

Scenarios for a Trans-European Nature Network: prioritisation methodology

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1 Background

International policy frameworks have set ambitious targets to accelerate conservation and ecosystem restoration. Protected areas (PAs) remain indispensable for mitigating threats, particularly habitat conversion and direct exploitation. To achieve meaningful and lasting outcomes for biodiversity and ecosystem services, spatial planning must identify top priorities for expanding and strengthening existing protected areas and for restoration, connectivity and sustainable management beyond the borders of PAs, in a way that accounts for projected scenarios of land use change and climate change.

NaturaConnect aims to design and develop a blueprint for a coherent and resilient Trans-European Nature Network (TEN-N) of conserved areas that protect at least 30% of land in the European Union, with at least one third of it under strict protection. Here, we develop an integrated spatial conservation framework for conserving and restoring European biodiversity that explicitly addresses resilience, comprehensiveness (covering multiple taxa, habitats, ecosystems and nature's contributions to people (NCP)), connectivity, climate and land use change, cost and equitable area sharing (Figure 1).

We used present and future distributions of terrestrial species (vertebrates, invertebrates, plants), habitats (terrestrial, freshwater and coastal), regulating and cultural NCP, climate-resilient areas, ecological connectivity, and other ecosystems of conservation concern (old-growth and primary forests, carbon-rich ecosystems). Based on this, we identify top priority areas for protecting 30% of European land (including a third under strict protection), for restoring 20% of ecosystems, and for sustainable management of landscapes in Europe.

This document presents an overview of the methods for **identifying where to conserve and restore areas in Europe** to maximise benefits for nature and people in current and future climate scenarios.

2. Methodology

2.1. Objectives and workflow

We developed high-resolution (1 km²) spatial prioritisation scenarios to identify priorities for (i) expanding protected areas to 30% of European land area, (ii) 10% under strict protection within the 30%, (iii) restoring 20% of ecosystems, and (iv) sustainable management of green infrastructure outside of protected and restored areas. We formulate this as a linear programming problem, using the R-package *prioritizr* (Hanson et al., 2019) and the Gurobi solver for fast identification of the optimal solution (Gurobi Optimization, 2024). We use a minimum shortfall objective function, to minimise gaps in coverage for species, habitats and key areas for nature's contributions to people (NCP) (Figure 1).

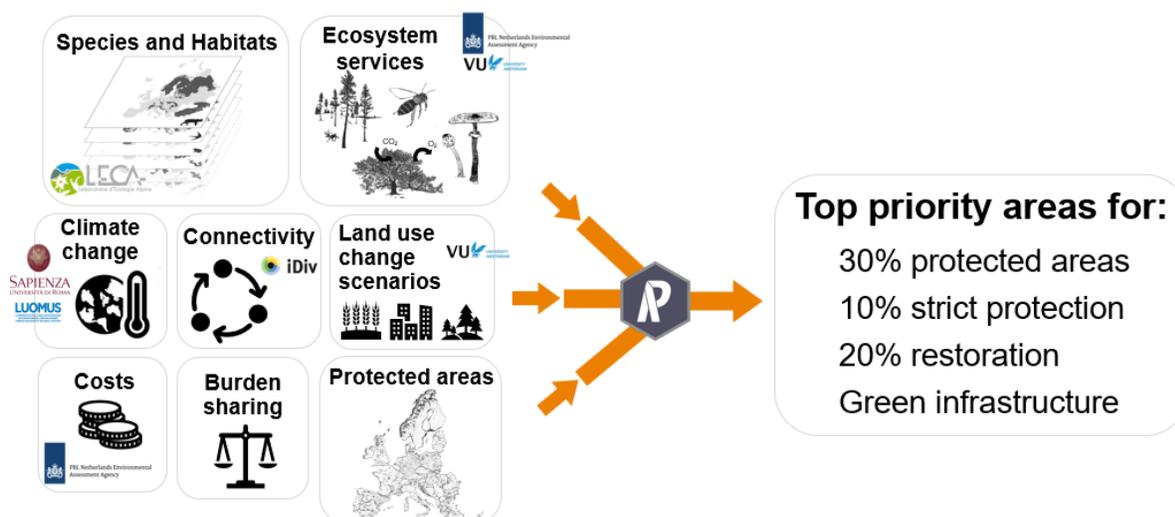


Figure 1. Overview of the framework for a connected and resilient Trans-European nature network.

Prioritisations for conservation, strict protection, restoration and green infrastructure (GI) are run in sequence. The sequence in each variant scenario (Figure 2) is as follows:

- (1) **Identify top priorities for 30% conservation**, expanding on existing protected areas.
- (2) **Identify top priorities for 10% strict protection**, within the 30%. These priorities expand on existing strictly protected areas.
- (3) **Identify top priorities for 20% restoration**. Feasible restoration transitions are informed by the current and future land system maps, as well as existing protected areas.
- (4) **Prioritise green infrastructure (GI) for sustainable management**, by ranking the rest of Europe in terms of multifunctional value for connectivity, NCP and any remaining gaps in species and habitats coverage outside of conservation and restoration priorities.

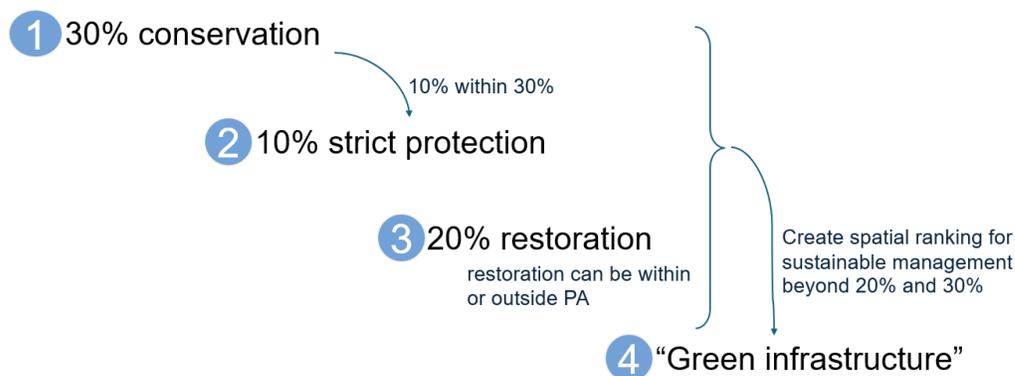


Figure 2: Overview of the prioritisation sequence for a given scenario variant.

2.2. Scenario variants

There is not one single possible configuration for a potential TEN-N, but rather different variant scenarios each with their own parameters and setup. Such a range of different variants enables us to investigate synergies, trade-offs, and co-benefits.

We develop a total of 144 scenario variants that systematically varied the following criteria

- **Baseline protected areas** as starting point to reach 30% (expanding on Natura 2000 only; or all protected areas) (x2)
- **Climate change**: Prioritise climate-resilient areas accounting for climate-driven shifts in species distributions (x2)
- **Connectivity**: Prioritise critical corridors for species movements and avoid fragmented habitats (x2)
- **Socio-economic costs**: Avoid high opportunity costs, or ignore costs to focus exclusively on benefits for biodiversity and NCP (x2)
- **Nature Futures Framework (NFF)**: Variation of nature value preferences and land use change scenarios (x3)
- **Equitable area sharing** for countries, bioregions, or no sharing constraints (x3)

3. Input data

3.1. Biodiversity features

Species and Habitats. The spatial planning includes all species and habitats of conservation importance for which there is sufficient occurrence data to model their distributions. Species included are all native to Europe and are either: endemic to Europe, listed in the Annexes of the Article 12 Birds Directive and Article 17 Habitats Directive, or listed threatened or near-threatened in the IUCN Red Lists of species (Global and European assessments). Habitats included are all listed in Article 17 of the Habitats Directive. We used current and future distributions of species and habitat distributions as biodiversity features. In total, we included in the prioritisation: 183 habitat types, 806 vertebrates, 238 plants, and 446 invertebrate species. EU Commission Guidance on protected areas specifically notes that remaining primary and old-growth forests and any significant areas of carbon-rich ecosystems, such as peatlands, should be strictly protected. Primary and old-growth forests are thus included as features, with a very high weight of 10,000 to ensure their selection in the output for conservation and strict protection.

Nature's Contributions to People (NCP). In the Nature as Culture and Nature for Society prioritisation scenarios, we use maps of key areas for NCP (Schipper et al., 2025) as features alongside species and habitat distributions. Specifically, NCP covered in the analyses are: 10 regulating NCP (Pollination; Soil erosion protection (Spencer, 2025); Carbon Sequestration and Carbon Stocks; Seed dispersal; Agricultural and forest pest control; Carrion elimination; Mosquito biocontrol; Regulation of tick-borne pathogens) and 8 cultural NCP: Wildlife watching; Wild foods foraging; Medicinal plants; Nature recreation; Heritage forests and Heritage agriculture; Birdsong; Species of Cultural Importance.

3.2. Feature-specific weights and targets

We use **weights** to ensure the selection of species or habitats of particular conservation concern (Arponen et al., 2005). Species or habitats known to be Critically endangered (CR) or in bad conservation status (U2) were given a weight of 5, Endangered (EN) a weight of 4; and Vulnerable (VU) or unfavourable conservation status (U1) a weight of 3. Near threatened (NT) and Data Deficient (DD) species or habitats were given a weight of 2. All other species and habitats were given a weight of 1.

Targets represent the amount of the spatial distribution of each species or habitat that should be maintained for the species or habitat to be in favourable conservation status, with the objective to

minimise target shortfall for species across the 30% protected areas, 20% restored areas, and green infrastructure across Europe.

For species and habitats, we assign area targets that aim to reduce extinction risk based on IUCN Red List criteria, inspired by previous studies (Fastré et al., 2021; Jung et al., 2021). For species and habitats that are threatened or in unfavourable conservation status (U1 and U2), the target is to protect 100% of their total distribution (D'Alessio et al., 2025; Davoli et al., 2025). For other species and habitats, we formulate the target to minimise the distance to extinction risk or ecosystem collapse, respectively, according to IUCN Red List criteria (Fastré et al., 2021; Jung et al., 2021). In the variants where NCP are included, the target for each NCP is set to 100% of the key areas providing the NCP.

3.3. Constraints and penalties

Protected areas. We use Natura 2000 sites and nationally-designated sites (NatDa) as locked in constraints in the solution for the 30%. For the 10%, we defined top priorities for strict protection to expand on reserves and national parks: we use IUCN protected area categories I and II which are typically used as baseline for strict protection (Cazzolla Gatti et al., 2023), in the absence of better data on existing strictly protected areas at the European level.

Climate resilience. We use the rank map output from T7.2 (Figure 3) which represents areas of high biodiversity importance accounting for climate change induced range shifts and connectivity between the current and future ranges of species subpopulations (Cavalcante et al., 2025, 2026). It is integrated in the prioritisation with a negative penalty to preferentially select climatically resilient priority areas.

Critical ecological corridors for species movement between protected areas. In the variant scenarios that consider ecological connectivity for the 30%, we add critical ecological corridors as input to the prioritisation, such that some priority areas are selected for their high importance as corridors (Dertien et al., 2025).

Socio-economic costs. We provide a set of scenarios that consider socio-economic costs alongside biodiversity features (Spencer et al., 2025). When using costs data, we incorporate these cost data in the problem as linear penalties with a penalty score.

Land available for conservation and restoration. We prevented the selection of additional area in settlements (rural, peri-urban and urban) and in areas with a high density of anthropogenic

infrastructure (industrial units, airports, mineral extraction sites, dump sites, roads and rail). To prioritise areas for ecological restoration, we focus on areas that are currently degraded but restorable: this includes all human-dominated land systems (medium to high intensity forests; medium to high intensity grasslands; all croplands; forest/crops mosaics and forest/grassland mosaics). For restoration, feasibility is defined by both 1) existing protected areas that are dominated by extractive land uses of medium to high intensity and 2) potential transitions in alternative nature-positive future land-use change scenarios (Venier-Cambron et al., 2025), with the narratives underlying these scenarios having been informed by a stakeholder consultation process following the Nature Futures framework (NFF) (Fornarini et al., 2024; Pereira et al., 2020).

3.4. Area sharing constraints

3.4.1. Area sharing constraints for the 30% conservation area target

Top priorities for protected area expansion are designed to complement existing protected areas and to close conservation gaps by minimizing target shortfall for all features.

To explore spatial priorities that balance biodiversity benefits with equitable area sharing between European countries and biogeographical regions, we create three scenario variants:

- A first set achieves 30% at the level of countries, in accordance with most national conservation strategies that aim to reach 30% at a national level. Because some countries (such as Bulgaria, Slovenia, Croatia) are already above 30% of protected area coverage, we allow for flexible sharing of area such that each country may achieve between 25% and 30% of their land area, to achieve a total of 30% area for conservation at the European level.
- A second set achieves 30% at the level of biogeographical regions, in accordance with EU policy guidance. Similarly to the country area shares, some biogeographical regions (Alpine, Macaronesia) are already above 30% of protected area coverage, thus we allow for flexible sharing of area such that each region may achieve between 25% and 30% of the total regional area, to achieve 30% at the European level. Note that our analyses showed that capping each biogeographical region at 30% performs poorly for species and habitats because some regions - Alpine, Macaronesia, Mediterranean - are already beyond or very close to 30%, but still have exceptional value for European biodiversity and high levels of coverage gaps remain for species and habitats in those regions.

- In a third set of scenarios, we identify optimal priorities that ensure 30% is achieved at the level of the EU, but without further constraints on area shares at the level of countries or regions. Although less realistic than the other two, this type of scenario enables to quantify the optimal gains under less constraints as a point of comparison, and may be relevant for countries or regions that are already at 30% or above, but would have the capacity to protect more.

3.4.2. Area sharing for the 10% strict protection

Some countries may designate more, or less, than 10% of their area. This was confirmed by stakeholders and member states' representatives. For example, Sweden has pledged over 10% of strict protected area coverage. However, some countries (e.g. France) already have interpreted the 10% as a national target in their own national strategies (as 'strong' protection). Hence, we explore three different burden sharing scenarios for the 10%, in line with the burden sharing scenarios for the 30% (i.e. national area sharing for 10% will be identified within the priorities for national area sharing for the 30% conservation, etc.). We implement a flexible burden sharing approach in the strict protection prioritisation, with a maximum of 15% per country, or region, to allow some flexibility. We explore three sets of variant scenarios for sharing strict protection area between countries and regions:

- A first set distributes the 10% at the level of countries, however because the 10% is a European-wide area target in the EU biodiversity strategy, and countries may designate more than 10% of area as strictly protected (e.g. Sweden), we allow up to 15% of area per country to be selected for strict protection in this variant.
- A second set distributes strict protection between biogeographical regions, such that each biogeographical region may have up to 15% of area selected for strict protection.
- A third set of variants identifies optimal priorities that ensure 10% is achieved at the level of the EU, but without further constraints on area shares at the level of countries or regions.

3.4.3. Area sharing for 20% restoration

Unlike the 30% target, there is no official policy recommendation on how to distribute restoration areas between European countries or biogeographical regions. Therefore, in line with the prioritisation for 30% and 10%, we explore alternative area sharing scenario variants for restoration with flexible area shares for 20% restoration across Europe:

- In the scenarios ensuring country-level sharing of area allocated to conservation and restoration, as for strict protection (see above), we allow flexible sharing for restoration, so that up to 30% of each country area may be restored, while achieving 20% of restored ecosystems at the European scale. We balance the total area allocated for both restoration and strict protection in each country such that the area budget for restoration per country is equal to 30% of the country area minus the amount of area selected as priority for strict protection in that country.
- In the scenarios ensuring biogeographical regional level sharing of area allocated to conservation and restoration, as for strict protection (see above), we allow flexible sharing for restoration, so that up to 30% of each biogeographical region may be restored, while achieving 20% of restored ecosystems at the European scale. We balance the total area allocated for both restoration and strict protection between biogeographical regions so that the area budget for restoration per region is equal to 30% of the biogeographical regions' area minus the amount of area selected as priority for strict protection in that region.
- A third set of variants identifies optimal priorities that ensures 20% of area is restored at the level of the EU, but without further constraints on area shares at the level of countries or regions. This variant is likely to be highly relevant ecologically as there is strong variation in the levels of ecological degradation across different countries in Europe, thus the 20% priorities for restoration should be targeted in the areas that would be most beneficial for biodiversity.

3.5. Example priority maps

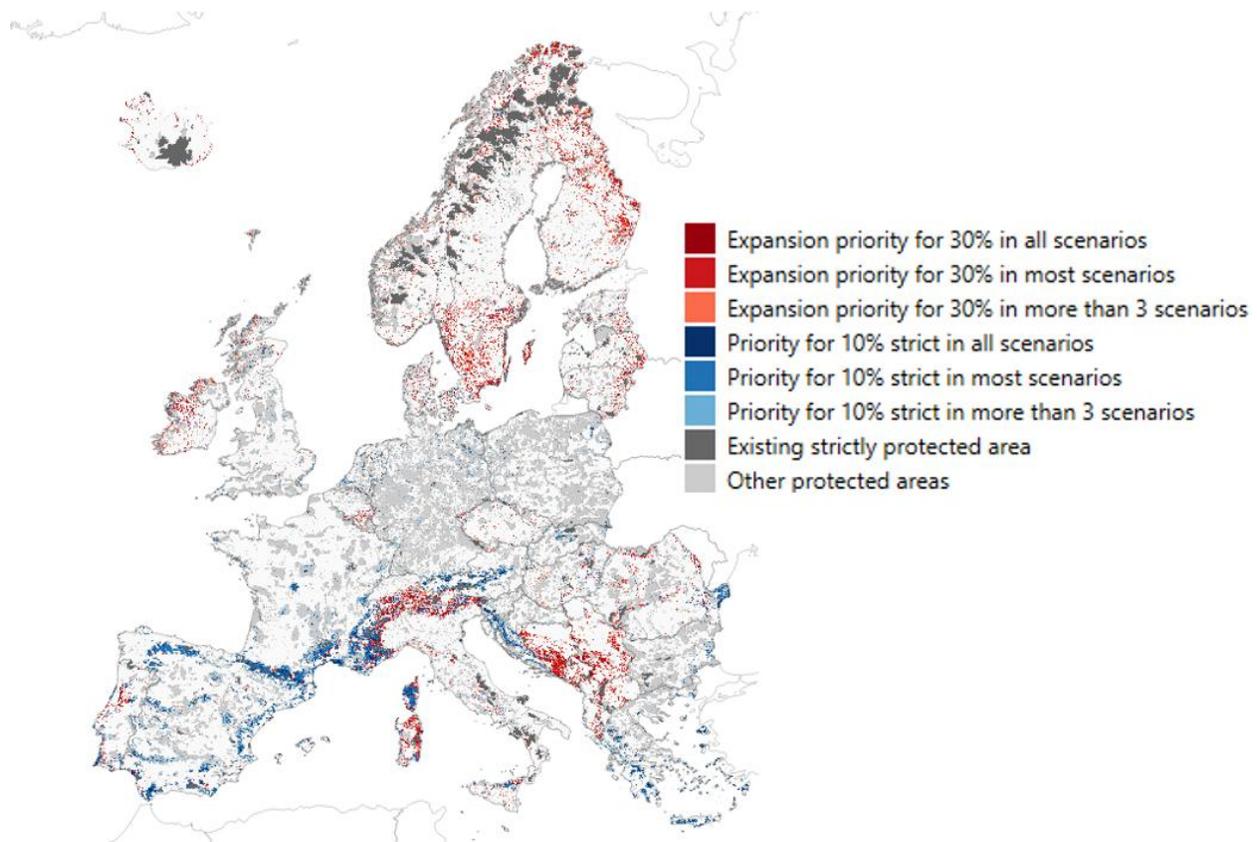


Figure 3: Example priority map for conservation and strict protection, with the level of consensus across 12 scenarios that consider country-level area sharing and all existing protected areas as a starting point for 30%. In this map, the 30% and 10% are distributed evenly between European countries. Red areas indicate top priorities to reach 30% of protected areas in Europe, expanding on existing protected areas (all designations). Blue areas show top priorities to reach 10% of strict protection in Europe and are nested within the 30%. The darker shades indicate a higher consensus across all scenarios: these consensus areas would be 'safe bets' for conservation expansion as they have value across all scenarios.

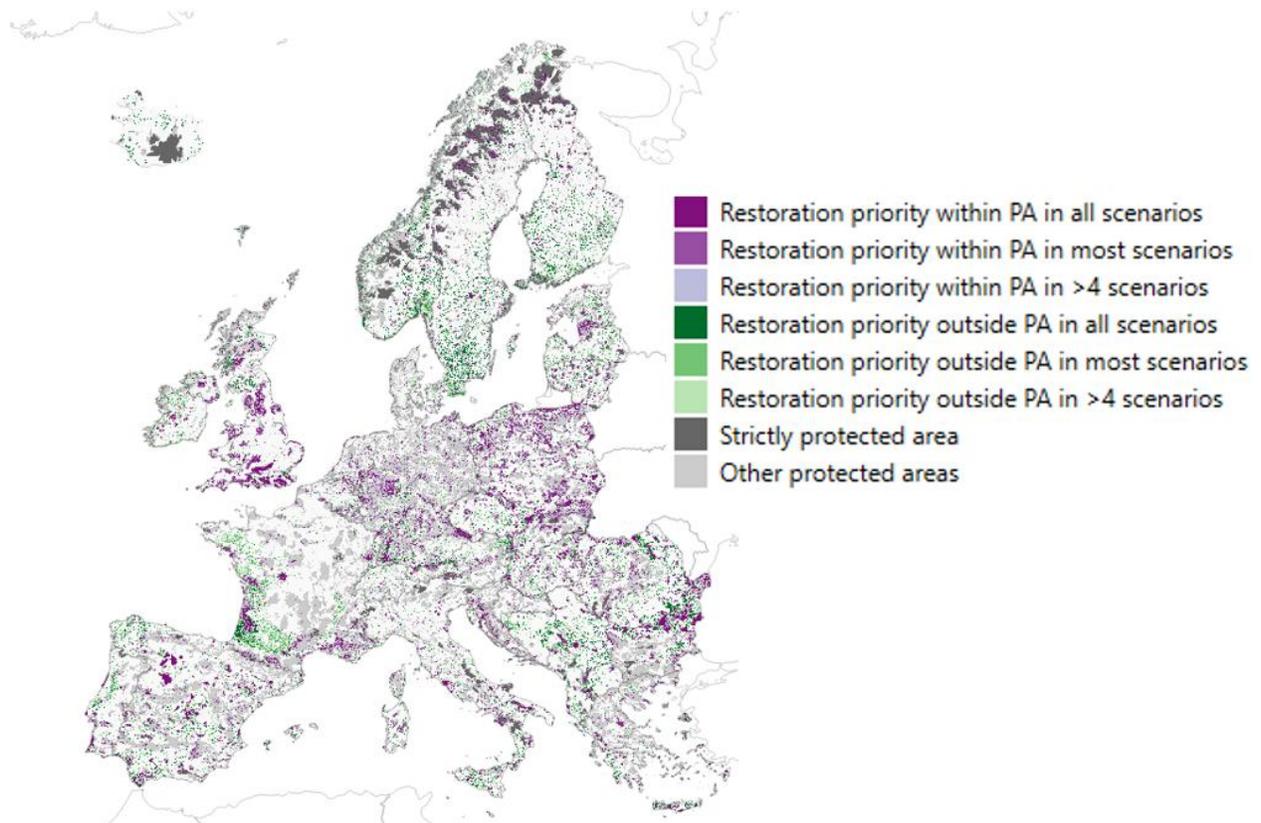


Figure 4: Example priority map for 20% restoration in Europe, including the level of consensus across 12 scenarios that consider country-level area sharing and all existing protected areas as a starting point for 30%. Restoration priority areas are coloured differently if they are identified within (purples) or outside (greens) existing protected areas (all designations). The darker shades indicate a higher consensus across all scenarios: these consensus areas would be 'safe bets' for conservation expansion as they have value across all scenarios.

References

- Arponen, A., Heikkinen, R. K., Thomas, C. D., & Moilanen, A. (2005). The Value of Biodiversity in Reserve Selection: Representation, Species Weighting, and Benefit Functions. *Conservation Biology*, 19(6), 2009–2014. <https://doi.org/10.1111/j.1523-1739.2005.00218.x>
- Cavalcante, T., Cimatti, M., Di Marco, M., & Kujala, H. (2026). *Climate-Resilient Spatial Prioritization and Connectivity Layers for European Vertebrates (T7.2, NaturaConnect)* [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.15553096>
- Cavalcante, T., Cimatti, M., Si-Moussi, S., Thuiller, W., Di Marco, M., & Kujala, H. (2025). Beyond species-level planning: The role of bioclimatic variation within species distributions. *bioRxiv*, 2025–10.
- Cazzolla Gatti, R., Zannini, P., Piovesan, G., Alessi, N., Basset, A., Beierkuhnlein, C., Di Musciano, M., Field, R., Halley, J. M., Hoffmann, S., Iaria, J., Kallimanis, A., Lövei, G. L., Morera, A., Provenzale, A., Rocchini, D., Vetaas, O. R., & Chiarucci, A. (2023). Analysing the distribution of strictly protected areas toward the EU2030 target. *Biodiversity and Conservation*, 32(10), 3157–3174. <https://doi.org/10.1007/s10531-023-02644-5>
- D'Alessio, A., Davoli, M., Rondinini, C., & Pacifici, M. (2025). 2030 conservation targets for European terrestrial mammals using the favourable conservation status concept. *Scientific Data*, 12(1), 591. <https://doi.org/10.1038/s41597-025-04878-0>
- Davoli, M., Jung, M., Visconti, P., Rondinini, C., D'Alessio, A., & Pacifici, M. (2025). *Improving the classification of wildlife conservation status to support nature protection in the European Union* (p. 2025.07.01.662537). *bioRxiv*. <https://doi.org/10.1101/2025.07.01.662537>
- Dertien, J., Ocegüera Conchas, E., Poulsen, N., & Fernandez, N. (2025). *Pan-European Functional Connectivity and Corridor Prioritization for Terrestrial Vertebrates* [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.17176766>
- Fastré, C., Van Zeist, W.-J., Watson, J. E. M., & Visconti, P. (2021). Integrated spatial planning for biodiversity conservation and food production. *One Earth*, 4(11), 1635–1644. <https://doi.org/10.1016/j.oneear.2021.10.014>
- Fornarini, C., D'Alessio, A., Dertien, J., Fernández, N., Moreira, F., Namasivayam, A. S., O'Connor, L., Pereira, H., Verburg, P., & Rondinini, C. (2024). *Scenario framework for TEN-N, translation of NFF storylines into indicators and scenario settings*. <https://doi.org/10.3897/arhpreprints.e134026>
- Gurobi Optimization. (2024). *Gurobi Optimizer Reference Manual*. <https://www.gurobi.com/documentation/>
- Hanson, J. O., Schuster, R., Morrell, N., Strimas-Mackey, M., Watts, M. E., Arcese, P., & Bennett, J. (2019). Prioritizr: Systematic Conservation Prioritization in R. *R Package Version 4.1.1.*, <https://CRAN.R-project.org/package=prioritizr>.
- Jung, M., Arnell, A., de Lamo, X., García-Rangel, S., Lewis, M., Mark, J., Merow, C., Miles, L., Ondo, I., Pironon, S., Ravillious, C., Rivers, M., Schepaschenko, D., Tallwin, O., van Soesbergen, A., Govaerts, R., Boyle, B. L., Enquist, B. J., Feng, X., ... Visconti, P. (2021). Areas of global importance for conserving terrestrial biodiversity, carbon and water. *Nature Ecology & Evolution*, 5(11), 1499–1509. <https://doi.org/10.1038/s41559-021-01528-7>
- Pereira, L. M., Davies, K. K., Belder, E., Ferrier, S., Karlsson-Vinkhuyzen, S., Kim, H., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., Sathyapalan, J., Schoolenberg, M., Alkemade, R., Carvalho Ribeiro, S., Greenaway, A., Hauck, J., King, N., Lazarova, T., ... Lundquist,

- C. J. (2020). Developing multiscale and integrative nature–people scenarios using the Nature Futures Framework. *People and Nature*, 2(4), 1172–1195. <https://doi.org/10.1002/pan3.10146>
- Schipper A (2025) Ecosystem services across Europe. D4.2Current and future natural capital and ecosystem services. ARPHA Preprints. <https://doi.org/10.3897/arphapreprints.e182685>
- Spencer, D. (2025). *Modelling the soil retention capacity of European landscapes for conservation and restoration measures* [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.15696473>
- Venier-Cambron, C., Scherpenhuijzen, N., Tita, D., Penna, M., Sandström, E., Sarita Namasivayam, A., Garcia, N., Levering, A., Hackbarth, T., & Verburg, P. (2025). *Land-use scenarios under the Natures Futures Framework* [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.17476213>