8 Additional Indicators of Green Space Management

8.1 Ecosystem service provision

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Ecosystem service provision (Applied and EO/RS combined)	Green Space Management
Description and justification	Studies such as the Millennium Ecosystem Assessment (2005) and the UK National Ecosystem Assessment (Watson et al., 2011), the MAES working group (under Action 5 of the European Biodiversity Strategy to 2020; https://ec.europa.eu/environment/pubs/pdf/factsheets/biodiversity_2020/2020%20Biodiversity%20Factsheet_EN.pdf), MAPPING and assessment of Ecosystems and their services (https://biodiversity.europa.eu/maes; also in support of the European Biodiversity Strategy), KIP INCA (https://ec.europa.eu/environment/nature/capital_accounting/index_en.htm), EnRoute (https://oppla.eu/groups/enroute) and Openness (operationalisation of ecosystem services) demonstrated the linkages between the natural environment, ecosystem services (ES) and human well-being. Urban greenspaces can deliver essential ES and a detailed map of urban GI can provide the baseline for measuring urban ES. Detailed spatial data is needed to identify service providing units, and GI is typically classified according to land cover and land use type. Most techniques therefore involve remote sensed data and modelling approaches. The role of novel Earth observation techniques and data sets is becoming increasingly important in environmental monitoring, both for biodiversity (Vihervaara et al. 2017), and for ecosystem services (Cord et al. 2017). Satellite Earth observation, as well as airborne and drone observations, have huge potential to improve quantification, mapping, and assessment of ecosystems and their services. Optical, radar, and Light Detection And Ranging (LiDAR) data can be used for direct measurements, or to gather information that feeds into the models. Mapping ecosystem service provision in these ways can be used to: • Set targets for ecosystem service provision; • Monitor change in ecosystem service provision over time; • Inform strategic planning decisions in relation to individual sites or networks of sites; • Assess the effects of different scenarios of design/management change on sites.

Definition	Measure number/quantity of a suite of ecosystem services to evaluate change in ES provision in relation to NBS.
Strengths and weaknesses	**Applied methods:** See EO/RS below. **Earth observation / Remote sensing methods:** The integration of RS technologies into ES concepts and practices leads to potential practical benefits for the protection of biodiversity and the promotion of sustainable use of Earth's natural assets. The last decade has seen the rapid development of research efforts on the topic of RS for ES (especially, in the context of spatially explicit RS and valuation of ES), which has led to a significant increase in the number of scientific publications. Remote sensing can be used for ecosystem service assessment in three different ways: direct monitoring, indirect monitoring, and combined use with ecosystem models. Some plant and water related ecosystem services can be directly monitored by remote sensing. Most commonly, remote sensing can provide surrogate information on plant and soil characteristics in an ecosystem. For ecosystem process related ecosystem services, remote sensing can help measure spatially explicit parameters. We conclude that acquiring good in-situ measurements and selecting appropriate remote sensor data in terms of resolution are critical for accurate assessment of ecosystem services. The assessment of ES is often limited by data, however, a gap with tremendous potential can be filled through Earth observations (EO), which produce a variety of data across spatial and temporal extents and resolutions. Despite widespread recognition of this potential, in practice few ecosystem service studies use EO. There are some challenges and opportunities to using EO in ecosystem service modelling and assessment which we can identify: • technical - related to data awareness, processing, and access (these challenges require systematic investment in model platforms and data management); • other challenges – more conceptual but still systemic; they are by-products of the structure of existing ecosystem service models and addressing them requires scientific investment in solutions and tools applicable to a wide range of models and approaches. As stated by a variety of research, more widespread use of EO for ecosystem service assessment will only be achieved if all of these types of challenges are addressed. This will require non-traditional funding and partnering opportunities from private and public agencies to promote data exploration, sharing, and archiving. Investing in this integration will be reflected in better and more accurate ES assessment worldwide.

	Remote sensing provides a useful data source that can monitor ecosystems over multiple spatial and temporal scales. Although the development and application of landscape indicators (vegetation indices, for example) derived from remote sensing data are comparatively advanced, it is acknowledged that a number of organisms and ecosystem processes are not detectable by remote sensing. The potential for applying remote sensing for analysis and mapping of ES efforts has not been fully realised due to concerns about ease-of-use and cost. Historically, RS data have not always been easy to find or use because of specialised search and order systems, unfamiliar file formats, large file size, and the need for expensive and complex analysis tools. That is gradually changing with increasing implementation of standards, web delivery services, and the proliferation of free and low-cost analysis tools. Although data cost used to be a common prohibitive factor, it is no longer a big stumbling block for most users except where high resolution commercial images are needed.
Measurement procedure and tool	A variety of methods exist from applied/public participation techniques through to earth observation/remote sensing approaches. 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 Indicator Metrics Reviews Env85_Applied and Env85_RS
Scale of measurement	**Applied methods:** See EO/RS below. **Earth observation / Remote sensing methods:** Remotely sensed data are inherently suited to provide information on urban vegetation and land cover characteristics, and their change at various geographical scales. However, the higher the resolution required, the more expensive would be RS data needed. In some cases, it would be better to use images provided by drones, but in this case permissions for survey mapping will be required and depends on the local and national / government regulations. Methods can be applied from small to large geographical scales but are linked to the limitations of the data sources.
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 Indicator Metrics Reviews Env85_Applied and Env85_RS
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 Indicator Metrics Reviews Env85_Applied and Env85_RS
Data collecti	Data collection frequency will depend on selected methods, for further details see applied or earth observation/remote sensing

on frequency	metrics reviews in: Connecting Nature Indicator Metrics Reviews Env85_Applied and Env85_RS
Level of expertise required	**Applied methods**: See EO/RS below. **Earth observation / Remote sensing methods**: It is important to clarify the resources that are needed to carry out ecosystem services assessments, such as technical and human resources, and the time needed for certain analyses. The methods vary greatly depending on the required expertise, availability of the data and its coverage, available software, time, and financial costs. The most suitable approach will depend on the research questions which need to be addressed, whether the study will be an assessment, or if maps are also required. For mapping methods, the level of scale should be considered. The limitations are often set by the availability of the data. For small research areas more detailed data sources, or even opportunities to conduct field measurements, may be available. However, for larger studies Earth Observation products may offer a solution for areas of poor data coverage. In addition to scale, it is also important to pay attention to the purpose of which the assessment is aimed at: Which biophysical units can and should be used to gain information on ecosystem services? Do we want to know if sufficient ecosystem service potential is available, or do we wish to quantify the rate at which the ecosystem service is delivered? Also, do we wish to deliver spatially explicit information for the chosen locations? The most suitable methods should be identified and selected according to the answers to these questions. Using a mixture of remote sensing and field methods appears to deliver the best results (e.g Mikolajczak et al., 2015; Vihervaara et al., 2017). Yet, this requires ecologists and remote sensing experts to collaborate closely with the newest methods and capabilities.
Synergies with other indicators	In comparison to conventional sources of information on urban environment, remotely sensed data are inherently suited to provide information on urban land cover characteristics and ecosystem services provisioning, and their change over time, at various spatial and temporal scales. Synergies and trade-offs between the type and quantity of UGS and ES supply can also be identified e.g., cooling, carbon storage and air purification demonstrate synergies as these are primarily being supplied by the same UGS types. The method can reveal differences between neighbourhoods in terms of amount and type of ES supplied, and can highlight possible ES shortages in neighbourhoods.
Connection with SDGs	All SDGs except 5; Providing opportunities for employment; Providing opportunities for urban agriculture; Health & Wellbeing benefits; Links to environmental education; Potential co-benefit in relation to clean water; Potential co-benefit in relation to sustainable and clean energy; Opportunities associated with improved economic growth; Opportunities associated with green technologies; Social equality;

	Sustainable urban development; Sustainable consumption and production; Climate change adaptation; Potential co-benefits related to more sustainable water management; Potential positive impact on habitat; Environmental Justice; Opportunities for collaborative working.
Opportunities for participatory data collection	**Applied methods:** RS review includes community participation. **Earth observation / Remote sensing methods:** Participatory activities can be combined with remote sensing analysis into an integrated methodology to describe and explain land-cover changes and changes in ES provision caused by them. In doing so, semi-structured interviews, focus group discussions, transect walks and participatory mapping can be used to identify and assess priority ES. Local community members and experts can together discuss which (positive) impact (benefits) the implemented NBS will have on various ES for local, regional, national and international users. This participatory process can help to identify priority ES (e.g., air purification, carbon sequestration, water regulation, soil protection, landscape beauty, biodiversity, etc.). The approach will reveal if there any strong variations in the valuation of different ES between local people and experts who apply RS techniques, between genders and between different status and income classes in the local communities. Scientific evidence has demonstrated that participatory tools, combined with free-access satellite images and repeat photography are suitable approaches to engage local communities in discussions regarding ES and to map and prioritise ES values (Brown & Donovan, 2014; Brown et al., 2012).
Additional information	
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8.2 Annual trend in vegetation cover in urban green infrastructure

Project Name: MAvES (Mapping, Assessment and Valuation of Ecosystems and their Services) (JRC-D3- Institutional project)

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Greenest urban green infrastructure and long-term trend in green spaces pattern	**Green Space Management**
Description and justification	This indicator examines how and in which direction vegetation cover changes within the Urban Green Infrastructure. Trend detection in Normalized Difference Vegetation Index (NDVI) time series can help to identify and quantify recent changes in ecosystem properties.
Definition	Urban green spaces make an important contribution to the liveability of cities. This indicator examinehow green are urban green infrastructure using remote sensing data. 1- The greenest value per UGI is derived