig. 2 | Share of harvested area by crop in 2015



Source: Official Agricultural Statistics (2014)

Annual deforestation in 2014:
8.5 kha

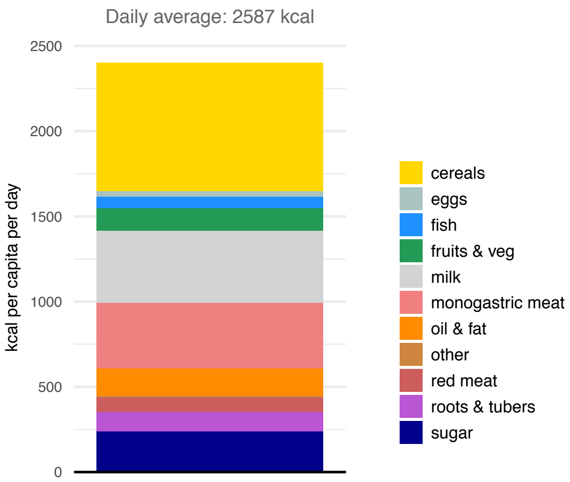
(Statistics Finland, 2019a)

Number of endangered species in 2019: 2,664

(Ministry of the Environment & Finnish Environment Institute, 2019)

Food & Nutrition

Fig. 3 | Daily average intake per capita at the national level in 2015



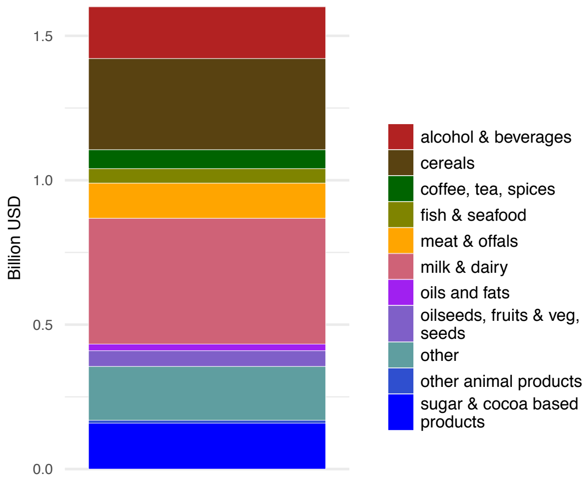
Source: National Institute for Health and Welfare (2017)

Share of obese
(greater than 30 Body Mass Index) in 2017:
Adult men 26.1%
Adult women: 27.5%

(National Institute for Health and Welfare, 2017)

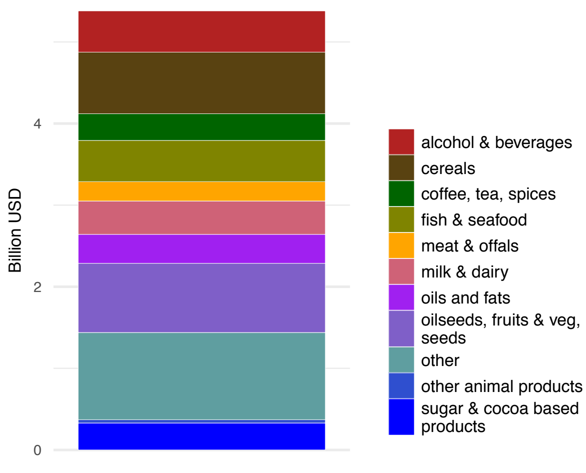
Trade

Fig. 4 | Main agricultural exports by value in 2015



Source: Official Statistics of Finland (2019)

Fig. 5 | Main agricultural imports by value in 2015



Source: Official Statistics of Finland (2019)

Deficit in agricultural trade in 2014: EUR 3.24 billion

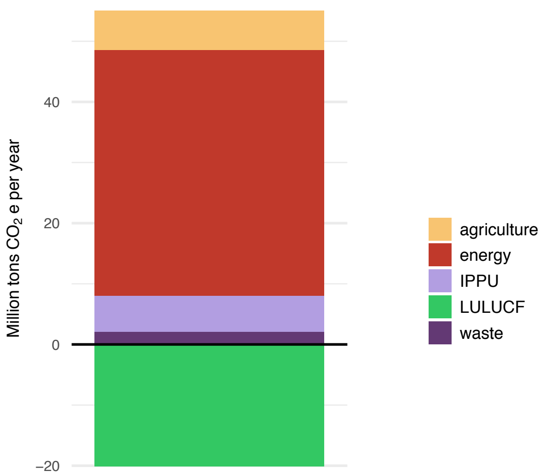
(Tullihallitus, 2019)

47th highest import value, and 43rd highest export value in the world in 2017

(Central Intelligence Agency, 2017)

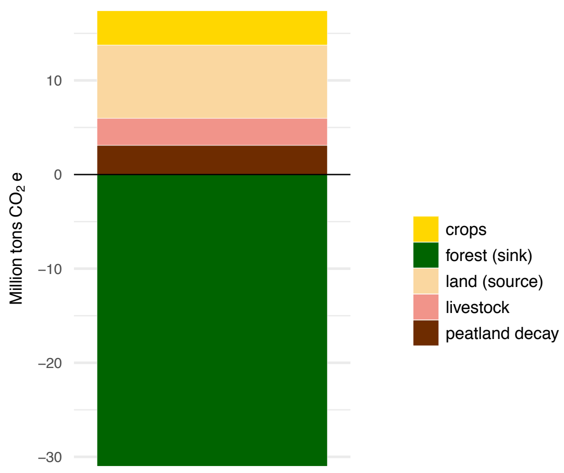
GHG Emissions

Fig. 6 | GHG emissions by sector in 2015



Source: Statistics Finland (2016)

Fig. 7 | GHG emissions from agriculture and land use change in 2015



Source: Statistics Finland (2016)

Finland

Main assumptions underlying the pathway towards sustainable land-use and food systems

For a detailed explanation of the underlying methodology of the FABLE Calculator, trade adjustment, and envelope analysis, please refer to sections 3.2: Data and tools for pathways towards sustainable land-use and food systems, and 3.3: Developing national pathways consistent with global objectives.

GDP GROWTH & POPULATION

	GDP per capita	Population
Scenario definition	GDP is expected to increase from USD 247 bln in 2015 to USD 462 bln in 2050, and GDP per capita from USD 45,057 to USD 78,428 (SSP2 scenario selected).	The population is expected to increase by 7.5% between 2015 and 2050 from 5.5 mln to 5.9 mln (SSP2 scenario selected).
Scenario justification	Annual GDP per capita is expected to increase by approximately 2.5% in 2018. GDP growth rate is expected to decrease to approximately 1% from 2020 onwards but will remain positive. The development of the GDP scenario is based on the 2018 Economic Survey of the Ministry of Finance of Finland (2018).	The development of the population scenario is based on estimations of Statistics Finland (2015).

TRADE

	Imports	Exports
Scenario definition	The share of total consumption which is imported increases: - from 47% to 71% for the share of rye imports, and - from 17% to 34% for the share of beef imports. The share of total consumption which is imported remains constant at 2010 levels for the other commodities.	Between 2010 and 2050, the exported quantity: - decreases from 370 kt to 185 kt for barley, - increases from 156 kt to 235 kt for milk, - decreases from 8 kt to 4 kt for pork, and - decreases from 335 kt to 168 kt for oats.
Scenario justification	Even if the imported share remains constant for most commodities, it can lead to large increase of imported quantities. For instance, imports of nuts and beans increase significantly up to 2050, from low levels of 2015 because of the dietary shift in our low carbon scenario on RuokaMinimi (Saarinen et al., 2019).	Based on long term estimations from DREMFIA sector model (H. Lehtonen, 2001; H. S. Lehtonen & Niemi, 2018).

Scenario signs no change small change large change

LAND

	Land conversion	Afforestation (small change)
Scenario definition	We assume that there will be no constraint on the expansion of the agricultural land outside beyond existing protected areas and under the total land boundary.	In our low carbon-scenario meat and milk consumption is assumed to decrease by 66%, and we assume 50% of freed grasslands to be reforested by 2050 leading to a reforestation target of 250 kha by 2050.
Scenario justification	Forest area has been very stable around 23 Mha for the past 50 years (Natural Resource Institute Finland, 2019). There is some conversion from forest land to human settlements (urbanization) and agricultural use. However, unutilized and marginal farmlands are afforested. Demand for farmland as a whole is not increasing despite a small population growth.	Reforestation of freed grasslands is based on expert estimations. 50% reforestation is ambitious, but by no means impossible.

BIODIVERSITY

	Protected areas (no change)
Scenario definition	The protected areas remain stable between 2000 and 2050.
Scenario justification	Based on data of Statistics Finland (2019b).

FOOD

	Diet (large change)	Food waste (no change)
Scenario definition	Between 2015 and 2050, the average daily calorie consumption per capita decreases slightly from 2,600 kcal to 2,500 kcal. Per capita consumption: - decreases by 66% for milk and meat, - increases for cereals, vegetables, pulses, and fish (cf. Discussion section). For the other food groups, there is no large shift in consumption.	Between 2015 and 2050, the share of final household consumption which is wasted remains stable at 10%.
Scenario justification	We base the diet in our low carbon scenario on "Ruokaminimi" project, to be soon reported. The main results are already available in the policy brief Saarinen et al. (2019).	There is scarce data on food waste at the household level.

Scenario signs no change small change large change

PRODUCTIVITY

	Crop productivity (small change)	Livestock productivity (small change)	Pasture stocking rate (no change)
Scenario definition	Between 2015 and 2050, crop productivity remains stable: - 3 t/ha for oats, - 3.2 t/ha for barley, and - 3.4 t/ha for wheat. And increases: - from 2.5 t/ha to 3.5 for rye, and - from 26 t/ha to 36 t/ha for potato.	Between 2015 and 2050, the productivity per head increases slightly for milk, chicken, eggs, and mutton, and a small decrease is expected for pork and beef: - chicken: from 1.4 to 1.5 kg/head, - milk: from 8.25 to 10.5 t/TLU, - eggs: from 19.6 to 25.6 kg/hen, - pork: from 80 to 85 kg/head, and - beef: from 330 to 350 kg/head.	The average livestock stocking density remains constant at 1.22 head/ha of pastureland between 2015 and 2050.
Scenario justification	Climate warming can be both beneficial and detrimental to crop production (Porter et al., 2014). While the growing season is expected to lengthen especially in the Boreal hemisphere (Ruosteenoja, Räisänen, Venäläinen, & Kämäräinen, 2016) climate change increases risks of e.g. floods and droughts (Schulz, 2009) and may also decrease productivity (Rötter et al., 2011). Successful adaptation to climate change through crop breeding and appropriate utilization of new cultivars may increase crop yields, in average, despite more frequent extreme weather events which decrease crop yields (Tao et al., 2017). Future crop yields depend on market prices of inputs and outputs and policy conditions. Overall, future crop yields are uncertain. Therefore, we assume that climate change has only minor effects on crop productivity, and thus crop productivity remains stable or might even increase for rye and potato.	Based on long term estimations from DREMFIA sector model (H. Lehtonen, 2001) based on recent applications (H. S. Lehtonen & Niemi, 2018).	Based on long term estimations from DREMFIA sector model (H. Lehtonen, 2001; H. S. Lehtonen & Niemi, 2018). In fact, pasturing is feasible only 4 months per year in southern Finland and less than 3 months per year in northern Finland, due to short growing period and cold winter when grass does not grow. Dairy cows also need other feed (e.g. cereals-based feeds and supplementary protein feed) during the growing period.

Scenario signs no change · small change · large change

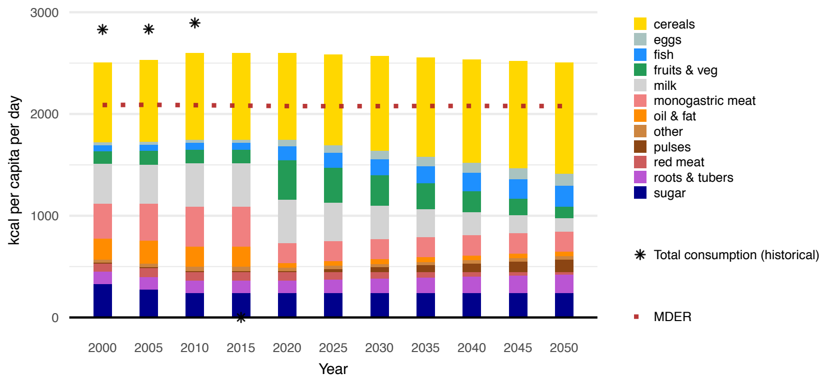
Results against the FABLE targets

The results for FABLE targets as well as "other results" are based on calculations before global trade harmonization.

Food security

Fig. 8 | Computed daily average intake per capita over 2000-2050

Note: The Minimum Daily Energy Requirement (MDER) is computed based on the projected age and sex structure of the population and the minimum energy requirements by age and sex for a moderate activity level. Animal fat, offal, honey, and alcohol are not taken into account in the computed intake.



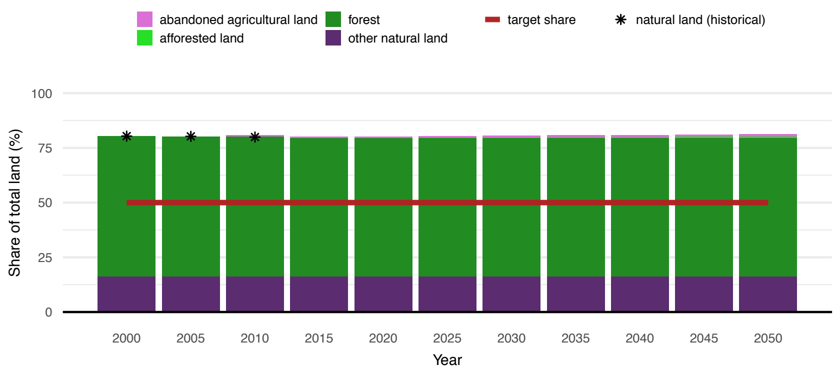
Historical data source: National Institute for Health and Welfare (2017)

According to our results average daily energy intake per capita increases from 2,500 kcal/cap/day to 2,600 kcal/cap/day in 2000-2015. Calorie intake remains relatively stable, reaching 2,500 kcal/cap/day over the period 2020-2050. In this scenario we assume decreased meat and milk consumption, which is substituted by fruits and vegetables, pulses, and cereals.

The computed average calorie intake is 25% higher than the minimum requirement (MDER) at the national level in 2050. In 2021-2050 total protein intake decreases by 10%. Nevertheless, in 2050, the share of protein from total calorie consumption is still about 15%, which is in line with Finnish nutrition and food recommendations (Fogelholm et al., 2014).

Biodiversity

Fig. 9 | Computed share of the total land which could support biodiversity over 2000-2050



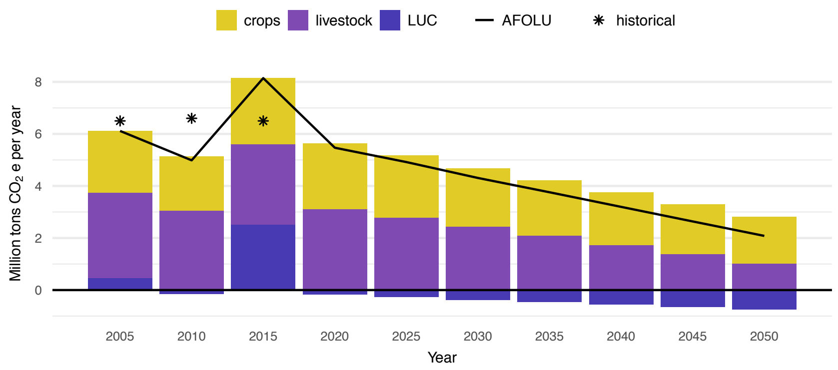
Historical data source: NA

Our results show that the Share of Land which could support Biodiversity (SLB) remains stable between 2000-2015 at 92%. This number is in line with estimates based on the land cover statistics of Natural Resources Institute Finland. We project a slight increase of SLB from 92% to about 93% in this sustainable scenario due to reforestation of mainly old pastures.

Compared to the global target of having at least 50% SLB by 2050, our results are above the target.

GHG emissions

Fig. 10 | Computed GHG emissions from land and agriculture



Historical data source: Statistics Finland (2015)

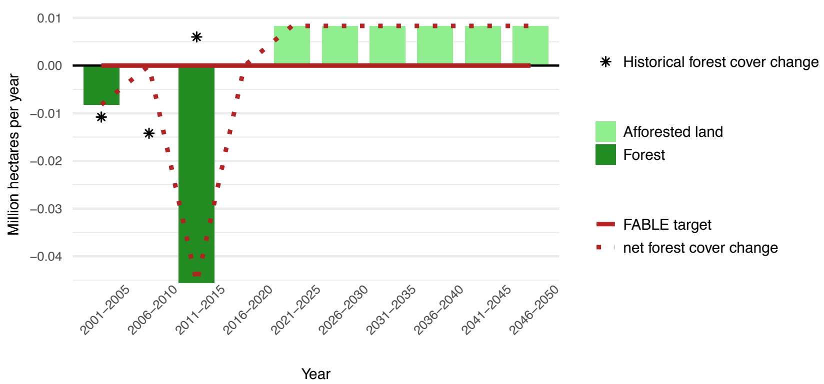
Note: AFOLU (Agriculture, Forestry and Other Land Use) is the sum of computed GHG emissions from crops, livestock and Land Use Change (LUC), emissions and sequestration from forestry are not included. Historical emissions include crops and livestock.

Our results show annual GHG emissions between 5 and 6 Mt CO_2e/year (outlier is year 2015 with high emissions from land use change, due to atypical year for barley in 2010 and model assumptions in agriculture land expansion) over 2000-2015 which decrease over time. These are slightly lower than in Regina et al. (2014), which estimates 6 Mt CO_2e/ year over the same period with a stable trend. Peak AFOLU GHG emissions are computed for the period 2005 at 5,6 Mt CO_2e/year. This is mostly driven by GHG emissions from livestock. Net AFOLU GHG emissions reach 2,1 Mt CO_2e over the period 2046-2050: 2,8 Mt CO_2e from agriculture and -0,7 Mt CO_2e from Land Use, Land-Use Change, and Forestry (LULUC). Negative net emissions from LULUC by 2050 are mainly explained by afforestation. At this current stage of development, the FABLE Calculator does not account for existing forests' sequestration.

Currently agriculture is considered as one of the burden sharing sectors in the EU climate policy. 39% reduction target in GHG emissions during 2005-2030 has been set for the burden sharing sector in Finland. This target is well reached in agricultural sector in our results. Furthermore, reduced need for farmland makes afforestation possible and this increases carbon sink in the LULUCF sector. Even more afforestation could be possible than assumed in this scenario. Hence this agricultural and land use change also contributes to achieving challenging climate targets such as 1.5 degree target.

Forests

Fig. 11 | Computed forest cover change over 2000-2050



Source historical data: Authors' calculations based on Luke data (2019)

For the low carbon scenario, as milk and meat production decreases, we assume roughly half of freed grasslands are reforested, resulting in a positive 42 kha net forest change per each 5-year period after 2020. The large changes in 2010-2015 are due to atypical years in barley cultivation. In 2010, large areas of barley were left uncultivated, and by 2015 barley areas were taken back in cultivation. In the Calculator, we assume agricultural land expansion occurs at the expense of forests based on historical data from FAO, hence the large decreases in forest area.

Compared to the global target of having zero or positive net forest change after 2030, these results are above the target.

Other relevant results for national objectives

Table 1 | Other Results

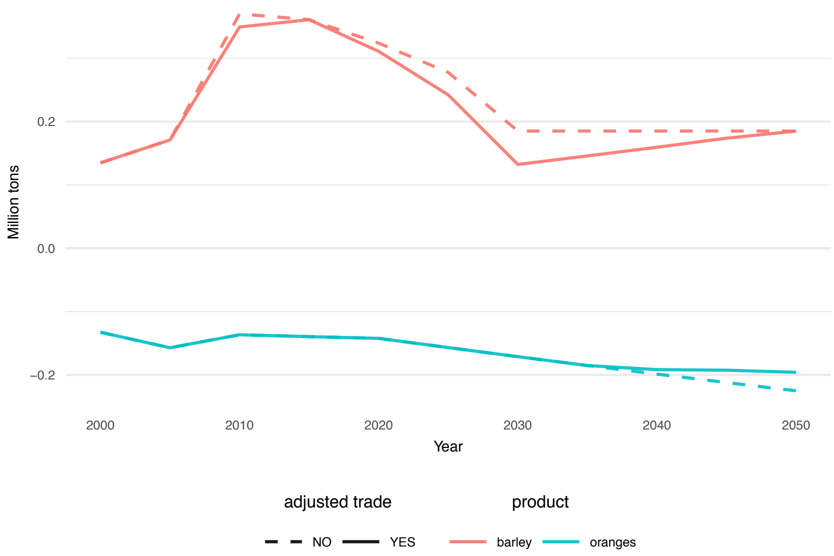
Variable	Unit	2000	2005	2010	2015	2020	2030	2040	2050
Barley									
Production	kt	1719	2035	1199	1677	1648	1301	1083	867
Exports	kt	135	171	370	361	324	185	185	185
Milk									
Production	kt	2417	2399	2302	2358	2412	1996	1532	1044
Exports	kt	395	347	156	166	176	196	215	235

Production of barley decreases by 50% by 2050. Exports decrease by 50% between 2010 and 2030 but remain stable for 2030 to 2050.

Production of milk remains stable until 2020, after which the consumption of milk begins to decrease, causing the production to decrease as well. Consumption decreases by 66% by 2050, and production follows this trend as well. Exports of dairy products, mainly milk powders, remain stable.

Impacts of trade adjustment to ensure global trade balance

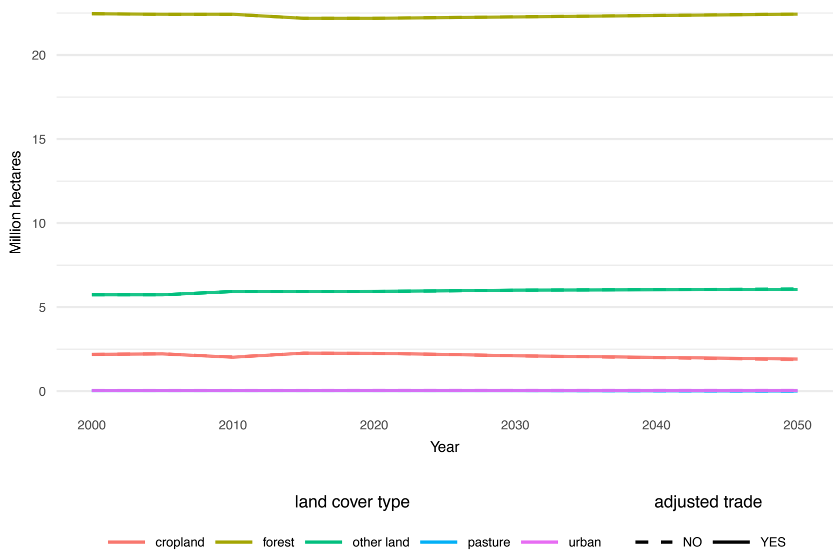
Fig. 12 | Impact of global trade harmonization on main exported/imported commodities over 2000-2050



Exports of barley decrease by about 10% on average when the trade is adjusted for global trade balance.

Imports of oranges remain the same until 2035, after which trade adjustment decreases the imports by up to 14%.

Fig. 13 | Impact of global trade harmonization on land use over 2000-2050



The trade adjustment for global trade balance has only minor effects on land use. All in all, the balancing has only a small effect on Finland's trade, thus the effect on FABLE's key targets is also small.

Discussion and next steps

Finland is committed to its Paris Agreement commitments and to the 1.5°C above pre-industrial levels target. The sector which shares the highest burden of greenhouse gas emissions has committed to 39% reduction by 2030, but agriculture – as a part of this burden sharing sector – has not been given explicit targets in greenhouse gas emissions abatement (Ministry of Environment, 2018). However, this 39% reduction target can be considered as one long-term goal. Our sustainable pathway results suggest that reaching this target is likely to require a significant shift in food consumption, agricultural production, and land use. New targets with more explicit commitments for agriculture can be expected in a few years. Agriculture is part of the Land Use, Land-Use Change, and Forestry (LULUCF) sector and specific measures on organic soils in agriculture could significantly contribute to decreasing greenhouse gas emissions from the LULUCF sector (Aakkula et al., 2019). Today, 10% of farmland is on organic soil, producing approximately 50% of CO_2 emissions from the overall farmland in Finland.

This sustainable pathway draws partly on the Low carbon agricultural scenario of Finland up to 2050 where very significant decreases in greenhouse gas emissions from agriculture are the priority. It has been relatively little discussed up to now, however Aakkula et al. (2019) and Saarinen et al. (2019) have recently analyzed some scenarios where significant reductions in agricultural greenhouse gas emissions will realize. But to the best of our knowledge, the analysis of the consequences of a strong dietary shift with the reduction of consumption of all meat and milk products by 67% is done here for the first time in the case of Finland or other Nordic countries. Protein intake of consumers from livestock production is replaced by increasing plant protein and fish consumption. Leguminous crops consumption, including peas, beans, and imported nuts, increases by a factor of 10. This is still feasible as the consumption levels in 2015 were very low. Expansion of the domestic food pea production is also relatively fast: the peas harvested area increases by a factor of 7.5, from 4 kha in 2010 up to 30 kha in 2050. Potato consumption increases gradually by 50% from 2015 level during 2021-2050. Potato, with low greenhouse gas emissions per ton produced, replaces a large part of imported durum wheat and rice. Consumption of fish (primarily Baltic herring with low GHG emissions) increases by 75 %. Human consumption of oats increases by 46% mainly due to increasing consumption of oat drinks. The use of other cereals for human consumption increases by 28%. While the diet changes significantly, daily calorie intake per capita remains stable during 2015-2050. With decreasing meat consumption, even though the consumption is substituted by pulses and fish, total protein intake decreases by 10% from 2015 levels, to about 84 g per capita per day, or about 15% of total calorie intake. This is still in line with Finnish nutrition and food recommendations (Fogelholm et al., 2014).

Much agricultural land is abandoned since areas of croplands used for feed production and grassland decrease to less than one third of the area in 2015. This is because domestic milk and meat production decreases by approximately 65%, following domestic consumption. We assume that exports are not competitive enough and do not increase due to higher production costs. However, there are some sustained exports and imports since there are quality and product type differences. Since the total agricultural production decreases significantly and shifts towards southern Finland, current agricultural support payments per hectare or per animal decrease significantly 2021-2050. Under the first pillar of the European Union's Common Agricultural Policy, payments (per hectare) and national payments coupled to livestock production (per animal) decrease by 30%.

However, under the second pillar of the Common Agricultural Policy, agri-environmental payments and payments for less favored areas are assumed to stay unchanged. These changes in agricultural support payments eliminate any risk of subsidy-driven production and subsidy-driven exports of agricultural products (even if this risk is rather low currently due to high production costs relative to the value of subsidies coupled to production). Hence domestic agricultural production closely follows domestic demand. Livestock production becomes more intensive in terms of land use. The remaining one third of livestock production is mostly produced in southern and middle parts of the country. This also implies that wheat is increasingly used as feed grain, thus, barley and oats are less used. Drinks made from oats become common but that has a small effect on total oats cultivation because oats have been an important feed grain. Decreasing livestock production drives down oats production despite increasing the use of oats for human consumption.

With regards to the FABLE Calculator, forestry sector is not included at the moment. As Finland's territory is predominantly covered by forests this sector is important when analyzing land-use allocation. In addition, the net trade specification in the Calculator hides some simultaneous exports and imports of the same commodity. Quality differences in e.g. wheat may imply that there are exports of feed quality wheat and imports of bread quality wheat. Hence the wheat production area would be larger and closer to the observed reality if both exports and imports of the same commodity would be accounted in the calculator.
In terms of implementing this sustainable pathway, the food consumption trend assumed in this study is the most important challenge. Regardless of the animated public debate on sustainable and climate friendly diets, the observed changes in the consumed quantities of meat, egg, and dairy products have been minor. However, new substitutes for meat and dairy products are coming to the market and they may trigger a large change in the next decade. Consumer behavior, however, is hard to predict or change, even by using policy instruments such as taxes. There are also other challenges, for example, there are still constraints on data availability for monitoring the evolution of land and food systems. Among policymakers, other priorities such as economic growth or employment, may reduce the focus on environmental issues. Law enforcement concerning the climate targets is still weak, and there are only few incentives for landowners to adopt effective GHG mitigation measures on organic soils.

To address these challenges the development of integrated policies would be key. As such, shifting agricultural policy to promote domestic plant-based alternatives to livestock products would increase the sustainability of crop farms. In addition, promoting sustainable fishing, and an increased use of Baltic herring for food instead of feed would be a positive change. Finally, creating incentives for cost effective GHG emission abatement on organic soils and carbon sequestration on mineral soils would also support this sustainable pathway for Finland. While reduced need of agricultural land for food production will release land area for afforestation and carbon sequestration, some relatively less productive farmlands, such as organic farming (Aakkula et al., 2019), could be afforested already now with little effect on agriculture and food security. Creating incentives for climate smart land use is as important as the agricultural change.

Units

% – percentage
bln – billion

cap – per capita

CO_2 – carbon dioxide

CO_2e – greenhouse gas expressed in carbon dioxide equivalent in terms of their global warming potentials

GHG – greenhouse gas

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

kha – thousand hectares

km^2 – square kilometer

kt – thousand tons

Mha – million hectares

mln – million

Mt – million tons

t – ton

TLU –Tropical Livestock Unit is a standard unit of measurement equivalent to 250 kg, the weight of a standard cow

t/ha – ton per hectare, measured as the production divided by the planted area by crop by year

t/TLU, kg/TLU, t/head, kg/head- ton per TLU, kilogram per TLU, ton per head, kilogram per head, measured as the production per year divided by the total herd number per animal type per year, including both productive and non-productive animals

tln – trillion

USD – United States Dollar

References

Aakkula, J., Asikainen, A., Kohl, J., Lehtonen, A., Lehtonen, H., Ollilla, P., … Tuomainen, T. (2019). Maatalous- ja LULUCF-sektorien päästö- ja nielukehitys vuoteen 2050. *Valtioneuvoston Selvitys- Ja Tutkimustoiminnan Julkaisusarja, 20*(Journal Article).

Central Intelligence Agency. (2017). *The World Factbook – Central Intelligence Agency* [Data set]. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html

Fogelholm, M., Hakala, P., Kara, R., Kiuru, S., Kurppa, S., Kuusipalo, H., … Roos, E. (2014). Terveyttä ruoasta, Suomalaiset ravitsemussuositukset. *Valtion Ravitsemusneuvottelukunta,* (Journal Article).

Lehtonen, H. (2001). *Principles, structure and application of dynamic regional sector model of Finnish agriculture.* Systems Analysis Laboratory, Helsinki University of Technology.

Lehtonen, H. S., & Niemi, J. S. (2018). Effects of reducing EU agricultural support payments on production and farm income in Finland. *Agricultural and Food Science, 27*(2), 124–137–124–137. https://doi.org/10.23986/afsci.67673

Ministry of Environment. (2018). Kohti ilmastoviisasta arkea - keskipitkän aikavälin ilmastopolitiikan suunnitelma vuoteen 2030. *Ilmastosuunnitelma 2030,* (Bills/Resolutions). Retrieved from https://www.ym.fi/Ilmastosuunnitelma2030

Ministry of Finance. (2018). Economic Survey, winter 2018 [Data set]. *Ministry of Finance Publication,* Vol. 2018.

Ministry of the Environment, & Finnish Environment Institute. (2019). *The red list of Finnish species* [Data set]. Retrieved from https://www.environment.fi/redlist

National Institute for Health and Welfare. (2017). *National FinHealth study* [Data set]. Retrieved from https://thl.fi/en/web/thlfi-en/research-and-expertwork/population-studies/national-finhealth-study

Natural Resource Institute Finland. (2019a). *Forest Resources – National Forest Inventory* [Data set]. Retrieved from https://www.luke.fi/en/natural-resources/forest/forest-resources-and-forest-planning/forest-resources/

Natural Resource Institute Finland. (2019b). *Official Agricultural Statistics* [Data set]. Retrieved from http://stat.luke.fi

Official Agricultural Statistics. (2014). *Statistics Finland - Agriculture, Forestry and Fishery* [Data set]. Retrieved from https://www.stat.fi/til/maa_en.html

Official Statistics of Finland. (2019). *Official Statistics of Finland* [Data set]. Retrieved from https://www.stat.fi/meta/svt/index_en.html

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., … Travasso, M. I. (2014). Food Security and Food Production Systems. (7.2.1. Food Production Systems). In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, … L. L. White (Eds.), IPCC. 2014. *Climate Change 2014: Impacts, Adaptation and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Barros, V. R., Field, C. B., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., Chatterjee, M., Ebi, K. K., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. & White L. L. (eds.), Vols. 1–Book, Section, p. 485). Cambridge, UK & New York, NY: Cambridge University Press.

Regina, K., Lehtonen, H., Palosuo, T., & Ahvenjärvi, S. (2014). *Maatalouden kasvihuonekaasupäästöt ja niiden vähentäminen.* Retrieved from MTT website: https://jukuri.luke.fi/bitstream/handle/10024/481727/mttraportti127.pdf?sequence=1&isAllowed=y

Rötter, R. P., Palosuo, T., Pirttioja, N. K., Dubrovsky, M., Salo, T., Fronzek, S., … Carter, T. R. (2011). What would happen to barley production in Finland if global warming exceeded 4 °C? A model-based assessment. *European Journal of Agronomy, 35*(4), 205.

Ruosteenoja, K., Räisänen, J., Venäläinen, A., & Kämäräinen, M. (2016). Projections for the duration and degree days of the thermal growing season in Europe derived from CMIP5 model output. *International Journal of Climatology,* 36(8), 3039–3055. https://doi.org/10.1002/joc.4535

Saarinen, M., Knuuttila, M., Lehtonen, H., Niemi, J., Regina, K., Rikkonen, P., … and Seppälä, J. (2019). Hallittu ruokavaliomuutos voisi tuoda ilmastohyötyjä, parantaa ravitsemusta ja säilyttää maatalouden Suomessa. Policy Brief. *Valtioneuvoston Selvitys- Ja Tutkimustoiminnan Artikkelisarja*, 2019(12).

Schulz, T. M. (2009). *Ilmastonmuutoksen vaikutukset Suomen maatalouteen. Vulnerability assessment of ecosystem services for climate change impacts and adaptation, Action 7: Assessment of impacts and adaptation measures for agricultural production, Deliverable 1: Review of warming impacts in boreal agriculture.*

Statistics Finland. (2014). *Environmental statistics yearbook 2014.* [Data set]. Retrieved from https://www.stat.fi/til/ymp_en.html

Statistics Finland. (2015). *Population projection 2015.* [Data set]. Retrieved from http://tilastokeskus.fi/til/vaenn/2015/index_en.html

Statistics Finland. (2019a). *Greenhouse gas emissions in Finland 1990 to 2017. National Inventory Report under the UNFCCC and the Kyoto Protocol. Submission to the European Union.* [Data set]. Retrieved from https://www.stat.fi/tup/khkinv/index.html

Statistics Finland. (2019b). *Protected areas in 2019* [Data set]. Retrieved from https://tilastokeskus.fi/tup/suoluk/suoluk_alue_en.html

Tao, F., Rötter, R. P., Palosuo, T., Díaz-Ambrona, C. G. H., Mínguez, M. I., Semenov, M. A., … Schulman, A. H. (2017). Designing future barley ideotypes using a crop model ensemble. *European Journal of Agronomy, 82,* 144–162. https://doi.org/10.1016/j.eja.2016.10.012

Tullihallitus. (2019). International trade statistics. *Ulkomaankauppatilastot.* [Data set]. Retrieved from https://tulli.fi/en/statistics