REMOTE SENSING OF EBVS FOR GLOBAL CHANGE MONITORING

ANDREW SKIDMORE, ITC, UNIVERSITY TWENTE
INTRODUCTION

BIODIVERSITY

- **BIODIVERSITY**: The variety of life and the natural patterns it forms including the ecological and evolutionary processes that sustain it
SPECIES OBSERVATION
EUROPEAN BADGER

- Map of life
- IUCN
- National data
  - UK
  - NL
- GBIF
Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.
INTRODUCTION
CRITIQUE OF BIODIVERSITY INDICATORS

- Ambiguous (100%)
- Unquantifiable (70%)
- Complex (mean=2.8 elements; many have 8)
- Redundant (33%)

Conservation Letters
A journal of the Society for Conservation Biology

POLICY PERSPECTIVE
Formulating Smart Commitments on Biodiversity: Lessons from the Aichi Targets
Stuart H. M. Butchart1,2,* , Moreno Di Marco3,4 and James E. M. Watson5,6

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DOI: 10.1111/con.12279
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GAPS IN BIODIVERSITY MONITORING

- The Living Planet Database and Index (WWF) holds time-series data for over 11,000 populations of more than 2700 vertebrate species from around the world.
- Systematic stratified designed to address bias within the data set

http://www.zsl.org/science/research-projects/lpi,1162,AR.html
SPECIES OBSERVATION
LIVING PLANET INDEX -- DATA

- Published data
- Generalised additive model
- Species are aggregated to taxonomic group
- Weighting by species richness

http://www.livingplanetindex.org/search
WHAT ARE ESSENTIAL BIODIVERSITY VARIABLES

- EBVs are a set of variables for
  - Monitoring biodiversity
  - Technically feasible
  - Practical and affordable
  - Ecosystem agnostic
  - Biological
HISTORY OF EBVS

- (1990-)2010: ECVs developed
- 2011-2020 CBD Aichi targets
- 2008 GEOBON initiated by GEO
- 2010: EBVs suggested
- 2013: Pereira et al in Science
- 2012 IPBES
- 2015: Skidmore et al in Nature
- 2016: Pettorelli et al in RSEC
- 2016: SBSTTA-20 Information Note

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ECVS

- 50+ GCOS Essential Climate Variables (ECVs) (2010)
- GEOSS/GEOBON Essential Biodiversity Variables (EBVs)
  - Land cover, fAPAR, LAI, biomass, (fire) disturbance, soil moisture, soil carbon

<table>
<thead>
<tr>
<th>Domain</th>
<th>GCOS Essential Climate Variables</th>
</tr>
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<tbody>
<tr>
<td>Atmospheric</td>
<td>- Surface: Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.</td>
</tr>
<tr>
<td></td>
<td>- Upper-air: Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).</td>
</tr>
<tr>
<td></td>
<td>- Composition: Carbon dioxide, Methane, and other long-lived greenhouse gases, Ozone and Aerosol, supported by their precursors.</td>
</tr>
<tr>
<td>Oceanic</td>
<td>- Surface: Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.</td>
</tr>
<tr>
<td></td>
<td>- Sub-surface: Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>- River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.</td>
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http://gosic.org/ios/MATRICES/ECV/ECV-matrix.htm
ECVS
GLOBAL WARMING

Global Mean Estimates based on Land and Ocean Data

Annual Mean
Lowess Smoothing

Temperature Anomaly (°C)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1880 1900 1920 1940 1960 1980 2000 2020

NASA GISS

http://data.giss.nasa.gov/gistemp/graphs/
REMOTE SENSING EBVS

- Long term, wide area coverage
- Repeatable, consistent, scale independent
- Definition → algorithm consistency in a product
- Biodiversity metrics → monitoring
DEFINITIVE LIST OF RS-EBVS

- Agreement between conservation and space agencies
- Methods to derive variables and satellites
- 10 RS-EBVs from GEOBON/ESA workshops

- GEOBON IC, new experts continually being introduced or self-nominated
- We propose 10 RS-EBVs to CBD SBBSTA-20 for endorsement
- Ongoing process…
**RS-EBVS SLOWLY EMERGE…**

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<th>Candidate RS-EBV</th>
<th>Potential support for Aichi targets</th>
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**10 RS-EBVs proposed in RS-EBV paper by Skidmore et al 2015**

**List of candidate RS-EBVs submitted to SBBSTA-20 of CBD**
CONTINUOUS RS-EBVS

- Direct retrieval
- Continuous: interval/ratio
- Physical - deductive
- Scalable: global to local
- In-situ data for validation

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Phenology maps of Europe in Julian days. A) onset on greenness (OG), B) end of senescence (EOS), C) length of the season (LS).
Leaf nitrogen (top) and canopy nitrogen (bottom) in savanna South Africa (Kruger NP to Sabi Sands). Red edge band of RapidEye

CONTINUOUS RS-EBVS
FUNCTIONAL DIVERSITY

Monitoring plant functional diversity from space
The world’s ecosystems are losing biodiversity fast. A satellite mission designed to track changes in plant functional diversity around the globe could deepen our understanding of the pace and consequences of this change, and how to manage it.

Walter Jetz, Jamey Cavender-Bares, Ryan Pautzick, David Schimel, Frank W. Davis, Gregory P. Asner, Robert Gundlach, Jens Kattge, Andrew M. Latham, Paul Moorecroft, Michael E. Scheepmaker, Mark P. Schödl, Fabian J. Schimel, Finnström Schröder, Ulrike Stahl and Susan L. Uri

ESA Innovator Project
RS for EBV
CONTINUOUS RS-EBVS
ECOSYSTEM STRUCTURE – VEGETATION HEIGHT

Tree height from helicopter – 116 point/m²

http://ezproxy.utwente.nl:2084/science/article/pii/S0303243416300873
CONTINUOUS RS-EBVS
INUNDATION
CATEGORICAL RS-EBVS

- Plant species distribution and abundance operational with airborne hyperspectral & lidar
  Very high resolution instruments directly observe large or gregarious animals

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CATEGORICAL RS-EBVS
SPECIES DISTRIBUTION

- WorldClim 1.4 ppt & temperature
- Ruggedness indices SRTM30
- Freshwater proximity HydroSHEDS & SRTM Water Body Data
- MODIS Vegetation Continuous Fields
- SPOT VEGETATION red & NIR

Bat species richness

Bat species endemism

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CATEGORICAL RS-EBVS
LAND COVER

A consistent set of global Land Cover products at 300m

3 consistent global LC maps for epochs 2000, 2005 and 2010
CATEGORICAL RS-EBVS

LAND COVER: INUNDATION → WETLAND

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CATEGORICAL RS-EBVS

- Indirectly retrieved from RS
- Subjective: Expert product iteration and thresholds
- Local-regional extent
- Accuracy (especially at local scales)

- Categorical (nominal, ordinal or dichotomous)
- Closer to biodiversity indicators (Aichi)
- Produced for a purpose
- Requires ancillary data
GLOBAL BIODIVERSITY OBSERVING SYSTEM
PROGRESS IN SATELLITES

- **Landsat**
  - Global acquisition and free
  - NASA Sustainable Land Imaging programme ensures data continuation for 25 years

- **Sentinel series S-2**
  - 5 day revisit
  - Free data until 2028
  - Refined red edge

- **NASA Global Ecosystem Dynamics Investigation Lidar**
- German Aerospace Centre
  - High resolution and hyperspectral EnMap
GLOBAL BIODIVERSITY OBSERVING SYSTEM

ACCURACY

http://upload.wikimedia.org/wikipedia/commons/f/fe/Enschede-topografie.jpg
http://www.earthzine.org/2012/07/25/pan-european-forest-maps-derived-from-optical-satellite-imagery/
http://forest.jrc.ec.europa.eu/download/data/google-earth-overlays/
Global map of forest height produced from NASA's ICESAT/GLAS, MODIS and TRMM sensors. Image credit: NASA/JPL-Caltech
GLOBAL BIODIVERSITY OBSERVING SYSTEM
RANKING OF EBVS

- **PRIORITY** 1 user and use fully identified. 3 variable less directly linked to science and policy questions

- **FEASIBILITY** 1 indicates maturity of science / technology / experience needed to make the observation, 3 indicates that significant R&D effort remains or that observations on the scale needed are technically, logistically or financially difficult or impossible to make

- **IMPLEMENTATION** 1 you can identify who needs to take action, what action needs to be taken and how to initiate such action. 3 indicates a complete lack of relevant infrastructure

- **STATUS** 1 fully operational network or service is in place making observations fit for purpose. 3 indicates that no or very limited action has been taken

Continuously measured & biophysical RS-EBV

- fAPAR P=1 F=1 I=1 S=2 (EO)
- Veg height P=1 F=2 I=3 S=3

Threshold based & thematic RS-EBV

- Land cover P=1 F=1 I=1 S=2
- Fire Disturbance P=1 F=1 I=1 S=2
- Other Disturbance P=2 F=2 I=2 S=3

*based on TOPC (Terrestrial Observation Panel for Climate)
RS-EBVS
LINKING CATEGORICAL WITH CONTINUOUS RS-EBVS

Tracking Biodiversity
Ten variables

- Proposed variables for satellite monitoring of progress towards the Aichi Biodiversity Targets.

Species populations
- Species occurrence

Species traits
- Plant traits (such as specific leaf area and leaf nitrogen content)

Ecosystem structure
- Ecosystem distribution
- Fragmentation and heterogeneity
- Land cover
- Vegetation height

Ecosystem function
- Fire occurrence
- Vegetation phenology (variability)
- Primary productivity and leaf area index
- Inundation

Indicator
- National CBD Aichi 5, 7, 9, 14, 15

Essential biodiversity variable
- Land cover categories
- Fragmentation
- Species occurrence
- Ecosystem distribution

Essential variable
- height
- Leaf area index
- Phenology
- Specific leaf area
- % vegetation cover

Measurement
- In situ
- Remote sensing

Categorical vs Continuous
- Most complex & multifaceted
- Threshold based, categorical & of increasing complexity

Biophysical, continuous, simple, global

In situ Remote sensing
CONCLUSIONS

- Remote Sensing community require a deeper understanding of ecological concepts and requirements to minimize semantic confusion.
- Biodiversity community needs to recognize the potential and limitations of image processing for biodiversity monitoring.
- Natural resource managers need to be trained in biodiversity and remote sensing.
- Research funding agencies (EC, NSF, etc) must lend their support.
- Conservation and space agencies must agree on a definitive set of biodiversity variables.
- Set up a structure to formalize the global mapping of biodiversity trends from space.

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THANKS FOR YOUR ATTENTION!