GUIDELINE

ANNEX TO GUIDANCE FOR DEMONSTRATING ECOSYSTEM SERVICES IMPACTS

FSC-GUI-30-006a V2-0 EN

FSC FORESTS FOR ALL FOREVER™

METHODOLOGIES BIODIVERSITY CONSERVATION (ES1)

Methodology descriptions include the ES impacts and example outcome indicators that fit followed by a brief description of the methodology, suitable local contexts, advantages and disadvantages, and where you can find the full methodology manual and/or any background information.

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES1.1	**Enhancement of natural forest cover**	
Extent of natural forest cover from restoration activities	Area of natural forest cover resulting from reforestation	ES1-A Satellite imagery and GIS
	Restored forest area as a proportion of total forest area	*Simple measurement or calculation*
Quality of natural forest cover from reforestation/ restoration activities	Forest density	ES1-B LiDAR ES1-J Index for Biodiversity Potential ✓
	Survival rate of planted native species	*Simple measurement or calculation*
	Variety of plant species composition	
	Diversity of forest structure	ES1-K Forest Integrity Assessment Tool ✓ ES1-B LiDAR
ES1.2	**Maintenance of Intact Forest Landscapes**	
Extent of Intact Forest Landscapes in the MU	Area of Intact Forest Landscapes	ES1-C Assessment of the Area of Intact Forest Landscapes ✓
	Area of Intact Forest Landscape core areas	*Simple measurement or calculation*
	Area of protected Intact Forest Landscapes	*Simple measurement or calculation*
ES1.3	**Maintenance of an ecologically sufficient conservation area network**	
ES1.4	**Enhancement of an ecologically sufficient conservation area network**	
Connectivity of the conservation area network	Connectivity of the conservation areas network	ES1-D Calculating Habitat Connectivity ES1-A Satellite imagery and GIS
	Connectivity to conservation areas outside the management unit	ES1-D Calculating Habitat Connectivity ES1-A Satellite imagery and GIS
	Connectivity to natural habitats outside the conservation areas network	ES1-D Calculating Habitat Connectivity ES1-A Satellite imagery and GIS
	Size of ecological corridor	ES1-A Satellite imagery and GIS
Habitat quality of the conservation area network	Area of the conservation area network within and outside the management unit (including representative sample areas, conservation zones, protection areas, connectivity areas, and high conservation value areas)	Area: *Measured as part of FSC-FM* Habitat quality: ES1-J ✓, ES1-K ✓
	Area with High Conservation Value (HCV)	Area: *Measured as part of FSC-FM* Habitat quality: ES1-J ✓, ES1-K ✓

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
Habitat quality of the conservation area network	Proportion of HCV area within the conservation area network	% of area: *Measured as part of FSC-FM* Habitat quality: ES1-J ✓, ES1-K ✓
	Area of habitats of conservation importance	Area: *Measured as part of FSC-FM* Habitat quality: ES1-J ✓, ES1-K ✓
	Area of suitable habitats for species with conservation value	Area: *Measured as part of FSC-FM* Habitat quality: ES1-J ✓, ES1-K ✓
	Area of large landscape level ecosystems and mosaics (HCV2)	Area: *Measured as part of FSC-FM* Habitat quality: ES1-L
ES1.5	**Maintenance of natural forest structure**	
ES1.6	**Enhancement of natural forest structure**	
Forest structure	Forest age class	
	Forest ecosystem structure	ES1-K Forest Integrity Assessment Tool ✓ ES1-B LiDAR
	Forest structural condition index	
	Forest vertical and/or horizontal structure	ES1-K Forest Integrity Assessment Tool ✓ ES1-B LiDAR ES1-J Index for Biodiversity Potential ✓
	Amount of standing and fallen deadwood and/or other important natural microhabitats	ES1-K Forest Integrity Assessment Tool ✓ ES1-B LiDAR ES1-J Index for Biodiversity Potential ✓
ES1.7	**Maintenance of native species diversity**	
ES1.8	**Enhancement of native species diversity**	
Native species diversity	Indices of native species assemblage or composition (e.g. Shannon diversity index)	ES1-E Environmental DNA ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring ES1-L Forest Intactness Index
	Proportion of native species classified as at risk	
Abundance or viability of focal, endemic or RTE species	Abundance of selected species	ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring
	Availability of selected species for sustainable traditional use (e.g. medicinal plants)	
Habitat availability within the management unit for focal, endemic, or RTE species	Area of available habitat	*Simple measurement or calculation*
	Suitability of habitat	ES1-K Forest Integrity Assessment Tool ✓ ES1-L Forest Intactness Index
	Habitat connectivity	ES1-D Calculating Habitat Connectivity
	Area protected from illegal hunting	ES1-H Acoustic monitoring
ES1.9	**Maintenance of functional biodiversity**	
ES1.10	**Enhancement of functional biodiversity**	

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
Ecological function	Pollination rates	ES1-I TESSA Pollination method 5: Flower visitation rate as a proxy
	Seed dispersal	
	Pest control	
	Gross or net primary production	
	Population dynamics	
Functional biodiversity	Species richness of native pollinators	ES1-E Environmental DNA
	Abundance of natural enemies (e.g. bats) that limit pests	ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring
	Variety of functional species groups	ES1-E Environmental DNA
	Diversity of morphological species traits	
	Diversity of soil microbiome	ES1-E Environmental DNA
Habitat availability within the management unit for functional biodiversity	Evidence of roosts and shelters in use by functional species	ES1-K Forest Integrity Assessment Tool
	Area of available habitat for functional biodiversity species	*Simple measurement or calculation*
	Suitability of habitat for functional biodiversity	ES1-K Forest Integrity Assessment Tool
	Availability of standing and fallen deadwood and/or other important natural microhabitats	ES1-K Forest Integrity Assessment Tool ES1-B LiDAR ES1-J Index for Biodiversity Potential
ES1.11	**Maintenance of rare, endemic, threatened or endangered habitats or ecosystems**	
ES1.12	**Enhancement of rare, endemic, threatened or endangered habitats or ecosystems**	
Extent of rare, endemic, threatened or endangered habitats or ecosystems	Area of endemic habitats or ecosystems	*Simple measurement or calculation*
	Area of ecosystems that are threatened or endangered	*Simple measurement or calculation*
	Area of ecosystems or habitats that are classified as threatened in national or international systems	*Simple measurement or calculation*
	Area of priority habitats and ecosystems for conservation at the global, regional, national, and/or local levels	*Simple measurement or calculation*
Condition of rare, endemic, threatened or endangered habitats or ecosystem	Ecological Integrity Index	
	Proportion of forest intactness areas	ES1-L Forest Intactness Index
	Disturbance level	ES1-K Forest Integrity Assessment Tool
	Presence of indicator species for good habitat/ ecosystem quality	ES1-E Environmental DNA
	Proportion of degraded habitats in relation to total	ES1-L Forest Intactness Index

ES1-A SATELLITE IMAGERY AND GIS

Impacts

- ES1.1: Restoration of natural forest cover
- ES3.3: Maintenance of water volume regulation
- ES3.4: Enhancement of water volume regulation
- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition
- ES4.3: Maintenance of soil stability and protection against soil erosion
- ES4.4: Enhancement of soil stability and protection against soil erosion

Outcome indicators

- Area of natural forest cover resulting from reforestation
- Natural forest cover for the management unit overlapping with the relevant watershed
- Proportion/percentage of land that is degraded over total land/forest area
- Percentage of waterbody shoreline with forest cover
- Extent of land with forest canopy or ground vegetation
- Protective forest on steep slopes
- Protective forest cover for wetlands and/or coastal areas
- Natural forest cover on vulnerable areas

Description

Remote sensing and Geographic Information Systems (GIS) are invaluable tools for quantifying and monitoring forest-related ecosystem services. Note that remote sensing based on satellite imagery for measuring carbon sequestration & storage, water quality and air quality is added as a methodology under those ES-specific modules. For data on Intact Forest Landscapes, see ES1-C.

Remote sensing involves both raw satellite imagery and derived datasets (value-added products). Raw satellite imagery typically requires pre-processing and can be used for deriving forest cover, vegetation indices or habitat assessments. Derived datasets include land cover maps, canopy height models and vegetation indices. Vegetation indices can be calculated from the difference in reflection from different spectral band wavelengths. Every index has its own formula and usually GIS software can help with these calculations. For example, the NDVI (normalized difference vegetation index) is frequently used in the determination of land cover and land-cover change and the Normalised Burn Ratio which is used to identify burned areas and provide a measure of burn severity.

There are several things to consider in the selection of satellite images. First, because as a forest manager you are looking at a management unit level, we recommend that you use remote-sensing data with a **medium to high spatial resolution**, i.e. minimum 30m. Second, a common problem with remote-sensing data is cloud cover. We recommend that you use a remote-sensing image with **little or no cloud cover**. Third, when comparing two or more satellite images, think about how **seasonality** may affect the quality and comparability of the images. Finally, temporal coverage ensures the possibility for time-series analysis and trend detection.

Some satellite imagery is available for download free of charge; access to other data may come at a cost or access may be restricted to certain types of users. The table below provides an overview of useful **open source satellite imagery**, their characteristics and how they can be accessed.

Satellite imagery data source	Characteristics	Access data
Landsat series (National Aeronautics and Space Administration (NASA)/United States Geological Survey (USGS)) Landsat-7: launched April 1999 Landsat-8: launched Feb. 2013 Landsat-9: launched Sept. 2021	Landsat-7's Enhanced Thematic Mapper Plus has 8 spectral bands, Landsat-8 and -9's Operational Land Imager has 9 and the Thermal Infrared Sensor has 2 spectral bands, All but 1 band at 30m resolution (some resampled from 60m or 100m), 1 band at 15m 16-day repeat coverage, 185 km swath width	Google Earth Engine NASA's Earth data QGIS Semi-Automatic classification plugin
Sentinel-2 (European Space Agency) 2A: launched June 2015 2B: launched March 2017 2C: launched Sept. 2024 (to replace 2A)	13 spectral bands, 4 bands at 10m, 6 bands at 20m and 3 bands at 60m resolution, 5-day revisit time, 290 km swath width	Copernicus data browser Google Earth Engine NASA's Earth data QGIS Semi-Automatic classification plugin

Visual interpretation can be an appropriate method for analysing deforestation or forest fragmentation. This will be easier for those experienced in visually analysing remote-sensing imagery. The NASA Earth Observatory provides a couple of general tips for interpreting a satellite image (Riebeek, 2013), as well as explanation about interpreting false-colour images (Riebeek, 2014).

Some remote sensing data sets can be viewed through dashboards such as Global Forest Watch (see ES1-C), although a subscription fee is often required for advanced features. **GIS software** can be used for more advanced data analyses. For example, QGIS is an open source and user-friendly software program, whereas Esri's ArcGIS is also user-friendly and has some additional features but comes with a paid subscription, and R and Python require advanced coding knowledge.

While the use of satellite imagery may make monitoring easier or more cost-effective, it is important to do in-situ **sampling/ field measurement** to complement satellite imagery data. In other words, make the link between the image and the field measurement values, for example based on data from a forest inventory or from sampling plots. Field measurement data includes the boundaries of the management unit/ ES project and species presence, biomass, soil condition or canopy density on the ground. It is easiest if sampling plots are square and of the same size as the spatial resolution of the satellite image (e.g. 10x10m or 30x30m), though corrections can be applied in GIS software.

Suitable contexts

All forests worldwide.

Advantages

- Cost-effective for large areas.
- Consistent and repeatable measurements.
- Scalable analyses.
- Rapid assessment.

Disadvantages

- Cloud cover and atmospheric interference.
- Limited direct measurement.
- Requires medium- to high level expertise or interest.
- Data management of heavy imagery.

Access

See links in table above for datasets, see links in text on data analysis and GIS software.

ES1-B LIDAR

Impacts

- ES1.1: Enhancement of natural forest cover
- ES1.5: Maintenance of natural forest structure
- ES1.6: Enhancement of natural forest structure
- ES4.3: Maintenance of soil stability and protection against soil erosion
- ES4.4: Enhancement of soil stability and protection against soil erosion
- ES7.1: Maintenance of air quality
- ES7.2: Enhancement of air quality

Outcome indicators

- Area of natural forest cover resulting from reforestation
- Diversity of forest structure
- Forest ecosystem structure
- Forest vertical and/or horizontal structure
- Leaf area index (LAI)

Description

LiDAR uses a laser to measure distances and helps to create a 3D image of the scanned objects. Often, the laser scanner is mounted on an airplane or a drone for LiDAR data from the air, though sometimes on a vehicle or tripod for terrestrial data and some satellites are equipped with a laser scanner.

There are multiple applications of data obtained through LiDAR, including forest structure, leaf area index. Given its high level of precision (5-15cm), there is no need for ground truthing.

WWF has developed guidelines on LiDAR for ecology and conservation (Melin et al., 2017). These guidelines explain how LiDAR works, what applications it has in forests, and where to access existing LiDAR data.

Suitable contexts

All forests worldwide, except dense tropical forests that LiDAR cannot penetrate.

Advantages

- Precise.

Disadvantages

- Expensive.
- Requires high-level expertise or interest.

Access

Guidelines on LiDAR for ecology and conservation (Melin et al., 2017):
https://www.wwf.org.uk/project/conservationtechnology/lidar.

Online source explaining what LiDAR is and how it can be used in a forest context:
https://www.neonscience.org/resources/learning-hub/tutorials/lidar-basics

ES1-C ASSESSMENT OF THE AREA OF INTACT FOREST LANDSCAPES

Impacts

ES1.2: Maintenance of intact forest landscapes

Outcome indicators

- Area of intact forest landscapes

Description

Global Forest Watch offers an online interactive map that allows users to explore and analyse data on tree-cover change on a global, national, or jurisdictional level. Global Forest Watch includes data on intact forest landscapes (IFLs). The IFL data set identifies unbroken areas of natural forest ecosystems that show no signs of significant human activity and that are large enough that all native biodiversity, including viable populations of wide-ranging species, could be maintained.

To map IFL areas, unfragmented landscapes of at least 50,000 ha in size, and with a minimum width of 10 kilometres were mapped from Landsat satellite imagery for the year 2000. The world IFL map was created through visual interpretation of Landsat images by experts. Subsequently, reassessments of IFL areas have been performed in 2013[1], 2016 and 2020. As a result, IFL areas as well as IFL area reductions are shown on the Global Forest Watch map.

The year 2016 IFL map can be used as the baseline (Annex B requires the IFL extent for January 1, 2017), so for the comparison you will be looking for any 'reduction in extent 2016-2020' in your MU.

Suitable contexts

All forests worldwide that include, or are part of, IFLs.

Advantages

- Cost-effective.
- User-friendly.

Disadvantages

- Debate over accurateness and intactness on the ground.
- Large area of forest may be classified as IFL.

Access

Access the interactive map via https://globalforestwatch.org/map/ (tab 'land cover').

Access the datasets directly via https://glad.umd.edu/dataset.

1 Potapov, P., M. C. Hansen, L. Laestadius, S. Turubanova, A. Yaroshenko, C. Thies, W. Smith, I. Zhuravleva, A. Komarova, S. Minnemeyer, and E. Esipova. 2017. "The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013." Science Advances 3: e1600821.

ES1-D CALCULATING HABITAT CONNECTIVITY

Impacts

- ES1.3: Maintenance of an ecologically sufficient conservation area network
- ES1.4: Enhancement of an ecologically sufficient conservation area network
- ES1.7: Maintenance of native species diversity
- ES1.8: Enhancement of native species diversity

Outcome indicators

- Connectivity of the conservation areas network
- Connectivity to conservation areas outside the management unit
- Connectivity to natural habitats outside the conservation areas network
- Habitat connectivity

Description

HABITAT CONNECTIVITY

To determine the level of habitat connectivity, you look at **forest patches that function as corridors or stepping stones** in the landscape. A corridor links two core forest units to each other (bridge) or it connects back to the same core forest unit (loop), whereas stepping stones are islands of forest.

This process is made up of the following steps:

1. Calculate the number of connectivity units (i.e. the number of corridors and stepping stones) and the area of each connectivity unit, as well as the total area of connectivity units.
2. Add a qualitative description of the strength of each of the connectivity units, detailing whether it is a stepping stone or a corridor and of which type (bridge or loop).
3. Describe the importance of the connectivity units, which two (core) forest patches are being connected (and which focal species' dispersal potential it affects).
4. Show that the connectivity units have not emerged as a result of a permanent loss of (core) forest area (e.g. by calculating habitat fragmentation).

HABITAT FRAGMENTATION

To calculate the level of habitat fragmentation, you need a **land-cover map of the forest** that is detailed enough to **include roads, villages, and other human development structures** (tree nursery, log landing site, etc.) within or in the direct surroundings of the forest. This can be spatially continuous remote-sensing data, such as high-resolution Landsat imagery (see ES1-A), combined with a map of the management unit depicting roads, villages, and other human development structures. In case the latter is not readily available, a mapping exercise will be a first step. With a GPS, field data can be collected that can subsequently be uploaded into a geographic information system (GIS) software program to create such map.

All forests within 100m of human development structures or non-forest land cover will be classified as **'edge forest'**; all other forest will be classified as **'core forest'**. Using GIS software, it is now possible to calculate the total core forest area and the total edge forest area. Further, an overview can be generated of the total number of core forest patches and their area (patch size).

For a more advanced calculation, the area weighted average core forest patch size (AWACFS) index can be determined. This index is based on the identification of core forest patches and accounts for their number and size. The larger the patch is, the higher its contribution in the calculation. The index formula is:

$$AWACFS = \sqrt{[\sum (c_i)^2 / \sum c_i]}$$

where c_i is the area of the core unit i, i = 1 to n (n is the total number of core forest patches).

Suitable contexts

Suitable for all types of forests. Easiest for organizations that have in-house GIS and mapping expertise.

Advantages

- Can be used by a non-expert who has basic GIS (and mapping) skills.
- Requires little time and monetary investment (assuming a map of forest infrastructure is readily available).

Disadvantages

- Need to navigate a lengthy document.

Access

Estreguil, C., and Mouton, C. (2009) *Measuring and Reporting on Forest Landscape Pattern, Fragmentation and Connectivity in Europe: Methods and Indicators* Joint Research Centre, Institute for Environment and Sustainability, Varese, 69 pp.: https://core.ac.uk/download/pdf/38615393.pdf

ES1-E ENVIRONMENTAL DNA (eDNA)

Impacts

- ES1.7: Maintenance of native species diversity
- ES1.8: Enhancement of native species diversity
- ES1.9: Conservation of functional biodiversity
- ES1.10: Restoration of functional biodiversity
- ES1.11: Maintenance of rare, endemic, threatened or endangered habitats or ecosystems
- ES1.12: Enhancement of rare, endemic, threatened or endangered habitats or ecosystems
- ES6.3: Maintenance of culturally valued populations or species
- ES6.4: Enhancement of culturally valued populations or species

Outcome indicators

- Indices of native species assemblage or composition (e.g. Shannon diversity index)
- Species richness of native pollinators
- Variety of functional species groups
- Diversity of soil microbiome
- Presence of indicator species for good habitat/ecosystem quality
- Outcome indicators of the type 'Culturally valued species or populations'

Description

Environmental DNA (eDNA) is DNA that is shed from an organism into the environment. The eDNA sequencing technique involves the **collection of samples in the environment**, for example water or soil, and subsequently **performing analyses in a laboratory** to extract DNA and run extracted DNA against an eDNA databank to identify species encountered in the samples.

Bruce et al. (2021) developed a practical guide to DNA-based methods for biodiversity assessment for the following sample types: aquatic eDNA, bulk invertebrates, benthic periphytic diatoms and soils/sediments. This guide includes key considerations in handling eDNA in the field (during collection of samples) and in the laboratory as well as guidance on sampling. Organisations offering eDNA analysis services may also provide helpful instructions on how to collect and transport samples.

Suitable contexts

Forests for which genetic reference data is available for the target species.

Advantages

- Non-invasive method.
- Elusive or cryptic species can be easier to detect than using traditional methods.
- No need for experts in the field, cost-effective.

Disadvantages

- No robust data on species abundance (only relative abundance), age or size distribution.
- Limited number of species included in eDNA banks as genetic reference data.

Access

Examples of organisations offering eDNA analysis services: NatureMetrics (UK/ Canada), CD Genomics (US), SGS (laboratory in Portugal)

Practical guide to DNA-based methods for biodiversity assessment (Bruce et al., 2021): https://ab.pensoft.net/article/68634/.

ES1-F FAUNA SPECIES SURVEY TECHNIQUES

Impacts

- ES1.7: Maintenance of native species diversity
- ES1.8: Enhancement of native species diversity
- ES5.3: Maintenance of populations of species of interest for nature-based tourism
- ES5.4: Enhancement of populations of species of interest for nature-based tourism
- ES6.3: Maintenance of culturally valued populations or species
- ES6.4: Enhancement of culturally valued populations or species

Outcome indicators

- Indices of native species assemblage or composition (e.g. Shannon diversity index)
- Abundance of selected species (of recreational interest)
- Diversity of cultural, historical or iconic species or populations which are used as emblems or cultural signifiers of some kind
- Richness of species deemed to have cultural, sacred or spiritual significance for people, including for Indigenous or traditional peoples' values and sense of belonging

Description

There is a choice of various fauna survey techniques dependent upon the species type and the specific purpose of the study, amongst other considerations. For the purpose of estimating species populations in FSC-certified forests, line transects are recommended for mammals and point counts (or point transects) are recommended for birds because they enable you to cover larger areas while making effective use of time. To ensure suitable techniques for surveying other types of animal (reptiles, amphibians, fish, invertebrates), we recommend you contact an expert about the most suitable sampling technique in your local context.

We recommend you divide the forest area into 2–6 different strata based on habitat, climate, altitude, land use, species abundance, accessibility of study sites, administrative or geopolitical boundaries, etc. (Sutherland et al., 2004).

General issues to consider with **fauna surveys** are:

- season and time of the day (when is a particular species active?)
- size of survey plots/length of transect line (e.g. 1 km transect line)
- general counting protocol
- recording units (identified by vision, hearing, other).

With **line transects** it is important for the following to be taken into account:

- recommended walking speed (e.g. 1 km/h)
- estimation of perpendicular distances.

With **point counts** it is important to use:

- 1-minute settling time after reaching the counting point
- 5- or 10-minute count periods
- two to three estimated distance bands (0–30 m and over 30 m; or 0–30 m, 30–100 m, and over 100 m)
- minimum 200 m between two counting stations.

We recommend you seek the involvement of at least one expert (e.g. from a nearby university or research institute, or a consultant) in the data collection design and data analysis, as well as a local expert in species identification.

Suitable contexts

Suitable for all types of forests with fauna inhabitants.

Advantages

- Direct measurement of species populations.

Disadvantages

- Need to involve expert(s).
- Time-consuming.
- Expensive.

Access

Based on:

Sutherland, W.J. (2000) *The Conservation Handbook – Research, Management and Policy*. Blackwell Science, Oxford, 296 pp.

Sutherland, W.J., Newton, I., and Green, R.E. (2004) *Bird Ecology and Conservation – A Handbook of Techniques*. Oxford Biology, Oxford.

ES1-G CAMERA TRAP SURVEYS

Impacts

- ES1.6: Conservation of species diversity
- ES1.7: Restoration of species diversity
- ES5.3: Maintenance/conservation of populations of species of interest for nature-based tourism
- ES5.4: Restoration or enhancement of populations of species of interest for nature-based tourism
- ES6.3: Maintenance of culturally valued populations or species
- ES6.4: Enhancement of culturally valued populations or species

Outcome indicators

- Abundance of selected species (of recreational interest)
- Outcome indicators of the type 'Culturally valued species or populations'

Description

A camera trap is a camera that takes a picture when triggered by an animal that comes in the camera's vision (e.g. using a passive infrared sensor that notices the infrared radiation from a warm-blooded animal). It works best for medium-large size mammals, but also for small mammals (>100 g) and birds, and to some extent for reptiles. Camera traps provide data on species location, population sizes, species diversity and how species are interacting. It is particularly **effective for species abundance monitoring**.

WWF-UK has created a manual for camera trapping. Note that this manual was published in 2017, and especially the development of artificial intelligence and software for data processing has advanced since. Two other camera trapping manuals are added below.

Suitable contexts

Forests with fauna biodiversity.

Advantages

- Little or no disturbance to wildlife
- Effective for nocturnal species
- Getting imagery of wildlife that can be used for engagement with potential sponsors and/or other stakeholders.

Disadvantages

- Data processing and analysis is time-consuming (and costly) if not partly automated (although the use of citizen science can be helpful)
- Costly (camera equipment)
- Interference by humans or wildlife
- Prone to malfunction in extreme environments (e.g. high precipitation, humidity).

Access

Access the WWF manual about camera trapping: https://www.wwf.org.uk/project/conservationtechnology/camera-trap.

Other camera trapping manual 1

Other camera trapping manual 2

ES1-H ACOUSTIC MONITORING

Impacts

- ES1.6: Conservation of species diversity
- ES1.7: Restoration of species diversity
- ES1.11: Maintenance of rare, endemic, threatened or endangered habitats or ecosystems
- ES1.12: Enhancement of rare, endemic, threatened or endangered habitats or ecosystems
- ES5.3: Maintenance/conservation of populations of species of interest for nature-based tourism
- ES5.4: Restoration or enhancement of populations of species of interest for nature-based tourism
- ES6.3: Maintenance of culturally valued populations or species
- ES6.4: Enhancement of culturally valued populations or species

Outcome indicators

- Abundance of selected species (of recreational interest)
- Presence of indicator species for good habitat/ecosystem quality
- Outcome indicators of the type 'Culturally valued species or populations'

Description

Animals use sound for communication, echolocation, sexual display, and defense of their territory. During (bio-) acoustic monitoring, those sounds are recorded to estimate fauna distribution, physiological state, abundance, and behaviour. Depending on the species, their sounds may be in the audible range sound spectrum (e.g. birds, monkeys, frogs), ultrasound (e.g. bats) or infrasound (e.g. elephant rumbles).

Besides collecting data on a **vocal species of interest** and their habitat use, acoustic monitoring is also used for **monitoring illegal activity** such as illegal hunting (gunshots) and illegal logging (chainsaw noise).

WWF-UK has created a manual about acoustic monitoring and data processing. Note that this manual was published in 2017, and especially the development of artificial intelligence and software for data processing has advanced since.

Suitable contexts

Forests with fauna biodiversity that produce sound, without a very noisy environment (e.g. if you're looking for birds but monkeys keep on calling so you don't hear the birds).

Advantages

- Non-invasive; little to no disturbance to wildlife
- Getting audio of wildlife that can be used for engagement with potential sponsors and/or other stakeholders.

Disadvantages

- Need expert involvement for recognition of vocalizations of fauna
- Data processing and analysis is very time-consuming (and costly) if not (partly) automated.

Access

Access the WWF manual about acoustic monitoring: https://www.wwf.org.uk/project/conservationtechnology/acoustic-monitoring

ES1-I TESSA POLLINATION METHOD 5: FLOWER VISITATION RATE AS A PROXY

Impacts

- ES1.9: Conservation of functional biodiversity
- ES1.10: Restoration of functional biodiversity

Outcome indicators

- Pollination rates

Description

Common animal pollinators that inhabit forests include bees, butterflies, moths, beetles, bats, flies, and wasps. Most are active at daytime, some at night (moths, bats). Summary of steps to record flower visitation rate:

1. Identify animal pollinated plants within and within 1km of the MU (see TESSA p.388 for guidance how to distinguish wind from animal pollinated flowers), and map their location
2. For each animal pollinated plant, delineate 3 zones from the MU: close (e.g. <150m), middle (e.g. 150-500m), far (e.g. 500m-1km)
3. During flowering season, lay-out at least 3 sample plots in each of the 3 zones, making sure each plot includes a determined number of flowers that can be observed at the same time
4. In each sample plot, count the number of flower visits by a pollinator during 15 minutes and record it on a field data recording sheet (see p.386 for a pollinators visitation frequency datasheet template). You may also specify the type of pollinator, see the pollinator identification guide (p.390).
5. For every plot, record the total number of flowers observed. Divide the total visits by the total number of flowers observed, so you have an average flower visitation rate per 15 minutes. Divide by 15 to get the average flower visitation rate per minute.
6. For each of the 3 zones, calculate the mean flower visitation frequency and the mean distance from the MU.
7. You can stop at step 7, there is no need to calculate the economic value of the pollination services (unless you want to).

Make sure the weather conditions are favourable for pollinator foraging (temperature 13° C or higher, little to no wind, dry), see the field observation protocol (p.384). Finally, ensure when comparing past and present value, that weather conditions are similar.

Suitable contexts

Forests where there is pollination by animals of cultivated and harvested wild goods within the MU or within 1km from the MU.

Advantages

- Relatively easy.

Disadvantages

- Weather conditions play a large role; they need to be favourable for pollinators, both for present value and baseline value measurements.

Access

Access TESSA's pollination method 5 (p.369): https://www.birdlife.org/tessa-tools/

ES1-J INDEX OF BIODIVERSITY POTENTIAL

Impacts

- ES1.1: Enhancement of natural forest cover
- ES1.5: Maintenance of natural forest structure
- ES1.6: Enhancement of natural forest structure
- ES1.9: Conservation of functional biodiversity
- ES1.10: Restoration of functional biodiversity
- ES3.3: Maintenance of water volume regulation
- ES3.4: Enhancement of water volume regulation

Outcome indicators

- Forest density
- Forest vertical and/or horizontal structure
- Amount of standing and fallen deadwood and/or other important natural microhabitats

Description

The index of potential biodiversity is based on a **rapid assessment of ten features** (or factors) that influence the capacity of forest stands to support animal, plant and fungal species: Diversity of native tree species (factor A), Vertical structure of the vegetation (B), Density of large standing and lying deadwoods (C and D), Density of very large living trees (E), Density of living trees bearing microhabitats (F), Presence of flower-rich open areas (G), Forest continuity over time (H), Diversity of aquatic habitats (I), and Diversity of rocky habitats (J).

Measured at stand or stand type level, for each factor a score between 0 and 5 is assigned by comparing field observations with a scale of thresholds, reflecting conditions that are unfavourable (score = 0) to favourable (score = 5) for biodiversity.

Suitable contexts

Developed for European forests larger than 0.5ha. National/ regional adaptations and field forms available for:

- France (French)
- Italy (Italian)
- Spain (Spanish)
- Catalonia (Catalonian)
- Temperate Europe and Mediterranean basin (English, French).

Advantages

- Detailed field survey protocol for a variety of forest contexts.
- Can be used by professional forester and, following training, by non-professional as well.

Disadvantages

- Geographically limited.

Access

Find the IBP documentation available for download via: https://www.cnpf.fr/ibp-index-biodiversity-potential

ES1-K FOREST INTEGRITY ASSESSMENT TOOL

Impacts

- ES1.1: Enhancement of natural forest cover
- ES1.5: Maintenance of natural forest structure
- ES1.6: Enhancement of natural forest structure
- ES1.7: Maintenance of native species diversity
- ES1.8: Enhancement of native species diversity
- ES1.9: Maintenance of functional biodiversity
- ES1.10: Enhancement of functional biodiversity
- ES1.11: Maintenance of rare, endemic, threatened or endangered habitats or ecosystems
- ES1.12: Enhancement of rare, endemic, threatened or endangered habitats or ecosystems
- ES5.3: Maintenance of populations of species of interest for nature-based tourism
- ES5.4: Enhancement of populations of species of interest for nature-based tourism

Outcome indicators

- Diversity of forest structure
- Forest ecosystem structure
- Forest vertical and/or horizontal structure
- Amount of standing and fallen deadwood and/or other important natural microhabitats
- Suitability of habitat (for functional biodiversity/ selected species)
- Evidence of roosts and shelters in use by functional species
- Disturbance level

Description

The Forest Integrity Assessment (FIA) tool is a simple and user-friendly checklist approach developed by the HCV Resource Network, supported by WWF. Assessments focus on **habitats as indirect proxies for biodiversity** rather than on species, using natural forest types little affected by large-scale human activities as reference.

Regionally adapted field forms with sets of yes/no scoring questions guide and standardize the assessments, adding up to a numerical value of forest integrity. Questions are formulated to address forest elements and features as they occur on a relatively limited assessment area, typically plots of 0.25-1 ha (the actual size depends on the visibility in the particular forest). The proposed sampling strategy is based on stratification of the forest and subsequent selection of plots along transect lines.

Field forms divide scoring questions into four sections:

1. structure and composition (tree size, regeneration, trees important for biodiversity, coarse woody debris, fire, other elements);
2. impacts and threats (commercial trees, visibility, invasive species, illegal hunting/poaching, logging, human forest clearing, accessibility);
3. focal habitats;
4. focal species (endemic to the area; rare, threatened, or endangered; or collected for traditional or medicinal purposes).

The FIA manual also has a section on evaluating the results and calculating the scores, including showing trends over time. Data analysis can be done using Microsoft Excel.

Reasonably consistent results are achieved after basic training. Smallholders may learn how to assess and monitor their woodlots during a day of field training. A couple of days may be needed to train people to consistently sample and monitor larger forests.

Suitable contexts

The approach is applicable both to larger forests and to remnant forest patches interspersed in agricultural and forestry landscapes.

The FIA manual is available in English, French, Spanish, Portuguese, and Indonesian.

Regional or national adaptation aims to further modify a generic template or adapt an already existing version for use in another region or country with similar forest types.

Regional/national adaptations (field forms) are available for:

- Chile (Valdivia moist temperate forest)
- Greater Mekong region (evergreen forest, dry and deciduous forest)
- Panama (tropical rainforest in Darién region)
- Scandinavia (generic)

Advantages

- Can be used by non-experts after basic training.
- Both data collection and data analysis are relatively easy.

Disadvantages

- No precise population data, due to the presence/absence character of the methodology.

Access

Manual: https://www.hcvnetwork.org/library/forest-integrity-assessment-tool-fiat-manual

Field forms:

- Chile: Valdivia moist temperate forest (Spanish)
- Greater Mekong region: dry and deciduous forest (English, Indonesian)
- Greater Mekong region: evergreen forest (English, Indonesian)
- Panama: tropical rainforest in Darién region (English, Spanish)
- Scandinavia: generic (English, Swedish)

ES1-L FOREST INTACTNESS INDEX

Impacts

- ES1.7: Maintenance of native species diversity
- ES1.8: Enhancement of native species diversity
- ES1.11: Maintenance of rare, endemic, threatened or endangered habitats or ecosystems
- ES1.12: Enhancement of rare, endemic, threatened or endangered habitats or ecosystems
- ES3.3: Maintenance of water volume regulation
- ES3.4: Enhancement of water volume regulation
- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition

Outcome indicators

- Indices of species assemblage or composition (trees)
- Suitability of habitat
- Proportion of forest intactness areas
- Proportion/percentage of forest/habitats that is degraded over total forest area
- Percentage of forest cover (in the relevant watershed) in undisturbed condition

Description

The Forest Intactness Index (FII) is a simple quantitative index, indicating above ground carbon stock and the degree of forest intactness/ degradation of a given stand in terms of the similarity/dissimilarity with the most pristine forest in a given management unit. The methodology is based on the ecological principle that logging directly influences tree-species (genus) assemblages. Combined with remote-sensing analysis, FII can be extrapolated to the entire landscape of the management unit as a map of forest 'intactness'.

The FII methodology is termed BOLEH (Biodiversity Observation for Land and Ecosystem Health), developed by the Kyoto University Forest Ecology Lab. The method consists of **fieldwork, analysis, and spatial extrapolation**. A total of 50 circular plots (20-m radius each) are placed over an entire management unit with a stratified random design. Tree genera (not necessarily species) are identified and the diameters at breast height (DBH) are measured for all trees DBH > 10 cm. A numerical analysis is applied to the obtained data to derive the FII of each plot. Subsequently, FIIs outside the 50 plots are estimated using Landsat satellite imagery with a special extrapolation technique. Thus, it is possible to depict the FIIs of the entire area of a management unit, where forest intactness is expressed as nMDS (non-metric multidimensional scaling) axis-1 scores.

Experiences with this methodology have shown that a team of five workers can generally finish all the fieldwork within one month without expert assistance. With repeated applications of this method to the same management unit at an extended time interval (e.g. five years), one can evaluate the spatial-temporal changes of forest intactness/ degradation due to forest management.

One of the advantages of this method is that responsible foresters can quantitatively verify biodiversity enhancement as an increment of mean FII values in their management units. Furthermore, carbon stock can be derived from the same dataset with an additional analysis. This method can be used to assess the bundle of biodiversity and carbon-stock services.

The FII manual has sections for adequate field sampling, numerical analyses, and remote-sensing analyses.

Suitable contexts

The FII methodology (BOLEH) has been developed primarily for the lowland dipterocarp production forests of Borneo, South-East Asia but not for plantation forests. The lead author indicates that it can be applicable to any natural production forests in any climate zones, where logging is the major driver of the conversion of tree-species composition.

Advantages

- Genus data can give the same accuracy as species data, thereby avoiding the need for taxonomic expertise.
- Statistical comparisons among and within management units are possible and can demonstrate biodiversity enhancement.

Disadvantages

- Extrapolation requires remote-sensing techniques and expertise.
- It is most suitable for flat or undulating terrain, but not for mountains.
- The FII methodology involves fieldwork which requires a time investment.

Access

2017 manual: http://www.rfecol.kais.kyoto-u.ac.jp/index%20(ratah%20index).html if problems arise contact FSC International via ecosystemservices@fsc.org

2024 updated manual: not yet online available, contact FSC International via ecosystemservices@fsc.org

Background scientific paper: Kitayama K., Fujiki S., Aoyagi R., Imai N., Sugau J., Titin J., Nilus R., Lagan P., Sawada Y., Ong R., Kugan F., Mannan S. (2018) Biodiversity observation for land and ecosystem health (BOLEH): A robust method to evaluate the management impacts on the bundle of carbon and biodiversity ecosystem services in tropical production forests. Sustainability, sustainability-343711; doi:10.3390/su10114224.

METHODOLOGIES CARBON SEQUESTRATION & STORAGE (ES2)

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES2.1	**Maintenance of forest carbon stocks through forest protection or conservation**	ES2-A FSC Carbon Monitoring Tool ✓ ES2-B Participatory carbon monitoring ✓ ES2-C Verra's Verified Carbon Standard (VCS) methodologies ES2-F Optical remote sensing for carbon
Forest carbon stocks	Carbon stocks in the ES project area	
ES2.2	**Maintenance of forest carbon stocks through responsible forest management**	ES2-A FSC Carbon Monitoring Tool ✓ ES2-B B Participatory carbon monitoring ✓ ES2-F Optical remote sensing for carbon
Forest carbon stocks	Carbon stocks across the entire management unit	
ES2.3	**Enhancement of forest carbon stocks through afforestation, reforestation and restoration**	ES2-A FSC Carbon Monitoring Tool ✓ ES2-B Participatory carbon monitoring ✓ ES2-C Verra's Verified Carbon Standard (VCS) methodologies ES2-D Gold Standard's Afforestation and Reforestation methodology ES2-E Plan Vivo Carbon Standard ✓ methodologies ES2-F Optical remote sensing for carbon
Forest carbon stocks	Carbon stocks in the ES project area	
ES2.4	**Enhancement of forest carbon removals through responsible forest management**	ES2-C Verra's Verified Carbon Standard (VCS) methodologies ES2-D Gold Standard's Afforestation and Reforestation methodology ES2-E Plan Vivo Carbon Standard methodologies ✓ ES2-F Optical remote sensing for carbon
Forest carbon stocks	Carbon stocks in the ES project area	
GHG emissions	GHG emissions related to forestry operations	
ES2.5	**Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions**	ES2-C Verra's Verified Carbon Standard (VCS) methodologies ES2-D Gold Standard's Afforestation and Reforestation methodology ES2-E Plan Vivo Carbon Standard methodologies ✓ ES2-F Optical remote sensing for carbon
Forest carbon stocks	Carbon stocks in the ES project area	
GHG emissions	GHG emissions related to forestry operations in the ES project area	

ES2-A FSC CARBON MONITORING TOOL

Impacts

- ES2.1: Maintenance of forest carbon stocks through forest protection or conservation
- ES2.2: Maintenance of forest carbon stocks through responsible forest management
- ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration

Outcome indicators

- Carbon stocks in the ES project area
- Forest carbon stocks estimated across the entire management unit
- GHG emissions related to forestry operations (in the ES project area)

Description

The FSC Carbon Monitoring Tool was developed to assess, monitor, and (if desired) simulate carbon stocks, carbon stock changes, and greenhouse gas emissions from forest operations. It consists of a Microsoft Excel workbook and a manual to assist in its use.

The Excel workbook has the following components:

1. General information
2. Monitoring tool
3. Simulation tool

The standard carbon pool included in the assessment is carbon density from trees (aboveground biomass and belowground biomass). It is up to the user to decide whether or not to include the following items in the assessment:

- carbon from shrubs (Intergovernmental Panel on Climate Change [IPCC] default value)
- carbon from deadwood (IPCC default value)
- carbon from litter (IPCC default value)
- carbon stored in wood products
- greenhouse gas emissions from fuel and fertilizer
- simulation.

The tool allows you to use your own data, or default values provided by the IPCC. For the purpose of demonstrating the positive impact of forest management on carbon stocks, we recommend you include three additional carbon pools (shrubs, deadwood, litter). It is not necessary to include carbon stored in harvested wood products, greenhouse gas emissions from fuel and fertilizers, or a simulation into the future.

The results show the carbon density per hectare for every carbon pool, the carbon stored in harvested wood products, total forest carbon stock, emissions per item, and the total carbon balance. In a separate table (or part) the carbon stock change is shown between two selected years.

Suitable contexts

Designed to run on Microsoft Excel 2010.

Suitable for tropical, temperate, and boreal forest ecosystems.

Works best if forest inventory data is available.

Advantages

- Developed specifically for FSC, so fits well.
- Easy – can be used by a non-expert.
- Default IPCC values can be used where no data is available.

Disadvantages

- In a biodiversity-rich forest, it will require a lot of data entry which can become time-consuming.
- Soil organic matter is not included in the calculation.
- Reduced reliability with less-detailed data (i.e. more use of preset default values).

Access

Access the Excel tool and manual via: https://fsc.org/en/ecosystem-services-for-forest-managers

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ES2-B PARTICIPATORY CARBON MONITORING

Impacts

- ES2.1: Maintenance of forest carbon stocks through forest protection or conservation
- ES2.2: Maintenance of forest carbon stocks through responsible forest management
- ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration

Outcome indicators

- Carbon stocks in the ES project area
- Forest carbon stocks estimated across the entire management unit

Description

This guidance highlights two methodologies for participatory carbon monitoring: the one developed by SNV for Vietnam and one developed by the Asian Network for Sustainable Agriculture and Bioresources for Nepal.

The SNV Participatory Carbon Monitoring method is a series consisting of three manuals: a manual for local people, a manual for local technical staff, and a field reference manual.

The **Manual for Local People** (Bao Huy et al., 2013a) includes measuring changes in forest area and forest status; and measuring aboveground carbon pools and other attributes in sample plots. Trees with a diameter at breast height (DBH) of or above 6 cm are measured, regeneration trees are counted when they measure a DBH below 6 cm and a height of at least 1.3 m, and bamboo (age and average DBH) can be included in the data collection. This manual further explains what equipment is needed in the monitoring exercise, how to use a GPS, how to establish nested circular permanent sample plots, and how to measure DBH. Finally, it includes various data sheets.

The **Manual for Local Technical Staff** (Bao Huy et al., 2013b) is the most comprehensive of the three. Besides the information given in the Manual for Local People, it includes data-collection preparatory activities such as mapping stratification and forest status, determining the number of sample plots, randomly distributing the sample plots per strata on a map, and entering them into a GPS. Further, it includes activities that happen after field data collection, including quality control, data synthesis, and analysis.

The **Manual for Field Reference** (Bao Huy et al., 2013c) is designed to be used as a quick reference guide while monitoring changes in area and forest status, determining the position of a sample plot, setting up a permanent sample plot, and measuring forest biomass and carbon in a sample plot.

The Asian Network for Sustainable Agriculture and Bioresources and a number of other organizations have developed guidelines for the Nepalese context to measure carbon stocks in community-managed forests (Subedi et al., 2010). This method includes multiple carbon pools (aboveground biomass, belowground biomass, deadwood, litter, and soil organic matter) so the guidelines are lengthier and more complex than the SNV manuals.

Suitable contexts

The SNV manuals are written for Vietnam, but the authors state the target groups for this manual to be agencies, organizations, and individuals responsible for forest management who are also facilitators of REDD+ programme implementation, implying that it can be applied more widely.

Advantages

- Simple, user-friendly manuals.

Disadvantages

- Only aboveground biomass is included in the SNV manual.

Access

Bao Huy et al. (2013a) available at https://www.researchgate.net/publication/323144419_Participatory_Carbon_Monitoring_Manual_for_Local_People

Bao Huy et al. (2013b) available at https://www.researchgate.net/publication/317380319_Participatory_Carbon_Monitoring_Manual_for_Local_Technical_Staff

Bao Huy et al. (2013c) available at https://www.researchgate.net/publication/332187277_Participatory_Carbon_Monitoring_Manual_for_Field_Reference

Subedi et al. (2010) available at https://ansab.org.np/publication/guidelines-for-measuring-carbon-stocks-in-community-managed-forests/

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ES2-C VERRA'S VERIFIED CARBON STANDARD (VCS) METHODOLOGIES

Impacts

- ES2.1: Maintenance of forest carbon stocks through forest protection or conservation
- ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration
- ES2.4: Enhancement of forest carbon removals through responsible forest management
- ES2.5: Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions

Description

There are various methodologies under Verra's Verified Carbon Standard program. The table below lists the ones applicable to forests and specifically to demonstrate the carbon impacts included in the FSC ES Procedure.

You skip the aspect of the methodology that is about the conversion from tons of carbon to verified carbon units.

Methodology	ES impact	Access
VM0003 Methodology for Improved Forest Management through Extension of Rotation Age	ES2.4: Enhancement of forest carbon removals through responsible forest management	https://verra.org/methodologies/vm0003-methodology-for-improved-forest-management-through-extension-of-rotation-age-v1-3/
VM0005 for Conversion of Low-Productive Forest to High-Productive Forest	ES2.4: Enhancement of forest carbon removals through responsible forest management / ES2.5: Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions	https://verra.org/methodologies/vm0005-methodology-for-conversion-of-low-productive-forest-to-high-productive-forest-v1-2/
VM0010 Methodology for Improved Forest Management: Conversion from Logged to Protected Forest	ES2.1: Maintenance of forest carbon stocks through forest protection or conservation	https://verra.org/methodologies/vm0010-methodology-for-improved-forest-management-conversion-from-logged-to-protected-forest-v1-4/
VM0012 Improved Forest Management in Temperate and Boreal Forests (LtPF)	ES2.1: Maintenance of forest carbon stocks through forest protection or conservation	https://verra.org/methodologies/vm0012-improved-forest-management-in-temperate-and-boreal-forests-ltpf-v1-2/
VM0035 Methodology for Improved Forest Management through Reduced Impact Logging (RIL-C)	ES2.5: Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions	https://verra.org/methodologies/vm0035-methodology-for-improved-forest-management-through-reduced-impact-logging-v1-0/ Module East and North Kalimantan, Indonesia, in standing Bornean dipterocarp forest: https://verra.org/methodologies/vmd0047-performance-method-for-reduced-impact-logging-in-east-and-north-kalimantan-v1-0/ Module Yucatan, Mexico: https://verra.org/wp-content/uploads/Performance-Method-for-Reduced-Impact-Logging-in-Tropical-Moist-Forest-of-the-Yucatan-Peninsula-27Jul21.pdf

Methodology	ES impact	Access
VM0045 Methodology for Improved Forest Management Using Dynamic Matched Baselines from National Forest Inventories	ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration/ ES2.4: Enhancement of forest carbon removals through responsible forest management/ ES2.5: Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions	https://verra.org/methodologies/methodology-for-improved-forest-management/
VM0047 Afforestation, reforestation and revegetation (ARR)	ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration	https://verra.org/methodologies/vm0047-afforestation-reforestation-and-revegetation-v1-0/

Suitable contexts

See individual methodology description.

Advantages

- Full methodology.

Disadvantages

- Requires professional expertise to use
- References to other standards and tools which need to be considered
- Certain aspects of the methodology are not applicable (e.g. conversion to verified carbon units).

Access

You will find the full list of active Verified Carbon Standard (VCS) methodologies, modules and tools here: https://verra.org/methodologies-main/#vcs-program-methodologies.

See the table above for the methodology-specific links.

ES2-D GOLD STANDARD'S AFFORESTATION AND REFORESTATION METHODOLOGY

Impacts

ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration

Outcome indicators

- Carbon stocks in the ES project area
- Forest carbon stocks estimated across the entire management unit

Description

The Gold Standard Methodology for Afforestation/ Reforestation (A/R) GHG Emission Reduction & Sequestration (2024) can be used to quantify carbon sequestration from afforestation and reforestation projects with the management objectives of conservation forest, selective logging and/or rotation forestry.

Since it allows for afforestation/reforestation projects with the management objective of (future) harvesting it includes the calculation of a long-term average baseline.

Suitable contexts

Projects that are centred around tree planting, sowing and/or assisted natural regeneration of forests.

Advantages

- Complete methodology, limited need for other tools or modules.

Disadvantages

- Requires professional expertise to use.

Access

Access the methodology here: https://globalgoals.goldstandard.org/403-luf-ar-methodology-ghgs-emission-reduction-and-sequestration-methodology/

ES2-E PLAN VIVO CARBON STANDARD METHODOLOGIES

Impacts

- ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration
- ES2.4: Enhancement of forest carbon removals through responsible forest management
- ES2.5: Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions

Outcome indicators

- Carbon stocks in the ES project area
- Forest carbon stocks estimated across the entire management unit

Description

Plan Vivo has a list of approved methodologies, modules and tools. Their Agriculture and Forestry Carbon Benefit Assessment Methodology (PM001, V1.0) provides carbon accounting procedures that can be used in smallholder agriculture and community forestry projects. The methodology refers to various modules and tools to execute steps in the methodology. It includes calculating leakage and uncertainty adjustment (to ensure conservativeness).

Note that step 10.2 (Plan Vivo Certificates) can be skipped when used in combination with the FSC ES Procedure.

Suitable contexts

Specifically for smallholders and community forests.

Advantages

- Wide applicability when it comes to activity and biomes (tropical, temperate, boreal).

Disadvantages

- Only applicable for smallholders and community forests
- Requires professional expertise to use
- References to other standards and tools which need to be considered.

Access

Access the Plan Vivo Agriculture and Forestry Carbon Benefit Assessment Methodology here: https://www.planvivo.org/pm001

Access the list of approved methodologies for use under the Plan Vivo Carbon Standard here: https://www.planvivo.org/pv-climate-methodologies.

ES2-F OPTICAL REMOTE SENSING FOR CARBON

Impacts

- ES2.1: Maintenance of forest carbon stocks through forest protection or conservation
- ES2.2: Maintenance of forest carbon stocks through responsible forest management
- ES2.3: Enhancement of forest carbon stocks through afforestation, reforestation and restoration
- ES2.4: Enhancement of forest carbon removals through responsible forest management
- ES2.5: Enhancement of forest climate benefits through increased carbon stock or reduction of GHG emissions

Outcome indicators

- Carbon stocks in the ES project area
- Forest carbon stocks estimated across the entire management unit

Description

With the surge and advances in remote sensing technology, coupled with the availability of free satellite data over time, the combination of field inventorying data and remote sensing-based approaches has become a popular choice for forest carbon estimation.

Key variables derived from optical remote sensing data for forest carbon estimation include spectral reflectance, vegetation indices, spatial texture, and forest canopy properties. Optical spectral reflectance has been widely used for estimating forest carbon due to its high sensitivity to vegetation canopy properties. Vegetation indices (normalised difference vegetation index, enhanced vegetation index, etc.) are designed to reduce the influence of external factors (e.g. soil background, atmospheric conditions), ensuring more accurate vegetation assessments.

When selecting satellite images for analysis, make sure the resolution is at least 30m, such as those generated by Sentinel-2 and LandSat (see ES1-A).

Remote sensing must be combined with field inventorying because forest carbon cannot be directly measured from space or air; therefore, estimation must be conducted by linking information derived from remotely sensed data to ground measurements selected for the respective purpose. For field sampling to complete the remote sensing data, the manual by Winrock may be useful.

Suitable contexts

All forests worldwide.

Advantages

- Cost-effective, especially for larger forest areas
- Ability to detect trends over time.

Disadvantages

- Susceptible to cloud cover obstruction, which is particularly challenging in tropical forests
- Poor penetration capability, primarily capturing horizontal structure while poorly representing vertical structure
- Underestimation in high-density forests and overestimation in low-density forests.

Access

Manual by Winrock on field sampling: https://winrock.org/wp-content/uploads/2016/03/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf

METHODOLOGIES WATER SERVICES (ES3)

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES3.1	**Maintenance of water quality**	
ES3.2	**Enhancement of water quality**	
Water quality	Water turbidity	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓ ES3-B Remote sensing for water quality
	Water temperature	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓ ES3-B Remote sensing for water quality
	Dissolved oxygen	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓
	Water pH	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓
	Bio-indicators of stream health (macro-invertebrates, fish)	ES3-D Stream Visual Assessment Protocol (SVAP) ✓
	Pathogens (bacteria, e.g. E. coli; viruses) in water	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓
	Nutrients (phosphorous, nitrogen) in water	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓
	Total suspended solids	ES3-B Remote sensing for water quality
	Level of sedimentation/ water sediment load (grams per litre)	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓ ES3-B Remote sensing for water quality
	Organic pollution: biochemical oxygen demand (BOD) and/or chemical oxygen demand (COD)	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓
	Level of metal contamination (e.g. mercury, arsenic, cadmium, lead)	ES3-A TESSA Water method 5A: measuring the contribution of a wetland site to water quality ✓

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES3.3	**Maintenance of water volume regulation**	
ES3.4	**Enhancement of water volume regulation**	
Native forest cover and density	Natural forest cover for the management unit overlapping with the relevant watershed	ES1-A Satellite imagery and GIS
	Native forest density	ES1-J Index for Biodiversity Potential
	Proportion of forest that is degraded over total forest area	ES1-A Satellite imagery and GIS
Watershed condition	Percentage of natural wetlands remaining	ES1-A Satellite imagery and GIS
	Percentage of forest cover in the relevant watershed in undisturbed condition	ES1-A Satellite imagery and GIS
	Percentage of forest that is degraded over total forest area	ES1-A Satellite imagery and GIS
	Percentage of waterbody shoreline with forest cover	ES3-D Stream Visual Assessment Protocol (SVAP)
Volume of water regulated	Volume of infiltration and groundwater re-charge	ES3-C Soil & Water Assessment Protocol (SWAT)
	Volume of runoff avoided or reduced	ES3-C Soil & Water Assessment Protocol (SWAT)
	Peak discharge reduction	
	Water flow	
	Level of flood protection	

ES3-A TESSA WATER METHOD 5A: MEASURING THE CONTRIBUTION OF A WETLAND SITE TO WATER QUALITY

Impacts

- ES3.1: Maintenance of water quality
- ES3.2: Enhancement of water quality

Outcome indicators

- Water turbidity
- Water temperature
- Dissolved oxygen
- Water pH
- Pathogens (bacteria [e.g. E. coli], viruses) in water
- Nutrients (phosphorous, nitrogen) in water
- Total suspended solids
- Level of sedimentation/water sediment load (grams per litre)
- Organic pollution: biochemical oxygen demand (BOD) and/or chemical oxygen demand (COD)
- Level of metal contamination (e.g. mercury, arsenic, cadmium, lead)

Description

This method helps you select appropriate water quality parameters to measure. It provides links to water test kits that can be ordered online. It can also aid in the selection of sampling sites and describes how to collect water samples. Parameters can subsequently be analysed in the field and/or sent to a laboratory for further analysis.

Note that TESSA refers to a wetland site, but the method can also be used to measure water quality of water bodies within the forest. This method is described on pp. 247-250 of the TESSA Water Method 5. Assessing water quality services.

Suitable contexts

All types of forests with water bodies that can be safely accessed to collect water samples.

Advantages

- User-friendly wording.

Disadvantages

- Potential need for analysis in laboratory.

Access

Peh et al. (2017): available for download via https://www.birdlife.org/tessa-tools/. Fill out the download request form on the web page. Go to page 247.

ES3-B REMOTE SENSING FOR WATER QUALITY

Impacts

- ES3.1: Maintenance of water quality
- ES3.2: Enhancement of water quality

Outcome indicators

- Water turbidity
- Water temperature
- Total suspended solids
- Level of sedimentation/ water sediment load

Description

There are various satellite sensors in orbit that, once images have been processed through the appropriate algorithm or index (e.g. Normalized Difference Chlorophyll Index (NDCI), normalized difference turbidity index (NDTI) or Total Suspended Solids (TSS) models), have the ability to measure water parameters.

Satellite imagery data source	Characteristics	Measures	Access data
Landsat series (NASA/USGS) Launched Landsat-7: April 1999 Landsat-8: Feb. 2013 Landsat-9: Sept. 2021	Landsat-7's Enhanced Thematic Mapper Plus has 8 spectral bands, Landsat-8 and -9's Operational Land Imager has 9 and the Thermal Infrared Sensor has 2 spectral bands, All but 1 band at 30m resolution (some of which resampled from 60m or 100m), 1 band at 15m 16-day repeat coverage, 185 km swath width	• water surface temperature • chlorophyll concentration • turbidity	Google Earth Engine NASA's Earth data QGIS Semi-Automatic classification plugin
Sentinel-2 (European Space Agency) Launched 2A: June 2015 2B: March 2017 2C: Sept. 2024 (to replace 2A)	13 spectral bands, 10m (20m and 60m) resolution, 5-day revisit time, 290 km swath width	• chlorophyll-a (high levels indicate algal growth or eutrophication, also used to measure harmful algal blooms) • turbidity • suspended sediments	Copernicus data browser Google Earth Engine NASA's Earth data QGIS Semi-Automatic classification plugin
PlanetScope (Planet Labs) 88 Dove satellites launched Feb. 2017, refreshed Aug. 2021	4 (prior to refresh) and 8 spectral bands (6 of which are interoperable with Sentinel-2), 3m resolution (very-high resolution), 1-day revisit time, 25 km swath width	Detecting smaller features in inland water bodies, such as pollutant plumes or vegetation growth	European Space Agency, limited access: • Upon submission and successful evaluation of a project proposal. • Only for EU member states + UK and their overseas territories plus Canada.

See ES1-A for the use of satellite imagery to measure outcome indicators of the type 'Native forest cover and density' and 'Watershed condition' (Impacts ES3.3 and ES3.4).

To properly interpret remote sensing data, field sampling data is necessary to interpret and validate satellite imagery data.

Suitable contexts

Forests containing water bodies that can be observed through satellite imagery.

Advantages

- Accessibility to remote areas
- Easy to track changes over time (observe a trend)
- Cost-effective.

Disadvantages

- Cloud cover.

Access

See table above for access to data sets.

Background sources:

Research Trends in the Use of Remote Sensing for Inland Water Quality Science: Moving Towards Multidisciplinary Applications

Remote Sensing Handbook, Volume V Water, Hydrology, Floods, Snow and Ice, Wetlands, and Water Productivity

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ES3-C SOIL AND WATER ASSESSMENT TOOL (SWAT)

Impacts

- ES3.3: Maintenance of water volume regulation
- ES3.4: Enhancement of water volume regulation
- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition

Outcome indicators

- Volume of infiltration and groundwater recharge
- Volume of runoff avoided or reduced
- Water runoff

Description

The Soil and Water Assessment Tool (SWAT)[2] is a model that allows **a number of physical processes to be simulated in a watershed**. There is an ArcSWAT and QSWAT environment to run the models. Section 2 of the SWAT theoretical documentation, starting at page 97 (120 in Adobe), is dedicated to hydrology. It includes two methods for estimating surface water runoff: the SCS curve number method and the Green & Ampt infiltration method. It also includes formulas for **calculating ground water recharge**, starting at page 169 (192 in Adobe).

The SCS curve number method is included in Appendix 1A of the volumetric water benefit accounting method as the recommended calculation method to **quantify avoided runoff and reduced runoff** resulting from land conservation and land restoration. It includes an illustrative example of reforestation and protection of riparian zones in Ghana (page 29). In SWAT Table 1:2-1, you can find the SCS curve number for woods. The hydrologic condition (poor, fair, good) classifications can be found in footnote 3 and the hydrologic soil group (A, B, C, D) classifications on the following page.

Suitable contexts

Developed in the US with updates making it internationally applicable. More tailored to agricultural land use, but forest (woods) is included as a land use category.

Advantages

- Mature tool.

Disadvantages

- Need to navigate a lengthy document
- Experience required with models.

Access

Soil and Water Assessment Tool Theoretical Documentation, Version 2009: https://swat.tamu.edu/media/99192/swat2009-theory.pdf, p.97 & p.169 (120 & 169 in Adobe)

Volumetric Water Benefits Accounting, Appendix A1 Curve Number Method: https://www.wri.org/research/volumetric-water-benefit-accounting-vwba-method-implementing-and-valuing-water-stewardship

Soil and Water Assessment Tool model: https://swat.tamu.edu/

2 Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams. 2011. "Soil and Water Assessment Tool Theoretical Documentation Version 2009." Texas Water Resources Institute. http://hdl.handle.net /1969.1/128050.

ES3-D STREAM VISUAL ASSESSMENT PROTOCOL (SVAP)

Impacts

- ES3.1: Maintenance of water quality
- ES3.2: Enhancement of water quality
- ES3.3: Maintenance of water volume regulation
- ES3.4: Enhancement of water volume regulation

Outcome indicators

- Bio-indicators of stream health (macro-invertebrates, fish)
- Percentage of waterbody shoreline with forest cover

Description

Using the Stream Visual Assessment Protocol (SVAP), version 2, different aspects of streams can be assessed and scored. Items included in the assessment are:

- channel condition and hydrologic alteration (flooding, withdrawals)
- extent and quality of riparian zone and bank stability (erosion signs)
- canopy cover (for cold- and warm-water streams)
- water appearance (colour, turbidity, odour) and nutrient enrichment
- manure presence
- barriers to fish movement, in-stream fish cover, presence of pools and riffles
- invertebrate habitat presence and macro-invertebrates observed (crustaceans (e.g. crayfish), molluscs (e.g. snails, mussel), spiders, and aquat¬ic insects)
- salinity.

Scoring is done on a scale of 1–10 and aided by descriptions of four states (equivalent to scores 10, 7, 3, and 1). The overall score is the total divided by the number of items included in the SVAP, but it is also possible to monitor scores for each of the items over time.

It is possible to focus on certain elements of the SVAP, depending on what outcome indicators are to be measured. It is particularly useful for monitoring 'bio-indicators of stream health' and to undertake ground-truthing of remote sensing data on the 'percentage of waterbody shoreline with forest cover'. Canopy cover of streams is related to the water temperature and water oxygen levels.

Suitable contexts

Developed for the United States of America nationwide, but authors encourage state and regional adaptation. Can possibly be useful for other countries, for which specific adaptation may be necessary, e.g. for the assessment of macro-invertebrates.

Advantages

- Simple, can be used by non-experts
- Cheap.

Disadvantages

- Limited suitability in terms of geographical context.

Access

US Dept. of Agriculture, National Resources Conservation Service (2009) available at https://www.wcc.nrcs.usda.gov/ftpref/wntsc/strmRest/SVAPver2.pdf

METHODOLOGIES SOIL CONSERVATION (ES4)

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES4.1	**Maintenance of soil condition**	
ES4.2	**Enhancement of soil condition**	
Soil properties and quality	Soil depth	ES4-F Visual Soil Assessment ✓
	Soil (aggregate) stability	
	Thickness of layer of soil organic matter	
	Organic matter content (%)	
	Soil pH	ES4-B Soil testing kits ✓
	Nutrient (e.g. nitrogen, phosphorous, potassium) content of soil	ES4-B Soil testing kits ✓
	Salt concentration in the soil	ES4-B Soil testing kits ✓
	Soil humidity/ moisture	ES4-C Soil sensors and tools
	Soil macro-fauna abundance	ES4-F Visual Soil Assessment ✓
Soil condition	Extent of land with forest canopy or ground vegetation	ES4-A Line-point transect forest cover and erosion assessment method ✓
	Percentage of forest cover in undisturbed condition	ES1-A Satellite imagery and GIS
	Proportion of forest that is degraded over total forest area	ES4-D UNCCD's computation of Land Degradation Neutrality
	Percentage of damaged soil	
	Degree of soil compaction in operated areas (roads and harvest areas)	ES4-E Soil penetrometer
	Water infiltration rate	ES4-C Soil sensors and tools
	Water runoff	ES3-C Soil and Water Assessment Tool
	Incidence of landslides	ES5-E Key informant interview ✓
	Productivity (forest and agricultural) per unit area	ES4-D UNCCD's computation of Land Degradation Neutrality

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES4.3	**Maintenance of soil stability and protection against soil erosion**	
ES4.4	**Enhancement of soil stability and protection against soil erosion**	
Forest cover on vulnerable or high- risk areas	Protective forest cover on steep slopes	ES1-A Satellite imagery and GIS
	Protective forest cover for wetlands and/or coastal areas	ES1-A Satellite imagery and GIS
	Natural forest cover on vulnerable areas	ES1-A Satellite imagery and GIS
	Degraded forest area as a proportion of total forest area	ES4-D UNCCD's computation of Land Degradation Neutrality
Soil erosion	Area affected by wind and/or water erosion	ES4-A Line-point transect forest cover and erosion assessment method ✓ ES4-F Visual Soil Assessment ✓
	Amount of erosion (cubic meters, area affected)	
	Soil erosion and sedimentation levels	
	Time spent on removal of sediment	ES5-E Key informant interview ✓
	Costs of removal of sediment	ES5-E Key informant interview ✓
	Impacts of sediment deposited by wind and/ or water erosion on nearby land or water bodies	ES5-E Key informant interview ✓
	Percentage of households within local communities affected by landslide	ES5-E Key informant interview ✓ ES5-C Household questionnaires ✓
Successful reforestation/ restoration activities	Area of natural forest cover resulting from afforestation/ reforestation	ES1-A Satellite imagery and GIS
	Restored forest area as a proportion of total forest area	*Simple measurement or calculation*

ES4-A LINE-POINT TRANSECT FOREST COVER AND EROSION ASSESSMENT METHOD

Impacts

- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition
- ES4.3: Maintenance of soil stability and protection against soil erosion
- ES4.4: Enhancement of soil stability and protection against soil erosion

Outcome indicators

- Extent of land cover with forest canopy or ground vegetation
- Area affected by wind and/or water erosion

Description

The line-point transect forest cover and erosion assessment method was developed by the Food and Agriculture Organization of the United Nations as a rapid assessment of forest protective function for soil and water. It records forest canopy, floor cover, and erosion evidence in 30 readings along two lines in a 20 × 20 m plot.

- **Forest canopy** (sky or leaf/vegetation) is recorded by using a densitometer device.
- **Floor cover** is recorded by classifying each of the measurement points into vegetation, roots, forest litter, stones/rocks, deadwood, or bare soil.
- For **erosion**, the following items are recorded per sampling site: the number of rills and gullies, their width and depth, and the general slope.

A team of three people is recommended to carry out these measurements.

Suitable contexts

Specifically designed for, but not limited to, developing countries.

Advantages

- Can be used by non-experts after limited training.
- Cheap.

Disadvantages

- No guidance is given on the number of plots that should be measured.

Access

Methodology: FAO (2015) available at http://www.fao.org/3/a-i4498e.pdf

Background research: Adikari, Y., and MacDicken, K. (2015) available at http://www.fao.org/3/a-i4509e.pdf

ES4-B SOIL TESTING KITS

Impacts

- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition

Outcome indicators

- Soil pH
- Nutrient (nitrogen, phosphate) content of soil
- Salt concentration in the soil

Description

There are various soil-testing kits available to do simple tests in the field by yourself – for example, pH, nutrients, and soil texture. Most will be geared towards agricultural use or gardening, but there are also forest-specific kits. It is recommended that you search online for these, using terms in the language of your country.

Suitable contexts

Advantages

- Easy to use after basic training or when enthusiastic.
- Forests where soil can be safely accessed for testing.

Disadvantages

- The more advanced soil testing kit, the more costly.

Access

Methodologies for a number of soil tests: https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf

Examples of ordering soil test kits & materials:

US: https://www.forestry-suppliers.com/c/soil-test-kits-strips/15-131-705?page=1 ; https://www.forestry-suppliers.com/c/soil-management/15?page=1

Australia: https://www.forestrytools.com.au/collections/soil-testing?srsltid=AfmBOoqBpQyWZp77GZTng9aELDA4DJGsve_xBjG4IVYG8n6A9znoVf_O

EU: https://www.eugardencenter.com/en/milwaukee-mt6003-npk-soil-test-kit.html

ES4-C SOIL SENSORS AND TOOLS

Impacts

ES4.1: Maintenance of soil condition

ES4.2: Enhancement of soil condition

Outcome indicators

- Soil humidity/moisture
- Water infiltration rate

Description

To measure soil humidity/ moisture, a Time Domain Reflectometry (TDR) or a Frequency Domain Reflectometry (FDR) sensor or capacitance can be used.

To measure water infiltration rate (or hydraulic conductivity), a mini disk infiltrometer can be used.

Suitable contexts

TDR sensors should not be used in high saline soils or soils with high bulk electrical conductivity or high attenuation.

Advantages

- Direct measurement.

Disadvantages

- Depending on the area to be covered, multiple sensors/tools may need to be acquired.

Access

Article explaining soil sensor technologies: https://soilsensor.com/sensors/sensor-technologies/

Article explaining the difference between TDR and FDR sensors: https://www.niubol.com/Product-knowledge/Differences-between-FDR-and-TDR-sensors.html

Mini disk infiltrometer manual: https://www.labcell.com/media/24285/20421_mini_disk_manual_web.pdf

Mini disk infiltrometer purchase: for example at metergroup (Germany/ US).

ES4-D UNCCD'S COMPUTATION OF LAND DEGRADATION NEUTRALITY

Impacts

- ES3.3: Maintenance of water volume regulation
- ES3.4: Enhancement of water volume regulation
- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition
- ES4.3: Maintenance of soil stability and protection against soil erosion
- ES4.4: Enhancement of soil stability and protection against soil erosion

Outcome indicators

- Proportion of forest that is degraded over total forest area
- Productivity (forest and agricultural) per unit area
- Degraded forest area as a proportion of total land area

Description

To measure land degradation, the following sub-indicators need to be measured:

- land cover and land-cover change (Land Cover Classification System/ Land Cover Meta Language)
- land productivity (Net Primary Productivity/ Normalized Difference Vegetation Index)
- carbon stocks with a focus on soil organic carbon, complying with the methodologies as stipulated in IPCC (2006).

A tiered approach is taken relating to how the measurements are to be carried out:

- tier 1 is through Earth observation and geospatial information
- tier 2 is statistical and based on estimated data for administrative or natural boundaries
- tier 3 is data led and based on surveys, assessment, and ground measurements.

Note that for measuring the present value, tier 3 needs to be used. Only SLIMF & CF can use tier 1 or tier 2 for measuring the present value.

To reach a conclusion with the results, the 'one-out, all-out' approach is used. This means that if any of the three indicators show significant negative change, it is considered a loss, and if at least one indicator shows a significant positive change and none show a significant negative change, it is considered a gain.

Suitable contexts

Designed for use by the United Nations, i.e. for national-level reporting with options given to calculate regional and global land degradation. Not limited to forest land use.

Available in English, French, and Spanish.

Advantages

- Comprehensive.
- Direct fit with Sustainable Development Goal 15.3.1.

Disadvantages

- Advanced GIS skills needed.
- Lengthy document, less user-friendly.
- Not developed for site-level measurements.

Access

Orr et al. (2017) available at https://www.unccd.int/sites/default/files/documents/2019-06/LDN_CF_report_web-english.pdf

Module E (chapter 7) is about monitoring the three sub-indicators and how to reach a conclusion on land degradation neutrality,

Page 109 (English version) presents a summary of the methodology.

ES4-E SOIL PENETROMETER

Impacts

- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition

Outcome indicators

- Degree of soil compaction in operated areas (roads and harvest areas)

Description

To measure soil compaction, a penetrometer can be used. This device mimics the growth of a plant root and its recordings are referred to as the cone index. At a soil resistance of more than 300 psi (psi = penetration resistance), plant roots will no longer be able to penetrate the soil, which is then identified as being compacted.

Suitable contexts

Any areas that are not extremely dry.

Advantages

- Can be used by non-experts after limited training.

Disadvantages

- There is different scoring by different operators of soil penetrometers.
- Depending on the area to be covered, multiple penetrometers may need to be acquired.

Access

Duiker (2002) available at https://extension.psu.edu/diagnosing-soil-compaction-using-a-penetrometer-soil-compaction-tester

Example of where to purchase a soil penetrometer: https://www.forestry-suppliers.com/c/soil-compaction-testers/15-131-706?page=1

ES4-F VISUAL SOIL ASSESSMENT

Impacts

- ES4.1: Maintenance of soil condition
- ES4.2: Enhancement of soil condition
- ES4.3: Maintenance of soil stability and protection against soil erosion
- ES4.4: Enhancement of soil stability and protection against soil erosion

Outcome indicators

- Soil depth (potential rooting depth)
- Soil macro-fauna abundance (earthworms)
- Area affected by wind and/or water erosion

Description

The Visual Soil Assessment (VSA) looks at a variety of soil indicators that are scored 0 (poor), 1 (moderate), or 2 (good). Scoring is made easy by comparing the field situation to photos or figures in the VSA field guide. Besides the above-mentioned example outcome indicators listed in Annex B, it provides methods on how to measure other soil parameters such as soil texture, soil structure, soil porosity, soil colour.

No specific VSA guide has been developed for forest land use yet. There is one guide developed for forest and pastoral land use (for forest land use only the soil indicators are relevant – up to page 33). However, the VSA lead author recommends using the VSA guide for orchards as the most suitable for use in forests (T.G. Shepherd, personal communication, 2017).

Suitable contexts

The VSA guide for forest and pasture land was developed in New Zealand for hill country uses. The VSA guide for orchards does not mention a particular area where it has been developed or a geographical scope for application.

Advantages

- Can be used by non-experts.
- Cheap.

Disadvantages

- Not specifically designed for forests.

Access

VSA guide for orchards: Shepherd et al. (2008) https://www.fao.org/4/i0007e/i0007e03.pdf

Shepherd and Janssen (2000) available via http://www.landcareresearch.co.nz/publications/books/visual-soil-assessment-field-guide/download-field-guide

METHODOLOGIES RECREATIONAL SERVICES (ES5)

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES5.1	**Maintenance of social-ecological benefits from forest recreation and/or tourism**	
ES5.2	**Enhancement of social-ecological benefits from forest recreation and/or tourism**	
Extent of areas protected and used for nature-based recreation	Area protected and used for nature- based recreation (e.g. forest bathing)	*Simple measurement or calculation*
	Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas and used as recreational, by ecosystem type	*Simple measurement or calculation*
	Coverage by protected areas of important sites for biodiversity conservation used for tourism visitation	*Simple measurement or calculation*
Facilities and services for visitors	Km of hiking trails with adequate accessibility	*Simple measurement or calculation*
	Coverage of interpretation panels	*Simple measurement or calculation*
	Sheltering/resting facilities for visitors	*Simple measurement or calculation*
	Adequacy of waste management processes	*Simple measurement or calculation*
	Trail signage and surface markings	*Simple measurement or calculation*
Visitor experience	Level of visitor satisfaction, feedback or reactions	ES5-A TESSA Recreation method 1: Census for estimating number of sites visits ✓ ES5-B Visitor questionnaires ✓
	Number of recurring visits per recreational experience	ES5-B Visitor questionnaires ✓
Benefits for local communities, Indigenous Peoples and/or traditional peoples from nature-based tourism	Level of wellbeing of local communities, Indigenous Peoples and/or traditional peoples (considering factors like health, education, income, housing infrastructure, etc.)	ES5-C Household survey ✓ ES5-D Focus group discussion ✓
	Number of new employments generated by recreational activities	ES5-D Focus group discussion ✓ ES5-E Key informant interview ✓
	Number of people/households involved in recreational activities	ES5-D Focus group discussion ✓ ES5-E Key informant interview ✓
	Level of income generated by recreational activities	ES5-C Household survey ✓
	Improvement of social needs (e.g. healthcare, education, food security) generated by recreational activities	ES5-D Focus group discussion ✓

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES5.3	**Maintenance of populations of species of interest for nature-based tourism**	
ES5.4	**Enhancement of populations of species of interest for nature-based tourism**	
For selected species of interest, indicators of population abundance	Abundance of selected species of recreational interest	ES1-G Fauna Species Survey Techniques ES1-H Camera trap surveys ES1-I Acoustic monitoring
	Number of charismatic species sightings (e.g. when birdwatching)	ES5-B Visitor questionnaires ✓
Evidence that the habitat is in suitable condition	Area of habitat of selected species protected	*Simple measurement or calculation*
	Suitability of habitat for selected species	ES1-K Forest Integrity Assessment Tool ✓
	Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type	*Simple measurement or calculation*

ES5-A TESSA RECREATION METHOD 1: CENSUS FOR ESTIMATING NUMBER OF SITES VISITS

Impacts

- ES5.1: Maintenance of social-ecological benefits from forest recreation and/or tourism
- ES5.2: Enhancement of social-ecological benefits from forest recreation and/or tourism

Outcome indicators

- Level of visitor satisfaction, feedback or reactions (expressed in number of visitors)

Description

To (count or) estimate the annual number of visitors, The Toolkit for Ecosystem Service Site-based Assessment (TESSA)'s recreation method 1 gives some useful tips and includes worked examples. We recommend you ignore the paragraph about an alternative state (which is TESSA's equivalent of a baseline to compare the present value against).

Suitable contexts

All types of forests, especially those with clear entry points (but without a visitor-counting system in place, e.g. because of the need to pay an entrance fee).

Advantages

- Simple, can be used by non-experts.
- Cheap.

Disadvantages

- The methodology is part of a comprehensive document, so you will need to look for the specific pages that are of interest (275-277).
- The alternative state and other information may be confusing and/or overwhelming.

Access

Peh et al. (2022)[3]: available for download via https://www.birdlife.org/tessa-tools/

Fill out the download request form on the web page. Go to page 275.

3 Peh, K. S.-H., Balmford, A. P., Bradbury, R. B., Brown, C., Butchart, S. H. M., Hughes, F. M. R., Ingwall-King, L., MacDonald, M. A, Pellier, A.-S., Stattersfield, A. J., Thomas, D. H. L., Trevelyan, R. J., Walpole, M. & Merriman, J. C. (2022) Toolkit for Ecosystem Service Site-based Assessment (TESSA). Version 3.0. Cambridge, UK. Available at: http://tessa.tools.

ES5-B VISITOR QUESTIONNAIRES

Impacts

- ES5.1: Maintenance of social-ecological benefits from forest recreation and/or tourism
- ES5.2: Enhancement of social-ecological benefits from forest recreation and/or tourism

Outcome indicators

- Level of visitor satisfaction, feedback or reactions
- Number of charismatic species sightings (e.g. when birdwatching)

Description

A questionnaire can be simple or elaborate, depending on the level of information that you would like to collect. Make sure to include questions about the forest, recreational facilities and/or the recreational experience for people.

Items that can be included are:

1. general information (e.g. length and purpose of visit, first time or recurrent visitor)
2. attributes of the forest (e.g. visual attractiveness and naturalness, cleanliness/unspoiled, number of charismatic species sightings)
3. recreation infrastructure availability and maintenance (e.g. paths, signposts, benches, lookout towers, information availability)
4. overall satisfaction
5. value/price rating (if applicable) or willingness to pay for ecotourism attributes.

For some attributes (1-4), visitors can be asked to select the level of appreciation on a Likert scale, for example from 1 to 5 (1 = poor, 2 = fair, 3 = average, 4 = good, 5 = excellent).

For the number of charismatic species sightings and the willingness to pay for ecotourism attributes, visitors or tour operators could be asked to indicate a quantification (or, if it is more practical, select a range, e.g. 0, 1–5, 6–10, 10–20, > 20 sightings or $$).

It is possible to add open questions (e.g. What did you enjoy most about your visit today?, How can we make improvements for our visitors?) as well as basic socio-demographic information about the visitors (where do they come from?). Note that adding more questions makes data analysis more comprehensive (and time-consuming), so it is worth thinking about what information you will need.

Suitable contexts

All types of forests that are accessible to visitors.

Advantages

- Simple, non-experts can use it after basic training.

Disadvantages

- For touristic areas, questionnaires may need to be available in multiple languages.
- Visitors may not be willing to participate in a questionnaire (especially if it is lengthy).

ES5-C HOUSEHOLD SURVEY (LOCAL COMMUNITY, INDIGENOUS PEOPLES AND/OR TRADITIONAL PEOPLES)

Impacts

- ES5.1: Maintenance of social-ecological benefits from forest recreation and/or tourism
- ES5.2: Enhancement of social-ecological benefits from forest recreation and/or tourism
- ES6.1: Maintenance of cultural and ancestral knowledge, practices and language
- ES6.2: Enhancement of cultural and ancestral knowledge, practices and language

Outcome indicators

- Level of wellbeing of local communities, Indigenous Peoples and/or traditional peoples (considering factors like health, education, income, housing infrastructure, etc.)
- Level of income generated by recreational activities

Description

When collecting data on the benefits for local communities, Indigenous Peoples and/or traditional peoples from nature-based tourism, you will probably need to combine household surveys with key informant interview(s) and/or focus group discussion(s).

For the household survey, make sure to include households in your sample from all surrounding communities and ensure a representation of households reflecting each community's population, e.g. based on level of wealth/poverty, level of education, migrants/natives, etc.

TESSA v3 contains a guidance on household surveys with some useful tips and further reading.

Suitable contexts

All types of forests where recreation take place and there are local communities, Indigenous Peoples and/or traditional peoples.

Advantages

- Quantitative data.

Disadvantages

- People may not be willing to participate in a questionnaire (especially if it is lengthy).

Access

TESSA's Guidance 5 Household surveys (p.543): https://www.birdlife.org/tessa-tools/

ES5-D FOCUS GROUP DISCUSSION

Impacts

- ES5.1: Maintenance of social-ecological benefits from forest recreation and/or tourism
- ES5.2: Enhancement of social-ecological benefits from forest recreation and/or tourism
- ES6.1: Maintenance of cultural and ancestral knowledge, practices and language
- ES6.2: Enhancement of cultural and ancestral knowledge, practices and language

Outcome indicators

- Level of wellbeing of local communities, Indigenous Peoples and/or traditional peoples (considering factors like health, education, income, housing infrastructure, etc.)
- Number of people/households involved in recreational activities
- Improvement of social needs (e.g. healthcare, education, food security) generated by recreational activities

Description

A focus group discussion consists of 8-10 participants that discuss a certain topic. In some cultural contexts, it is best to separate a focus group discussion with men from one with women. It is a qualitative method and is effective in identifying village-/ community-level facilities and services, and common level of wellbeing as well as any community-level improvements from forest recreation activities.

Suitable contexts

All types of forests where recreation take place and there are local communities, Indigenous Peoples and/or traditional peoples.

Advantages

- Cost-effective.

Disadvantages

- People may not be willing to participate in a focus group discussion.

ES5-E KEY INFORMANT INTERVIEW

Impacts

- ES5.1: Maintenance of social-ecological benefits from forest recreation and/or tourism
- ES5.2: Enhancement of social-ecological benefits from forest recreation and/or tourism
- ES6.1: Maintenance of cultural and ancestral knowledge, practices and language
- ES6.2: Enhancement of cultural and ancestral knowledge, practices and language

Outcome indicators

- Number of new employments generated by recreational activities
- Number of people/households involved in recreational activities

Description

A community leader or recreational business director can be interviewed to provide information on involvement and/or employment from the local community in recreational activities.

Suitable contexts

All types of forests where recreation take place and there are local communities, Indigenous Peoples and/or traditional peoples.

Advantages

- Cost-effective.

Disadvantages

- Difficult to obtain quantitative data.

METHODOLOGIES CULTURAL PRACTICES & VALUES (ES6)

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES6.1	**Maintenance of cultural and ancestral knowledge, practices and language**	
ES6.2	**Enhancement of cultural and ancestral knowledge, practices and language**	
Extent of protected areas or sites in the forest that are of importance for cultural practices	Indigenous land protected or area protected based on evidence as a result of cultural activities, cultural heritage, identity or sense-of-belonging	*Simple measurement or calculation*
	Sacred sites or sites nationally designated or recognized to possess high cultural value.	*Simple measurement or calculation*
	Area covered by Indigenous Cultural Landscape	*Simple measurement or calculation*
	Extent of sites of special intellectual, scientific, archaeological interest or used for educational activities	*Simple measurement or calculation*
	Sites used for cultural awareness, cultural exchange, or of cultural and spiritual importance that are protected	*Simple measurement or calculation*
Socio-cultural and environmental benefits resulting from their connection to the forest	Educational, training, capacity building or learning activities and materials developed to reveal cultural and historic significance of protected areas, and people engaged	ES5-C Household survey ✓ ES5-D Focus group discussion ✓ ES5-E Key informant interview ✓
	Events used for high spiritual, intergenerational, traditional or bequest significance conducted in the areas (e.g. storytelling, folklore, dance, songs or art ceremonies and initiatives)	ES6-A Questionnaire ✓
	Transference of Indigenous or traditional knowledge and languages intergenerationally (e.g. by recognising and using Indigenous terms for sites and practices)	ES6-A Questionnaire ✓ ES5-D Focus group discussion ✓
	Activities that recognize and enhance the contribution of Indigenous, traditional, cultural knowledge and practices to wellbeing and environmental conservation	ES6-A Questionnaire ✓

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES6.3	**Maintenance of culturally valued populations or species**	
ES6.4	**Enhancement of culturally valued popula-tions or species**	
Culturally valued species or populations	Diversity of cultural, historical or iconic species or populations which are used as emblems or cultural signifiers of some kind	ES1-E Environmental DNA ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring
	Richness of species deemed to have cultural, sacred or spiritual significance for people, including for Indigenous or traditional peoples' values and sense of belonging	ES1-E Environmental DNA ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring
	Existence of endangered species which preservation is required for heritage or identity values or future generations	ES1-F Environmental DNA ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys
	Species associated to spiritual, traditional or culturally relevant food, knowledge, therapeutic and medicinal activities	ES1-E Environmental DNA ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring
	Species important to sustain livelihoods, subsistence and food sovereignty	ES1-E Environmental DNA ES1-F Fauna Species Survey Techniques ES1-G Camera trap surveys ES1-H Acoustic monitoring
Habitats protected by traditional, Indigenous practices	Area of selected species protected by Indigenous and traditional cultural practices	*Simple measurement or calculation*
	Proportion of important sites for terrestrial and freshwater biodiversity that are under Indigenous or traditional sustainable management	*Simple measurement or calculation*
	Habitat protected from external pressures, using Indigenous and traditional knowledge (e.g. control of wildfires)	*Simple measurement or calculation*

ES6-A QUESTIONNAIRE

Impacts

- ES6.1: Maintenance of cultural and ancestral knowledge, practices and language
- ES6.2: Enhancement of cultural and ancestral knowledge, practices and language

Outcome indicators

- Events used for high spiritual, intergenerational, traditional or bequest significance conducted in the areas (e.g. storytelling, folklore, dance, songs or art ceremonies and initiatives)
- Transference of Indigenous or traditional knowledge and languages intergenerationally (e.g. by recognising and using Indigenous terms for sites and practices)
- Activities that recognize and enhance the contribution of Indigenous, traditional, cultural knowledge and practices to wellbeing and environmental conservation

Description

TESSA provides an example of a questionnaire template for cultural services benefits, including spiritual and religious, sense of place, identity, social relations/community benefits, education and ecological knowledge.

To be able to analyse that transference of knowledge and language happened over generations, make sure to include different generations in the sampling population.

For more tips on questionnaires, see ES5-B/ ES5-C.

Suitable contexts

Forest contexts where there are multiple generations of Indigenous Peoples and/ or traditional peoples reachable to administer the questionnaire.

Advantages

- Quantitative data.

Disadvantages

- People may not be willing to participate in a questionnaire (especially if it is lengthy).

Access

Access TESSA's cultural method 1C (p.499-502): https://www.birdlife.org/tessa-tools/

METHODOLOGIES AIR QUALITY (ES7)

ES impact		
Outcome indicator type	**Example outcome indicator**	**Suggested methodologies**
ES7.1	**Maintenance of air quality**	
ES7.2	**Enhancement of air quality**	
Air quality	Critical loads of atmospheric deposition of nitrogen and/or sulphite	ES7-C i-Tree tools ES7-B Deploying sensors in the forest
	Concentration of NO_2 and/or O_3	ES7-A Remote sensing for air quality ES7-B Deploying sensors in the forest
	$PM_{2.5}$ or PM_{10}	ES7-C i-Tree tools ES7-A Remote sensing for air quality
	Bio-indicators of air quality such as lichens, mosses	ES7-D Surveying bioindicators ✓
Forest structure	Leaf area index (LAI)	ES1-A Satellite imagery and GIS ES1-B LiDAR
	Forest vertical and/or horizontal structure	ES1-B LiDAR
	Forest structural condition index	

ES7-A REMOTE SENSING FOR AIR QUALITY

Impacts

- ES7.1: Maintenance of air quality
- ES7.2: Enhancement of air quality

Outcome indicators

- Critical loads of atmospheric deposition of nitrogen and/or sulphite
- Concentration of NO_2 and/or O_3
- $PM_{2.5}$ or PM_{10}
- Leaf area index (LAI)

Description

The Copernicus Atmospheric Monitoring Services consists of a set of satellites focusing on air quality, climate forcing, ozone and UV radiation. It performs atmospheric measurements, with high spatio-temporal resolution, relating to air quality, climate forcing, ozone and UV radiation. The Sentinel-5 mission consists of high resolution spectrometer system operating in the ultraviolet to shortwave infrared range with 7 spectral bands. It has a maximum revisit time of 4 days. Among air quality data monitored are the following parameters O_3, NO_2, SO_2, and aerosols (e.g. $PM_{2.5}$, PM_{10}).

It is also possible to calculate the leaf area index (LAI) from satellite images, for example from Sentinel-2. Besides using satellite imagery, the LAI can also be obtained using LiDAR data (see ES1-B).

Suitable contexts

All forests worldwide.

Advantages

- Cost-effective.

Disadvantages

- Requires medium-level expertise or interest.

Access

Upon registration, access datasets through: https://identity.dataspace.copernicus.eu/auth/realms/CDSE/protocol/openid-connect/auth?client_id=sh-a696e3be-b074-4baa-9e76-b10bee279c85&redirect_uri=https%3A%2F%2Fshapps.dataspace.copernicus.eu%2Fdashboard%2F%23%2F&state=ab36f0ea-e837-40d8-8220-66f7927a

ES7-B DEPLOYING SENSORS IN THE FOREST

Impacts

- ES7.1: Maintenance of air quality
- ES7.2: Enhancement of air quality

Outcome indicators

- Critical loads of atmospheric deposition of nitrogen and/or sulphite
- Concentration of NO_2 and/or O_3
- $PM_{2.5}$ or PM_{10}

Description

If there is no air quality data readily available for your forest area, you can also decide to set up a monitoring system using sensors. Dry sampling is done through air quality filters/ samplers in the field, while wet sampling involves collecting precipitation. Both dry and wet samples are typically analysed in the laboratory.

Suitable contexts

Forests where sensors can be installed with limited risk of interference (e.g. weather conditions, damage by animals or humans).

Advantages

- Site-level, precise data.

Disadvantages

- Need expertise.
- Costly.

Access

Ozone sensor: https://www.clarity.io/products/clarity-node-s

ES7-C i-TREE TOOLS

Impacts

- ES7.1: Maintenance of air quality
- ES7.2: Enhancement of air quality

Outcome indicators

- Critical loads of atmospheric deposition of nitrogen and/or sulphite
- Concentration of NO_2 and/or O_3
- $PM_{2.5}$ or PM_{10}

Description

i-Tree tools offers a number of tools to estimate the benefits of individual trees as well as the benefits at the landscape level. Some tools need to be downloaded and installed, others work via your web browser. i-Tree Landscape provides data on various air quality parameters (under the tab health risk), including O_3 and $PM_{2.5}$.

Suitable contexts

Continental United States.

Advantages

- Readily available data.

Disadvantages

- Need to invest some time to become familiar with the program.
- Limited geographical coverage.

Access

Access the i-Tree tools via: https://www.itreetools.org/

ES7-D SURVEYING BIOINDICATORS

Impacts

- ES7.1: Maintenance of air quality
- ES7.2: Enhancement of air quality

Outcome indicators

- Bioindicator species

Description

Bioindicators are living things that indicate the health of an ecosystem. Examples of air quality-related bioindicators used are:

- Lichens, to measure nitrogen and sulphur levels
- Mosses
- Plant leaves, to study ozone damage to plants
- Spider webs

One way to monitor bioindicators is to set up field plots and undertake sampling of bio-indicators' diversity. The presence/ absence, diversity and abundance will indicate the levels of air quality in the forest.

It is important to note that presence and survival of bioindicators is also dependent on other factors including habitat availability, water, nutrients and sunlight.

Another possibility is to send bioindicator samples to a laboratory for analysis of absorbed pollutants through bioaccumulation analysis (e.g. of heavy metals). This will indicate to what extent the forest is acting as a filter, absorbing pollutants in the air.

Suitable contexts

Forests in geographies where bioindicators of air quality are present.

Advantages

- Possibility to measure the filter function of the forest.

Disadvantages

- For bioaccumulation analysis, need to involve a laboratory.

Access

Manual for monitoring lichens for nitrogen air quality (UK): https://www.apis.ac.uk/nitrogen-lichen-field-manual.

OPAL Air Survey using lichens and tar spot fungus as bioindicators (UK): https://www.imperial.ac.uk/opal/surveys/airsurvey/.

Since bioindicators are geographically specific, you are advised to look for locally applicable monitoring tools or guidance (in your country language).

FORESTS FOR ALL FOREVER

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