A Prototype decision support system: UnderSCORE

Accounting for the forest understorey when making management decisions in an era of environmental change

SUMMARY: **1.** A Europe-wide questionnaire showed that decision-makers in temperate forests are concerned about biodiversity, climate change and forest regeneration. **2.** The understorey relates to all these aspects, and plays a known functional role in forest ecosystems. **3.** There were no tools available to predict understorey development over time or space **4.** We present a prototype DSS (UnderSCORE) that accounts for the forest understorey, and will help inform management decisions, with particular applicability to strategic decision-makers. **5.** We provide a tutorial in this report and welcome feedback on the tool. UnderSCORE hopes to develop further to meet your needs.

ASSESSING THE NEED(S) OF UnderSCORE

PREMISE: When making or influencing decisions for forest management, an important consideration is how **environmental changes** will alter forest biodiversity and functions. Currently, decision-making in forest management focusses predominantly on trees and **ignores the herbaceous layer** (the understorey). A crucial oversight, as the understorey is a biodiversity reservoir and can influence forest functioning (e.g. tree regeneration, nutrient cycling). Knowing how environmental changes and management interventions will affect the understorey, is necessary to **reach management objectives**. A Decision Support System (DSS) would facilitate an understanding on this topic and provide support in related decision problems.

We aimed to develop such a tool through UnderSCORE. UnderSCORE is a proof-of-concept application of the knowledge developed during the **European Research Council (ERC) PASTFORWARD** project to benefit policy makers and forest managers. Similar tools are currently unavailable and would be beneficial for adherence to **major policy schemes** such as Natura 2000, the European Biodiversity strategy and the Clean Air Outlook. Framed in an **ERC Proof of Concept Grant**, we were able to explore the potential for a tool that can predict understorey dynamics in response to environmental change and management interventions.

RESEARCH: We sent a questionnaire to 800+ decision-makers of various occupations from across Europe, asking about their perceived **management challenges, motivations and targets**. In this questionnaire, we did not initially reveal the understorey focus to prevent bias in responses. Later, we explored what kind of understorey **output data and requirements** decision-makers would need from a potential Decision Support System (DSS) to match their management objectives. In tandem, we reviewed the available literature for any available DSS with an understorey component. A summary of results is presented in the next section, but for more details, we refer to the published study in Forest Ecology and Management[1].

RESULTS: The questionnaire yielded 100 complete responses from 20 countries, on which we based the geographic working extent of UnderSCORE (Figure 1). Without a distinction between occupation, decision-makers considered **biodiversity**, **climate change** & **forest regeneration** as "very important". Meanwhile, the understory was regarded as simply "important", even though the understorey has a known functional role influencing the main focus areas. Replies for **Specific Understorey targets** indicated again the importance of biodiversity (species of conservation concern) and tree regeneration in its management. Additionally, we found a severe lack of DSS that consider understorey dynamics, especially within changing environmental conditions.

Occupation participants

Total responses: 100
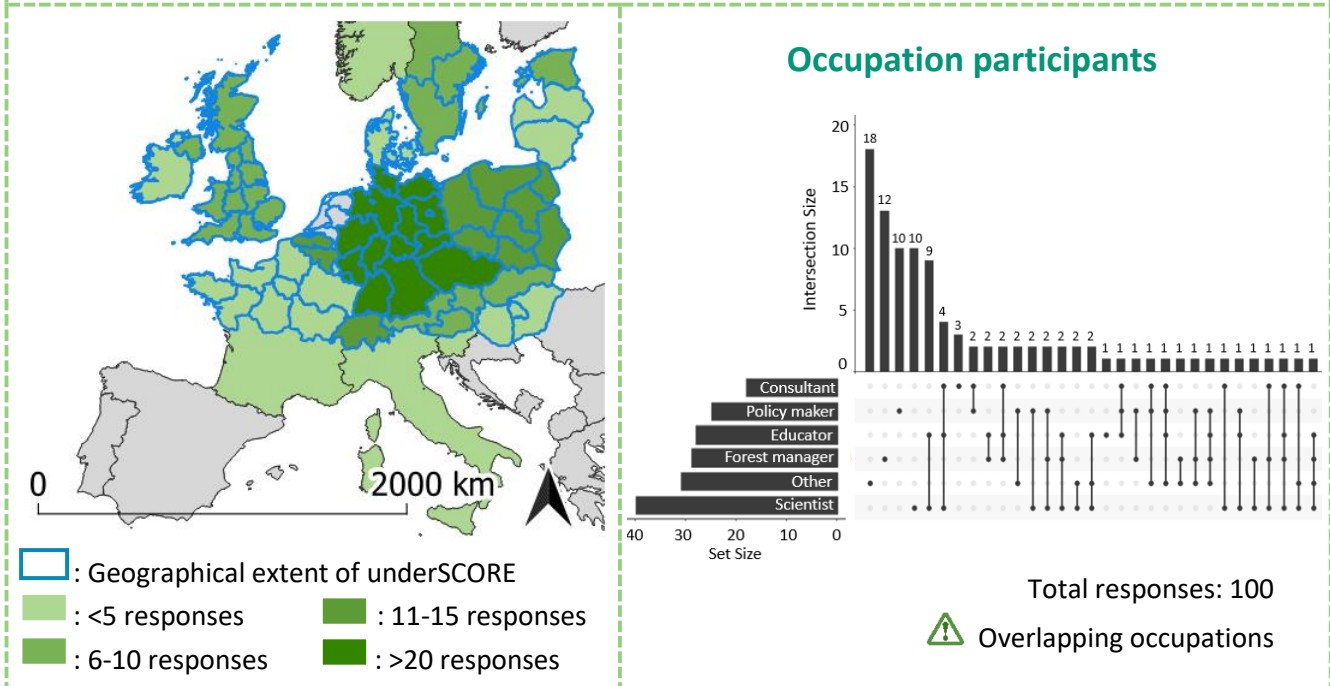
⚠ Overlapping occupations

Figure 1: <u>Left</u>: the countries with participants for the questionnaire are coloured in different shades of green, depending on the number of participants. The regions that UnderSCORE can predict understorey dynamics for, have a blue contour. <u>Right</u>: The occupations of the participants.

UnderSCORE AS A PROOF OF CONCEPT

UnderSCORE is an understorey DSS **prototype**. This means the work towards a final DSS is still one in progress. We invite your feedback and suggestions to improve this tool for you, as potential future users (**Contact us**).

UNDERSCORE…	
DOES	**Does NOT**
✓ Use average environmental conditions of the EU regions	✕ Use fine-scale local environmental conditions
✓ Use fixed climate change and N deposition scenarios	✕ Use dynamic climate change and N deposition scenarios with feed-backs
✓ Use a statistical approach	✕ Use a mechanistic approach
✓ Predict based on trends in datasets	✕ Predict based on physical processes
✓ Predict large-scale trends	✕ Predict trends for specific forest sites
✓ Work for temperate forests	✕ Work for other forest types
✓ Work for ancient forests (at least forest since 1850)	✕ Work in other regions than the EU
	✕ Look at land-use legacy

HOW TO USE UNDERSCORE

We demonstrate how UnderSCORE works using a case-study. We will go through the possible inputs and adjustments that can be made and how these influence the output. **Box 1** summarises the input and output data variables. For more information on the methods, a technical manual[4] is available.
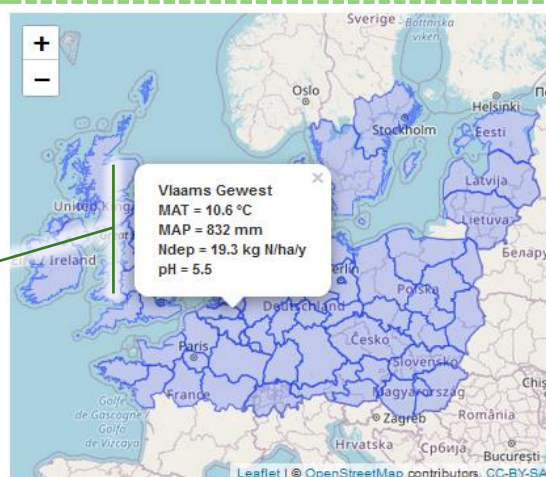
The case-study we will examine here, looks to the influence of a change in canopy cover for forests in Flanders. We want to see what will happen when Flanders can reach a lower deposition than the targets set in the Clean Air Outlook and when the world will follow the SSP2 scenario (see **Box 1** for information on these scenarios). We will look at forests that initially have an open canopy cover in 2020. Then, we will look at the impact of differing management, first so the canopy remains open; secondly with a resulting closed canopy in 2050.

INPUTS

1. Select a region

Choose the administrative (Level 1 NUTS) region of interest, here Flanders.

Pop-up detailing the **current** average environmental conditions* in the temperate ancient forests of that region
↳ used in the underlying model

Vlaams Gewest
MAT = 10.6 °C
MAP = 832 mm
Ndep = 19.3 kg N/ha/y
pH = 5.5

Leaflet | © OpenStreetMap contributors, CC-BY-SA

*See Box 1 for more information on these regional input variables

---

2. Select Scenarios

Regional trends towards the **future**:

Initial choice between two scenarios* for future nitrogen (N) deposition.
We want to see the outcome of the Clean Air Outlook, so select that option.The target is reached in 2030 and then stays constant.
In Business as usual, N deposition stays the same.

Initial choice between four of the five SSP scenarios* for future temperature change
We want to see the outcome of temperature change in SSP2, so select that option

N deposition scenario

| Business as usual ▲ |
| Business as usual |
| Clean Air Outlook EU |

MAT in a Shared Socioeconomic Pathway (SSP) scenario

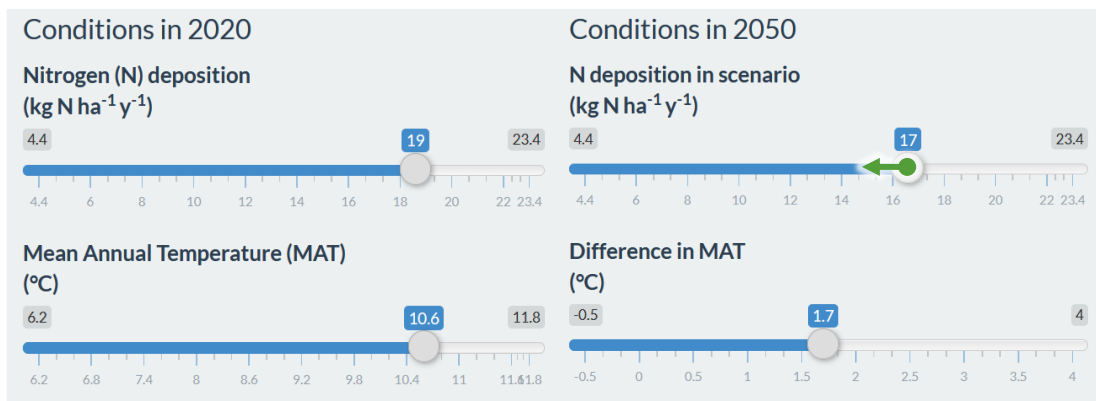| SSP 1 - Sustainability ▲ |
| SSP 1 - Sustainability |
| SSP 2 - Middle of the road |
| SSP 3 - Regional rivalry |
| SSP 5 - Fossil-fueled development |

*See Box 1 for more information on these scenarios and the corresponding input variables.

↓ Automatic selection of corresponding input variables ↓

Conditions in 2020

Nitrogen (N) deposition (kg N ha^{-1} y^{-1})
4.4 — 19 — 23.4

Mean Annual Temperature (MAT) (°C)
6.2 — 10.6 — 11.8

Conditions in 2050

N deposition in scenario (kg N ha^{-1} y^{-1})
4.4 — 17 — 23.4

Difference in MAT (°C)
-0.5 — 1.7 — 4

We can see that the choice of the region and the scenarios **set the sliders to correspond** with the values for current and future conditions. The sliders give the option to let users adjust the input values of their region. E.g. in the case they want to **tune the input conditions** to a known within-region MAT or N deposition. After all, aggregated regional data can obscure existing within-region variation.
For the **case-study**, we assume Flanders would do slightly better than reaching the Clean Air Outlook EU target. We change the automatically selected value of 17 to 15 kg N ha^{-1} y^{-1}.
There are no sliders for the other variables, as we assume these averages will stay constant over time and there are no real policy objectives related to soil conditions (pH) and precipitation (MAP).

Canopy closure

| Open ▲ |
| Closed |
| Intermediate (selective harvest) |
| Open |

Canopy closure

| Open ▲ |
| Closed |
| Intermediate (selective harvest) |
| Open |

Next, we have the ability to include information on the canopy closure for the current situation and in 2050 (Closed (100%), Intermediately closed/selective harvest (75%), Open (25%)). Canopy closure can be strongly influenced by **management decisions and interventions**. A more open canopy or canopy gaps, heightens **light availability** on the forest floor, eventually influencing the understorey.
For the **case-study**, we want to see what will happen when we keep an open canopy in forests and when we change management to go to a closed canopy.
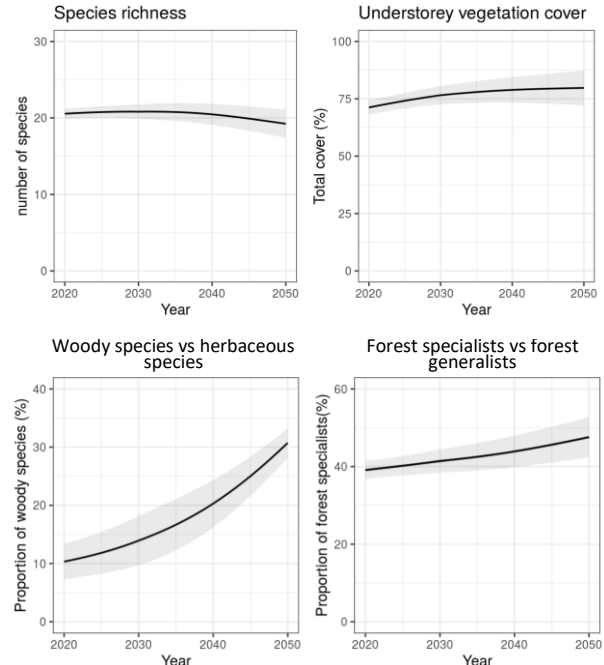
OUTPUT

Open canopy in 2050
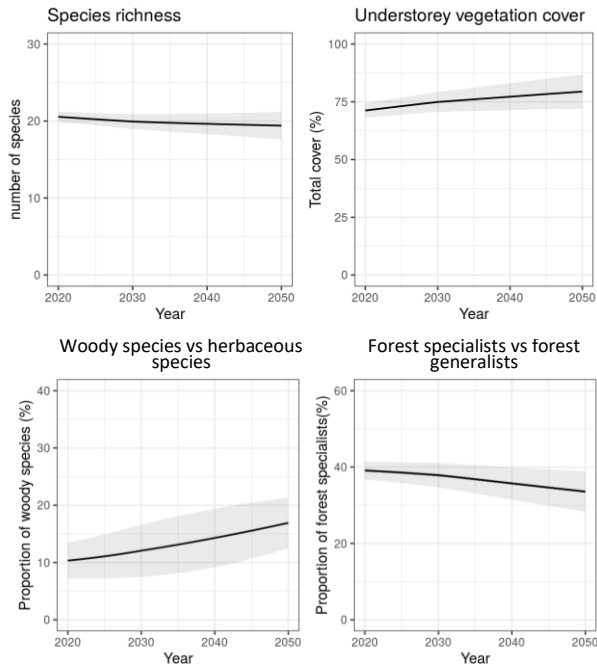
Closed canopy in 2050

The output of UnderSCORE consists of four graphs, each **predicting a trend** in an understorey characteristic, with a **confidence interval of 95%**. We can see that species richness and understorey vegetation cover will not be greatly affected by management interventions that change the canopy cover. However, characteristics related to the **composition** are influenced, which is of management and conservation concern.

When managing **towards a closed canopy** in 2050, there will be a much **greater rise in the proportion of woody species**. This includes tree seedlings and saplings, suggesting a better tree regeneration.

There will also be a **rise in the proportion of forest specialists**, compared to a rise for generalists when keeping the canopy open.

Box 1: Short summary of the input and output variables in UnderSCORE. A technical manual[4] is available for an in depth explanation on calculations of used values and the development of the underlying model.

Input variables – current and future environment

MAT or Mean Annual Temperature and **MAP** or Mean Annual Precipitation are used as **climatic variables**. They were calculated as **long term means**. For the current data this was for the period 1980-2015 with the help of the CRU TS3.4 climate database. We assumed this average MAP would not change over time. The future difference in MAT due to climatic change, has important repercussions and existing policy implications (see SSP scenarios below).

PH is used as an variable on the average (top-) **soil condition** for forests within each region. We assumed these average pH would remain the same over time. The values were calculated with the help of SoilGrids.

N (nitrogen) DEPOSITION is used as a variable to show the **effects of pollution**. Excessive N deposition has adverse effect on ecosystems, including acidification and eutrophication, both leading to biodiversity losses. Values were calculated from the latest available data (2018) of EMEP.

CANOPY CLOSURE has an effect on light availability, N deposition and local temperature. A loss in canopy cover will all lead to a more rapid response of the understorey to environmental change. The impact of tree harvest on canopy closure can be reduced by selective cutting.

The CLEAN AIR OUTLOOK EU is a policy package that sets short term targets per country for the reduction of atmospheric pollutants, among which nitrogen deposition. It aims to improve air quality, especially in cities, by supporting research and innovation and promoting international cooperation. Major drivers for the program are the health benefits to humans and the lowering of environmental pressure.

The SSP SCENARIOS are existing policy scenarios, describing pathways leading to specific amounts of greenhouse gas emissions. Scenarios include trends in population, economic growth, education, urbanisation and the rate of technological development. WorldClim v2.1 uses different global climatic models to make future climate projections for SSP 1, 2, 3 and 5. This is why only these four SSP are available as climatic scenarios. The average MAT for each region in 2050 was calculated from their data for the period of 2041-2060.

SSP1 – Taking the green road: The world moves towards a more sustainable path. Development becomes more inclusive and **respects environmental boundaries**. Human wellbeing becomes more important than economic growth. Reduced inequality and resource and energy use. Global population does not grow beyond 8.5 billion people and returns to the current level by 2100.

SSP2 - Middle of the road: Social, economic and technological trends don't shift much from historic patterns. Development and income growth proceeds unevenly across countries. Slow progress in achieving the sustainable development goals. **Some environmental degradation and some improvements**. Some decline in resource and energy use. Population growth is moderate and levels off after 2050.

SSP3 - A rocky road (regional rivalry): Resurgent nationalism causes an increasing (policy) focus on domestic issues. Focus on achieving energy and food security within own regions. Decline in developing education and technology. Economic development is slow & consumption material intensive. Inequalities worsen and there is **strong environmental degradation in some regions**. Population growth is low in industrialized and high in developing countries.

SSP5 – Taking the Highway (fossil-fuelled development): Increasing investment in and reliance on technology and human capital for sustainable development. Global markets become more integrated. Continued exploitation of fossil fuel and strong resource and energy use. Global population does not grow beyond 8.5 billion people and returns to the current level by 2100. Global economy grows rapidly and **local environmental problems are successfully managed** (e.g. air pollution).
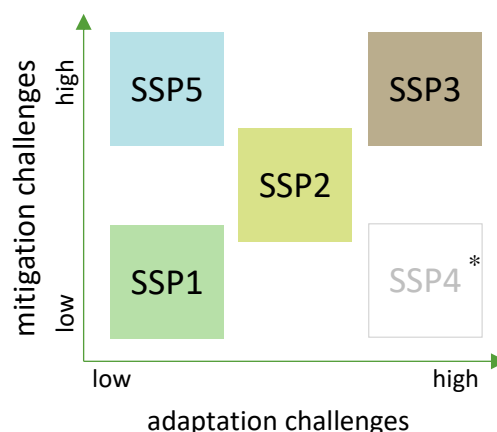
Output variables – understorey characteristics

RICHNESS: The number of species in the understorey in an average 100 m² vegetation plot.

COVER: The total ground cover of the understorey. 100% means that there is no bare ground and the forest floor is fully covered with vegetation. This can also be seen as a proxy for the biomass of the understorey.

WOODY SPECIES: Proportion of woody species in a 100 m² plot. 100% means that all species in the plot would be woody (tree seedlings, shrubs).

FOREST SPECIALISTS. Proportion of forest specialists in a 100 m² plot. Forest specialists are plant species that "love" dark forests, such as bluebell (*Hyacinthoides non-scripta*). Forest specialists are generally of high conservation concern. In contrast FOREST GENERALISTS are favored by forests with open canopies, that are bright.

FORESTREPLOT is a unique database of vegetation resurvey plot records in Europe and North America. It contains information on both understorey and overstorey community composition, for two points in time. For the underlying model in UnderSCORE, only the European plots were retained that were not coniferous and not on previously agricultural land.

PASTFORWARD is a scientific research project, focusing on how the herb layer in temperate forests changes in time, in response to global change. It has, among others, resurveyed almost 200 plots in 19 European regions. Apart from the vegetation composition, MAP, MAT and atmospheric N deposition were also recorded for each plot. This data was used to complement that from forestREplot.

* not included in UnderSCORE: SSP4 – A road divided (inequality): Increasing inequality across and within countries. The energy sector becomes diversified while **environmental policies focus on local issues** around middle and high income areas. There is increasing social unrest. Population growth is moderate and levels off after 2050.

CONTACT US

As a prototype UnderSCORE is a test phase. We want to know what the added value of the tool is already, to you as strategic decision and/or+ policy makers and how we can improve it. As such, we would like to invite your feedback on the outputs, the scope, user friendliness and any other aspects of the tool to enhance functionality.

Prof. dr. ir. Kris Verheyen
+32 (0)9 264 90 27
Kris.Verheyen@UGent.be

BIBLIOGRAPHY

1.   Blondeel, H. *et al.* The need for an understory decision support system for temperate deciduous forest management. *For. Ecol. Manage.* **480**, 118634 (2021).

2.   Gilliam, F. S. The Ecological Significance of the Herbaceous Layer in Temperate Forest Ecosystems. *Bioscience* **57**, 845–858 (2007).

3.   Landuyt, D. *et al.* The functional role of temperate forest understorey vegetation in a changing world. *Global Change Biology* **25**, 3625–3641 (2019).

4.   Blondeel, H., Landuyt, D., Perring, M. P. & Verheyen, K. *UnderSCORE: A proof-of-concept Understorey Decision Support System - Technical Manual*. (2020). URL: http://hdl.handle.net/1854/LU-8681752