Ecological Economics 201 (2022) 107553

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

A new composite indicator to assess and monitor performance and drawbacks of the implementation of Aichi Biodiversity Targets

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ARTICLE INFO

Keywords:
Composite indicators
Aichi Targets
BoD-DEA models
Governance
Nature conservation
International conservation policies

ABSTRACT

This paper proposes a new composite indicator for the assessment of the implementation of Aichi Targets (ATCI) following a benchmarking approach simultaneously considering performance and drawbacks. ATCI is based on 37 indicators related to the 5 Aichi Strategic Goals and its aggregated scores and ranks are calculated using three BoD-DEA models to integrate performance and drawback scores for Targets. ATCI was applied to 21 European countries and its scores were mapped and classified into four groups according to their location in performance-drawbacks space: S1) Caution, S2) Excellence, S3) Fragility and S4) Catching up. Countries in S1 and S3 are recommended to mitigate drawbacks to facilitate the implementation of the Aichi Targets. Results showed that 52% of the countries (Italy, Hungary, Greece, Czechia, Belgium, Poland, Portugal, Spain, Latvia, Slovenia and Slovakia) should pay urgent attention to the Aichi Targets since they show the highest limitations. Based on limitations, two country profiles were identified: countries with high economic development, high population density and corresponding impacts on biodiversity, and countries of medium/low economic development, weak governance and few drawbacks related to human impacts on the environment. These impacts, however, can be aggravated if their economic situation improves and institutional constraints are not addressed.

1. Introduction

The accelerated loss of biodiversity brought about by humans in the last millennia is a reality agreed upon by the scientific community. The devastating results of human action on ecosystems shown by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) confirmed the increasing conversion of the world's large terrestrial biomes to agricultural land use, the loss of genetic variability of wild and domestic species, and a decline in the number of species and the homogenization of their distribution. This and other assessments support international initiatives to tackle biodiversity loss. The Strategic Plan for Biodiversity 2011–2020, approved during the tenth meeting of the Conference of the Parties of the Convention on Biological Diversity (CBD) held in Nagoya, Aichi Prefecture, Japan, with the support of 196 countries, seeks to foster the implementation of the CBD through five strategic goals aimed at reducing the pressure on biodiversity and ensuring the implementation and scope of the plan (CBD, 2010). This plan was materialized in 20 biodiversity-related targets (Aichi Biodiversity Targets) that were to be achieved within a decade. Undoubtedly, this is an important initiative to implement decisive actions to halt the dramatic decline of biodiversity worldwide. However, it is essential to be able to objectively quantify the progress of this international commitment in order to measure its impact and effectiveness, as well as to have an honest representation of the degree to which countries are complying with it and the difficulties they find it its implementation.

The first global analysis on the progress of Aichi Targets (AT) provided a 2020 forecast based on historical trends in pressures, states, benefits and responses (Tittensor et al., 2014). They used 55 indicators associated with 16 ATs and a time series analysis to predict the worldwide effects of ATs in 2020. In a different evaluation, Han et al. (2014) selected 4 key indicators to measure AT achievement at the regional and national levels (Forest coverage and rate of gross forest cover loss, Red List Index, Protected Area coverage in key biodiversity areas and Quality-weighted freshwater provision from natural ecosystems to downstream human population) and applied them to measure progress in the Tropical Andes, African Great Lakes and Greater Mekong. The highest rate of loss of species was found in the Tropical Andes, while the greatest concern for fresh water provisioning was observed in the

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https://doi.org/10.1016/j.ecolecon.2022.107553
Received 16 November 2021; Received in revised form 6 June 2022; Accepted 22 July 2022
Available online 30 July 2022
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Greater Mekong countries. There were also large differences in the efforts made by neighboring countries to safeguard key biodiversity areas, such as Mozambique and Tanzania. In this way, these indicators allow for a quick and broad assessment of the state of conservation of biodiversity and for identifying trends and patterns.

Other researchers addressed achievements at the individual AT level. Cooper et al. (2019) measured the progress of AT 1 (biodiversity value awareness and steps requires for its conservation and sustainable use) by tracking the use of biodiversity-related keywords in 31 different languages in online newspapers, social media and Internet searches. They identified temporal patterns in which biodiversity-related conversations were less frequent on the weekends. Moreover, the scores of the global indicator they developed varied greatly from country to country with Ecuador, Ethiopia, Guatemala, Canada, Fiji and New Zealand scoring high on all platforms. Shepherd et al. (2016) assessed the progress of AT 14 (restoration and conservation of ecosystem services) using 21 indicators related to the status, benefits and access to 13 ecosystem services essential for human well-being. Their results showed that 60% of the benefit indicators displayed positive trends, while 86% of the status indicators showed decline of natural capital.

The studies above were carried out prior to 2020 and focused primarily on trend analysis to make predictions. More recently, Buchanan et al. (2020) provided an up-to-date global analysis on the progress of eight ATs (1,4,5,7,11,12,19,20) using 11 indicators. They measured progress by comparing the results provided in the 5th and 6th National Reports on progress on Biological Diversity and analyzing their relationship with governance, GDP per capita, population density and degree of urbanization. The results showed that 24.2% of the countries were moving forward, 22.3% were moving away and 53.5% remained unchanged with respect to ATs. In addition, they identified that progress made towards the ATs was related to good governance and, to a lesser extent, high GDP per capita, population density and degree of urbanization.

This research and institutional reports (e.g., IPBES, 2019) have provided valuable information for the planning of the UN 2030 Agenda for Sustainable Development and 2030 Biodiversity Targets. They have also highlighted issues that need to be urgently addressed. Studies such as Marques et al. (2014) have shown the need to prioritize biodiversity targets by bringing to the table the debate on urgent conservation actions and long-term sustainable actions. They introduced a framework to identify and prioritize urgent actions based on the correlation between different objectives and the time invested-time to be achieved ratio. They concluded that, given the current decline in biodiversity, urgent action should be taken to ensure the achievement of strategic objectives B (Reduce the direct pressures on biodiversity and promote sustainable use), C (To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity) and D (Enhance the benefits to all from biodiversity and ecosystem services), which focus on controlling direct pressures on biodiversity and ecosystems and provide noticeable results in the short term. Other studies shed light on the need to consider the complex and inescapable relationship between social, economic and institutional and ecological systems, as well as the challenges that these interrelationships may pose for the achievement of conservation objectives. The pioneering biodiversity conservation policies that emerged some 150 years ago consisted primarily of national policies. In the last century, these conservation policies have shifted from focusing on habitat and species to placing particular emphasis on integrating conservation with social objectives (Bonn et al., 2020). This transformation from ecological to social-ecological systems implies that the indicators used to measure the status and progress of conservation programs ought to be updated. In this sense, Hill et al. (2015) stressed the need to include socio-ecological constraints that are obstacles to the implementation of ATs or measuring their achievements. Their results showed that, based on such constraints, only 2 ATs would be fully achieved, while 3 ATs would be partially achieved. Cook and Davíðsdóttir (2021) identified interlinkages between macro-economic indicators of well-being and Sustainable Development Goals. They provided a conceptual framework based on the use of alternative measures of economic well-being, in addition to traditional well-being measures such as GDP and emerging indicator sets, in order to perform macro-economic evaluation and more realistically measure the economic wellbeing of a country.

Driscoll et al. (2018) defined the current biodiversity crisis by identifying in a hierarchical or sequential manner the elements involved in such a crisis. In other words, they identified indicators, in a staggered, non-linear manner, at various levels. This makes it possible to comprehensively monitor human behavior and that of the institutions that drive biodiversity loss and that, to date, have hindered progress towards achieving global biodiversity targets. They concluded that some factors, such as government monitoring, corruption, population size, and the threat posed by some industries, are not being adequately managed, which affects the attainment of the ATs. Meehan et al. (2020) presented a set of indicators to measure the achievement of AT 11 (17% of terrestrial and inland water areas and 10% of coastal and marine areas in protected areas), while also considering governance, economic, social, and ecological dimensions. The study identified 16 indicators associated with six quality elements: Equitable management, Integrated (into wider landscape and seascape), Areas of importance, Well-connected, Ecologically representative and Effective management.

The literature review on the topic reveals that there is an urgent need for comprehensive and rigorous indicators to assess and monitor international conservation policies. These indicators are key to analyze achievements, as well as to provide useful information in deciding among competing policy options. However, although the fifth and sixth reports of the Convention of Biological Diversity (CBD) noted that there was substantial variation among countries in the level of progress they had made towards each of the ATs, there has been no formal analysis of available data for this purpose. Indeed, the lack of concordance between indicator-based national progress and that assessed by the CBD highlights the uncertainty that may exist regarding the measurement of progress towards targets at the national level (Buchanan et al., 2020).

In Europe, since 2003 and in parallel to the CBD, a number of processes have been applied to develop biodiversity indicators. In fact, there are extensive lists of indicators to measure different elements of biodiversity. However, although in the present case it is important to analyze the progress of each AT separately, composite indicators are particularly useful for effectively communicating broader trends in biodiversity (Mace and Baillie, 2007). To this date, no composite indicator that takes into account the structural constraints to the implementation of ATs has been developed for measuring their achievement per country. Out of the six papers concerned with measuring AT achievement, only Cooper et al. (2019) proposed an aggregated index to measure the achievement of AT 1. The remaining papers reviewed here assessed the progress of each indicator separately (Table 1).

Although providing important approaches and methods to the

Table 1
Studies analyzing performance for Aichi Targets, described in terms of targets addressed, use of aggregation procedures and number of indicators included.

Reference	Aichi Target	Aggregation	Number of indicators
Han et al. (2014)	Global (4 key AT: 5,11,12,14)	No (Trend analysis)	4
Tittensor et al. (2014)	Global (16 ATs)	No (Pre2010-Post-2010/ Trend analysis/ estimation)	55
Shepherd et al. (2016)	AT 14	No (Tracking of trend-Trend analysis)	21
Cooper et al. (2019)	AT 1	Average	3
Buchanan et al. (2020)	Global (8 ATs)	No (Before-after; progress analysis)	11
Meehan et al. (2020)	AT 11	No	16

assessment of the achievement of the ATs, these studies presented a partial analysis of the achievement of the ATs, focusing on one or few ATs. Tittensor et al. (2014) was an exception by providing a very complete assessment of the progress of the worldwide achievement of the ATs, although they only considered, as the remaining studies, the achievement of ATs, not limitations to their achievement. In this study we present a new index to assess and monitor in a flexible and combined way both performance and drawbacks of the implementation of Aichi Biodiversity Targets.

2. Constructing composite indicators to assess global biodiversity targets

Composite indicators (CI) are useful for the implementation, monitoring and improvement of public policies, as they provide more information and are more easily interpreted than individual key indicators. Since the early 20th century, the pursuit of methods to address sustainable development policies evaluation has produced an array of indicators potentially leading to information fatigue and information overload by decision-makers (Jollands, 2006). For this reason, the past two decades have seen the development of a number of aggregate indicators, such as the popular Ecological Footprint Indicator and the Living Planet Index (Global Footprint Network, 2021; Living Planet Index, 2016; Tittensor et al., 2014). Despite the emergence of empirical index proposals, not much literature has been produced on the critical methodological aspects associated with the construction of aggregate indicators to measure the success of international conservation policies. The construction of CIs is not an easy task and several issues may condition their effectiveness.

In designing a CI there is a common procedure that can be broken down into six stages: i) selection of variables and dimensions, ii) calculation of the value of the sub-indexes, iii) weighting of variables, iv) aggregation, v) calculation of the final value, and vi) evaluation of the robustness of the indicator (Juwana et al., 2012). Some of these stages are extremely relevant in the way they affect the metrics and their meaning.

For instance, the weighting of variables stage (iii) is extremely important in the CI design since it can greatly condition its final result. Equal weighting is the most common method used in the development of CIs (Greco et al., 2019). Although it may be perceived as "neutral equal weighting it is not truly neutral since the criteria analyzed do not always bear the same importance (Fernández Martínez et al., 2020). Thus, the equal weighting method is not able to differentiate between essential and less important indicators and treats them all in the same way (Greco et al., 2019). Other processes of assigning weights to variables include individual, stochastic or participatory methods. Individual weights are established by the analyst according to his/her knowledge and/or previous experience. This approach is usually used as it is very easy to apply (OECD, 2008). Stochastic weighting processes establish weights using simulation methods, or probabilistic or optimization models. Weighting based on participatory processes incorporates weights as determined by decision-makers, experts, stakeholders or the general public. The main limitation of participatory methods is the large amount of resources and time they require, although they are particularly suitable for dealing with conflicting issues such as those involved in natural resources management (de Castro-Pardo and Azevedo, 2021). In designing CIs that involve the participation of several actors, the aggregation process is usually twofold, including the aggregation of the assessment of each participant and the aggregation of simple indicators into a single composite index.

Aggregation (stage iv) is another key step in the construction of CIs (Munda, 2005). Most CIs proposed to date to assess biodiversity or sustainability globally use additive aggregation models based on the equal weights method. The Living Planet Index compares changes in the weighted averages of 14,152 animal populations of 3706 species of mammals, birds, reptiles, amphibians and fish from around the world (Living Planet Index, 2016). The Red List Index also uses a weighted additive method of the number of species in each IUCN Red List category (Butchart et al., 2004) for birds, mammals, amphibians, cycads and warm-water reef-forming corals. Butchart et al. (2010) evaluated the achievements of the 2010 CBD targets with 31 indicators, which they aggregated using a simple additive model. Buckland et al. (2011), proposed a geometric mean for aggregating biodiversity indices, which is based on partially compensatory aggregation. Ruiz and Cabello (2021) have also put forward a mathematical model that allows for a partial compensation of the simple indicators to measure sustainability in a more general way.

Linear programming models, such as some BoD-DEA (Benefit of Doubt - Data Envelopment Analysis) models, allow for the aggregation of indicators from an optimization point of view under conditions of uncertainty. Another advantage is that they provide a benchmarking approach, as well as they facilitate the use of participatory methods that, despite being subject to restrictions, grant flexibility to the process.

In this paper, we propose a CI built sequentially based on a BoD-DEA model to assess the global performance of countries in the implementation of Aichi Biodiversity Targets by simultaneously considering the level of achievement and the limitations (drawbacks) found in their application. This CI (ATCI) and its calculation at national level allows for the identification of countries or regions where ATs are underachieved and the factors that contribute to performances lower than expected which can be used to support improvements nationally and regionally. This paper also reports on the application of this CI to the assessment of 21 European countries considering a total of 37 indicators, 25 of which are performance indicators and 12 are drawback indicators, for the 18 terrestrial ATs. This study does not seek to measure the progress of countries with respect to ATs. Our aim is to provide a method that offers a snapshot of the state of the countries in terms of benchmarking at the same time that considers the structural limitations for the implementation of ATs. The information obtained through the application of this method makes it possible to perceive the current condition of the countries, useful to address conservation policy in the future, such as the Strategic Plan for Biodiversity 2021–2030 (CBD, 2021) or the EU Biodiversity Strategy for 2030 (European Environment Agency, 2021). Such information also conforms the basis for the development of a methodology for rigorous and realistic monitoring of the objectives included in these programs.

3. Materials and methods

3.1. Selection of dimensions and variables

The selection of simple indicators followed on a three-tiered hierarchical structure. Level 1 comprises the five goals of the CBD Strategic Biodiversity Plan 2010–2020 (dimensions). Level 2 lists the 18 ATs related to terrestrial ecosystems (targets), i.e., all but 6 and 10. Lastly, level 3 includes 25 performance indicators and 12 drawback indicators (Tables 2 and 3). It was based on the indicators suggested in the CBD strategic plan, the literature reviewed before (Introduction) and the availability of data in all the countries in Europe. We selected, at least, one performance indicator by AT. When data was available, we selected additional indicators to provide a more complete assessment of particular ATs as long as there was no correlated among indicators. Drawback indicators less specific than performance indicators and were selected at the dimension level. These indicators assess simultaneously several AT within the same goal. For example, Worldwide Governance Index is related to all the ATs in Goal E (Enhance implementation through participatory planning, knowledge management and capacity building). The indicators have been selected taking also in consideration the desirable characteristics for global biodiversity indicators of Jones et al. (2011): cost-effectiveness, capacity to provide reliable information at multiple levels about diverse taxonomic groups, status and trends of biodiversity components, usability in frequent reporting,

Table 2
Description of performance indicators selected to assess the implementation of Aichi Biodiversity Targets by Strategic Goal. Indicators (+) are of the type "more is better" and indicators (−) are of the type "less is better". Indicators marked with an asterisk were transformed to ensure good performance.

Strategic Goals	Targets	Performance Indicators	Year	Units	Data Source
A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society	1. By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably	1.1. Regular and occasional behavior towards environmentally-friendly products (2012) (+)	2012	Percentage	European Comission (2013)
	2. By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems	2.1. People at risk of poverty or social exclusion in rural areas (−)	2019	Percentage	Eurostat
	3. By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socioeconomic condition	3.1.Environmental policy stringency (+)	2015	Unitless	OCDE
	4. By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits	4.1. Ecological Footprint (−)	2016	Global hectares per capita	Global Footprint Network
B. Reduce the direct pressures on biodiversity and promote sustainable use	5. By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced	5.1. Area of wooden land as proportion of land area (+)	2020	Percentage	Eurostat
	7.By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity	7.1. Percentage of forest under Forest Stewardship Council (FSC) or Pan-european Forest Certification (PEFC) (+)	2015	Percentage	Maesano et al. (2018)
		7.2. Common farmland bird index (+)	2017	Unitless	Eurostat
	8. By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity	8.1. Pollution, grime or other environmental problems (−)	2019	Percentage	Eurostat
		8.2. Ammonia emissions from agriculture (−)	2018	Kg per hectare	Eurostat
	9. By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment	9.1. Invasive alien species by known spp. (−)	2020*	Percentage	EASIN
C. To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity	11. By 2020, at least 17% of terrestrial and inland water, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes	11.1. Terrestrial Protected area (%) (+)	2019	Percentage	Eurostat
		11.2. Average proportion of Terrestrial Key Biodiversity Areas (KBAs) covered by protected areas (%) (+)	2019	Percentage	Eurostat
	12. By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained	12.1. Threatened species (mammals) as % of known species (−)	2020*	Percentage	OECD
		12.2. Threatened species (birds) as % of known species (−)	2021*	Percentage	OECD
		12.3. Threatened species (vascular plants) as % of known species (−)	2021*	Percentage	OECD
	13. By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained,	13.1. Proportion of local breeds classified as being at risk as a share of local breeds with known level of extinction risk (%) (−)	2019	Percentage	United Nations (SDG)
			2021*	Number	United Nations (SDG)

(continued on next page)

Table 2 (*continued*)

Strategic Goals	Targets	Performance Indicators	Year	Units	Data Source
	and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity	13.2. Number of local breeds stored within a genebank collection (+)			
D. Enhance the benefits to all from biodiversity and ecosystem services	14. By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable	14.1. Proportion of population using safely managed drinking water services (%) (+)	2017	Million cubic meters (weighted)	Eurostat
		14.2. Useful Plant Indicator (in situ) (+)	2021*	Unitless	International Center for Tropical Agriculture–CIAT
	15. By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification	15.1. Variation of forest area (2010−2020) (+)	2010–2020	Percentage	Eurostat
	16. By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation	16.1. Registered records in platforms to shared genetic resources (+)	2021*	Number	CBD (ABSCH)
E. Enhance implementation through participatory planning, knowledge management and capacity building	17. By 2020 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan	17.1. Environmental democracy index (+)	2015	Unitless	Environmental Democracy Index
	18. By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels	18.1. Rural depopulation (Change 2010–2019) (−)	2010–2019	Percentage	World Bank
	19.By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied	19.1. Number of species occurrence records accessible through the Global Biodiversity Information Facility (+)	2021*	Unit	GBIF
	20. By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011–2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels	20.1. Environmental protection investment per capita (€/inhabitant) (+)	2018	€ pc	Eurostat

meaningfulness to the public and capacity to respond predictably to policy changes.

Some of the indicators have already been used in previous studies. For instance, 4.1, 5.1, 7.1, 11.2, 12.1, 12.3, and 19.1 were used by Buchanan et al. (2020). Tittensor et al. (2014) used indicators similar to 3.1, 4.1, 7.1, 7.2, 11.2, 12.1, 12.2 and 12.3. Indicators 1.1, 11.1, and 20.1 are based on indicators used by Buchanan et al. (2020), slightly modified in our study. Indicators 2.1.D, 3.1.D., 3.2.D. and 11.2.D. are supported by the results of Driscoll et al. (2018) and Buchanan et al. (2020).

The indicators (Table 2, Table 3), by strategic goal (dimension), were as follow.

Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society. The assessment of this goal comprised 4 performance and 3 drawback indicators associated with ATs 1 to 4.

Performance indicators:

1.1. Attitudes towards green behaviors (positive, regular and occasional, responses regarding behavior towards environmentally-friendly products): measures the amount of positive responses to consumer willingness to buy "green" products (European Comission, 2013).

2.1. People at risk of poverty or social exclusion in rural areas: indicator of low quality of life in rural communities (Eurostat, 2021).

3.1. Environmental policy stringency: measures environmental stringency, which is the degree to which environmental policies place an explicit or implicit price on polluting or environmentally-damaging behavior (OECD, 2021).

4.1. Ecological Footprint index: measures how fast people consume resources and generate waste compared to how fast nature can absorb waste and generate resources (Buchanan et al., 2020; Tittensor et al., 2014).

Drawback indicators:

2.1.D. Gini Index: index of income inequality (Buchanan et al., 2020; Driscoll et al., 2018).

3.1.D. Fragility States Index: index that highlights the normal pressures that all states experience, but also identify when those pressures

Table 3
Description of drawback indicators selected to assess the implementation of Aichi Biodiversity Targets by Strategic Objective.

Strategic Goals	Targets	Drawbacks Indicators	Year	Units	Data source
A	2	2.1.D. Gini Index (Income inequality)	2019	Unitless	Eurostat
	3	3.1.D. Fragility States Index	2020	Unitless	Eurostat
	4	4.1.D. Knowledge Economy Index-Innovation-friendly environment (+)	2018	Unitless	European Commission
B	5	5.1.D. Intensity of use of forest resources (ratio)	2018	Unitless	Eurostat
	8	8.1.D.Density vehicles	2017	Passenger cars per km^2	Eurostat
C	11	11.1.D. Road density	2018	Length of roads/total surface (%)	Eurostat
		11.2.D. Population density	2018	Persons per km^2	Eurostat
D	14	14.1.D. Climate-change performance index (+)	2021	Unitless	CCPI
		14.2.D. Water exploitation index	2017	Percentage	European Environment Agency
	15	15.1.D. Estimated soil loss by water erosion by land cover type (tonnes per hectare)	2016	Tonnes per hectare	Eurostat
		15.2.D. Burnt areas	2018	ha	Eurostat
E	17, 18, 19, 20	E.D. Worlwide Governance Index (+)	2019	Unitless	World Bank

Indicators (+) are indicators of the type "more is better" type and indicators (−) are of the type "less is better" type. Indicators marked with an asterisk were transformed to ensure good performance. See Table 3 for description of Goals and Targets.

are outweighing a states' capacity to manage them (Buchanan et al., 2020; Driscoll et al., 2018).

4.1.D. Innovation-friendly environment: indicator of countries' unwillingness to innovate in terms of sustainability (European Comission, 2019)

Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use. This goal is assessed based on 6 performance and 2 drawback indicators associated with ATs 5,7,8 and 9.

5.1. Area of wooden land as proportion of land area (Buchanan et al., 2020; Tittensor et al., 2014).

7.1. Percentage of forest under Forest Stewardship Council (FSC) or Pan-European Forest Certification (PEFC) programs by country (Buchanan et al., 2020; Tittensor et al., 2014).

7.2. Common farmland bird index, that measures the rate of change in the occurrence of common farmland birds in relevant sites (Tittensor et al., 2014).

8.1. Pollution, grime or other environmental problems: indicator describing the situations where citizens feels pollution, grime or other environmental problems to be a problem for the household, assessed through the annual EU-SILC survey (Eurostat, 2021).

8.2. Ammonia emissions from agriculture: the amount of ammonia (NH3) emissions as a result of agricultural production, comprising manure management, inorganic N-fertilizers and animal manure applied to soil as well as urine and dung deposited by grazing animals. Ammonia emissions per hectare are calculated using the total utilised agricultural area of the relevant year as denominator (Eurostat, 2021).

9.1. Invasive alien species (Tittensor et al., 2014): the number of invasive alien animal and plant species with High Impact of Member States Concern and of European Union Concern (EASIN, 2021).

Drawback indicators:

5.1.D. Intensity of use of forest resources: this indicator refers to the intensity of use of forest resources (timber) relating the actual harvest or tree fellings to annual productive capacity of forests. It is calculated as the ratio roundwood (removals) /growing stock of forests (in percentage) where removals of roundwood comprising all wood felled and removed from the forest and other wooded land or other felling sites: private forests, state forests and other publicly owned forests. Growing stock of forests is the volume of all living trees by forest or wooded land that have more than a minimum diameter at breast height.

8.1.D. Vehicle density: indicator of pollution from passenger cars considering that growth of the vehicle fleet hinders pollution control, measured through the number of passenger cars per km^2. Passenger car is "a road motor vehicle, other than a moped or a motorcycle, intended for the carriage of passengers and designed to seat no more than nine persons (including the driver) (Eurostat, 2021).

Strategic Goal C. To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity. It contains 6 performance indicators and 2 drawback indicators associated with ATs 11–13.

Performance indicators:

11.1. Terrestrial Protected area: proportion of land classified as conservation (Tittensor et al., 2014), measured based on terrestrial areas belonging to the EU's Natura 2000 network (Eurostat, 2021).

11.2. Average proportion of Terrestrial Key Biodiversity Areas (KBAs) covered by protected areas (Buchanan et al., 2020). This indicator complements indicator 11.1. by taking into account protected sites by country.

12.1., 12.2., 12.3. Threatened species (mammals, birds, plants, respectively) as % of known species (Buchanan et al., 2020; Tittensor et al., 2014). Threatened species are those in IUCN Red List categories Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) (OECD, 2021).

13.1. Proportion of local breeds classified as being at risk as a share of local breeds with known level of extinction risk, indicating threats to the genetic diversity of local breeds (United Nations, 2021).

13.2. Number of local breeds stored within a genebank collection: represents stored animal genetic resources required to reconstitute local breeds in case of extinction. This indicator is related to the monitoring framework endorsed by the FAO Commission on Genetic Resources for Food and Agriculture (United Nations, 2021).

Drawback indicators:

11.1.D. Road density (Meehan et al., 2020): represents limitations for conservation of species and habitats relative to the reduction of landscape permeability, leading to habitat loss and increasing habitat fragmentation (Bennett, 2017), measured by the total length of roads per km^2.

11.2.D. Population density (Buchanan et al., 2020): the ratio of annual average population and land area. "The land area concept (excluding inland waters) should be used wherever available; if not available then the total area, including inland waters (area of lakes and rivers) is used" (Eurostat, 2021). Human population density contributes to ecosystem loss and fragmentation (The Royal Society, 2005). Researchers have shown a strong correlation between population density and the number of threatened mammal and bird species by nation (e.g. McKee et al., 2004). Other studies found a strong negative relationship between the size of protected areas and human population density (Luck, 2007) and others alerted for threats posed by increasing population growth to biodiversity (e.g. Cunningham and Beazley, 2018).

Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services. It includes 4 performance and 4 drawback indicators associated with ATs 14–16.

Performance indicators:

14.1. Proportion of population using safely managed drinking water services: the percentage of people using drinking water from an improved source that is accessible on premises, available when needed and free from faecal and priority chemical contamination; improved water sources include piped water, boreholes or tubewells, protected dug wells, protected springs, and packaged or delivered water (World Bank, 2021).

14.2. Useful Plant Indicator: this indicator shows the conservation status of useful wild plants (food, medicine, shelter, etc.) and is calculated based on the assessment of almost 7000 wild useful plants to determine how comprehensively their diversity is safeguarded in Parks, Reserves, and other official protected areas (in situ*)*. Every species was assigned a score between 0 (poor) and 100 (excellent) in terms of their current conservation (International Center for Tropical Agriculture–CIAT, 2019).

15.1. Variation of forest area: includes the recovery (or loss) of forest area due to natural causes or human interaction. The indicator is assessed as the change ratio of forest area by country between 2010 and 2020.

16.1. Registered records in platforms to share genetic resources: represents the willingness of countries to share their genetic resources and is assessed by the number of national records in the ABS-Clearing House (CBD.ABSCH, 2021). "The Access and Benefit-sharing Clearing-House is a platform for exchanging information on access and benefit-sharing established by Article 14 of the Nagoya Protocol, as part of clearing-house mechanism under Article 18, paragraph 3 of the Convention" (CBD, 2021).

Drawback indicators:

14.1.D. Climate-Change Performance Index: captures the deterioration of the socio-ecological-atmosphere system. The index considers Greenhouse Gas Emissions, Renewable Energies, Energy Use and Climate Policy to assess the current efforts and progress of countries in the EU and elsewhere, and "measures how well countries are on track to meet the global goals of the Paris Agreement by evaluating the current status and future targets of each category with reference to a well-below 2°C pathway" (CCPI, 2021).

14.2.D. Water exploitation index: represents water resources exploitation or the total water demand over the water resource (European Environment Agency, 2021); it is calculated as the mean annual total demand for freshwater divided by the long-term average freshwater resources

15.1.D. Estimated soil loss by water erosion and land cover type: indicates the degradation of the socio-ecological-soil system according to the level of loss of one of their key components. The indicator estimates soil loss by water erosion processes (rain splash, sheetwash and rills) for agricultural areas and natural grassland (Eurostat, 2021).

15.2.D. Burnt areas: reports on the degradation of the socio-ecological-forest land system due to wildfires. The indicator collects the total burnt areas (in hectare per year) as the ratio mean of the last three years/mean of the last five years (in percentage). San Miguel-Ayanz et al. (2018) used a similar calculation to present forest fires in 2018 in some European and North Africa countries. This measure avoids potential extreme values associated with a year with outliers.

Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building. It consists of 4 performance indicators and 1 drawback indicator associated with ATs 17–20.

Performance indicators:

17.1. Environmental democracy index: it involves three mutually-reinforcing rights: the right to freely access information about environmental quality and problems, the right to participate meaningfully in decision-making processes, and the right to seek enforcement of environmental laws or compensation for damages. This idea materializes through 75 law-related indicators (Environmental Democracy Index, 2021).

18.1. Rural depopulation: loss of rural population assessed as the population change rate in rural areas between 2010 and 2019 (Eurostat, 2021).

19.1. Number of species occurrence records accessible through the Global Biodiversity Information Facility (GBIF) (Buchanan et al., 2020): represent science data sharing by countries (GBIF, 2019).

20.1. Environmental protection investment per capita (Buchanan et al., 2020): this indicator is assessed as the percentage of the national expenditure on environmental protection divided by population in each country. National expenditure on environmental protection is the sum of the total output (environmental protection market output, environmental protection non-market output and environmental protection ancillary output), plus gross fixed capital formation and net acquisition of non-financial, non-produced assets for environmental protection activities, minus intermediate consumption of environmental protection services by specialist producers, plus VAT and other taxes less subsidies on environmental protection services, plus imports of environmental protection services, minus exports of environmental protection service, plus transfers received by the rest of the world from general government and minus transfers paid by the rest of the world to general government, corporations and households (Eurostat, 2021).

Drawback indicators:

E.D. Worldwide Governance Indicator (Buchanan et al., 2020; Driscoll et al., 2018): this index measures the quality of governance of countries addressing simultaneously six dimensions of governance: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption.

3.2. Data collection and treatment

The data for direct use or index calculation have been collected from world and European databases such as CBD, Climate Change Performance Index (CCPI), European Alien Species Information Network (EASIN), Environmental Democracy Index, European Comission, Eurostat, Global Biodiversity Information Facility (GBIF), Global Footprint Network, OECD, United Nations and World Bank and/or publications such as Maesano et al. (2018) (Tables 2 and 3).

The data used for analysis were collected from time series or composite indicators presented or calculated at a given time. Given that the purpose of this study is not to conduct a diachronic study of ATs achievements, but rather to describe the current situation of Aichi Targets implementation with potential application to guide and monitor conservation policy in the future, we have used the most recent data available for the 21 countries analyzed. Thus, 73% of the indicators refer to data collected after 2018 and 24% to data collected between 2015 and 2018. Only 3% of the data refer to years earlier than 2015.

Only 0.5% of missing values have been detected for performance indicators 3.1. (Estonia, Latvia) and 12.3. (France, Portugal). In both cases, missing values were replaced by minimum values.

Some indicators were adjusted to ensure a good fit for all countries. These correspond to the indicators in Tables 2 and 3 marked with an asterisk that were calculated using data available in the above-mentioned databases, but whose units of measurement were transformed to ensure good performance.

All indicators were normalized using Max-Min or Min-Max rescaling methods. Type (+) indicators were calculated by first subtracting the value of the variable from the minimum value and then dividing by the difference between the maximum and the minimum values. Type (−) indicators were calculated by first subtracting the value of the variable from the maximum value and then dividing by the difference between the minimum and the maximum values. All indicators were, therefore, expressed in values ranging between 0 and 1.

3.3. ATCI construction

The Aichi Targets Composite Index (ATCI) was constructed sequentially in three stages: i) aggregation of the Dimension Performance Indicators (DPI); ii) aggregation of the Dimension Drawbacks Indicators (DDI); and iii) aggregation of the DPI and DDI in the ATCI indicator. In all stages, the aggregation process adopted both optimal (DPI^{OP}, DDI^{OP}, $ATCI^{OP}$) and equal weighting approaches (DPI^{EQ}, DDI^{EQ}, $ATCI^{EQ}$). Although both use an additive linear aggregation process, the optimal approach is based on computer benchmarking among the indicators of all the countries analyzed, while the equal weighting approach assigns the same relative importance to all the indicators of each country. Consequently, whereas the optimal weighting approach yields comparative results, the equal approach yields individual results. Calculations were made in Lindo v18.0 software (Lindo Systems Inc.,Chicago, IL, USA).

3.3.1. Optimal dimension performance and optimal dimension drawback indicators

A "Benefit of the Doubt" approach was used to the aggregate calculation of the optimal dimensions relative to performance and drawback indicators. The BoD approach has its origins in the Data Envelopment Analysis (DEA), although it is applied to environments of inaccurate information. DEA is a linear programming technique that evaluates a set of homogeneous production units on the basis of input and output variables in an uncertain environment, that is, where the weights associated with these variables are not known, nor is the form of the function that relates these variables. The very name "benefit of the doubt" represents the essence of this type of model emphasizing its potential to obtain the most appropriate weighting scheme for each decisional unit from the data available (Cherchye et al., 2011). The BoD model places the performance of a decisional unit in relation to the rest of the decisional units, assigning the highest weights to the first indicators and vice versa; thus, the model selects the most favorable set of weights for each unit of analysis (Guaita Martínez et al., 2020). The only difference with respect to traditional DEA models is that only the output variables are fixed, considering one input dummy variable with a value equal to 1 for each unit of analysis. A large number of publications have already used this approach successfully in the construction of composite indicators, such as Cherchye et al. (2007), Karagiannis (2017) or Verbunt and Rogge (2018).

The underlying idea of this study is that the good relative performance of a given country in a particular indicator reveals that said indicator is important for that country. Under this assumption, in order to aggregate the individual indicators selected for each Aichi strategic goal, we propose the model described in eqs. 1 to 4.

Model 1.

$$DPI_c^{OP} = max \sum_{i=1}^{m} w_{c,i} I_{c,i}^{P} \tag{1}$$

s.t.

$$\sum_{i=1}^{m} w_{c,i} I_{j,i}^{P} \le 1 \tag{2}$$

(m constraints, one for each country j)

$$\frac{w_i I_{j,i}^{P}}{\sum_{i=1}^{m} w_i I_{j,i}^{P}} \ge \beta_i \tag{3}$$

$$w_{c,i} \ge 0 \tag{4}$$

(n constraints, one for each indicator i)where $j = 1,2, \ldots..,$m and $i = 1,2, \ldots\ldots..,$n, DPI_c^{OP} is the dimension optimal performance indicator of decision unit c, $w_{c,\ i}$ is the weight of the decision unit c regarding indicator i, $I_{c,\ i}^{P}$ is the indicator i for each decision unit c, $I_{j,\ i}^{P}$ is the indicator i for each country j and β_i is a bound parameter that represents the minimum contribution of indicator i to each country j, regarding all indicators.

Similarly, model 2 was used to aggregate the drawback indicators of each dimension. Given that the (−) type indicators have been normalized inversely, the best results belong to the highest scores and vice versa. Thus, the objective is again to maximize the weighted sum of drawback indicators. Model 2 is described in eqs. 5–8.

Model 2.

$$DDI_c^{OP} = max \sum_{i=1}^{m} w_{c,i} I_{C,i}^{D} \tag{5}$$

s.t.

$$\sum_{i=1}^{m} w_{c,i} I_{j,i}^{D} \le 1 \tag{6}$$

(m constraints, one for each country j)

$$\frac{w_i I_{j,i}^{D}}{\sum_{i=1}^{m} w_i I_{j,i}^{D}} \ge \varepsilon_i \tag{7}$$

$$w_{c,i} \ge 0 \tag{8}$$

(n constraints, one for each indicator i)where $j = 1,2, \ldots..,$m and $i = 1,2, \ldots\ldots..,$n, DDI_c^{OP} is the drawback optimal dimension indicator of decision unit c, $w_{c,\ i}$ is the weight of the decision unit c regarding indicator i, $I_{c,\ i}^{D}$ is the indicator i for each decision unit c, $I_{j,\ i}^{P}$ is the indicator i for each country j and ε_i is a bound parameter that represents the minimum contribution of indicator i to each country j, regarding all indicators.

Constraints (3) and (7) allow for the implementation of a participatory approach. In addition, they can be useful in breaking ties and improving the discriminatory power of the model (Wong and Beasley, 1990).

3.3.2. The optimal ATCI

The Optimal ATCI ($ATCI^{OP}$) is the result of the aggregation of the results of each dimension of the performance indicators and drawback indicators and it is calculated as a linear combination of models 1 and 2. As a result, $ATCI^{OP}$ was calculated for each country, making it possible to rank the 21 European analyzed countries using model 3 as follows:

Model 3

$$ATCI_c^{OP} = max\, \lambda \left(\sum_{i=1}^{n} w_c DPI_c^{OP} \right) + (1-\lambda) \left(\sum_{i=1}^{n} w_c DDI_c^{OP} \right) \tag{9}$$

s.t.

$$\sum_{i=1}^{m} w_{c,i} DPI_{j,i}^{OP} \le 1 \tag{10}$$

$$\frac{w_i DPI_{j,i}^{OP}}{\sum_{i=1}^{m} w_i DPI_{j,i}^{OP}} \ge \beta_i \tag{11}$$

$$\sum_{i=1}^{m} w_{c,i} DDI_{j,i}^{OP} \le 1 \tag{12}$$

$$\frac{w_i DDI_{j,i}^{OP}}{\sum_{i=1}^{m} w_i DDI_{j,i}^{OP}} \ge \varepsilon_i \tag{13}$$

$$w_{c,i} \geq 0 \quad (14)$$

Lambda is a control parameter to establish the linear convex combination of models 1 and 2. When λ = 1 the model provides an evaluation based exclusively on performance indicators, disregarding drawback indicators (ATCI-P^{OP}). When λ = 0, the model provides an evaluation based exclusively on drawback indicators, disregarding performance indicators (ATCI-D^{OP}). When λ = 0.5, the model provides an assessment based on both performance and drawback indicators (ATCI^{OP}). In some studies, such as de Castro-Pardo and Azevedo (2021), the λ parameter has been successfully used to establish the linear convex combination between Linear Programming models.

3.3.3. Equal approach

The calculation of the composite performance, drawback, and combined indicators from an equal weighting approach has been carried out using a linear additive aggregation model where all the indicators for each country were weighted following an equal weighting model.

Eq. 15 was used to calculate the Aichi Targets Composite Indicator based on Performance (ATCI-P^{EQ}).

$$ATCI - P_j^{EQ} = \sum_{i=1}^{n} w_{ij} I_{ij}^{P} \quad (15)$$

where $w_{ij} = \frac{1}{n}$ and I_{ij}^{P} is the performance indicator i of the country j.

Similarly, Eq. 16 was used to calculate the Aichi Targets Composite Indicator based on Drawbacks (ATCI-D^{EQ}).

$$ATCI - D_j^{EQ} = \sum_{i=1}^{n} w_{ij} I_{ij}^{D} \quad (16)$$

where $w_{ij} = \frac{1}{n}$ and I_{ij}^{D} is the performance indicator i of the country j.

Lastly, the ATCI^{EQ} was calculated using the averages of ATCI-P^{EQ} and ATCI-D^{EQ}.

3.3.4. Vulnerability ratio

Once ATCI−P^{EQ} and ATCI − D^{EQ} have been calculated, the vulnerability ratio (VR) was calculated as shown in eq. 17.

$$VRj = \frac{ATCI - D_j^{EQ*}}{ATCI - P_j^{EQ*}} * 100 \quad (17)$$

where $ATCI - D_j^{EQ*}$ is DDI^{EQ} for each country j transformed by a Min-Max inverse normalization process so that higher scores are assigned to countries with more drawbacks and lower scores are assigned to countries with fewer drawbacks using the equation:

$$\frac{x - x_{máx}}{x_{mín} - x_{máx}} \quad (18)$$

$ATCI - D_j^{EQ*}$ represents the Equal Aggregated Performance Index of country j, which has been normalized using a Max-Min rescaling method using the equation:

$$\frac{x - x_{min}}{x_{max} - x_{min}} \quad (19)$$

VRj represents the excess of drawbacks over the rate of performance. When $VRj > 100$, the proportion of drawbacks of country j outnumbers its performance and can be considered vulnerable. When $VRj = 100$, the proportion of drawbacks of country j is similar to its performance. When $VRj < 100$, the drawbacks of country j is overtaken by its performance and can be considered not vulnerable.

4. Results

4.1. Performance

The scores of performance indicators by country and dimension ($\lambda =$ 1) showed that Denmark, Sweden and the United Kingdom are the countries with higher general performance (Table 4). Model 1 (Eqs. 1–4) was used for the calculation of the indicator for each dimension (goal), whereas model 3 (Eqs. 9–14) was used for the aggregate calculation when $\lambda = 1$. In total, we performed 126 iterations of model 1: one per country, per dimension and to calculate the aggregate indicator. To ensure representation of all indicators, a threshold of 0.01 was set for the weights of the drawbacks (Eq. 4), as well as a β_i threshold of 0.001.

The dimension with the highest scores was dimension C (To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity). All countries except Austria, Belgium, and Sweden have obtained scores above 0.8. The countries that scored best in dimension A (Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society) were Austria, Denmark, France, Germany, Hungary, the Netherlands and the United Kingdom. The best results in dimension B (Reduce the direct pressures on biodiversity and promote sustainable use) were obtained by Estonia, Finland, Greece, Ireland, Latvia, Portugal and Sweden whereas Dimension D (Enhance the benefits to all from biodiversity and ecosystem services) was topped by Belgium, Denmark, the Netherlands, Sweden, and the United Kingdom. Denmark, the Netherlands, Sweden and the United Kingdom reached better scores in dimension E, which represents the basic requirements for the implementation of the AT. ATCI-P^{OP} indicates that, overall, Denmark, Sweden and the UK have the best combined performance of all countries (max score), whereas Latvia, Estonia, Poland and Hungary have the lowest scores, although relatively high and near 0.9.

4.2. Drawbacks

The drawback scores for countries in Europe per dimension displayed in Table 5 were calculated using model 2 (Eqs. 5–8) and the aggregate calculation was performed using model 3 when $\lambda = 0$ (Eqs. 9–14). A total of 126 iterations of model 2 have been carried out, one per country, per dimension and for the combined indicator. To ensure representation of all indicators, a threshold of 0.01 was set for the weights of the drawbacks (Eq. 6), as well as a ε_i threshold value of 0.001.

The aggregate results show that the countries with the lowest level of drawbacks are Finland and Sweden. As concerns the analysis of each dimension, Denmark, Finland, and France led dimension A whereas the

Table 4
Optimal Dimension Performance Indicators (DPI^{OP}) and optimal Aichi Targets Composite Indicators based on Performance (ATCI-P^{OP}) scores per country in Europe.

	DPI^{OP} Dimension (goal)					
Country	A	B	C	D	E	ATCI-P^{OP}
Austria	1.000	0.941	0.472	0.895	0.842	0.936
Belgium	0.881	0.597	0.749	1.000	0.703	0.902
Czechia	0.898	0.870	1.000	0.789	0.456	0.911
Denmark	1.000	0.905	1.000	1.000	1.000	1.000
Estonia	0.296	1.000	1.000	0.849	0.233	0.891
Finland	0.871	1.000	0.840	0.962	0.858	0.994
France	1.000	0.777	0.999	1.000	0.932	0.980
Germany	1.000	0.895	1.000	0.989	0.753	0.973
Greece	0.857	0.914	1.000	0.987	0.478	0.952
Hungary	1.000	0.914	0.950	0.738	0.269	0.898
Ireland	0.669	1.000	1.000	1.000	0.551	0.976
Italy	0.968	0.744	1.000	0.727	0.507	0.904
Latvia	0.295	1.000	1.000	0.906	0.085	0.882
The Netherlands	1.000	0.207	1.000	1.000	1.000	0.930
Poland	0.717	0.953	1.000	0.916	0.042	0.894
Portugal	0.827	1.000	1.000	0.551	0.409	0.932
Slovakia	0.916	0.952	1.000	0.975	0.255	0.941
Slovenia	0.880	0.915	1.000	0.811	0.481	0.922
Spain	0.889	0.890	1.000	0.892	0.669	0.943
Sweden	0.961	1.000	0.725	0.990	1.000	1.000
United Kingdom	1.000	0.907	1.000	1.000	1.000	1.000

Table 5
Optimal Dimension Drawbacks Indicators (DDI^{OP}) and optimal Aichi Targets Composite Indicators based on Drawbacks ($ATCI\text{-}D^{OP}$) scores per country in Europe.

	DDI^{OP}					
	Dimension (goal)					
Country	A	B	C	D	E	$ATCI\text{-}D^{OP}$
Austria	0.942	0.872	0.816	0.989	0.844	0.966
Belgium	0.961	0.599	0.262	0.992	0.620	0.849
Czechia	0.944	0.717	0.753	0.980	0.451	0.877
Denmark	1.000	0.798	0.753	1.000	0.959	0.953
Estonia	0.752	0.969	0.973	0.992	0.657	0.932
Finland	1.000	1.000	1.000	0.999	0.980	1.000
France	1.000	0.874	0.818	0.993	0.617	0.932
Germany	0.568	0.751	0.661	0.987	0.796	0.872
Greece	0.501	1.000	0.877	0.916	0.000	0.831
Hungary	0.666	0.940	0.814	0.975	0.032	0.832
Ireland	0.656	0.904	0.890	0.974	0.777	0.909
Italy	0.377	1.000	0.870	0.685	0.115	0.807
Latvia	0.359	1.000	0.974	1.000	0.329	0.868
The Netherlands	0.917	0.470	0.269	0.995	0.913	0.856
Poland	0.701	0.816	0.783	0.982	0.203	0.842
Portugal	0.742	0.765	0.999	0.825	0.612	0.896
Slovakia	0.999	0.895	0.862	0.996	0.257	0.903
Slovenia	0.981	0.907	0.824	0.985	0.492	0.914
Spain	0.469	0.899	0.976	0.663	0.363	0.827
Sweden	0.990	1.000	0.986	1.000	1.000	1.000
United Kingdom	0.795	0.814	0.671	0.992	0.716	0.897

best scores in dimension B were obtained by Finland, Greece, Italy, Latvia and Sweden. Finland obtained the best score in dimension C. Dimensions D and E were topped by Denmark, Latvia, and Sweden respectively.

4.3. *Combined results*

Table 6 shows the global ATCI indices scores and the rankings of countries obtained from these applying optimal and equal weighting approaches. Scores were calculated by applying model 3 (eqs. 9–14) when $\lambda = 0.5$. In doing so, following a benchmarking approach, we added the dimensions' index scores previously calculated by taking into account the performance and drawback indicators in an aggregated manner. In total, model 3 was applied 21 times, once for each country. To ensure the representation of all indicators, a minimum value of 0.01 was set for all weights, β_i=0.001 and ε_i=0.001.

Table 6
Scores countries in Europe for Aichi Targets Composite Indicators obtained with optimal ($ATCI^{OP}$) and equal weighting ($ATCI^{EQ}$) and respective rankings. For $ATCI^{OP}$, λ=0.5.

Country	$ATCI^{OP}$ (Score)	$ATCI^{OP}$ (Rank)	$ATCI^{EQ}$ (Score)	$ATCI^{EQ}$ (Rank)
Austria	0.939	7	0.597	6
Belgium	0.872	18	0.463	19
Czechia	0.894	14	0.490	17
Denmark	0.977	3	0.721	2
Estonia	0.912	12	0.548	10
Finland	0.997	2	0.715	3
France	0.956	4	0.648	4
Germany	0.923	8	0.568	9
Greece	0.909	13	0.447	20
Hungary	0.865	20	0.472	18
Ireland	0.943	6	0.596	7
Italy	0.855	21	0.438	21
Latvia	0.875	17	0.516	13
The Netherlands	0.893	15	0.523	12
Poland	0.868	19	0.507	15
Portugal	0.915	11	0.509	14
Slovakia	0.922	9	0.568	8
Slovenia	0.918	10	0.540	11
Spain	0.885	16	0.495	16
Sweden	1.000	1	0.744	1
United Kingdom	0.949	5	0.605	5

The top-ranked countries according to the results of these metrics were Sweden, Finland, Denmark, France and the United Kingdom, whereas the lowest ranked countries vary with the approach followed: Italy, Hungary, Poland, Belgium and Latvia and for the optimal weighting approach and Italy, Greece, Belgium, Hungary and Czechia for equal weighting. The differences between approaches were not evidenced for the first positions but were stronger in the bottom part of the ranking. Greece and Czechia are in the lowest positions for equal and the Netherlands and Latvia for optimal weighting. This means that the Netherlands and Latvia have a greater relative distance to the best positions than Greece and Czechia, and that the former pair losses positions when the optimal approach is used. An arithmetic mean is generally used to construct composite indicators. When the value of the weights is uncertain, methods based on equal apportionments are not appropriate because they favor the decisional units (in this case, countries) with a lower relative performance.

Fig. 1 shows the scores of the composite indices when drawbacks were considered with performance in the analysis (λ=0.5) and when only performance indicators were considered (λ=1).

All countries except Austria, Estonia, Finland and Sweden scored worse when drawbacks were considered in the analysis. More importantly, there are differences in ranking positions when drawbacks are taken into consideration. This suggests that drawback indicators combined in the indices affect the perception of countries overall implementation of Aichi Targets. In particular, the countries most affected by incorporating drawbacks into the analysis were Italy, which fell from the 16th to the lowest position in the rankings, Greece, which fell from 8th to 16th, and Spain, which fell from 9th to 15th. The remaining countries worsened their positions, although to a lesser extent, except for Austria, which raised from 11th to 7th, and Sweden, which maintained its position in the ranking.

Fig. 2 shows spatially the distribution of ATCI scores in Europe when exclusively performance (λ=1) or drawbacks (λ=0), and performance and drawbacks combined together (λ=0.5) are considered in the calculation.

4.4. *Vulnerability*

The results yielded by the vulnerability ratio indicate that Italy is the most vulnerable country in terms of implementation of ATs, followed by Greece, Belgium, Hungary, Czechia and Spain, in that order (Fig. 3).

Since vulnerability implies a surplus of drawbacks in comparison to performance, biodiversity conservation goals in the most vulnerable countries can be at risk when some drawbacks void the effect of conservation actions. For instance, Greece, showed the highest (best) scores regarding the percentage of protected areas and threatened mammals and vascular plants as % of known species. However, Greece showed also one of the worst scores in terms of % of burned area. This is a serious constraint since fires can cancel all the positive indicators (performance) and jeopardize biodiversity conservation.

Regarding their relative position in relation to performance (DPI) and drawbacks indicators (DDI), countries were classified into four categories (Fig. 4):

S1) Caution: high performance-high drawbacks;
S2) Excellence-high performance-low drawbacks;
S3) Fragility: low performance-high drawbacks; and.
S4) Catching up: low performance-low drawbacks.

Countries in category S1 (The Netherlands, Germany and the United Kingdom) have achieved high levels of performance although presenting strong drawbacks for the AT implementation. This hints at a great effort in biodiversity conservation, but at the same time, it also suggests that these countries should be cautious and keep track of limitations to the implementation of ATs. Ireland, France, Denmark, Finland, and Sweden

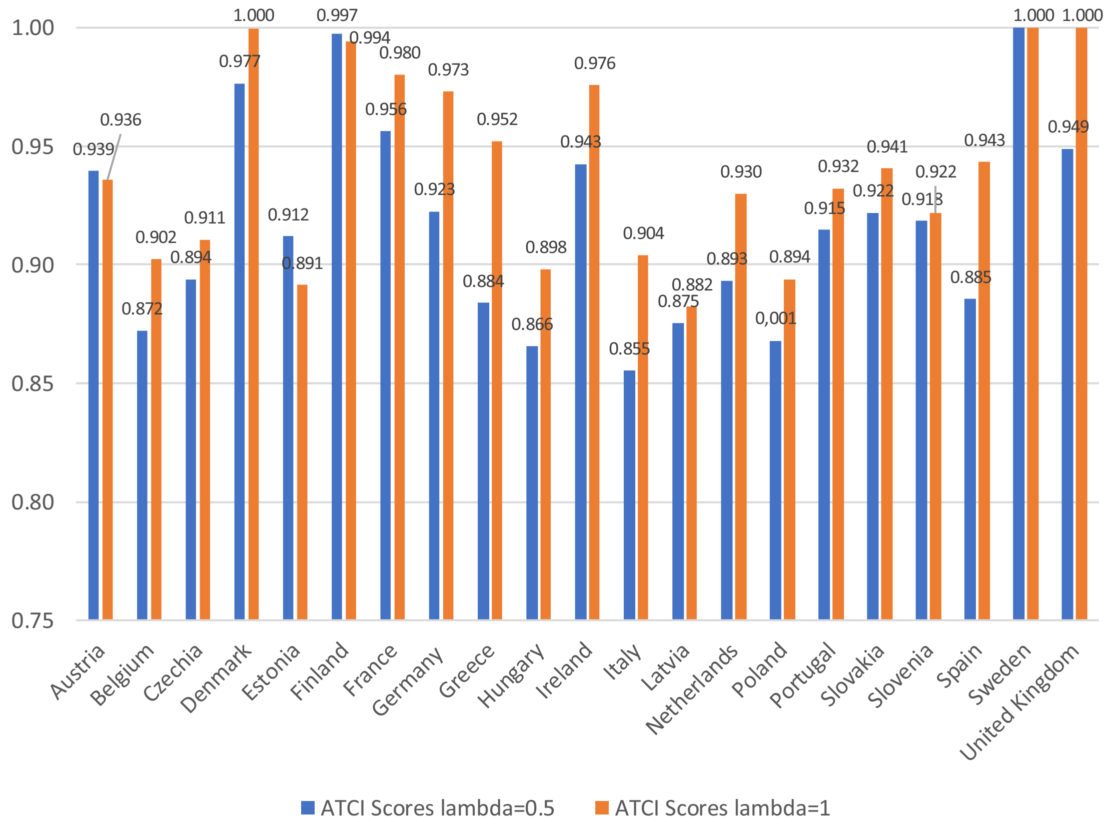

Fig. 1. ATCI scores including the assessment of drawbacks and performance (λ=0.5) and exclusively performance (λ=1). Values on top of each bar indicate the position of each country in the respective ranking.

(S2) perform well as concerns the AT and, moreover, are in control of possible drawbacks that could jeopardize their future implementation. Category S3 includes the countries with the most difficulties to implement the ATs. On the one hand, they have partially failed in the achievement of the ATs and they also face strong difficulties in their implementation. This group of countries consists of Italy, Belgium, Greece, Hungary, Spain, Poland, Portugal, Czechia, Latvia, Slovakia, and Slovenia. This is the largest group of the four categories and should be considered a priority for international conservation policies and efforts should be focused on actions aimed at improving conditions to meet ATs. Category 4 comprises two countries only: Estonia and Austria. These countries do not face severe difficulties in the implementation of the ATs although their level of performance is low. This may indicate that they are on the way to achieving ATs, provided that suitable institutional conditions have been ensured, and/or that further efforts to conserve biodiversity are made.

Table 7 summarizes the standardized results of the $\boldsymbol{ATCI} - D^{EQ}$ and $\boldsymbol{ATCI}^{EQ} - P^{EQ}$ indices, in percentage, and category for countries in Europe, highlighting the major trends observed above.

5. Discussion

In this study we propose a methodology for measuring a country's level of achievement of ATs at the same time that it considers limitations, problems, obstacles and other adverse conditions (drawbacks) to their implementation. Given that no other composite indicators have been previously developed to deal with all the ATs at country level including indicators of problems associated with their implementation, there are no published results we could use for comparison purposes. However, some interesting comparisons can be drawn by looking at the results of publications that analyzed progress in the achievement of some ATs.

Cooper et al. (2019) developed a composite indicator to measure AT1 at the country level based on Biodiversity searches. Using an indicator based on 4 individual indices for four ATs, our results for goal A (Table 4) showed a high convergence with those of Cooper et al. (2019). In both cases, the countries with the best scores in Europe were Austria, Germany, Sweden and Denmark.

Buchanan et al. (2020) provided a measure of the progress of 11 indicators of ATs before and after 2010, which may offer some perspective on the results in this paper.

Their results showed that indicator 4.1-Ecological Footprint (AT4), fell short of the targets set in practically all of Europe. The results of our analysis show poor results in general, with Hungary, Greece and Spain being the best positioned countries. Although these countries obtained the most favorable scores in terms of performance, they also presented the most serious limitations associated with this target (AT4) and goal A.

With respect to indicator 5.1., Buchanan et al. (2020) found positive progress in Central European countries and little or no progress in the rest of the continent.

Our results, in which Finland, Sweden, Estonia and Austria obtained the best scores, are consistent with theirs. The fact that the Nordic countries did not make significant progress according to the results of Buchanan et al. (2020) is probably due to their already good results prior to 2010.

If we look at drawbacks, Portugal, the Netherlands and Belgium have the most important drawbacks related to goal 2 (Reducing direct pressures on biodiversity and ecosystems). Considering that these countries have not made progress in achieving targets in this goal, they are in the most critical situation. In Europe, a recovery of forest cover has been noted since 2015 (Ceccherini et al., 2020) due to the promotion of different reforestation initiatives and land abandonment caused by rural depopulation. Reforestation is not only important for timber production and employment generation, but also for recreation, quality of life and

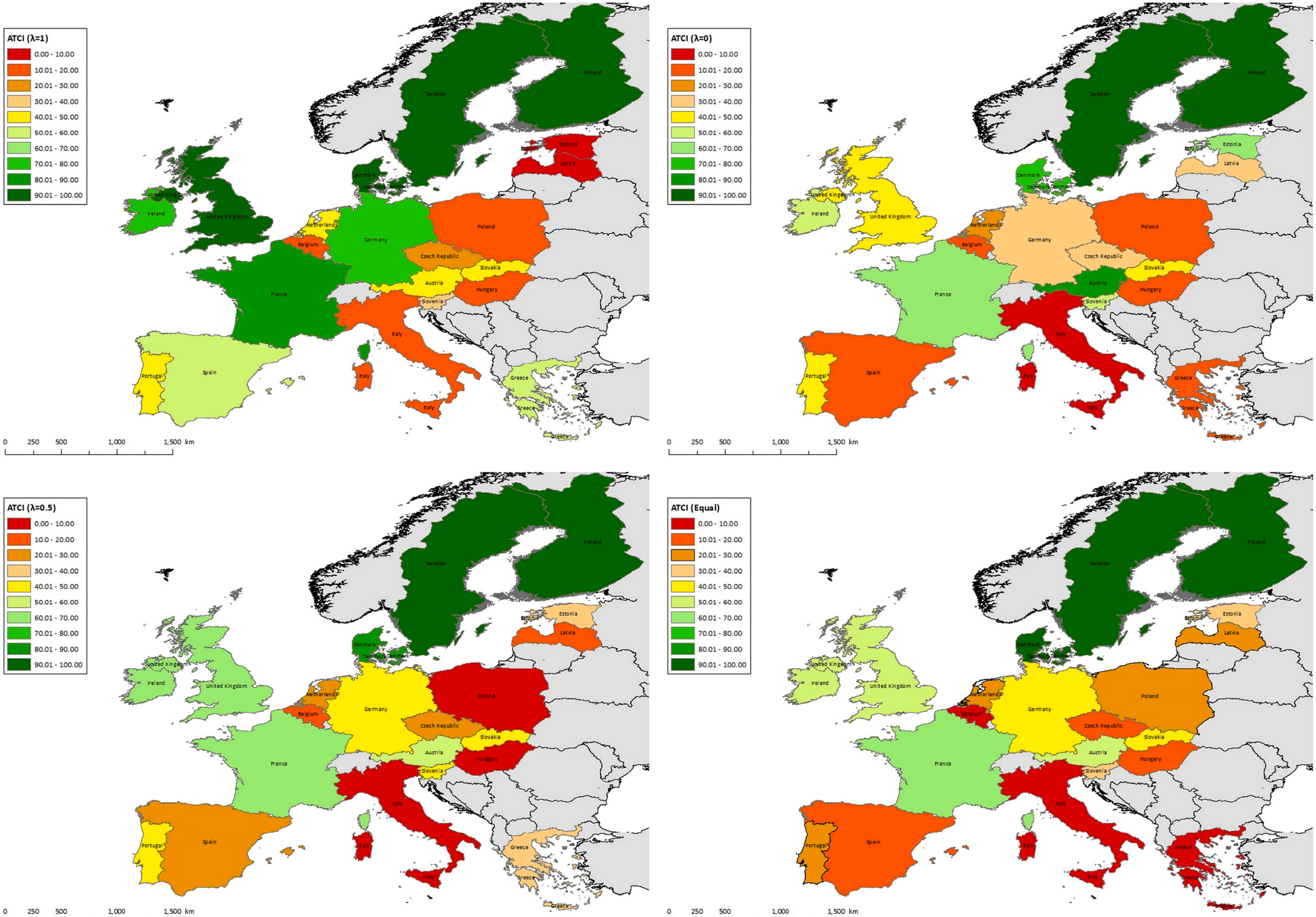

Fig. 2. Maps of countries in Europe according to ATCI calculated with optimal weighting for λ=1 (top left), λ=0 (top right), and λ=0.5 (bottom left), and equal weighting (bottom right).

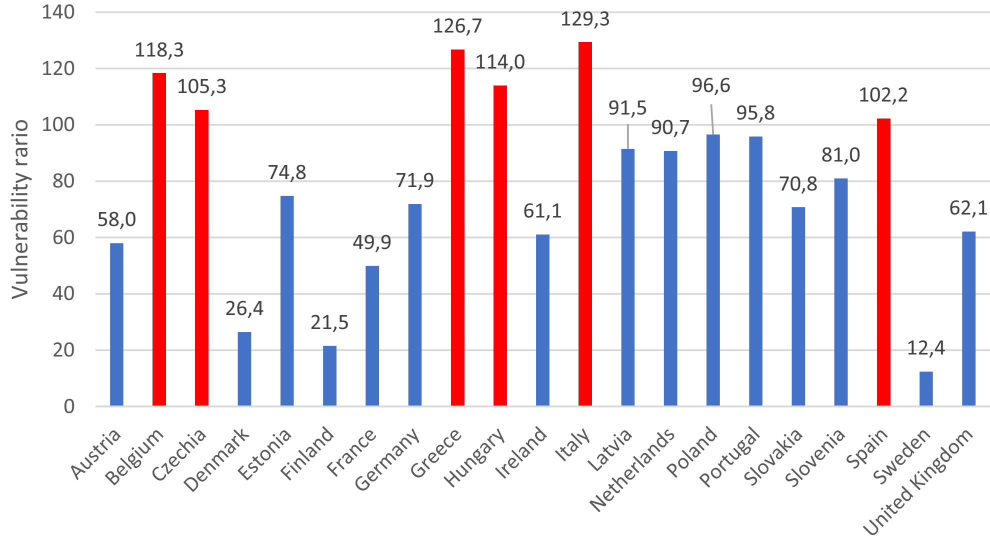

Fig. 3. Vulnerability ratio (VR) in European countries.

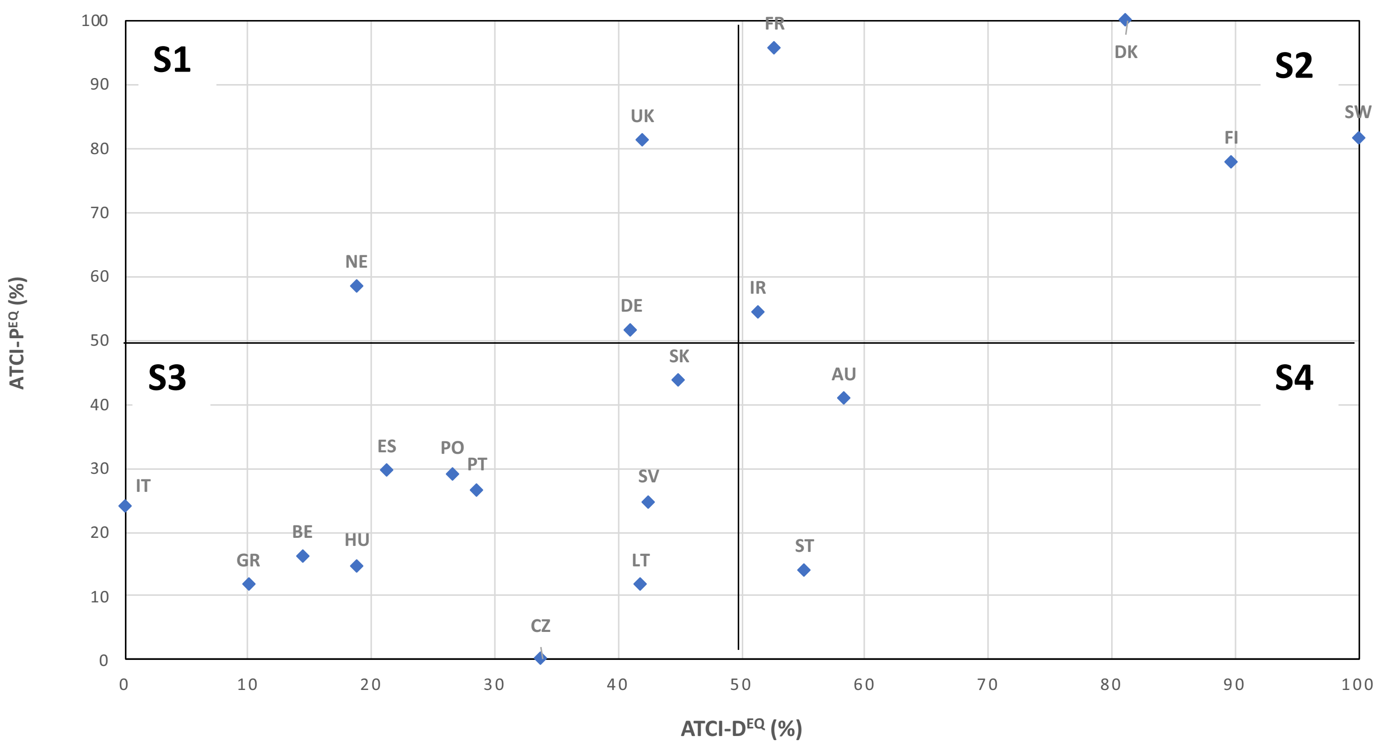

Fig. 4. Classification of European countries based on their levels of performance (DPI) and drawbacks (DDI). See description of categories S1 to S4 in the text.

other socio-economic benefits. However, recovering forest land per se does not necessarily result in conservation of biodiversity as it implies changes in the diversity of species of different groups. For instance, the number of species of vascular plants is negatively affected by afforestation but fungi and soil invertebrates respond to afforestation with an increase in species richness (AFFORNORD, 2008). The number of surface invertebrate and bird species are generally not affected by reforestation, although species composition and breeding densities are affected (AFFORNORD, 2008).

The most beneficial progress, according to the work of Buchanan et al. (2020), was made regarding indicators 7.1. (except in Greece and the north of Italy), 11.1, and 11.2. in most of Europe. As concerns performance, our results are consistent with these findings. Despite the fact that the percentage of protected areas for biodiversity in Europe has been a satisfactorily achieved AT, our analysis of drawbacks shows that some countries with high percentages of protected areas have significant constraints associated with the risk of landscape fragmentation. Among these countries are Belgium, the Netherlands, the UK, and Germany. Despite the efforts to protect areas of high ecological value, most developed countries suffer from limitations associated with the high density of roads and other large infrastructures that can turn protected areas into “conservation islands”. Landscape fragmentation is considered one of the major causes of the alarming decline of European wildlife populations, as it has dramatic consequences for wildlife such as through collisions with vehicles, preventing access to resources, facilitating the spread of invasive species, reducing the extent and quality of habitat,

Table 7
Final classification of European countries in terms of their position in relation to Equal $ATCI - D^{EQ}$normalized (%) and Equal $ATCI - P^{EQ}$normalized (%).

Countries	$ATCI - D^{EQ}$ Norm (%)	$ATCI^{EQ} - P^{EQ}$ Norm (%)	Category	
Germany	41.08	51.45	S1	Caution
Netherlands	1.77	58.36	S1	Caution
United Kingdom	41.95	81.09	S1	Caution
Denmark	81.16	100.00	S2	Excellence
Finland	89.71	77.78	S2	Excellence
France	52.68	95.56	S2	Excellence
Ireland	51.32	54.16	S2	Excellence
Sweden	100.00	81.62	S2	Excellence
Belgium	14.39	15.98	S3	Fragility
Czechia	33.70	0.00	S3	Fragility
Greece	10.01	11.59	S3	Fragility
Hungary	18.83	14.62	S3	Fragility
Italy	0.00	23.93	S3	Fragility
Latvia	4.82	11.69	S3	Fragility
Poland	26.55	29.03	S3	Fragility
Portugal	28.56	26.56	S3	Fragility
Slovakia	44.95	43.62	S3	Fragility
Slovenia	42.48	24.64	S3	Fragility
Spain	21.23	29.42	S3	Fragility
Austria	58.30	40.85	S4	Catching up
Estonia	55.11	13.97	S4	Catching up

and isolating animal populations (EEA-FOEN, 2011). Additionally, noise and traffic pollution also threaten the well-being and quality of life of human populations (EEA-FOEN, 2011). Although real efforts have been made in the development of ecological corridors to alleviate the effects of fragmentation, new socio-cultural constraints have been identified that may hinder the success of these interventions, and which some authors have termed as "anthropogenic resistance" (Ghoddousi et al., 2021).

The indicators associated with the AT12 showed significant progress in northern Spain and Portugal, southern Sweden, Italy and part of the eastern countries (Buchanan et al., 2020). In the rest of Europe, moderate or negligible progress was achieved. Central European countries, such as Germany, Austria, and the United Kingdom, were the countries that fell short of the set goals (Buchanan et al., 2020). Our method showed similar results, with central European countries performing less favorably in terms of endangered species rates.

In Buchanan et al. (2020) indicator 19.1. (Number of species occurrence records in GBIF) showed positive progress in Sweden, Central Europe and Italy, moderate or null in the rest of the countries, except in Finland, which experienced a setback with respect to this indicator. Our results showed that Sweden and France performed best.

Buchanan et al. (2020) found no data to measure the progress of indicator AT 20.1. in Europe. Our results showed that the best scores were for Denmark, Belgium, and Sweden.

As concerns methodology, it is undeniable that there is a need to develop tools that allow for the monitoring of the state and progress of conservation from a socio-ecological perspective. Socio-ecological systems support such a close human-nature relationship that research regarding these systems should rely more on their interactions and emergent properties than on their components. In this sense, work should continue to develop and improve tools and methodologies to measure, analyze and monitor these systems in an integrated manner. Little attention has traditionally been paid to the aggregation process in the construction of composite indicators. BoD models and the benchmarking approach are very useful under conditions of uncertainty. The suggested model highlights the gaps in country performance to visualize the problems more clearly and provides the best possible results in comparative terms. This contrasts with an arithmetic mean, which smooths the global result by evenly distributing the individual results, thus, making it difficult to clearly visualize the worst results and detect problems at an early stage. We strongly recommend further work on methodological and model improvements for the development of composite indicators. Adequate tools for diagnosis, analysis and monitoring may be key in the success of future conservation strategies.

The post-2020 global biodiversity agenda urges to rebuild biodiversity, well-being, and sustainability (Turnhout et al., 2021). Achieving biodiversity conservation objectives is a must, but so is doing so in an efficient manner. By agreeing to the Strategic Plan for Biodiversity 2011–2020, 196 countries increased investment in conservation (AT 20), expanded the extension of protected areas of special importance for biodiversity and ecosystem services (AT 11), and made efforts aimed at preventing species from becoming extinct (AT 12). However, evidence shows very limited progress on these targets, especially those related to conservation outcomes and an alarming disparity between the decline in biodiversity rates and the speed at which conservation actions are carried out (Di Marco et al., 2016). Such results point to the need to make additional efforts and improve the efficiency of conservation programs and strategies.

Benchmarking results, when performance and drawbacks indicators were simultaneously considered (Table 6) showed countries such as Sweden, Finland, Denmark, France and United Kingdom as the those performing best, while Italy, Hungary, Poland, Belgium, Latvia, Spain and the Netherlands did not perform so well. These results showed that the former countries have the capacity to the full implementation of the ATs. On the contrary, the lowest ranked countries seem to be less likely toto fully implementing the ATs.

When performance and drawbacks indicators were separately analyzed, the results showed four groups of countries according to their relative position the performance (DPI) and drawbacks indicators (DDI) space, in terms of implementing the ATs. The countries included in S1 (Caution), The Netherlands, Germany, and the United Kingdom, present limitations but obtained a good relative performance. The main limitations of these three countries were found in goals A, B and C while they obtained good results in dimensions 4 and 5. Prior to normalizing the results, the scores obtained by Germany and the UK are not a cause for concern. However, since the distances between all countries with respect to Sweden, Finland and (mostly) Denmark are so large, the rescaling process has "pushed" these countries to lower values than they have actually attained. The case of the Netherlands is different. The indicators associated with goal B and C presented the worst results for road density, vehicle density, population density and intensive use of forest resources. Although most of the performance indicators for this country were fairly high, those associated with goal B were once again among the worst.

The countries listed in S2 (Excellence) were those with the highest relative performance and the lowest level of drawbacks. Sweden, Denmark, France, Finland and Ireland comprise this group.

Group S3 (Fragility) includes countries with relatively low performance and high limitations for implementing the ATs. Most of these countries ranked worse when constraints were considered in the overall assessment. Italy, Hungary, Greece, Czechia, Belgium, Poland, Portugal, Spain, Latvia, Slovenia and Slovakia comprise this group. In particular, the most vulnerable countries (Belgium, Czechia, Greece, Hungary, Italy and Spain) obtained a vulnerability ratio above 100, meaning that drawbacks outweigh performance. The main drawbacks were related to goals A, D and E, except for Belgium that were in goals B, C and D. Czechia, Greece, Hungary, Italy and Spain scored <0.5 points (out of 1) in the governance index and, with the exception of Czechia, in the income inequality (except Hungary), state fragility, innovation and climate change indicators. Greece and Spain also presented low scores in the water exploitation index and Italy in soil erosion indices. Conversely, Belgium exhibited a different behavior. The country showed low scores in indicators in goal B (use of forest resources and vehicle density) and C (road density and population density) and in the index associated with climate change in goal D. Belgium also yielded low values in the industrial innovation indicator (goal A), although it obtained good score in the rest of indicators of this dimension (income inequality and fragility of the countries). The results of group S3 show two country profiles as regards the drawbacks of the ATs: countries with medium/low economic development, whose drawbacks are associated with the quality of institutions and governments, and countries with higher economic development, whose drawbacks are associated with heavy demographic pressure and what it entails for the environment, such as the heavy occupation of space by transport infrastructure or the intensity of natural resources exploitation. The former, in addition to the current difficulties in achieving the ATs, will have additional difficulties if their economic development increases and the current constraints are not addressed. The latter must work on adopting measures to remedy and compensate for the pressure they exert on the environment.

Group S4 (Catching up) includes Austria and Estonia. Given that these two countries have few drawbacks, including them in the analysis improves their ranking. This means that both countries currently have favorable conditions for the successful implementation of conservation policies. However, their favorable conditions result from different causes that should be analyzed separately. Austria performed very well in all drawbacks goal indicators, while Estonia scored well in goals B, C and D, mainly due to the good results of indicators associated with high population densities and anthropic pressure on the environment (e.g., a highly developed road network or advanced industrial development). On the other hand, the scores of dimensions A and E, associated with institutional and cultural development, such as income inequality, state fragility, entrepreneurship-related innovation, and good governance obtained worse results. A look at the GDP of both countries reveals that Austria belongs in the top percentile and Estonia in the bottom percentile in Europe (Eurostat, 2019). Once again we found countries with different levels of socio-economic development which, despite being in the same set (S4) and exhibiting a similar confortable position in terms of balance of performance and drawbacks, should be monitored differently. Austria's conditions are adequate to implement ATs in a sustainable manner and investing in biodiversity conservation policies would be cost-effective. Estonia's current status is identical but if improvements in its economic development (at least as measured based on socioeconomic indicators) take place, it may hinder its capacity to implement the ATs. What is more, the success it has seen in its impact on biodiversity as a result of a low economic development disappears.

Our results should be interpreted with some caution. Both the normalization and the benchmarking approaches used in this study focus on distances of scores between individual countries and countries with higher scores. Therefore, countries with the worst results may not necessarily have obtained absolute bad results, being however at greater distances from best-performing countries.

6. Conclusions

The method developed in this study, showed to be useful to address conservation goal and targets combining levels of performance and drawbacks based on composite indicators. The results generated by this novel model provided useful information about performance and difficulty in meeting the Aichi Targets, emphasizing the vulnerability of some countries and anticipating future problems regarding the achievement of conservation strategies. The method provides valuable information to describe the current condition of European countries to face and implement conservation strategies in the future, such as the Strategic Plan for Biodiversity 2021–2030 or the EU Biodiversity Strategy for 2030, and it is a useful tool for rigorous and realistic monitoring of the objectives of these programs. The application of our methodology has identified Denmark, Finland, France, Ireland and Sweden as the countries that when it comes to ATs perform best and experience the lowest level of drawbacks in their implementation. In order to evaluate their replicability in other European countries, it would be advisable to revise the policies being implemented not only those related to conservation, but also to social and economic strategies. Austria and Estonia have performed at a lower level when compared to the countries above, although they do not face severe limitations. This entails an opportunity for obtaining better results in the achievement of conservation objectives without having to make considerable investments. The opposite scenario is that of Germany, the Netherlands and the United Kingdom, which have obtained a good relative performance but also face important limitations associated, fundamentally, with high population density. The remaining countries, Belgium, Czechia, Greece, Hungary, Italy, Latvia, Poland, Portugal, Slovenia, Slovakia and Spain, reported significant problems in the implementation of the ATs, as well as a poor relative performance. These countries should first work to mitigate the drawbacks identified to ensure the proper implementation of targets and objectives of current and future biodiversity strategies.

The analysis of drawbacks has identified two profiles of countries. On the one hand, countries of high economic development whose limitations are associated with high population densities and anthropic pressure on the environment and on the other hand, countries of medium/low economic development whose limitations are associated with low institutional quality but not with anthropic pressure. The former should adopt compensation measures and invest in strategies to increase the efficiency and sustainability of production processes. The latter should adopt measures aimed at improving the governance of their institutions, improving the quality of life of rural communities and developing a social base favorable to biodiversity conservation. If these setbacks are not addressed, the impact on biodiversity can be expected to worsen as these countries develop economically.

The results of this study should be interpreted taking into account that it was not possible to analyze all European countries due to lack of data. Although approximations could have been used, we preferred to work with fewer countries but with complete datasets in order to obtain rigorous results. Given the fact that we have applied a benchmarking approach, incorporating new countries would inevitably change both the scores and the rankings of the indicators applied. The limitations of this study in particular, and the construction of indicators in general, are associated with the lack of homogeneous data available from country to country over time. Thus, it would be advisable for public administrations to make an effort to harmonize and collect data on a continuous basis over time. Communication and data collection should be ensured in a coordinated manner at an international level in order to facilitate the construction of homogeneous databases. This would, in turn, allow for comparisons between different countries and regions, at least in Europe, and facilitate the effective monitoring of conservation policies, the early detection of difficulties and the mitigation of problems.

Future research in this model should be oriented towards a more detailed analysis of the importance of individual drawback and performance indicators. Moreover, this should be done based on participative approaches to estimate weights to drawback and performance indicators to further refine results and to allow for trade-off analysis among factors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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