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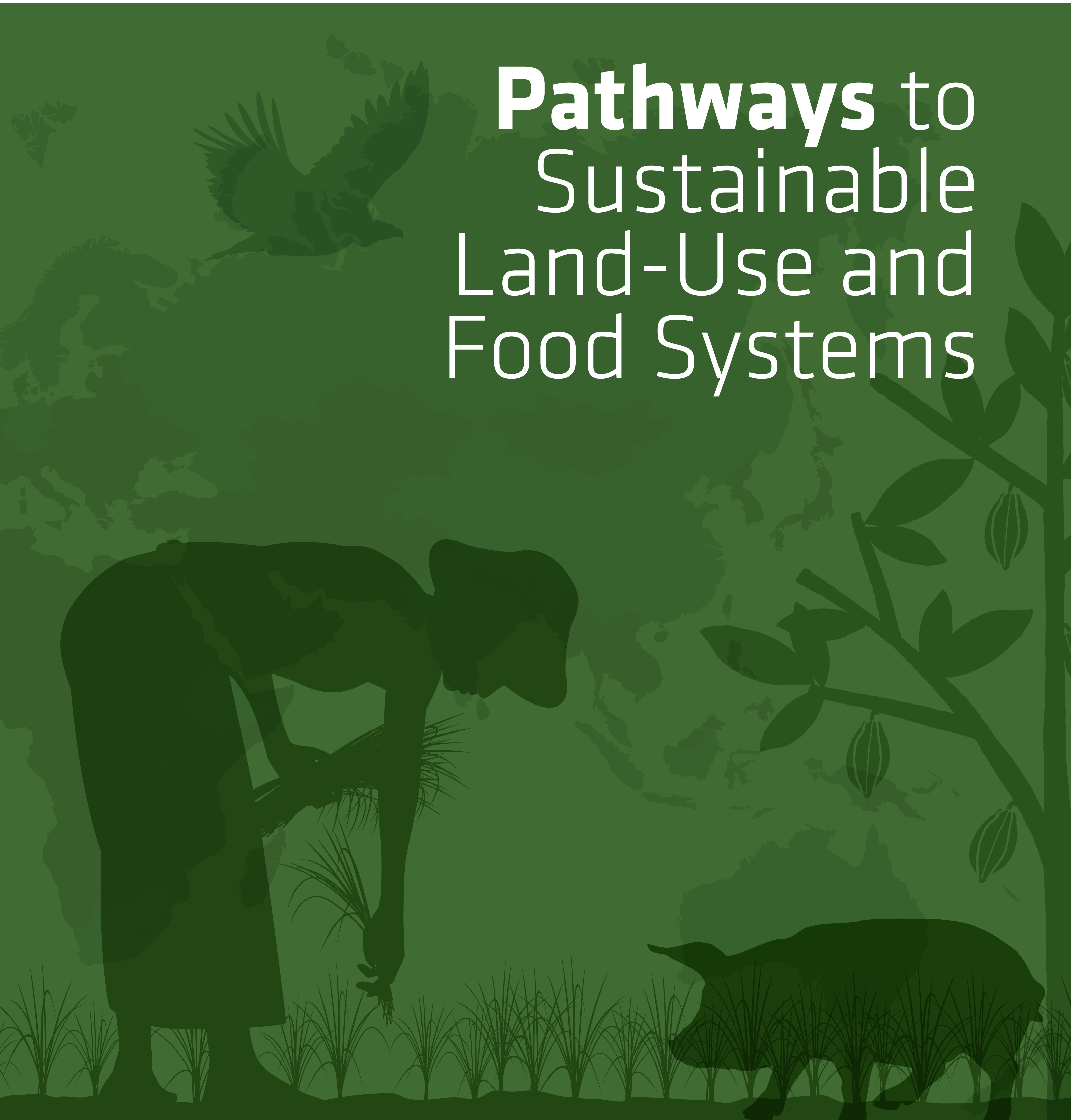
The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



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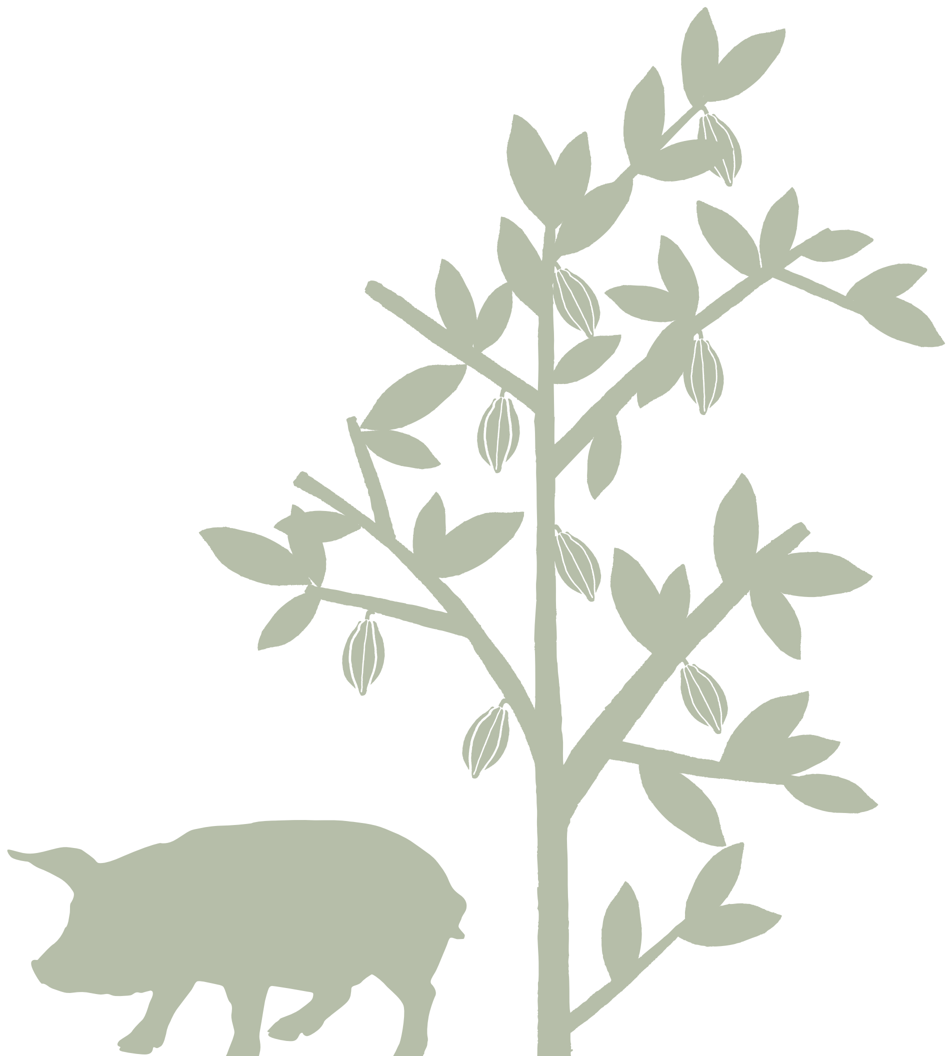
2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems in Finland by 2050



Finland

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This chapter of the 2020 Report of the FABLE Consortium *Pathways to Sustainable Land-Use and Food Systems* outlines how sustainable food and land-use systems can contribute to raising climate ambition, aligning climate mitigation and biodiversity protection policies, and achieving other sustainable development priorities in Finland. It presents two pathways for food and land-use systems for the period 2020-2050: *Current Trends and Sustainable*. These pathways examine the trade-offs between achieving the FABLE Targets under limited land availability and constraints to balance supply and demand at national and global levels. We developed these pathways in consultation with national stakeholders and experts, including from the Ministry of Agriculture and Forestry, the Central Union of Agricultural Producers and Forest Owners (MTK), and the Natural Resources Institute Finland (Luke), and modeled them with FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019) and the DREMFIA agricultural sector model (Lehtonen, 2015). See Annex 1 for more details on the adaptation of the FABLE Calculator to the national context.

Climate and Biodiversity Strategies and Current Commitments

Countries are expected to renew and revise their climate and biodiversity commitments ahead of the 26th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 15th COP to the United Nations Convention on Biological Diversity (CBD). Agriculture, land-use, and other dimensions of the FABLE analysis are key drivers of both greenhouse gas (GHG) emissions and biodiversity loss and offer critical adaptation opportunities. Similarly, nature-based solutions, such as reforestation and carbon sequestration, can meet up to a third of the emission reduction needs for the Paris Agreement (Roe et al., 2019). Countries' biodiversity and climate strategies under the two Conventions should therefore develop integrated and coherent policies that cut across these domains, in particular through land-use planning which accounts for spatial heterogeneity.

Table 1 summarizes how Finland's NDC treats the FABLE domains. According to the NDC, Finland has committed to reducing its GHG emissions by 40% by 2030. This includes emission reduction efforts from agriculture, forestry, and other land use (AFOLU). Envisaged mitigation measures from agriculture and land-use change include soil carbon sequestration, measures relating to the use of peatlands, and the handling and treatment of manure. Under its current commitments to the UNFCCC, Finland does not mention biodiversity conservation.

Table 1 | Summary of the mitigation target, sectoral coverage, and references to biodiversity and spatially-explicit planning in current NDC

	Total GHG Mitigation					Mitigation Measures Related to AFOLU (Y/N)	Mention of Biodiversity (Y/N)	Inclusion of Actionable Maps for Land-Use Planning[1] (Y/N)	Links to Other FABLE Targets
	Baseline		Mitigation target		Sectors included				
	Year	GHG emissions (Mt CO_2e/yr)	Year	Target					
(EU) NDC (2016)	1990	71.2	2030	At least 40% reduction	Energy, industrial processes, agriculture, land-use change and forestry, and waste	Y	N	N	Forests

Note. "Total GHG Mitigation" and "Mitigation Measures related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019), except for the GHG emissions baseline, which comes from Statistics Finland (Statistics Finland, 2020)
Source. EU (2016)

1 We follow the United Nations Development Programme definition, "maps that provide information that allowed planners to take action" (Cadena et al., 2019).

Table 2 provides an overview of the national biodiversity targets listed in the National Biodiversity Strategies and Action Plan (NBSAP) from 2013, as listed on the CBD website, which are related to at least one of the FABLE Targets (CBD, 2020). In comparison, the national protected land area target falls clearly below the global FABLE Target, while the significantly negative GHG emissions from Finland's LULUCF sector (Statistics Finland, 2020) is compatible with the national target on carbon stocks and the FABLE Target of zero or negative LULUCF emissions.

Table 2 | Overview of the latest NBSAP targets in relation to FABLE targets

NBSAP Target	FABLE Target
(5) **By 2020, the loss of all natural habitats has been halted, and the degradation and fragmentation of natural habitats have been significantly reduced.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(7) **By 2020, areas under agriculture, aquaculture and forestry are managed and utilised sustainably, ensuring the conservation of biodiversity**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(14) **By 2020, ecosystems that provide essential services, including services related to water, health, livelihoods and well-being, are restored and safeguarded, taking into account socioeconomic and cultural considerations**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(15) **Finland participates in global efforts to restore at least 15 per cent of degraded ecosystems**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(11) **By 2020, Finland's network of protected areas and the measures applied to conserve biodiversity in the use of other areas together cover at least 17 per cent of the terrestrial environments and inland waters of the country, and 10 per cent of coastal and marine areas**	**BIODIVERSITY:** At least 30% of global terrestrial area protected by 2030
(15) **By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced through conservation and restoration**	**GHG EMISSIONS:** Zero or negative global GHG emissions from LULUCF by 2050

Brief Description of National Pathways

Among possible futures, we present two alternative pathways for reaching sustainable objectives, in line with the FABLE Targets, for food and land-use systems in Finland.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by low population growth from 5.5 million inhabitants in 2020 to 5.9 million in 2050, minimal agricultural expansion in line with historical trends, a low afforestation target, no change in the extent of protected areas, moderate productivity increases in the agricultural sector (low increase in crop yields, moderate increase in livestock productivity, and a significant increase in labor productivity on livestock farms), no change in diets, and no change in agricultural policy (see Annex 2). This corresponds to a future based on current policy and historical trends that would also see considerable progress with regards to changes in farm structure, growth in farm size, and agricultural labor productivity (Lehtonen, Niskanen, Karhula, & Jansik, 2017). Moreover, as with all FABLE country teams, we embed this Current Trends Pathway in a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m^2 (RCP 6.0), or a global mean warming increase likely between 2°C and 3°C above pre-industrial temperatures, by 2100. We assume that trends in technological change continue and that adaptation to climate change is moderate. Consequently, climate change challenges to crop production (Hakala, Hannukkala, Huusela-Veistola, Jalli, & Peltonen-Sainio, 2011) are sufficiently addressed to avoid crop yield losses and a small (5-10%) increase in crop yields is gradually attained by 2050 (Tao et al., 2015). Our model includes the corresponding climate change impacts on crop yields by 2050 for wheat, barley, oats, oilseeds, potatoes, peas, sugarbeet, and forage grass (see Annex 2).

Our Sustainable Pathway represents a future in which significant efforts are made to adopt sustainable policies and practices and corresponds to an intermediate boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future would lead to slightly higher crop yields and significantly decreased consumption of livestock-based foods (see Annex 2). A significant decrease in the consumption of livestock-based foods would lead to declining area for pasture and feed production, half of which would be forested by 2050. Protected areas and population growth would remain unchanged compared to the Current Trends Pathway. This corresponds to a future based on responsible consumer behavior, strategic adaptation to climate change, and market changes at the farm and food-industry levels, also incentivized by effective climate policy. Consequently, higher crop yields aided by new crop cultivars adapted to longer and warmer growing seasons (+10-20% between 2020-2050, which is consistent with Tao et al., 2015) and reduced demand for feed crop production would free up farmland not used in agriculture. Afforestation of a part of this farmland, as well as greenhouse gas mitigation in peatlands, provide opportunities for GHG mitigation (Aakkula et al., 2019; Koljonen et al., 2020). Structural change in agriculture including growth in farm size and increases in labor productivity development also remain unchanged as compared to the Current Trends Pathway. With the other FABLE country teams, we embed this pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

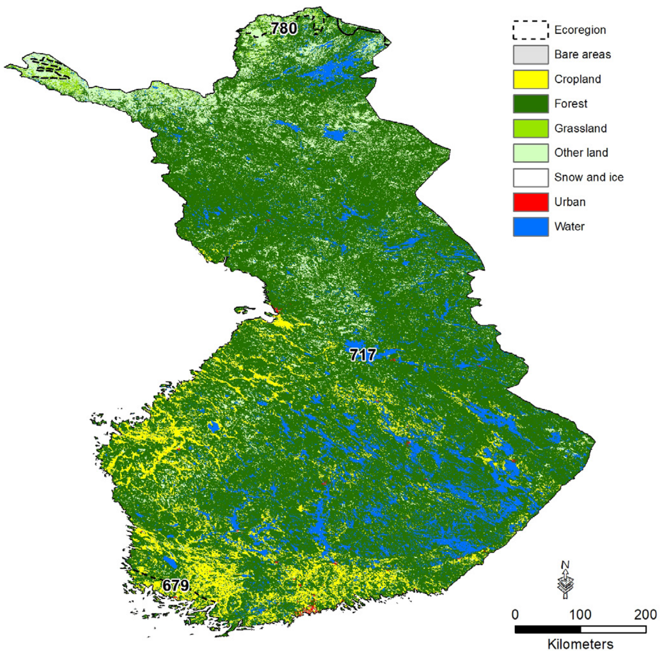
Land and Biodiversity

Current State

In 2015, Finland was covered by 74% forest land, 7% cropland, <1% grassland, <1% urban, and 19% other natural land. Most of the agricultural area is located in southern and western parts of the country while forest and other natural land can be mostly found in central, eastern and northern Finland (Map 1). Challenges to biodiversity in Finland include the gradual decline in biodiversity in managed forests and croplands. These concerns are addressed by Finland's National Biodiversity Strategy and Action Plan (Ministry of Environment, 2020).

We estimate that land where natural processes predominate[2] accounted for 61% of Finland's terrestrial land area in 2015 (Map 2). The ecoregion 780-Scandinavian Montane Birch forest and grasslands hold the greatest share of land where natural processes predominate, followed by 717-Scandinavian and Russian taiga and 679-Sarmatic mixed forests (Table 3). Across the country, while 5Mha of land is under formal protection, falling short of the 30% zero-draft CBD post-2020 target, only 17% of land where natural processes predominate is formally protected. This indicates that managed forests, which dominate land use in ecoregions 717-Scandinavian and Russian taiga and 780-Scandinavian Montane Birch forest and grasslands are also likely to play an important role for biodiversity conservation in the future. The National Biodiversity Strategy and Action Plan (Ministry of Environment, 2020) outlines actions to ensure the improved protection of these at-risk areas.

Map 1 | Land cover by aggregated land cover types in 2010 and ecoregions



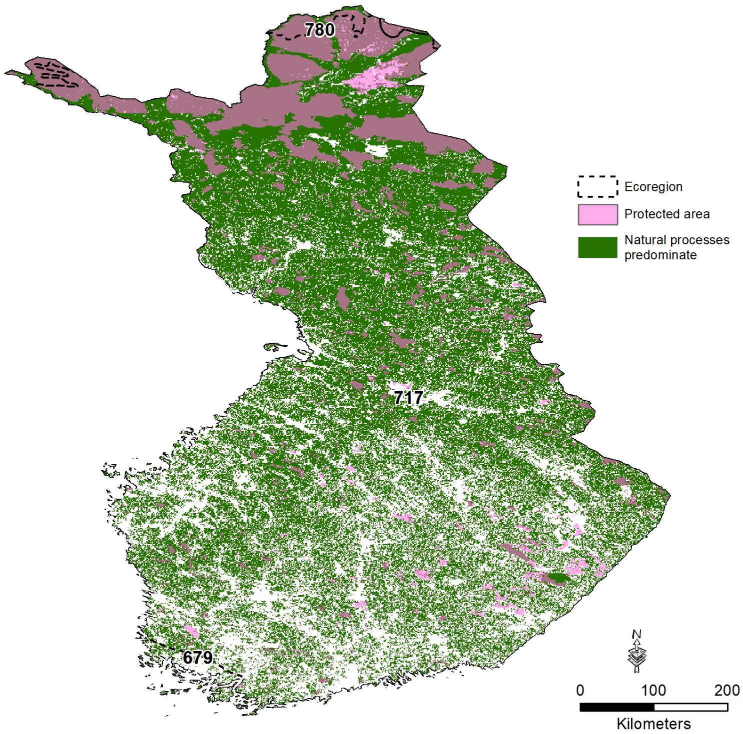
Note. Correspondence between original ESACCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 3.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)

2 We follow Jacobson, Riggio, Tait, and Baillie (2019) definition: "Landscapes that currently have low human density and impacts and are not primarily managed for human needs. These are areas where natural processes predominate, but are not necessarily places with intact natural vegetation, ecosystem processes or faunal assemblages".

Finland

Approximately 56% of Finland's cropland was in landscapes with at least 10% natural vegetation in 2015. These relatively biodiversity-friendly croplands are most widespread in ecoregion 717-Scandinavian and Russian taiga, followed by 780-Scandinavian Montane Birch forest and grasslands and 679-Sarmatic mixed forests. The regional differences in the extent of biodiversity-friendly cropland can be explained by the share of low intensity grass forage production.

Map 2 | Land where natural processes predominated in 2010, protected areas and ecoregions



Note. Protected areas are set at 50% transparency, so on this map dark purple indicates where areas under protection and where natural processes predominate overlap.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International (2019), intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

Table 3 | Overview of biodiversity indicators for the current state at the ecoregion level[3]

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with >10% Natural Vegetation within 1km² (%)
679	Sarmatic mixed forests	360	2.2	36.2	2.7	97.3	127.8	55.1
717	Scandinavian and Russian taiga	32 444	12.6	63.5	16.9	83.1	2485.0	55.9
780	Scandinavian Montane Birch forest and grasslands	381	78.2	97	79.1	20.9	0.03	100

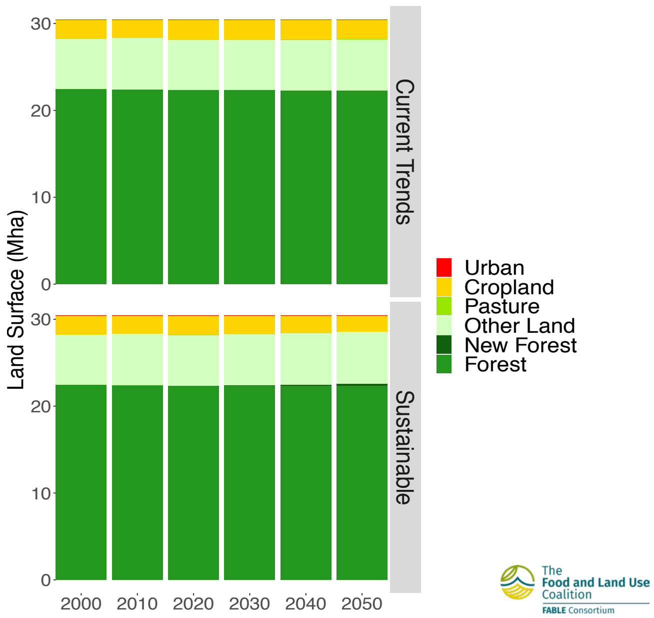
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); cropland, natural and semi-natural vegetation – ESA CCI land cover 2015 (ESA, 2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International 2019, intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including no changes in diets, a small increase in population, and no expansion of agricultural land beyond 2010 levels. There is no planned afforestation and reforestation. Protected areas remain unchanged at 5Mha, representing 16% of total land cover (see Annex 2).

By 2030, we estimate little change in land cover in the Current Trends Pathway. This is due to little to no change in diets and population growth, which leads to stable agricultural production. We also assume that agricultural policy incentives influencing crop allocation and cultivated land area will remain close to current levels, even though the real value of farm payments will gradually decrease as the European Union (EU) and national agricultural budget is unlikely to increase (Lehtonen & Niemi, 2018). All available farmland will not

Figure 1 | Evolution of area by land cover type and protected areas under each pathway

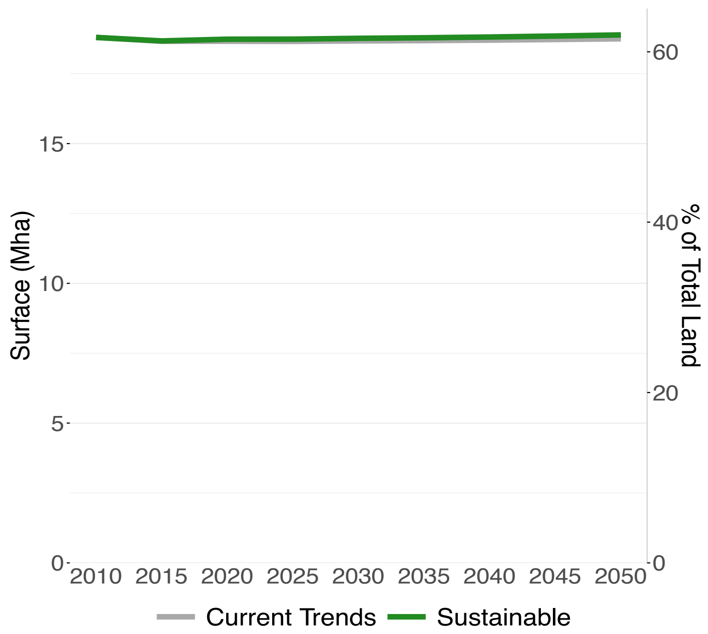


Source: Authors' computation based on FAOSTAT (FAO, 2020) for the area by land cover type for 2000.

3 The share of land within protected areas and the share of land where natural processes predominate are percentages of the total ecoregion area (counting only the parts of the ecoregion that fall within national boundaries). The shares of land where natural processes predominate that is protected or unprotected are percentages of the total land where natural processes predominate within the ecoregion. The share of cropland with at least 10% natural vegetation is a percentage of total cropland area within the ecoregion.

be used for production as areas will be set aside for the purpose of accessing significant farm payments. Thus, the farm payments keep all farmland in cultivation and the cropland area changes very little, if at all. In addition, forest land area may decrease slightly due to urban expansion. These trends remain stable over the period 2030-2050 (Figure 1).

Figure 2 | Evolution of the area where natural processes predominate



In the Sustainable *Pathway*, assumptions on reduced consumption of livestock-based foods and increased crop yields result in decreasing demand for farmland. Increasing demand and production of protein crops (e.g. peas and oilseeds) utilize only a fraction of the land area freed up from livestock feed production. Decreased farm support per hectare, and animal, also result in decreasing utilized agricultural land. The main assumption that affects land use is climate policy which incentivizes afforestation. Thus 0.2Mha of cropland (9% of cropland area in 2015) is afforested over the period 2020-2050. Protected areas do not change (see Annex 2).

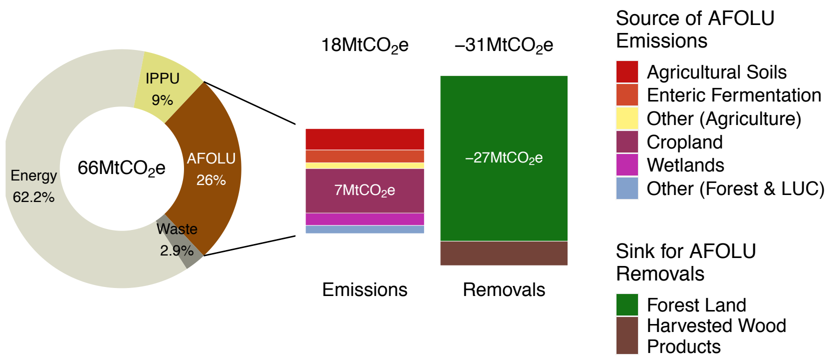
Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in Finland in the Sustainable Pathway: (i) impact on agricultural land, (ii) impact on afforested land. This leads to a small (1%) increase in the area where natural processes predominate by 2050. While this may be considered negligible, the negative direction of change is clearly reversed (Figure 2). Achieving a significant increase in the areas in which natural processes predominate is challenging to realize as they already cover 93% of land area (74% forest land and 19% other natural land). Agricultural area decreases by 9% through afforestation in the Sustainable Pathway, but this contributes to a small change in overall land use since agricultural land currently represents only 7% of land area. Increasing the combined share of forest land and other natural land close to 95-100% of land area would mean a significant change or downscaling of human activities.

GHG emissions from AFOLU

Current State

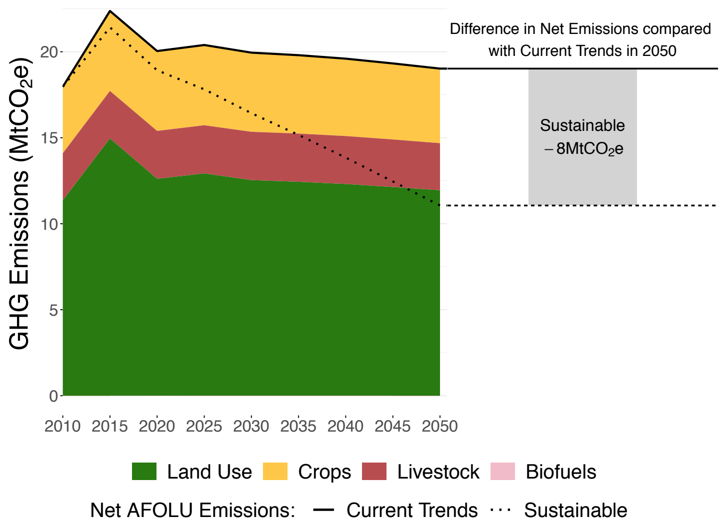
Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 26% of total emissions in 2015 (Figure 3). Agricultural soils (especially CO_2 from peatlands) is the principle source of AFOLU emissions, followed by cropland (N_2O emissions) and enteric fermentation (CH_4). This can be explained by the fact that peatlands account for 11% of cultivated lands, which produce more than 50% of Finland's GHG emissions for agriculture (Statistics Finland, 2020). Large areas of peatlands with thick layers of peat were converted to croplands between 1918-1940 and 1945-1960 due to 36,000 farm families losing their farms, lands, and homes in the Second World War (Kotta, 2017). A large share of peatlands has been kept in agricultural use because of their importance for agriculture and rural livelihoods, especially in remote rural areas with few alternative sources of income. Peatlands are often well suited for grass forage cultivation for dairy and beef production but less suited for crop production. Older investments in dairy and beef production in peatland areas maintain peatland soils in their agricultural production, especially if there are few incentives or possibilities to shift production to mineral soils (Lehtonen, Peltola, & Sinkkonen, 2006; Regina

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 2015



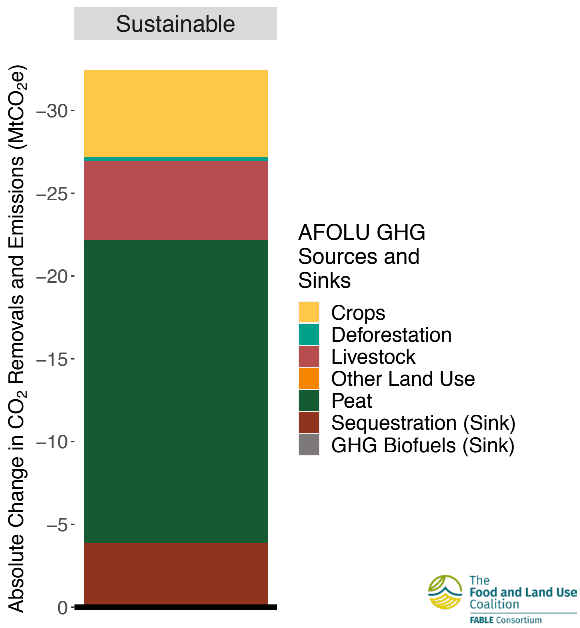
Note. IPPU = Industrial Processes and Product Use
Source. Adapted from GHG National Inventory (UNFCCC, 2020)

Figure 4 | Potential AFOLU emissions reductions by 2050 by trajectory compared to Current Trends



et al., 2015). Emissions from croplands (feed crop production requiring inorganic fertilizers) and enteric fermentation are also significant since agriculture in Finland (Statistics Finland, 2020) is traditionally based on livestock, and especially dairy and beef production, because of the difficult climate and natural conditions for crop production in large parts of the country (Niemi & Väre, 2019). Approximately 70% of agricultural land is used for animal feed production (OSF, 2020). Hence livestock production, directly or indirectly, is the main driver of GHG emissions.

Figure 5 | Cumulated GHG emissions reduction computed over 2020-2050 by AFOLU GHG emissions and sequestration source compared to the Current Trends Pathway



Pathways and Results

Under the Current Trends Pathway, the fluctuation of the GHG emissions calculated using the FABLE Calculator in Figure 4 is because of the technicalities in the calculation procedure. However, there is a small 5% decrease in GHG emissions 2020-2050 with the strongest relative reduction computed for crops (-6%). This small change in GHG emissions is understandable since there is little change in production and land use in the Current Trends Pathway (Figure 4). In 2050, organic soils (peatlands used in agriculture and forestry) is the largest source of emissions (12.4 Mt CO_2e/yr), crops are the second largest with 4.4 Mt CO_2e/yr, and livestock is the third largest with 2.7 Mt CO_2e/yr. Land use change in agriculture acts as a small sink (-0.4 Mt CO_2e/yr).

In comparison, the Sustainable Pathway leads to a reduction of AFOLU GHG emissions by -42% in the period of 2020-2050 compared to the Current Trends Pathways (Figure 4). The potential emissions reductions under the Sustainable Pathway is dominated by a reduction in GHG emissions from organic soils, crops and livestock. Furthermore, there is a significant carbon sink (-1.4 Mt CO_2e in 2050) in land use change due to the afforestation of 200 kha of agricultural land which is no longer needed for agricultural production due to decreased demand and production of livestock products. The most important drivers of this very significant 42% emission reduction are the changes in diets, especially decreases in red meat consumption, and the consequential decreases in feed (cereals and forage grass) production on organic soils.

Compared to Finland's commitments under UNFCCC (Table 1), our results show that AFOLU could contribute to as much as 28% of its total GHG emissions reduction objective by 2050. Such reductions could be achieved through the following policy measures: decreasing agricultural production on organic soils (share of peatlands out of all agricultural land decreasing from 10.5% to 7.9%; -140 000 ha), promoting diet changes so that more protein crops and fish, but less red meat and dairy products, are consumed, and incentivizing afforestation of agricultural land (with mineral soils) for carbon sequestration. These measures could be particularly important when considering options for NDC enhancement (Table 1) and the ambitious national policy target of a carbon neutral Finland 2035 and carbon negative one soon thereafter (Government of Finland, 2019, 2020).

Food Security

Current State

The "Triple Burden" of Malnutrition

Undernutrition

<2% of the population undernourished in 2016. (Statistics Finland, 2017).

Micronutrient Deficiency

25% of the population are deficient in vitamin A and D; 20% of men are deficient on vitamin C and riboflavin (Valsta et al., 2018).

More than 50% of women are at the risk of deficiency of iron, not necessarily deficient (Valsta et al., 2018).

Overweight/ Obesity

26% of the population, and 25% of adults and 22% of children were obese in 2017. These shares have increased since 2011 (Koponen, Borodulin, Lundqvist, Sääksjärvi, & Koskinen, 2018).

67% of the population, and 62% of women and 72% men were overweight in 2017. These shares have increased since 2011 (Koponen et al., 2018).

Disease Burden due to Dietary Risks

65% of men and 50% of women are reported to have increased blood pressure, at least slightly, which increases risks to cardiovascular diseases. Increased blood pressure is often attributable to dietary risks (Koponen et al., 2018).

15% of men and 10% of women suffer from diabetes. 60% of people over 30 years old have increased cholesterol levels, partly attributable to dietary risks. 14% of men and 7% of women older than 50 years suffer from cardiovascular diseases, which can be caused by dietary risks (Koponen at al. 2018). Cardiovascular diseases were the immediate cause of death in 36% (equally for men and women) of all deaths in Finland 2017 (Statistics Finland, 2017).

Table 4 | Daily average fats, proteins and kilocalories intake under the Current Trends and Sustainable Pathways in 2030 and 2050

	2010	2030		2050	
	Historical Diet (FAO)	Current Trends	Sustainable	Current Trends	Sustainable
Kilocalories (MDER)	2,805 (2,087)	2,788 (2,077)	2,677 (2,078)	2,787 (2,078)	2,607 (2,078)
Fats (g) (recommended range	120 (62-94)	119 (62-93)	105 (59-89)	119 (62-93)	92 (58-87)
Proteins (g) (recommended range	96 (70-245)	95 (70-244)	93 (67-234)	95 (70-244)	89 (65-228)

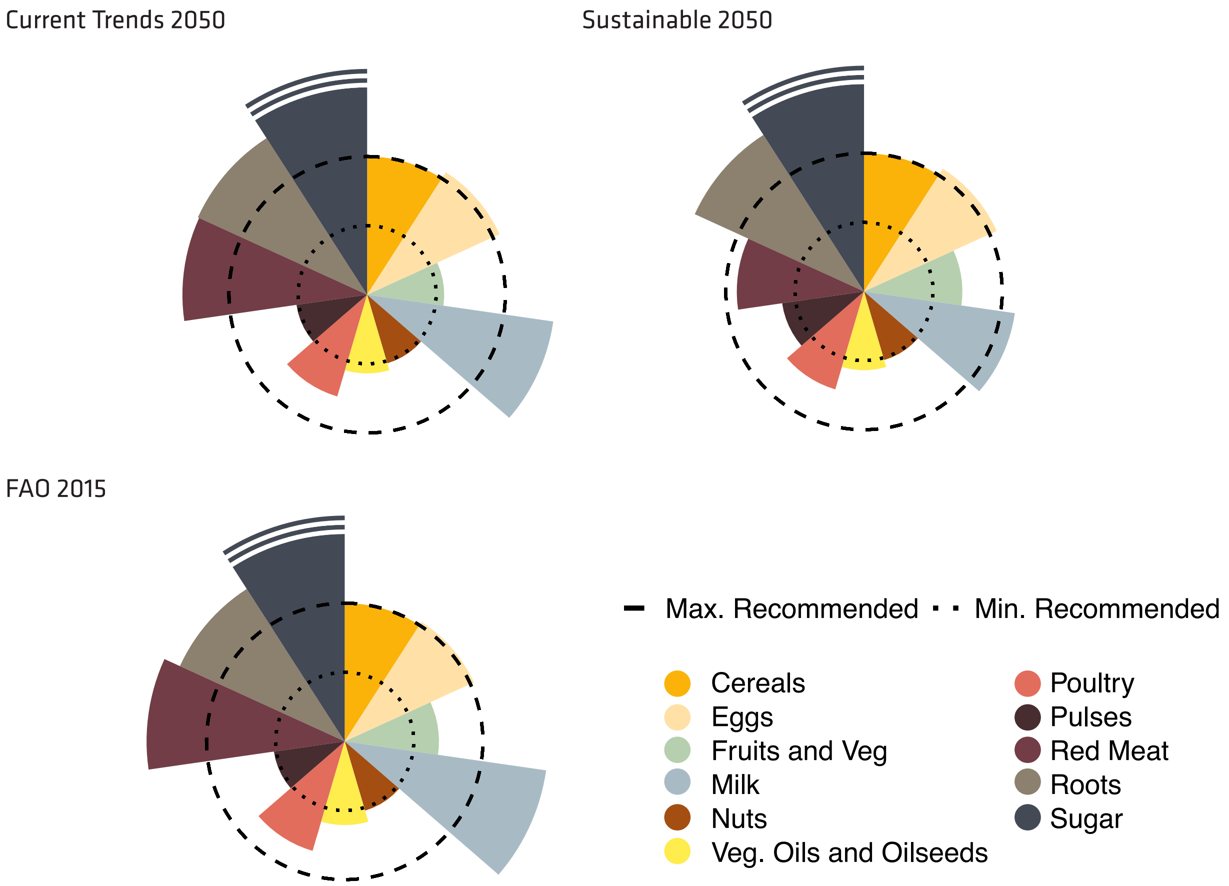
Notes. Minimum Dietary Energy Requirement (MDER) is computed as a weighted average of energy requirement per sex, age class, and activity level (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) and the population projections by sex and age class (UN DESA, 2017) following the FAO methodology (Wanner et al., 2014). For fats, the dietary reference intake is 20% to 30% of kilocalories consumption. For proteins, the dietary reference intake is 10% to 35% of kilocalories consumption. The recommended range in grams has been computed using 9 kcal/g of fats and 4kcal/g of proteins.

Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 34% higher in both 2030 and 2050 (Table 4). The current average intake is mostly satisfied by cereals and animal products, especially dairy products and meat. We assume that the consumption of animal products, as well as other food categories, will stay the same between 2020 and 2050. Compared to the EAT-Lancet recommendations (Willett et al., 2019) animal products, especially red meat, white meat and dairy products are over-consumed while fruits and vegetables, pulses and nuts are in the lower range of recommended intake (Figure 6). Moreover, while fat intake per capita exceeds the dietary reference intake (DRI) in 2030 and 2050, protein intake remains within the recommended range.

Under the Sustainable Pathway, we assume that diets will transition towards fruits and vegetables and protein crops, and away from red meat and dairy products. The ratio of the computed average intake over the MDER decreases to 29% in 2030 and 25% in 2050 under the Sustainable Pathway. Compared to the EAT-Lancet recommendations (Willett et al., 2019), the consumption of sugar, dairy products, and roots is high and still remains outside of the recommended range of consumption. However, fruit and vegetable consumption has increased, and red meat consumption has decreased and is now within the recommended range (Figure 6). The fat intake per capita exceeds the dietary reference intake (DRI) in 2030 and also slightly in 2050, nevertheless showing significant improvement compared to the Current Trends Pathway (Table 4). Increased consumer guidance and information will be particularly important to promote this shift in diets.

Figure 6 | Comparison of the computed daily average kilocalories intake per capita per food category across pathways in 2050 with the EAT-Lancet recommendations



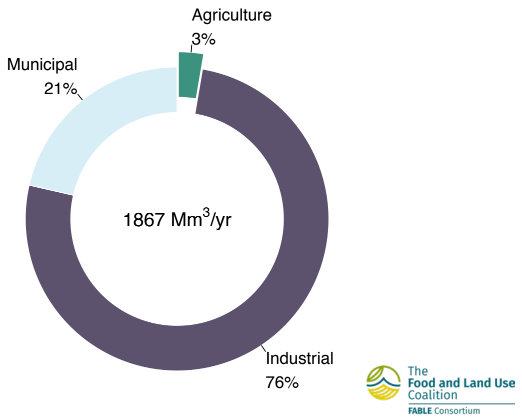
Notes. These figures are computed using the relative distances to the minimum and average recommended levels (i.e. the rings), therefore the different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended values for cereals: when the kcal intake is smaller than the average recommendation it is displayed on the minimum ring and if it is higher it is displayed on the maximum ring.

Water

Current State

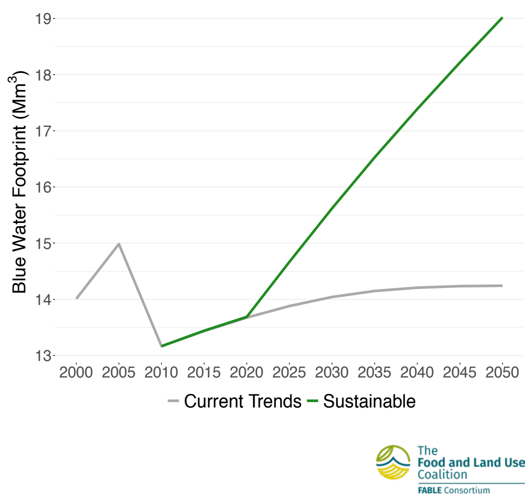
Finland, located in northern Europe between the 60th and 70th parallel north latitudes, is characterized by relatively harsh climatic conditions from an agricultural point of view. The growing season, which ranges from early to late May to late August or September with temperature sums of 900-1600 degree days, is suitable for a limited number of crops. Winter wheat, winter rye, grain legumes, and winter oilseed rape are cultivated in southern parts of the country (Peltonen-Sainio et al., 2013) but crop production is dominated by spring cereals such as barley and oats for animal feed (OSF, 2020). Annual precipitation, which averages between 550-700 mm, is clearly higher than annual evapotranspiration. However, early summer drought (from May to June) often limits crop yields since a large part of annual precipitation occurs over the period August to December (Ministry of the Environment and Statistics Finland, 2017; Tao et al., 2015). Nevertheless, irrigation is mostly limited to horticulture and seed crop production. The agricultural sector represented 3% of total water withdrawals in Finland (OSF, 2018) (Figure 7). Moreover, in 2016, 2.5% of agricultural land was equipped for irrigation, almost half of which is for potato, representing a small fraction of estimated-irrigation potential (OSF, 2018). Irrigation, either sprinkler or drip irrigation, was used in open air vegetable and berry production and in greenhouse production (OSF, 2018). The most exported crops (oats, wheat, and barley) are not irrigated, thus their annual production and export volumes are highly variable due to weather conditions affecting crop yields.

Figure 7 | Water withdrawals by sector in 2016



Source. Adapted from AQUASTAT Database (FAO, 2017)

Figure 8 | Evolution of blue water footprint in the Current Trends and Sustainable Pathways



Pathways and Results

Under the Current Trends Pathway, annual blue water use remains stable between 2000-2015 (14 and 13 Mm^3/yr), before plateauing at 14 Mm^3/yr between 2030 and 2050, respectively (Figure 8), with vegetables and potato production accounting for most of the computed blue water use for agriculture by 2050[4]. In contrast, under the Sustainable Pathway, blue water footprint in agriculture reaches 16 Mm^3/yr in 2030 and 19 Mm^3/yr in 2050, respectively. This increase in blue water use is due to the increasing vegetable production. However, drip irrigation (see Annex 2) improves the water-use efficiency of irrigation (Pajula & Triipponen, 2003).

4 We compute the blue water footprint as the average blue fraction per tonne of product times the total production of this product. The blue water fraction per tonne comes from Mekonnen and Hoekstra (2010a, 2010b, 2011). In this study, it can only change over time because of climate change. Constraints on water availability are not taken into account

Resilience of the Food and Land-Use System

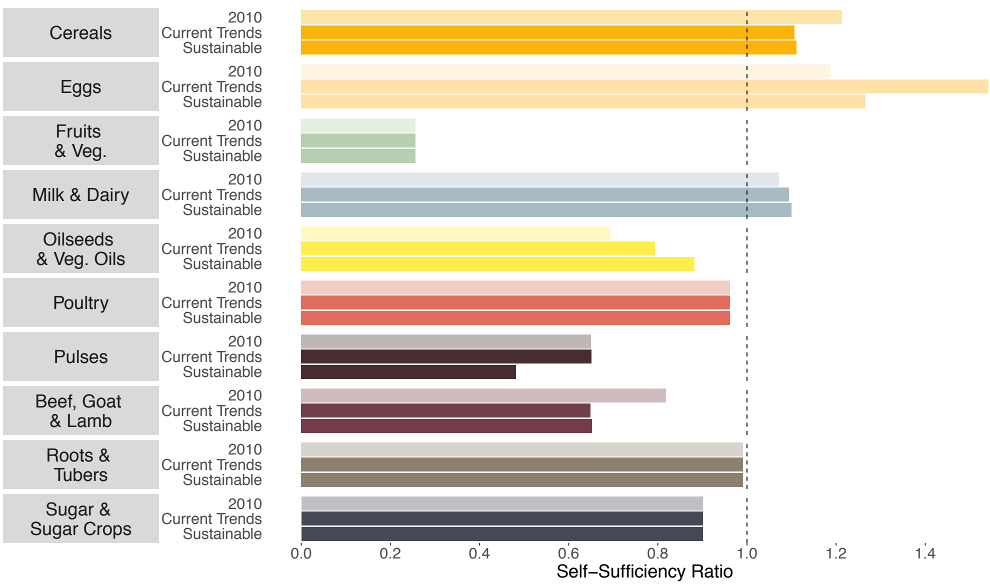
The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge Finland's resilience to agricultural-trade and supply disruptions across pathways: the rate of self-sufficiency and diversity of production and trade. Together they highlight the gaps between national production and demand and the degree to which we rely on a narrow range of goods for our crop production system and trade.

Self-Sufficiency

In Finland, 70-80% has been used as a proxy for self-sufficiency of food, as in the recent COVID-19-related food-security discussion (Niemi, 2020; Pihlanto, 2020). Providing an exact estimate of food self-sufficiency is challenging because of the large differences in the share of domestic production out of consumption per product, the shares of which vary over different years due inter-annual fluctuations in imports and, for example, annual crop yields (Niemi, 2020; Niemi & Väre, 2019; OSF, 2020). Very recently, Finland was ranked the 5th best country in terms of food security in the world. One key reason was the high share of domestic ingredients used in foods consumed in Finland (The Economist, 2020).

Under the Current Trends Pathway, we project that Finland would be self-sufficient in cereals, eggs, and dairy in 2050, almost self-sufficient in poultry, roots and tubers, with self-sufficiency decreasing in beef but increasing only in oilseeds, with the other products staying constant from 2010 to 2050 (Figure 9). The product groups for which Finland depends the most on imports to satisfy internal consumption are fruits and vegetables and pulses. This dependency will remain rather stable until 2050. Under the Sustainable Pathway, by 2050, Finland remains self-sufficient in cereals, eggs, and dairy, and almost self-sufficient in poultry, roots and tubers, as in the Current Trends Pathway. However, Finland would be less self-sufficient in pulses and nuts because of increasing consumption and unfavorable climatic conditions to grow these crops.

Figure 9 | Self-sufficiency per product group in 2010 and 2050



Note. In this figure, self-sufficiency is expressed as the ratio of total internal production over total internal demand. A country is self-sufficient in a product when the ratio is equal to 1, a net exporter when higher than 1, and a net importer when lower than 1.

Diversity

The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

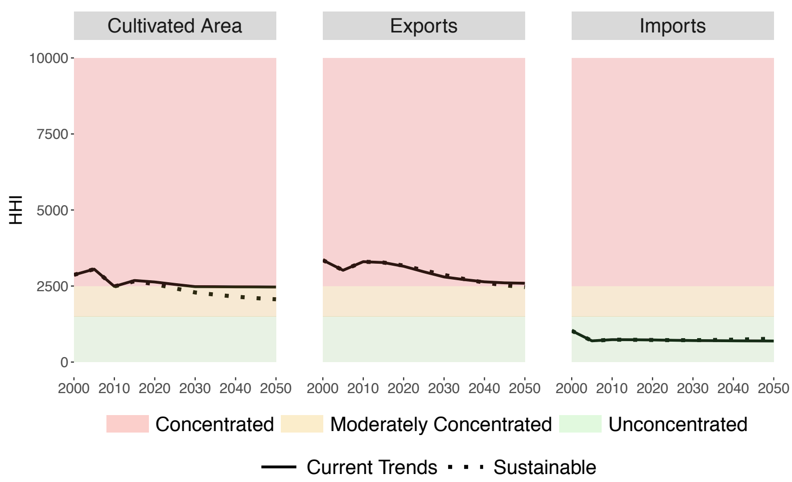
- **Cultivated area:** where concentration refers to cultivated area that is dominated by a few crops covering large shares of the total cultivated area, and diversity refers to cultivated area that is characterized by many crops with equivalent shares of the total cultivated area.
- **Exports and imports:** where concentration refers to a situation in which a few commodities represent a large share of total exported and imported quantities, and diversity refers to a situation in which many commodities account for significant shares of total exported and imported quantities.

We use the same thresholds as defined by the U.S. Department of Justice and Federal Trade Commission (2010, sec. 5.3): diverse under 1,500, moderate concentration between 1,500 and 2,500, and high concentration above 2,500.

In Finland, crop production has been and is currently dominated by cereals and grass forage production for feed (OSF, 2020), crop exports have been heavily dominated by barley, oats and wheat, depending on the weather and harvest conditions affecting the crop yields (OSF, 2019a, 2019b), while crop imports are less concentrated since a large number of crops, especially fruits and vegetables, are imported (OSF, 2019b).

Under the Current Trends Pathway, we project the high concentration of crop exports to continue although to decrease gradually. This is due to excess production of cereals not being very profitable in a country where crop yields are lower than in most other countries in Europe. We also project low concentration of imports to continue. These trends show rather low diversity and low competitiveness of crop production over the period 2010-2050. In contrast, under the Sustainable Pathway, we project slowly increasing diversity of crop production since cereals production for feed will decrease and vegetable and oilseed production will increase. This change is slow but significant up to 2050. Increased diversity of crop production and reduced monocultures also support slightly higher crop yields per hectare in the Sustainable Pathway compared to the Current Trends Pathway. Diversity of crop imports will also stay high in the Sustainable Pathway since fruits and vegetable consumption increases. Consumption and imports of nut and pulse crops also increase slightly. Diversity of exports only increases slightly in the Sustainable Pathway, compared to the Current Trends Pathway (Figure 10).

Figure 10 | Evolution of the diversification of the cropland area, crop imports and crop exports of the country using the Herfindahl-Hirschman Index (HHI)



Discussion and Recommendations

The outcomes of the two pathways, Current Trends and Sustainable, clearly show that even without drastic changes in diets, productivity, food trade, land use, or GHG abatement, gradual and consistent changes in the same direction will cause very large changes in the entire Finnish agriculture and food system. The key driving force in this development is food consumption. If there is lower demand for animal products and increased demand for fruits and vegetables and protein crops, producers will have no option but to follow. Sustainable production practices are another key point that must be ensured, specifically productivity increases need to be attained with improved utilization of production inputs. This requires improved quality of agricultural soils (e.g. water retention and soil pH), improved crop protection and crop rotation, which can be promoted by, for example, more diversified crop production which may also improve biodiversity and resilience at the farm level. Large scale, often monocultural, cultivation of feed crops in highly specialized farms in specialized production regions would diminish with decreased demand for animal-based foods. Instead, protein crops as well as expanding fruit and vegetables production could diversify land use both at farm and regional scale.

Nevertheless, large scale, efficient, and productive livestock farms and related production chains are also needed in the future as the consumption of livestock products is unlikely to rapidly decrease. Instead, 50-70% of current demand and production may remain close to year 2050. Animal products have clear advantages in human nutrition, especially for children and elderly people, because of, for example, iron, zinc, vitamins B12 and D, as well as calcium and selenium, all of which are not easily obtained from purely vegetarian or vegan diets. However, decreasing the consumption of animal-based foods would have positive health effects for many people in Finland since high cholesterol and blood pressure as well as cardiovascular diseases are often linked to high saturated fat intake. Reasonable volume of advanced and more sustainable livestock production with more efficient and accurate input use is also useful for maintaining soil quality and biodiversity with the means of rotational grasslands, including high nature valued biotopes, and advanced manure management. Animal farms can also produce biogas for energy and utilize more effective nutrient recycling.

Our results suggest that decreased animal production is needed for large scale land use change necessary for the effective reduction of GHG emissions from agriculture. A large part of GHG emissions originate from croplands while relatively less coming from enteric fermentation of animals and manure management, even though decreasing methane and nitrous oxide from animal production is also important. Reduced livestock production would nevertheless decrease feed demand and overall level of fertilization and nitrous oxide emissions from soils. Specific measures for decreasing GHG emissions from organic soils prove to be effective in reducing greenhouse gas emissions. With decreased demand for livestock products, all peatlands currently under cultivation are not needed in agricultural production, thus part of them could be rewetted, afforested, or even abandoned, resulting in significant GHG emission reductions per ha. Decreased cultivation area of feed crops would also free up some mineral soils. Afforesting these mineral soils can produce a significant reduction in GHG emissions over long run, though much less per hectare than from organic soils. More accurate accounting for peatlands and their productivity and GHG emissions could improve the analysis significantly when finding cost-effective approaches for long-run sustainability. In addition, we do not account for other environmental effects, such as possible nutrient leaching to watercourses. These, however, require more specialized studies.

Our results suggest that all these changes together may contribute up to a 42% reduction in AFOLU emissions by 2050. The key driver to launch this kind of change are more climate-, environment-, and health-conscious consumer behaviors. To obtain these reductions, it is not necessary for all people to become vegans but many must halve their consumption of livestock products. It is also important that the land-use changes and productivity developments described in this chapter have the opportunity to be effectively realized. This requires investments in agricultural research and development. In addition, to obtain the required large-scale changes in agriculture, economic incentives for change are pivotal. Productivity does not increase without effort. However, the costs linked to this or other large-scale changes in agriculture are not analyzed in this study.

There also have to be sufficient incentives for farmers to implement effective land use changes and other means of decreasing GHG emissions. For example, lost farm subsidies due to afforestation, re-wetting peatlands, and lost incomes due to changes in production practices (diversification or reduction of fossil-based inputs) should be compensated, at least partly, for farmers who need to find profitable and feasible alternatives already in the near future. Launching this change and seeing the long-run big picture of these developments is the main challenge for policymakers as well as for the society at large.

Annex 1. List of changes made to the FABLE Calculator to adapt it to the Finnish context

- Extended possible feed types to typical Finnish feeds
- Included feed efficiency scenarios: possible to increase or decrease the required feed per TLU
- Extended productivity shifters to product-specific multipliers
- Extended import and export scenarios to product-specific scenarios
- Included a custom extension to take peatland soil emissions in agriculture into account

Annex 2. Underlying assumptions and justification for each pathway

POPULATION Population projection (million inhabitants)

Current Trends Pathway	Sustainable Pathway
The population is expected to reach 5.9 million by 2050. Based on Statistics Finland (2015). (SSP2 scenario selected)	The population is expected to reach 5.9 million by 2050. Based on Statistics Finland (2015). (SSP2 scenario selected)

LAND Constraints on agricultural expansion

Current Trends Pathway	Sustainable Pathway
We assume no expansion of agricultural land beyond 2010 agricultural area levels. This is because cultivated farmland area has remained stable since 2000 (OFS, 2020). We assume that there will be no expansion of the agricultural land on existing protected areas.	Same as Current Trends.

LAND Afforestation or reforestation target (1000 ha)

Current Trends Pathway	Sustainable Pathway
We assume that deforestation will not be fully halted beyond 2030. However, the rate of deforestation remains very small (Aakkula et al., 2019). We did not take afforestation into account in this pathway (no afforestation scenario selected).	We assume that deforestation will be halted and afforestation of unused farmland results in slightly increased forest area beyond 2030. We assume total afforested/reforested area to reach 0.2 Mha by 2050. (LowCarbon scenario selected)

BIODIVERSITY Protected areas (1000 ha or % of total land)

Current Trends Pathway	Sustainable Pathway
Protected areas remain stable: by 2050 they represent 16% of total land.	Same as Current Trends.

PRODUCTION Crop productivity for the key crops in the country (in t/ha)	
Current Trends Pathway	**Sustainable Pathway**
By 2050, crop productivity reaches: • 3.4 tonnes per ha for barley • 3.3 tonnes per ha for oat • 3.7 tonnes per ha for wheat Based on Tao et al. (2015)	By 2050, crop productivity reaches: • 3.6 tonnes per ha for barley • 3.5 tonnes per ha for oat • 3.9 tonnes per ha for wheat Based on Tao et al. (2015)
PRODUCTION Livestock productivity for the key livestock products in the country (in t/head of animal unit)	
By 2050, livestock productivity reaches: • 11,000 kg milk per head for dairy cows • 360 kg per head for cattle bulls • > 30 piglets per sow Based on food industry expert consultations.	Same as Current Trends.
PRODUCTION Pasture stocking rate (in number of animal heads or animal units/ha pasture)	
By 2050, the average ruminant livestock stocking density is less than 1 TLU/ha. Based on Lehtonen et al. (2017)	Same as Current Trends.
PRODUCTION Post-harvest losses	
By 2050, the share of production and imports lost during storage and transportation is only slightly reduced.	By 2050, the share of production and imports lost during storage and transportation is reduced by 20% Based on Silvennoinen et al. (2015)

TRADE Share of consumption which is imported for key imported products (%)	
Current Trends Pathway	**Sustainable Pathway**
By 2050, the share of total consumption which is imported is: • 50% for cheese • 35% for beef • 10 % for poultry Based on Lehtonen (2015)	Same as Current Trends.
TRADE Evolution of exports for key exported products	
By 2050, the volume of exports is: • Significantly decreased for cereals • Slightly increased for dairy products • Remained unchanged for other products Based on Lehtonen (2015)	Same as Current Trends.

Finland

FOOD Average dietary composition (daily kcal per commodity group or % of intake per commodity group)	
Current Trends Pathway	**Sustainable Pathway**
By 2030, the average daily calorie consumption per capita: • remained unchanged for animal products • remained unchanged or slightly increased for fruits and vegetables • remained at low levels for pulses and nuts (expert opinion)	By 2030, the average daily calorie consumption per capita is: • decreased significantly for animal products • increased significantly for fruits and vegetables • increased moderately for pulses and nuts Based on Saarinen et al. (2019)
FOOD Share of food consumption which is wasted at household level (%)	
By 2030, the share of final household consumption which is wasted at the household level is unchanged. Based on expert opinion	By 2030, the share of final household consumption which is wasted at the household level is decreased moderately. Based on Silvennoinen, Heikkilä, Katajajuuri, & Reinikainen (2015)

BIOFUELS Targets on biofuel and/or other bioenergy use	
Current Trends Pathway	**Sustainable Pathway**
By 2050, biofuel production is at a small scale and based on few biogas plants utilizing manure and excess forage grass biomass as input. Based on Niemi & Väre (2020)	By 2050, biofuel production is at a moderate scale and based on few biogas plants utilizing manure and excess forage grass biomass as input. Based on Niemi & Väre (2020)

CLIMATE CHANGE Crop model and climate change scenario	
Current Trends Pathway	**Sustainable Pathway**
By 2100, global GHG concentration leads to a radiative forcing level of 6 W/m2 (RCP 6.0). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO2 fertilization effect. The results are similar to the ones by Tao et al. (2015)	By 2100, global GHG concentration leads to a radiative forcing level of 2.6 W/m2 (RCP 2.6). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO2 fertilization effect. The results are similar to the ones by Tao et al. (2015)

Annex 3. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on Map 1

FABLE classes	ESA classes (codes)
Cropland	Cropland (10,11,12,20), Mosaic cropland>50% - natural vegetation <50% (30), Mosaic cropland><50% - natural vegetation >50% (40)
Forest	Broadleaved tree cover (50,60,61,62), Needleleaved tree cover (70,71,72,80,82,82), Mosaic trees and shrub >50% - herbaceous <50% (100), Tree cover flooded water (160,170)
Grassland	Mosaic herbaceous >50% - trees and shrubs <50% (110), Grassland (130)
Other land	Shrubland (120,121,122), Lichens and mosses (140), Sparse vegetation (150,151,152,153), Shrub or herbaceous flooded (180)
Bare areas	Bare areas (200,201,202)
Snow and ice	Snow and ice (220)
Urban	Urban (190)
Water	Water (210)

Units

°C – degree Celsius

% – percentage

/yr – per year

cap – per capita

CO_2 – carbon dioxide

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

g – gram

GHG – greenhouse gas

ha – hectare

kcal – kilocalories

kg – kilogram

km^2 – square kilometer

km^3 – cubic kilometers

kt – thousand tonnes

m – meter

Mha – million hectares

Mm^3 – million cubic meters

Mt – million tonness

t – tonne

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

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

t/TLU, kg/TLU, t/head, kg/head- tonne per TLU, kilogram per TLU, tonne 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

USD – United States Dollar

W/m^2 – watt per square meter

yr – year

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