10.24 Biodiversity Conservation

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Biodiversity conservation (Applied and EO/RS combined)		**Biodiversity**
Description and justification	Biodiversity generates a wide range of benefits to society (ecosystem services) therefore its conservation is essential to achieving Sustainable Development Goals (SDGs) and to meet the United Nations Convention on Biodiversity (CBD) Aichi Biodiversity Targets. Measuring net changes to biodiversity to monitor gains or losses as a consequence of NBS can be undertaken using various methodologies, involving either primary observations of species or assessments of habitat extent/quality as a proxy for biodiversity value. Key drivers include: • Assisting local authorities to evaluate their progress in urban biodiversity conservation (for example against Aichi/national/local biodiversity targets); • Ensuring NBS contributes positively to biodiversity conservation; • Serving as a public platform upon which biodiversity awareness raising exercises can be launched.	
Definition	Measure net change in individual (native) species numbers, functional richness, vegetation cover, conservation priority species in area affected by NBS using more applied and participatory methods or earth observation/remote sensing methods.	
Strengths and weaknesses	**Applied methods**: Ad-hoc, unstructured recording can restrict scientific value but can catalyse community engagement. Structured, systematic monitoring programmes, including citizen science, can be an important mechanism for ascertaining population trends over time. **Earth observation/Remote sensing methods**: Remote sensing has been increasingly contributing to timely,	

	accurate, and cost-effective assessment of biodiversity-related characteristics and functions during the last years. Various studies have demonstrated how satellite remote sensing can be used to infer species richness. However, most relevant studies constitute individual research efforts, rarely related with the extraction of widely adopted Convention on Biological Diversity (CBD) biodiversity indicators (Petrou et al., 2015).
Measurement procedure and tool	A variety of methods exist from applied/public participation techniques through to earth observation/remote sensing approaches. **Applied participatory methods**: Counts of species (species richness) have commonly been used as a surrogate for measuring biodiversity for conservation at local and broader scales, and taxa are often categorized according to rarity/local conservation concern (see The Royal Society, 2003 for a framework for measuring biodiversity for conservation). Measurements of population sizes of individual species (abundance), particularly umbrella species (Roberge and Angelstam 2004) (species which if protected, indirectly protect many other species comprising the ecological community of their habitat), can be a more sensitive indicator of change. However, collecting the data on the population dynamics of single species can be resource intensive. Adopting participatory/citizen science approaches can provide a mechanism to reduce resource intensity but can, typically, only be applied to relatively easy to identify species. Selecting appropriate metrics will depend on the objectives of the study, and whether direct measurement is required, or whether a proxy/surrogate measurement may be sufficient. Typically, extrapolations are made from collecting a stratified random sample. Repeat surveys must be undertaken to monitor change against a baseline survey. Analytical techniques will be related to sampling strategies (i.e., diversity or species quality indices, multivariate modelling, etc). Pocock et al. (2015) have developed a checklist of priority attributes for developing a biodiversity monitoring programme that includes 25 attributes that range from elemental to aspirational. This can be used as a checklist to clarify objectives and justify investment in resources and provides an excellent resource for local authorities or city stakeholders wanting to establish monitoring programes. The National Biodiversity Network (James, 2007) has an

	online handbook which provides comprehensive guidance on running a biological recording scheme that could potentially be used for site assessment, land-use planning and environmental policy development. The Natural History Museum (NHM) has a guide for specifically developing citizen science recording schemes (Tweddle, 2012). The Wildlife Trust Biodiversity Benchmark provides a framework to achieve continual biodiversity enhancement and protection on landholdings by developing an action plan, recording the baseline (PEA - habitats & species), and conducting periodic monitoring to assess performance against targets. Examples of citizen science projects that could be applied to NBS projects: Glasgow's buzzing - community bee recording project in partnership with Buglife, creating and enhancing wildflower meadows across the City, carrying out invertebrate surveys (sweep nets of parks before/after meadow creation/enhancement) and raising community awareness of biodiversity (Bairner, 2016) Urban butterfly project - recording butterflies in urban greenspaces 3 times during spring/summer to measure species/abundance using iRecord Butterflies app RSPB Big Garden Birdwatch/Big Schools Birdwatch – annual snapshot of bird diversity NHM Bioblitz – community Bioblitz, typically a 24 hour census, recording as many species as possible. This is typically also associated with use of citizen science recording methods (e.g iNaturalist https://www.inaturalist.org/) When selecting species to target for evaluation of benefits, there are generally two strategies: selecting species that are local, national or international conservation priority species, and selecting representative umbrella species that are indicators of high biodiversity. When selecting umbrella species, it is generally advisable to select a range of species that are representative of a range of taxa (Sattler et al. 2014) and ensure that there is a local focus to this selection in terms of species associated with site of high biodiversity (Caro 2010).

Earth Observation / Remote Sensing methods:

It is important to foster research and monitoring of biodiversity to determine the best assemblages of species to achieve the most efficient NBS, including the optimization of multiple economic, ecological and social benefits and exploration of trade-offs created by NBS. This can be achieved by collection of new data in the field and the use of remote sensing to gather comprehensive data on additional benefits, to complement existing data and observation.

Biodiversity includes multiscalar and multitemporal structures and processes, with different levels of functional organization, from genetic to ecosystemic levels. One of the most widely used methods to infer biodiversity is based on taxonomic approaches and community ecology theories. However, gathering extensive data in the field is difficult due to logistic problems, especially when aiming at modelling biodiversity changes in space and time, which assumes statistically sound sampling schemes. In this context, airborne or satellite remote sensing allows information to be gathered over wide areas in a reasonable time. Most of the biodiversity maps obtained from remote sensing have been based on the inference of species richness by regression analysis. Estimating compositional turnover (β-diversity) might add crucial information related to relative abundance of different species instead of just richness. Presently, few studies have addressed the measurement of species compositional turnover from space. There are novel techniques to measure β-diversity from airborne or satellite remote sensing proposed by Roccini et al. (2017), mainly based on:

- multivariate statistical analysis,
- the spectral species concept,
- self-organizing feature maps,
- multidimensional distance matrices,
- Rao's Q diversity.

Each of these measures addresses one or several issues related to turnover measurement.

High temporal resolution remote sensing images together with vegetation phenological features can achieve more accurate identification of vegetation types. Yan et al. (2018) integrated object-based classification data with vegetation phenological information derived from multi-temporal WorldView-2 images to identify grass and tree types. Senf et al. (2015) found that adding phenological patterns captured by multi-seasonal Landsat imagery can better discriminate shrublands and woodlands that would otherwise be a challenging task in single-date Landsat imagery. Moreover, utilizing the 3D structures provided by LiDAR imagery in combination with the hundreds of narrow spectral bands provided by hyperspectral (HS) imagery can enable the identification of more vegetation types. Xia et al. (2018) constructed an ensemble classifier to integrate HS and LiDAR data, and used it to identify several tree types and three grass types. Alonzo et al. (2014) used a crown-level integration of HS and LiDAR data to identify 29 common tree species in urban regions

Drone mapping is described as a tool for monitoring ecosystem restoration. Plant communities with different plant cover and species composition reflect spectral bands in different rates and this information reflects state and disturbances of mire ecosystems (peatlands). Usage of drones gives higher resolution data compared to other remote sensing options, and is suitable for plant community level monitoring, but at the same time there is a trade-off between spatial resolution and mapping area.

Various indicators are used to assess the status and trends of components of biodiversity, measure pressures, and quantify biodiversity loss at the level of genes, populations, species, and ecosystems, at various scales (Butchart et al. 2010; EEA 2012; Petrou et al. 2015). Several sets of such indicators have been proposed by organizations, scientists, and policy makers (EEA 2012; Feld et al. 2009; Petrou et al., 2015; Strand et al. 2007).

They can be either directly measured or calculated using statistical models and may have a global, regional, or national applicability. Among the most widely adopted sets are the ones proposed by the United Nations (UN) Convention on Biological Diversity (CBD), aiming at monitoring the progress towards the achievement of the defined targets at global scale (AHTEG 2011). Further efforts include the definition of more directly measured variables, to enhance indicator extraction, such as the Essential Biodiversity Variables (EBV) proposed by the Group on Earth Observations Biodiversity Observation Network (GEO BON) (Pereira et al. 2013).

Although in-situ campaigns are the most accurate way of measuring certain aspects of biodiversity, such as the distribution and population of plant and animal species, in

	many cases, they have proven particularly costly, time demanding, or impossible (Buchanan et al. 2009; Gillespie et al. 2008). Alternatively, remote sensing (RS) data from airborne or satellite sensors are increasingly being employed in biodiversity monitoring studies (Nagendra et al. 2013; Bergen et al. 2009). Offering repetitive and cost-efficient monitoring of large areas, RS data can provide precious information nearly impossible to be acquired by field assessment alone (Nagendra et al. 2001, 2013). Recently, essential biodiversity variables (EBVs) were identified (Pereira et al., 2013) (Table 1) and defined as variables, or a group of linked variables, that allows quantification of the rate and direction of change in one aspect of the state of biodiversity over time and across space (Pettorelli et al., 2018). EBVs are planned to harmonise assessment of biodiversity monitoring at any scales, and to support the aims of the Convention on Biological Diversity and IPBES. From the start, satellite remote sensing has been expected to be an important methodology for the derivation of EBVs, and indeed, satellite remote sensing EBVs (SRS-EBVs) have been conceptualised as the subset of EBVs whose monitoring relies largely or wholly on the use of satellite-based data (Luque S et al. 2018).

Table 2 gives a summary of the different types of remote sensing data that is useful in biodiversity monitoring.

Table 1. Essential biodiversity variables and use of RS (based on Walters et al., 2013)

ESSENTIAL BIODIVERSITY VARIABLES	SPATIAL RESOLUTION SATELLITE IMAGERY WITH TYPE OF MEASUREMENT SCALES (INCLUDING AVAILABLE REMOTE SENSING SENSORS)	RELEVANCE AND RELATED INFORMATION FOR BIODIVERSITY
TEMPORAL PHENOLOGY METRICS	Low/coarser spatial resolution (Global Scale) (MODIS, AVHRR etc.)	Phenology types, Forest / Non Forest, Deforestation and Biomass burning.
HABITAT STRUCTURE, ECOSYSTEM EXTENT AND FRAGMENTATION	Medium spatial resolution (Regional Scale) (Landsat, IRS, SPOT etc.)	Forest type distribution and agricultural expansion
HABITAT TYPES AND STRUCTURES, AND ECOSYSTEM COMPOSITION BY FUNCTIONAL TYPE	High spatial resolution (Local scale) (IKONOS, QuickBird, Rapid Eye historic GeoEye, WorldView-2 etc.)	Species-level distribution, canopy diameters, stand-level analysis, individual tree detection, to differentiate species at a finer scale.
HABITAT TYPES AND STRUCTURES	Active remote sensing data	Habitat degradation monitoring by generation of 3D structures

Table 2. Remote Sensing Data Useful for Biodiversity Monitoring

REMOTE SENSING DATA	BIODIVERSITY MONITORING
COARSE SPATIAL RESOLUTION (MODIS, AVHRR)	Forest / Non Forest, Biomass burning studies at global scale.
MEDIUM SPATIAL RESOLUTION (LANDSAT, IRS, SPOT)	Indicators of overall species richness and diversity at regional scales, forest type distribution and agricultural expansion
HIGH TEMPORAL RESOLUTION DATA (MULTI SEASON DATA OR IMAGES CORRESPONDING TO SPECIFIC SEASONS)	Information on invasion species and other species of interest (e.g. using images acquired corresponding to critical phonological stages of flowering or leaf senescence

For further details on measurement tools and metrics, including those adopted by past and current EU research and innovation projects can be found in: Connecting Nature Environmental Indicator Metrics Review Report

Scale of measurement	**Applied methods**: Typically more local or project scale but can be used to capture data at city scale. Scale is typically related to recorded networks and their scale. **Earth observation / Remote sensing methods**: at various geographical scales. Satellite remote sensing technology in the last decade has empowered interdisciplinary research at regional and local scale with high temporal resolution in order to provide information about changes in species distribution, habitat degradation and fine-scale disturbances of forests
Data source	

Required data	Required data will depend on selected methods, for further details see applied and earth observation/remote sensing metrics reviews in: Connecting Nature Environmental Indicator Metrics Review Report
Data input type	Data input types will depend on selected methods, for further details see applied or earth observation/remote sensing metrics reviews in: Connecting Nature Environmental Indicator Metrics Review Report
Data collection frequency	Data collection frequency will depend on selected methods, for further details see applied or earth observation/remote sensing metrics reviews in: Connecting Nature Environmental Indicator Metrics Review Report
Level of expertise required	**Applied methods**: Professional ecological consultants and scientific/ecological expertise are needed to design and implement and/or support citizen scientists monitoring schemes and data analysis (depending on the scheme or whether an existing scheme is adopted). If identification of target species is not straightforward, expertise can be required for the monitoring also. **Earth observation/Remote sensing methods**: Expertise in mapping and interrogation of data using GIS software is typically required. Level of expertise required is greater with increasing complexity of software processing. Typical “multi-spectral” sensors with 4 to 20 carefully selected and well-calibrated bands provide a great deal of information, and adding more bands can help with specific issues. “Hyperspectral” sensors can have more than 200 bands and can provide a wealth of information to help, for example, identify specific species. Processing such datasets requires special expertise and satellite-based hyperspectral sensors are not yet common. Other sensor types include radar and lidar which actively emit electromagnetic energy and measure the amount that is reflected—these sensors are useful for measuring surface height as well as tree canopy characteristics and surface roughness. Lidar is generally more precise than radar and ideal for measuring tree height. Radar is particularly useful where cloud cover is a problem (for instance, in the biodiversity-rich tropical rainforests) because it penetrates clouds.
Synergies with other indicators	The significance of urban land-system synergies and spatial governance are increasingly emerging towards sustainable targets (also regarding the biodiversity conservation) and liveable environments in cities. Satellite remote sensing, process-based models and big data are playing pivotal roles for obtaining spatially explicit knowledge for the purpose of biodiversity conservation and better planning for managing cities. Thus, synergy will be provided through

	the integration of governance with remote sensing, modelling and big data. In relation to direct measures of supporting/increasing biodiversity, there could be synergies with landuse change, greenspace area and accessibility to greenspace (wildlife areas).
Connection with SDGs	All except SDGs 1 and 5: Biodiversity underpins food production; Links between biodiversity and health & wellbeing benefits; Links to environmental education; Links between biodiversity and water quality; Links between biodiversity and clean energy (biosolar, biofuel); Job creation; Improved green infrastructure and industry associated with biodiversity (potential disservices also); Social equality in relation to access to nature; Sustainable urban development; Biodiversity a good indicator of responsible consumption; Climate change adaptation; More sustainable water management; Biodiversity benefits; Environmental Justice in relation to biodiversity; Opportunities for collaborative working
Opportunities for participatory data collection	**Applied methods**: Such monitoring schemes offer great opportunities for citizen participation. This can be a mechanism to increase the scale and extent of the monitoring, and to increase community engagement with, and awareness of, urban biodiversity. **Earth observation / Remote sensing methods**: It is today possible to integrate remote sensing data and in situ observations to monitor several essential biodiversity variables such as habitat structure and phenology. In this context, municipalities should explore the possibilities of launching citizen science projects and consider the possibility in general that within cities, local knowledge on biodiversity and ecosystem services may reside in many different groups within civic society. Here, we can face the challenges related to scaling, boundaries, locally adapted indicators and scoring which can be met by each municipality developing their interpretation of what scale and what boundary is the most appropriate, what definitions to use, and what set of sub-indicators may best reflect the local ecological and cultural context. However, there are some challenges that are not easily addressed at the municipal level and need input from the research community.
Additional information	
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Earth observation / Remote sensing methods:
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