



# Europe's Land Future?

*Opportunities to use Europe's land to fight climate change and improve biodiversity—  
and why proposed policies could undermine both.*

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## Europe's Land Future?

### *Highlights for Policymakers*

- Europe has high potential to reduce its land footprint, the land used to supply its agricultural products and wood. Europe's land use and meat and milk consumption are already high, so likely declines in population and increases in crop yields by 2050 can reduce this land footprint.
- This decline has a critical climate role. Even in future baseline projections, climate models estimate that reductions in Europe's footprint (from 10 to 50 million hectares) offset some expansion of agricultural land globally. That holds down net global deforestation, still often estimated at hundreds of millions of hectares. Most climate strategies require stable or reduced global agricultural area to preserve forests, savannas, and their carbon. To succeed, they require more progress everywhere, including larger than baseline reductions in Europe's footprint.
- Net global cropland expansion has likely increased to 12 million hectares per year in the last eight years studied. By 2050, conversion at this rate would reduce forests and savannas by an area the size of India.
- Europe's agricultural footprint includes 24 million hectares of foreign land used to supply net agricultural imports, which contributes to global deforestation. We estimate Europe's land "outsourcing" causes a loss of 400 million tons of CO<sub>2</sub> per year. These losses roughly cancel out Europe's forest carbon sink.
- By reasonably increasing crop yields and reducing biofuels to 2010 levels, Europe can simultaneously eliminate its global outsourcing and reduce its own cropland by 16.5 million hectares (~16% of cropland). Moderate reductions in milk and meat consumption could push the reduction to 30 million hectares. Spared land could be used to restore more carbon and biodiversity in Europe and/or save forests abroad.
- Although Fit for 55 goals include restoring more carbon and biodiversity in Europe, bioenergy provisions would leave little or no land to do so or to reverse outsourcing. Commission modeling estimates Europe will import more wood for energy and devote 22 million hectares to energy crops by 2050, roughly equal to 1/5 of Europe's cropland. Modeling also foresees a loss of 10 million hectares of biologically diverse, semi-natural grasslands.
- Expanded biomass use primarily results from the plan's false treatment of biomass as "carbon neutral." Carbon neutral means that emissions of CO<sub>2</sub> from the burning of wood or biofuels are ignored. As a result, power plants, households, aviation, and shipping have perverse incentives to burn biomass.
- Carbon neutral rules treat land as having no carbon opportunity cost. As a result, the Fit for 55 plan encourages more bioenergy regardless of how much it reduces land available to restore forests and carbon in Europe or how much it increases deforestation abroad by increasing Europe's foreign land footprint.
- Improved LULUCF requirements in Fit for 55 could encourage Member States to reduce wood harvests but would not fundamentally alter the incentives felt by energy users to burn biomass. The more Member States place a "foot on the brake" in the supply of their own biomass, the more the "foot on the pedal" driven by bioenergy rules will accelerate use of land overseas via increased imports of wood, biofuels, or biomass. Likewise, if Europe dedicates more European cropland to energy crops, Europe will import more food and feed.
- The EU's Forest Strategy for 2030 explicitly acknowledges that increased wood harvest for bioenergy or other wood products will increase global warming for decades.
- The EU can fix Fit for 55 by factoring the carbon opportunity cost of land into its climate calculations for bioenergy. It can also adopt goals to reduce its land footprint, including explicit goals to reverse its outsourcing, and strengthen policies to increase crop yields and to reduce demand for meat, milk, and wood.

## *Executive Summary*

The European Union has ambitious goals to reduce its greenhouse gas emissions and to restore its depleted biodiversity. To achieve each goal, diverting agricultural land and production forests to other uses must play a key role. Such alternative uses could aim to increase carbon storage and biodiversity by restoring habitats in Europe. Less discussed, these goals could also include preserving carbon storage and biodiversity abroad by reversing Europe's large, net imports of agricultural products. These net imports mean that Europe's global land footprint is contributing significantly to deforestation and habitat loss abroad.

To contribute to these goals, Europe must reduce what can be called its land carbon footprint. This footprint is the reduced carbon storage in vegetation and soils on agricultural and forest lands used to supply Europe's consumption of wood and agricultural products. This report finds that Europe has significant potential to do so and identifies potential priorities for carbon sequestration and biodiversity restoration.

We also find that the European Commission's "Fit for 55" plan as proposed, although it contains many other valuable climate requirements, would overall increase Europe's land carbon footprint through multiple laws encouraging the use of bioenergy from energy crops and wood. European Commission modeling results imply less biodiversity both within and outside Europe, limited carbon sequestration gains within Europe, and more loss of forests and other habitats outside Europe. These limitations could be fixed.

### **The Need to Reduce Europe's Land Carbon Footprint**

Rising global demand for land requires that Europe reduce the land devoted to its consumption if the world is to stabilize the climate and protect biodiversity. Nearly all climate stabilization and biodiversity strategies require the world stop expanding agricultural land area to preserve natural habitats and the carbon stored in their vegetation and soils. Many seek to build more carbon in forests. Yet the global population will likely add 2 billion people by 2050. In addition, most of the world's people, who today on average consume milk and meat at roughly one quarter the rate of Europeans, will likely raise their consumption toward one half of current European levels. These diet shifts will require more agricultural land per calorie consumed. Reflecting these increases in demand, nearly all models project large expansion of agricultural land globally. Recent evidence reveals agricultural land is expanding at record rates and far beyond model predictions.

By contrast with most of the world, Europe is in a good position to reduce its land carbon footprint because Europe has already transformed its landscape and reached high levels of consumption, which can now be scaled back. Europe converted 75% of its forests to agriculture by 1900, but they have started to expand back. After high growth, Europe's population is now likely to decline. Europe's meat, milk and wood consumption have already reached high levels and can grow little more. By stabilizing or reducing demand, and continuing to increase crop yields, Europe can reduce agricultural area needed to supply its own consumption.

Most global land use projections for 2050 accordingly estimate that Europe will reduce its cropland by millions of hectares (by 11–51 million hectares according to one model comparison). Unless Europe does so, agriculture will expand even more on a net basis globally. Yet, the same analyses still project large-scale overall global deforestation and habitat loss under business as usual. To protect both climate and biodiversity, all regions, including Europe, must do more to reduce their land carbon footprints.

### **Potential to Reduce Europe’s Land Carbon Footprint**

Modeling suggests that Europe has realistic potential to reduce its footprint by far more than it currently plans. Using the Globagri model, we estimate that Europe<sup>1</sup> can reduce its cropland area by 16.5 million hectares by 2050, roughly 16%. Doing so requires that yields grow at rates estimated by the UN Food and Agriculture Organization and that Europe consume no more biofuels than it did in 2010. If Europe could combine these efforts with reduced consumption of meat and milk products by 17%, it could reduce its agricultural land area by nearly 30 million hectares. Although less studied, opportunities also exist to reduce Europe’s consumption of wood through more cascading of wood uses, and by reducing wood burned directly for energy.

### **Priority Uses of Land for Carbon Storage and Biodiversity Within Europe**

If Europe can reduce its land carbon footprint, it has many valuable opportunities to benefit the climate and biodiversity both inside and outside Europe. Some opportunities are synergistic while others involve trade-offs.

#### Carbon sequestration within Europe

Sequestering more carbon within Europe provides one valuable use of land. Europe’s growing forests remove roughly 400 million tons of CO<sub>2</sub> from the air each year. After accounting for degrading peatlands and other carbon losses, Europe’s land overall has an annual net “carbon sink” of roughly 300 million tons. Although valuable, this sink primarily reflects the ongoing growth of forests reestablished between 1900 and 1990, plus the stimulation of plant growth by climate change itself, through longer growing seasons and higher CO<sub>2</sub> concentrations in the atmosphere. The beneficial effects of these legacy and climate effects are already counted when the world sets climate mitigation requirements. Counting this sink again as mitigation is therefore inappropriate double-counting. Europe agreed to this principle when developing rules for the Kyoto Protocol.

However, Europe has opportunities to add to this sink through additional efforts that do properly count as mitigation. The top priority involves rewetting the EU’s roughly 4 million hectares of peatlands that are drained for agricultural use, and whose soils breakdown and release large quantities of carbon. Restoring

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<sup>1</sup> Unless otherwise indicated, Europe in this paper refers to the EU-27 plus the United Kingdom. Our main modeling results, including those from the Globagri model and our estimates of carbon opportunity costs, include the four EFTA countries, five EU candidate countries (not including Turkey), and other small municipalities, whose economies are closely linked to the EU.

more forests, and harvesting existing forests less, particularly for wood burned directly for energy, provide other key opportunities.

### Biodiversity within Europe

A second use could be to stabilize and restore some of Europe's badly depleted biodiversity. Overall, one third of Europe's vertebrate species are threatened with extinction. A large fraction of birds, mammals and reptiles are all threatened, and fish, mollusks and amphibians have even higher rates of threat. Of Europe's vascular plants, roughly 30% are considered threatened both within Europe and globally. Insects are declining in overall abundance, and 60% of assessed insect species are in unfavorable status.

Preserving and restoring these diverse species requires a broad range of habitats. Land restoration efforts therefore need to be carefully targeted, and habitats need to be carefully managed if Europe is to make significant progress in stabilizing its overall biodiversity.

Preserving and recreating older, more natural forests is one priority. Only 3% of Europe's forests are old-growth, and their diverse vegetation and abundant dead wood support high biodiversity. To expand old-growth habitat, one strategy would be to cease nearly all commercial forestry on some older, production forests and transition them toward more natural conditions through such techniques as limited cuttings to increase dead wood. Reforesting agricultural land with fast growing, commercial species could then maintain wood available for harvest. The combination could also maximize carbon gains by preserving older carbon stocks and supplementing them with fast growing new forests.

Preserving and restoring Europe's diverse, semi-natural grasslands and associated woodlands is also a biodiversity priority even though reforesting them would generally sequester more carbon. These grasslands represent a minority of European grasslands and, while typically producing limited food, support diverse plant species, butterflies and other insects and birds. Restoring agricultural lands to buffer these existing habitats could also be a priority.

Restoring microhabitats in agricultural landscapes, such as wetlands, hedgerows, and small woodlots may also be an efficient use of land to address the needs of many farmland species, whose declines have received particular attention. For most farmland bird species, the literature attributes these declines generally to "agricultural intensification." But this term can refer to a range of changes within production systems. Increased research is needed to identify specific management changes that can assist biodiversity while continuing to increase yields. Because yield increases are needed to free up agricultural land for habitat, whether in Europe or abroad, agricultural changes that fail to do so would leave little or no land for most biodiversity needs.

### **Carbon and Biodiversity Outside Europe**

From a global perspective, eliminating Europe's net imports of agricultural products has the highest potential to store carbon and preserve biodiversity on a global basis. Europe is a net importer of agricultural products, some for food, but

increasingly to make biofuels and other industrial products. One study has found that, after factoring in both imports and exports, Europe uses 24 million hectares of land outside Europe to supply itself agricultural products.

This “appropriation” of land abroad adds to the global demand for agricultural land and therefore contributes to the loss of forests and other habitats. Reducing Europe’s food production at the expense of producing more food abroad is a poor exchange: land conversion is mostly occurring in the tropics where yields are lower overall, requiring more land for the same food. Carbon stocks and biodiversity per hectare also tend to be much higher, resulting in high environmental costs when cropland shifts from Europe to the tropics.

Using the concept of carbon opportunity costs, we estimate that Europe’s net imports of agricultural products increase atmospheric CO<sub>2</sub> by roughly 400 million tons per year. This number represents the quantity of carbon that forests and other natural habitats outside Europe could maintain per year over roughly 30 years if not used for agricultural production to supply Europe. This “land carbon trade deficit” roughly equals Europe’s domestic forest carbon sink.

Europe can eliminate and even turn this deficit into a surplus either by importing fewer agricultural products or by exporting more. The Globagri model scenarios reported above (and in the main body of this report), which could reduce cropland by 16 to 29 million hectares in Europe, would all eliminate Europe’s land trade carbon deficit.

### **Fit for 55 Plan**

The European Commission’s proposed “Fit for 55” plan (“Plan”), now mostly incorporated into legal proposals, includes many ambitious targets to address climate change by shifting away from fossil fuels. Supporting documents pledge strong efforts also to restore the EU’s biodiversity.

Yet because these proposed laws mostly treat bioenergy as “carbon neutral,” their enactment would create powerful incentives to use more land and wood for bioenergy. While the laws count the emissions from using fossil fuels to produce bioenergy fuels, the CO<sub>2</sub> released by burning the bioenergy fuels are not counted and thus wrongly treated as “carbon neutral.” This is an error. Although the plant growth that eventually becomes biofuels absorbs carbon from the air, it takes land to grow plants. The cost of devoting land to bioenergy is therefore the lost use of that land for other purposes. These costs include directly storing carbon in existing or new forests or producing food, which would increase the capacity to preserve or restore forests and other habitats elsewhere while meeting rising food demands. The carbon neutral assumption in effects treats land as “free” from a climate perspective even as it reduces land for all these other purposes.

According to the European Commission’s own modeling, the result will not be to spare agricultural land for other uses but instead to convert it to bioenergy production. The modeling projects 22 million hectares of energy crops by 2050, equal to one fifth of the EU’s cropland today. The modeling also projects conversion of at least 10 million hectares of semi-natural grasslands to energy crops or highly managed forests, leading to the loss of perhaps one half of this

biologically diverse resource. Although the net effects might be a small increase in carbon sequestration within Europe, this effect is uncertain and at best modest compared to alternative uses of this land. Rather than improving biodiversity in Europe, these land use changes would likely reduce it. Overall, the effect will be a continuation and possibly an increase in the outsourcing of Europe's land uses, leading to more deforestation and habitat loss in the tropics, and therefore global net carbon and biodiversity losses.

There are good reasons to believe the Commission's modeling still underestimates the land use consequences of the Plan. This modeling estimates no increase in the use of wood for bioenergy between 2015 and 2030. But use of wood for bioenergy has already grown since 2015. The bioenergy industry also estimates increased use of wood, and specific legislative provisions were added to make burning wood for electricity easier in Eastern Europe. The model also relies on an increase in use of wood residues for bioenergy that are more than double estimates by others of the maximum potential residues that could possibly be harvested in European forests at today's wood harvest levels. Without such residues, more wood or energy crops would be needed.

A separate LULUCF proposal would increase the requirements for European member states to preserve their forest carbon sinks and create some incentives to increase it. Commission documents claim these national provisions counteract the treatment of bioenergy as carbon neutral. But this proposal would not alter the incentives to use bioenergy felt by actual energy users, such as power plants, factories, and airlines. Bioenergy would remain carbon neutral to these industries and therefore a viable way to meet obligations to reduce emissions. LULUCF rules may encourage Member States to restrict wood harvests, or to convert agricultural land to forest plantations, to preserve or increase their domestic carbon sinks. If so, the bioenergy incentives will encourage more imports of wood and food, and therefore more outsourcing of Europe's land carbon footprint.

Europe has also proposed a "Farm to Fork" strategy that has no mention of yields. This is a limitation. Goals to reduce agricultural pollution are important for biodiversity, but some goals, if not carefully implemented, would heavily reduce yields according to some analyses. Some small effects on yields might be an acceptable trade-off for input reductions, but they must occur in the context of large, overall increases in yields to avoid large, additional land-clearing and net biodiversity loss globally. A released Forest Strategy would also encourage more harvests and uses of wood in products, which will reduce the EU's forest carbon sink. Combining reductions in yields and incentives for more wood products with the LULUCF restrictions would further increase incentives to outsource Europe's biomass demand.

Although the largescale expansion of bioenergy would undermine carbon storage and biodiversity goals, its purpose is to help reduce energy emissions and, to some extent, create negative emissions. Yet, these claims are based on the accounting error of treating bioenergy as carbon neutral. The rules implicitly assign carbon reductions to the use of the land to grow plants to replace fossil fuels, but they do not count any cost from the loss of the use of this land for other purposes. These opportunity costs must be factored into any accurate analysis of bioenergy. When factoring in these costs, the uses of bioenergy are likely to be adverse at least for decades. Even in exceptional scenarios, any net climate gains

from bioenergy use will be far lower than assumed by the Fit for 55 directives because they ignore land use costs entirely. This omission will encourage bioenergy when other options are preferable.

The expressed goal of increased harvests for wood products is also to reduce carbon emissions by replacing other carbon-intensive materials, such as construction materials. That theory also ignores the carbon costs of more wood harvest. The EU Forest Strategy explicitly acknowledges in a single sentence that increased wood harvest for products would increase global warming for decades ((Commission 2021b), p.5).

## **Conclusions and Recommendations**

The root of the limitations in the Fit for 55 plan is an analytical contradiction in its treatment of land. Designing land use policies to enhance the climate and biodiversity is inherently an exercise in land allocation. If land is used for one purpose, it is not used for another. Each use has benefits but giving up other potential uses carries an opportunity cost. Currently, the most critical energy policies in the Fit for 55 package, and the modeling on which they are based, ignore these costs.

These land problems are fixable, and if fixed, would benefit climate change and biodiversity:

1. To properly allocate land, the Fit for 55 directives need to be amended so that provisions regarding bioenergy and wood use no longer treat biomass as carbon neutral. This could be done in several ways, but the ideal approach would be to factor the “carbon opportunity cost” of land into all climate accounting. That means, for example, the greenhouse gas costs of energy crops should factor in the reduced global capacity to store carbon by using that land for energy rather than for food or to sequester carbon directly. When harvesting wood, the reductions in carbon storage over a reasonable period of years, such as 20 or 30 years, would be factored into all calculations.
2. Europe should adopt explicit targets to reduce its effects on global land use, i.e., to reduce its land carbon footprint.
3. Europe should craft a comprehensive policy package to achieve these goals, including strategies to increase crop yields and reduce demand for land-intensive products. To meet global climate goals, it is critical that these two strategies be pursued in tandem. One option could be to give Member States a target for reducing their land area carbon footprints.
4. The EU should adopt incentives to encourage Member States to implement a highly targeted policy to enhance biodiversity and carbon storage. At the time of publication, the European Commission is contemplating a biodiversity directive that would include numerical targets and build on the Natura 2000 system and Habitats Directive. That is a sound, general approach.

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# 1. Introduction

Europe<sup>2</sup> has ambitious goals to reduce its greenhouse gas emissions and to restore its depleted biodiversity. For each goal, land is intended to play a key role, whether to store more carbon, provide better habitat, or to produce materials that replace fossil fuels. What makes improvements possible is, first, Europe's great transformation of its land in the past for agriculture and forestry to supply Europe's high consumption of land-based products, including meat, milk, and wood products. Given this great transformation of its landscape into agriculture and intensively managed forests, Europe has high potential to scale back.

The prospect of improvement now also results from the potential to stabilize demand and increase yields. Europe's population is likely to modestly decline, and its consumption of milk and meat should at a minimum stabilize at its very high level. So long as agricultural yields continue to grow, the prospect exists to free up some existing agricultural land for non-consumptive uses. Other opportunities exist to reduce wood demand. Taking advantage of these opportunities can reduce Europe's "land carbon footprint," the quantity of carbon lost from land used to supply Europe's consumption.

Some of Europe's "good fortune," however, is the result of legacy effects or the effects of climate change itself. Europe's forests are expanding in part due to the ongoing regrowth of forests reestablished in the past several decades due to the decline of agricultural land and wood fuel harvests. Much of this contraction of the agricultural land base was due to the decline of traditional forms of bioenergy. Much increased carbon sequestration in forests and possibly grasslands is due to higher carbon dioxide in the atmosphere and higher precipitation and longer growing seasons due to warmer temperatures. These are important "benefits" to the climate, but they mostly do not represent the fruits of additional mitigation efforts and are incorporated into climate projections already.

Some of Europe's "good fortune" is also of greater concern because it has arisen by outsourcing some of Europe's demand for agricultural land. Others have noted that Europe's recent reforestation is coupled to increasing imports of food and feed that stimulate comparable areas of deforestation in the tropics. By our estimate, Europe has become a large-scale net user of land around the world. When measured by quantity of carbon lost from plants and soils to produce various forms of biomass, Europe's imports greatly exceed its exports.

Assuming Europe can reduce the agricultural land needed to feed itself, what should Europe do with this "surplus land"? A related question is what Europe should do with the continuing growth of its forests, and potentially

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<sup>2</sup> Unless otherwise noted, Europe as defined in this report includes the present (as of Jan. 2022) twenty-seven countries of the EU (EU27) plus the United Kingdom (UK). We generally reserve "EU" to refer to the current policy discussions which will affect the current EU27 Member States.

expanded growth if more European land is devoted to forest. We see three major options that may to some extent be synergistic but in other ways competitive:

- These surplus land resources can be used to sequester more carbon and to directly reduce climate change.
- They could also be used to restore some of Europe's highly challenged biodiversity, for which there are multiple competing demands with different degrees of benefit for carbon sequestration.
- These lands could also be used to contribute more to the world's demand for food and wood to avoid further deforestation and habitat loss outside of Europe. One goal could be to reduce or eliminate Europe's use of foreign land to feed Europe. An even stronger goal could be to become a net contributor of food to the world, helping to meet the world's rising demand for food without clearing more land.

This report addresses the question of what Europe could do to advance these goals. The report first examines the prospect for reducing agricultural land to feed Europe, as well as the prospect of maintaining or achieving a higher carbon sink in Europe's regrowing forests (**Section 2**). This report then looks at the different potential priorities for contributing to the conservation of Europe's highly depleted biodiversity, potential priorities for carbon sequestration, and the synergies and competition between the two goals (**Sections 3 & 4**). It also examines the potential climate benefits of Europe's contribution to global food needs. We then compare these findings with emerging European policies, and with some external policy recommendations (**Sections 5, 6, & 7**).

Overall, we find many ways Europe could use a surplus of agricultural land to feed itself, to benefit climate change and biodiversity, and/or to support these goals abroad. Doing so, however, requires recognizing that using land one way will often not benefit another; in other words, each land use has an opportunity cost. Achieving significant benefits in Europe, and achieving significant benefits for the world at large, requires careful prioritization and efforts to maximize the benefits from every hectare. Numerous analyses and plans exist that inform the EU's pursuit of any one goal but the costs of *not* using land to meet other goals are frequently ignored. Because these analyses fail to acknowledge the world's fixed availability of land, they are only of partial use in informing Europe's plans at this critical juncture in its history.

This paper also addresses the emerging policy landscape in the EU. We find strong reasons for concern. Europe has high potential to contribute to climate change mitigation both by sequestering more carbon itself and by contributing to global food supplies. Europe also has high potential to boost its biodiversity. Yet, driven by a failure to acknowledge the opportunity cost of land use, Europe's proposed "Fit for 55" policy package would direct available land for none of these three priorities. Instead, land will be given over to bioenergy and potentially to increase harvests and uses of wood. The proposed policies

appear to be based on a misunderstanding of their climate benefits, precisely because the claimed benefits of using land to produce bioenergy ignore the opportunity costs—the costs of not using that land for other purposes. In terms of carbon, these costs are the alternative opportunities to sequester carbon in European lands and to reduce pressure to expand agricultural land abroad. As for biodiversity, the costs are the foregone opportunity to create high-quality habitat or prevent its further destruction, whether at home or abroad.

This report offers some recommendations for how to correct course and move forward.

## 2. European Land Use Trends and Causes

Since 1900, Europe's forest area has been recovering, but these forests remain highly managed overall. Meanwhile, Europe's grasslands, wetlands, and other important habitats have continued to decline. This section briefly explores the history and drivers of these land use changes and their implications for policy.

### 2.1. Land Use and Trends Since 1900

Europe, as used in this report, comprises an area of more than 400 million hectares of land. Of this, roughly 170 million hectares are forests, 100 million hectares are cropland, 82 million hectares are grasslands, and 26 million are shrublands (Eurostat 2021b). In addition, 19 million hectares are artificial (urban) land, and 14 million hectares are open water (ibid.).

The area of forest in Europe today represents a partial recovery from a former low point. While historical reconstructions vary, by common estimate, forests once covered approximately 80% of pre-modern Europe, and by the end of the Industrial Revolution, deforestation by human activities had more than halved that area (Kaplan, Krumhardt, and Zimmermann 2009) (Wallerstein 1974) (Bradshaw and Sykes 2014) (European Environment Agency 2018b). According to the HILDA model reconstruction led by Dr. Richard Fuchs, forests occupied just one quarter of European land as of 1900.<sup>3</sup>

In the 20th Century, European forests began to recover. Forest area in Western Europe increased by nearly 30% in the 50 years following World War II, and an estimated 20% and 16% in Central and Eastern Europe, respectively (Commission 2021g). As of 2018, nearly 40% of European land was covered by forests (Eurostat 2021b). In the last two decades alone, the area of forest in the EU increased by approximately 10% (Eurostat 2021d).

Forests have regrown by occupying three quarters of the 58 million hectares that left agricultural use, roughly one half of which came from cropland and the other from grassland, according to HILDA reconstructions.<sup>1</sup> (Other smaller uses of this abandoned agricultural land include increased human settlement.) Several developments contributed to this decline in agricultural land, which are useful for evaluating current and future policy:

- Europe's population has grown by roughly 100 million people since the middle of the last century, but the rate of growth has declined substantially (Eurostat 2021c). The growth rate was approximately 0.7

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<sup>3</sup> These figures are based on a data provided by R. Fuchs representing output from the Historic Land Dynamics Assessment (HILDA) model and underlying a number of peer-reviewed papers including (R. Fuchs et al. 2013; Richard Fuchs et al. 2015). Europe by this definition includes the EU27 plus the UK but does not include Croatia.

million persons per year between 2005–2021, compared to 3 million per year in the 1960s (ibid.).

- Both crop yields and the feed efficiency of producing milk and meat have grown dramatically over the last 60 years (Agnolucci and De Lipsis 2020) (Capper 2011). This means less land is required to produce the same amount of food.
- Following World War I, Europe experienced declines in traditional bioenergy (i.e., animal feed) as the demand for horses and other draught animals declined. According to one reconstruction, the reduction in draught animals in Western Europe since 1913 reduced the production of animal feed (measured by its biomass) in an amount equal to roughly 80% of the increase in food consumption by people.<sup>4</sup> More than half of this reduction occurred after 1961. According to this same reconstruction, the decline of traditional bioenergy in Eastern Europe was even more dramatic: the decline in use of feed for draught animals and wood fuel was *double* the increase in food for people when measured by biomass. Overall, these declines in traditional bioenergy freed up vast areas of agricultural land for reforestation and other uses.
- Although per capita consumption of all animal products grew overall from 1961–2018 (mainly because of large growth in Southern Europe), per capita consumption of meat from ruminants (beef, sheep, and goat) declined by roughly 30% from peak levels (FAOSTAT 2021). These reductions have a disproportionate effect on reducing Europe’s agricultural land base as ruminant meat globally uses at least five times more productive land than other animal products (Searchinger, Wiersenius, et al. 2018). A report for the European Commission projects modest further declines in per capita beef consumption in the EU (Commission 2020b).
- Europe has also greatly expanded its reliance on imported food and feed, in effect substituting agricultural land outside of Europe for agricultural land within Europe. We discuss the scope and significance of this offshore shift below.

Although these changes have freed up surplus land, allowing forests to expand and accrue benefits for carbon and biodiversity, these changes have also accrued significant biodiversity costs. As discussed in more detail below, nearly all Europe’s forests remain highly managed, with major implications for biodiversity (FOREST EUROPE 2020) (European Environment Agency 2020a) (European Environment Agency 2016). Intensification of European agriculture has included shifts from diverse, highly extensive “mosaic” grazing lands that supported relatively abundant plant, insect, and other animal species to intensively managed pastures with limited grass species and reduced biodiversity (Dengler et al. 2020) (Eriksson 2021). Intensification of cropping

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<sup>4</sup> See Table 11 in (Malanima 2020b) and (Malanima 2020a). These data represent the energy content of biomass and therefore do not directly correspond to utilized land area.

and livestock farming has also led to increased nitrogen and pesticide pollution, which also poses serious challenges to Europe's biodiversity (European Environment Agency 2020a).

Only relatively small portions of Europe's native habitats remain intact (Janssen and Rodwell 2016). In addition to semi-natural grasslands, wetland ecosystems are among those highly affected. By 1900, Europe had drained vast areas of wetlands, and by 2000, had likely lost around 70% of what remained, mainly due to drainage for agriculture and human settlement (European Environment Agency 2010) (Davidson and Davidson 2014). Wetlands have continued their decline even in recent decades, decreasing by approximately 35% between 1970–2013 (Darrah et al. 2019).

## 2.2. Forest Stock & Production

The recovery of forest area from 1900 and other factors explain why European forest's wood content (i.e., stock) has grown (FOREST EUROPE 2020).<sup>5</sup> The volume of wood in European forests increased by approximately 50% between 1990–2020 (ibid.). The growth in forest stock has made it possible for the EU to increase its wood harvests: production in 2020 was 20% higher than in 2000 (Eurostat 2021e).

Europe's increasing wood stock can be attributed primarily to three factors:

- Expansion of forest area as agricultural area declined along with the aging of the trees established (Grassi et al. 2018). Although little documented, experts generally also cite a large decline in the household harvest of fuelwood from early in the 20<sup>th</sup> century and including in World War II. The reduction in grazing in forests, often because of legal rules, probably also had a major effect on increasing forest carbon stocks (Gingrich et al. 2021)
- Increased tree growth rates due to carbon dioxide fertilization, nitrogen deposition, and a changing climate, including greater precipitation in some areas, warmer temperatures, and longer growing seasons (Pretzsch et al. 2014; Ciais et al. 2008; Kauppi, Posch, and Pirinen 2014; Kint et al. 2012; Hellmann et al. 2016; de Wergifosse et al. 2020). Although the relative contribution of these environmental factors to increased tree growth in Europe is debated, most studies attribute the majority to beneficial climate effects as opposed to changes in forest age structure and composition (Ciais et al. 2008; Bellassen et al. 2011). A changing climate is also causing much faster growth of commercial trees, causing more rapid "self-thinning" as they push out smaller trees, leading to more merchantable timber (Pretzsch et al. 2014).

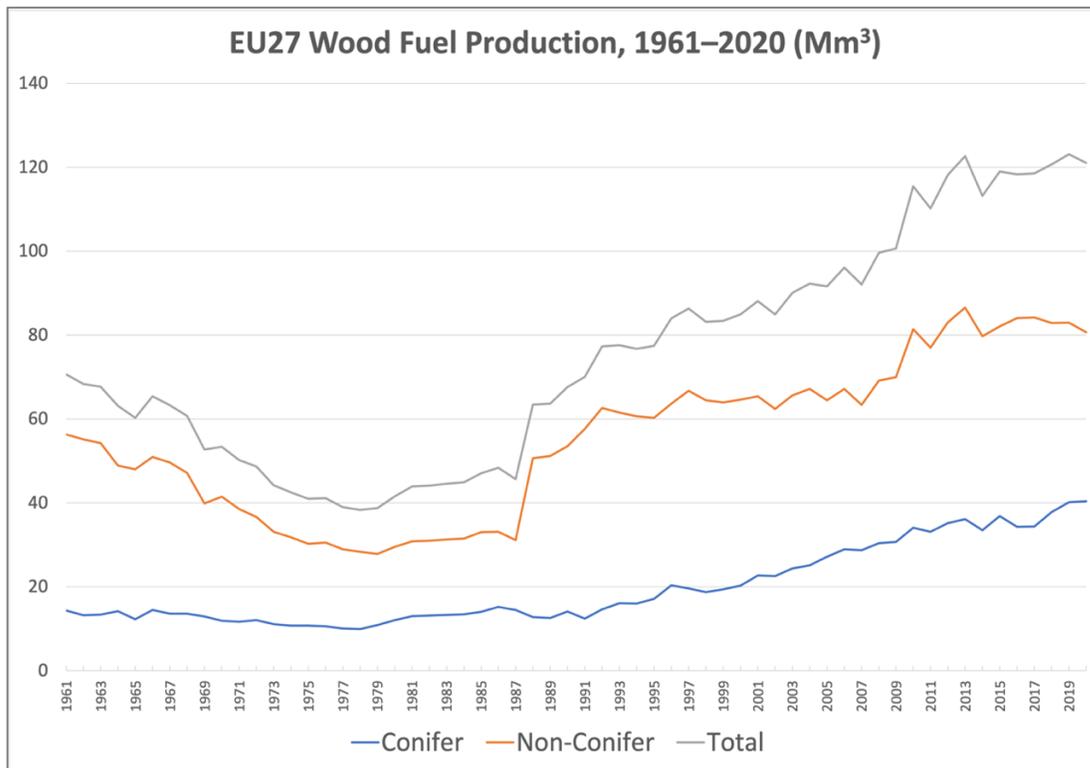
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<sup>5</sup> Europe here is defined as the FOREST EUROPE signatory countries (45 European countries including the European Union).

- The indirect land sparing effect of intensive forest management. Increased timber yield per hectare per year of forest makes it possible, at least in theory, to leave more forests unharvested elsewhere while maintaining the same harvest levels (Betts et al. 2021).

In recent years, the net growth rate of Europe’s forests (i.e., growth in excess of harvest), has declined. Increasing use of wood for fuel is an important factor (Figure 1). Fuelwood consumption and the share of fuelwood in total roundwood production have increased since 2000 in most EU countries (Eurostat 2021f). About a quarter of roundwood production in 2019 in the EU-27 was harvested and used immediately as fuelwood (+6% over 2000), in addition to the burning of waste wood that is a by-product of other wood panel production (Eurostat 2021e). About half of renewable energy in Europe derives from wood (European Parliament 2021).

**Figure 1.** Wood fuel production in the EU27, 1961–2020.



**Caption:** Data Source: FAOSTAT, “Forestry Production and Trade.” Mm<sup>3</sup>: millions of cubic meters. Figure 1 here displays FAOSTAT data. A query of EUROSTAT data indicates a slightly larger increase in fuelwood, but it is not immediately evident what explains this accounting difference. Sharp jump in 1986 reflects a large increase in data completeness.

Some of the EU’s increased wood fuel consumption is supplied by large increases in imported wood pellets. Four of the five largest importers and consumers globally are in Europe (UK, Denmark, Italy, Belgium, and Germany) and, together with the Republic of Korea, account for 80% of global

imports (FAO 2019). Between 2014–2018 imports of wood pellets increased by 48% in the UK, by 69% in Denmark, and by lesser but still significant amounts in Italy and Belgium (*ibid.*). The UK by itself accounts for 32% of all imports of wood pellets globally (*ibid.*).

### 2.3. Europe’s LULUCF Major Carbon Sink and Sources

The recovery of forests is the source of the EU’s large reported “forest carbon sink,” equal to roughly 10% of Europe’s annual greenhouse gas emissions (European Environment Agency 2020b). The average annual net emissions from the LULUCF sector reported between 2000–2019 was slightly over 300 MMt CO<sub>2</sub>eq ((European Environment Agency 2021), Fig. 1).<sup>6</sup> This figure represents roughly 430 MMt CO<sub>2</sub>eq in a gross sink from growing forests and harvested wood products and emissions from areas other than forests of roughly 130 MMt CO<sub>2</sub>eq (European Environment Agency 2021). Due in part to aging forest stocks and increasing natural disturbances, and in part to increased wood harvest, the EU-reported net sink has declined over the last few years to 249 MMt CO<sub>2</sub>eq in 2019 (European Environment Agency 2021).

Croplands are the main sources of emissions in the LULUCF sector and approximately half of the reported emissions from cropland are from drained peatland soils (Böttcher et al. 2021). Drained peatlands emit vast quantities of carbon when oxygen penetrates drying soils, breaking down carbon stocks that would otherwise be stable or even increase. Agricultural peatland areas in the EU-27 (cropland and grassland) account for 33% of total reported agricultural emissions in the EU despite only comprising about 3% of total reported agricultural area (N. & Martin and Couwenberg 2021).<sup>7</sup> In total, emissions from organic agricultural soils account for 4% of EU’s total reported (and corrected) emissions from all sectors (*ibid.*). Note that this accounting excludes the additional emissions generated from forestry activities on peatlands (reported emissions from the drainage and rewetting of organic and mineral soils in forest lands was approximately 6 MMt CO<sub>2</sub>eq in 2018; see Table 6.32 in (European Environment Agency 2020b)).

Official estimates of peatland emissions in the EU are likely to substantially underestimated. A 2021 report from the Greifswald Mire Centre (GMC) compared the emissions from agricultural peatlands reported by the EU-27 countries in the 2020 National Inventory Report with those produced by a comprehensive independent analysis (Martin et al. 2021). Reported emissions amounted to 92 MMt of CO<sub>2</sub>eq while corrected emissions were estimated at 166 MMt of CO<sub>2</sub>eq, nearly twice the “official” numbers. A 2018 report from GMC concluded that “countries generally underestimate the area of drained organic soils” and highlighted “considerable discrepancies between the Global

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<sup>6</sup> Note that (Böttcher et al. 2019) cite the average reported LULUCF net sink at 320 MMt CO<sub>2</sub>eq over the same time frame. In contrast, data provided in Figure 1 in (European Environment Agency 2021) puts this number at 303 MMt CO<sub>2</sub>eq.

<sup>7</sup> When corrected, agricultural areas account for 27% of emissions; see supplementary data table in Martin et al. 2021.

Peatland Database [maintained by the GMC] and reporting by Estonia, Romania, Ireland, the UK, Austria, and Hungary,” (Barthelmes 2018).

## **2.4. International Consequences of Europe’s Changes in Land Use**

Europe’s forest expansion has also been made possible by increasing reliance on agricultural imports. These imports are part of Europe’s land carbon (and biodiversity) footprint. Today, a growing research community seeks to quantify the impacts of Europe’s trade on global land use changes (e.g., deforestation). In effect, research in this space seeks to answer the question: *how much do Europe’s imports and exports either increase or reduce agricultural land use outside of Europe?* Here, we refer to this effect as the “land carbon trade deficit or surplus.”

### **2.4.1. Existing estimates of the role of Europe’s imports**

A substantial body of research has found that Europe has been “offshoring” its land use, contributing to deforestation and other losses of habitat abroad (see (Kastner et al. 2021) for a review). Fuchs, Brown, and Rounsevell (2020) estimated that while Europe had expanded its own forest area by 13 Mha between 1990 and 2014, around 11 Mha was deforested outside the EU, mostly to serve increased demand for oilseed crops and derived products (Richard Fuchs, Brown, and Rounsevell 2020). Three-quarters of this foreign deforestation is connected to oilseed production in Brazil and Indonesia. Pendrill et al. (2019) and Sandström et al. (2018) estimate that annual, tropical deforestation-related emissions were equivalent to a substantial fraction of the total domestic agricultural emissions in most European countries and account for roughly 13–30% of the total carbon footprint of average European diets (Pendrill et al. 2019; Sandström et al. 2018). Carbon, land, and resource footprints vary substantially at the subnational level in Europe, with wealthy areas of Europe known to have a much higher biodiversity footprint (Wilting et al. 2021; Koslowski et al. 2020).

Data underlying Kastner et al. (2021) provides an estimate of the net land use effects of agricultural trade by Europe. This analysis credits European agricultural exports for reducing agricultural land area abroad while imports increase foreign land area. This analysis found that in 2010 Europe in effect “appropriated” for its own use 24 million hectares of foreign land on a net basis.<sup>8</sup>

### **2.4.2. Our analysis using “carbon opportunity costs”**

From a greenhouse gas (GHG) accounting perspective, the key focus is not just the quantity of hectares abroad that Europe “appropriates” for its own use,

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<sup>8</sup> Data provided by T. Kastner. Note that the estimation of net foreign land use here is not the primary focus of Kastner et al. 2021.

but how much carbon is lost from native vegetation and soils due to this use. The pertinent questions become: *How much carbon is lost from forests and other native habitats to produce the food and other crops that Europe imports? How does this compare to the carbon saved outside Europe as a result of Europe's exports?* For accounting purposes, this calculation should adjust for the quality of land used, as land used to produce some crop types can store more carbon than that used for other crop types.

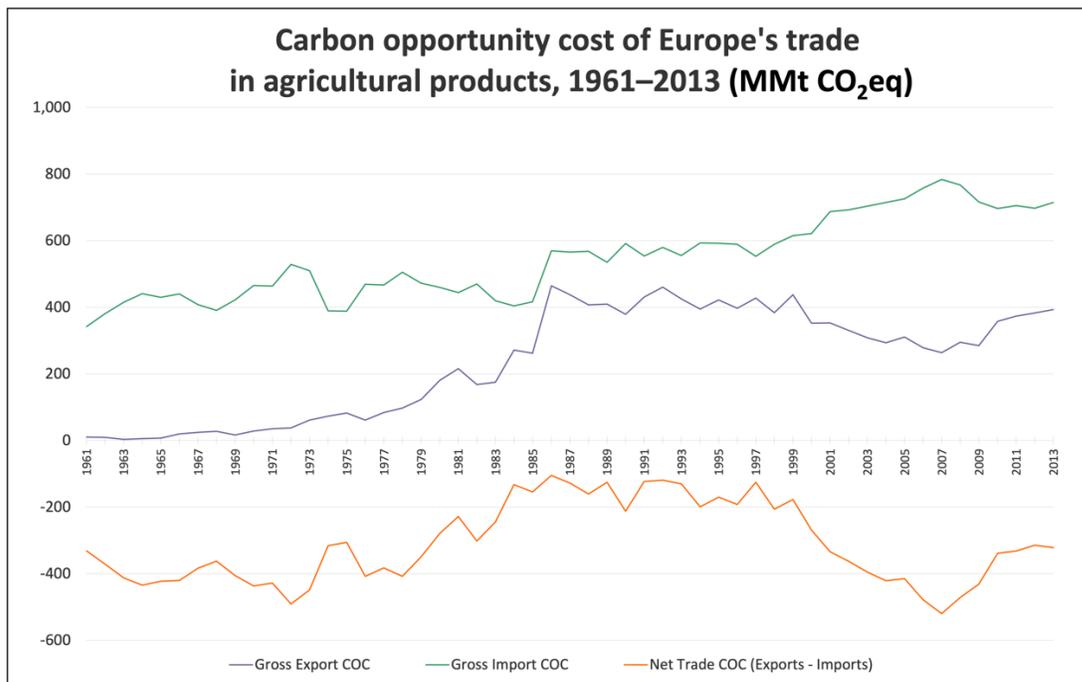
This calculation is aided by employing the concept of a “carbon opportunity cost” (Searchinger, Wiersenius, et al. 2018). Carbon opportunity costs provide an annualized measure of the average quantity of carbon lost from vegetation and soils globally to produce a ton of a particular food item. For example, to transform land to enough cropland to produce one ton of soybeans, the world loses on an annualized basis 5.9 tons of CO<sub>2</sub> in carbon not stored in vegetation and soils (Searchinger, Wiersenius, et al. 2018). Multiplying Europe's quantities of imports and exports of each crop (or other food or feed item) by the corresponding carbon opportunity cost provides an estimate of the impacts of Europe's domestic production and consumption decisions on global forest carbon stocks.

Applying carbon opportunity costs to FAO trade data between 1986–2013, we find that Europe<sup>9</sup> relies heavily on foreign agricultural land, implicitly displacing large quantities of carbon (Figure 2). Europe exports large quantities of wheat and dairy products, some pork, and smaller quantities of many other products. But the land foreign countries save by not producing these imported foods themselves is greatly overshadowed by the land used to supply European demand for soy, palm oil, sugar, coffee, and cocoa, among other products. The total net annual carbon opportunity cost of these imports in 2010–2013 was roughly 400 MMt CO<sub>2</sub>eq (Figure 2). This carbon cost can be thought of as Europe's annual “land trade carbon deficit,” and it is roughly equivalent to Europe's annual average domestic forest carbon sink between 2010–2020 (FOREST EUROPE 2020) (European Environment Agency 2020b).

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<sup>9</sup> Our main modeling results in this report, including those from the Globagri model and our estimates of carbon opportunity costs, define Europe as the EU27 plus the four EFTA countries, five EU candidate countries (not including Turkey), and other small municipalities, whose economies are closely linked to the EU.

**Figure 2.** Carbon opportunity cost (MMt CO<sub>2</sub>eq) associated with Europe’s trade in agricultural products (1961–2013).



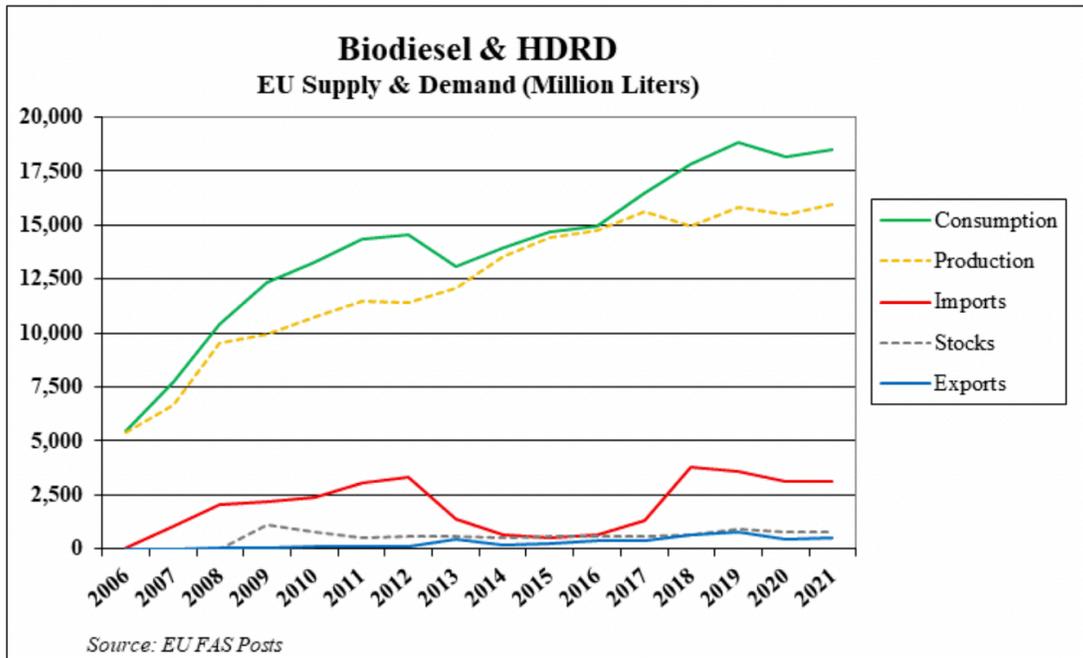
**Caption:** Europe is a strong net “importer” of land carbon emissions generated abroad. Trade represents the imports and exports to and from Europe, as defined, to the rest of the world (i.e., total trade minus intra-Europe trade). Europe here is defined as the EU27 + UK + 4 EFTA countries + 5 EU candidate countries (excl. Turkey) + 11 other small European principalities and jurisdictions. Trade data source: FAOSTAT. MMt: million metric tons. COC: Carbon opportunity cost. COC coefficients are derived from (Searchinger, Wirsenius, et al. 2018). Sharp jump in 1986 reflects a large increase in data completeness.

### 2.4.3. Role of Europe’s non-food agricultural demand

Increased demand for non-food products, such as biofuels, detergents and lubricants, are an important driver of Europe’s increased appropriation of foreign lands. Bruckner et al. (2019) analyzed the EU’s global landuse footprint for agricultural products other than food and found that Europe in 2010 appropriated 18 million hectares of land abroad for non-food products such as biofuels, detergents, and other lubricants (Bruckner et al. 2019). According to this analysis, land abroad constitutes two thirds of Europe’s total land used for these products. This demand has grown rapidly, more than doubling from 1995 to 2010 globally.

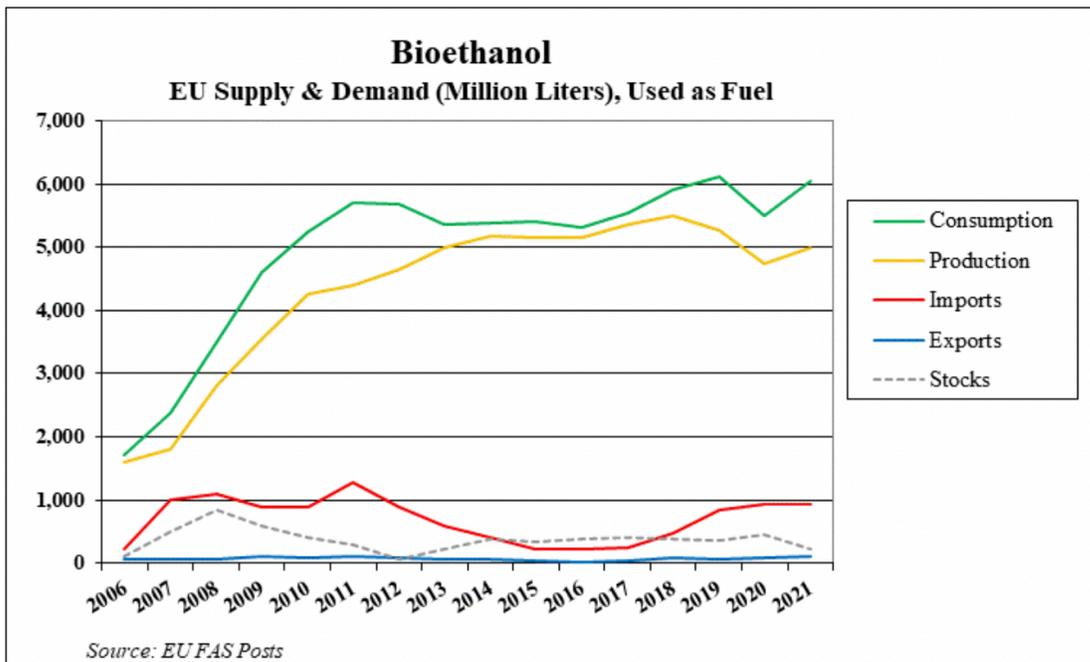
Much of Europe’s non-food agricultural land use is for biofuels. Since 2010, biofuel demand has continued to grow, particularly for biodiesel (Figures 3 & 4).

**Figure 3.** EU supply and demand of biodiesel and hydrogenation-derived renewable diesel (HDRD).



Caption: EU here includes the EU27 and the UK. Source: reprinted from "2021 Biofuels Annual Report." Global Agricultural Information Network, United States Department of Agriculture (USDA 2021b).

**Figure 4.** EU supply and demand of bioethanol.



Caption: EU here includes the EU27 and the UK. Source: reprinted from "2021 Biofuels Annual Report." Global Agricultural Information Network, United States Department of Agriculture (USDA 2021b).

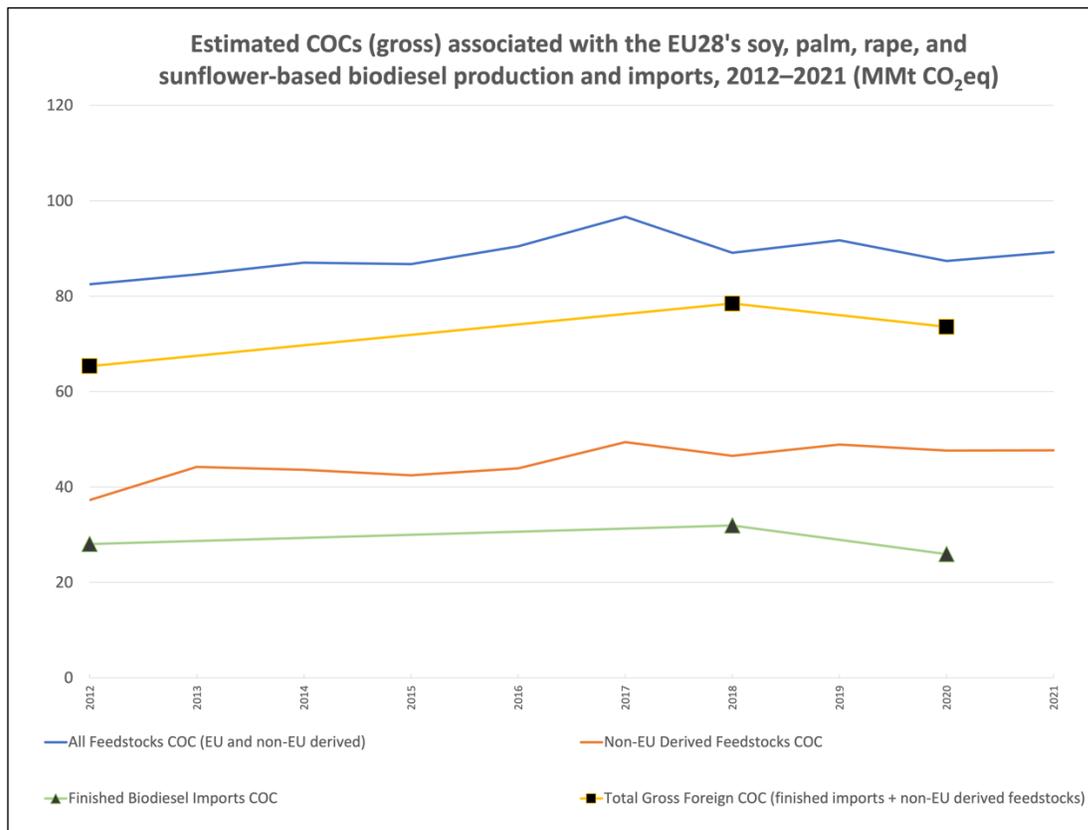
Although these figures show most of Europe's biofuels are produced domestically, this production relies heavily on imports of vegetable oils and other feedstock crops. The European Commission estimates that 7.4 million hectares of land was required for the production of crops for EU biofuel consumption in 2018, of which 3.4 million hectares (46%) were located within the EU and 3.8 million ha (51%) outside the EU (Commission et al. 2020).

We apply the same methodological approach as above (see **Section 2.4.2**) to estimate the carbon opportunity cost associated with Europe's demand for non-food oilseed crops used as biodiesel feedstocks.<sup>10</sup> We also estimate the carbon opportunity costs embodied in Europe's imports of finished biodiesel. In 2018, the combined carbon opportunity costs of Europe's imported biofuels and non-EU derived biofuel feedstocks reached roughly 80 million tons CO<sub>2</sub>eq (Figure 5), which is roughly one fifth of Europe's land trade carbon deficit.

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<sup>10</sup> We average slightly different estimates from the European Commission's 2020 Renewable Energy Progress Report and Annual Reports from United States Department of Agriculture Global Agricultural Information Network (GAIN) of the types of crops used for European biofuels.

**Figure 5.** Carbon opportunity costs (COCs) associated with the EU28 production and imports of soy, palm, rape, and sunflower-based finished biodiesel and biodiesel feedstocks.



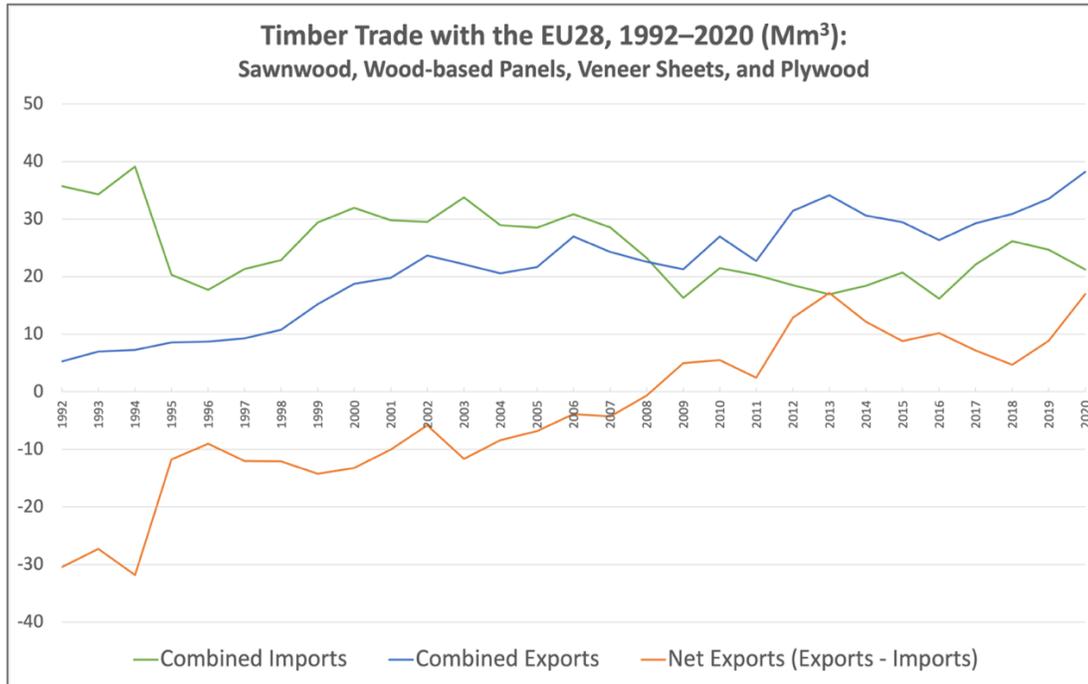
**Caption:** Estimated COC associated with the EU28’s consumption of soy, palm, rape, and sunflower biodiesel feedstocks, both global and non-EU derived, are estimated for the continuous time series, 2012–2021 (blue and orange lines). COC associated with imports of finished soy, palm, rape, and sunflower-based biodiesels are only estimated for the years 2012, 2018, and 2020 (green line). Total gross foreign COC (yellow line) represents the addition of the non-EU derived feedstock COC and foreign feedstocks embodied in finished biodiesel imports; total foreign COC is only estimated for 2012, 2018, and 2021. Green and yellow trend lines do not capture interannual variation. MMt: million metric tons. Data sources: USDA GAIN “EU Oilseeds and Products Annual Report, 2021” (USDA 2021a); USDA GAIN “EU Biofuels Annual Report” (USDA 2021b); FAOSTAT for EU crop yield data.

#### 2.4.4. Net wood trade balance

Wood trade data is challenging, but according to our analysis, the EU-28 is a modest net exporter of wood (Figure 6). Until 2008, the EU was a net importer, but since then, due to rising harvests, it has become a modest net exporter. In 2020, the EU-28’s net exports reached 17 million cubic meters of different finished wood products (Figure 6). According to Eurostat, the EU28 also recently became a net exporter (~3 million cubic meters) of rough industrial wood.

Although Europe is a net exporter, these exports represent only 4% of the EU-28's production of wood, which means that Europe consumes 96% of its own production.

**Figure 6.** Timber trade of finished wood products with the EU28, 1992–2020 (Mm<sup>3</sup>).



**Caption:** Timber trade between the EU28 and the world. Includes sawnwood, wood-based panels, veneers sheets, and plywood. Data source: EUROSTAT. Mm<sup>3</sup>: millions of cubic meters.

## 2.5. Observations on Europe’s Recent Land Use Trends

This summary of Europe’s land use trends and drivers leads to some useful observations for thinking about how to use Europe’s land to meet its own climate, biodiversity, and sustainability goals while also contributing to these goals in other regions of the world:

- Some of the beneficial effects of Europe’s land use change, such as the growth of Europe’s forest carbon sink, are the result of changes in European behavior that also “benefit” global biodiversity and carbon storage in land by reducing the need for agricultural land. Most prominently, these changes include a stabilizing population, a large decline in draught animals, reductions in consumption of ruminant meat since around 1970, and vast increases in crop yields and livestock production efficiencies.
- Benefits of Europe’s land use changes are, however, also made possible by increasing reliance on other parts of the world to produce

crops for Europe, including crops for both food and industrial use. We do not provide our own estimate of how much this total “offshoring” has grown since 1900, but the data and literature show large increases in net reliance on imports in the last few decades. These imports include food and non-food, including bioenergy. Reforestation within Europe has largely been matched by increased use of land and deforestation outside of Europe. By our calculation, the greenhouse gas consequences of this reliance on foreign agriculture roughly offsets Europe’s domestic forest carbon sink.

- A significant portion of Europe’s carbon sink, possibly a majority, results from higher CO<sub>2</sub> in the atmosphere and other aspects of climate change and appropriately should not be credited to Europe as proactive mitigation. As discussed below, Europe plans to take credit for this carbon sink in meeting net neutrality by 2050.

### 3. Europe's Potential to Reduce Demand for Land for Food, and Wood Harvests

The EU's Green Deal promises to restore Europe's ecosystems and biodiversity while reaching climate neutrality by 2050 (Commission n.d.). As an intermediate target, Europe's 'Fit for 55' 2030 Climate Target Plan sets a goal of modestly increasing Europe's net land-based carbon sink to 310 MMt of CO<sub>2</sub>eq/year (Commission n.d.). Several environmental NGO's have criticized this target as inadequate, pushing instead for a 600 MMt per year target (Climate Action Network Europe 2021; World Wildlife Fund 2021).

There are two basic ways Europe can achieve these land use goals without appropriating more of the world's land outside of Europe. One option is to produce more food on existing agricultural land and possibly more wood growth per hectare in Europe's forests. The other option, not mutually exclusive, is to reduce European consumption.

Fortunately, Europe has clear potential to reduce the area of agricultural land needed to feed itself:

- One major reason is a projected decline in Europe's population. Europe's population, 515 million people today, is expected to fall by 17 million people between 2020 and 2050, and more rapidly in the second half of this century (United Nations Department of Economic and Social Affairs 2019). One recent study suggests Europe's population decline could be greater than expected by the end of the century (Vollset et al. 2020). In addition, European crop yields and livestock feed efficiencies have continued to grow and will likely continue to do so (Searchinger et al. 2021). Combining declining consumption with increased yields means reduced land use required to feed Europe.
- Another primary reason is that, unlike people in the developing world, Europe's per capita consumption of land-intensive foods is already so high that consumption is unlikely to increase further. Since 1961, Europe's consumption of land-intensive foods greatly increased, driven by a rough doubling of per capita consumption of meat and milk in Southern Europe (FAOSTAT 2021). Reducing this high per-capita consumption rate as Europe's overall population declines gives Europe the potential to further reduce its global land and resource demands (though proposed policies could have the opposite effect, such as incentivizing increased consumption of bioenergy).

For these reasons, and although modeling assumptions vary greatly, global land use projections typically predict a decline in the agricultural land base in Europe by 2050 under business-as-usual conditions. One comparison across five global land use models estimates reductions of 11–54 million hectares of

cropland within Europe (Schmitz et al. 2014).<sup>11</sup> (Changes in pastureland were not presented but probably also decline in these model runs.) However, like many model comparison studies, it is not easily discernible how these estimated reductions in European cropland interact with projections of future trade in food, namely imports.

A recent analysis by the World Resources Institute provides some insights of what can be achieved by 2050 when explicitly accounting for this future trade balance. Output from the Globagri-WRR model used in the report *Creating a Sustainable Food Future*, estimates a decline in European cropland by 16.5 million hectares (Searchinger et al. 2019). This scenario also contemplates a virtual elimination of Europe's global land trade deficit, as measured by carbon opportunity costs.<sup>12</sup> Model results suggest Europe has potential both to use more land in Europe for carbon and biodiversity goals, and to eliminate its land carbon trade deficit. One necessary element to achieve these twin goals, however, is holding European biofuel consumption to the share of transportation fuels that biofuels provided Europe in 2010. Table 1 shows potential reductions in cropland under different scenarios.

Achieving these land and land carbon trade savings in also scenarios also requires yield gains. Yields in the "reference" scenario (Scenario 1 in Table 1) reflect the FAO's yield growth assumptions (Alexandratos and Bruinsma 2012). Achieving some of these yield gains would appear relatively easy, such as those for maize and barley; yield gains for wheat, rapeseed, and olives are likely to be more challenging. Yields in the "enhanced" growth scenario (Scenario 2) contemplate a 20% faster yield growth rate between 2010–2050 compared to the "reference." Estimated reduction in cropland in Europe would be over 20.5 million hectares. Achieving these accelerated yield increases will require significant effort, especially in light of increasing negative climate impacts on yields in Europe (Ray et al. 2019; Zhao et al. 2017). The yield increases of Europe's five largest crops by harvested area that would need to be achieved to satisfy each of these two scenarios are displayed in Table 2.

Europe can further reduce its agricultural land base through reductions in food loss and waste (Scenario 4), or in reduced domestic consumption of land-intensive foods, such as meat and milk (Scenario 3). The 17% reduction in Scenario 3 would be Europe's equitable contribution to achieve a 10% reduction from likely future global consumption levels. In this scenario, Europe could free up nearly 30 million hectares of land.

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<sup>11</sup> These scenarios are based on the IPCC SSP2 medium growth pathway and assume that climate change impacts on crop yields will be fully mitigated (no climate change), which is generally consistent with IPCC mitigation analyses for the temperate zone.

<sup>12</sup> *Creating a Sustainable Food Future* also contemplates an 8 million hectare increase in pastureland in Europe, an output associated with an underlying model constraint that assumes large increases in European exports to contribute toward a vast increase in global beef consumption (+90%) between 2010–2050. Fortunately, the rate of increase in ruminant meat is occurring at roughly half this projected rate.

In another scenario (not presented in Table 1) modeling just a 50% reduction in Europe’s consumption of ruminant meat (as part of a global reduction of ruminant meat by those who eat a great deal), Europe would free up 12 million hectares of pasture in addition to 19 million hectares of cropland.

**TABLE 1.** European Food Futures and Modeled Land Use Changes.

Scenario	Description	Cropland change (million hectares)
1	Reference Scenario; adopts FAO yield growth assumptions	-16.5
2	European and global yields grow 20% faster than estimated by FAO	-20.6
3	Projected European future consumption of animal products (meat, dairy, fish) reduced by 17% and global consumption by 10%	-28.4
4	European and global food waste reduced by 10%	-18.8

**TABLE 2.** Yields required to satisfy Globagri Scenarios 1 (“reference”) and 2 (“enhanced”) from Table 1. Crops represent the EU27’s five largest crops in 2020 by area harvested.

Crop	Total Harvested Area, 2018 (Mha)	Yield, 2016–2020, (avg) (FAOSTAT) (tons/ha)	"Reference" Yield, 2050 (projected) (tons/ha)	% Yield Change "Reference"	"Enhanced" Yield, 2050 (projected) (tons/ha)	% Yield Change "Enhanced" Scenario
Wheat	24.1	5.48	6.89	26%	7.65	40%
Barley	11.1	4.80	5.04	5%	5.35	11%
Maize	8.7	7.75	8.12	5%	8.70	12%
Rapeseed	5.8	3.04	4.03	32%	4.50	48%
Sunflower-seed	4.2	2.29	2.62	15%	2.98	30%
Olives	5.0	2.66	4.91	85%	5.97	124%

The same principles apply to Europe's wood use. Europe's overall consumption of wood grew 17% between 2000 and 2019, and half of that growth came from increased consumption of wood fuel.<sup>13</sup> As in the case of food, there is large, growing international demand for wood. Simply reducing wood harvests in Europe may not be the most effective way to support climate mitigation efforts as global wood demand rises. By reducing its own demand for wood, Europe can potentially offset some of this rising global demand and relieve pressure to deforest areas of high carbon and biodiversity value. We highlight two important ways that Europe could accomplish this:

- Reduced demand for wood can occur by making more efficient uses of waste woods, often referred to as “cascading” use of wood (Risse et al. 2017). In this approach, wood products or byproducts generated in one manufacturing process are used or recycled in other processes, thereby maximizing the useful life of harvested wood. One estimate put potential demand savings from cascading at 3–14% of southeastern Germany's total annual wood supply (although only 7% if measured by global warming potential due to some offsetting emissions; see (Höglmeier et al. 2015). In general, life cycle assessments (LCAs) that compare primary versus cascading wood use in European supply chains generally find reductions in emissions and land use requirements (Faraca, Tonini, and Astrup 2019; Bais-Moleman et al. 2018; Höglmeier, Weber-Blaschke, and Richter 2014).
- Another way to reduce wood demand in Europe would be to reduce the roughly 25% of wood harvested that is deliberately harvested and burned for energy (Eurostat 2021e).

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<sup>13</sup> These results are outputs of the Carbon Harvest Model (CHARM) developed by the World Resources Institute. This model utilizes FAO statistics on forest harvests and wood uses but breaks the reported statistics down into different categories of consumption.

## 4. Synergies and Trade-offs in the Potential Uses of Reduced Agricultural Land and Wood Demand

The potential reduced need for agricultural land to feed Europe, as well as the potential to reduce European wood consumption, implies that Europe has an opportunity to use newly available land to address land-based carbon and biodiversity goals. Europe could advance these concurrent goals in different ways. Europe could:

- Use that newly available land to sequester more carbon in Europe.
- Elect to provide more habitat to support vulnerable European species and ecosystems.
- Use the available land area to improve its “land trade balance” with the rest of the world. This land could be used to sustain or increase domestic production of certain products to lessen implied land use appropriations abroad and avoid associated losses of carbon and biodiversity in those regions.
- Use the available land are to produce more bioenergy or wood to replace fossil fuels or carbon-intensive materials.

What land uses—and the balance between them—should Europe favor to maximize net benefits for climate change and biodiversity?

In this section, we move iteratively through the three, broad potential land use strategies outlined above. We begin with possibilities for direct carbon sequestration (**Section 4.1**). We then evaluate the priorities for restoring biodiversity and examine the synergies and trade-offs with carbon sequestration (**Section 4.2**). Next, we explore the value for carbon and biodiversity of improving Europe’s “land carbon trade balance” (**Section 4.3**).

Europe could alternatively use the available land area to produce more bioenergy or wood to replace fossil fuels or carbon-intensive materials, such as concrete and steel. Because the European Commission is currently proposing to devote much European land for these purposes, we discuss the implications of this land use option in our discussion of the current European policy landscape in Section 5.

### 4.1. Priority Opportunities to Sequester More Carbon in Europe

Europe can directly mitigate climate change by sequestering more carbon in European vegetation and soils. Several papers have already set forth pathways to increase Europe’s LULUCF carbon sink (e.g. (Böttcher et al. 2021)).

Assuming reduced agricultural land use, the three major opportunities for increased carbon sequestration are to: (1) rewet peatlands, (2) reforest land, and (3) harvest existing forests less intensively. Because others have also suggested ways of increasing carbon sequestration on working agricultural lands, we briefly discuss this option as well, and why we consider the approach to be less promising.

#### 4.1.1. Peatlands

Peatlands are areas with soils containing high levels of organic matter due to continuous saturation by water, which blocks oxygen from penetrating and therefore inhibits decomposition of that organic matter. Over time, peatlands in Europe have accumulated large carbon stocks, up to four to five times more carbon than Europe's forests (Swindles et al. 2019; Böttcher et al. 2021). Draining peatlands causes large releases of carbon and other greenhouse gases by allowing oxygen to penetrate the soils, activating decomposition (Pérez Domínguez et al. 2020).

Recent best estimates suggest that, on average, drained boreal and temperate peatlands used for cropping likely release around 38 tons of CO<sub>2</sub>eq per hectare per year, while drained pasture varies from roughly 25–30 tons (Wilson et al. 2016). Some regional estimates can be even higher. For example, standard emissions estimates in Denmark are 45 tons of CO<sub>2</sub> per ha (Searchinger et al. 2021). These emissions will generally continue for decades until the peat is fully depleted (Hiraishi et al. 2014). When rewetted, peatlands tend to generate more methane, which reduces the overall greenhouse gas benefits; however, because rewetting agricultural wetlands eliminates the substantial majority of emissions, it is viewed as net positive for the climate (Huang et al. 2021; Günther et al. 2020; Morris 2021).

Although full rewetting is needed to stop CO<sub>2</sub> releases, Evans et al. (2021) report that maintaining water tables at no deeper than 45 cm below the surface in cropland peat and 25 cm in grassland peat could reduce present-day peatland emissions by 65% if applied globally, which is equivalent to an 11.5% reduction in all global CO<sub>2</sub> emissions from land use (Evans et al. 2021). These relatively more modest rewetting strategies (i.e., as opposed to full rewetting) might allow for some crop production to continue, although at the cost of most biodiversity benefits.

The EU has 12 million hectares of drained peatlands, half of its overall peatland area (Tanneberger et al. 2021). Although the EU reports peatland emissions of 92 million tons of CO<sub>2</sub>eq, evidence suggests the actual number could be nearly twice as high (Martin et al. 2021). Many EU member countries do not report complete or consistent data in regards to peatland emissions and underreport drained peatland area, emissions factors, or both (Barthelmes 2018) (Dr. Franziska Tanneberger, personal comm.)

By one estimate, roughly 4 million hectares of drained peatlands in the EU are used for agriculture (Böttcher et al. 2021). This number could be grossly

underestimated given that it is based on an outdated and significantly lower estimate of total area of drained peatland. A study by the UBA in Germany estimates that 48 million tons of CO<sub>2</sub> could be mitigated per year following the rewetting of 2 million hectares of drained peatland, roughly 50% of organic soils under agricultural production (Duscha et al. 2019). Another study estimates the mitigation potential of 42 million tons of CO<sub>2</sub> per year by 2030 (Pérez Domínguez et al. 2020).

#### 4.1.2. Forests

Reestablishing forests, particularly on cropland, is a second major strategy for sequestering more carbon. Forest carbon sequestration rates naturally fluctuate and depend on tree species, forest age, site conditions, and management practices (Puhlick et al. 2020; Garcia-Gonzalo et al. 2007; de Vries et al. 2006; Pérez-Cruzado et al. 2012; Solberg et al. 2009; G. J. Nabuurs et al. 2008)(Kalliokoski et al. 2020a). Generally, mean sequestration rates are likely to be higher in Atlantic and Central European forests (reaching ~3–4 tons of carbon per ha per year) compared to boreal and Mediterranean sites (reaching ~1 ton of carbon per ha per year; (G. J Nabuurs and Schelhaas 2002; Searchinger, Wirsenius, et al. 2018; Searchinger et al. 2021). These calculations include soil carbon increases, which would likely not occur when reforesting pasture under continuous use (Bárcena et al. 2014)(Guo and Gifford 2002). The carbon sequestration potential in Europe therefore depends on where forests are restored.

The *type* of forest established also has a significant effect on sequestration potential. Highly managed plantation forests will often grow faster in the first few decades compared to more natural forests. Natural forests will tend to grow faster in later years (i.e., after plantations forests are harvested) and ultimately store more carbon (G. J Nabuurs and Schelhaas 2002; Pérez-Cruzado et al. 2012). Monoculture forests are also generally more prone to drought and disease are therefore less stable for carbon storage in the long-term (see citations in (Waring et al. 2020).

The increased threat of forest die offs under climate change is significant in Europe. For instance, the exceptional drought beginning in 2018 in Central Europe resulted in a massive bark beetle infestation, widespread tree mortality, and salvage cutting on more than a million hectares of dead and dying spruce forests.

A forest management strategy that transitioned older, planted forests to more “close-to-nature” forests without harvest, while replacing the foregone harvest with faster growing forests, is one option that could increase carbon sequestration rates without impacting timber productivity. This strategy may also increase forest resilience to increased climate impacts. We discuss this management option further below.

Another option to increase forest carbon sequestration is simply to harvest forests less. In 2019 in the EU, logging felled approximately 63% of the annual

forest growth, known as the “net increment” (Eurostat 2021d). This suggests that the remaining third of annual growth roughly corresponds to Europe’s estimated 400 MMt annual forest carbon sink and that a relatively small reduction in harvesting could have relatively high returns for sequestration. A simple back-of-the-envelope calculation signals that reducing annual harvests to 50% of the net increment (roughly a 20% reduction in wood harvest) could sequester roughly 140 million tons more CO<sub>2</sub> per year.

How decreased wood harvests translate into higher forest carbon sinks is not so simple however, as the precise effect on carbon storage depends also on the types of wood harvested and used. Some evidence suggests that the EU’s forest sink is starting to saturate as trees age, leading some scientists to recommend increased harvests in order to stimulate growth of younger forests (Gert Jan Nabuurs et al. 2013). However, the cost of generating these younger forests is a large up-front loss of carbon, only partially offset by uses of wood products. Several recent studies have estimated that reductions in harvest rates leads to increases in the forest carbon sink, and vice versa (Kalliokoski et al. 2020a)(Soimakallio et al. 2021; Vizzarri et al. 2021). A study by the European Commission’s own Joint Research Center corroborates this finding (Grassi, Fiorese, et al. 2021).

#### **4.1.3. Grasslands**

Another way to sequester soil carbon is to convert cropland to grasslands. The soil carbon gain associated with this land use change varies greatly from one study to another. One meta-analysis, drawing mostly upon studies in temperate regions, found average soil carbon gains of 3.2 tons of CO<sub>2</sub>eq per hectare per year (Conant et al. 2017). Other studies have estimated much lower soil carbon gains, e.g. (Lugato et al. 2014).

Some studies have found that the carbon content in soils under existing European grasslands is increasing and that grasslands are net sinks of greenhouse gases (Chang et al. 2015; Chang et al. 2021). Others are skeptical, pointing to evidence that soil carbon sequestration in grasslands saturates (Smith 2014; Johnston et al. 2009). One possible explanation offered by those studies that report increased carbon is that grasslands, like forests, are sequestering more carbon because of increased carbon dioxide in the atmosphere. Overall, maintaining grasslands likely helps to sequester carbon, although not as much as would occur if the grassland became a forest.

An important question pertaining to grassland management is how much soil carbon can be gained through improved grazing practices. Although studies have frequently found soil carbon gains following improved grazing, these studies typically focus on contexts in which poor practices have created the conditions for improvement (Conant et al. 2017). Other studies emphasize that the potential to sequester carbon through improved grazing is uncertain, context-dependent, and often easily reversible (Godde et al. 2020).

A focus in many grazing management studies on field-level effects at the expense of landscape or global effects has also led to overestimates of soil carbon sequestration potential. For instance, evidence that links lower herd density with soil carbon gains in European grasslands has led to suggestions that Europe could achieve carbon neutrality in grazing systems by further reducing herd density (Soussana, Klumpp, and Ehrhardt 2014). Such a strategy, however, would come at the expense of greater agricultural land use overall, either in the form of more imports and land conversion outside Europe or less land available for reforestation within Europe. Another study reported soil carbon gains when grazing rather than haying grasslands, suggesting that shifts from haying to grazing could sequester additional soil carbon (Senapati et al. 2014). However, a simple possible explanation for this finding was that cattle redeposited their manure (and therefore its carbon and nutrients) in the grasslands when grazing. In the haying system, this carbon was otherwise deposited in barns. Furthermore, this analysis fails to account for the carbon gains that ultimately occur on other agricultural fields where the manure is applied.

One possible way to gain additional soil carbon when converting cropland to grassland, while avoiding compensating conversion of land elsewhere to cropland, is to grow grass for animal feed instead of crops. In Denmark, there is an effort to replace annual crops grown for silage, in which the whole crop grain and stalk is fed to cattle, with high-yielding, high protein grasses (Searchinger et al. 2021). The grasses can then be pressed, so that 20% of the total biomass becomes a high protein feed. This feed can replace soybean meal while the leftover dried grass provides good forage for dairy cows. Overall, a couple hundred thousand hectares of silage maize could potentially be replaced by high protein grasses in Denmark, which could increase soil carbon as well as generate other soil benefits.

Ideally, grasses could replace annual crops more broadly as feed crops if they could be processed economically into a form as digestible as grains. Today, this is technologically but not economically feasible (Searchinger et al. 2021). The potential benefits of this technological breakthrough justify extensive research efforts in this area.

#### **4.1.4. Croplands**

Estimates of the potential for croplands to sequester carbon vary widely (e.g., compare the findings of (Paustian et al. 2016) with (D. Powlson, Whitmore, and Goulding 2011)). The recent “EU Soil Strategy for 2030” claims a potential for carbon sequestration in mineral soils in the range of 11–38 MMt CO<sub>2</sub>eq per year through a variety of practices (Commission 2021h). These estimates rely primarily on the previous work of (Lugato et al. 2014).

In general, we agree with the skeptics who argue that the potential for soil carbon gains on working croplands is limited (Searchinger and Ranganathan 2020; Searchinger et al. 2019). As described in these references, most of the large estimates of soil carbon sequestration potential in croplands involve converting

cropland to forests or other uses or avoiding deforestation rather than practices that actually increase carbon on working lands. Other claimed soil carbon gains at the field-scale do so, in effect, by moving carbon from one place to another rather than sequestering more total carbon overall. As described in an example case earlier, applying manure on one field will build soil carbon at that location, but likely comes at the expense of applying that same manure somewhere else, so that the total quantity of soil carbon overall remains the same (D. S. Powlson, Whitmore, and Goulding 2011). "No-till" farming is another practice often viewed as leading to durable soil carbon gains. The effects of no-till on soil carbon are less certain when analyzing soil at depths down to a full meter, where soil carbon is most durable in the long-term. The fact that many farmers who employ no-till practices still need to occasionally plow these fields, or simply the fact that farmland can change hands, are two reasons why soil carbon gained via no-till may be short-lived.

Cover cropping is one practice that is likely to sequester soil carbon, and this practice has clear value for reducing nitrogen loss (Wood and Bowman 2021; Bolinder et al. 2020; Searchinger et al. 2021). Uncertainty remains around the long-term benefit of using cover crops due to differences in soil carbon measurements at depths to one meter and possible increases in nitrous oxide (Searchinger and Ranganathan 2020; Lugato, Leip, and Jones 2018).

Expansion of agroforestry may also provide some potential carbon gains although we are skeptical of the large magnitudes cited by certain studies. For example, (Kay et al. 2019) claims enormous potential for agroforestry to build carbon in Europe. However, our examination of the citations in Kay et al. (2019) suggests that nearly all the agroforestry systems considered would either displace agricultural land with coppicing systems or would displace annual crops with perennial crops, such as fruit trees. Because both instances would require reducing production of annual crops, expansion of agroforestry is likely to come out of the budget for reduced cropland, which means it comes at the expense of reforestation or would require more imports. In addition, many of the carbon gains per hectare claimed in these studies for agroforestry—up to 7 tons of carbon per ha per year—are implausible because they greatly exceed the carbon gains typically found in full reforestation of around 3 tons of carbon per hectare per year (Searchinger, Wirsenius, et al. 2018; Searchinger et al. 2021). Even so, there are some innovative ideas for increased use of trees within annual cropping systems, and possibly higher use in grazing systems.

#### **4.1.5. Summary of Carbon Sequestration Potential in Europe**

According to this survey, the most promising opportunities for sequestering more carbon in the EU include rewetting peatlands, increasing forest area, and reducing wood harvest, particularly for fuelwood. Although all are promising, each must fit within Europe's overall land use budget. Fewer drained peatlands and more forest area generally require reducing either Europe's cropland area or its agricultural area overall. Reducing fuel wood will require replacing that wood with alternative energy sources, which, depending

on the fuel type and where it is sourced, will require varying amounts of land. We are more skeptical of large potential for soil carbon sequestration on working agricultural lands.

## **4.2. Priority Opportunities for Restoring Europe’s Biodiversity**

If the EU can reduce its need for agricultural land, what are the opportunities and priorities for enhancing biodiversity? Could such efforts also sequester carbon? For many threatened European species, conservation depends not just on habitat protection, restoration, and expansion but on curbing invasive species, pollution, and sometimes excess hunting, among other factors (EEA 2020). Regardless, habitat preservation and restoration remain paramount.

This section explores the habitat conservation priorities to preserve and restore European biodiversity. The complexity of measuring and monitoring EU biodiversity and prescribing optimal habitat targets that meet the needs of multiple species is significant. This complexity emphasizes both the importance of preserving existing high-value habitats and of carefully targeting restoration to achieve large-scale benefits. Most forms of habitat restoration would also sequester carbon, but some trade-offs exist.

### **4.2.1. Status of the EU’s Biodiversity**

Europe is home to a vast number of species across many diverse taxa, each of which has different critical habitat needs, and many of which are often highly specific. Because European landscapes have been highly altered by human activities, the status of Europe’s biodiversity overall is low and declining. Meanwhile the needs for biodiversity conservation are broad and varied.

Biodiversity can be measured in different ways, which can lead to different recommendations for conservation activities. For example, restoration can alternatively focus on habitats with the most species or on those habitat types with the greatest species at threat of extinction. The length and quality of data used also matters.

For instance, because the length of our biodiversity datasets is generally much shorter than the history of human land use change on the European continent, these data represent only a “snapshot” in time. For the last couple thousand years, large parts of the continent were managed for low-intensity agriculture, resulting in a “mosaic” of pastoral grasslands, cropland, and forest fragments. Just in the last century or two has European agriculture dramatically intensified, leading to more homogenous landscapes. In any event, Europe was originally dominated by forests, and would so if humans were to disappear tomorrow.

When biodiversity planning, it is important to remember that conservation targets will depend on the historical “baseline” that is chosen, and the size and assemblage of species populations present at that time. Many of Europe’s “long-term” biodiversity monitoring datasets date back 50 years or less and some European taxa are just now the subject of comprehensive monitoring. Using this data will inherently focus attention on the conservation of species that adapted well to Europe’s earlier mosaic farming systems while deemphasizing species that were already in poor condition 50 years ago.

Regardless of the measure, the overall signal in Europe is clear: Europe’s biodiversity is greatly diminished and continues to decline. These declines are reflected across all of Europe’s major taxa<sup>14</sup>:

- **Vertebrate animals:** Of the 1,282 species of vertebrates in Europe, one third are threatened with extinction (IUCN 2019; Hermoso et al. 2019).
- **Birds:** Of 463 protected bird species in Europe, 39% are threatened or near-threatened status at the EU level (European Environment Agency 2020a).<sup>15</sup> Total numbers of all birds have also declined by 17-19% since 1980 (560–620 million birds) driven primarily by a decline in a few relatively abundant species (Burns et al. 2021). By another measure, roughly one third of assessed bird populations reveal declining trends in both the short and long-term. In more hopeful news, 23% and 29% of assessed breeding population trends are increasing in the short-term and long-term, respectively (see figures 2.5 and 2.6 in (European Environment Agency 2020a).
- **Mammals:** Of 353 assessments of mammal populations across the EU, 60% find an unfavorable (“poor” or “bad”; see footnote 11) status and about a quarter of assessed mammal populations are actively worsening (see Figure 3.20 in (European Environment Agency 2020a).

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<sup>14</sup> Note that conservation status information is reported differently between sources (i.e., between the Birds Directive, the Habitats Directive, and other sources like the IUCN Red List assessments). We have followed the terminology as used and described in the latest “State of Nature” report (EEA 2020). Interpretation of information reported as the number of assessed populations (“assessments”) is as follows: more than one complete assessment of a species might be reported under the Habitat or Birds Directives by a given Member State, in order to capture the regional population statuses or subspecies’ population status within a country. Unless otherwise explicitly stated, a statistic based on the number of assessed populations (e.g. “353 assessments of mammals”) should be interpreted as the total number of populations assessments reported in aggregate at the EU-level, and not as the number of total mammal species natively found in the EU region. Conservation status data based on a number or proportion of “assessed species” should be interpreted as the number of total species that have been assessed, and not necessarily representative of the total number of species of that taxa found in the EU region. Many species have yet to be comprehensively assessed for their conservation status at both the Member State and EU levels.

<sup>15</sup> The nomenclature systems used to describe the official conservation status of birds, habitats, and other animals differs slightly between reporting sources. In the latest “State of Nature” report, “bad” and “poor” status correspond to “threatened” and “near-threatened” for birds, respectively, and to “unfavorable-bad” and “unfavorable-inadequate” for habitats and other species. See Table 1.1. in (European Environment Agency 2020a).

- **Reptiles:** Of 137 assessments of reptile populations across the EU, 60% are unfavorable and a quarter of those are actively declining (see Figure 3.20 in (European Environment Agency 2020a)).
- **Fish, amphibians, and mollusks:** Aquatic species are in particularly unfavorable condition. Roughly 70% of assessments of fish (358 assessments), amphibians (151 assessments) and mollusks (87 assessments) have unfavorable status (Figure 3.20 in (European Environment Agency 2020a)). One half of fish assessments and amphibian assessments and one third of mollusk assessments are not only unfavorable but also declining.
- **Insects (including butterflies):** Of 315 assessments of insect species across Europe, 60% are in unfavorable condition and more than half of these populations are deteriorating (Figure 3.20 in (European Environment Agency 2020a)). A growing body of evidence suggests widespread losses in insect abundance, biomass, and species richness, especially in agricultural areas in Europe, but also in forests (Seibold et al. 2019; Hallmann et al. 2017). These declines are of great concern not only for insects themselves but also because of the critical roles insects play in ecosystem functions, such as pollination and food supply for other species (Wagner 2020).

Butterflies are of special concern, both because of human appreciation for them and because their conservation status is better assessed (Butterfly Conservation Europe 2020; Warren et al. 2021). In 2010, roughly 20% of 435 assessed species were threatened or near threatened, and a third of all assessed species showed declining populations (Van Swaay et al. 2010). According to one index, grassland butterfly populations have declined an estimated 40% since 1990 (Warren et al. 2021; Butterfly Conservation Europe 2020).

- **Plants:** Of 20,000–30,000 vascular plant species in Europe (depending on definition), only 2,730 native European plant species have been assessed for their conservation status, and 29% were found to be threatened not just within Europe but also at a global level (Pain et al. 2021). A Red List assessment of 4,624 native European plant species found that about a quarter were threatened in geographical Europe (IUCN 2020). Of the 54 species that are found only or almost only in Europe, 39% are threatened or near threatened (European Environment Agency 2020a).

At least 37% of continental Europe's 454 native tree species are threatened or near-threatened, and more than half of those tree species are found only in Europe (Pain et al. 2021; Rivers et al. 2019). Ferns and bryophytes (mosses, liverworts and hornworts) are of similar high concern (García Criado et al. 2017; Hodgetts et al. 2019)

- **Fungi:** Although fungi are poorly monitored, a typical estimate is that Europe has over 75,000 fungal species (Ainsworth et al. 2018; Senn-Irlet et al. 2007). Of these, most occur only underground while more than 15,000 have above-ground components that appear as mushrooms. Fungi play critical ecological functions in the basic functions of soils and ecosystem processes (White 2004; Clemmensen et al. 2015; Cairney and Meharg 2002; Steidinger et al. 2019; Baltruschat et al. 2019). One group has critical symbiotic relationships with approximately 80% of plant species (Gonçalves 2021).

Overall, fungi have been neglected in the global conservation conversation (Gonçalves 2021; see The Global Fungal Red List Initiative). As of January 2022, only 550 out of millions of fungal species globally have been assessed for the IUCN (IUCN 2021). At least 125 of these species are found in Europe, many of which are Vulnerable or Endangered (European Council for the Conservation of Fungi, n.d.). Despite global and regional data limitations, decline of fungal populations have been locally reported from many European countries, some of which have conducted national fungal “red list” assessments (Ainsworth et al. 2018; European Council for the Conservation of Fungi n.d.).

#### **4.2.2. Biodiversity benefits of restoring major habitat types**

Because the habitats needed by many of these threatened species are complex and cannot be restored immediately, the immediate conservation priority is to protect what little remaining high-value habitat remains in Europe. Preserving these habitats is the primary focus of Europe’s Natura 2000 network of protected areas.

Ranking restoration priorities raises difficult questions when considering the full breadth of biodiversity needs. For instance, where should abandoned agricultural land be allowed to grow into a mature natural forest and where should this land be actively managed for the maintenance of semi-natural grasslands?

To analyze these challenging questions, we focus first on Europe’s major habitat types. We attempt to characterize the relative returns to biodiversity from conservation activities within these habitat types by using a simple “low/moderate/high” ranking system. Because of the complexity of biodiversity, generalized statements will not adequately capture all the specific local and regional nuance across the EU.

#### **Peatlands & Biodiversity**

In general, restoration of peatlands has a “moderate” potential to restore priority biodiversity. In their natural conditions, peatlands support a range of vegetation types and associated animals, which drainage has greatly harmed (IBPES 2018; Fraixedas et al. 2017). Peatlands also merit attention because

roughly 70% of EU national status assessments on peatlands (bogs, mires, and fens combined) report continued deterioration despite their already degraded status (see Figure 3.15 in (European Environment Agency 2020a).

Peatlands tend to be dominated by grasses and shrubs so their restoration can contribute to the needs of bird species that utilize these habitats. Restoring peatlands also has the potential to provide wet grassland habitat that is a priority conservation goal for a select group of declining wetland bird species, such as the Northern Lapwing (*Vanellus vanellus*) and Black-tailed Godwit (*Limosa limosa*). In some situations, restoring peatlands can probably also benefit downstream aquatic habitats.

Despite these losses, peatlands receive only our “moderate” score in part because intact peatlands typically support only a moderate diversity of plant and animal species, relative to some other high-priority European habitats, like semi-natural grasslands (described below). In addition, restoring the full balance of truly native peatland vegetation is not necessarily possible, and sometimes quite challenging, due to the changes in soils after years of intensive agriculture (Dinesen, Lars, Anders, and Carsten 2021).

Overall, properly restoring peatlands can be valuable for biodiversity, but its highest value will be in reducing carbon losses.

### **Forests & Biodiversity**

Restoration of some forest types is a priority for the protection of European biodiversity. Although the area of forest in Europe has expanded, Europe’s forests are nearly all highly managed. As a result, many forest-dependent species are still threatened.

Although EU forest area has grown substantially since 1900, “forests managed to varying degrees of intensity have replaced almost all of Europe’s natural forests” (European Environment Agency 2020a). Roughly a quarter of forests in Europe contain only one species (mostly conifers), roughly 80% hold only 1 to 3 tree species, and only 5% of forests have six or more tree species (FOREST EUROPE 2020).<sup>16</sup> Three-quarters of forests in Europe area are even-aged, meaning that the trees were all planted at the same time (ibid.).

Only about 3% of the EU’s forests are old-growth or primary (covering 1.2% of EU total land area), and these old forests exist generally in small pockets within larger, disturbed landscapes (Barredo et al. 2021). Country-level survey data suggests that approximately 90% of these primary forests exist in Sweden, Bulgaria, Finland, and Romania (ibid.). 87% of the EU’s mapped old-growth forests are “strictly protected,” (ibid.). It is likely that other isolated pockets of old-growth forests remain in the 44 million hectares of the EU that has yet to

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<sup>16</sup> See Figures 4.1-1 and 4.1-2. Europe is defined here as the Forest Europe signatory countries.

be adequately assessed for such forest stands (Francesco M. Sabatini et al. 2020; Francesco Maria Sabatini et al. 2021; Barredo et al. 2021; O'brien et al. 2021).

The intensive management of European forests contributes to the decline of European forest species despite the increase in forest area since 1900. Common forest bird species appear relatively stable, but threatened forest bird populations show few improving trends (European Environment Agency 2020a; Birdlife International 2021; Pan-European Common Bird Monitoring Scheme 2020). Among all forest habitat types, only 13% show improving trends at last assessment (European Environment Agency 2020a). Although the challenges of forest-dwelling birds receive less attention than farmland bird species, roughly one quarter of all European birds associated with forest habitats are declining. This is in comparison to 30% of species associated with farmland and grasslands (Birdlife International 2021). According to Member State assessments, 79% of forest bird populations are “insecure,” which is an even higher rate than reported for farmland bird species in those assessments (European Environment Agency 2020a). As discussed briefly at the beginning of Section 4.2.1, the finding that fewer forest bird species are declining compared to farmland bird species may partially reflect the fact that forest species have been in poorer condition longer, their populations already reduced by historical deforestation of the continent.

While birds are most well-covered in biodiversity monitoring schemes, forests are also reservoirs of other large taxa that have received relatively little attention, including fungi, insects, and amphibians (Wetzel et al. 2018). There is evidence that some of these taxa may be declining rapidly in forests (e.g., (Seibold et al. 2019), and efforts are just recently underway to comprehensively assess the conservation status of others (e.g., (Gonçalves et al. 2021).

Although evaluating the effects of specific forest management activities on forest biodiversity can be difficult, there is a general consensus that increasing the diversity of forests (from the level of individual trees to whole landscapes) enhances biodiversity.<sup>17</sup> At the level of an individual forest, this means managing forests to have denser and more complex understories, diverse canopy heights, tree microhabitats, and dead wood. Although plantation forests can provide benefits for more common species, they are less supportive of the forest specialists most at risk in Europe (Pedley et al. 2019; Felton et al.

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<sup>17</sup> Overall, evaluating the effects of forest treatments on forest biodiversity and ecosystem services can be difficult due to the challenge of isolating the causal mechanisms that link specific management activities to desired biodiversity outcomes. Controlling for important confounding variables (e.g., spillover effects and impacts of management history) in experimental settings is difficult and conclusions drawn from one forest type are not necessarily applicable elsewhere (i.e., between climate zones; (Chaudhary et al. 2016). Conclusions also depend critically on how a study measures biodiversity (e.g., species richness is not on its own a useful metric; (Duguid and Ashton 2013). Prescriptive management becomes even more difficult given that management adjustments to benefit some taxa may have negative effects on other taxa (Paillet et al. 2010). Overall, key knowledge gaps and obstacles remain to the widespread adoption of close-to-nature forestry approaches in Europe (Mason et al. 2022; Hertog, Brogaard, and Krause 2021).

2021; Rédei et al. 2020; Ónodi et al. 2021; Rodríguez-Pérez, Herrera, and Arizaga 2018; Camprodon et al. 2015).

The benefit of enhancing dead and dying wood in forests is well-supported by the science. One estimate suggests that 20–40% of forest dwelling species in Europe depend on dead or dying wood at some point in their life cycle (Bauhus, Baber, and Müller 2018). Dead wood is particularly critical for a range of beetles and fungi, mosses and liverworts, and certain rare forest birds, like woodpeckers (Pötzelsberger, Schuck, and den Herder 2021) (Tomao et al. 2020). Proposed thresholds of dead wood volume needed to support dependent species range from twice to ten-times the volumes that are most common in Europe today.<sup>18</sup>

Appropriate harvests appear capable of enhancing biodiversity in Europe’s highly managed forests, in some instances. Young forests can support relatively high biodiversity, especially when these forests are allowed to regenerate through natural stages, without artificially dense plantings or heavy thinning (Hilmers et al. 2018; Swanson et al. 2011). Desirable harvests would be those that support a diversity of forest ages and types at both local and landscape levels (Schall et al. 2020).

Although important knowledge gaps remain, the literature suggests a few potential priorities for conserving forest biodiversity:

- First, there is a strong scientific consensus for strictly protecting and enhancing Europe’s remaining estimated 5 million hectares of old growth forests (Francesco M. Sabatini et al. 2020; Barredo et al. 2021). Because protecting these forest patches will be insufficient to stabilize populations of some vulnerable forest species, protecting and managing adjacent forests will be necessary to provide connected habitat that contains essential habitat elements (e.g., dead wood) (Pötzelsberger, Schuck, and den Herder 2021).
- Second, a good case exists for transitioning older managed forests toward forests that resemble more natural old growth forests. Older forests tend to accumulate higher levels of dead wood and diverse understories, and therefore should often have potential with the right management to recreate many of the habitat values of true old growth (Vandekerkhove et al. 2012). This is the plan for some Danish state forests, a process which begins by selecting forest sites with high promise for this transition. Commercial logging will be prohibited in these forests except for some initial cuttings to increase the structural complexity of the forest, to create light gaps and clearings, and to remove exotic coniferous tree species (Dinesen, Lars, Anders, and Carsten 2021).

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<sup>18</sup> Thresholds from 20 to 50 cubic meters per hectare and up to 100 cubic meters have been proposed for rarer species (Müller and Bütler 2010). By contrast, the average volume of deadwood in Europe’s forests is 11.5 cubic meters per hectare, and varies considerably between European countries and regions (Tomao et al. 2020; FOREST EUROPE 2020).

- Third, reductions in the agricultural land base can be used to plant a combination of natural forests and some highly managed forests. The previous two recommendations would likely reduce wood supply, but this can be replaced by additional, intensively managed forests. Other new forests can be selectively established with more natural vegetation to achieve important biodiversity goals.
- Fourth, reestablished natural and managed forests can serve as strategic buffers and linkages for and among diversity hotspots, including forests but also other open habitats like grasslands and woodland savannahs. This will be especially important to allow for plant and animal populations to shift their ranges with a changing climate. For example, some of the highest levels of tree species endemism and hotspots of threatened tree species in Europe are found in the main mountain ranges on the continent, and other localized and insular systems (Rivers et al. 2019). These species will be especially vulnerable to the impacts of climate change.

As a rule, we think there are strong potential carbon sequestration benefits from a strategy that involves maintaining older forests unharvested and planting fast-growing, more managed forests on agricultural land. Although older forests show declining rates of carbon sequestration, these forests store large, and growing quantities of carbon (although the magnitude is somewhat debated) (Gundersen et al. 2021; Luyssaert et al. 2008; Zhou et al. 2006; Yang, Luo, and Finzi 2011). If these old forests are harvested, only a small fraction of the carbon is preserved in long-lived wood products, the rest lost relatively quickly (FAO, ITTO, and United Nations 2020). When combined with effective protections for old and aging forests, using new abandoned cropland to establish faster growing tree species for wood production would in effect use fast-growing forests to help save carbon in older forests.

### **Grasslands & Biodiversity**

Some types of grasslands provide exceptional biodiversity although many do not. Conserving and restoring those grasslands and grassland/woodland complexes that have high biodiversity-value is a leading priority. This conservation priority focuses on the restoration of very extensively grazed lands whose food production is modest.

Sources differ on the estimated total area of grasslands within Europe due to different definitions and detection methods. The HILDA dataset (see footnote 1) identifies 110 million hectares of grasslands within the EU28, which likely includes a variety of shrubland and grassland mixes. In contrast, EUROSTAT identifies 82.5 million hectares of grasslands in the EU28 in 2018, roughly equally distributed in Western, Eastern and Mediterranean Europe, and with a relatively smaller area in the Nordic-Baltic region. Of these grasslands, roughly three quarters (622 million hectares) are “permanent grasslands,” defined as grasslands that have remained as such for at least five consecutive years. This category does not include truly natural grasslands which are limited to relatively small alpine, tundra, and coastal areas, and

which are maintained only by environmental conditions (unlike so-called “semi-natural” grasslands, discussed below).

The relative biodiversity value of different types of grasslands greatly differs. Within permanent grasslands, the first sharp distinction is between the two thirds that are improved grasslands (i.e., pastures and meadows) used for intensive grazing and the nearly one third, characterized as “rough grazing” areas (Eurostat 2021a; Herzon et al. 2021). Improved grasslands are typically comprised of one or at most a few species of highly productive grass species and are regularly fertilized and tilled. The area of “rough grazing” loosely corresponds to the area of semi-natural grasslands in Europe, grasslands that are typically characterized by far lower grazing levels, little to no inputs or tillage, and more diverse vegetation. These grasslands are maintained by grazing and other human activities and evolved with traditional pastoral systems over thousands of years. Grasslands in this category can range from arid grasslands in Spain to humid meadows in central and northern Europe.

Semi-natural grasslands are some of the most species-rich habitats in Europe (European Environment Agency 2020a; Dengler et al. 2020). Some support a highly diverse mix of vascular plants: 76 species have been described from 1 square meter of wooded meadow in Estonia (Sammul, Kull, and Tamm 2003). High plant species diversity in turn supports high invertebrate and vertebrate diversity: 63% of Europe’s butterfly species (274 of 436) rely on dry calcareous grasslands and steppes, and up to 74% of Europe’s Orthoptera species (grasshoppers and allies) depend on grasslands (Van Swaay et al. 2006; Hochkirch et al. 2016). Semi-natural grasslands are also valuable for wild pollinators (Olmeda et al. 2019). Roughly 30% of Europe’s bird species are also associated with grasslands (Nagy 2009). Grassland birds are declining overall and 33 species are threatened or near-threatened (Birdlife International 2021; Burns et al. 2021). Although we are not aware of a comprehensive breakdown of grassland birds’ preferences between highly managed and semi-natural grasslands, specialist grassland species generally benefit more from the presence of intact semi-natural grasslands than intensively managed grasslands.

Areas in Europe classified as “high nature value” farmland (HNVF) are largely comprised of semi-natural grasslands. Studies that estimate the total extent and regional proportions of HNVF in Europe have arrived at different conclusions (compare (Dengler et al. 2020; Török and Dengler 2018)) due to inconsistent definitions and data challenges (Zomeni et al. 2018; Byrne et al. 2021). Using Eurostat’s “rough grazing” category as a loose proxy, this would suggest that 20 million hectares of semi-natural grasslands exist in Europe. In general, higher levels of agricultural land qualify as HNVF in Southern and Eastern Europe than in Western and Northern regions. Yet vestiges remain everywhere: the EEA reports that 17 different types of protected grasslands are still found in the Atlantic region of Europe (European Environment Agency 2020a).

The area of semi-natural grasslands has declined over hundreds of years (Dengler et al. 2020). Regional studies in Western Europe have estimated declines by more than 95%.<sup>19</sup> More such grasslands remain in Eastern Europe but one study estimates a 50% decline in this region (Török and Dengler 2018). The limited Eurostat data available (2013–2016) shows declines in “rough grazing” even as permanent grasslands have modestly increased overall (Eurostat 2021a).

The protection of biologically diverse, extensive grasslands has a number of implications for future European land use policy:

- First, a primary goal should be the conservation of those grasslands that are indeed high nature value. These areas have been in decline from multiple land use conversions, whether from conversion to intensive grasslands, croplands, or urban development, or from afforestation and reforestation (European Environment Agency 2020a).
- Second, particularly in the western region of Europe, restoring some intensive grasslands to a more diverse mix of species is an important biodiversity goal (Harries et al. 2014). Achieving the levels of plant biodiversity found in intact HNV grasslands would likely take considerable sustained management over time. In areas where these grasslands were lost to vegetation encroachment, however, recovery can be rapid (Ubach et al. 2020; Colom, Traveset, and Stefanescu 2021).

There is a possible tension, however, between preservation and restoration of semi-natural grasslands and carbon sequestration, and potentially also with food production. Allowing forests to regrow will typically sequester more carbon and supply more wood. Additionally, intensively- managed grasslands produce far more milk or meat, while typically resulting in lower methane emissions per kilogram of output (Wirsenius et al. 2020). Due to these tradeoffs, we believe the protection or expansion of semi-natural grasslands in the face of rising global demands, should appropriately be viewed as a “land-sparing” strategy, even if these grasslands do produce at a low level.

### **Cropland & Biodiversity**

In general, cropland and cropland mosaics (i.e., a mixed pattern of cropland, pasture, small woodlots, and artificial surfaces) support low biodiversity compared to other major habitat types in Europe, despite occupying roughly one quarter of Europe’s land.

A key policy question is the following: to what extent can shifts to less intensive cropland agriculture boost biodiversity in Europe? And to what

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<sup>19</sup> Although definitions vary, one study estimated a 97% of unimproved grasslands in England and Wales between 1932–1984 (Fuller 1987); another the loss of 99% of semi-natural grasslands in Finland between since 1880 (Luoto et al. 2003); and another, the loss of over 96% of semi-natural grasslands in a single Swedish province since 1900 (Cousins et al. 2015).

extent does this shift induce a reduction in biodiversity value elsewhere due to land conversions, domestic or abroad, needed to meet rising global demands?

Significantly, the term “intensity” can refer to many different aspects of production. Intensity can be measured as a loss in extent of non-cropland parts of an agricultural landscape (“microhabitats”), such as hedgerows, small woodlots, grassed or forested buffer strips, and wetlands. Intensification can be measured as the extent or frequency of land fallowing as part of a rotation or the inclusion of grazing rotations along with cropping. When grasslands are incorporated into production systems, intensification can also be measured as the frequency of haying and resowing, and the level of fertilization. Intensification can also be measured as the extent of drainage of naturally wet soils for cropland production.

Intensification can also be measured as an overall level of chemical inputs. Increased nitrogen pollution, primarily through ammonia releases, leads to increased deposition of nitrogen into native habitats, favoring the development of some plant species over others and reducing biodiversity in European grasslands (Stevens et al. 2010; 2004). Increasing potency and application rates of insecticides, herbicides, and other chemicals, and the synergistic effects among pollutants, are likely significant drivers of the large reduction of insect populations described through much of Europe (Warren et al. 2021). Higher inputs and more frequent plowing also reduce the quantity and diversity of insects and other hexapods, worms, and microorganisms in agricultural soils (Tsiafouli et al. 2015).

Biodiversity stands to benefit from reductions in cropping intensity along any of these dimensions, but the costs and benefits from the standpoint of other land uses are not equal. From the standpoint of costs, the primary issue is whether the cropping changes will reduce food production in general, and annual crops in particular. Annual crops produce far more food per hectare than grazing cattle, sheep, or goats, whether crops are consumed directly, or indirectly through products like chicken, pork, and eggs (Searchinger, Wiersenius, et al. 2018; Wiersenius et al. 2020). As a result, switching from annual crops to grazing causes less land overall to be available for other purposes, holding food production constant. From this standpoint, devoting more land to cropland “microhabitats” is likely to sacrifice less food production than requiring that large areas of cropland be left fallow on a permanent or rotating basis.

Declines in farmland bird species are a critical concern, but more clarity on their needs is necessary for effective conservation strategies. Perhaps due to data limitations and the complexities and cost of measuring and monitoring biodiversity, studies commonly cite “agricultural intensification” writ large as the primary driver of farmland bird species decline (Birdlife International 2021; European Environment Agency 2020). This broad driver could refer to many different changes, such as: fewer microhabitats, more inputs, switching from grazing to cropping, increasing field size, or less fallow land, among others. Addressing these different components of “intensification” will have different

consequences for food production, and therefore for the ability to provide more habitat for other biodiversity.

For instance, a recent paper reports that the Little Bustard (*Tetrax tetrax*) and other farmland birds benefit specifically from the presence of fallowed farm fields, which by definition produce no food (Traba and Morales 2019). One question is how these species' needs can be met with a strategy that requires less reduced output than a broad program of fallowing. We generally suspect that for most farmland bird species, the loss of non-crop microhabitats is a primary causal driver in their decline. However, this is not the only factor, and for some species, perhaps not the dominant one.

Some low-opportunity cost strategies may be able to return meaningful benefits for biodiversity in agricultural landscapes. These strategies include reducing field sizes and reorganizing the composition and configuration of crops and fields (Sirami et al. 2019; A. E. Martin et al. 2020; Bullock et al. 2021; Boetzl et al. 2021). Detangling how much of these beneficial effects are due to a larger ratio of microhabitats and how much is due instead to spatial and compositional arrangements at local and landscape levels is necessary to inform "win-win" policies (Haan, Zhang, and Landis 2020; Hass et al. 2018).

Reducing agricultural pollution is also critical for biodiversity. There is some evidence that microhabitats, such as more planted field boundaries can in some contexts reduce the need for pesticides. Yet this effect is uncertain and context-specific, and more research is needed where this approach can be successful (Gagic et al. 2021; Larsen and Noack 2020).

Reducing agricultural pollution overall without reducing food is challenging because, by definition, that requires reductions in pollution per kilogram of food. If inputs decline, but yields decline at the same rate, pollution will not reduce unless food production declines. Input reductions that significantly reduce yields even have potential to increase global use of fertilizer and pesticides because of the equivalent, or even higher, use by major exporting countries outside Europe (Richard Fuchs, Brown, and Rounsevell 2020). Given the scope of the challenge, innovations are required to reduce pollution substantially while maintaining food production although many innovations are promising (Searchinger et al. 2021). There might be acceptable trade-offs between some reduction in inputs and small impacts on yields. Yet, if such efforts are to avoid massive additional land clearing, any trade-offs must occur in the context of overall increases in yields matching demand change.

From the perspective of carbon, some strategies could increase carbon held in agricultural mosaics, ranging from soil carbon if lands were reestablished in grasslands, to woodlots and hedgerows. Overall, however, reducing cropland intensity is likely to be a less carbon-efficient strategy than reforestation, rewetting of peatlands and preservation of semi-natural grasslands.

## **Aquatic Habitats & Biodiversity**

Although they receive far less attention, Europe's aquatic and marine species—those that depend on rivers, lakes, wetlands and marine waters—are generally in even worse shape than Europe's terrestrial species: 30% of fish and mollusk species in Europe have a bad conservation status (European Environment Agency 2020a). Seabirds, waterfowl, and waders are three of the most at-risk groups of birds in Europe, according to Birdlife International (Birdlife International 2021). Two primary drivers of these losses are the ongoing losses of wetlands (see Box 4.2 in (European Environment Agency 2020a) and Europe's dramatic restructuring of rivers. Nearly all of Europe's rivers have multiple dams and are bound by levees that cut them off from their natural floodplains.

Restoring habitat on agricultural lands can help improve aquatic habitats in two ways. Some species can be directly benefited by wetland restoration. For others, restoration must be part of a watershed-level project to restore healthy hydrologic flows and the natural water regime. Examples of these kinds of projects in recent years in Europe include some efforts to set back levees, to reconnect rivers to their natural floodplains, and to restore those floodplain habitats, up to 90% of which are degraded (European Environment Agency 2019). Examples of floodplain restoration projects include national efforts, such as restoration of the Regge River in the Netherlands, as well as international coordination, as in the restoration of the Danube River, shared by 11 EU Member States and 19 countries in total (Climate Adapt 2021; European Environment Agency 2018a; 2019). These types of efforts typically require larger-scale engineering of the landscape and often have higher expense. Opportunities for such projects may be motivated in response to Europe's increasing flood risks associated with climate change, such as those that decimated southwestern Germany in 2021.

Because the areas of restored wetlands and other aquatic habitats are likely small relative to the biodiversity benefits gained, such restoration opportunities are viewed as a high biodiversity priority. Apart from peatlands, the effect on climate is likely to be small. While restored wetlands generate more methane, they also sequester more carbon although the details are now generally too uncertain to project with confidence (Hinshaw and Wohl 2021; Were et al. 2019).

### **4.2.3. Summary of European Biodiversity Priorities & Relationship to Carbon Sequestration**

We draw the following conclusions from the review above:

- Europe's vast transformation of its lands and waters have led to widespread biodiversity declines. To stabilize and restore this biodiversity, effective management and planning must focus simultaneously at the level of individual species and habitats, to landscape and EU-level policy.

- Because the habitat needs of European species' needs are varied, the highest priority is preserving and then restoring rare habitats. High-priority habitats include older, more natural forests and diverse, semi-natural grasslands and grassland/woodland complexes. Some of the most valuable grasslands have low agricultural output and should correctly be thought of as habitats foremost.<sup>20</sup>
- Because many species rely on specialized habitats that require active management (e.g., semi-natural grasslands), permanent restoration must be paired with a high-level of sustained management effort to achieve high conservation benefits. Habitat needs for many species are sufficiently complex that new habitats must have time to mature and cannot simply be rotated, or established and then promptly neglected. The goal should be to achieve the most biodiversity value as possible in land that is put aside for biodiversity purposes.
- Other species will benefit from changes in agricultural practices and agricultural habitats. Some changes will entail larger tradeoffs with food and wood production or carbon sequestration. Other changes will entail only a small opportunity cost, and, in general, these should be emphasized where possible. For declining farmland bird species, we recommend an initial focus on restoring important microhabitats and continued research that can help to identify the most efficient ways to stabilize biodiversity in agricultural landscapes.
- Although not a major focus of this paper, reducing agricultural pollution is critical to solving Europe's biodiversity crisis. They require a range of additional efforts to reduce them while maintaining yields.

Agricultural land does not necessarily have to be turned into natural habitat to help stabilize biodiversity. For example, replanting highly managed production forests on agricultural land can supply wood and enable connectivity between core areas of primary forests and other habitats (Orlikowska et al. 2020; Mikusiński et al. 2021). Restoration of grassland, riparian, and cropland microhabitats, both within and adjacent to valuable protected areas, can buffer and connect the most diverse existing areas of such habitats, many of which are highly fragmented (Portaccio et al. 2021; Lawrence, Friedrich, and Beierkuhnlein 2021; de la Fuente et al. 2018).

- Although most biodiversity strategies are likely to simultaneously generate some carbon sequestration benefits, the range of gains is variable. Fortunately, some biodiversity priorities are also carbon

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<sup>20</sup> This is also the conclusion of several other papers, which have proposed a “three-compartment” approach to biodiversity conservation in Europe (Feniuk, Balmford, and Green 2019; Betts et al. 2021; Phalan et al. 2011). In this land use strategy, a land budget is divided among areas dedicated to high-intensity food production, areas for shared agricultural productivity and other co-benefits, and the remaining to natural habitats.

priorities, especially within the context of forest and peatland management.

### **4.3. Europe's opportunity to preserve carbon and biodiversity abroad**

Reducing the footprint needed for Europe's own consumption can also be used to preserve carbon and biodiversity abroad.

#### **4.3.1. Where the world is now, where the world is headed, and where it needs to be to stabilize climate and biodiversity**

As both our and others' analysis has found, Europe in effect "appropriates" large quantities of agricultural land abroad to satisfy its own consumption and in doing so contributes to global conversion of forests, savannas, and losses of carbon and biodiversity. The importance of closing this "land carbon trade deficit" is heightened by the great social and environmental costs of this ongoing deforestation and other land use changes outside of Europe.

Emissions from global deforestation and other ongoing agricultural expansion are estimated at roughly 4 billion tons of CO<sub>2</sub> per year, with another 1 billion tons from ongoing degradation of peatlands (Searchinger et al. 2019; Le Quéré et al. 2018; Houghton and Nassikas 2017). This amounts to roughly 10% of total annual GHG emissions globally from all sources (Le Quéré et al. 2018). Agricultural conversion likely caused the gross loss of 10 million hectares of forest cover per year from 2001 to 2015 (Curtis et al. 2018). Gross forest cover loss has continued to grow since 2000, rising from an annual average of 16.5 million hectares between 2000–2004, to 26.8 million hectares between 2016–2020.<sup>21</sup>

Agriculture is also expanding on a net and accelerating basis. The rate of net agricultural expansion has for a time been uncertain (due to methodological and data challenges) (Searchinger et al. 2019). A recent study fills this gap using robust methods: net expansion of annual cropland rose from 5.1 million ha per year between 2004–2007 to 10 million ha per year between 2013–2019 (Potapov et al. 2021). Expansion of permanent crops, such as rubber and oil palm, are additional to this estimate: FAOSTAT estimates the net land use requirements of these crops at roughly 2 million ha per year over the last ten years. Pasture expansion has been an even larger source of forest conversion on a gross basis in the tropics compared to cropland expansion. Vast areas of both biodiverse forest and woody savannas have transitioned to pasture (Gibbs et al. 2010; Aide et al. 2013; Skidmore et al. 2021).

Even as the world continues to clear land at an accelerating rate, most climate strategies aimed at holding warming to 2 C°, and nearly all those

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<sup>21</sup> Data retrieved online from Global Forest Watch, World Resources Institute, on February 10, 2022. <https://www.globalforestwatch.org/dashboards/global/>.

would hold warming to 1.5 C°, require that emissions from land use change cease almost immediately. Most scenarios also require that agricultural land for food decline so that more land can be reforested or used for other purposes to address climate change (Rogelj et al. 2018; Sanderson, O'Neill, and Tebaldi 2016; Searchinger et al. 2019).

Despite the need to reduce global agricultural land, virtually all projections are that the world will clear more land for agriculture absent major new efforts to reduce demands and to increase output per hectare. Driving this expansion are continuing increases in the global population, likely to reach 9.8 billion by 2050 (UNDESA 2019). Demand for meat and milk is also increasing as the world's poor, who presently eat very little, increase their incomes. Typical estimates are that the world is on a course to demand more than 50% more crops in 2050 relative to 2010, and 70% or more meat, milk and other animal products (Searchinger et al. 2019; Valin et al. 2014). Many models agree that increases in consumption will drive ongoing expansion of cropland and pasture through 2050, ranging typically from around 200 million hectares to more than 500 million hectares (Schmitz et al. 2014; Tilman and Clark 2014; Bajželj et al. 2014; Searchinger et al. 2019). If net cropland expansion continues at the rate observed over the last few years, cropland expansion between 2020 and 2050 alone would exceed 300 million hectares.

There are fewer estimates of increases in future global demand for wood products, but large growth is also likely between now and 2050. According to FAO statistics, global wood consumption has almost doubled between 1961 and 2020, following almost a straight line of growth which shows no evidence of abating (FAOSTAT). According to one global model, FAO projects roughly a 50% growth in demand for timber and paper products between 2015–2050 (Buongiorno 2015). A forthcoming paper from WRI reports a similar projection.

Although deforestation and agricultural expansion are occurring throughout the tropics, sub-Saharan Africa has had the highest recent rates of cropland expansion and presents a particular challenge to avoid more deforestation. The regional population is likely to almost double between 2020 and 2050 according to mid-range UN estimates. Meanwhile, crop yields are currently low. Using the Globagri-WRR model, WRI estimated that cropland would expand in this region by 100 million hectares between 2010 and 2050; pasture has the potential to expand even more. This expansion is expected to occur even if crop yields grow by 2–2.5 times 2010 levels as is assumed by the FAO. This projection also conforms with FAO assumptions that per capita consumption of milk and meat in sub-Saharan Africa will rise by 2050 to only one quarter of present consumption in the U.S. and Europe. Others evaluating these challenges have similarly found it highly unlikely that the region can become self-sufficient in staple crops by 2050 without large cropland expansion (van Ittersum et al. 2016; Searchinger et al. 2015).

This ongoing expansion of agriculture and wood harvest is contributing to vast losses of biodiversity. A major UN report recently found that 1 million species are threatened with extinction, a rate of extinction now being called the

earth's sixth mass extinction event (Ceballos et al. 2015). There is broad agreement that habitat loss due both to permanent land conversion and to loss of primary forests is the main driver (Pimm et al. 2014; IPBES 2019). One recent paper estimated that 80% of all threatened terrestrial bird and mammal species are imperiled by agriculture-driven habitat loss (Tilman et al. 2017). Forest harvests and conversion of land to plantations in the tropics also have high biodiversity costs (Watson et al. 2018).

#### **4.3.2. How Europe can use its own land to help the world**

Given where the global demand for land, food, and wood is headed, and the critical climate and biodiversity crises the world faces, what can Europe do with its own land?

In the face of these global challenges, using more European land to meet global food and wood supplies has great value. Continuing to run a large “land trade deficit,” as Europe has been doing, more than undermines any benefits of increased carbon storage and biodiversity within Europe.

One value of producing both more food and wood in Europe, rather than in the tropics, is because of Europe's current land-efficiency advantages. European production on average requires less land because of higher yields and therefore lower costs for carbon and biodiversity (Johnson Justin Andrew et al. 2014). The land-efficiency advantages in Europe are even greater for livestock products (Wirsenius et al. 2020; Herrero et al. 2013). As a general rule, biodiversity is at least an order of magnitude greater in the tropics than in the temperate zone, and in some locations even greater. (For a global map of vertebrate biodiversity, see (Searchinger et al. 2015); and for vascular plant biodiversity, see (Kreft and Jetz 2007). Moreover, in Europe, while the potential benefits reforesting Europe (for carbon and biodiversity) are accrued slowly over time, losses of carbon and biodiversity occur quickly when forests are cleared in the tropics, some of which may be irreplaceable.

There is also an equity argument which says that Europe should do more than just erase its land trade deficit but instead become an affirmative “saver” of global land. Two important reasons why Europe now is able to reduce its demand for agricultural land are (1) it already cleared so much land in the past, and (2), because its consumption of land-intensive products such as meat, milk and wood is already so high. Given this baseline, Europe can and equitably should do more to meet rising demand in other countries as their incomes rise. In fact, this equitable contribution is implicit in most global land use strategies that rely on dietary change, as they rely on greater reductions in meat and milk by Europeans and other large consumers than others to help save land around the world (Searchinger et al. 2019; Springmann et al. 2018).

Europe is a relatively small net exporter of wood, but given the likely growing global demand for wood, there is also a strong carbon and biodiversity argument for Europe to continue and even grow these exports. From an equity perspective, Europe's current forest carbon sink largely results

from its prior large-scale forest clearing and the fertilization effects of carbon dioxide. In addition, because Europe has already so heavily transformed its forests, and because it harvests using efficient techniques, the carbon and biodiversity costs of these harvests are also relatively lower.

Exactly how Europe balances its own domestic goals versus those of the world raises challenging but important questions. From a global climate and biodiversity perspective, however, there is no gain from just transferring Europe's agricultural land needs abroad. Regardless of any considerations of fairness, the rest of the world is unlikely on its own to avoid all land use change that warms the climate and therefore harms Europe as well. It is in Europe's self-interest to help avert that expansion.

#### **4.4. Summary of Section 4: Europe's Priority Opportunities to Achieve Biodiversity and Climate Goals, in the context of rising global demands.**

This section of the report has described how Europe has the potential to reduce its requirements for agricultural land to feed itself. This opportunity is enabled by a declining population and potential gains in crops or livestock yields. The opportunity can be expanded on if Europe makes a conscientious effort to produce more food per hectare and to reduce meat consumption and food loss and waste. Europe also has potential to reduce its demand for wood and maintain, or grow, its role as a net exporter.

Europe's reduced demand for land can lead to a variety of valuable benefits for addressing climate change and biodiversity, both within Europe and abroad. Those benefits could include helping to avoid land use change abroad by, at a minimum, eliminating Europe's "land trade deficit." Benefits could also be achieved through various ways of storing more carbon on habitats in Europe and simultaneously recover some of Europe's declining biodiversity.

Exactly how and how much Europe can reduce its demand on land resources, and exactly how it should divide the potential benefits between these three categories, are debatable and challenging questions. Europe's could end up adopting a range of reasonable goals—for carbon, food, and biodiversity—for how it plans to use its land. Whatever mix of these goals it chooses, Europe must at a minimum attempt to make efficient uses of land that are fully cognizant of the inherent tradeoffs.

## 5. The Emerging Plans of the European Union and their Implications for Global Land Use, Biodiversity, and the Climate

The EU has now offered a range of ambitious, environmental policy statements regarding each of these goals (Commission 2021a). They include broad promises to improve the EU's biodiversity (Commission 2020c), to achieve net zero carbon emissions in the EU in ways that incorporate carbon sequestration in the EU (Commission 2021b), and to stop the EU's contribution to deforestation abroad (Commission 2021f).

At this time, the EU's emerging policies do not prioritize any of these three opportunities in Europe's available land budget. Instead, the EU's proposed policies would devote most of Europe's potentially available agricultural land to meeting additional consumptive uses, particularly bioenergy, and potentially increased use of wood products. As discussed below, the EU's proposed laws and policies will encourage Europe to continue to outsource its land use in ways that will sacrifice biodiversity and larger gains in potential carbon storage on European lands and abroad. The effects on land use may undermine climate change goals and will at a minimum make less progress than alternatives.

### 5.1. Fit for 55 Policies: Bioenergy, Wood Products, & Agriculture

The most significant policies that affect Europe's future land uses are those intended to reduce greenhouse gas emissions from energy, which are set forth in legislation proposed in the European Commission "Fit for 55" policy package (Commission 2021a). These include:

- A strengthened Emissions Trading System (ETS) requiring larger emissions reductions from factories and power plants. In various ways, the transportation sector is also newly incorporated into the ETS (Commission 2021c).
- An amended Renewable Energy Directive (RED) requiring that each of the EU's Member States achieve 40% renewable energy by 2030. The proposals also include a variety of specific requirements related to energy use in transportation (Commission 2021d).
- A new law that requires that airlines reduce their emissions by switching to "sustainable aviation fuels," which are to consist primarily of biofuels and synthetically produced renewable fuels, such as from hydrogen. The sustainable aviation fuel requirement reaches 63% in 2050 (Searle 2021). A similar law requires fuels used by maritime shipping to reduce the greenhouse gas intensity of fuels by 75% by 2050 (Searle 2021).

Each of these laws has many detailed provisions, some of which include disincentives to use certain types of bioenergy (see summary in (Searle 2021)). Perhaps most significantly, biofuels from food and feed crops are limited to 7% of total transportation fuels for ground transportation. First generation biofuels also do not qualify for meeting requirements for greenhouse gas reductions or low carbon fuels for aviation or shipping. Mandatory requirements for electric cars or synthetic fuels also restrict the maximum potential use of biofuels (Searle 2021).

The new law also limits most Member States by 2025 to subsidizing use of wood in power plants to those that also produce heat (i.e., combined heat and power plants, or CHP). But as the environmental organization FERN has noted, this restriction is unlikely to have much effect because most power plants already generate at least some heat (FERN 2021). Furthermore, coal-dependent parts of the EU are exempt from this provision, including many countries in Eastern Europe.<sup>22</sup> These countries are those most likely to use biomass rather than solar or wind because they can claim climate reductions by co-firing biomass in existing coal plants, or by retrofitting some whole boilers to run on biomass, and in that way keep their power plants in operation.

Despite these limitations, the pivotal characteristic common to all these laws is that burning biomass is viewed as carbon neutral. The new energy policy package strengthens greenhouse gas reduction requirements, whether generally or in regard to particular fuel types. In each case, however, the emissions from burning biomass are excluded from the accounting of emissions. The emissions from the use of fossil fuels made to produce the biomass are counted, such as fossil energy used in growing crops or running refineries, but not the carbon released from burning or refining the biomass itself.<sup>23</sup> If bioenergy is produced on land that is converted from forests or other high carbon stocks, emissions are either attributed to that land use change or the biofuel cannot count toward the new low carbon energy or fuel requirements. However, the laws create strong incentives to burn biomass generated by harvesting wood in existing forests or by growing energy crops or other crops on existing agricultural land.

This incentive structure inherently treats the land used to grow bioenergy feedstocks as a free asset from a climate perspective. In other words, using Europe's land for bioenergy has no carbon opportunity cost. The theory behind ignoring this carbon cost is that burning biomass only releases the carbon absorbed by the plant during its growth cycle, and so only recycles carbon

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<sup>22</sup> The proposed directive exempts the “regions identified in a territorial just transition plan...due to its reliance on solid fossil fuels.” (Commission 2021d).

<sup>23</sup> The proposed changes to the RED and ETS and relevant implementing legislation do not alter the critical provisions related to calculating emissions factors of biomass, which will remain at zero. The relevant language in the proposed changes to the ETS is modified to state that the “emission factor for biomass” must comply with the “sustainability and greenhouse gas emission saving criteria” established in RED II. The emission factor for biomass remains at zero despite these changes. See Appendix V (Part C, item 13), and Appendix VI (Part B, item 13) in (Commission 2021d) and Annex IV, Part A in (Commission 2021c).

rather than adding carbon to the air. But it takes land to grow plants. If that land were not used to produce bioenergy, it could (and almost always would) be used for another purpose more valuable to combating climate change. Those uses could produce food, thereby reducing the need to convert land elsewhere to produce the same food or sequester carbon and create habitat through restoration of native vegetation. In effect, the treatment of biomass as carbon neutral ignores rising global land use demands for any of the purposes discussed in this paper. Meanwhile, the energy sector has an incentive to harvest and burn trees in place of fossil fuels because these emissions don't count despite multiple studies demonstrating that doing so increases carbon in the atmosphere for decades to centuries (see references in (Searchinger, Beringer, et al. 2018a)).

The Fit for 55 package also includes revisions to the so-called Land Use and Land Use Change (LULUCF) regulations, which assign responsibilities to Member States regarding the storage of carbon in land (Commission 2021e).<sup>24</sup> The proposed law assigns Member States mitigation responsibilities, the sum of which must equal or exceed a sink of 310 million tons CO<sub>2</sub> by 2030. That is a modest increase over the total average annual net sink of roughly 300 million tons since 1990 (Commission 2020e). The law also sets an objective that the sink fully offset emissions from agricultural production processes by 2035.

The proposed LULUCF regulations also change the carbon accounting approach significantly. In the past, and at least until 2025, for complicated reasons, EU climate rules give Member States much less incentive to increase the removal of carbon from the air through their land sinks.<sup>25</sup> Under a new approach after 2026, Member States will be responsible for achieving specified levels of sinks, i.e., removing specified levels of carbon through their land sectors. In its public statements, the Commission argues that “[t]his breakthrough addresses the earlier broad criticism that emissions from biomass in energy production were not accounted for under previous EU law,” (Commission n.d.). In a limited way, that is true, as the approach should increase the incentives countries experience to maintain carbon in their forests. If wood is harvested for energy in Europe, the resulting reduction in carbon in the forest is now more likely to be “counted” somewhere as having a net effect of increasing the EU's overall reported emissions. If EU countries otherwise fear that they may not have a large enough carbon sink in their land, they may be less likely to encourage their power plants to burn wood harvested domestically. It is also possible that EU countries will in some way restrict harvesting their own forests for biomass to prevent energy use by other EU Members States.

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<sup>24</sup> See summary and supporting documents at [https://ec.europa.eu/clima/eu-action/european-green-deal/delivering-european-green-deal/land-use-forestry-and-agriculture\\_en#ecl-inpage-875](https://ec.europa.eu/clima/eu-action/european-green-deal/delivering-european-green-deal/land-use-forestry-and-agriculture_en#ecl-inpage-875).

<sup>25</sup> Countries have been responsible mainly for ensuring that their activities do not cause a net loss in their carbon sinks, and have been able to project future sinks in ways that made it easy to meet these targets (Grassi, Stehfest, et al. 2021).

But several major limitations remain:

- First, these rules do nothing by themselves to reduce the incentives for actual energy users to use biomass of any kind otherwise allowed. The EU legislation would directly provide power plants, shipping companies, and airlines strong incentives to use biomass regardless of any additional incentives. To hold down biomass consumption, the countries from which biomass originates would need to regulate this use and we are aware of little, if any, precedent for policies designed to prevent the dedication of land to energy crops or to prevent harvests of wood for energy use. Doing so not only faces political but also practical obstacles. For example, if wood or any other biomass is produced in that country, it can have multiple uses, and it is not clear how a country could stop its eventual use for energy alone after export, even if desired. In addition, to work fully, any financial disincentive imposed on harvesting wood in an exporting country should be adjusted precisely to match the financial incentive generated by Europe's ETS or awarded in another country to burning wood. That subsidy for burning wood is likely to vary by country and over time, making any matching disincentive difficult to implement.
- Second, these rules do nothing to reduce incentives from one country in Europe to take biomass from another, including wood. So long as the wood is coming from other countries, each EU country can still claim mitigation credit by burning it.
- Third, this rule does nothing to stop EU countries from using biomass imported from outside the EU for energy. Europe is already importing much of its wood pellets from the U.S., Russia, and Canada among other countries, and the potential to produce more wood pellets from traditional EU sources is limited (Flach, Lieberz, and Bolla 2020).
- Fourth, this rule does nothing to prevent the diversion either of existing cropland or existing wood harvests into energy use, and thereby substituting with more wood product imports or fewer wood exports. This pattern of diversion has occurred in the EU with vegetable oil. As Europe diverted more of its canola oil to biodiesel, its imports of palm oil and other vegetable oils increased heavily (Baral and Malins 2015).

Overall, despite some constraints, such as limiting use of crop-based biofuels, these proposed laws would create powerful incentives to use more biomass.

Based on these incentives, modeling for the European Commission projects more than a doubling of bioenergy use between 2015 and 2050, from 152 MTOE

to 336 MTOE (Commission 2020e, Figure 79).<sup>26</sup> To appreciate the volume of biomass required, if this increase were to be entirely met by wood, it would require roughly 900 million cubic meters of additional wood harvest. That is a 650% increase over Europe's total existing wood harvest for all fuelwood purposes today.<sup>27</sup>

Moreover, the more than doubling of biomass use underestimates the effects on natural resources. Most biomass energy in 2015 was what might be called "traditional bioenergy," in the form of wood burned when making paper and wood products, traditional firewood burning by households, and the incineration of some municipal solid waste.<sup>28</sup> The new sources of biomass will require far more land for energy crops, wood harvests deliberately for bioenergy, or challenging efforts to increase residue use. The EU modeling claims that of the increased biomass, 56% will come from grass or woody energy crops, 13% will come from agricultural residues, 9% will come from forest residues, and 20% will come from various sources of waste. (Commission 2020e, Figure 79).

Even as the proposed directive encourages more use of biomass, the LULUCF regulation would discourage harvesting of wood in Europe itself. One likely incentive would be to import more wood. Some of the EU's own modeling accordingly projects increases in imported wood from about 3 million tons of oil equivalent in 2015 to 13 in 2050 (Commission 2020e, Figure 80).

There are also reasons to believe these projections may underestimate the bioenergy use that would result from the new incentives. For example, the modeling projects a decline in stemwood for bioenergy by 2030 compared to 2015 (Commission 2020e, Figure 79) even though Europe has been steadily increasing the use of stemwood for energy since 2015 (Flach, Lieberz, and Bolla 2020). This projection also runs counter to the projections by industry observers of increases in European wood pellet consumption by 30–40% between 2021–2026 alone (Businesswire 2021), the vast majority of which utilizes stemwood. Moreover, the modeling projections implicitly assume that the exemption from subsidy rules the EU has proposed for coal-intensive countries will have little

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<sup>26</sup> The EU modeling, incorporated into the Fit for 55 Impact Assessment, relied on the PRIMES model to estimate future energy sources and uses. These projections were then provided to IIASA, who used the GLOBIOM model to estimate land impacts and more precise sources of biomass. The modeling used different scenarios and was done before finalization of the proposed plan and directives. The numbers presented here for 2050 reference the "MIX" scenario, which most closely resembles the ultimate proposed legislation.

<sup>27</sup> This calculation assumes 19 GJ per ton of dry matter, and an average weight of .45 tons per cubic meter of European wood harvest (see Table S1 of (Searchinger, Beringer, et al. 2018a)). The increase of 184 MTOE requires 900 million cubic meters compared to roughly 120 million cubic meter annual fuelwood harvest today (FAOSTAT).

<sup>28</sup> Biosolids (essentially wood) municipal and industrial waste, and waste gas comprised 113 of the 139 MTOE of biomass in 2015 according to (Commission 2020e, Figure 78). Some of the biosolids were in the form of deliberately harvested wood, but most wood included in this analysis is the burning of wood as part of paper and wood product manufacture or the burning of residues (Commission and Joint Research Centre 2019).

consequence. It is unclear why the European Commission would create such exemptions unless some power plants or countries are intending to use it.

In addition to these proposed directives, the Commission has also released two policy documents, yet to be turned into legislation, that if followed would have large implications for EU land uses:

- The Commission’s “Forest Strategy for 2030” announces a broad goal to increase the use of wood (Commission 2021b). The document includes some quick references to bioenergy, but focuses more on using wood for other materials, including construction.
- The Farm to Fork Strategy released as part of the Green New Deal in 2020 includes goals to increase organic production to 25% of agricultural land, and to reduce pesticide use by 50%, and fertilizer use by 20% (Commission 2020a). It also contains some broad policy statements to increase crop use as part of the circular economy—in other words endorsing more use of biomass for non-food uses. The strategy, however, contains no discussion of increasing crop yields nor does it include any mention of “yield” whatsoever.

Put together, the proposed directives create powerful incentives to devote more agricultural land to biomass for energy while the Farm to Fork strategy would at a minimum make it challenging to increase crop yields. The Forest Strategy would encourage additional uses of wood for materials, while the LULUCF directive would encourage countries to reduce their wood harvest. As discussed more below, the combined incentives are to encourage the EU to rely more heavily on agricultural land and forests outside the EU for its food and wood.

## **5.2. Implications of Fit for 55 for Land Use, Biodiversity, and EU Carbon Sequestration**

What are the implications of the “Fit for 55” policies for the uses of European land, carbon storage, biodiversity, and Europe’s land carbon trade deficit?

Modeling for the 2030 Climate Target Plan Impact Assessment (hereafter “Impact Assessment”) projects that bioenergy will, in effect, consume vast areas of the EU’s agricultural land and biologically diverse semi-natural grasslands ((Commission 2020e, Figure 85).<sup>29</sup> The modeling projects that the EU will establish 22 million hectares of energy crops, which equals more than one fifth of total EU cropland today, and establish 8 million hectares of managed forest. In turn, the modeling projects cropland will decline by 17

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<sup>29</sup> Note the “Impact Assessment” is presented in two volumes with figures. Tables showing the data for the figures are also provided separately. We reference the report figures but use the tabular data for accuracy.

million hectares and pasture by 3 million hectares. “Other natural lands” will decline by 11 million hectares. Somewhat strangely, the tables provided also show an additional decline of little-used grassland by 13 million hectares although the tables do not indicate to what use this land will be devoted. The implications are that Europe will devote far less area to food, far less area to biologically diverse habitats, and far more area to bioenergy.

The Impact Assessment states that the land required to produce energy crops “is taken from cropland previously dedicated to the production of conventional biofuel and from other natural land” ((Commission 2020d), p. 104). However, as indicated above, the EU itself estimates that “only” 3.4 million hectares of EU land are now devoted to food- and feed-based biofuels (Commission et al. 2020). Because production of these biofuels in the projections decline by only 55%, land devoted to these biofuels should only decline by roughly 55% ((Commission 2020e) Figure 79). These calculations imply that more than 90% of the increased land for energy crops therefore comes at the expense of either food production or other natural lands.<sup>30</sup>

This analysis also likely underestimates either the land or the forests that would have to be devoted to bioenergy to meet these targets. Instead of harvesting more stemwood to burn in Europe, the analysis claims that Europe will burn for energy 73 million tons of dry matter from forest residues (Commission 2020e) Figure 79).<sup>31</sup> But that is at least 75% more than the maximum potential forest harvest residues available even if Europe were to increase its harvests from present levels by roughly 50% up to the maximum allowable forest harvest consistent with current harvesting rules (Verkerk et al. 2019).<sup>32</sup> At existing wood harvest levels, the estimated residues are 260% of maximum harvestable residues. Moreover, the best evidence is that only a few percent of potentially harvested residues are actually harvested in Europe today, which indicates large economic and practical challenges (Searle and Malins 2013).

Under these projections, bioenergy would not only absorb any potentially “liberated” cropland available to improve the EU’s biodiversity, but the EU would also destroy broad parts of the semi-natural grasslands and

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<sup>30</sup>  $122 \text{ Mha} - (.55 * 3.4 \text{ Mha}) = 20.13 \text{ Mha}; (20.13 \text{ Mha} / 22 \text{ Mha}) * 100 = 91.5\%$

<sup>31</sup> Figure 79 provides an estimate of 32 MTOE in the mix 2050 scenario, which requires 74 million tons of dry matter at 18 GJ per ton of dry matter in residues.

<sup>32</sup> The 2030 Climate Target Impact Assessment ((Commission 2020e) Figure 59) claims that forest residues will supply 31.65 MTOE of energy in the “Mix” 2050 scenario that most closely resembled the actual Fit for 55 proposals. At 18 GJ/tDM, that requires 73.7 million tons of dry matter. Verkerk et al. estimates 50 million tons of DM from forest residues available with maximum harvest of forests in 40 European countries under current harvest rules, of which 84% is available in the EU-27 plus the UK, or 42 million tons of DM. This figure includes stumps, whose harvest for bioenergy would be prohibited under the new rules of the Renewable Energy Directive. (Commission 2021, see Amendments to Article 29 at p. 46). At existing wood harvest levels, the available residues would proportionately drop to 28 million tons of DM. See “Commission Presents Renewable Energy Directive Revision (July 14, 2021) ([https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14\\_en](https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14_en)).

grassland/ woodland habitats discussed above that hold important pieces of Europe's remaining biodiversity. The Impact Assessment claims that impacts on biodiversity within the EU will roughly equal out because the benefits to biodiversity of converting cropland to energy crops will offset the costs of converting these semi-natural lands to energy crops. This claim is not credible. It is based on a crude method that assigns a single percentage score for biodiversity to broad different kinds of lands based on levels of disturbance. Although energy crops such as coppice willow and miscanthus on the whole support more species than annual crops, they are still monocultures and support mainly generalist species and others that are already present in surrounding habitats, some of which may be just as abundant in annual crop fields (Vanbeveren and Ceulemans 2019) (Tudge, Purvis, and De Palma 2021) (Bellamy et al. 2009). By contrast, as discussed above, the semi-natural grasslands that would be replaced support a diverse range of plant, butterfly and other species that are otherwise rare in Europe (European Environment Agency 2020a).

Biodiversity would be further harmed by the increase in intensity of European forest management and the removal of dead wood in the form of forest residues. The Impact Assessment indicates that the increased removals will occur in "managed forests" and that the intensity of forest management overall will increase by 13% (Commission 2020e) p. 104). As discussed above, biodiversity strategies for European forests contemplate an increase in dead wood in forests, in contrast to these large removals projected in the modeling.

Regarding carbon sequestration within the EU, the modeling projections probably imply some carbon gains, but far less than might be achieved.

On the positive side, around 8 million hectares of agricultural land or grass/shrublands would be converted to managed forest, which should sequester more carbon. Conversion of annual crops to both willow and miscanthus would also likely build some soil carbon, at least for a few years (Georgiadis et al. 2015). However, the higher estimated rates of soil carbon gains in dedicated energy crop systems tend to come from studies that last only a few years and that focus on soil carbon in only the upper soil horizon rather than studies that focus on longer time frames and at greater depths (Hansen et al. 2004) (Lockwell, Guidi, and Labrecque 2012). The great majority of these soil carbon gains in energy grass systems are also likely in the form of so-called "particulate organic matter" (Zimmermann, Dondini, and Jones 2013). Particulate organic matter consists of very small pieces of vegetation that are subject to more rapid decomposition than more stable forms that are residues of microbial carbon (Cotrufo et al. 2019) (Buckeridge et al. 2020). Most of the possible energy crops must also be re-plowed periodically, creating a potential to lose some and possibly much of any soil carbon gained.

On the negative side, the decline in semi-natural grasslands and grassland-woodland complexes, even with conversion to energy crops, has potential to cause losses of both soil organic carbon and vegetative carbon in shrubs and scattered trees (Holder et al. 2019). Some studies find no change in soil organic carbon when converting grasslands to miscanthus (Zatta et al. 2014) (Zang et

al. 2018), but these studies only focus on the effects of one harvest cycle and do not seem to focus on the soil carbon effects of converting semi-natural grassland/woodlands that have existed for a relatively long history. As mentioned above, one reason for doubt is that miscanthus, the genus of highest-yielding grass energy crops, must be regularly reestablished with re-plowing, exposing soil to degradation. In contrast, semi-natural grasslands (pastures and meadows), are likely to remain unplowed.

The large reliance on forest and crop residues for bioenergy also poses a threat to soil carbon. There is good evidence that harvesting of forest residues reduces forest soil carbon (Achat et al. 2015) (James and Harrison 2016) (Repo et al. 2014). The Impact Assessment projections also rely on a doubling of the harvest of crop residues in Europe, removing more than 60 million tons of additional biomass (dry matter) per year, or roughly 30 million tons of carbon (authors' calculations based on (Commission 2020e, Figure 79). This removal of carbon inputs to the soil will likely reduce soil carbon although there is some uncertainty about the size of the effect (Olofsson 2021). The Impact Assessment modeling has separate projections for increases in soil carbon in cropland based on unspecified management practices. This lack of specification makes these projections impossible to analyze but the loss of carbon from residues would certainly make such achievements harder.

Overall, the balance of these changes seems likely to improve the carbon balance on European lands, but far less than could be achieved by alternative uses of this land. The areas projected to be devoted to new forests are small relative to the reduction in agricultural land.

Perhaps the largest consequence of the EU's proposed plans is that no effort is made to reduce Europe's land carbon trade deficit and thereby to reduce the real effect of European consumption on global deforestation. The combination of incentives in the directives to preserve carbon sequestration in Europe plus the incentives to switch European land to energy crops encourages continued or even increased out-sourcing of Europe's land use requirements. The projected reduction of European cropland by one fifth to produce energy crops means less food production in Europe than would otherwise occur.

Rather than reduce its appropriation of foreign land, the European Commission has instead proposed a law that will restrict imports of many agricultural products if they are generated on recently deforested land (Commission 2021f). But the main effect will be to obtain imports from other cropland and pasture converted from forests and other native habitats in the past while others consume the output from recently deforested land. The driver of deforestation in the form of increased demand will remain.

The Impact Assessment does not provide information about projected future EU imports and exports of agricultural products in its baseline or scenarios, so it is not possible to determine the European Commission's projection of the EU's "land carbon trade deficit" under the Fit for 55 plan. As discussed earlier in this report, Globagri modeling found that it could be possible to eliminate the land trade carbon deficit by 2050 and still free up 16

million hectares of cropland. It is possible, therefore, that the EU could come close to eliminating its land area carbon deficit even while reducing cropland by 17 million hectares. However, this Globagri result requires both large yield gains, and holding biofuels at their 2010 levels. There are no policies in the Fit for 55 package that explicitly supports yield increases and the plan encourages greater use of biofuels.

Impact Assessment model projections also appear to make no room for restoring those 4 million hectares of agricultural land that use drained peatlands. The proposed LULUCF regulations do provide incentives to countries to rewet their peatlands. But if Member States do restore a significant quantity of peatlands while producing 22 million hectares of energy crops, the EU would have to remove even more agricultural land from production. That would contemplate even greater reliance on land outside of the EU.

In addition, the Impact Assessment modeling projects a four-fold increase from 2015 levels in imported “solid biomass” (i.e., wood) for bioenergy (Commission 2020e, Figure 80). Assuming this wood comes from wood pellets, that would require roughly 65 million cubic meters of additional wood harvests for Europe beyond 2015 levels, equivalent to roughly 40% of annual Canadian harvest levels.<sup>33</sup> At the same time, the Impact Assessment modeling indicates that wood harvests in the EU would decline to meet LULUCF requirements (although by how much is not specified). In addition to new wood imports for energy, this change implies an increased reliance on harvests of forests outside the EU to meet existing demand for timber and paper products.

The Forest Strategy for 2030 and Farm to Fork policies could lead to yet more outsourcing of Europe’s land uses. The Forest Strategy contemplates increased harvest and use of wood in Europe for different products. At the same time, the LULUCF directive encourages less harvest of wood, as is reflected in the Impact Assessment modeling. The only way to accomplish both would be to either export less or import more wood.

The Farm to Fork strategy also sets targets that would make it very challenging to increase crop yields, which are necessary to free up agricultural land in the EU without entirely relying on more imports. Although there are examples of organic production that maintain crop yields, the great majority of organic production has lower crop yields, particularly over multiple years (de Ponti, Rijk, and van Ittersum 2012). Increasing, or even maintaining yields, while reducing pesticides by 50% is challenging; doing so while reducing fertilizer by 20% might be impossible. For example, nitrogen use efficiency for

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<sup>33</sup> Imported “solid biomass” for energy would increase from 3 MTOE in 2015 to 13 in 2050 instead of declining to 0 in the baseline (Commission 2020e, Figure 80). These imports would require roughly 30 million tons of dry matter in wood, which would require roughly 65 million cubic meters of wood. Canada harvested 156.2 million cubic meters of wood in 2018. Source: <https://www.nrcan.gc.ca/our-natural-resources/forests/state-canadas-forests-report/timber-being-harvested-sustainably/indicator-volume-harvested-relative-sustainable-wood-supply/16550>.

wheat production in Europe is already around 60%.<sup>34</sup> The Globagri modeling to 2050 suggests European wheat yields would need to increase by 38% to eliminate the EU's land carbon trade deficit. Doing so while reducing nitrogen inputs by 20% would require supplying less nitrogen than is removed by the nitrogen in the wheat grain, which would mean more than 100% nitrogen use efficiency. Doing so would require mining nitrogen from soils, which in turn causes loss of soil carbon.

Reducing both nitrogen and pesticide pollution from agriculture is important, but doing so in a way that reduces yields would likely not only require bringing more land into production abroad but could even lead to more overall pesticide and fertilizer use globally (Richard Fuchs, Brown, and Rounsevell 2020). Analysts at the USDA estimate that the EU "Farm to Fork" strategy would reduce European agricultural production by 7%, drive up worldwide food prices by 9%, and induce social welfare costs of \$96 billion (Beckman et al. 2020). As discussed, there might be acceptable trade-offs between some reduction in inputs and small impacts on yields, but any trade-offs must occur in the context of overall increases in yields matching demand change. That calls for a major push to advance a number of promising technologies (Searchinger et al. 2019).

Overall, the Fit for 55 package implies declines in biodiversity in the EU, a large sacrifice of the potential to store more carbon within Europe, and a sacrifice of the potential to help reduce deforestation, and carbon and biodiversity losses abroad.

### **5.3. Implications for greenhouse gas emissions overall**

Although the focus on bioenergy in the 2030 Climate Target Plan sacrifices carbon storage within the EU, its purpose is to reduce greenhouse gas emissions from energy use and thereby to reduce carbon in the atmosphere overall. Will it?

One definite answer is that it will not reduce carbon emissions at the level estimated by the European Commission. This is because the projections for bioenergy use are based on the treatment of burning biomass as carbon neutral. As discussed above, that is equivalent to ignoring all the potential benefits this land would provide if this land were not used to produce biomass but rather for alternative uses. The fact that Europe is outsourcing its land use, and thereby contributing to deforestation and other land use changes abroad vividly illustrates these carbon costs.

Many of the bioenergy uses contemplated by EU modeling are for the generation of power, including biomass supplied by stem wood and energy crops. Multiple papers have shown that harvesting stem wood to supply electricity will increase carbon in the atmosphere for decades to centuries (see citations in (Searchinger, Beringer, et al. 2018a)).

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<sup>34</sup> Data underlying (Zhang et al. 2015).

Other biomass would come from energy crops, and EU modeling estimates a yield of 11 tDM/ha/year.<sup>35</sup> At that yield, one hectare of willow used for electricity in place of natural gas might save around 9 tons of CO<sub>2</sub>/ha/year from fossil emissions (authors' calculations). However, if the same land were used for forest growth, a reasonable carbon sequestration rate for many decades would be 11 tons of CO<sub>2</sub> per hectare per year. The EU modeling also contemplates some use of energy crops for cellulosic biofuels. At the same yield, a high-end estimate, assuming the biofuel replaced oil, might be around 8 tCO<sub>2</sub>/ha/year (authors' calculations). Again, this is a lower sequestration rate than if the same land was used to establish a forest.

All these calculations also assume that bioenergy replaces fossil fuels, but so long as there are other viable energy alternatives, the proper comparison is with another carbon-free or low-carbon energy source. Combining other low-carbon sources of energy with alternative uses of land not only reduces greenhouse gas emissions from energy use but also allows land to store more carbon. Alternative energy sources, such as solar and wind, seem particularly achievable for the 44% of bioenergy that the modeling projects would be used in the power sector ((Commission 2020e), Figure 77).

Regardless of this comparison between reforestation and use for energy crops, the most significant tradeoff, from a carbon perspective, exists between using land for energy crops and saving forests and woody savannas outside of Europe. In effect, Europe is proposing to switch more of its cropland from food to energy crops and shift this food production abroad. This pathway stands to further accelerate the already rapid global expansion of agricultural land. At its essence, the salient comparison is between the carbon savings gained from a hectare of energy crops in Europe and the loss of carbon due to agricultural expansion abroad. For virtually any type of habitat, the carbon losses would exceed the carbon savings substantially over 30 years (Searchinger, Beringer, and Strong 2017).

Impact Assessment modeling projects that some of the biomass will be used not just for bioenergy but for "BECCS," which is bioenergy with carbon capture and storage.<sup>36</sup> In BECCS, biomass is burned for energy and then the carbon released is captured and put underground. The theory is that BECCS provides "negative emissions," i.e., absorbs carbon, because the growth of the crops absorbs the carbon, and by capturing this carbon when burned and putting it underground, the net effect is negative. As for other uses of bioenergy, this

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<sup>35</sup> These yields are implied by the quantity of biomass from energy crops and area of energy crops indicated in the Impact Assessment.

<sup>36</sup> Figure 77 in (Commission 2020e) projects that 106 MTOE of biomass will be used for electricity-generation while Figure 46 indicates that 151 TWh of electricity will use BECCS, which is equivalent to 13 MTOE. Figure 46 appears to refer to final energy (electricity generated) while the 106 MTOE appears to refer to the gross energy in biomass. Depending on the conversion ratio assumed, the BECCS percentage of biomass could therefore be more than a third of the total electricity generation.

assumption ignores the opportunity cost of not using the land for other purposes.

When factoring in land use costs, the carbon accounting for BECCS fundamentally changes. Estimates of whether BECCS generates net gains when factoring in land use costs vary depending on a range of factors, such as energy crop yields, the existing land uses displaced, and the losses of carbon in the various steps of harvesting, processing, burning, and capturing carbon (see discussion in (Harper et al. 2018)). So long as Europe's diversion of food to energy crops is at the expense of using more agricultural land abroad, generating a net carbon sink would be doubtful and uncertain because the precise lands converted abroad will always be impossible to know for sure.<sup>37</sup> The biodiversity costs are also likely to be severe. Even if BECCS were to result in net gains, those gains would be far less than claimed by the modeling, which assumes the use of land has no carbon opportunity cost.

This fixed global land budget explains why important advisory bodies, such as the Energy Transitions Commission, recommend against devoting agricultural land to bioenergy, even BECCS, unless and until some combination of yield gains and dietary transitions can free up additional agricultural land (Energy Transitions Commission 2021).

The proposed Forest Strategy to increase the harvest of wood for various wood products could further increase emissions. There are many papers claiming that using wood for long-lived products benefits the climate, but as illustrated by (Lippke et al. 2012), these papers nearly all treat uses of wood as carbon neutral. When wood is harvested and turned into timber products, some of the carbon remains stored in timber products, but the vast majority is typically released relatively quickly in such forms as decomposing roots and forest residues, bark that is commonly burned for energy, the wood that is used for paper products and discarded or burned to make that paper and other small-cuttings and wastes that are commonly burned. When counting greenhouse gas emissions from wood use, these papers do not count any of this carbon. The theory is that this "biogenic" carbon is carbon neutral so long as forests are sustainably managed. That is the same theory used to justify wood harvest for bioenergy and is flawed for the reasons discussed above.

When studies do factor in the loss of biogenic carbon, they typically obtain different results. These studies analyze the results of wood harvests for the total quantity of carbon stored versus released, which includes carbon stored in wood products and carbon sequestered by regrowing forests after harvest, but also the carbon that was lost from the original forest, including its foregone

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<sup>37</sup> The appropriate comparison here is between the savings in the use of energy crops grown in Europe for BECCS with the carbon lost by converting additional land outside of the Europe, likely in the tropics. Thus, what matters is the yields and resulting carbon savings of energy crops in Europe versus the carbon losses to replace that level of food in the tropics. Crop yields outside of Europe are typically much lower, and carbon losses higher, so it is likely than more than one hectare of land outside of Europe is required to replace the crops that are no longer produced in Europe (Johnson Justin Andrew et al. 2014).

carbon sequestration. These studies typically find that harvesting wood increases carbon in the atmosphere for at least decades (e.g., see (Kalliokoski et al. 2020a) (Skytt, Englund, and Jonsson 2021)).<sup>38</sup>

Surprisingly, even though the new EU Forest Strategy calls for more harvest of wood for products, it comes to the same conclusion that such harvests will increase global warming for decades. In a single sentence in the middle of page 5, citing a report by the European Commission's Joint Research Center, the strategy reads: "As indicated in recent studies, in the short to medium term, i.e., until 2050, the potential additional benefits from harvested wood products and material substitution are unlikely to compensate for the reduction of the net forest sink associated with the increased harvesting," (Commission 2021b). Reducing the "net forest sink" means increasing carbon in the atmosphere, so the statement means that warming will likely increase at least until 2050.

Overall, the effects of European proposals seem likely to lead to more needs to expand agricultural land outside of Europe, to reduce rather than increase European biodiversity, and to store less carbon in European forests and other lands.

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<sup>38</sup> Note that (Kalliokoski et al. 2020a) find the same general result when also factoring in changes in albedo.

## 6. Summary of Conclusions

This survey of European past, present, and future land uses proposed under the Fit for 55 package leads to a few overall conclusions.

- *Europe has the potential to substantially reduce the land resources it “appropriates” for human uses.*

In the next 30 years, Europe has major opportunities to reduce the land resources it “appropriates” for its own consumption. If Europe could achieve challenging but reasonable targets for crop yield growth and just stabilize its meat and milk consumption, it could free up 16 million hectares of cropland and eliminate its “land carbon trade carbon deficit.” If Europe could hold down demand for wood through greater recycling and cascading of wood uses, it could build up its forest carbon stocks and improve its forest biodiversity. Even this scenario, however, still contemplates large global deforestation. If Europe could boost its yields even more and *reduce* its milk and meat consumption and food losses and wastes moderately, it could save enough land to become a net contributor to global food supplies while still freeing up extensive areas of land to sequester carbon and restore Europe’s own biodiversity.

- *Europe’s fortunate land use position results from Europe’s heavy appropriation of land in the past and does not alter the importance of reducing land use and using land savings wisely to store carbon and improve biodiversity.*

Europe’s present potential to restore carbon and biodiversity reflects Europe’s vast clearing of forests and transformation of its landscape in the past. Some of Europe’s forest regrowth since 1900 has resulted from human achievements that help to hold down the demand for agricultural land. These achievements include high crop yield gains, stabilizing population, and in recent decades, a decline in per capita consumption of beef and lamb. The development of cars and tractors was also an important land use achievement in this sense by freeing up vast areas of land used for bioenergy in the form of feed for draught animals. But other reasons for forest growth are incidental, such as the feedback effects of climate change itself. Some are even harmful, such as Europe’s intensive and ongoing drainage of wetlands to boost crop production, and its outsourcing land uses for food, bioenergy and other industrial products. Understanding these different components has two important implications:

One is that Europe should not properly claim mitigation credit for these incidental or harmful effects. Europe and other countries already receive “credit” for the stimulation of plant growth by climate change because these effects are already built into models and deemed to hold down climate change. When setting emissions targets, these beneficial feedback effects are already assumed, so they cannot count additionally as credits toward meeting

emissions targets. Under the Kyoto Protocol, complex rules have at times allowed the EU to take partial credit for this carbon sink when determining if its overall emissions comply with Protocol limits (Commission 2020d), pp 22-23). But recognizing the physical reality, signatories to the Kyoto Protocol agreed that participating countries should not be entitled to claim credit for these feedback effects (Macey, Hare, and Chen 2011). Although standard IPCC global accounting rules do enable Europe to claim credit for outsourcing its land use requirements, and then using its own land for bioenergy or forest growth, that is a problem with these rules. Doing so does not actually contribute to solving climate change.

Another implication is that Europe's present status neither reduces the practical need for Europe to reduce its appropriation of land for human consumption nor its moral obligation to do so. Europe is in a position to have positive land use change mainly because Europe achieved so much negative land use change in the past. Other countries are at different stages of development. The world is unlikely to reduce, let alone reverse, the losses of carbon and biodiversity from land use change unless Europe makes a major contribution.

- *If Europe reduces the land used for its own consumption, it still needs to carefully target how it uses the freed land resources to achieve both domestic and global carbon storage and biodiversity goals.*

Europe has three valuable ways in which it can use land resources no longer needed for its own consumption.

On a global scale, the most valuable use is likely to produce food in a manner that helps reduce global agricultural land expansion. Although restoring carbon and habitat in Europe is valuable, producing food in Europe is generally less environmentally costly because of its high yields as well as the relatively high biodiversity and existing carbon stocks in the tropics. Nearly all countries produce and will continue to produce the vast majority of their food themselves. But for the world to stabilize its land use, Europe needs to switch from being a net "importer of land" to being a net exporter. Although that capacity will also depend on market forces, EU policy should not block that role.

Europe also has valuable ways in which it can sequester carbon and enhance its biodiversity, some synergistic and some in tension with each other. Primary carbon goals include rewetting its agricultural peatlands and reestablishing forests. To gain high biodiversity benefits, it can transition its older forests into more natural conditions while replacing timber stocks with younger, faster-growing, managed species. On the other hand, although Europe might sequester more carbon by replacing semi-natural grasslands with plantation forests, doing so would likely come with high costs to biodiversity.

The complexity of biodiversity requires careful targeting and management of restoration to achieve high biodiversity benefits. Much of the attention in recent years has flowed to the decline of total bird populations in Europe and of common species, which are of concern. Yet these declines may obscure the challenge of already rare birds and the vaster number of species in less visible categories that were already vulnerable, and which continue to decline, including plants, insects, fungi, and mammals. Their stabilization and recovery will require recreating more diverse and complex habitats than those typically available in highly managed landscapes. In this way, the opportunity costs of land use also apply to habitat planning.

- *Europe's Fit for 55 Plan sacrifices both global and domestic carbon storage and biodiversity for bioenergy and potentially wood products.*

Although the broader EU Green Deal promises benefits to biodiversity and carbon storage within Europe, the Fit for 55 directives seem destined to sacrifice most, if not all, of these goals in the interest of bioenergy. Based on the EU's own modeling, the EU would devote 22 million hectares of croplands to bioenergy, roughly a fifth of present crop area, which would come out of existing cropland for food and Europe's semi-natural grasslands and grassland/woodlands. If this modeling is accurate, some carbon sequestration gains are likely but not guaranteed—and far less than those that might be achieved. Biodiversity would likely suffer overall and certainly would not improve. There are also many reasons the underlying modeling may underestimate the uses of land and wood for bioenergy; if the land needs are larger, providing the bioenergy will sacrifice yet more carbon storage and biodiversity.

The EU's proposed plans would also at a minimum result in far more adverse land uses outside Europe than Europe would induce in the absence of these new policies. In addition to diverting vast areas of land to bioenergy, the plan at best pays no attention to boosting yields and arguably stands to undermine yields depending on how the Farm to Fork strategy is implemented. The Fit for 55 plan discusses reductions in meat consumption but offers no incentives for EU countries to achieve them.

## 7. Recommendations

What explains the limitations we have identified in the Fit for 55 Plan, and how could they be fixed?

The root of the problem, we believe, is an analytical contradiction. Designing land use policies to enhance the climate and biodiversity is inherently an exercise in land allocation. If land is used for one purpose, it is not used for another. There are benefits and costs. Currently, the EU's policies, and therefore modeling, ignores key costs. The EU's bioenergy policies instruct energy users to treat land as a carbon-free asset. They implicitly assign carbon reductions to the use of the land to grow plants to replace fossil fuels, but they do not count any cost from the loss of land uses for other purposes.

Part of the error lies also in ignoring overseas impacts. In response to the proposed LULUCF regulations, some Member States might decide to reduce forest harvests to preserve their carbon sink. But the directives provide no incentives to European countries to avoid relying on land outside their countries (whether within or outside the EU) for more of their food, wood, or biomass uses. Given the incentives to use land for bioenergy, the more some European countries protect their forests from harvest or conversion, the more likely land will be converted, and wood harvested outside Europe.

The projected effects on biodiversity equally reveal no sense of trade-offs within a fixed land budget. The EU strongly emphasized the need to enhance biodiversity in its official communication for the Fit for 55 Plan:

*“The twin climate and biodiversity crises cannot be treated in separately. We either solve the climate and nature crises together, or we solve neither. This also means that we should not take more resources than the planet can afford to share with us. If we help delicate land and ocean ecosystems recover, they can provide for life on the planet and fulfil their role in the fight against climate change. Restoring nature and enabling biodiversity to thrive again is essential to absorb and store more carbon,”* (Commission 2021a).

Unfortunately, the dedication of vast areas of land to bioenergy leaves no additional land to enhance biodiversity. And the conversion of semi-natural grasslands to energy crops and highly managed forests is even likely to further harm EU biodiversity.

At the time of this writing, the European Commission has yet to release a proposed biodiversity directive. That directive could require some additional habitat restoration. If it does, without reducing the bioenergy demands, even more agricultural land will be removed from production, and the effects on land use, carbon, and biodiversity abroad will only be greater.

Overall, the 2030 Climate Target Plan Impact Assessment and Fit for 55 policy package reveal no conscious planning of how to use land within a fixed

budget. There is no significant discussion of land use priorities or trade-offs. There is no discussion of the role or importance of crop yield gains, let alone how to achieve them. Although the Impact Assessment provides some hint of potential benefits from dietary changes, it suggests no way forward to shift diets. Most broadly, there appears to be little awareness of the global implications of the EU's land use decisions at all, in short, no awareness of the need to reduce Europe's land carbon footprint.

The basic recommendations of this report therefore ultimately involve properly weighing benefits and costs of different land uses:

1. Europe needs to reform its accounting for carbon so that it no longer treats land as free in its laws and policies for energy use and use of wood products. The basic principle is to factor in the "carbon opportunity cost" of land, which is essentially the carbon storage or ongoing sequestration forgone due to the uses of land for other purposes, such as bioenergy. When the alternative use of land is to store carbon as forest or other habitat, the carbon opportunity cost is the carbon storage lost over an appropriate policy period, such as 20 or 30 years. That total storage includes the reductions in carbon stored in forests due to increased harvests but also any increases in carbon stored in wood products. When the alternative use of land is to produce food, the carbon opportunity cost needs to be some reasonable measure of the carbon that is likely to be lost to replace that food elsewhere. (See discussions of different accounting approaches in (Searchinger et al. 2021)). To obtain results that provide net benefit to the climate, these costs should apply whether the biomass derives from inside or outside the EU.
2. Europe should adopt explicit goals to reduce its effects on global land use. Proper carbon accounting of bioenergy would avoid making the challenge worse, but it would not inherently encourage European countries to reduce their effective appropriation of land abroad, which Europe could achieve through yield gains, dietary changes, and other reductions in demand. At present, so long as the food or biomass is produced abroad, under standard reporting formats to the IPCC, Europe is not responsible for the emissions it causes. Europe has recently proposed legislation that would lead to avoiding imports of foods and biomass from recently deforested land (Commission 2021f) Although that can have some benefits, Europe contributes to this deforestation so long as it has a land trade deficit and therefore increases the demand abroad for agricultural land. Europe should adopt goals at a minimum to eliminate this deficit and that ideally include a contribution toward meeting rising global food demands.
3. Europe should craft a comprehensive policy package to achieve these goals. One group of policies should seek to increase crop yields. Others should aim to reduce demand for land-based products or land-intensive products, such as by moderating consumption of animal products and reducing food loss and waste. One idea could be to give

countries a target for reducing what could be called their “land area carbon footprints.” That would be the quantity of carbon that is lost from vegetation and soils to produce the land-based carbon products consumed in the country. Both increasing yields and reducing consumption of land-intensive products would contribute toward such a goal.

4. Finally, the EU should adopt incentives to encourage countries to implement a highly targeted policy to enhance biodiversity and carbon storage. At the time of writing, the European Commission is contemplating a biodiversity directive that would have numerical targets and build on the Natural 2000 system and habitats directive. That is a sound, general approach. In turn, funds provided through the Common Agricultural Policy for environmental objectives might support the restoration components.

Ultimately land is a limited resource. The underlying challenges we have identified involve a failure to recognize that limitation and to evaluate any use of land against its alternative uses.

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