Linking actions to outcomes for biodiversity in Nordic forestry

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Abstract

The lack of a unified biodiversity metric to measure outcomes against a company's biodiversity ambitions and societal conservation goals has hindered the implementation of a rigorous, science-based approach to biodiversity actions by companies. Here we propose that the Species Threat Abatement and Restoration (STAR) metric offers a science-based framework for forestry companies to measure and disclose their impact on biodiversity at the species level for spatial and temporal scales relevant to link the company's actions to biodiversity outcomes. STAR could be integrated into the business decision support system of a forestry company to prioritize the biodiversity investments that most efficiently reduce species' extinction risks through threat abatement and habitat restoration. Such an application of STAR could quantify the company's biodiversity contributions credibly and transparently and allows them to be considered relative to business profitability.

Introduction

It is three decades since the role of business in delivering positive contributions to biodiversity began to attract notable attention (e.g. Kelly and Hodge, 1996; Stone et al. 1997; Wehrmeyer and Tyteca, 1998). Whilst some businesses started to set corporate objectives for reducing negative impacts on biodiversity and enhancing positive impact 25 years ago (Rainey et al. 2015) there has been no consensus on how outcomes for biodiversity can be aligned with business practice in a measurable way at meaningful scale. This has contributed to an apparent lack of ambition and hindered wide uptake of integrated conservation and business planning and the resulting positive outcomes for biodiversity.

Numerous corporate and civil society initiatives were established over this period to deliver this outcome as a standardised approach to business operations, including the Energy and Biodiversity Initiative, the Cross Sector Initiative on Biodiversity, and the Business and Biodiversity Offsets Programme, but all were unsuccessful in going beyond highly localised outcomes that were not scaled into an industry-wide approach. There are numerous reasons for this failure, but one common issue has been the inability to fully and permanently integrate planning for biodiversity outcomes directly into business planning via a universally agreed outcome measure (zu Ermgassen et al. 2022; Hawkins et al. 2024): the opposite situation is true for climate action where CO_2 outcomes are easily measured from activity planning.

There is renewed impetus, and urgency, in addressing this challenge following the adoption of the Kunming-Montréal Global Biodiversity Framework (KMGBF: CBD 2022a), and its monitoring framework (CBD 2022b) that outlines how progress towards these global biodiversity goals and targets will be measured. The importance of this is also recognised by a range of initiatives intended to emphasise the importance of business playing a full role in delivery of the KMGBF (e.g. Finance for Biodiversity, Business for Nature and the Taskforce for Nature-related Financial Disclosure). In addition, there is a drive to develop and embed science-based targets and target-setting for biodiversity in businesses and financial institutions (e.g. Andersen et al. 2020). What is needed now is a concerted effort to integrate science-based approaches into decision-making in business for nature-positive outcomes that contribute to 'halting and reversing nature loss from a 2020 baseline so that by 2030 nature is visibly and measurably on the path of recovery' (Nature Positive Initiative).

Here we describe an initiative designed to do this, by aligning business decision-making in forestry with scientifically robust planning for positive and measurable biodiversity outcomes. We do this by: a) introducing the context, which is a Nordic forestry enterprise; b) describing the science-based approach being taken; and c) explaining how the science-based approach is being aligned with corporate decision-making. We also highlight some challenges with applying science-based target-setting for biodiversity in a forestry company and outline how they can be overcome. Our hope is that this could begin the widescale recalibration of the forestry industry towards the Goals and Targets of the KMGBF through supporting implementation of relevant National Biodiversity Strategies and Action Plans (NSBAPs). This could provide stimulus to expand certain types of forestry planning to enable and expand renewable material provision to a biobased society.

Nordic forestry and biodiversity

Forestry companies harvesting trees as raw material for renewable packaging and paper, wood construction and bioenergy, profoundly influence biodiversity across the landscapes that they operate in. In the Nordics, here defined as Finland, Sweden and Norway, forested lands have been used by people for centuries and this has impacted the structures and functions of the forest, including biodiversity (Ashton and Kelty 2018). Today's production forests are dominated by even-aged stands mostly managed with rotation cycles of 60-100 years including management interventions for regeneration, thinning and final harvesting (e.g. Mönkkönen et al. 2022). These forests with even-aged stands produce significantly more timber than forests of a century ago (Kauppi et al. 2022), while at the same time many species linked to long canopy continuity and trees of high age have been continuously declining (e.g. Savilaakso et al. 2021).

In accordance with environmental legislation and certification, the standard practice of forestry companies to mitigate negative biodiversity effects of even-aged forestry is retention forestry combined with voluntary set-asides (Simonsson et al. 2016). Retention forestry includes leaving trees in parts of an even-aged stand that have features identified as important for biodiversity (Gustafsson et al. 2020). Voluntary set-asides, whereby forested land is omitted from standard forestry operations, target areas of particular importance for biodiversity to ensure habitat continuity over time (Siitonen et al. 2001). Voluntary set-asides can also be managed for conservation purposes to maintain habitat features that otherwise may be lost due to forests' natural succession (Timonen et al. 2010).

Retention forestry in combination with voluntary set-aside has had a positive effect on local biodiversity (Suominen at al. 2015; Gustafsson et al. 2020). On the other hand, it has been criticized for its 'one-size-fits-all' application, and specifically for not taking into consideration the natural variability of landscapes and particular habitat requirements of the most threatened species (Kuuluvainen et al. 2019). However, the lack of suitable analytical decision support tools makes it challenging to implement a coherent strategy that includes biodiversity-promoting measures across landscapes and forest holdings to reach specified conservation targets for species.

Moreover, companies' investments in more active biodiversity management beyond the standard practice to meet legislation and certification requirements could be further incentivized. To achieve this, a performance metric that transparently and credibly discloses a company's biodiversity investments and achievements and allows comparison of performance among companies would be beneficial. Ideally such a metric should be able to measure a company's contribution to national, regional and global biodiversity targets. Hence, there is a need for a biodiversity metric that can support forestry decision-making by identifying and quantifying biodiversity-promoting measures in forests. Such a metric would be required to ensure positive outcomes for threatened species and their habitats, while also serving as a benchmark for a forestry company's biodiversity performance.

A science-based approach for a forestry company to set measurable targets for species

A science-based approach requires using the best available knowledge and analytical evidence to set targets for biodiversity outcomes (e.g. Andersen et al. 2020). If applied appropriately this can, in broad terms, guide managers to achieve clearly stated and measurable outcomes. Successful biodiversity management for forestry necessitates actions at significant spatial and temporal scales. Thus, to prevent biodiversity efforts from becoming anecdotal—such as targeting a specific biodiversity feature at an arbitrary location with unclear outcomes over time—it is essential for a forestry company to adopt tools that allow ecologically meaningful targets to be set over realistic temporal and spatial scales. Moreover, to be operationalizable biodiversity management must be fully integrated into the forestry company's routine decision-making process, also enabling it to be considered relative the company's profitability.

To fit such a purpose, biodiversity assessment needs to accommodate spatial variation of species and provide specific guidance for management actions to avoid, reduce, remediate, and compensate for impacts and to identify positive opportunities. We argue that the Species Threat Abatement and Restoration (STAR) metric meets such criteria (Mair et al. 2021) and can be useful for a forestry company to set science-based biodiversity targets and develop actions to achieve them. The STAR metric is a structured approach designed to identify which biodiversity threats have the greatest impact on species' extinction risk within a defined landscape and can pinpoint where in the landscape extinction risk could be decreased (Mair et al. 2021). The STAR metric uses three data sources to quantify the potential positive impact of measures aimed at reducing threats and/or restoring habitats in a landscape: a) species' extinction risk as assessed by global Red-lists, b) documented threats to species, and c) species' current area of habitat (AOH) data and restorable AOH (natural habitat that has been lost and could be restored). The STAR metric has been applied in various contexts, including for terrestrial vertebrates globally (Mair et al. 2021), at subnational levels (Chaudhury et al., 2022), for marine species (Turner et al. 2024), at national levels for endemic plants (Mair et al., 2023), and in quantifying national extinction-risk footprints (Irwin et al. 2022).

The application of STAR to standard forestry decision making

Forestry business decision-making relies on forestry planning, which involves finding the best possible forestry operations across a given landscape to achieve desired outcomes (Bettinger et al. 2016, Eyvindson et al. 2018). These planning problems are often complex. For instance, managing a forest landscape over several decades to ensure an annual and even flow of harvested timber from numerous stands, each with unique features such as tree ages, species, timber volumes, soil fertility, and biodiversity values, requires advanced calculations.

Forestry decision support systems are software designed to facilitate solutions to such problems (Vacik & Lexer, 2014) and are commonly used by forest owners for business decision-making (Borges et al. 2014, Ulvdal et al. 2023). For STAR to serve the purpose of a forestry company, it needs to be integrated into these business decision support systems. This integration ensures that the biodiversity outcomes of a specified forest management scenario are correctly understood by the decision-maker. In other words, the biodiversity outcomes are relevant to the same geographical and temporal scales as the forest growth and yield outcomes, enabling economically justifiable decisions on potential trade-offs between forest growth and yield versus biodiversity.

In the case of Sweden, the Heureka forestry decision support system was developed as a joint research effort in forestry planning between academia and industry in the early 2010s (Wikström et al. 2011, Lämås et al. 2023). The Heureka system uses extensive forest data to predict forest growth and yield outcomes over time, based on forest management scenarios (Lämås et al. 2023). Other countries have developed similar systems, e.g. SIMO in Finland (Rasinmäki et al. 2009, Packalen et al. 2013). While it is common for forestry planning systems to include aspects of biodiversity (Nordström et al. 2019), the simplified way biodiversity is represented in common forestry planning systems has been criticised due to e.g. weak connections to drivers of biodiversity change (Hunault-Fontbonne & Eyvindson 2023). Decision-making on biodiversity management using a system like Heureka can however be improved by linking it to the outputs of forest management scenarios to biodiversity models. For example, Moor et al. (2022) evaluated biodiversity in forest management scenarios using species distribution models (SDMs) of birds, fungi and lichens. The outputs of SDMs in the form of species' distributions across forest landscapes can in turn be linked to STAR to produce STAR scores of the specified forest management scenarios. Hence, the suit of data and models proposed in Fig. 1 enables a forestry decision support system that can prioritise between different forest management scenarios for a specified forest landscape towards reducing the extinction risk of the most vulnerable species. This because the STAR metric quantifies threats driving extinction risk in any given location in the landscape and thus supports identification of actions to reduce threats and/or support restoration of habitats for vulnerable species.

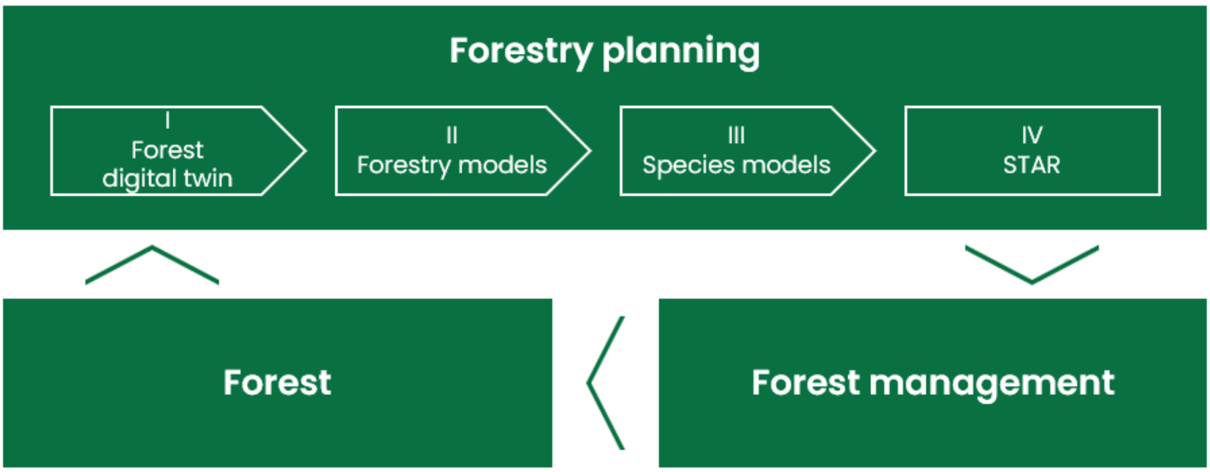

Figure 1. A schematic representation of how a forestry company can integrate STAR into its forestry planning, enabling evaluation of forest management scenarios while considering extinction risk of vulnerable, red-listed species. The forestry planning defines stand-level forest management alternatives including estimations of outcomes for economy and biodiversity, which can be combined to cost-efficiently reduce extinction risk with specificity in time and space. Components in the planning chain are ordered in a sequential chain of data and models to integrate predictions for economy and biodiversity, and hence enable an evaluation of trade-offs: Forest data (i) input to forestry models must be geographically precise and include key biodiversity variables. Forestry models (ii) capture how forests change over time and under management with tree growth as a cornerstone process. Species distributions models (iii) predict the response of species to the forest management. The output from the species models is aggregated with Red-list information into a STAR score (iv). The outcome of forestry planning determines forest management which in turn determines the outcomes of tree growth and biodiversity in the forest.

We consider that STAR offers the following to forestry corporates aiming for a real and measurable positive impact on biodiversity: *a) Spatial Preciseness* which is crucial for forestry operations that cover extensive and varied landscapes (Hawkins et al. 2023), b) *Temporal Preciseness* as STAR can be informed by models for forest dynamics (Fig. 1) that reflect changes over time, enabling predictions for if and when set biodiversity ambitions will be fulfilled*, c) Transparency and Auditability* for disclosing biodiversity outcomes over time in a standardized manner, facilitating stakeholder trust and regulatory compliance (Mair et al. 2024)*, and d) Policy Alignment* measuring the company's contribution towards global, regional, and national biodiversity policy targets.

However, applying STAR in a forestry context presents scalability and granularity challenges. STAR was developed to encompass various land types and land-use types, not solely forests and forestry in isolation. Therefore, fine-tuning STAR to reflect responses to forest management actions over the different timescales used in forestry is necessary and in preparation (Mair et al. manuscript). This requires forest data input to be more geographically explicit and include key biodiversity variables, surpassing the traditional data used for forestry decision-making. Leveraging forest "big data" and Artificial Intelligence (AI) offers a promising way forward. For instance, forestry companies are exploring forest digital twin methods that combine traditional forestry data with other data, including biodiversity-relevant data, to optimize management at the finest possible scale (Tagarakis et al., 2024). As such data becomes increasingly integrated into the forestry planning framework (Fig. 1) this will enable a link between biodiversity management input and biodiversity outcomes.

Defining and measuring a forestry company's target of net positive impact on biodiversity

In the company operating model, targets need to be measurable and linked to key performance indicators (KPIs) to be achieved. As of today, there is no agreed framework for companies for how to set such targets and KPIs for biodiversity. In the early 2000s the Net Positive Impact on biodiversity concept was used increasingly by companies operating in the land-use sector as an ambition to ensure that positive impacts on biodiversity from corporate operations would outweigh the negative ones (e.g. Rainey et al. 2014). This was to be achieved through the so-called mitigation hierarchy, i.e. a series of actions that included avoiding and reducing impacts, rehabilitating affected species and landscapes, and offsetting any residual impacts (Rainey et al. 2014). However, defining "Net Positive Impact" proved challenging for a range of reasons, including difficulties defining the biodiversity baseline, and many corporates have abandoned the target (da Silva et al. 2019).

We suggest that STAR offers a potential solution to this dilemma by providing a way of quantifying a desired "Net Positive Impact" as an expected reduction in species' extinction risk across a landscape because of abated threats and restored habitats. This is because STAR can be used to identify the most urgent threats and where they have their impacts on threatened species, and consequently guide spatially precise, efficient and prioritized abatement actions.

Conclusion

There is widespread recognition that the forestry sector must reduce its negative impacts on biodiversity and act on the urgency of a biodiversity approach that ensures progress towards the target of the Kunming-Montreal protocol to halt human induced extinction of known threatened species. Forestry heritage is rooted in regulations and certifications standardized across the landscape, applying measures that promote similar habitat structures everywhere rather than targeting threatened species. The challenge is to go beyond regulations and certifications so that investments result in real and measurable species threat abatement and restoration that can be disclosed in compliance with emerging frameworks like the Taskforce on Nature-related Financial Disclosures (2022) and used to set science-based targets for nature. Integrating the STAR metric into a forestry company's normal decision support system can serve the purpose of underpinning adaptive and sustainable forest management balancing nature values with economic profitability.

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