Supplementary A

Table S1. EBVs and RS/eDNA biodiversity products. For each Essential Biodiversity Variable class and category, the Remote Sensing and eDNA biodiversity products (RS/eDNA biodiversity products) that could be used to measure the EBVs are listed (Skidmore et al., 2021). Similarly, biodiversity information that can be derived from environmental DNA is categorized with EBVs (listed in *italic*).

EBV class	EBV candidate	RS/*eDNA* biodiversity product
Genetic composition	Intraspecific genetic diversity	not applicable
	Genetic differentiation	not applicable
	Effective population size	not applicable
	Inbreeding	not applicable
Species populations	Species distributions	Species richness
		Species diversity indices (Simpson, Shannon, alpha, beta, gamma)
		Presence/absence
		evenness
		Species diversity indices (Simpson, Shannon, alpha, beta, gamma)
	Species abundances	Species abundance
		Forest species and age class
		Population density (distribution)
		Relative abundance of taxonomic unit
Species traits	Phenology	Green-up (start of season)
		Senescence (end of season)
		Peak season (max of season)
	Morphology	Leaf dry matter content
		Specific leaf area
	Physiology	Gross primary productivity
		Net primary productivity
		Leaf area index
		Chlorophyll content and flux
		Foliar N/P/K content
		Polyphenols
		lignin
		Cellulose
		Non-structural carbohydrates
Community composition	Community abundance	Number or percentage of species which grow or occur together
	Taxonomic/phylogenetic diversity	Taxonomic (species diversity/richness)
		Functional diversity
		Phylogenetic diversity
		Taxonomic identity/composition
		Functional composition
Ecosystem functioning	Primary productivity	Gross primary productivity
		Net primary productivity
		Leaf area index

		Specific leaf area
		Foliar N/P/K content
		Evapotranspiration
		Fraction of absorbed photosynthetically active radiation
		Ecosystem soil moisture
		Carbon cycle (sequestration)
		Carbon cycle (below-ground biomass and carbon)
		Carbon cycle (above-ground biomass)
		Chlorophyll content and flux
	Ecosystem phenology	Land surface phenology peak (max of season)
		Land surface phenology green-up (start of season)
		Land surface phenology senescence (end of season)
	Ecosystem disturbances	biological effects fire disturbance (occurrence, direction, duration, abruptness, magnitude, extent, frequency)
		biological effects of irregular inundation
		biological effects of pest and disease outbreak
Ecosystem structure	Live cover fraction	land cover (vegetation type)
		fraction of vegetation cover
		plant area index profile (canopy cover)
	Ecosystem distribution	above-ground biomass
		leaf area index
		urban habitat
		ecosystem fragmentation
		ecosystem structural variance
		Landscape diversity (gamma)
	Ecosystem vertical profile	ice cover habitat
		deadwood habitat
		vegetation canopy height
		habitat structure
		biological effects fire disturbance (occurrence, direction, duration, abruptness, magnitude, extent, frequency)
		biological effects of Irregular inundation

Table S2. Essential Biodiversity Variables and their description (GEO-BON, 2022).

EBV class	EBV candidate	Description
Genetic composition	Intraspecific genetic diversity	The variation in DNA sequences among individuals of the same species
	Genetic differentiation	Divergence in genetic composition (identity and frequencies of alleles) among multiple populations
	Effective population size	The number of individuals in an idealized population that will exhibit the same amount of genetic diversity loss as the population under consideration
	Inbreeding	Mating between related individuals
Species populations	Species distributions	The species occurrence probability over contiguous spatial and temporal units addressing the global extent of a species group
	Species abundances	Predicted count of individuals over contiguous spatial and temporal units addressing the global extent of a species group
Species traits	Morphology	The variation in physical attributes of organisms of the same species
	Physiology	Chemical or physical functions promoting organism fitness and responses to environment
	Phenology	Presence, absence, abundance or duration of seasonal activities of organisms
	Movement	Behaviours related to the spatial mobility of organisms such as dispersal and migration routes
Community composition	Community abundance	The abundance of organisms in ecological assemblages
	Taxonomic/phylogenetic diversity	The diversity of species identities, and/or phylogenetic positions, of organisms in ecological assemblages
	Trait diversity	The diversity of functional traits of organisms in ecological assemblages
	Interaction diversity	The diversity and structure of multitrophic interactions between organisms in ecological assemblages
Ecosystem functioning	Primary productivity	The rate at which energy is transformed into organic matter primarily through photosynthesis
	Ecosystem phenology	Duration and magnitude of cyclic processes observed at the ecosystem

		level, such as in vegetation activity, phytoplankton blooms, etc.
	Ecosystem disturbances	Abrupt deviances in the functioning of the ecosystem from its regular dynamics
Ecosystem structure	Live cover fraction	The horizontal (or projected) fraction of area covered by living organisms, such as vegetation, macroalgae of live hard coral
	Ecosystem distribution	The horizontal distribution of discrete ecosystem units
	Ecosystem vertical profile	The vertical distribution of biomass in ecosystems, above and below the land surface

Table S3. An overview of the policies, management plans and grey literature from Australia, Finland The Netherlands and Germany from which forest conservation indicators were selected for use in this study.

Country	Policy documents/ grey literature	English translation
Australia	Australia's State of the Forests report 2018	not applicable
Finland	Suomen Metsätilastot (Peltola, 2019)	Finnish forest Statistics
	Monimuotoisuudelle arvokkaiden metsäympäristöjen tunnistaminen METSO-ohjelman luonnontieteelliset valintaperusteet 2016–2025 (Syrjänen et al., 2016)	Diversity identification of forest environments Metso Natural Science Selection Criteria 2016 - 2025
Germany	Indikatorenbericht 2010 zur Nationalen Strategie zu Biologische vielfalt (BMU, 2010)	Indicator report 2010 on the National Strategy on Biodiversity
	Indikatoren für ein integratives Monitoring in deutschen Groβschutzgebieten (Kowatsch et al., 2011)	Indicators for integrative monitoring in large German protected areas
The Netherlands	Werkwijze Monitoring en Beoordeling Natuurnetwerk – Natura2000/PAS (Van Beek et al., 2014)	Monitoring and Assessment Method Nature network – Natura2000/PAS
	Toekomstvisie Veluwezoom Natuurmonumenten (Natuurmonumenten, 2014)	Future vision Veluwezoom Natuurmonumenten
	Spectacular bryologische ontwikkelingen op en rond dood naaldhout in 'Neerlands Thüringen' (Zuidoost Veluwe) (Bijlsma & Hoedt, 2008)	Spectacular bryological developments on and around coniferous deadwood in Southeast Veluwe
	Dood hout en biodiversiteit (Akkerhuis et al., 2005)	Deadwood and biodiversity
	Door de bomen het bos zien, zo beheert Staatsbosbeheer de bossen (Staatsbosbeheer, 2016)	Management of forests by Staatsbosbeheer
	Beheerplan Natuur, landschap en cultuurhistorie (Veluwe, 2015)	Managementplan nature, landscape en cultural history
	Algemeen Beleidsplan 2020-2025 'Internationale allure' (Veluwe, 2019)	Policy Plan 2020-2025 'International allure'
	Natuurvolgend bosbeheer (Kroondomein, 2008)	Natural forest management

Summary of policies, management plans and grey literature

In the Netherlands, a national monitoring method is in place that lists indicators for each vegetation type, among which are forests (Van Beek et al., 2014). In many cases, a protected forest is managed by more than one organisation. This is also true for one of the largest forest areas in the Netherlands, National Park de Veluwe, which we focused on as a typical forest area in the Netherlands. All area managers (except private landowners) must adhere

to this policy, however, each has their own management plan as well. This is why, in the case of the Netherlands, there are more documents listed than for the other countries (Kroondomein, 2008; Natuurmonumenten, 2014; Staatsbosbeheer, 2016; Veluwe, 2015, 2019). Additional grey literature written by or for area managers (Akkerhuis et al., 2005; Bijlsma & Hoedt, 2008), specifically targeting deadwood and its benefits for forest areas, were also included. From the organisation that manages Bavaria National Park in Germany (National Park Bayerischer Wald), we have acquired policy documents (BMU, 2010; Kowatsch et al., 2011) describing goals, targets and indicators for forest areas and protected areas at large. We have also acquired documents from Finnish institutions concerned with forest conservation and management (Peltola, 2019; Syrjänen et al., 2016). Australia, being another continent, has a completely different biome than Northern Europe. Large forest areas are protected, but trees are harvested as well. Roughly every six years, Australia's State of the Forests report is published, in which conservation metrics of forests and forest-dwelling species are reported. The latest report (ABARES, 2018) is used in this study as a source of forest conservation indicators. Other forest management-related papers are also used as references (Burrows, 2008; G. Woldendorp & Keenan, 2005; G Woldendorp et al., 2002).

Supplementary B

List S1. Forestry backgrounds of The Netherlands, Germany, Finland and Australia.

The Netherlands were nearly completely covered with forests until approximately 2000 years ago. Since then deforestation destroyed 98% of the forest. Afforestation by private landowners and the state has resulted in an estimated current forest cover of about 10 % (Mohren & Vodde, 2006). Forests land are owned by private landowners, the state, local authorities and nature conservation organizations. Forests are part of estates and have a conservational as well as recreation and timber production.

German forests have been the subject of intense use since the Middle Ages. The demand for timber, energy production, mining, iron smelting and construction was so high, it resulted in an impedimpending timber shortage. In the 18th century, foresters designed a strategy for sustainable forestry and woodland management and reforestation began. Nowadays, bark beetle infestation threatens forests. Almost half of the forests are privately owned, the other half is owned by the federal or state government. Sustainable forest management along with timber production is still the main strategy, but conservation and recreation purposes are equally important (BMEL, 2014).

On the other hand, Finland is Europe's most densely forested country. Forests cover about 75% of the land area. One-third of the country's export earnings come from forests, 60% of forests are privately managed by families that produce three-quarters of wood raw material. Environmentally sustainable forestry was adopted in 1994 (Runesson, 2021). An important feature of forest management is retention trees, trees that are left while the area is being cut. This improves patch recovery (Koivula et al., 2014; Kuuluvainen et al., 2019).

Forests in Australia host diverse and unique ecosystems that are subject to a range of pressures such as extreme weather events, invasive species, fires, and land clearing. Approximately 17% of Australia is covered with forest, making up 3% of the world's forests. The various forest types are valued for their goods and services such as wood, carbon sequestration and storage, soil and water protection as well as recreation (ABARES, 2018). The different biome and the different values placed on Australia's forests likely contribute to the forest indicators being differently categorized across EBVs than for Northern European policies. Especially 'carbon sequestration' (categorized within the EBV 'ecosystem functioning') is an indicator that is not prominent in Northern European policies. These results also suggest that international directives and targets work to harmonize policies. For the harmonization of policies on a global scale, perhaps global agreements could more prominently advocate harmonization.

References Supplementary A & B

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Supplementary C Indicator List

Table S4. The indicators that were selected from the literature, per country. If the column 'measured unit' is blank, it was not specified. The indicator description was then used for further assessment.

Policies

country	generic objective	goal	indicator	indicator variable	measured unit	document type	reference
The Netherlands			Structural elements	Mixed forest	% of area surface	national monitoring plan	Van Beek, J.G., et al. 2014
				European forest	% of area surface		
				shrubs and open areas	% of area surface		
				Vertical structure ('layers')	% of area surface		
				Substantial deadwood	number per hectare		
				Substantial living trees	% of area surface		
			Plant species	Species	presence		
			Breeding birds	Species	presence		
			Environmental conditions	Nitrogen deposition	kg N/ha/y		
			Spatial conditions	Connected to other forest patches	ha		
The Netherlands	Development of biologically diverse, large, undisturbed and complete forest communities	Increase in naturalness of forests	Deadwood	Standing and lying deadwood		local management plan	Natuurmonumenten (2014)
		More natural forests	Self-regulation	Diversity in structure			
				Diversity in composition			
			Effects of grazing	Horizontal structure	mosaic		
				Vertical structure	layers		
				Different growth forms plants (morphology)			

				Open areas			
The Netherlands	More structural variance		Structural variance	Planting of oak trees	species	local management plan	Stichting De Hoge Veluwe (2015)
				Removal of other trees	species		
	Reduction of exotic species			Exotic species	presence		
The Netherlands	Active management to improve biodiversity		Nutrient cycling	Stone dust	acidification	local management plan	Stichting De Hoge Veluwe (2019)
			Structural elements	Horizontal strucuture	patches		
			Structural elements	Vertical structure	layers		
			Red list species	Species	presence		
The Netherlands	Functioning forest ecosystem		Natural processes	Various developmental stages	presence	local management plan	Kroondomein (2008)
			Diversity in species	Tree species	species present		
			Diversity in tree age	Tree age	years		
			Varied structure	Tree size	diameter		
				Deadwood amount	number per hectare		
The Netherlands	Multifunctional forests		Natural processes	Various developmental stages	presence	local management plan	Staatsbosbeheer (2016)
					deadwood amount		
					open spaces		
Germany	Biodiversity and landscape quality		(changes in) population of bird species	Typical species	presence	national monitoring plan	BMU (2010)
			Endangered species	Red List species	presence		
			conservation of habitats	Index value			
			conservation of species				
			Invasive species		number of species		
			Protected areas		total protected area		
Germany	Basic indicators forests		Age group structure/stages of development		age range	national monitoring plan	Kowatsch, A. et al. (2011)

			Tree species composition	The proportion of tree species	The proportion of tree species		
			Natural development		The proportion of untreated areas after natural events (Relation to events)		
					Total volume (m3), of which standing (%)		
	Protection of natural budget and biodiversity		Protected areas		(nr of) legally appointed areas		
			Core zone	undisturbed dynamics	area size		
			Habitat types		habitat types (map)		
			Important species (for management)		species		
			Water quality				
			Fragmentation	area size	hectare		
Finland	To contribute to halting the and the decline of forest species and consolidate biodiversity in a favourable development by 2025		Sites with the most valuable species composition	Red list species	presence	national monitoring plan	
				Stand diversity	species		
					age		
					dominance		
				old growth	presence		
			Forest structure	Stand structure	tree regeneration		
					windthrow frequency		
				Openness	canopy gaps		
				Foliage presence	canopy coverage		
				Area size	hectare		
				Presence of groundwater influenced forest types	presence		
				Deadwood species	hardwood/softwood		

				Decay stage	decay stage		
				Volume of decaying wood	m3/ha		
				Amount of decaying wood			
				Interconnectedness	fragmentation		
				Quantity of decaying wood			
				Quality of decaying wood			
				Burnt wood	presence		
				Lying deadwood	presence		
				Standing deadwood	presence		
			METSO habitat types area size	Herb-rich forests	hardwood		
				Heathland forests with plenty of decaying wood			
				Wooded mires and the wooded margins of open mires			
				Forests adjacent to springs and pools			
				Swampy woodlands and wooded flood meadows			
				Wooded cliffs, bluffs and boulder fields important for biodiversity			
				Wooded habitats on calcium-rich bedrock and ultra-fine alkaline soil			
				Sunlit slopes on sandy esker ridges			
				Wooded heritage biotopes			
				Biodiversity sites along emergent coastlines			
Australia				Forest-dwelling species for which ecological information is available	level of information that is available	National policy report	ABARES 2018

				The status of forest-dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	number of protected species with a conservation status		
				Representative species from a range of habitats monitored at scales relevant to regional forest management			
				Native forest and plantations of indigenous timber species which have genetic resource conservation mechanisms in place			
				Area of forest burnt by planned and unplanned fire			
				Scale and impact of agents and processes affecting forest health and vitality			
				Area of forest by forest type and tenure	hectare		
				Area of forest by growth stage	hectare		
				Area of forest in protected area categories	hectare		
				Fragmentation of forest cover	edge fraction		
				Forest associated species at risk from isolation and the loss of genetic variation, and conservation efforts for those species			
Australia				Tree species	presence	National policy report	Woldendorp 2002
				Basal area of live trees	diameter class (cm)		
					position		

				Spatial distribution of coarse woody debris	orientation		
					length		
				Density per unit area			
				Stump height	height		
				Stump DBH	cm		
				Volume and mass of coarse woody debris	volume		
				Volume and mass of coarse woody debris	mass		
				Log decay class	class		

Scientific/grey literature

country	generic objective	variable	measured unit	document type	reference
The Netherlands	Relevance of dead wood for bryophytes	Decay stage	years	dutch grey literature	Bijlsma, R. & Hoedt, A. T. (2008)
The Netherlands	Relevance of dead wood for arthropods	Tree species	species	dutch grey literature	Jagers op Akkerhuis G.A.J.M., et al. (2005)
		Preference of arthropod for specific deadwood			
		Standing dead tree size	diameter		
		Lying tree size	diameter		
		Abiotic properties	sun exposure		
			shadow		
			moisture availability		
		Microhabitats	presence of fungi		
			presence of wood		
			presence of bark		
			presence of burned wood		

			presence of tree cavities		
		Amount of dead wood	m3/ha		
		Distance between deadwood	meter		
		Tree species	species		
	Relevance of dead wood for macrofungi	Decay stage	years		
		Tree size	diameter		
			volume		
			surface		
		Fungi succession	fungi species		
		Deadwood fraction	percentage		
		Moss coverage	moss coverage		
		Soil surface contact			
		Amount of dead wood	amount		
			continuity		
		Forest history	fragmentation		
		Habitat quality	fungi species		
		Habitat diversity (mix living/dead trees)	substrate		
	Relevance of dead wood for bryophytes	Habitat diversity (lying deadwood)	amount		
		Habitat	tree species		
			lying deadwood		
			standing deadwood		
			forest fragmentation		
		Decay stage	years		
		Tree size (Fischer, 1992)	diameter		
			volume		
Germany		Phytosociological relevé of vegetation	total number species	scientific	Fischer, A. (1992)

	Vegetation development following natural destruction of the tree layer		cover degree		
		Structural development			
		Counting of saplings	number		
		Special investigations	vegetation of small-scaled patches of disturbed soil		
			mass of deadwood		
			developmental success of planted saplings		
Germany	Long-term development of near-natural forests after abandonment of economic use and the effect on biotic as well as on abiotic components of the ecosystems		tree growth	scientific	Heurich, M., et al. (2010)
			phenology		
			litterfall		
			stand growth		
			crown condition		
			foliage chemistry		
			microbial composition		
			vegetation		
			vegetation structure		
			stand growth		
			bird population		
Germany	Quantifying the dependency of various taxa on the environmental factors that determine their local distribution	Canopy cover	area covered %	scientific	Bässler, C., et al. (2009)
		Bedrock cover	area covered %		
		Waterbody cover	area covered %		
		Gaps	area covered %		
		Diameter breast height	cm		
		Stand age	mean age in years		
		Understorey cover	mean vegetation height < 1m in %		

		Canopy maximum height	meter		
		Canopy mean height	meter		
		Canopy standard deviation	meter		
		Wood debris	CWD fractions		
			decay level		
			length		
			diameter		
		Taxonomic groups	presence (species)		
Finland	Possibility of rehabilitating forest structure and species composition through logging, deadwood creation and fire	Stand structure tree seedlings <2m	location	scientific	Vanha-Majamaa, I., et al. (2007)
			microhabitat		
		Understorey vegetation	vegetation cover		
			species composition		
		Moss coverage	tree species		
			tree log length		
			tree log diameter		
			tree decay stage		
			tree bark coverage		
			moss species composition		
		Biodiversity key species	beetle species richness		
			aspen abundance		
Finland	Tree retention in forest management (harvesting)	Standing trees in area after harvesting	number per hectare	scientific	Kuuluvainen, T., et al. (2019)
		Minimum DBH for retention trees	tree size		
		Retention tree volume	number per hectare		
			tree species		
			size class		
			level of retention (proportion of		

			living retention trees)		
			m3/ha		
Finland	Effect of forest restoration by fire on polypores (fungi)	Volume of dead wood	m3/ha	scientific	Penttilä, R., et al. (2013)
		Polypore species	richness		
			abundance		
			composition		
		Diameter breast height	tree size		
Finland	Economically profitable management systems that result in forests good for recreation and biodiversity maintenance	Spatial heterogeneity	spatial heterogeneity	scientific	Pukkala, T., et al. (2011)
		Presence of large trees	presence		
		Canopy gaps	canopy gaps		
		Stand volume	m3/ha		
		Number of trees	per hectare		
		Tree size distribution	height		
		Tree age	years		
		Tree diameter	cm		
Finland	To examine how forest structure and biota are affected when timber is harvested by varying the spatial and temporal scales of felling	Species groups - insects		scientific	Koivula, M., et al. (2014)
		Species groups - fungi			
		Species groups - vegetation			
		Forest structure - decaying wood - coarse woody debris			
		Forest structure - decaying wood diameter	cm		
		Forest structure - tree retention	%		
		Forest structure - decaying wood height standing			
		Forest structure - gaps of varying size			
		Tree growth and regeneration	natural regeneration		
Finland	To assess the immediate response of the understorey	Bryophyte species	abundance	scientific	Jalonen, J. & Vanha-Majamaa, I. (2001)
		Vascular plant species	abundance		

		vegetation to different felling methods			
Finland	Compilation of key forest statistics	Total protected forest area	hectares	scientific	Peltola, A., et al. (2019)
		Growing stock volume	m3/ha		
		Age of forest stands	years		
		Habitats of special importance	forest type		
		Threatened species of forests by habitat	number		
		Mean volume of decayed and other dead trees on forest land	m3/ha		
		Tree species dominance and pure and mixed stands on forest land	% of area		
		Preserving the special features and retained stock of valuable habitats in roundwood removals in non-industrial, private forests	% of area of valuable habitats		
		Retention trees in clear fellings in non-industrial, private forests	% of clear-cutting areas		
		The quality of water protection activities in non-industrial, private forests	% of felling areas		
Australia		Forest age class	class	scientific	Woldendorp, G. (2005)
		Above-ground biomass			
		Biomass by latitude			
		Mass			
		Proportion of above-ground biomass			
		Volume			
Australia		Changing species assemblages		scientific	Burrows, N. (2008)
		Changing species diversity			
		Alterations in live and dead vegetation composition			
		Alterations in live and dead vegetation structure			
		Changed habitat characteristics			
		Changes in nutrient cycling			

References Supplementary C

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