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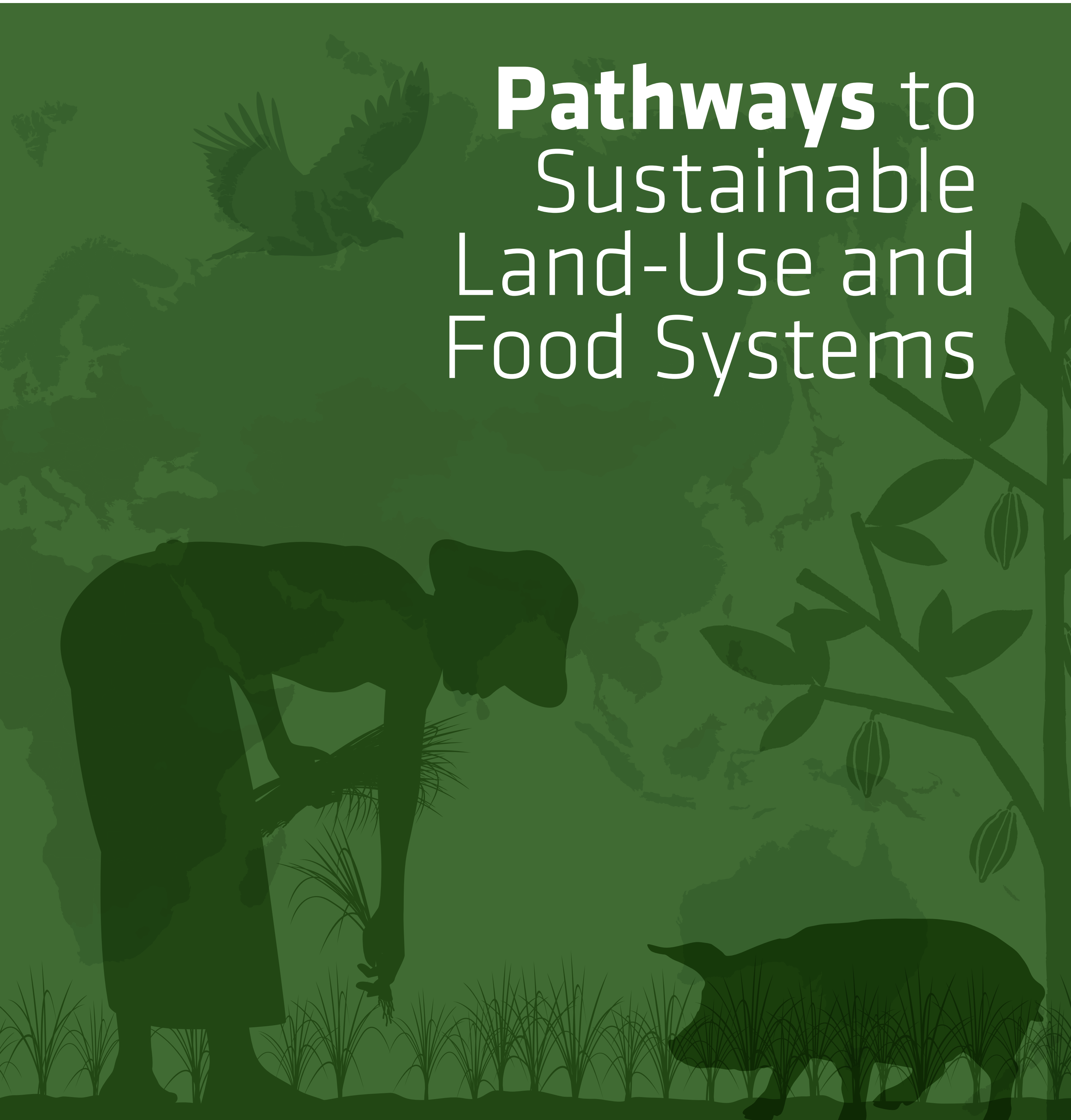
The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



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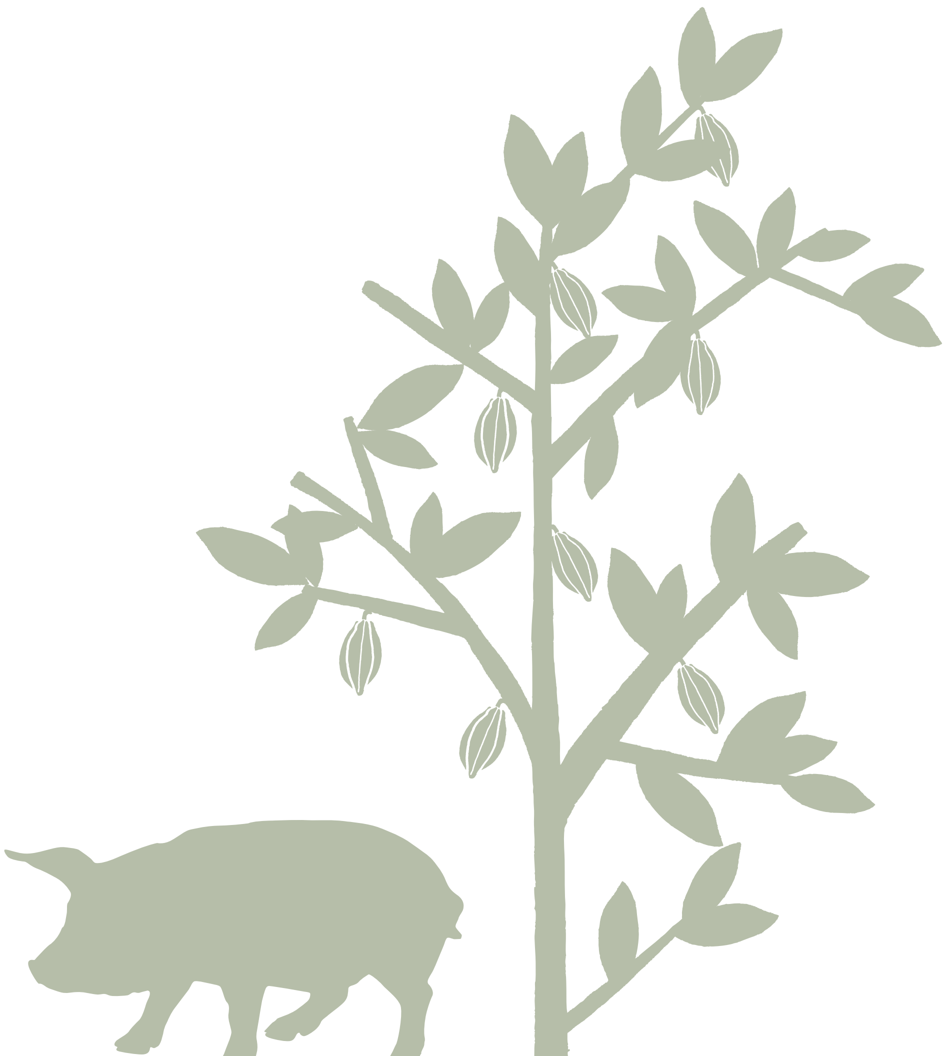
2020 Report of the FABLE Consortium

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



Russian Federation

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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 Russia. 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. These pathways were prepared within RANEPA's state assignment research program using assumptions based on official documents from the Russian Government on pathways until 2030 and 2050 and in consultation with stakeholders and experts at the Russian Ministry of Agriculture, the Soil Department of Lomonosov Moscow State University, and the Institute of Global Climate and Ecology (IGCE, Moscow, Russia). They were modeled with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019).

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 Russia's draft Long-Term Low Emissions and Development Strategy (Government of Russia, 2020d) treats the FABLE domains. According to the LT-LEDS base scenario, Russia is projected to increase its GHG emissions by 31.6% (in all sectors of the economy) by 2030 compared to 2017. The projected 2,077 Mt CO_2e of emissions in 2030, including forestry and other land use (FOLU) sequestration, are 33% lower than Russia's emissions in the 1990s. The LT-LEDS base scenario's projected changes in the FOLU sector are not particularly ambitious and lead to a decrease in sequestration from the current levels of -577.8 Mt CO_2e to -246 Mt CO_2e in 2030. Meanwhile, emissions from agriculture are projected to increase from 128 Mt CO_2e to 144 Mt CO_2e in 2030. Nevertheless, the draft LT-LEDS also provides theoretical assumptions of measures that could lead to a potential reduction of almost 263% in agricultural emissions, which could turn the sector into a net carbon sink reserve [p. 48, table 6 of Government of Russia, 2020d]. Envisaged mitigation measures from agriculture include the optimal use of organic (manure) fertilizers, measures to tackle soil erosion, and decreasing carbon loss on cropland and increasing carbon-sink capacity on pastures. The maximum theoretical ambition in the FOLU sector is to improve the carbon sequestration capacity from -577.8 Mt CO_2e to -723 Mt CO_2e in 2030 (page 48, table 6 of Government of Russia, 2020d). Measures to increase the sequestration ambition in the Russian FOLU sector include measures against forest fires, optimization of wood cutting technologies, replacing conifers with broadleaf and mixed forest trees, economic stimulation for life-long timber-product production, and land rehabilitation projects. Under its current commitments to the UNFCCC, Russia does not mention biodiversity conservation.

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

	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					
LT-LEDS (2016)	2017	1,577.8	2030	2,077	Energy, industry, agriculture, LULUCF, waste	Y	N	N	Water, forests

Source: Government of Russia, 2020d

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 2015, as listed on the CBD website (CBD, 2020) which are related to at least one of the FABLE Targets. According to this document Russia accepts that "by 2020, no less than 50% of exploited and protected forest are sustainably managed which ensure the conservation of biodiversity," which is close to the FABLE Targets on maintaining enough land for biodiversity protection. Currently, Russia does not have biodiversity policies in place beyond 2020.

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

NBSAP Target	FABLE Target
By the year 2020 the rate of natural habitat loss, including those of forests and grass ecosystems, are cut by at least half and completely halted where it is necessary. The degradation and fragmentation of habitats is also significantly decreased.	**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
Sub-target: By 2020, no less than 50% of exploited and protected forest are sustainably managed which ensure the conservation of biodiversity.	**DEFORESTATION:** Zero net deforestation from 2030 onwards
By 2020, the recovery of forests and their stable accumulation of carbon has been ensured on 15% of all degraded agricultural lands. Owing to increased efforts for conservation of existing forests, their carbon losses have been decreased by 17%.	**DEFORESTATION:** Zero net deforestation from 2030 onwards **GHG EMISSIONS:** Zero or negative global GHG emissions from LULUCF by 2050
Sub-target: By 2020 no less than 20% of all agricultural lands are managed and used in accordance to biodiversity conservation goals.	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
By 2020, the total area of terrestrial [...] territories with regulated resource use policies and which play a key role in the provision of ecosystem services is increased to the point where it composes 17% of all terrestrial territories	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate

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 the Russian Federation.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by a sharp decline in population (from 146 million in 2015 to 135 million in 2050), no constraints on agricultural land expansion, no afforestation target, no change in the extent of protected areas, low productivity increases in the agricultural sector, no change in diets, no forest land expansion, and no biofuel policy (see Annex 1). This corresponds to a future based on current policy and historical trends that, in line with the aims of current policy makers in Russia, would see an increase in agricultural area (Government of Russia, 2015, 2020a), an increase in agricultural exports (Government of Russia, 2020b, 2020c), and low-ambition forestry policy (Government of Russia, 2020d), which is expected to show an unfortunate decrease in carbon sequestration from the current level of -577 Mt CO_2 (IGCE, 2020) to -246 Mt CO_2 in 2050 (Government of Russia, 2020d). 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, barley, rice sunflower and soy (see Annex 1).

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 a more moderate decline in population (from 146 million in 2015 to 144.5 million in 2050), no increase in cropland area as a result of the implementation of a possible high-yield policy, and moderate growth of livestock productivity. This corresponds to a future with significant potential to close the yield gap for several key crops that currently have low yields in Russia (Schierhorn et al., 2014) and opportunities to reduce GHG emissions from land use (Romanovskaya et al., 2019). However, due to gaps in the literature and in policy action, the costs of possible policy measures to achieve high yields, high carbon sequestration, and sustainable land-use change remain uncertain. With the other FABLE country teams, we embed this Sustainable Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

Land and Biodiversity

Current State

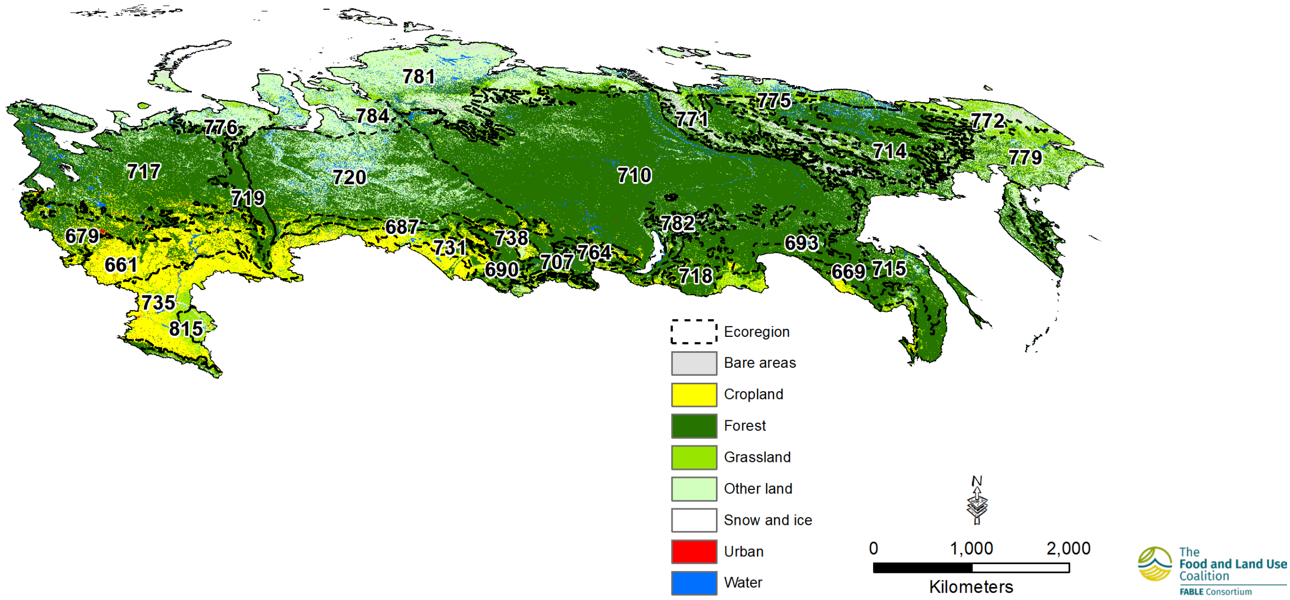
In 2010, Russia was covered by 3% cropland, 7% grassland, 54% forest, and 36% other natural land. Most of the agricultural area is located in the southwest, the Volga river basin, the Southern Ural and Southern Siberia while forest and other natural land can be mostly found in the northwest and Far East, as well as North, Central and Eastern Siberia (Map 1). Most of the territory is favorable for biodiversity due to its remoteness and low-population density, which is especially the case in areas where natural processes predominate (mostly territories with forest and other natural land). However, this poses an additional challenge to properly collect data and conduct year-to-year observations to monitor the accounting for species.

We estimate that land where natural processes predominate[2] accounted for 83% of Russia's terrestrial land area. The 710-East Siberian Taiga holds the greatest share of land where natural processes predominate, followed by 720-West Siberian Taiga and joint territory of 717-Scandinavian and Russian Taiga (Annex 3). Across the country, while only 9% (150 Mha) of land is under formal protection, falling short of the 30% zero-draft CBD post-2020 target, only 11% of land where natural processes predominate is formally protected. This indicates that more research is needed to understand how remote areas contribute to biodiversity protection, and how climate change might impact species migration in or near areas with higher population density.

In 2010 approximately 28% of Russia's cropland was in landscapes with at least 10% natural vegetation (Jacobson et al., 2019). These relatively biodiversity-friendly croplands are most widespread in 735-Pontic steppe, followed by 661-East European Forest steppe, and 679-Sarmatic Mixed forests. The regional differences in the extent of biodiversity-friendly cropland can be explained by differences in data aggregation and official misclassification of large abandoned territories as cropland (Russian Registry Agency, 2020)[3].

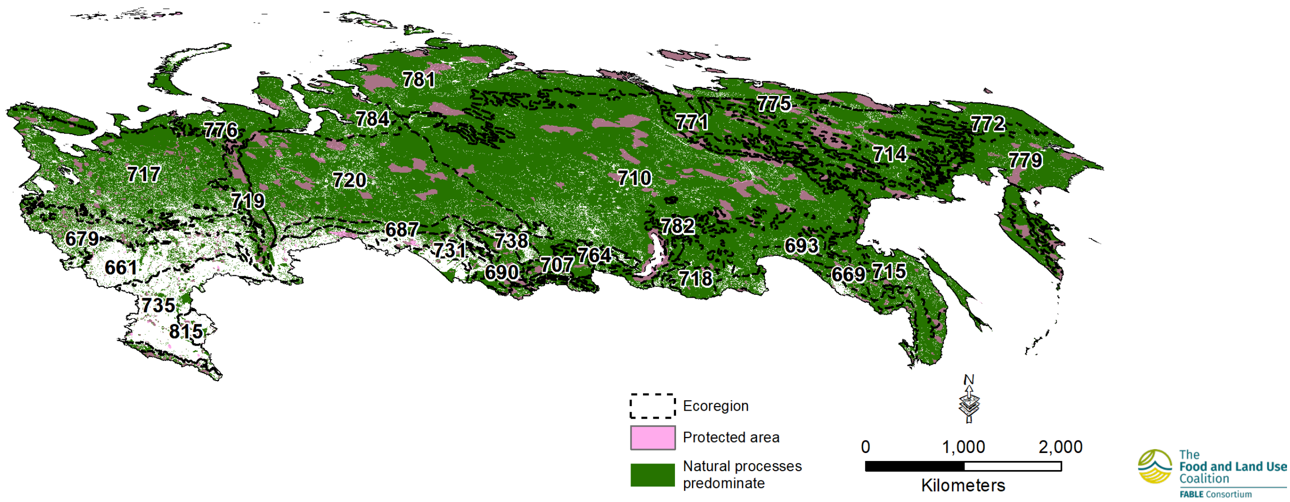
2 We follow Jacobson, Riggio, Tait, and Baillie (2019) definition: "Landscapes that currently have low human density and impacts and are not primarily managed for human needs. These are areas where natural processes predominate, but are not necessarily places with intact natural vegetation, ecosystem processes or faunal assemblages".
3 According to Jacobson et al., 170 Mha is used for cropland, while, in fact, Russia cultivates around 93 Mha of cropland annually (approximately 80 Mha of sown area and 13 Mha of fallow land in 2017-2019) and uses 40 Mha for pastures and hayland (Statistical Agency of Russia, 2020). This together equals 133 Mha of agricultural land. It is possible that the methodology employed by Jacobson et al. included abandoned land (37 Mha). We obtained this result by comparing the ploughed land in 1990 (130 Mha), and the current cropland (93 Mha). By combining the data from Russian sources, we obtained 170 Mha, which includes annual cultivated cropland, pasture and hayland, and abandoned land. This result is precisely the estimate Jacobson et al. provided for cropland in Russia.

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



Sources: countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)
Notes: Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 2.

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



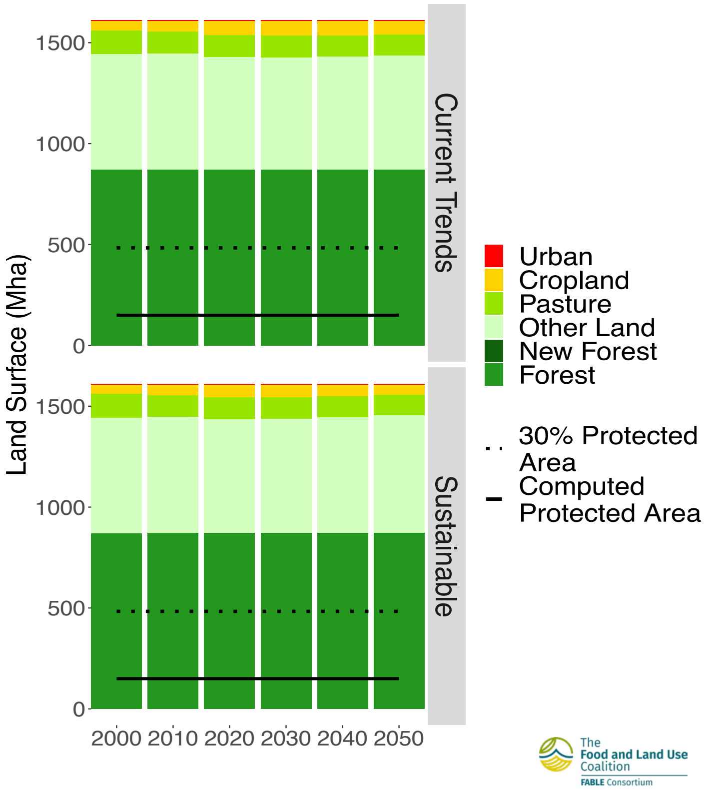
Notes: Protected areas are set at 50% transparency, so on this map dark purple indicates where areas under protection and where natural processes predominate overlap.
Sources: countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes 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)

Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including the planned increase in the use of former abandoned land as cropland or pastures by 2030, as stipulated in the Russian Plan for Efficient Agricultural Land Use (Government of Russia, 2020a), no planned afforestation by 2030, and maintaining protected areas at 150 Mha, the equivalent of 9% of total land cover (Annex 1). The main difference between our assumptions and estimates on cropland use, compared with the Russian Plan for Efficient Agricultural Land Use (Government of Russia, 2020a) is that our model projects a 3 Mha increase by 2030, while the Plan proposes a 12 Mha increase. It is important to specify that this plan does not reveal the type of land that will be increased (cropland or pastures, or both) or their proportions. The Plan also does not contain any justification behind Russia's need to increase the agricultural land by 12 Mha, thus possibly reducing fallow land (currently approximately 13 Mha). Our estimates instead are based on the necessity to increase crop production (especially wheat, barley, and oil crops) for the development of Russia's agricultural exports.

By 2030, we estimate that the main changes in land cover in the Current Trends Pathway will result from a 3 Mha increase in cropland area and a 2.6 Mha decrease in pasture area. This trend evolves over the period 2030-2050: cropland area decreases by 3.7 Mha while pasture decreases by 6.1 Mha as a result of declines in cattle and sheep herds. Other types of land (forests and other natural land) cover more than 83% of Russia's land surface, and our projections indicate it is likely to stay constant over time (Figure 1). The expansion of the planted area for wheat, sunflower, and barley explains 86% of total cropland expansion between 2010

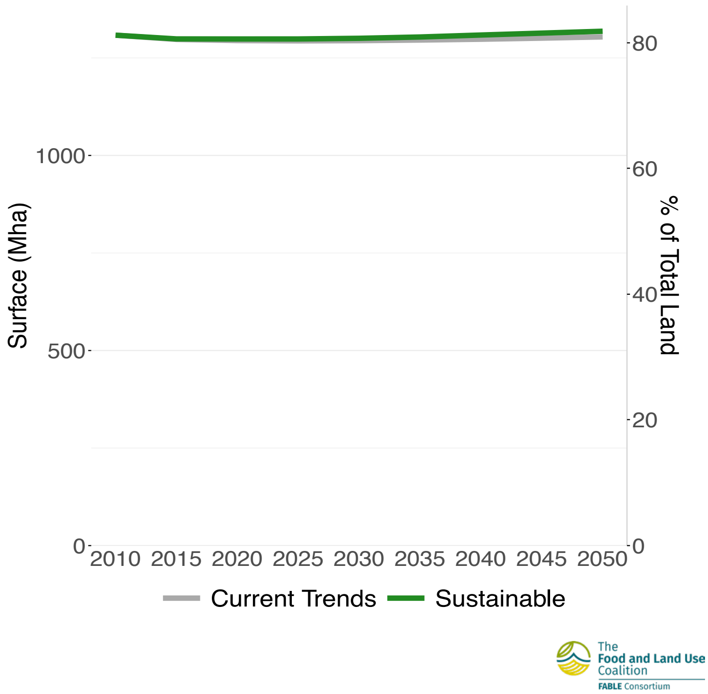
Figure 1 | Evolution of area by land cover type and protected areas under each pathway



Source. Authors' computation based on FAOSTAT land cover map (FAO, 2020) for the area by land cover type for 2000, and the World Database on Protected Areas (UNEP-WCMC, & IUCN, 2020) from 2000 for protected areas for years 2000, 2005 and 2010.

and 2030. For wheat, most expansion is explained by growing external demand for staple crops. For sunflower, the expansion is explained by the government policy to promote sunflower oil exports (as of July 1st 2020, Russia implemented a 20% export tariff on sunflower seeds to increase the domestic supply of sunflower for vegetable oil processing). Finally, for barley, the expansion is driven by the growth of domestic demand and exports. Pasture decline is mainly driven by decreasing herds and higher resource-use efficiency, which could contribute to the abandoning of pastures and their possible transformation in future carbon sinks. Livestock productivity per head and ruminant density per hectare of pasture remains constant over the period 2020-2030. Since Russian cropland and pastures comprise barely 15% of total land area, the changes in their use will not affect most of the land where natural processes predominate.

Figure 2 | Evolution of the area where natural processes predominate



In the Sustainable Pathway, assumptions on agricultural land expansion have been changed to reflect possible yield increases of major crops (Government of Russia, 2015; Schierhorn et al., 2014). These include a decrease of cropland area by 10 Mha and decline of pastures by 9 Mha over the period 2030-2050, which only influence the expansion of other land. Protected areas stay constant, but we assume an increase of new forest area by 2 Mha in 2050 as a very conservative but feasible objective (see Annex 1).

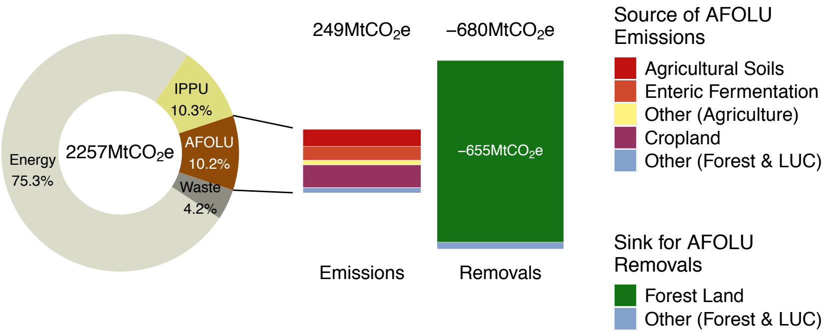
Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in Russia in the Sustainable Pathway: the agricultural area (cropland and pastures) will decrease by 22 Mha, compared to the 5.4 Mha decrease in the Current Trends Pathway in 2050 (Figure 2). This will lead to an increase in the area where natural processes predominate and biodiversity protection. In addition, these changes compared to the Current Trends Pathway are explained by possible advances in technology and industry which will contribute to more rational land use (partly described in Romanovskaya et al, 2019 and Government of Russia, 2020d – p. 48, table 6).

GHG emissions from AFOLU

Current State

Greenhouse gas emissions inventory (UNFCCC, 2020) is the principle source of data for Forestry and Other Land Use (FOLU) emissions, comprising forests, agricultural land, wetlands, urban area, and other land territories, where most sequestration is accounted in forests (655 Mt CO_2e/yr), followed by 24 Mt CO_2e/yr in grassland in 2017 (Figure 3). The other land use types of FOLU are sources of net-emissions. This can be explained by the fact that almost 53% of Russia is comprised of forests with high potential for carbon sequestration. Using the method of accounting from the National Inventory Report (IGCE, 2020), direct GHG emissions from FOLU accounted for 577 Mt CO_2e/yr of removals compared to 2,155 Mt CO_2e/yr emissions from all sectors of the Russian economy in 2017.

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

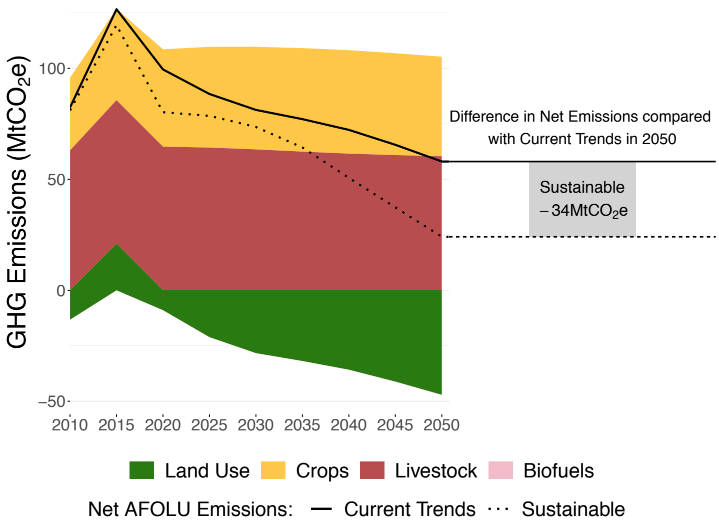


Note. IPPU = Industrial Processes and Product Use
Source. Adapted from GHG National Inventory (UNFCCC, 2020)

Pathways and Results

Under the Current Trends Pathway, annual GHG emissions from AFOLU decrease to 81 Mt CO_2e/yr in 2030, before reaching 58 Mt CO_2e/yr in 2050 (Figure 4). In 2050, livestock is the largest source of emissions (60 Mt CO_2e/yr), followed by crop cultivation (45 Mt CO_2e/yr) while land-use change (LUC) acts as a sink (-47 Mt CO_2e/yr). Over the period 2020-2050, a decrease in GHG emissions is caused by a decline in

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

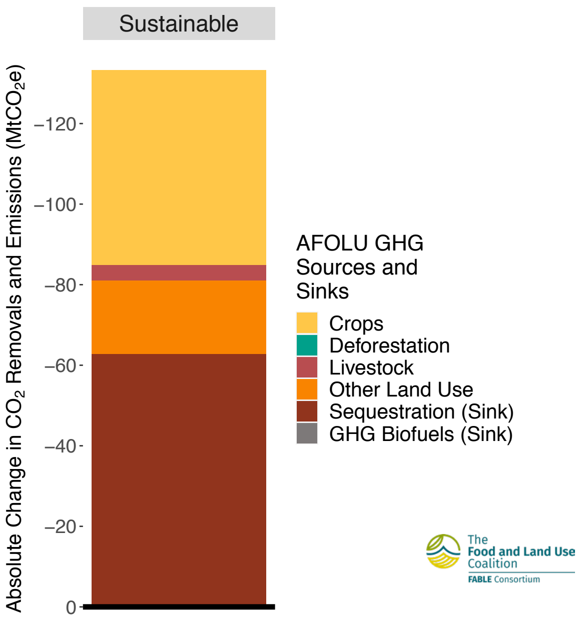


crop and pasture areas that are transformed into other land categories with natural vegetation regrowth, which serves as additional carbon sink.

In comparison, the Sustainable Pathway leads to a reduction of AFOLU GHG emissions by 25% in 2020-2050 period (Figure 4) – from 58 Mt CO_2e/yr to 24 Mt CO_2e/yr in 2050 compared to the Current Trends Pathway. The potential emissions reductions under the Sustainable Pathway is dominated by a reduction in GHG emissions from livestock and crops (Figure 5). Higher yield and livestock productivity are the most important drivers of this reduction. Currently, due to low productivity levels in Russia, productivity increases are technically feasible (Schierhorn et al., 2014, and Romanovskaya et al., 2014) and could be achieved by applying resource-saving techniques, and better agronomic technologies (Government of Russia, 2020d). Under the Sustainable Pathway, the GHG emissions from agricultural activities further decrease due to the abandoning of agricultural areas that become other types of land, forming an additional carbon sink. This trend is very similar to the Current Trends Pathway, but with larger volumes of land sparing and thus larger carbon sequestration by 2050 (-69 Mt CO_2e/yr in the Sustainable Pathway, compared to -47 Mt CO_2e/yr in the Current Trends Pathway).

To interpret these findings, it is important to note that the underlying data in the FABLE Calculator and the Russian National GHG Inventories (IGCE, 2020) account for GHG emissions differently. For example, the Inventories classify agricultural emissions as part of economy-wide emissions, while the FABLE Calculator, following the IPCC methodology, classifies them within Agriculture, Forestry and Other Land Use. The official Inventories account for annual removals in the forestry sector when forest area does not change, while the FABLE Calculator takes into account only the emissions or removals caused by approved land used change, such as a decrease in cropland area in favor of other land area, which causes emission removals as a result of natural vegetation regrowth. These differences in accounting explain the moderate amount of historical and future emissions sequestration in the Russian land sector and will need to be addressed in future analyses.

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



Compared to Russia's commitments under UNFCCC (Table 1), our results show that AFOLU could contribute to capturing only a small share of total GHG emissions in Russia (2.3% - 3.3%, or sequestrating respectively 47 Mt CO_2e/yr and 69 Mt CO_2e/yr) across both pathways compared to 2,077 Mt CO_2e of economy-wide emissions projected in the draft LT-LEDS. It is important to note, that other research shows that potential reductions could be much larger - 9% in the agricultural sector (mostly due to resisting soil erosion on cultivated land), and almost 30% in LUC sector (mostly due to forest management) (Romanovskaya et al., 2019).

Food Security

Current State

The "Triple Burden" of Malnutrition

Undernutrition	Micronutrient Deficiency	Overweight/ Obesity
2.5% of the population undernourished in 2017. This share has decreased two-fold since 2000 (World Bank, 2020).	23.3% of women of reproductive age and 25.7% of children under 5 suffered from anemia in 2016, which can lead to maternal death (World Bank, 2020). 57.5% of adults are deficient in vitamin D; 12.6% in vitamin B; 12.6-34.5% in vitamin A; 5.3-10.8% in vitamin E; and 67.3% in carotene. Multivitamin insufficiency (the lack of three or more vitamins) was found in 22-38% of adults (Kodentsova et al. 2017).	21.3% of children (5-19 years) were overweight in 2016 (World Health Organization, 2020). The growth of obesity rate in the general adult population in Russia was 0.4% per year in the period 2000-2012. Men experienced higher growth rates in obesity from 2005-2012 (0.61% per year) compared with the period 2000-2005 (0.44% per year) (Martinchik et al., 2015).

Disease Burden due to Dietary Risks

63.3 deaths per year (per 100,000 people) were attributable to dietary risks in 2017 (Ministry of Health of Russia, 2020). This increased by 28% from 2012.

3.2% of the population suffers from diabetes, which can be attributable to dietary risks (Ministry of Health of Russia, 2020).

Table 3 | 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)	3,107 (2,057)	3,094 (2,073)	3,052 (2,073)	3,094 (2,079)	3,094 (2,079)
Fats (g) (recommended range)	89 (69-103)	89 (69-103)	89 (68-102	89 (69-103)	89 (69-103)
Proteins (g) (recommended range)	98 (78-272)	98 (77-270)	97 (76-267)	98 (77-270)	98 (77-270)

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 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.

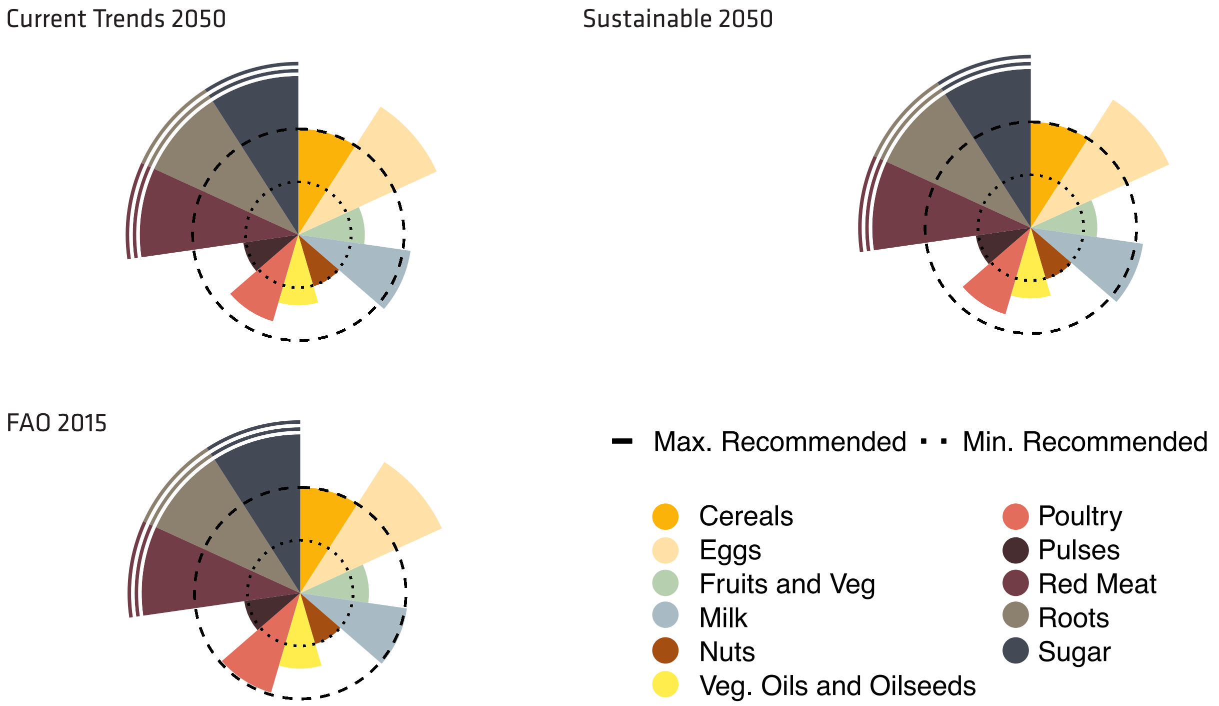
Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 49.2% higher in 2030 and 48.8% higher in 2050 (Table 3). The current average intake is mostly satisfied by cereals (38% of calorie intake), while animal products represent 22% of the total calorie intake. We assume that the consumption of animal products will be stable between 2020 and 2050. The consumption level of all other products remains the same in the projection period because Russia does not have a national policy to increase the consumption of specific food products.

We assume no changes in diets between the Current Trends and Sustainable pathways due to the absence of a national nutrition pathway. However, according to the EAT-Lancet recommendations (Willett et al., 2019), Russia should shift its consumption towards a higher intake of fruits and vegetables, and a lower intake of cereals and sugar, to achieve healthy diets. This is close to what researchers recommend when comparing the recent food production trends and food consumption patterns, indicating that appropriate, evidence-informed food and nutrition policies might help address Russia's burden of non-communicable diseases (NCD) on a population level (Lunze et al., 2015).

Russian Federation

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 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 and roots indicate that the average kilocalorie consumption of these food categories is significantly higher than the maximum recommended.

Water

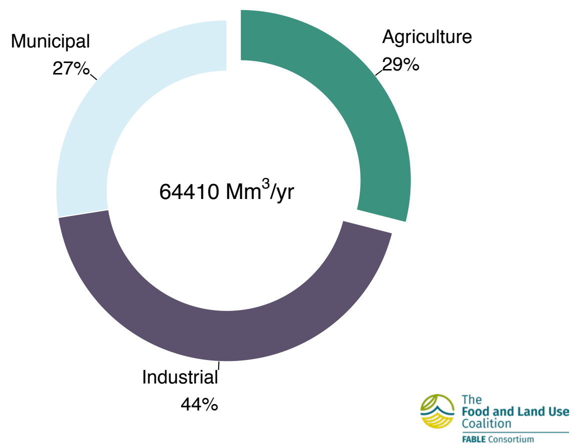
Current State

Russia is characterized by diverse climatic regions due to its large territory. In agricultural areas (see Land and Biodiversity section) annual precipitation mostly occurs during autumn and winter, while other regions it also occurs in the spring. Summers are usually dry. The agricultural sector represented 29% of total water withdrawals in 2015 (Figure 7; FAO). Moreover in 2016, 2.5% of agricultural land was equipped for irrigation, representing 50% of estimated-irrigation potential (Statistical Agency of Russia, 2020). A significant portion of irrigated land is dedicated to rice production, around 20% of which is exported (Rosstat, 2020).

Pathways and Results

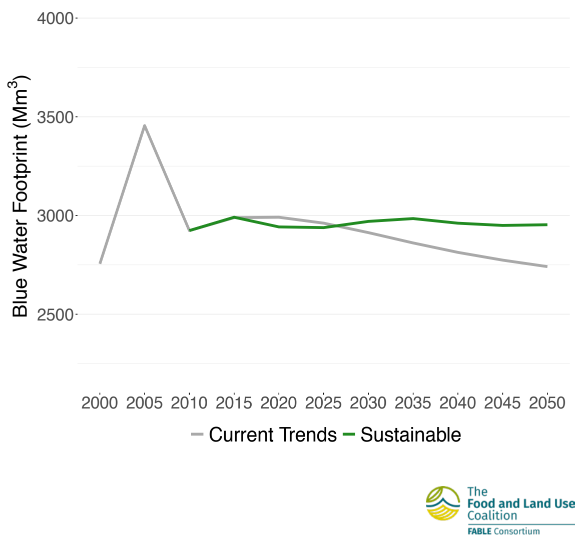
Under the Current Trends Pathway, annual blue water use is projected to increase between 2000-2015 (2,755 Mm^3/yr and 2989 Mm^3/yr), before decreasing to 2,913 Mm^3/yr and 2,741 Mm^3/yr in 2030 and 2050, respectively (Figure 8), with vegetables accounting for 60% of the water intake in 2050[4]. Under the Sustainable Pathway, Russia is projected to use 7% more blue water. This increase is mainly due to an increase in rice and vegetables 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



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 Russia'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.

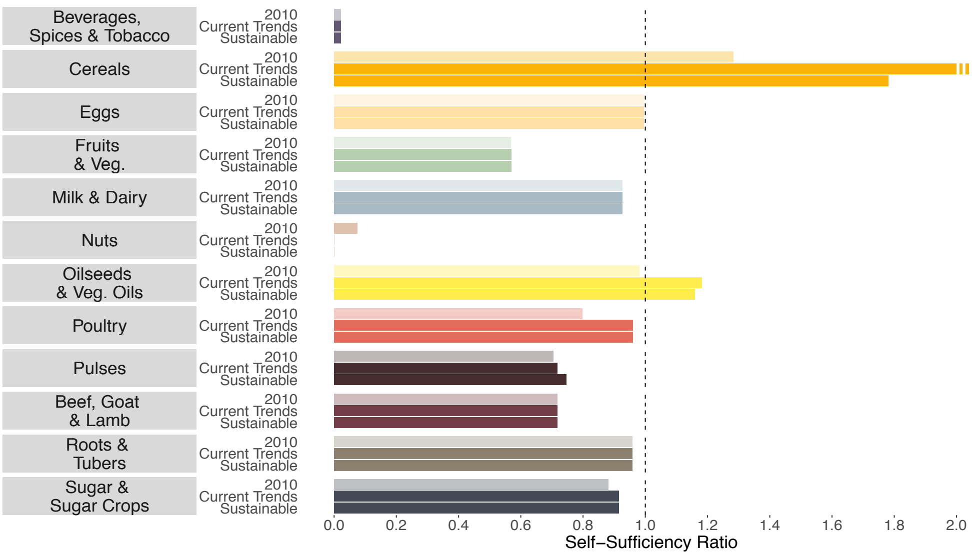
Self-Sufficiency

Russia is self-sufficient in cereals, oilseed, and potato, and in recent years succeeded in increasing the internal production of meat and sugar. However, Russia still relies on imports of specific fruits and vegetables, and milk products (Statistical Agency of Russia, 2020).

Under the Current Trends and Sustainable Pathways, we project that Russia would remain self-sufficient in cereals, eggs, and oilseeds and vegetable oils. However, it is important to note that we have not been able to capture several recent trends which have seen Russia become self-sufficient, and every begin exporting, poultry and pork meat. In addition, Russia has large sugar beet production and recently became a net exporter of sugar in 2020. However, it will still have to rely on imports of beef, nuts, fruits, dairy products, roots and tubers and some vegetables (tomatoes and cucumbers).

In the mid-term (3-5 years), Russia needs to expand its capacity to increase exports of sugar, oilseeds, pork, and poultry, which are currently over-produced, thus keeping prices low. The priority for Russia is to find the markets to sell these products.

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. The discontinuous lines on the right side of this figure, as appear for cereals, oilseeds and vegetable oils, indicate a high level of self-sufficiency in these categories.

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:

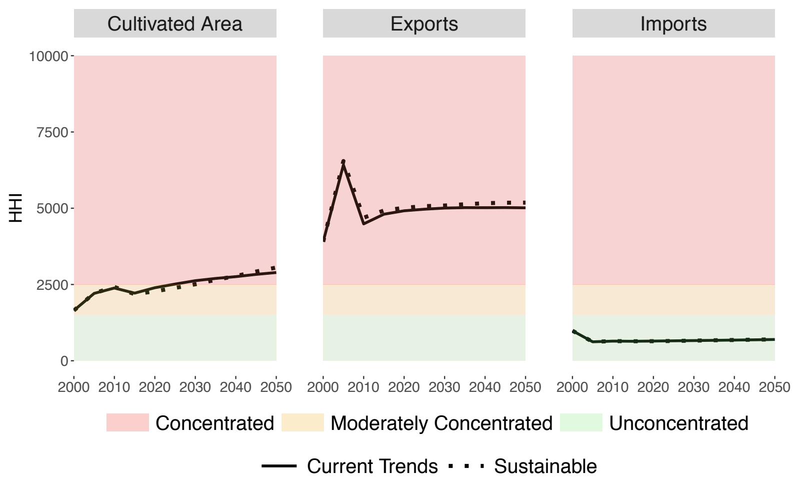
- **Cultivated area:** where concentration refers to cultivated area that is dominated by a few crops covering large shares of the total cultivated area, and diversity refers to cultivated area that is characterized by many crops with equivalent shares of the total cultivated area.
- **Exports and imports:** 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.

According to historical data, Russia's exports are highly concentrated (HHI of 4,000 in 2010) due to the prevalence of cereals and oilseed in Russian agricultural foreign trade. Imports have a low concentration index due to the diversity in the range of products that Russia imports. The crop area shows the most interesting dynamics shifting from low concentration in 2000 to high concentration in 2020 and beyond. This high concentration could be explained by the fact that Russian agricultural producers have historical experience with and good equipment to grow cereals (mostly wheat and barley) as well as sunflower. Therefore, shifting to other crops has been more difficult for them, due to lower technological knowledge and the absence of policy incentives. The high concentration in crops could also be explained by the devaluation of the ruble in 2014, which significant favored Russian agricultural exports.

Under the both the Current Trends and Sustainable Pathways, we project that the high concentration of crop exports and low concentration if crop imports will remain constant. As for the diversification of cropland area, the HHI moderately increases in the Sustainable Pathway, which indicates that the share of wheat and oilseeds will be moderately higher than in the Current Trends Pathway.

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

Our estimates show that Russia has great capacity for continued agricultural growth with fewer land resources. In both pathways, Russia enjoys an increase in production, a rise in exports, and a minor decrease in agricultural land use (although the growth rates of this decline differ across pathways), which leads to a decrease in GHG emissions from agricultural and land use. This is in line with national agricultural-development trends over the last decade, and thus serves as a good platform for further achievements. Previous work has demonstrated that Russia can further boost yield growth, especially for cereals like wheat (Schierhorn et al., 2014), and reduce GHG emissions in the agricultural and land-use sector (Romanovskaya et al., 2019). However, this capacity is not reflected in current policy documents, including the Agricultural strategy and draft LT-LEDS (Government of Russia, 2020d). Consequently, our projections for agricultural land use and GHG emissions (including those in the Sustainable pathway) were rather moderate, and not ambitious. According to the draft LT-LEDS, Russia has great capacity to increase its ambition in terms of FOLU carbon sequestration through the application of resource saving technologies and policy measures. These policies include measures against forest fires, optimization of wood cutting technologies, replacing conifers with broadleaf and mixed forest trees, economic incentives for long-life-timber production, and land rehabilitation projects (LT-LEDS). The agricultural sector can also contribute through the application of carbon saving measures, including through optimizing the use of manure as fertilizer, tackling soil erosion issues, decreasing carbon loss on cropland, and increasing carbon sink capacity of pastures. Unfortunately, the draft LT-LEDS considers these measures to be theoretical and they are not set out as concrete steps for policy action.

In terms of biodiversity policy, it is mostly disconnected with agricultural and food production development because these policy scopes tend to address different geographical areas. Most agriculture is practiced in the southwest and south (near the Black Sea) and in Southern Siberia, while most of the territories in the north, Siberia, and Far East are uninhabited and uncultivated, thus serving as a biodiversity-friendly zone. In terms of biodiversity conservation, Russia serves as a good natural protective territory because of its numerous remote areas with no human interference, which creates untouched natural conditions for species that live in Russian forests, shrublands, tundra, and steppes. Forest fires represent the greatest threat for biodiversity in the forests of the Far East (Wu et al., 2018; Shvidenko et al., 2011) and Russia still needs to improve its control and prevention policies against fires that threaten forests, wild animals, and civilians. Moreover, it still has to increase its capacity and allocate resources to properly document the number of wild animals and to trace their possible migration due to global warming, which is crucial for Russia's northern territories.

Russia has extensive agricultural land which is productive but currently abandoned. This land could be used to produce food to satisfy domestic demand, or for exports to meet external demand, and thus contribute towards global food security. Current Russian development programs aim to use at least 12 Mha of this type of land for the purposes explained in previous sections (Government of Russia, 2020a). However, these government programs do not specify whether this land rehabilitation – from abandoned to cultivated – will be economically efficient, and which environmental drawbacks it will entail. Previous research has shown that only 5 Mha of abandoned land in Russia could be used efficiently with low or minimal ecological discrepancies (Meyfroidt et al, 2016). Official data reveals that Russia has already increased its cropland by 6 Mha during the period 2010-2019 (Rosstat, 2020). Part of this land had a natural vegetation cover similar to pastures and produces high GHG emissions during the first year of ploughing (IGCE, 2020). According to National GHG Inventories, in 2011 the cultivation of 0.8 t/ha caused 34 TCO_2 per hectare in GHG emissions, compared to only 0.6 TCO_2 per hectare on annually cultivated cropland.

In our pathways, we attempted to distinguish between different approaches to cropland expansion. Our estimates in the Current Trends Pathways show that Russia can increase its crop area by only 3 Mha by 2030, which increases crop production – driven by domestic and external demand. In the Sustainable Pathway we assume that Russia can increase its production partly by closing the yield gap. We suggest that Russia will not change the crop area until 2030 but will sufficiently decrease its cropland area by 10 Mha between 2030 and 2050, turning it into an additional carbon sink achieved through productivity gains. Thus, if policies are applied to save land and increase crop productivity, Russia could achieve the necessary growth in production and contribute to carbon sequestration called for under the Paris Agreement.

The main limitations of our approach are related to our estimates for GHG emissions, the problems to define the adequate growth rate of forests area, estimates in meat production during the historical period, and differences with Russia's official statistics for nutrient content.

For the GHG emission estimates, out analysis includes land-use types (forests, pasture, cropland etc.) that are similar to Russia's National GHG Inventories (IGCE, 2020). However, the FABLE Calculator does not allow us to estimate full GHG removals in areas where natural vegetation cover does not change for long periods, such as forests, which is a net sequester of almost 600 Mt CO_2, and pastures, 80 Mha which are classified as a source of net-emissions (IGCE, 2020). In the FABLE Calculator, we only estimate emissions from agricultural activities whose estimates are similar to IGCE results and GHG emissions and removals from land use change, such as conversion of cropland to other land in cases where yields increase. Therefore, our total AFOLU emissions are significantly different from estimates of total AFOLU emissions in Russia's National GHG Inventories. Nevertheless, in terms of dynamics of fluxes, the FABLE Calculator captures emissions from land use change that are close to those of the Inventories. For example, both the estimates in the Russian National GHG Inventories and the FABLE Calculator agree that when cropland is abandoned to be used as other land, it becomes a net sequester of carbon.

Regarding forests, we did not allow the FABLE Calculator to extend Russia's forest area. There are two main reasons behind this decision. First, we do not have an appropriate source or action plan in the current Russian forest sector that looks at long-term developments. Second, when we calculated the forest land expansion in the FABLE Calculator, results led to a large increase in carbon sequestration that does not correspond to current draft LT-LEDS. Nevertheless, we applied the possible new forest growth concept, but only for the Sustainable Pathway. This is necessary to demonstrate that Russia still has a large potential to increase its carbon sinks.

Additionally, several sectors are not yet properly captured in our model. Specifically, it does not yet capture the rapid growth of Russia's pork and poultry sectors which occurred in the last 15 years (2000-2015). The FABLE Calculator estimated 2.7 Mt for poultry meat production in 2015, when in reality it reached 4.5 Mt (Rosstat, 2020). Similarly, pork meat production was estimated to be 2.5 Mt in 2015, when in reality it reached 3 Mt. Finally, the proper estimates of the nutrient content of consumed food in the historical period needs to be further refined. For our 2010 estimates, the kcal food consumption is 17% higher, specifically 28% higher for proteins and 15% lower for fats compared with official data for the respective year (Rosstat, 2020).

Out next steps will be to focus on improving the FABLE Calculator to address these discrepancies and by including additional land-use variables. For example, the FABLE Calculator currently only includes one type of pasture (120Mha), while in Russia there are used pastures (around 40 Mha), which serve as a net-emitter of GHG, and almost 80 Mha of unused pastures which likely serve as a net carbon sink, even though this dynamic is not currently revealed in the National GHG Inventories. We will also improve the estimates for pork and poultry production to approach the current levels and apply it to current national plans for Russia to become a net exporter of pork and poultry.

Annex 1. Underlying assumptions and justification for each pathway

Please note that this represents the value by 2050, or change in 2050 compared to 2010, or trend over 2010-2050.

POPULATION Population projection (million inhabitants)

Current Trends Pathway	Sustainable Pathway
The population is expected to decrease from 146 million to 135 million in 2050. This is a rather conservative scenario based on current decrease of Russian population (UN_medium scenario selected).	The population is expected to decrease from 146 million in 2020 to 144.5 in 2050. This assumption is based on current government programs to financially support families that give birth to two or more children. Although we have not seen specific plans and projections for the future population growth numbers. (UN_instant replacement scenario selected)

LAND Constraints on agricultural expansion

Current Trends Pathway	Sustainable Pathway
Based on the government's current strategy for Russian rural development 2030 (Government of Russia, 2015), and the Project State Program for Russian Agricultural Land Rehabilitation and Melioration 2030 (Government of Russia, 2020a). (FreeExpansion scenario selected)	We assume no agricultural land expansion beyond 2010 agricultural area levels. In recent years Russia faced over-production of major crops like grains and sugar beet, which led to sharp decreases in prices (in 2008, 2017, and 2019). Currently there is no measure in place to support prices and the supply management in terms of its limitation of cultivated crop area. We assume this scenario if price supports or supply support mechanisms are implemented. (NoExpansion scenario selected)

LAND Afforestation or reforestation target (Mha)

Current Trends Pathway	Sustainable Pathway
We do not expect afforestation because the Russian draft LT-LEDS does not mention any possible increase of the forest area.	We assume total afforested area to reach 2 Mha by 2050 (BonnChallenge scenario selected). Even though Russia is not a signatory member of the Bonn agreement, Russia has enough land to increase forest area by 2 Mha to 2050. Also, according to current statistics, Russia manages to keep forest restoration of average 0.8 Mha every year (Statistical Agency of Russia, 2020).

BIODIVERSITY Protected areas (% of total land)

Current Trends Pathway	Sustainable Pathway
Protected areas remain stable based on historical trends: by 2050 they represent 9% of total land. Due to the absence of biodiversity policy in Russia and based on our estimates with Russian FABLE Calculator	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: • 2.5 tons per ha for wheat. • 1.3 tons per ha for sunflower. • 4.2 tons per ha for barley. Based on current productivity levels on our estimates with Russian FABLE Calculator.	By 2050, crop productivity reaches: • 3.0 tons per ha for wheat. • 1.8 tons per ha for sunflower. • 5.5 tons per ha for barley. We assume that Russia will continue to improve cropland productivity based on historical crop yield trends. There are, however, currently no sources, either official or in the literature, to prove this. Based on our estimates with Russian FABLE Calculator.

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: • 85 % by 2050 for apples. • 31 % by 2050 for beef. • 40 % by 2050 for tomato. Based on current trends and on our estimates with Russian FABLE Calculator.	Same as Current Trends

TRADE Evolution of exports for key exported products (million tons)

Current Trends Pathway	Sustainable Pathway
By 2050, the volume of exports is: • 51.6 million tons by 2050 for wheat. • 3.8million tons by 2050 for sunflower oil. • 6.6 million tons by 2050 for barley. Based on current trends and on our estimates with Russian FABLE Calculator.	By 2050, the volume of exports is: • 41.9 million tons by 2050 for wheat. • 3.8 million tons by 2050 for sunflower oil. • 5.0 million tons by 2050 for barley. Based on our estimates with Russian FABLE Calculator.

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 3094 kcal and is: • 1161 kcal for cereals. • 145 kcal for fruits and vegetables. • 682 kcal for animal products (kcal sum of meat, milk, eggs, animal fat). Due to the absence of National Nutrition policy and based on our estimates with Russian FABLE Calculator.	Same as Current Trends.

BIOFUELS Targets on biofuel and/or other bioenergy use

Current Trends Pathway	Sustainable Pathway
"No change" scenario was chosen because Russia does not have a specific biofuel policy, and Russian food and production balance sheets do not identify separately the biofuel use of produced crops. This impedes estimating the capacity for biofuels.	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/m^2 (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 CO_2 fertilization effect.	By 2100, global GHG concentration leads to a radiative forcing level of 2.6 W/m^2 (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 CO_2 fertilization effect.

Annex 2. 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)

Annex 3. Overview of biodiversity indicators for the current state at the ecoregion level[5]

	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 at > 10% natural vegetation within 1km²(%)
650	Caucasus mixed forests	5751	32	59	52	49	661	50
654	Central European mixed forests	3414	5	39	12	88	1 886	28
658	Crimean Submediterranean forest complex	2216	8	57	13	87	656	29
661	East European forest steppe	57962	5	25	18	82	41917	15
666	Hokkaido deciduous forests	1094	24	92	26	74	46	67
669	Manchurian mixed forests	9554	14	93	14	86	295	61
679	Sarmatic mixed forests	47255	9	58	15	86	13652	44
685	Ussuri broadleaf and mixed forests	19721	9	94	9	91	267	71
687	Western Siberian hemiboreal forests	22393	7	72	9	91	5 329	52
690	Altai montane forest and forest steppe	2539	9	95	9	91	143	75
693	Da Hinggan-Dzhagdy Mountains conifer forests	9741	8	94	8	92	6	93
707	Sayan montane conifer forests	31960	16	93	16	84	1 026	76
710	East Siberian taiga	390852	7	94	8	93	1 953	62
712	Kamchatka taiga	1526	18	98	18	82	1	98
713	Kamchatka-Kurile meadows and sparse forests	13986	19	98	19	81	108	82
714	Northeast Siberian taiga	112601	11	97	11	89	151	93
715	Okhotsk-Manchurian taiga	39961	8	93	9	91	133	96
716	Sakhalin Island taiga	6478	5	93	6	95	94	58
717	Scandinavian and Russian taiga	147537	6	82	7	93	7068	61

5 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.

	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 at > 10% natural vegetation within 1km²(%)
718	Trans-Baikal conifer forests	16281	10	86	9	91	983	58
719	Urals montane forest and taiga	17500	21	89	23	77	381	72
720	West Siberian taiga	167412	9	91	9	91	2191	65
726	Daurian forest steppe	11211	2	75	2	98	1506	70
731	Kazakh forest steppe	37431	12	39	23	78	21450	30
732	Kazakh steppe	14156	4	26	12	88	10631	18
734	Mongolian-Manchurian grassland	267	77	97	79	21	3	96
735	Pontic steppe	64489	5	14	26	74	47495	17
736	Sayan Intermontane steppe	3374	9	82	11	89	352	51
737	Selenge-Orkhon forest steppe	2580	3	76	4	96	291	68
738	South Siberian forest steppe	16223	6	51	10	90	6633	40
741	Amur meadow steppe	7059	15	67	20	80	1972	35
746	Suiphun-Khanka meadows and forest meadows	1558	6	67	5	95	553	46
749	Altai alpine meadow and tundra	2748	33	90	35	65	55	96
764	Sayan alpine meadows and tundra	5917	8	94	9	92	174	94
771	Cherskii-Kolyma mountain tundra	55777	13	99	13	87	51	99
772	Chukchi Peninsula tundra	29324	8	98	8	92	12	98
773	Kamchatka tundra	11840	21	99	21	79	29	85
774	Kola Peninsula tundra	5227	6	91	6	94	2	97
775	Northeast Siberian coastal tundra	21945	23	95	24	76	44	96
776	Northwest Russian-Novaya Zemlya tundra	27147	7	95	7	93	2	86

Russian Federation

	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 at > 10% natural vegetation within 1km²(%)
777	Novosibirsk Islands Arctic desert	3480	100	99	100	0	0	N/A
778	Russian Arctic desert	8729	16	42	9	91	0	N/A
779	Russian Bering tundra	47142	9	97	9	91	237	99
781	Taimyr-Central Siberian tundra	94600	14	95	14	86	45	99
782	Trans-Baikal Bald Mountain tundra	21807	8	99	8	92	21	94
783	Wrangel Island Arctic desert	722	100	100	100	0	0	N/A
784	Yamal-Gydan tundra	40500	8	91	7	93	2	100
815	Caspian lowland desert	8615	18	28	60	40	700	68
826	Great Lakes Basin desert steppe	2200	15	82	15	86	131	94

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)

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

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

km^2 – square kilometer

km^3 – cubic kilometers

m – meter

Mha – million hectares

Mm^3 – million cubic meters

Mt – million tons

t – ton

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

t/ha – 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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