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Three billion new trees in the EU's biodiversity strategy: low ambition, but better environmental outcomes?

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Supplementary material for this article is available online

Abstract

The EU Biodiversity strategy aims to plant 3 billion trees by 2030, in order to improve ecosystem restoration and biodiversity. Here, we compute the land area that would be required to support this number of newly planted trees by taking account of different tree species and planting regimes across the EU member states. We find that 3 billion trees would require a total land area of between 0.81 and 1.37 Mha (avg. 1.02 Mha). The historic forest expansion in the EU since 2010 was 2.44 Mha, meaning that despite 3 billion trees sounding like a large number this target is considerably lower than historic afforestation rates within the EU, i.e. only 40% of the past trend. Abandoned agricultural land is often proposed as providing capacity for afforestation. We estimate agricultural abandoned land areas from the HIstoric Land Dynamics Assessment+ database using two time thresholds (abandonment since 2009 or 2014) to identify potential areas for tree planting. The area of agricultural abandoned land was 2.6 Mha (potentially accommodating 7.2 billion trees) since 2009 and 0.2 Mha (potentially accommodating 741 million trees) since 2014. Our study highlights that sufficient space could be available to meet the 3 billion tree planting target from abandoned land. However, large-scale afforestation beyond abandoned land could have displacement effects elsewhere in the world because of the embodied deforestation in the import of agricultural crops and livestock. This would negate the expected benefits of EU afforestation. Hence, the EU's relatively low ambition on tree planting may actually be better in terms of avoiding such displacement effects. We suggest that tree planting targets should be set at a level that considers physical ecosystem dynamics as well as socio-economic conditions.

1. Introduction

Biodiversity in Europe is declining at an unprecedented rate, so that the provision of many ecosystem services is under threat [1]. Although several international conservation policies have been initiated to slow down the rate of biodiversity loss, they have failed to do so [2, 3]. None of the 20 Aichi Biodiversity Targets have been fully achieved at the global level, and only six targets have been partially achieved [4]. The post-2020 global biodiversity framework sets new goals for 2050 and associated milestones and action plans for 2030, in an attempt to overcome the shortcomings of previous efforts [5]. National and local level action plans are required to implement the global targets.

Set against this backdrop, the European Union (EU) has aligned its Biodiversity Strategy for 2030 with the post-2020 global biodiversity framework [6], which establishes milestones and action plans to accomplish the global target of the Convention on Biological Diversity. One of the main goals of the EU Biodiversity Strategy is 'to restore nature and ensure sustainable management', including quantitative targets such as 'planting at least 3 billion additional trees in the EU by 2030' [6, p 9]. The commission's working document on the 3 billion trees planting target, along with the New EU Forest strategy 2030, provide additional insights into how this target might be achieved. Yet, the further implementation guideline is still under development [7, 8]. Moreover, there have been several critiques of this target based on: (a) a lack of consideration of ecological constraints [9], (b) a lack of spatial coherence [10], and (c) the absence of an indicator to monitor the progress in achieving the target [11].

Furthermore, the EU strategy lacks consideration of the consequences for land use/cover change of such policy measures. Large-scale tree planting has the potential to require large land areas that can cause undesired conflicts among different land-based objectives such as food or fodder production, or other land-based climate change mitigation options [12–14]. Furthermore, countries that increase their domestic forest cover areas often displace deforestation through commodity imports [15, 16]. About 26% of the global deforestation has been caused by international demand and trade, mostly in food [17]. Europe is one of the regions for which domestic forest area increases have displaced deforestation to other parts of the world [17, 18].

As with other EU-level regulations such as the Common Agricultural Policy (CAP), the Biodiversity Strategy takes a top-down approach. The European Commission (EC) sets out its policy aims and member states (MSs) define their own options and strategies for implementation based on national conditions and priorities [19]. In the case of the CAP, this top-down process often diminishes the initial ambition in terms of environmental protection and sustainability and the negotiation process between the EC and MS is often not transparent [19, 20]. Likewise, EU forest policy relies on the relationships between EU-level priorities and MS-level operations and the differences between these often lead to failure in achieving the EU-level policy goals [21, 22].

In this study, we explore different options for the implementation of the EU's 3 billion tree planting target. We estimate the potential land areas that would be required to support this number of new trees per MS from (a) historic trends in forest extension, (b) suitable areas for potential tree species in each MS, and (c) planting on abandoned agricultural land. We also compare national afforestation targets with the EU level target. In light of the analytical results, we discuss the broader sustainability consequences of achieving the 3 billion tree target.

2. Methods and materials

2.1. Optimal options for each member state

2.1.1. Tree density calculation

Translating numbers of trees planted into a land use area requires insight into national level differences in the tree species that are grown and their planting densities. The most common tree species in each country were derived from Mauri *et al* [23], who provide information on the natural distribution of European tree species. We assumed that the most abundant tree species from these data were the most abundant tree species per country, thus were assumed to be species adapted to local conditions. Using mixture of those species to design planting compositions we avoided the introduction of exotic species and thus supporting local biodiversity. This is also consistent with the policy aim of the EU Biodiversity Strategy 2030 to follow the rule of 'full respect of ecological principles' when planting 3 billion trees [6, p 9]. From this list, we derived three alternative species compositions based on ecological compatibility of the most abundant species under natural conditions, which became a basis for the planting options for each MS (supplementary table 1). All the options consist of a mixture of several species.

The tree planting densities of these species compositions were derived from a literature review (for the list of literature, see supplementary material 2). We used a gap-filling method, when information about certain tree species in certain countries was missing. The detailed procedure of the gap-filling process is provided in the supplementary material 1. When the tree density of a certain species in a country was reported in the literature with a range (e.g. 3000–5000 tree ha^{-1} for *Fraxinus excelsior* in Germany), we considered the lower bound of the range in our analysis. The tree density is especially of importance when controlling the stem quality in traditional forestry whose major purpose is timber production [24]. As the purpose of the tree planting in our analysis is ecological restoration rather than timber production, we used the lower bound. The tree planting densities for each species were averaged per option (see supplementary material 2).

2.1.2. Ecologically suitable areas

We determined the area of each country that is suitable for planting each tree species using chorology maps from Caudullo *et al* [25]. which provide a synthetic overview of species distribution range. In their data, they also used a digital elevation model as background information. For the more detailed information about the coverage of species and data sources, readers refer to Caudullo *et al* [25]. Where chorologies existed for multiple varieties of a species, we merged these into a single chorology. The chorology map was rasterised into a 10 × 10 km grid for each country.

2.1.3. Selection of optimal options for MSs

When multiple options (up to three) were available for a grid cell within a country (supplementary table 1), we chose the geographically optimal option based on maximising the number of trees. When an area was suitable for all three options, the option with the maximum number of trees was chosen. When the suitable areas did not overlap within a country, multiple options with multiple species were considered in different areas within a country. The optimal number of trees per ha was mapped onto the 10 km grid. In addition, we also calculated the minimum number of trees to provide a range of options for the number of trees per country.

2.2. Historic trend

The historic trend in afforestation was calculated from the Land use data provided by the Food and Agricultural Organisation of the United Nations (FAO), FAOSTAT database[9]. Among forty-one categories of FAO Land use classes, 'Forest land', 'Naturally generating forest' and 'Planted forest' were compiled for the period from 1990 to 2019. The 'Forest land' category is a sum of 'Naturally generating forest' and 'Planted forest'. The definition of each category is summarised in the supplementary material 1.2. For a business-as-usual (reference) projection of forest area from 2021 to 2030, we used a linear model based on the same period (last ten years) from 2010 to 2019.

2.3. Abandoned agricultural land

Abandoned agricultural land has often been discussed as providing capacity for afforestation in order to respond to environmental policy goals [26]. Therefore, we aim to explore the potentially required land area for planting three billion trees on abandoned agricultural areas. Here we follow the definition of abandoned land as 'the cessation of agricultural activities on a given surface of land and not taken by another activity (such as urbanisation or afforestation)' [27, p 202]. We used the HIstoric Land Dynamics Assessment+ (HILDA+) database to create an EU-wide abandoned land map [28]. HILDA+ defines annual land use changes between six land use/cover classes (cropland, pasture/rangeland, forest, unmanaged grass/shrubland, sparse/no vegetation and urban) from 1960 to 2019 at a 1 km spatial resolution [29]. We estimated abandoned land as the areas that were cropland in 1960 but remained as unmanaged grass/shrubland or sparse/no vegetation in 2019. However, land that was already abandoned some time ago is expected to have developed mature vegetation, including trees, through a process of natural succession. Hence, we assumed that these areas would not be used for tree planting because cutting down mature vegetation to plant new trees is not desirable. To account for this, we considered the year of the last land use change event to unmanaged grass/shrubland or to sparse/no vegetation using two time thresholds; five and ten years before 2019. If a grid cell was 'unmanaged grass/shrubland or sparse/no vegetation' for longer than the threshold years (meaning that the last event was before 2009 or 2014 for ten-years [30] and five-years [31], respectively), it was not considered to be a potential area for tree planting. The resulting abandoned land areas were then matched with the areas of ecologically suitable and optimal options in each MS.

[9] www.fao.org/faostat/.

2.4. National afforestation target

To compare the European-level policy target and MS-level objectives for the 27 MS, we reviewed national afforestation targets for each MS through the grey literature. When available, policy documents that were officially published by each MS were used. If such documents were not available, we used alternatives such as those provided by organisations such as Forest Europe or press releases. The relevant references for each MS policy target are provided in table 1.

3. Results

3.1. Tree planting options

The average tree planting density for all options per country is 2931 trees per ha (supplementary table 1), hence on this basis 3 billion trees would occupy an average land area of 1.02 Mha (min. 0.81 and max. 1.37 Mha). However, planting density varies greatly between the different options and geographically between countries (average s.d. = 871 trees per ha). There was no difference in the number of trees across options for Bulgaria and Croatia, while it varies greatly for some countries such as Portugal and Spain depending on which option is chosen. The average number of trees per ha across options was 1844 trees and 2038 trees for Portugal and Spain, respectively. However, their standard deviations across the options were 2544 trees per ha and 1766 trees per ha, for Portugal and Spain, respectively, resulting from the low planting density of Mediterranean oaks (45 trees per ha) (supplementary table 1). The maximum average planting density per ha was found in the Czech Republic with 4416 trees (s.d. 1467 trees per ha), resulting from the high planting density for Scots pine in particular (10 000 trees per ha). Tree planting densities vary for the same species depending on the location. Scots pine in particular can be planted at a maximum density in the Czech Republic, whereas the minimum number of trees per ha for the same species was only 1800 trees per ha in Finland (Europe-wide average is 5067 trees per ha) (supplementary table 1).

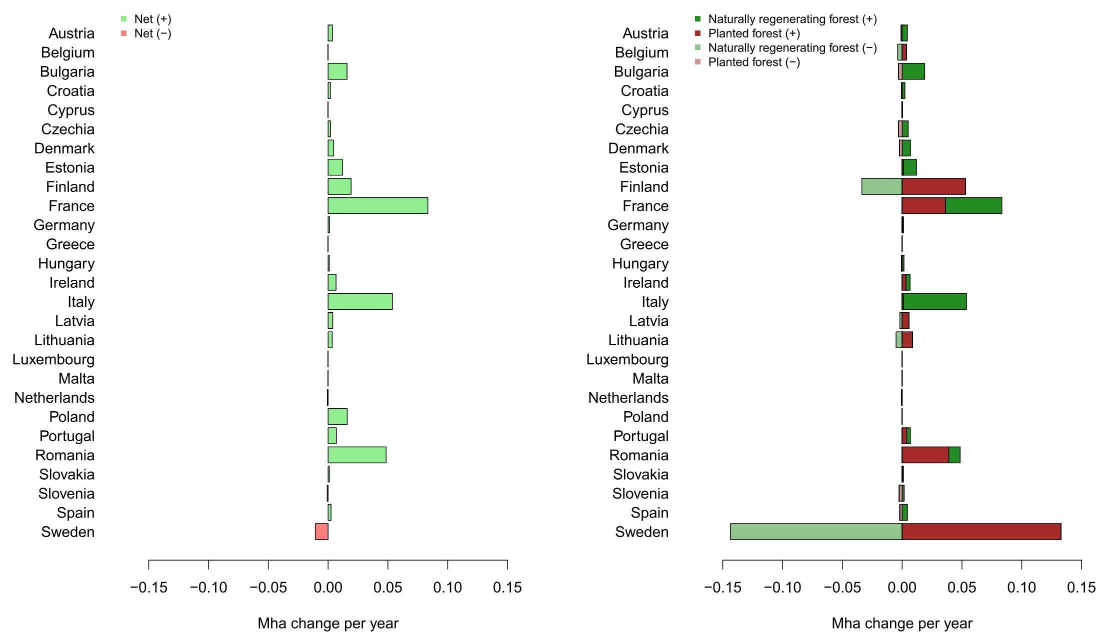

Figure 1. Net Change in forest land per each Member State (2010–2019). left: net change in total forest land, right: composition of the forest land with naturally generating forest (green) and planted forest (brown).

The number of different tree species found in the planting options is 47 across the EU27 countries. The most common tree species among the options is *Pinus sylvestris*, which is found in 17 countries.

3.2. Historic trend in afforestation

The European forest area has increased over the last decades although the rate of increase has declined more recently (supplementary figure 1). The pattern of changes in forest area differs amongst the EU 27 countries (figure 1). While France had massive forest expansion at a rate of 0.083 Mha per year, forest area in Sweden has declined by 0.01 Mha per year on average (figure 1, left). France experienced increases in both naturally generating forest and planted forest (figure 1, right). Most countries' forest expansion occurred mainly through natural regeneration (figure 1, right), while new forests in Sweden and Finland were mainly planted. Sweden had the largest increase in planted forest area (0.133 Mha per year), yet its naturally generating forest has declined (0.143 Mha per year), which has resulted in an overall decline in forest area. Some countries such as Luxembourg, Malta, Cyprus and Croatia have had relatively little, or no change, over the last ten years.

Based on the historic trend, the projected increase in forest area to 2030 is 3.19 Mha based on the historic trend, which is about a 2% increase compared to the year 2019 (from 159.05 Mha to 162.24 Mha in 2030). This area of forest would accommodate 11.1 billion trees based on the average planting density calculated here, which is 3.7 times higher than the 3 billion trees planting target. The maximum number of trees was found in Italy with an additional 2.47 M trees followed by France with 2.37 M trees and Romania 2.26 M trees. Sweden, Slovenia, and the Netherlands had a negative trend (figure 2).

3.3. Abandoned land in Europe

In the EU27, 8.8 Mha of land was abandoned since 1961, which could accommodate 25 billion trees based on the optimal planting density per country, i.e. more than 8 times the EU target. When we only consider the areas that were abandoned less than 10 years ago (since 2009) and five years ago (since 2014) as being suitable for tree planting, the available areas reduce to 2.6 Mha (accommodating 7.2 billion trees) and 0.2 Mha (accommodating 741 million trees) (figure 3). This implies that recently abandoned land could provide space for the 3 billion tree target, assuming that succession vegetation through natural regeneration has not already become established. However, more recently abandoned land (five years ago), whilst unlikely to have developed mature vegetation, is also unlikely to provide sufficient area for the EU target. There are, moreover, implications for alternative uses of abandoned land, such as for food production, that are discussed later.

Figure 4 shows the location of ecologically suitable areas for the optimal options that overlap with abandoned agricultural land. Poland has the most abandoned land since 2009 where optimally 1789 M trees in total could be planted, followed by Italy with 1561 M trees and Hungary with 994 M trees (figure 3(a)). Recently abandoned areas are much less common in Poland (figure 4(b)). Italy has the most

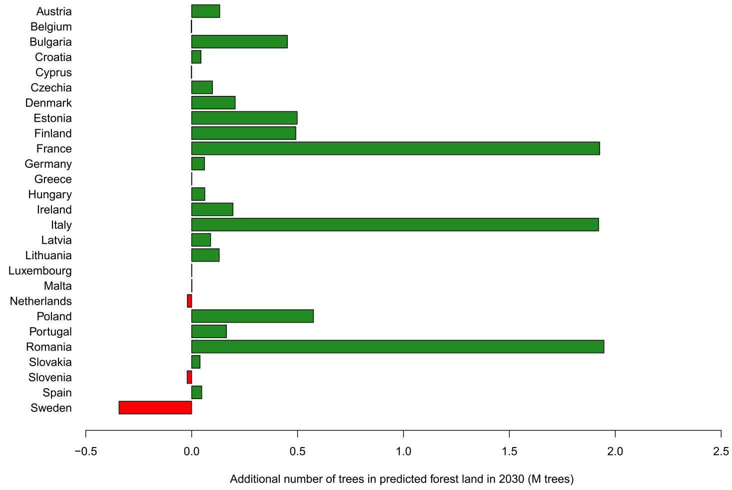

Figure 2. Additional number of trees in predicted forest land in 2030 (MHa).

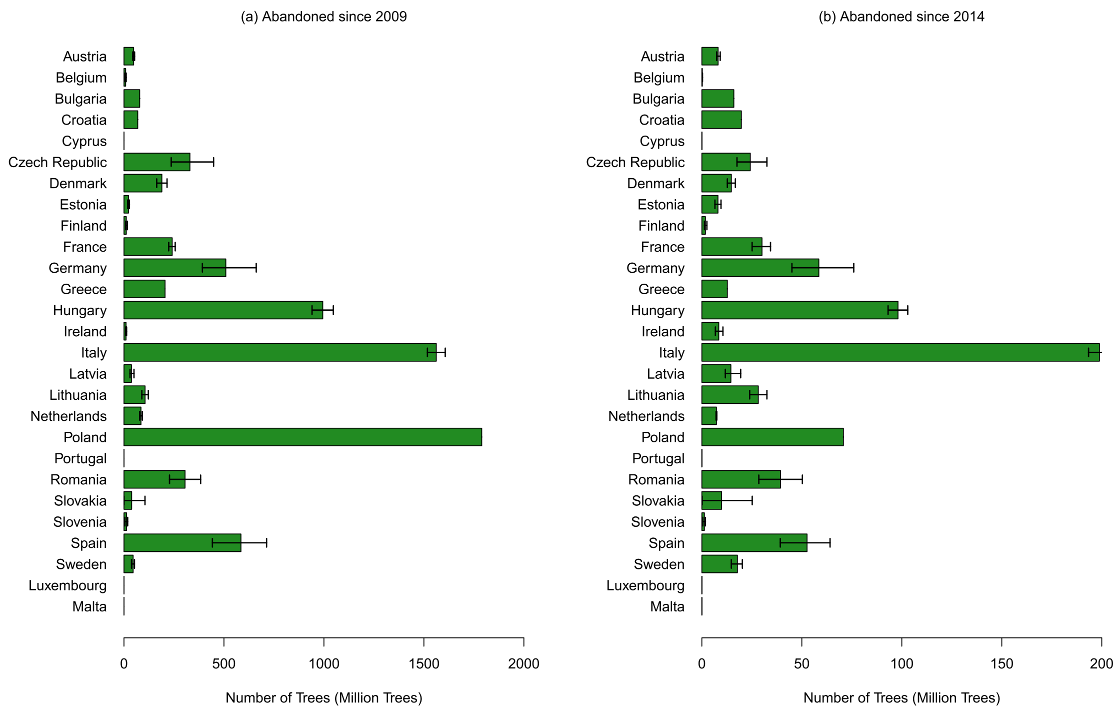

Figure 3. Number of trees that can be planted in abandoned agricultural areas in each MS: (a) Abandoned since 2009, (b) Abandoned since 2014. Error bars show a range between the maximum (optimal) and the minimum number of trees that can be planted in the same area depending on the option.

abandoned areas when considered only from 2014, potentially allowing 198 M trees followed by Hungary with 98 M trees and Poland with 70 M trees figure 4 also shows that abandoned areas are more concentrated in Eastern Europe.

3.4. National Policy

Amongst the 27 EU MS, 15 MS set specific quantitative targets for afforestation or tree planting, although four of these are not consistent with the 2030 time limit or have no time limits (table 1). The other 12 MS did not set a specific quantitative target, but rather a qualitative target such as 'sustainable management'. In general, when available, the specific targets are even higher than the ecologically suitable agricultural abandoned land where tree planting could occur. For example, Poland aims at afforestation on 1.5 M ha, whereas the ecologically suitable agricultural abandoned land since 2009 is about 0.9 Mha. Hence achieving this target would necessitate additional land use change, e.g. conversion of agricultural land to forest.

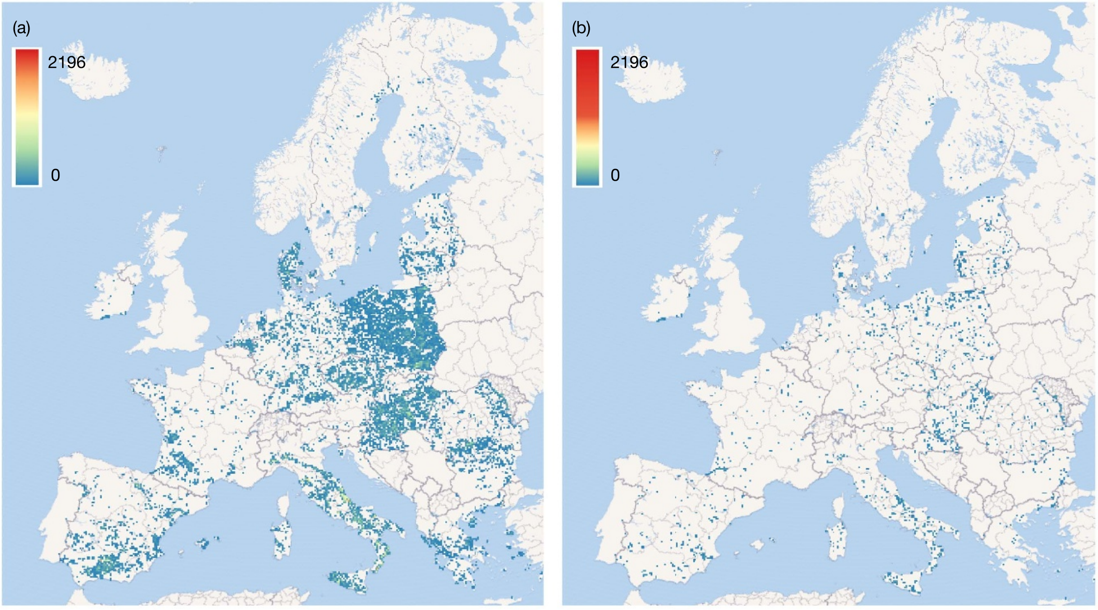

Figure 4. Map of the number of trees that can be planted in areas where ecologically suitable areas for the optimal options overlap with abandoned agricultural areas in each MS. Average number of trees per ha in abandoned areas (10 km resolution): (a) Abandoned since 2009, (b) Abandoned since 2014.

Table 1. Summary of forest policy in each member state.

Member state	Policy target	Evaluation	Source
Austria	Increase in the forest area in regions with low forest cover until 2030	no specific quantitative target mentioned	[32]
Belgium	Encourage a change in land use to increase carbon storage	no specific quantitative target mentioned	[33]
Bulgaria	Forestation of 2000 ha bare forest lands and afforestation of 2500 ha of an abandoned agricultural land and on land eroded or threatened by erosion until 2030	Specific and quantitative target	[32]
Croatia	The forests and the forest land cover 47.5% of the total surface area for the period 2016–2025	Specific and quantitative target	[34, p 205]
Cyprus	Starting from around 70,000 trees in 2020, it is planned to reach 300 000 tress planted per year in 2030	Specific and quantitative target	[35, p 242]
Czechia	Rural Development Programme will support afforestation of 920 ha of agricultural land between 2014–2022	Specific and quantitative target, but limited time frame	[36]
Denmark	Before the end of the 21st century, forested landscapes cover 20%–25% of the total area	Specific and quantitative target	[32]
Estonia	Sustainable forest management	no specific quantitative target mentioned	[37]
Finland	Increase of the annual increment in all forests from 105 M m^3 in 2013 to 115 M m^3 in 2025	Specific and quantitative target	[32]
France	50 million trees	Specific and quantitative target, but no time mentioned	[38]
Germany	Maintaining and improving the forest's capacity to act as a carbon sink, sustainable forest management to maintain multiple function of forest	no specific quantitative target mentioned	[39, 40]
Greece	10 million trees in about 50 000 hectares by 2030	Specific and quantitative target	[41]

(Continued.)

Table 1. (Continued.)

Member state	Policy target	Evaluation	Source
Hungary	Increase in the forest cover from 21% to 27% of land area	Specific and quantitative target	[42]
Ireland	Increasing forest cover from 10.7% to 18% by 2046	Specific and quantitative target	[43]
Italy	Sustainable forest management	no specific quantitative target mentioned	[32]
Latvia	NA	no specific quantitative target mentioned	
Lithuania	Afforestation of 30,000 ha according to the National Forestry Sector Development Programme for 2012–2020	Specific and quantitative target, but limited time frame	[32]
Luxembourg	Targeting biodiversity-rich afforestation and reforestation campaigns	no specific quantitative target mentioned	[44]
Malta	No political actions mentioned	no specific quantitative target mentioned	
Netherlands	100 M trees by 2030 by State Forest Management	Specific and quantitative target	[45]
Poland	Afforestation of 1.5 million hectares of post-agricultural land by 2050, an increase in the proportion of the country under forest to 33%	Specific and quantitative target	[46, 47]
Portugal	Sustainable forest management	no specific quantitative target mentioned	[32]
Romania	A total of 2500 new forests will be planted	Specific and quantitative target	[48]
Slovakia	NA	no specific quantitative target mentioned	
Slovenia	NA	no specific quantitative target mentioned	
Spain	Nearly 4 million ha increase of forest area by 2032	Specific and quantitative target	[32]
Sweden	multifunctional sustainable management	no specific quantitative target mentioned	[32]

4. Discussion

Tree planting, potentially, is considered to have biodiversity and climate change mitigation benefits. However, afforestation programmes can cause undesired consequences with respect to ecological, biophysical and socio-economic aspects [49]. It can be beneficial when the areas are severely disturbed sites such as by soil erosion [50] or sites with low biodiversity value [51], yet the negative impacts on biodiversity have been also found as it simplifies the habitat [9, 52–54]. Therefore, tree-planting targets require careful implementation based on understanding wide-scale biophysical processes [55] and the importance of current and potential tree populations in local conditions [56].

Planting density is critical as it determines the required land area for afforestation for a tree-based target. We found the average tree planting density to be 2931 trees per ha based on a literature review, which is about two times higher than the guidelines provided by the European Commission (average 1000 to 1500 trees per ha) [8]. Those guidelines do not provide further details about the assumptions used to arrive at this density level. Another previous remote-sensing-based study reported substantially lower tree density values relative to a comparable area [57]. However, remotely-sensed products base their tree density assessment on existing mature forest canopy cover expressed in area [56]. This implies that their calculations are mainly related to (sub-) mature forests, where trees are bigger, and therefore less dense than in newly planted forest where density is a factor for controlling competition with shrubs and herbaceous plants. Additionally, it is well known that the relationship between forest area and tree (biomass) densities is not always linear [58, 59]. As planting densities vary greatly between species and across geographies [60], they need to be considered differently in each country.

European forest areas have expanded over the last 30 years, although the rate of expansion has declined [28, 61], which is also shown in our analysis (supplementary figure 1). If the recent (last ten year) forest expansion rate continued for the next ten years, it would provide more than 3 times more forest area than the EU tree planting policy target. Furthermore, the 3 billion tree policy target is much lower than the targets other global afforestation initiatives such as the Bonn Challenge, which aims at restoring 350 Mha of deforested and degraded land globally by 2030 [62, 63]. An area proportional attribution of the Bonn Challenge target to Europe (4.36%) would give an increase in forest area of 15.26 Mha by 2030 [63]. Also, Europe's regional initiative, ECCA30, aims to restore 30 Mha of degraded and deforested land in Europe, the Caucasus and Central Asia into restoration by 2030 [64].

In addition, our result showed that the cause of increased forested land is different depending on the MS. Unlike other countries, forest expansion in Sweden and Finland occurred through planting. It can be explained that Northern European countries have predominance of private ownership of forest [32] that strongly relies on timber markets.

Nevertheless, further land use change is likely to be required to meet the 3 billion tree planting target as well as national targets. France had the largest forest expansion over the last ten years (supplementary figure 1). As with other European countries, France has experienced agricultural intensification, mechanisation, and an increase in average farm sizes as well as several policy incentives to promote afforestation after WWII [65, 66]. However, there are also trade-offs between the carbon sequestration benefits of afforestation and the environmental disbenefits associated with agricultural intensification that should be carefully considered [66, 67]. Furthermore, international agricultural trade (i.e. food imports to Europe) can be the cause of deforestation elsewhere in the world [68]. For example, emissions from tropical deforestation have been estimated to be about 15% of the EU food consumption carbon foot print [69].

Similarly, abandoned agricultural areas have expanded across Europe because of agricultural intensification, globalisation of agricultural markets, and a shift to post-socialist governance in Eastern Europe [29, 70, 71]. The important drivers of agricultural abandonment in Europe include unsuitable biophysical conditions and low farm structural stability such as weak land markets, low market access opportunities, and a lack of on-farm investments [72]. Secondary succession or re-vegetation occurs after abandonment, which leads to either forests, shrubland, or extensive use for hobby farming or horse boarding depending on the surrounding biophysical factors and social factors [31, 73]. However, tree planting on abandoned land does not account for the counter-factual of supporting the use of this land for food production, and thus reducing the displacement effects of food imports causing deforestation in other parts of the world.

Whilst European forest areas are already expanding into these abandoned agricultural areas as a result of afforestation, ecosystem restoration by natural succession and climate change [73, 74], the ecological consequences of agricultural abandonment remain unclear [70, 75]. One study highlighted that 65% of case studies in Europe reported negative ecological consequences of agricultural abandonment [75]. European farmland is sometimes associated with a high value for biodiversity with a large proportion of species with a higher conservation value, especially on low-intensive farmland [75, 76], whereas forests are often associated with relatively fewer species compared with agricultural land with high biodiversity value [75, 77]. However, given the various issues discussed here, it is critical to manage the consequences of abandonment and the use of abandoned land in an ecologically appropriate manner.

We used two thresholds, five and ten years since abandonment, to identify the areas potentially available for tree planting to acknowledge the positive effects of natural re-vegetation processes. Some areas experience re-vegetation in a relatively short period of time (3–5 years) [refers to the review studies 31, 73]. Such natural processes are sometimes recognised to be more sustainable than active restoration through replanting, since they are cheaper and species are already adapted to the local climate and biophysical conditions [73, 78]. They may, however, be limited by seed availability for some species if there are insufficient mature individuals in the surrounding landscape. Ecosystem restoration by natural regeneration can also increase biodiversity and water quality in the short term, and reduce soil erosion [31, 79]. Poorter *et al* [79], for example, showed that biodiversity and ecosystem functioning recover more quickly in naturally regenerated forest than in planted forest in the tropics. It is also important to weigh the ecological value of grassland ecosystems created by revegetation against the value of tree plantations in the first place. A meta-analysis revealed a slightly increased species richness after agricultural land abandonment in the Mediterranean Basin [80]. Conversely, natural succession is sometimes considered to be negative since it can also lead to landscape homogeneity and the loss of cultural landscapes [31, 73, 81]. Whether planting trees after agricultural abandonment leads to a benefit for biodiversity or for ecosystem restoration varies greatly from region to region and therefore cannot be clearly determined.

When exploring the different time-based, abandonment thresholds, the suitable areas for planting trees reduced markedly from 8.8 Mha since 1961 to 2.6 Mha and 0.2 Mha for ten-year and five-year thresholds, respectively. The causes of agricultural abandonment have changed through time. Early agricultural abandonment (1961–1990) can be explained by socio-economic factors such as the collapse of the Soviet Union [82–84]. More recent abandonment (1990–2020) was mostly caused by bio-physical conditions in the Mediterranean region such as in Italy [31, 85, 86]. Increased droughts and temperature anomalies have altered agricultural abandonment in the past and will likely affect tree planting strategies, especially in southern Europe, in the future.

Moreover, other policy developments will also alter the pattern and extent of agricultural land abandonment. As an EU response to Russia's invasion of Ukraine, the EU now allows food crop production on set-aside land and will expand the cropland area by 4 Mha [87]. Set-aside policy in Europe was first established in 1988 to control overproduction then abolished in 2007 followed by the fallow land policy which aimed to promote farmland biodiversity [88, 89]. The set-aside or fallow land policies promoted insect, bird and plant diversity [90, 91]. EU sanctions following the Ukraine-Russia war will probably affect land use in Europe, and therefore will have a direct impact on the available land that could potentially be used for afforestation.

5. Conclusion

This study explored different planting options for 3 billion new trees that are ecologically suitable for each MS. We show that although 3 billion trees sounds ambitious, this target falls short of the historic trend in forest expansion, the potentially available agricultural abandoned land, national afforestation targets, and global initiatives such as the Bonn Challenge. Moreover, the large variation in the planting densities for different species in each MS suggests that expressing afforestation targets as a number of trees could be inefficient and potentially lead to failure. Hence, we suggest that the MS would be better placed in planning planting actions based on locally suitable planting densities on available land.

Historic afforestation within the EU has been associated with deforestation in other parts of the world embodied in food imports (e.g. Fuchs *et al* [68]). Hence, greater afforestation ambition within the EU could have negative impacts on biodiversity elsewhere in the world. We argue, therefore, that the EU's relatively low level of proposed tree planting is appropriate from an environmental perspective given the potential negative impacts of further afforestation on deforestation elsewhere in the world. This highlights the importance for policy makers of understanding and therefore minimising the displacement effect of further EU tree planting. Without this, afforestation in the EU would simply outsource the problem of biodiversity loss to other parts of the world.

Data availability statement

The data cannot be made publicly available upon publication because they are not available in a format that is sufficiently accessible or reusable by other researchers. The data that support the findings of this study are available upon reasonable request from the authors.

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Conflict of interest

The authors declare no conflicts of interest.

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