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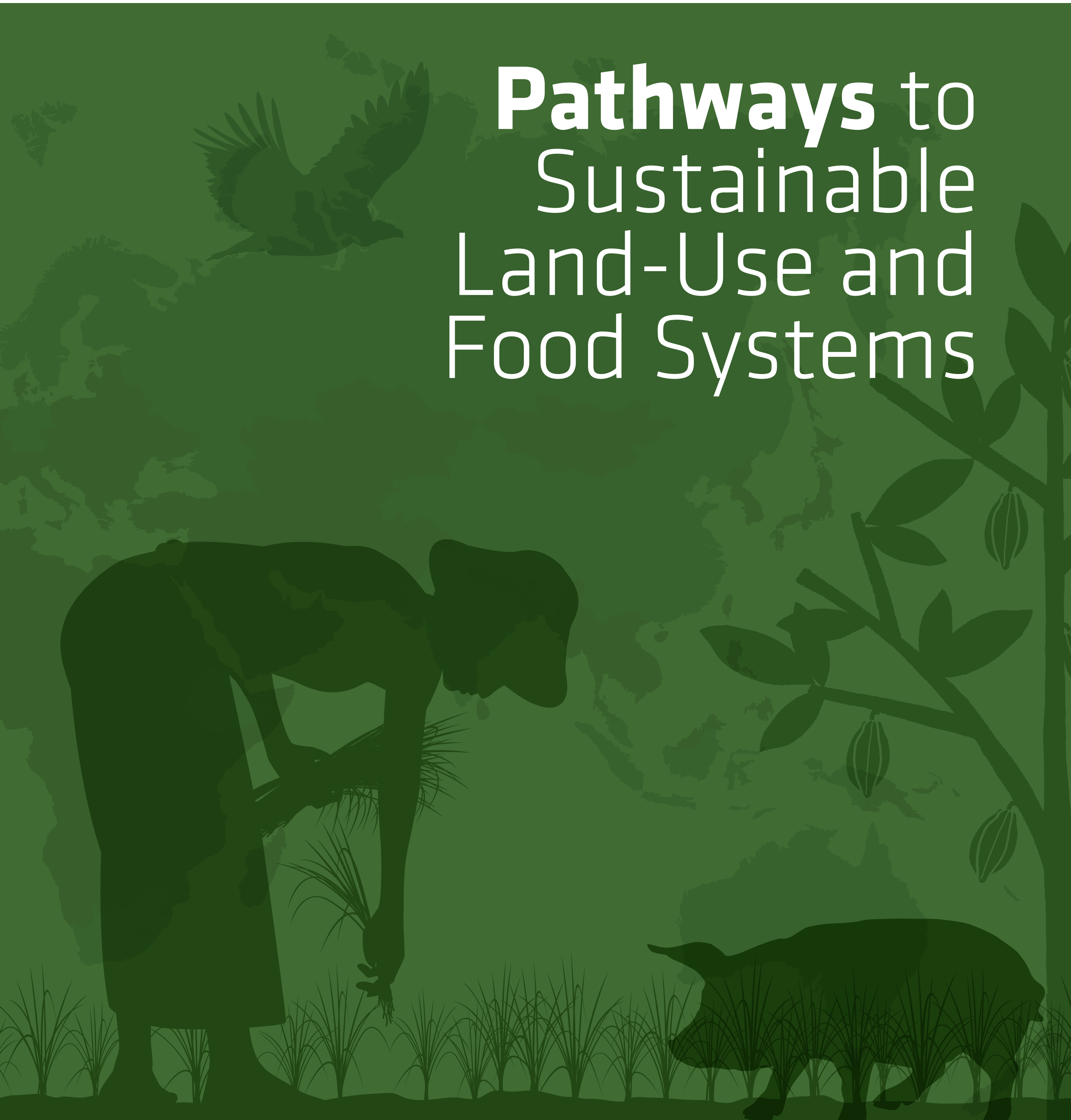
The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



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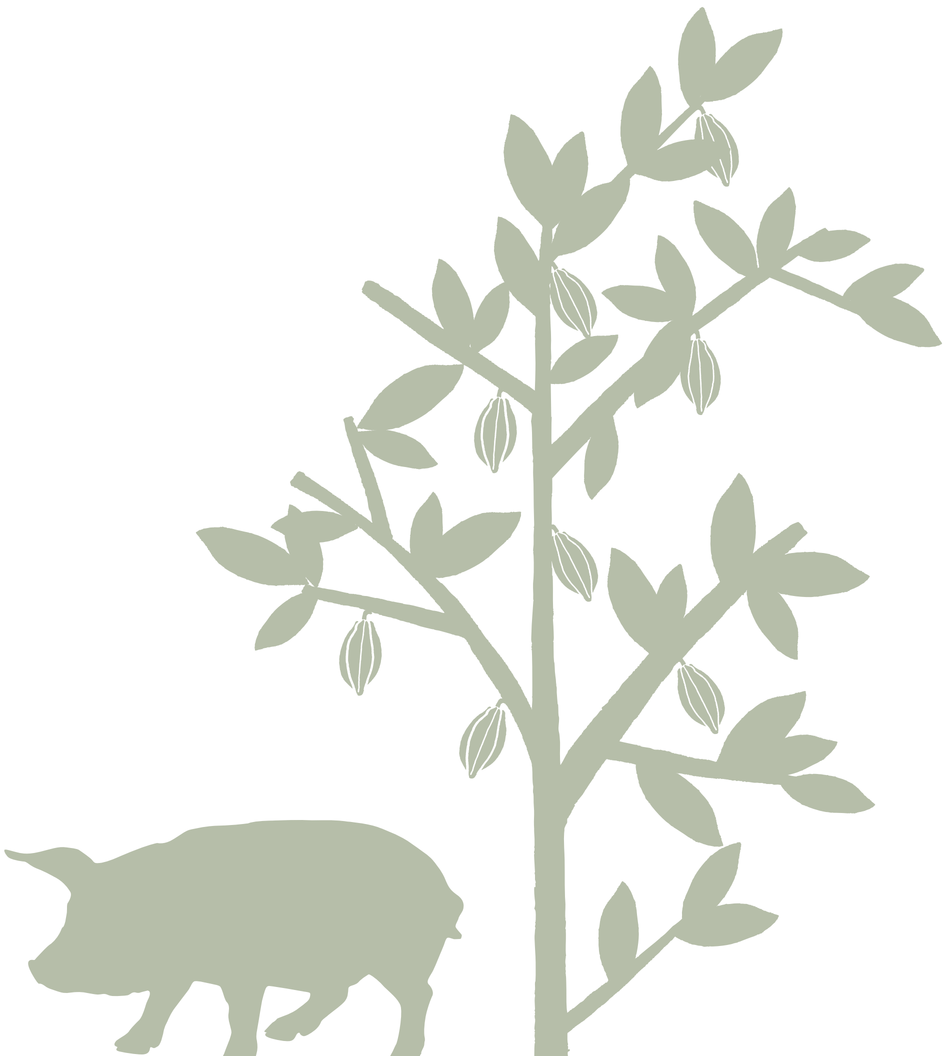
2020 Report of the FABLE Consortium

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



Norway

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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 Norway. 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 and modeled them with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019). See Annex 1 for more details on the adaptation of the model 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 Norway's NDC treats the FABLE domains. According to the NDC, Norway has committed to reducing its GHG emissions by 50% by 2030 compared to 1990. This includes emission reduction efforts from agriculture, forestry, and other land use (AFOLU). The NDC does not detail the specific measures for emissions cuts in the AFOLU sectors. These measures are instead followed up in separate sector "climate plans", for example for agriculture the *landbrukets klimaplan* (Norges Bondelag, 2020c). Envisaged mitigation measures from agriculture and land-use change include, but are not limited to, the phasing out of fossil fuels and increasing biofuel usage, improved feed quality and feed additives for livestock, breeding programs, improved drainage, improved fertilizing practices, and carbon capture through the use of biochar and capture crops. The agricultural sector climate plan aims to reduce emissions by 5 Mt CO2e over the period 2021–2030 without reducing food waste and meat consumption (Government of Norway, 2020b; Norges Bondelag, 2020c). The forestry sector plans for active forestry, where forest products can replace fossil fuel use and other products. The sector aligns its activities with the EU guidelines through the LULUCF regulations. The resulting source/sink effects depend significantly on which reference pathway is used, and how the balance between carbon emissions and uptake is calculated. The current strategy envisages an increase of soil carbon uptake in forests and has a strong focus on increased use of residual materials (AHO et al., 2016; Treindustrien, 2016). Under its current commitments to the UNFCCC, Norway 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					
NDC (2017)	1990	52	2030	50% reduction	energy, industrial processes and product use, agriculture, land-use change and forestry, and waste	Y	N	N	N

Note. "Total GHG Mitigation" and "Mitigation Measures related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019)
Source. Norway (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 targets listed in the National Biodiversity Strategies and Action Plan (NBSAP) from 2016, as listed on the CBD website (CBD, 2020), which are related to at least one of the FABLE Targets. Comparing the FABLE and NBSAP targets in terms of deforestation and biodiversity, it appears that while the FABLE Targets include a target for zero net deforestation, this is not part of the NBSAP targets. For biodiversity, FABLE Targets include a specific amount of global terrestrial area protected by a certain year, which is not included in the NBSAP targets. Norway shows strategies to safeguarding plant and genetic diversity, for example aiming to improve landscape diversity and management of semi-natural habitats within existing protected landscapes in order to maintain their conservation value. It is also taking action to identify 70,000 areas as key biotopes, corresponding to almost 1% of the total area of productive forest. In-situ conservation programs by the Norwegian Genetic Resource Centre have identified flora species and crop wild relatives to be safe guarded. However, it lacks strong policies for example conserving (agro-) biodiversity ex-situ.

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

NBSAP Target	FABLE Target
(4.2) **All forestry areas will be sustainably managed by 2020.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards
(4.1) **By 2020, the diversity of habitat types in forests will be maintained or restored; this will include safeguarding genetic diversity and important ecological functions and services.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards **BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(4.5) **Management of all harvested stocks of forest animals and plants will be ecosystem-based, and they will be harvested sustainably by 2020.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards
(2.1, 3.1, 4.1, 5.1, 6.5) **By 2020, the diversity of habitat types in freshwater, forest, wetlands, mountain and in cultural landscapes will be maintained or restored**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(6.5) **By 2020, the diversity of habitat types in cultural landscapes will be maintained or restored; this will include safeguarding genetic diversity and important ecological functions and services.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(2.3, 4.3, 5.2, 6.6) **A representative selection of wetlands, forest habitat, mountain habitat and habitat types in the cultural landscape will be protected for future generations, and the conservation value of protected areas will be maintained or restored.**	**BIODIVERSITY:** At least 30% of global terrestrial area protected by 2030

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 Norway.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by medium population growth based on SSP2 (from 5 million inhabitants in 2020 to 7 million in 2050) accompanied by a slow urban expansion, no expansion of agricultural areas, no afforestation target, no change in the extent of protected areas, no productivity increases in the agricultural sector, a decrease in food waste, an evolution of diets towards national dietary recommendations with more vegetables, grains and fruits, more fish, and reductions in especially red meat consumption (Annex 2). This corresponds to a future based on current Norwegian policy and historical trends. 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. Our model includes the corresponding climate change impacts on crop yields by 2050 for wheat (see Annex 2).

Our Sustainable Pathway represents a future in which 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 a similar population growth with a slow urban expansion but under different conditions, based on SSP1. As in the Current Trends Pathway, there is no expansion of agricultural areas, no afforestation target, no change in the extent of protected areas and no productivity increases in the agricultural sector. However, this pathway includes a stronger decrease in food waste and an evolution towards a more sustainable diet with more vegetables, grains and fruits, more fish, and higher reductions in red meat compared to the Current Trends Pathway (see Annex 2). This corresponds to a future where measures in Norway trigger a change towards a more sustainable diet and a strong reduction in food waste, while land use would remain under constraints similar to the present state. With the other FABLE country teams, this Sustainable Pathway is embedded 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.

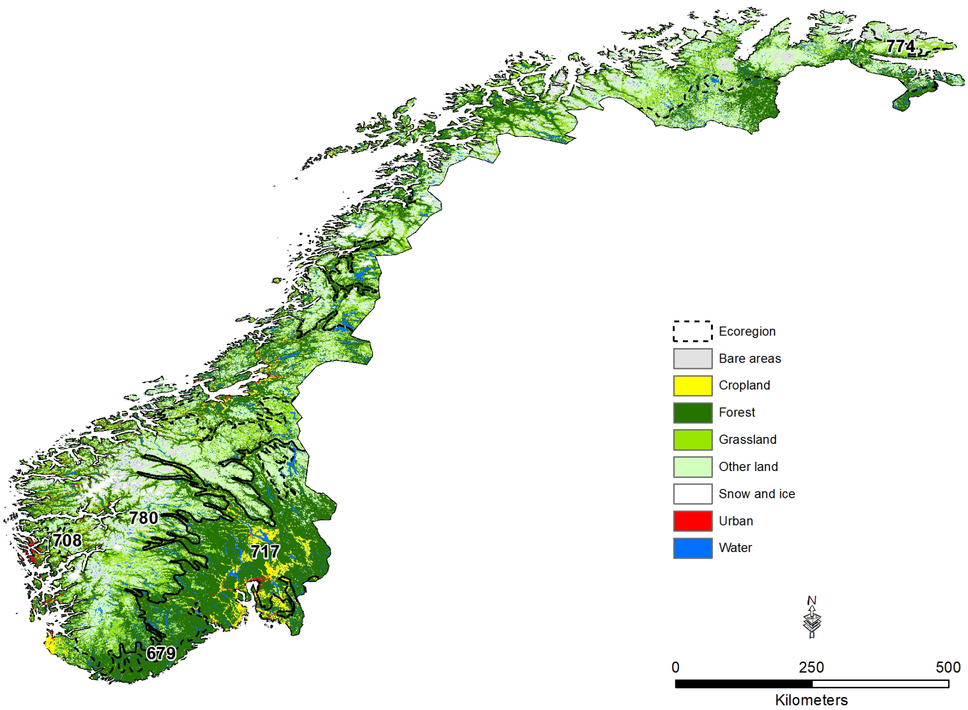
Land and Biodiversity

Current State

In 2010, Norway was covered by 2.5% cropland, 0.5% cultivated grassland, 25.5% forest, 0.6% urban and 71% other natural land. Most of the agricultural area is located in the south while forest and other natural land can be found almost everywhere in the country (Map 1). In Norway, biodiversity hot spots are located in the most populated areas (Miljødirektoratet, 2020) as urban expansion puts endangered species under pressure. Furthermore, in Norway, 90% of threatened species are assumed to be adversely affected by future climate change.

We estimate that land where natural processes predominate[2] accounted for 67% of Norway's terrestrial land area in 2020 (Map 2). The category 780-Scandinavian Montane Birch forest and grasslands holds the greatest share of land where natural processes predominate, followed by 717-Scandinavian and Russian Taiga and 708-Scandinavian coastal conifer forests (Table 3). In the model, across the country, while 5.4 Mha of land is under formal protection, falling short of the 30% zero-draft CBD post-2020 target, only 20% of land where natural processes predominate is formally protected. Recent findings (Miljødirektoratet, 2020) show that while Norway is coming closer to the goal of protecting a representative share of Norwegian nature, a considerable number of threatened species are located outside protected areas. This indicates that protection alone is not enough: a sustainable use and management of nature outside conservation areas is also crucial to stop the loss of natural diversity.

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

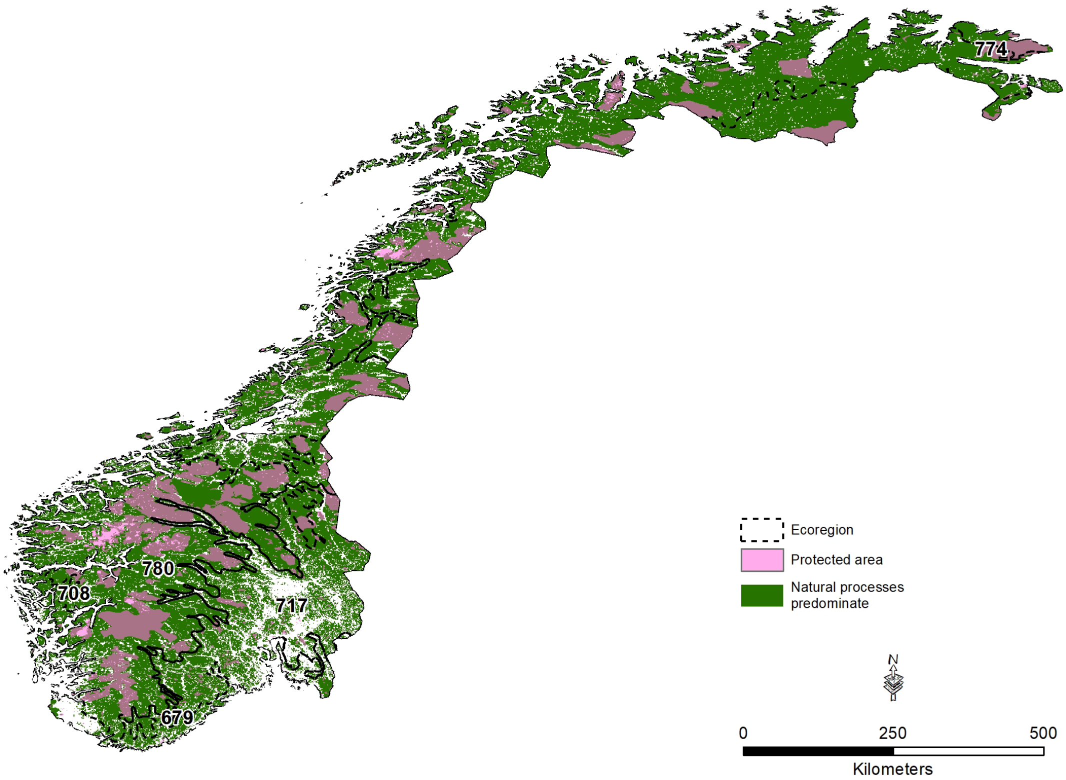


Note. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 3.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)

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".

Approximately 60% of Norway's cropland is in landscapes with at least 10% natural vegetation in 2020. These relatively biodiversity-friendly croplands are most widespread in ecoregion categories 774-Kola Peninsula tundra, followed by 780-Scandinavian Montane Birch forest and grasslands and 708-Scandinavian coastal conifer forests. The regional differences in the extent of biodiversity-friendly cropland can be explained by the landscape in Norway. Due to Norway's very complex topography, with high mountains, agriculture is possible in only a few locations (see Map 1).

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	896.9	3.1	52.9	3.9	96.1	106.6	48
708	Scandinavian coastal conifer forests	1709.8	5.4	56	7.5	92.5	122.9	53.4
717	Scandinavian and Russian taiga	9721.5	8.8	72.5	11.4	88.6	655.4	53.1
774	Kola peninsula tundra	365.6	38.6	92	41	59	0.398	96.2
780	Scandinavian Montane Birch forest and grasslands	18274.5	23.3	86.7	24.7	75.3	208.7	90.7

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)

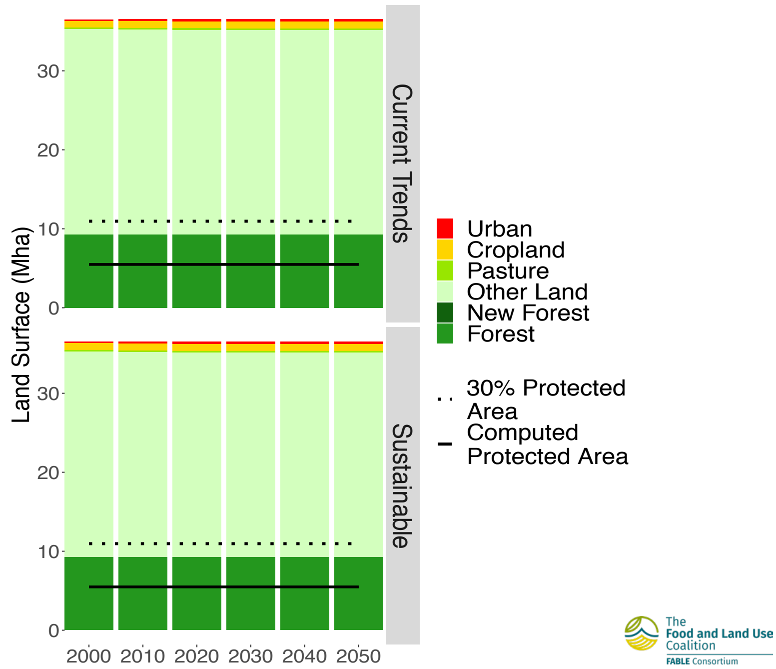
3 The share of land within protected areas and the share of land where natural processes predominate are percentages of the total ecoregion area (counting only the parts of the ecoregion that fall within national boundaries). The shares of land where natural processes predominate that is protected or 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.

Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including slow urban expansion, no constraints on land conversion beyond protected areas, no expansion of agricultural land beyond its current area and no planned afforestation or reforestation. Protected areas remain at 5.4 Mha, representing 15% of total land cover (see Annex 2).

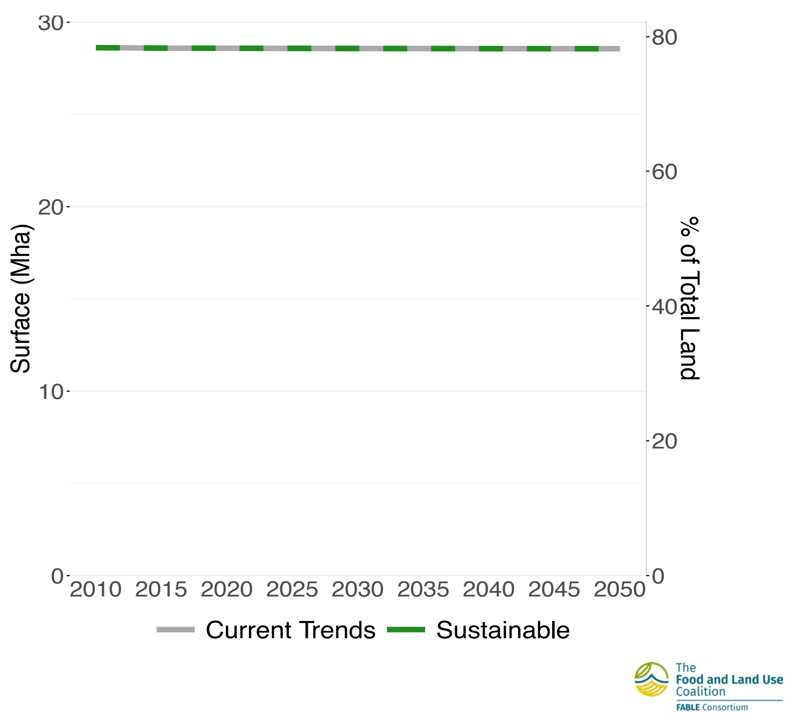
By 2030, the model suggests that the main changes in land cover in the Current Trends Pathway will result from a small increase in urban areas and a resulting decrease of other land area. This trend continues over the period 2030–2050 (Figure 1). In the Sustainable Pathway, assumptions are very similar to the Current Trends Pathway with similar changes in land distribution (see Annex 2). The main reason for the similarity between the pathways is that it is unlikely that land use will change significantly in Norway in the coming decades. Agricultural land could expand into new areas, but this is mostly constrained to peat soils, which is prevented by specific policies. These small changes in land cover are also related to a moderate increase in urban areas due to the slow increase in population and the increase in the density of populated areas. Finally, there has been a large growth in forest areas since the 1940s so there is not a lot of room left for afforestation. On the other hand, there are currently no clear drivers for deforestation as land would not be suitable for agriculture and urban expansion is moderate.

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, and the World Database on Protected Areas (UNEP-WCMC & IUCN, 2020) from 2020 for protected areas for years 2000, 2005 and 2010.

Figure 2 | Evolution of the area where natural processes predominate

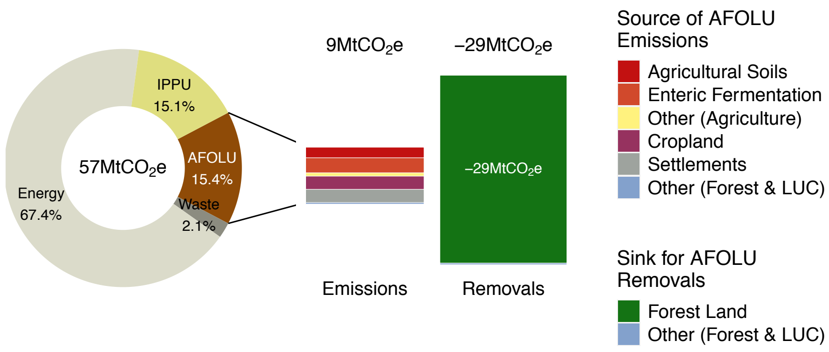


GHG emissions from AFOLU

Current State

Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 15.4% of total emissions in 2017 (Figure 3). Enteric fermentation is the principle source of AFOLU emissions followed by settlements, cropland, agricultural soils and other (agriculture). This can be explained by the fact that Norway is self-sufficient in meat from ruminant livestock (Helsedirektoratet, 2020) and that the total forest area has not changed very much in recent decades (UNFCCC, 2020b).

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 2017

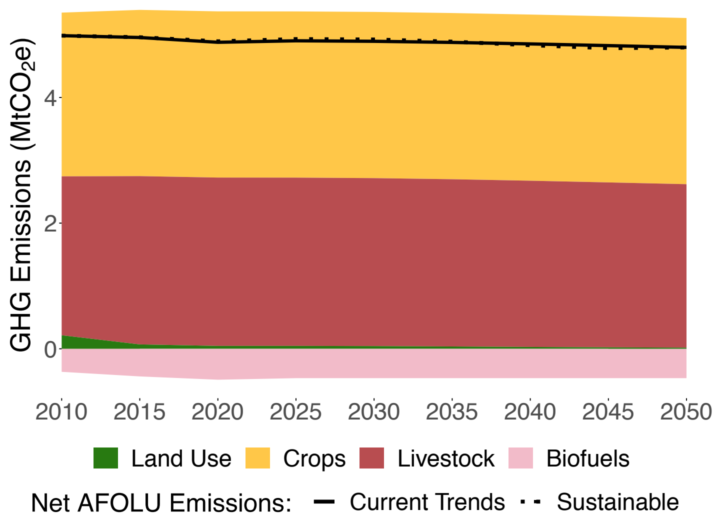


Source. Adapted from GHG National Inventory (UNFCCC, 2020a)
Note. IPPU = Industrial Processes and Product Use

Pathways and Results

Under the Current Trends Pathway, annual GHG emissions from AFOLU remain stable over the period 2020 to 2050, at around 4.9 Mt CO_2e/yr and 4.8 Mt CO_2e/yr (Figure 4). In 2050, agriculture and livestock are the largest sources of emissions. The Sustainable Pathway leads to similar AFOLU GHG emissions (Figure 4). The potential slight emissions reductions under the Sustainable Pathway is dominated by a reduction in GHG emissions from livestock (Figure 5). Dietary change that leads to declining meat consumption is the most important driver of this reduction. In this context, the contribution of AFOLU to total GHG emissions is limited. It is important to note

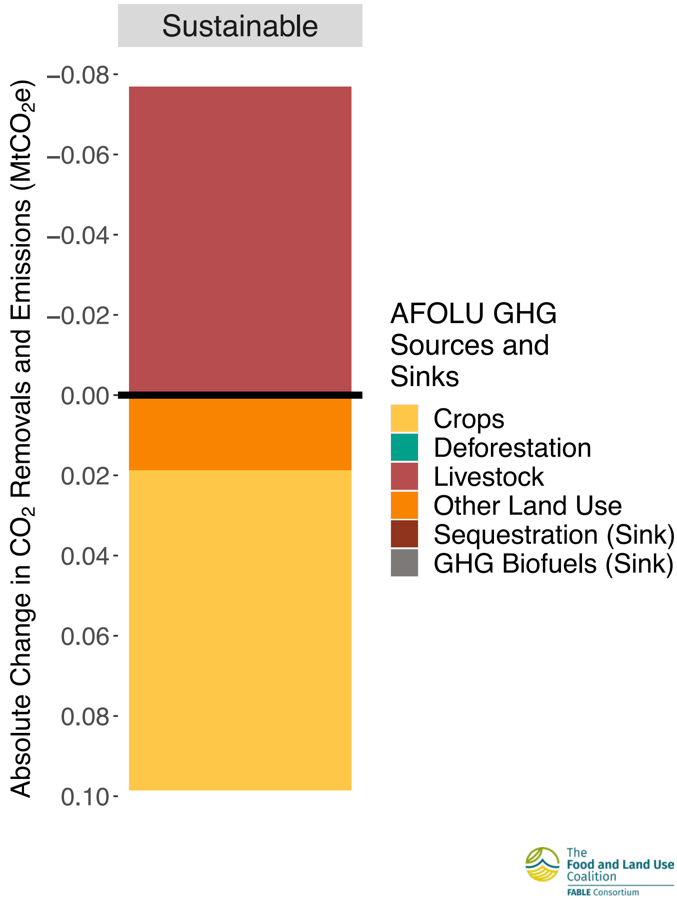
Figure 4 | Projected AFOLU emissions and removals between 2010 and 2050 by main sources and sinks for the Current Trends Pathway



that Figure 3 is based on data from the UNFCCC's national GHG inventory while Figures 4 and 5 are based on FABLE Calculator projections. Currently, the cultivation of organic soils is not accounted for in our projections for Norway's land-use and food systems pathways.

In Norway, reductions in GHG emissions from AFOLU could be achieved through a number of different policy measures. Farmer unions have made a new plan for decreasing emissions based on several measures such as a change in feed supplements to reduce methane emissions, a move from fossil fuels to biofuels or smarter- and reduced-use of fertilization (Norges Bondelag, 2020c). In the meantime, the forestry sector is planning to use active forestry where forest waste products can replace fossil fuel use; the current strategy envisages an increase in soil carbon uptake in forests and an increased use of residual materials. All these measures could contribute to decreasing GHG emissions from AFOLU. These measures were not included in our Sustainable Pathway for a number of reasons. Some of these options are quite speculative, in particular those for which certain technologies are not yet available for commercial application. Therefore, we consider them as part of a Sustainable High Ambition Pathway, which we did not develop, and not suitable for a Sustainable Pathway. Some measures have not been implemented for technical reasons as the FABLE Calculator needs more development on the forestry sector. Finally, some issues such as biofuels were left untouched due to time constraints.

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



Food Security

Current State

The "Triple Burden" of Malnutrition

Undernutrition

Child poverty has recently become a growing concern in Norway over the last 20 years as 100,000 children grow up in low income families, which is often a factor leading to undernutrition (Bufdir, 2020). Undernutrition is also a considerable problem among the elderly (Devik, 2019).

Micronutrient Deficiency

22.4% of women and 21% of children under 5 suffered from anemia in 2017, which can lead to maternal death (IHME, 2020).

5% of the population are deficient in vitamin A, which can notably lead to blindness and child mortality. 1.2% are deficient in iodine, which can lead to developmental abnormalities (IHME, 2020).

Lack of vitamin D is an issue in Norway, particularly among non-western immigrants (Nasjonalt Råd for Ernæring, 2018).

Overweight/ Obesity

Around 25% of middle-aged men and 20% women were classified as obese with body mass index of 30 kg/m^2 in Norway in 2017. Moreover 60% of adults were overweight in 2017. These rates have increased since 2000 (NIPH, 2017).

Between 15 and 20% of children were overweight or obese in 2017. This proportion has stabilized in the last decade (NIPH, 2017).

Disease Burden due to Dietary Risks

0.13% of deaths are attributable to nutritional deficiencies, which represents 1.0 deaths per year (per 100,000 people) in 2017 (IHME, 2020).

17% of the population suffers from diabetes and 10% from cardiovascular diseases, which can be attributable to dietary risks (IHME, 2020).

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)	2,916 (2,088)	2,667 (2,093)	2,794 (2,093)	2,358 (2,089)	2,471 (2,089)
Fats (g) (recommended range	154 (65-97)	125 (59-89)	130 (61-91)	113 (54-81)	116 (54-81)
Proteins (g) (recommended range	115 (73-255)	85 (67-233)	88 (69-240)	80 (60-211)	85 (61-212)

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 27% higher in 2030 and 13% higher in 2050 (Table 4). The current average intake is satisfied by eggs, fish, milk, red meat, root vegetables, sugar, animal fat and animal products. Animal products and animal fat represent 33% of the total calorie intake. This pathway results in an increase in the consumption of eggs and nuts between 2020 and 2050 while the consumption of cereals, fish, fruit and vegetables, red meat, sugar is assumed to decrease. Looking at the EAT-Lancet recommendations (Willett et al., 2019), red meat, fish, eggs, roots, sugar, and animal fat are over-consumed in 2050 while cereals, fruits and vegetables, nuts, oilseed and vegetable oils, and pulses are in the lower, but within the recommended range (Figure 6). Moreover, fat intake per capita exceed the dietary reference intake (DRI) in 2030 and 2050 but decreases between 2030 and 2050 while the protein intake remains stable. This can be explained by a decline in the consumption of pork and red meat (Table 4).

Under the Sustainable Pathway, we assume that diets will transition towards a more sustainable diet with the consumption of fruits and vegetables reaching the average EAT-*Lancet* recommendation in 2050 and where less red meat is consumed. The ratio of the computed average intake over the MDER decreases to 33% in 2030 and 18% in 2050 under the Sustainable Pathway. This pathway results in an increase in the consumption of eggs, nuts, fish, fruits and vegetables between 2020 and 2050 while the consumption of cereals and red meat is assumed to decrease. Compared to the EAT-Lancet recommendations, the consumption of fish, eggs, roots, sugar and animal fat remains outside of the recommended range (Figure 6). Moreover, the fat intake per capita still exceeds the dietary reference intake (DRI) in 2030 and 2050 while the protein intake remains stable, showing almost no improvement compared to the Current Trends Pathway.

To go towards more sustainable diets in Norway, several measures could be introduced such as using food taxes and subsidies (Abadie, Galarraga, Milford, & Gustavsen, 2016). There is also the option of acting indirectly on consumer preferences and consumption habits (Milford, Le Mouël, Bodirsky, & Rolinski, 2019), for instance through information, education policy, and increased availability of ready-made plant-based products. The latter could be of key importance for mitigating an increase in meat consumption and promote consumption of low-fat and low-emission products.

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

Current Trends 2050

Sustainable 2050

National Statistics 2015

Notes. These figures are computed using the relative distances to the minimum and maximum 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. The discontinuous lines that appear at the outer edge of sugar indicate that the average kilocalorie consumption of this food category is significantly higher than the maximum recommended.

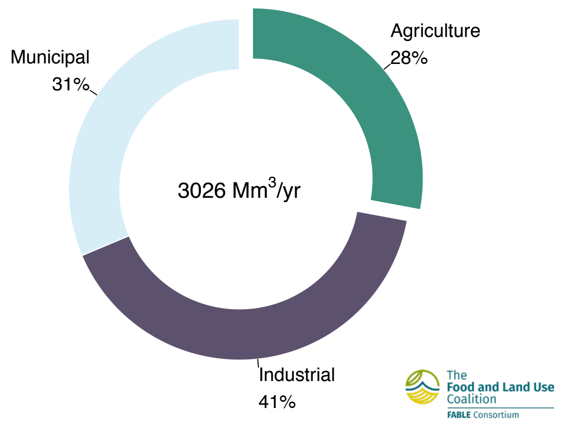
The Food and Land Use Coalition
FABLE Consortium

Water

Current State

Norway is characterized by a marine climate in the west with, by comparison with eastern Norway, cool summers, mild winters and high precipitation rates (2250 mm average annual precipitation). In contrast, Eastern Norway is sheltered by mountains and has an inland climate with warmer summers, cooler winters and generally less precipitation (760 mm average annual precipitation). Because of temperature variations through the year and across the country, precipitation in Norway falls both as rain and snow. In terms of agriculture, the sector represented 28% of total water withdrawals in 2006 (FAO, 2016; Figure 7). Agricultural water withdrawal is defined as the annual quantity of self-supplied water withdrawn for irrigation, livestock, and aquaculture purposes. In 2008, the total irrigated area was about 130 kha, which represents 14% of Norway's agricultural area. Most of these irrigated areas are found in eastern Norway. Data are lacking on the individual crops that are irrigated but the most important irrigated crops seem to be vegetable crops, potatoes, and cereals (Riley & Berentsen, 2009).

Figure 7 | Water withdrawals by sector in 2006-2007

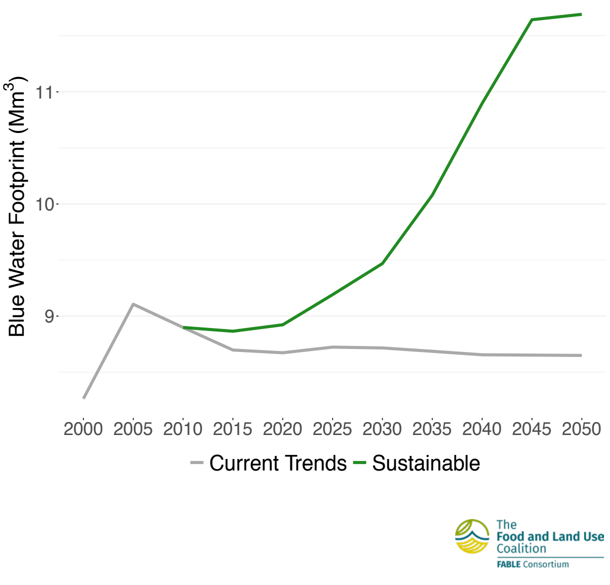


Source. Adapted from AQUASTAT Database (FAO, 2017)

Pathways and Results

Under the Current Trends Pathway, annual blue water use increases between 2000-2015, from 8.3 Mm^3/yr to 9.1 Mm^3/yr, before reaching 9.6 Mm3/yr and 10.4 Mm^3/yr in 2030 and 2050 (Figure 8), with potato and vegetables accounting for 62% and 32%, respectively, of computed blue water use for agriculture by 2050[4]. In contrast, under the Sustainable Pathway, the blue water footprint in agriculture reaches 10.4 Mm^3/yr in 2030 and 14 Mm^3/yr in 2050. These increases in water use for both the Current Trends and Sustainable Pathways are explained by a potential increasing need in irrigation due to climate change (i.e. potential droughts).

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



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

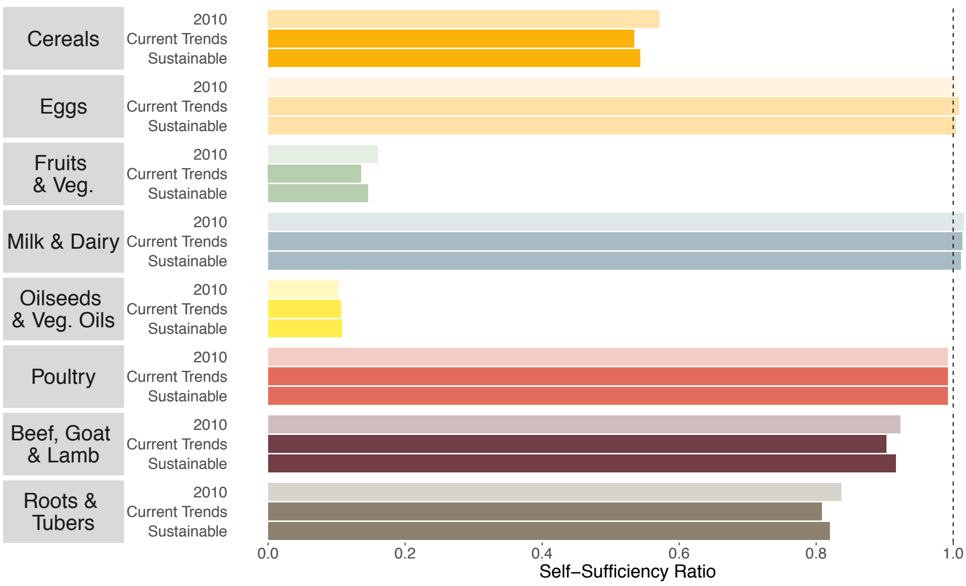
The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge Norway's resilience to agricultural-trade and supply disruptions across pathways: the 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

Norway is largely self-sufficient (80-100%) when it comes to animal products such as meat, cheese, eggs, and fish, being a net exporter of seafood. For vegetable and grain products, Norway is only partly self-sufficient (10-60%), with production depending, among other variables, on annual climate variations (www.regjeringen.no). Norway is largely dependent (80-95%) on imports of sugar, oils, and other fats. Overall Norway has less favorable conditions for agriculture than many other countries as the growing season is short, there is a cool climate, and farmlands only take up a small portion of the land.

Under the Current Trends and Sustainable Pathways, we project that Norway would be largely self-sufficient in eggs, dairy, poultry, beef and lamb, and roots and tubers in 2050, with self-sufficiency by product group remaining stable for the majority of the products from 2010 – 2050 (Figure 9). The product groups where the country depends the most on imports to satisfy internal consumption are fruits and vegetables and oilseeds and vegetable oils. This dependency remains stable until 2050. The self-sufficiency measures for animal products presented here do not account for the fact that a significant amount of animal feed is imported.

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

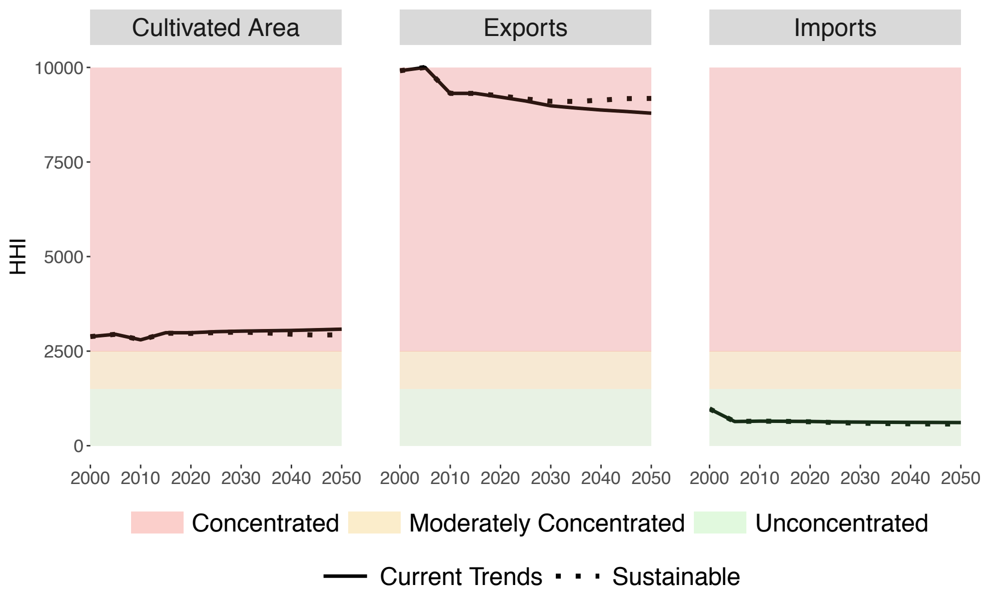
The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

- **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, section 5.3): diverse under 1,500, moderate concentration between 1,500 and 2,500, and high concentration above 2,500.

The HHI for crop exports is very high, indicating a very concentrated export market for crops, but as Norway's level of crop exports is very low, this has little significance. Norway exports fish and fish products and imports cereals, roots, pulses, dairy and eggs. Meanwhile, the HHI for crop imports is very high, reflecting a highly diverse sourcing of imported crops and crop products. Crop production is dominated by cereals, leading to a high HHI for planted area. Under the Current Trends and Sustainable Pathways, the HHI index remain stable over the period 2010–2050 for both exports and imports (Figure 10). This means that exports are not more diversified in the future while imports remain highly diverse.

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

In this work, two pathways related to potential changes in food and land-use are compared for Norway: Current Trends and Sustainable Pathways. The Current Trends Pathway follows today's policies, and our Sustainable Pathway represents a future in which efforts are made to adopt sustainable policies and practices that correspond to an intermediate boundary of intentionally feasible action. A justification for the choices made in each pathway can be found in Annex 2. As a result, the pathways are rather similar, and assume a similar population growth, no agricultural expansion but an increase in water usage for irrigation, no afforestation target, no change in the extent of protected areas, and no productivity increases in the agricultural sector. Both pathways also assume a decrease in food waste and an evolution towards a more sustainable diet however these changes are stronger in the Sustainable Pathway (see Annex 2). Another difference between the two pathways is the choice in RCP scenario for including the impact of climate change on crop yields: RCP6.0 for the Current Trends Pathway and RCP2.6 for the Sustainable Pathway. This corresponds to the Sustainable Pathway, in a future where measures in Norway would trigger a change towards a more sustainable diet and a strong reduction in food waste, while land-use would have similar constraints as the present. Without a "Sustainable High Ambition" pathway, our results do not show significant reductions in environmental impacts by 2050.

One key reason for the similarity between the pathways is that there is a low likelihood that land use will change significantly in Norway. Agricultural land could expand into new areas, but largely this is constrained to areas on peat soils, and there are specific policies accepted and being detailed to prevent this. As a result, we do not see significant potential for expansion of agriculture. However, our results do show some changes of land use within agriculture. While irrigation is not widely installed in Norway, in the context of climate change, with expectation of longer and deeper periods of drought, irrigation could see considerable expansion.

Potential trade-offs in the food and land-use system are related to the current main focus on livestock production and linked to pastures and feed production. A scenario of reduced meat consumption will reinforce the ongoing shrubification process especially in outfield pasture areas. This will decrease the total area of such cultural landscapes and reduce the biodiversity linked to these areas, especially in the northern and rural areas of Norway that depend on livestock. Consequently, it may also reinforce the process of farms going out of business, which is contrary to policy targets to keep rural areas populated. On the other hand, a concentrated effort to use agricultural land optimally, with grazing in areas with no other options and food production in areas with high quality agricultural land (a process called re-canalization) will reduce these trade-offs, free up land for food production, and is projected to increase self-sufficiency (Vangelsten, 2017) and substantially increase the potential area for potato and vegetable production (6-7 times; Mittenzwei, Milford, & Grønlund, 2017).

Our results show that changes in land use, agriculture, and food consumption can contribute to achieving national climate targets and policies, but by itself certainly cannot achieve the climate goals Norway has set. To achieve ambitious climate goals such as a low-emission society by 2050 (Govt of Norway, 2020), including all sectors becomes necessary, including agriculture. The changes in diet we propose are also not sufficient to meet the EAT-*Lancet* recommendations in terms of emission reductions but are more closely linked to national dietary recommendations, which mainly emphasize the public's nutritional health.
Our results may also influence national biodiversity policies. In Norway, around 90% of threatened species are negatively affected by land use change. While hotspots are mainly found near rural areas (Miljødirektoratet, 2020), shrubification of pasture areas due to discontinued or reduced grazing is assessed to negatively affect around 685 species (Henriksen & Hilmo, 2015). This highlights that biodiversity

management is not only about protection of areas, but also of management and intervention in existing habitats. Changes in diet supporting a reduction in grazing livestock may reinforce this declining trend in pasture areas. Furthermore, as described earlier, changes in livestock may also affect policy targets to maintain the population in rural areas (district policy) if no alternative production or livelihoods are developed for these areas.

We stress careful consideration of the following selected limitations of the model and pathways in the interpretation of the results. The FABLE Calculator stills need to be improved and have more features to better represent Norway as, for example, through better inclusion of forests, which is very important for Nordic countries. Moreover, we have noticed several errors in the FAO datasets used in the FABLE Calculator, many of which we managed to fix (see Annex 1), but several likely remain. Examples include a high calculated crop export index for Norway (in reality, Norway does not export many crops at all, so this error has little impact due to its low absolute level) and many other mismatches in data such as: 1) a high calculation for fish consumption (based on a high production of fish); 2) productivity and growth rate mismatches in meat and eggs due to errors in number of hens and chickens; 3) crop growth rates estimated from few data points but with highly fluctuating yields in particular crops; etc. The pathways also have their own limitations since the RCP choice influences the model and choices of definition also play a role. For example, sustainable livestock productivity was interpreted as sustainable when not increasing, because this would rely on less sustainable practices such as more imports of concentrated feed from developing countries. Finally, some issues such as biofuels were left untouched due to time constraints.

This latter point is an example of some of the next steps and remaining work to be done. Some issues remain in the FABLE Calculator, and some of the historical data should still be replaced by more accurate data from national registries (see Annex 1). Also, a forest module should be added to reflect this sectors impact on land, the climate, and the environment. Finally, the results of a recent food system transformation dialogue that took place in January 2020 should be incorporated in the pathways and interpretation of results.

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

- Modification of the scenario for diets to include the scenarios based on Mittenzwei et al. (2019): RefPathway and MG2020.
- Modification of the scenario on water efficiency to include a higher use of water for irrigation instead of a more efficient use of water as Norway does not yet use irrigation on a large scale.
- Several changes have been made in the FABLE Calculator to include more accurate historical data, using available national datasets:
    - Correction of land areas: as urban expansion was too high, we corrected this to a lower rate related to population growth.
    - Correction in feed for animals: inclusion of oats and rapeseed as a feed for animals.
    - Correction of the protein intake: fish was not included correctly in the calculator. The consumption of fish was too high as it was based on the high production of fish.
    - Correction of the productivity and growth rate: mismatches in meat and eggs due to errors in number of hens and chickens.

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 7 million by 2050 (SSP2). Based on (KC & Lutz, 2017). (SSP2 scenario selected)	The population is expected to reach 7 million by 2050 (SSP1). Based on (KC & Lutz, 2017). (SSP1 scenario selected)

LAND Constraints on agricultural expansion	
Current Trends Pathway	**Sustainable Pathway**
We assume no expansion of agricultural land beyond 2010 agricultural area levels. Agricultural land could expand into new areas, but largely this is constrained to areas on peat soils, and there are specific policies accepted and being detailed to prevent this.	Same as Current Trends
LAND Afforestation or reforestation target (1000 ha)	
We do not expect afforestation/reforestation. The total forest area has not changed very much since 1990 (UNFCCC, 2020b) and we expect this trend to continue. Since 1990, 1,648 km2 has been deforested in Norway but there is also natural regrowth with forest in the mountains and some afforestation.	Same as Current Trends

BIODIVERSITY Protected areas (1000 ha or % of total land)	
Current Trends Pathway	**Sustainable Pathway**
Protected areas remain stable: by 2050 they represent 15% of the total land area. Recent findings (Miljødirektoratet, 2020) show that while Norway is getting closer to the goal of protecting a representative share of Norwegian nature, a considerable number of threatened species are located outside protected areas.	Same as Current Trends

PRODUCTION Crop productivity for the key crops in the country (in t/ha)

Current Trends Pathway	Sustainable Pathway
Apart from changes driven by the climate change scenario, no changes were made to crop productivity in Norway in the FABLE Calculator. Because the climate change scenarios did not include yields for the top-three crops in Norway (barley, oats, and potatoes), the yields of these three are therefore the same in 2050 as in 2010.	Same as Current Trends

PRODUCTION Livestock productivity for the key livestock products in the country (in t/head of animal unit)

Current Trends Pathway	Sustainable Pathway
By 2050, livestock productivity reaches: • 3600 kg per head for chicken.	By 2050, livestock productivity reaches: • 3400 kg per head for chicken.

PRODUCTION Pasture stocking rate (in number of animal heads or animal units/ha pasture)

Current Trends Pathway	Sustainable Pathway
By 2050, the average ruminant livestock stocking density is 5.82 TLU/ha.	Same as Current Trends

PRODUCTION Post-harvest losses

Current Trends Pathway	Sustainable Pathway
By 2050, the share of production and imports lost during storage and transportation remains stable. This is based on the assumption behind this scenario, keeping similar practices as today.	By 2050, the share of production and imports lost during storage and transportation is reduced by 50%. Based on (Government of Norway, 2017).

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 remains stable compared to 2010. Overall Norway has less favorable conditions for agriculture than many other countries as the growing season is short, there is a cool climate and farmlands only represent a small portion of the land. So, we expect imports to remain stable in the future.	Same as Current Trends

TRADE Evolution of exports for key exported products (tons)

Current Trends Pathway	Sustainable Pathway
By 2050, the volume of exports is: • 26,420 tonnes by 2050 for milk • 910 tonnes by 2050 for eggs • 880 tonnes by 2050 for pork	By 2050, the volume of exports is: • 23,620 tonnes by 2050 for milk • 450 tonnes by 2050 for eggs • 600 tonnes by 2050 for pork

Norway

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 is 2,667 kcal and is: • 646 kcal for cereals • 359 kcal for milk • 327 kcal for plant oils Based on the “referanse bane” of Mittenzwei, Walland, Milford, & Grønlund (2020).	By 2030, the average daily calorie consumption per capita is 2,794 kcal and is: • 678 kcal for cereals • 335 kcal for milk • 349 kcal for plant oils Based on the “2/3 kjøtt, kostråd” diet of Mittenzwei et al., (2020).
FOOD Share of food consumption which is wasted at household level (%)	
By 2030, the food loss is reduced by 20%. This is based on the fact that the issue of food loss has gained importance in Norway but is addressed to a smaller extent compared to the sustainable pathway.	By 2030, the food loss is reduced by 50%. Based on the dietary change towards national dietary recommendations, linked to health (Helsedirektoratet, 2016) and linked to the agricultural sector (Government of Norway, 2019)

BIOFUELS Targets on biofuel and/or other bioenergy use	
Current Trends Pathway	**Sustainable Pathway**
By 2050, biofuel production from rapeoil increases by 8% compared to 2010.	Same as Current Trends

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.	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.

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

kha – thousand hectares

km^2 – square kilometer

km^3 – cubic kilometers

m – meter

Mha – million hectares

mm – millimeters

Mm^3 – million cubic meters

Mt – million tonnes

t – tonnes

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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