REMOTE SENSING OF EBVS TO MONITOR BIODIVERSITY

Andrew Skidmore,
ITC, University Twente

INTRODUCTION

BIODIVERSITY: THE VARIETY OF LIFE

INTRODUCTION

WHY BIODIVERSITY MATTERS: THE EXAMPLE OF ECOSYSTEM SERVICES

INTRODUCTION

WHAT IS THE PROBLEM?

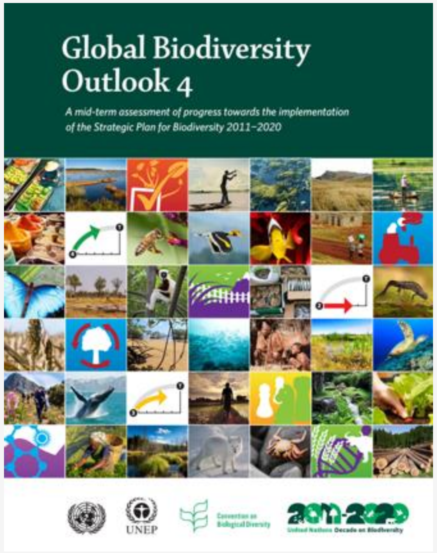
- Global biodiversity loss is intensifying
- National biodiversity monitoring programmes differ widely

INTRODUCTION

BIODIVERSITY INDICATORS

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.

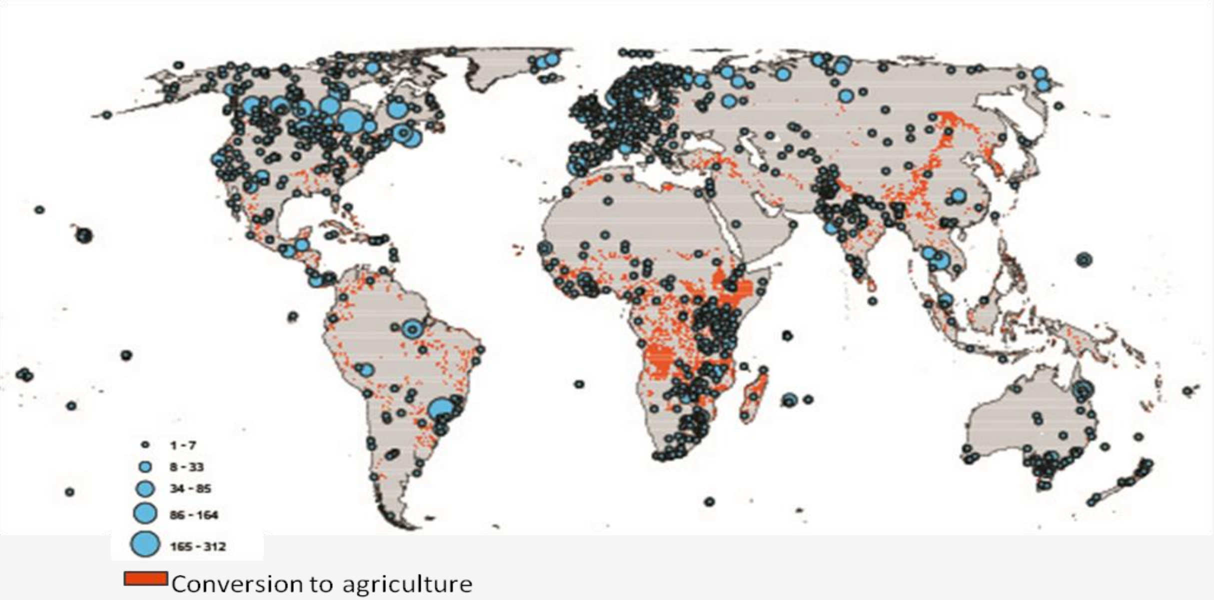


GEO RESPONSE: BIODIVERSITY AND ECOSYSTEM ACTIVITIES

- GEO Biodiversity Observation Network (GEO BON)
- GEO ECO (Ecosystems)
- GEO GNOME (Mountains)
- GEO Wetlands
- EO4EA (Ecosystem Accounting)
- Global Forest Observation Initiative (GFOI)

GAPS IN BIODIVERSITY MONITORING

- The Living Planet Database Index (WWF) holds time-series data for over 16,000 populations of more than 3500 species
- Systematic stratified designed to address bias within the data set
- Use EO to fill the gaps

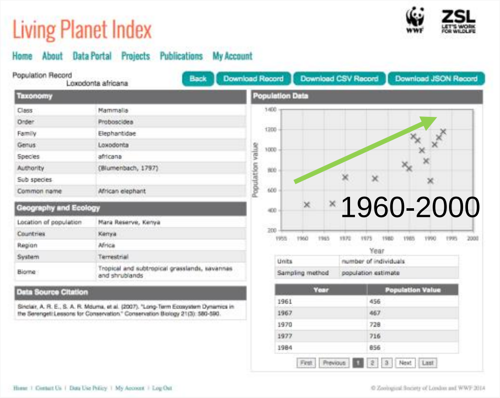


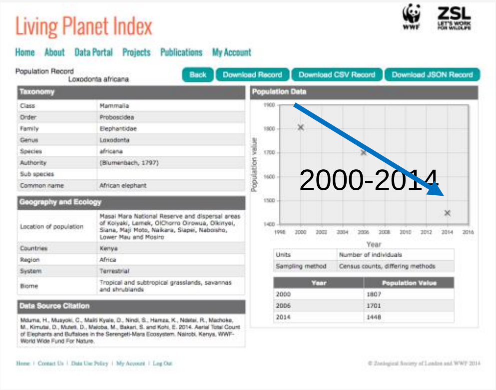
http://www.zsl.org/science/research-projects/lpi,1162,AR.html

TEMPORAL GAPS IN BIODIVERSITY

LIVING PLANET INDEX – AFRICAN ELEPHANT

- Mara reserve

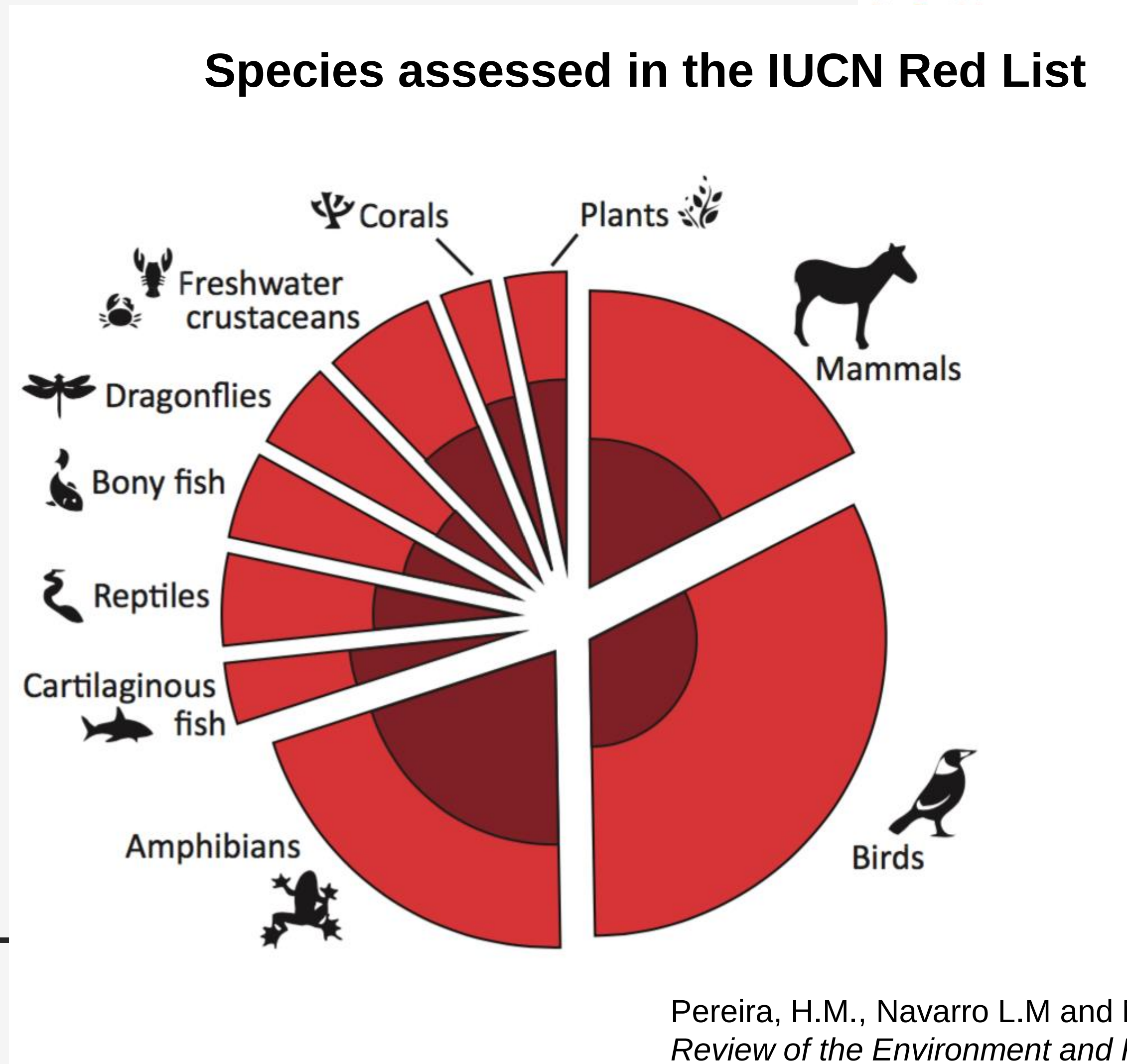


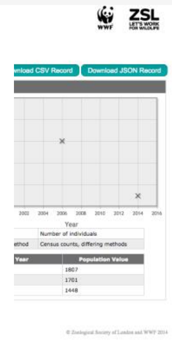


http://www.livingplanetindex.org/search

TAXONOMIC GAPS IN BIODIVERSITY

LIVING PLANET INDEX – AFRICAN ELEPHANT

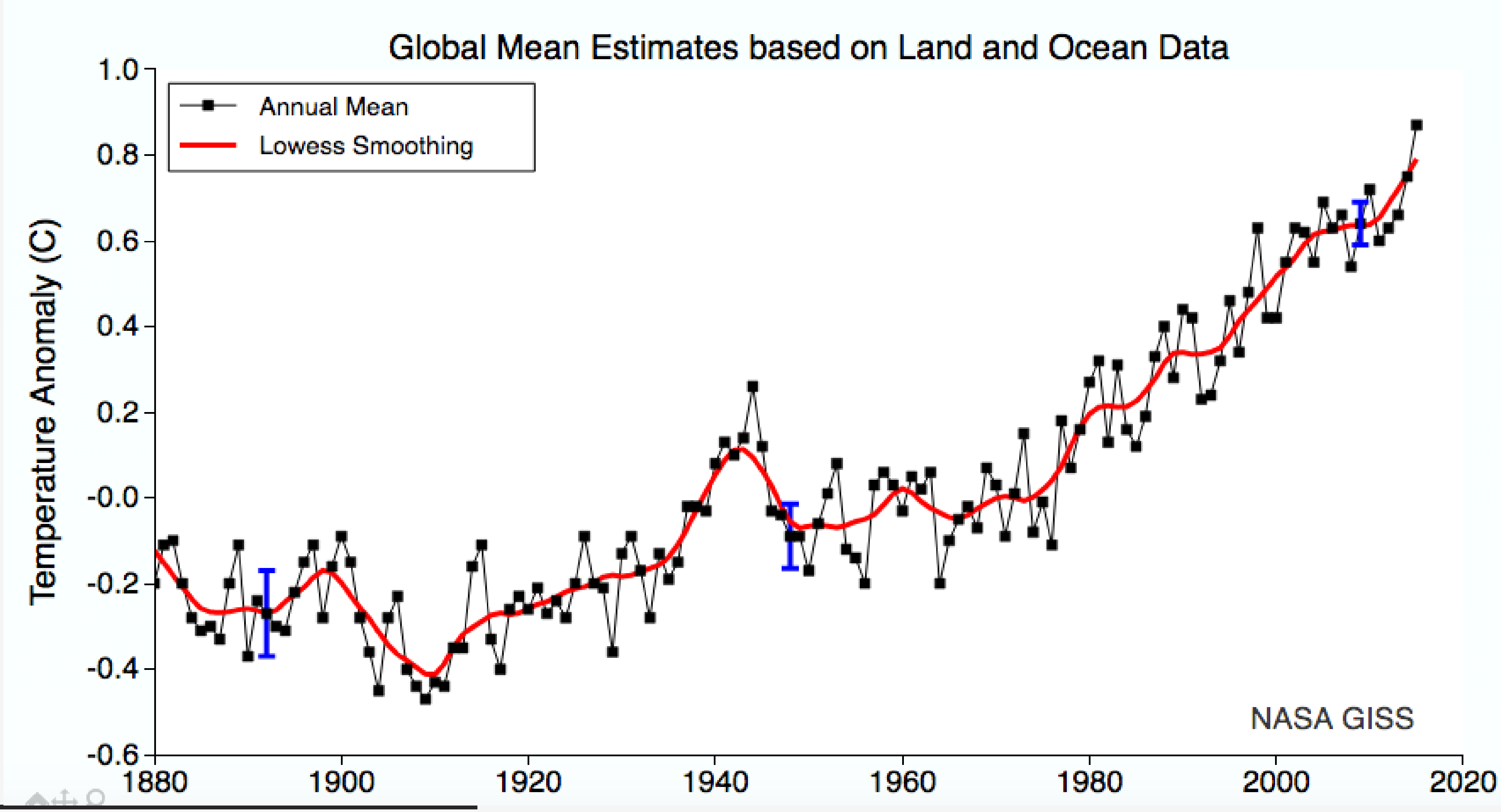




Pereira, H.M., Navarro L.M and Martins I.S. (2012) *Annual Review of the Environment and Resources*.

ECVS

GLOBAL WARMING

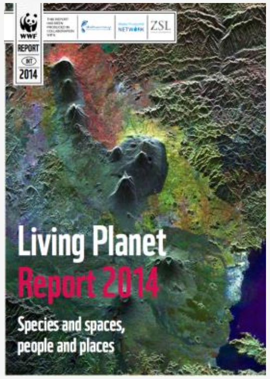


http://data.giss.nasa.gov/gistemp/graphs/

INDICATORS USING SPECIES OBSERVATION

LIVING PLANET INDEX, TRENDS

- A single indicator (like temperature increase)
- Problems: weighting, technique changes over time
- Scalability
- Comparison



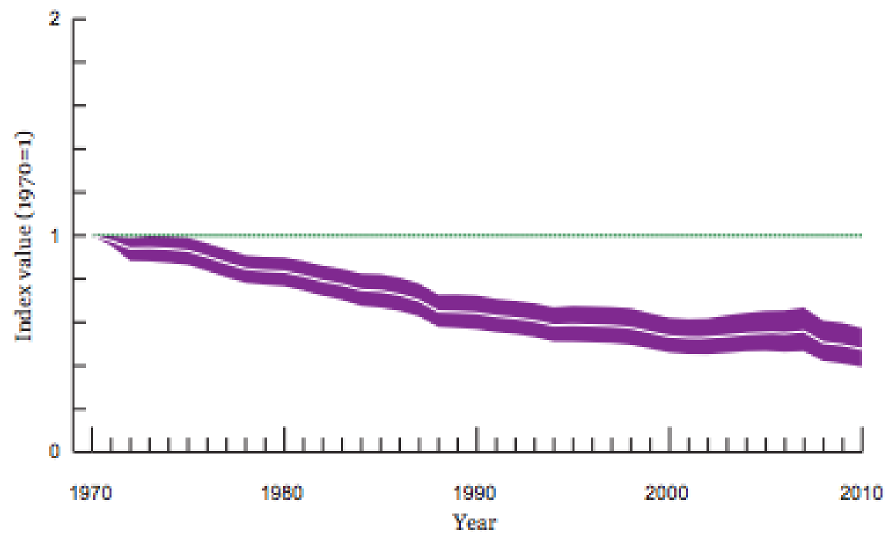
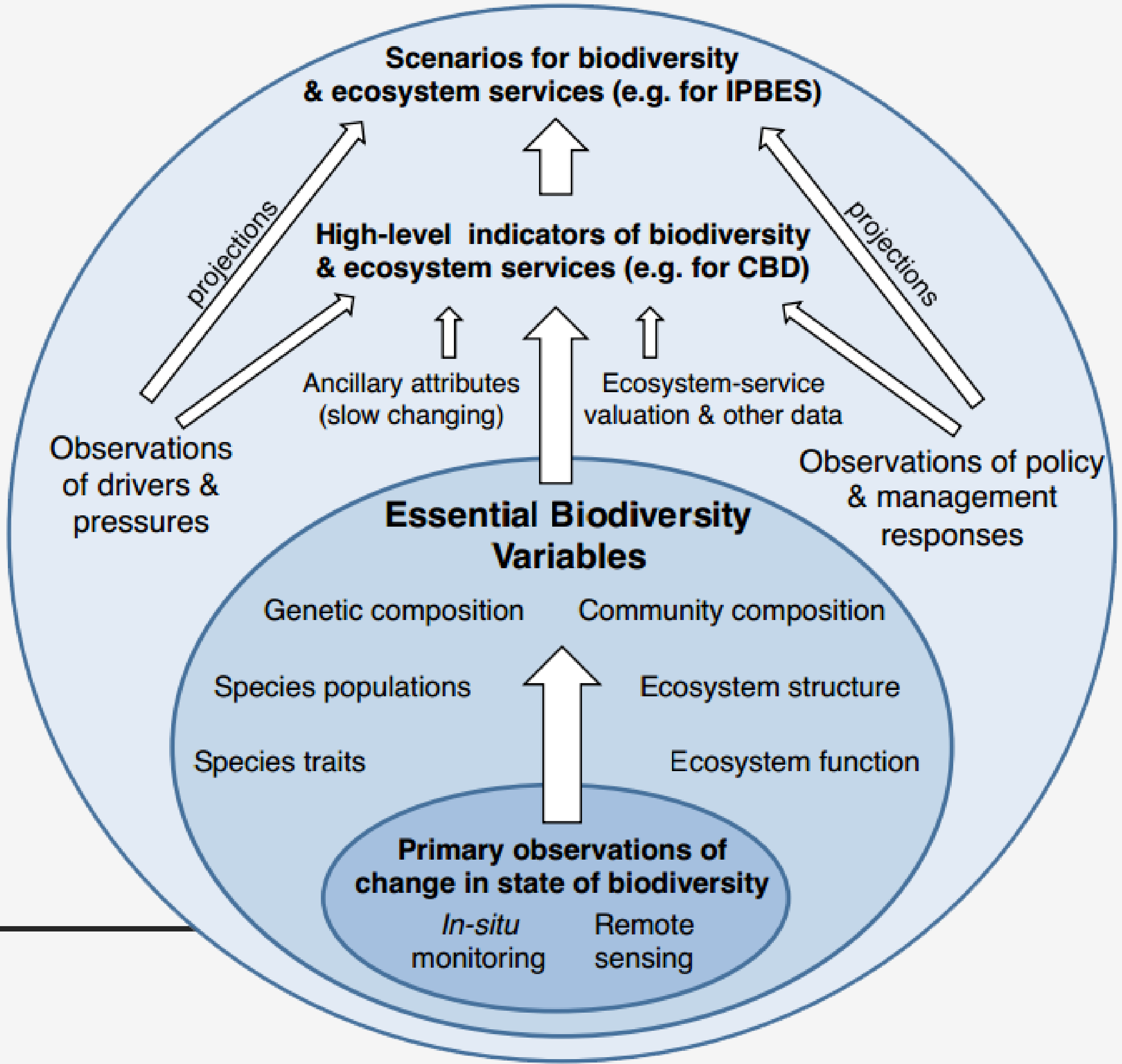


Figure 5: Global Living Planet Index shows a decline of 52 per cent between 1970 and 2010 (WWF, ZSL, 2014).

http://www.livingplanetindex.org/search

WHAT ARE ESSENTIAL BIODIVERSITY VARIABLES (EBVs)



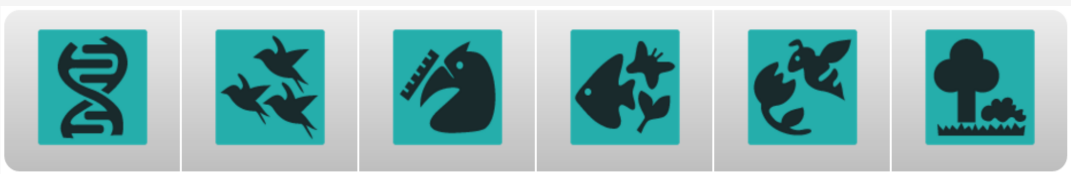
Pereira et al 2013 Nature

WHAT ARE ESSENTIAL BIODIVERSITY VARIABLES (EBVs)

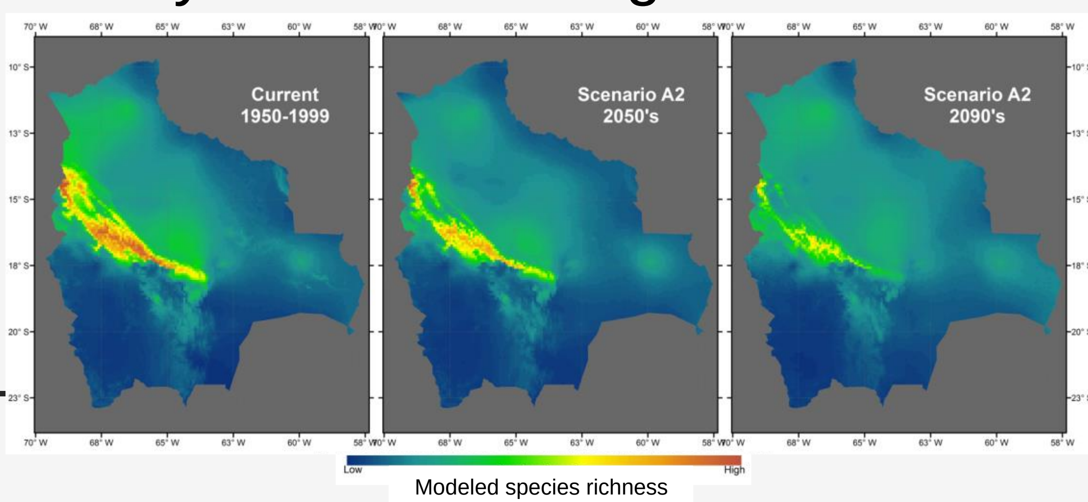
Characteristics of the EBVs:

- Quantifiable
- Repeatable
- Feasible
- Ecosystem agnostic

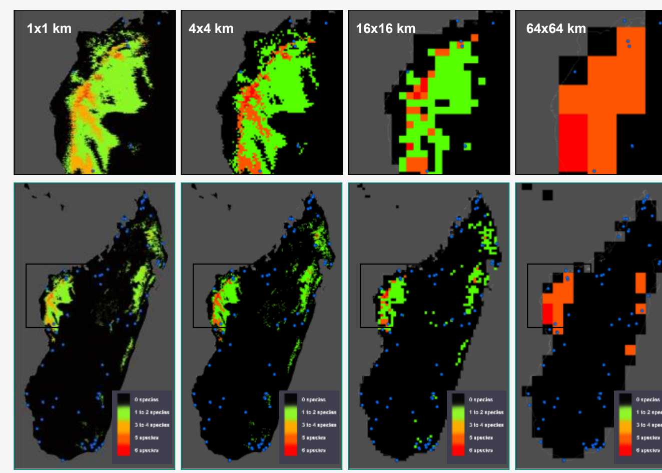
Cover all dimensions of biodiversity



Ability to detect change



Allow aggregation and disaggregation



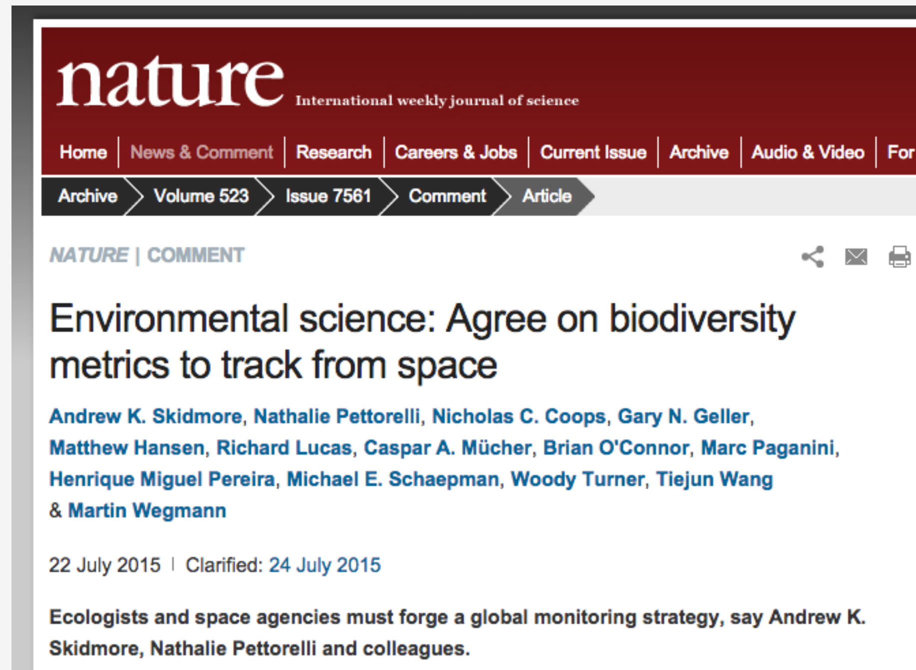
Slide from Miguel Fernandez (GEO BON/i

WHAT ARE ESSENTIAL BIODIVERSITY VARIABLES (EBVs)

EXAMPLES OF CANDIDATE ESSENTIAL BIODIVERSITY VARIABLES					
EBV class	**EBV examples**	**Measurement and scalability**	**Temporal sensitivity**	**Feasibility**	**Relevance for CBD targets and indicators (*1*,*9*)**
Genetic composition	Allelic diversity	Genotypes of selected species (e.g., endangered, domesticated) at representative locations.	Generation time	Data available for many species and for several locations, but little global systematic sampling.	Targets: 12, 13. Indicators: Trends in genetic diversity of selected species and of domesticated animals and cultivat plants; RLI.
Species populations	Abundances and distributions	Counts or presence surveys for groups of species easy to monitor or important for ES, over an extensive network of sites, complemented with incidental data.	1 to >10 years	Standardized counts under way for some taxa but geographically restricted. Presence data collected for more taxa. Ongoing data integration efforts (Global Biodiversity Information Facility, Map of Life).	Targets: 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15. Indicators: LPI; WBI; RLI; population and extinctic risk trends of target species, forest specialists in forests under restoration, and species that provid ES; trends in invasive alien species; trends in climatic impacts on populations.
Species traits	Phenology	Timing of leaf coloration by RS, with in situ validation.	1 year	Several ongoing initiatives (Phenological Eyes Network, PhenoCam, etc.)	Targets: 10, 15. Indicators: Trends in extent and rate of shifts of boundaries of vulnerable ecosystems.
Community composition	Taxonomic diversity	Consistent multitaxa surveys and metagenomics at select locations.	5 to >10 years	Ongoing at intensive monitoring sites (opportunities for expansion). Metagenomics and hyperspectral RS emerging.	Targets: 8, 10, 14. Indicators: Trends in condition and vulnerability c ecosystems; trends in climatic impacts on community composition.
Ecosystem structure	Habitat structure	RS of cover (or biomass) by height (or depth) globally or regionally.	1 to 5 years	Global terrestrial maps available with RS (e.g., Light Detection and Ranging). Marine and freshwater habitats mapped by combining RS and in situ data.	Targets: 5, 11, 14, 15. Indicators: Extent of forest and forest types; mangrove extent; seagrass extent; extent of habitats that provide carbon storage.
Ecosystem function	Nutrient retention	Nutrient output/input ratios measured at select locations.	1 year	Intensive monitoring sites exist for N saturation in acid-deposition areas and	Targets: 5, 8, 14. Indicators: Trends in delivery of multiple ES; tren

WHAT ARE REMOTE SENSING EBVs?

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



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Archive > Volume 523 > Issue 7561 > Comment > Article

NATURE | COMMENT

Environmental science: Agree on biodiversity metrics to track from space

Andrew K. Skidmore, Nathalie Pettorelli, Nicholas C. Coops, Gary N. Geller, Matthew Hansen, Richard Lucas, Caspar A. Mücher, Brian O'Connor, Marc Paganini, Henrique Miguel Pereira, Michael E. Schaepman, Woody Turner, Tiejun Wang & Martin Wegmann

22 July 2015 | Clarified: 24 July 2015

Ecologists and space agencies must forge a global monitoring strategy, say Andrew K. Skidmore, Nathalie Pettorelli and colleagues.

RS-EBVs SLOWLY EMERGE…

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 hetrogeneity
- Land cover
- Vegetation height

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

10 RS-EBVs proposed in RS-EBV paper by Skidmore et al 2015

EBV Class	Candidate RS-EBV	Potential support for Aichi targets
Species populations	Species distribution*	4,5,7,9,10,11,12,14,15
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Species traits	Phenology (e.g., leaf-on and leaf-off dates; peak season)	5,9,11,12,14,15
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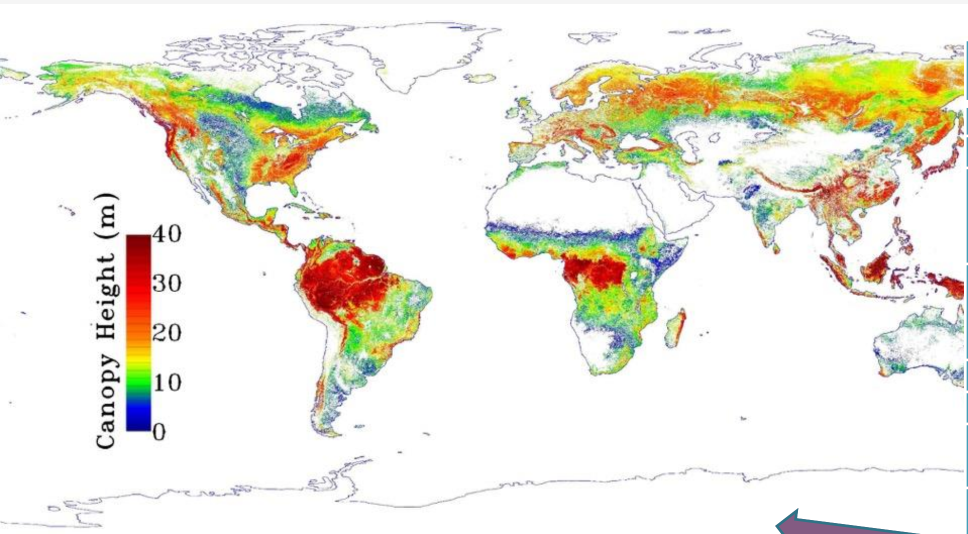
Ecosystem structure	Habitat structure (e.g., height, crown cover and density)	5,7,9,14,15
Ecosystem structure	Ecosystem extent and fragmentation	5,11,12,14,15
Ecosystem structure	composition by land cover	5,7,10,12,14,15

List of candidate RS-EBVs submitted to CBD

Continuous variables
Categorical variables

CONTINUOUS RS-EBVs

ECOSYSTEM STRUCTURE – VEGETATION HEIGHT



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JOURNAL OF GEOPHYSICAL RESEARCH
Biogeosciences
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JGR
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Mapping forest canopy height globally with spaceborne lidar

Marc Simard, Naiara Pinto, Joshua B. Fisher, Alessandro Baccini

First published: 19 November 2011 Full publication history

DOI: 10.1029/2011JG001708 View/save citation

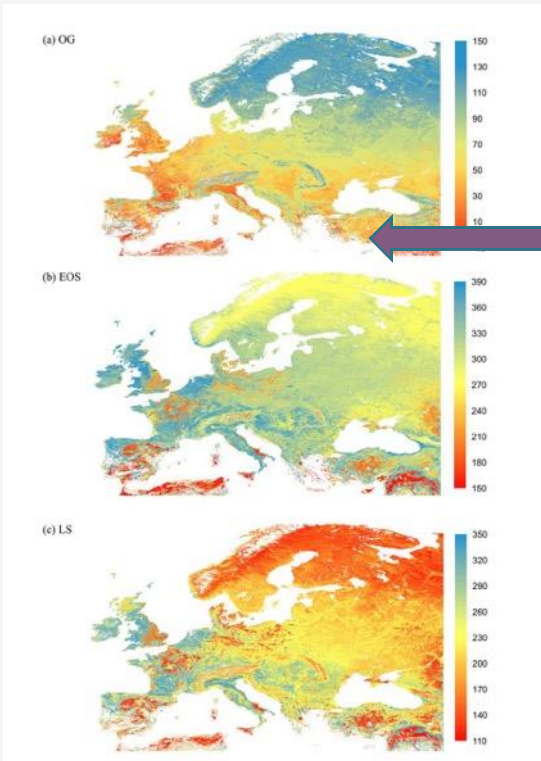
Global map of vegetation height produced from NASA's ICESAT/GLAS, MODIS sensors. Image credit: NASA/JPL-Caltech

http://webmap.ornl.gov/wcsdown/dataset.jsp?ds_id=10023

CONTINUOUS RS-EBVs

PHENOLOGY

Phenology maps of Europe in Julian days. A) onset on greenness (OG), B) end of senescence (EOS), C) length of the season (LS).



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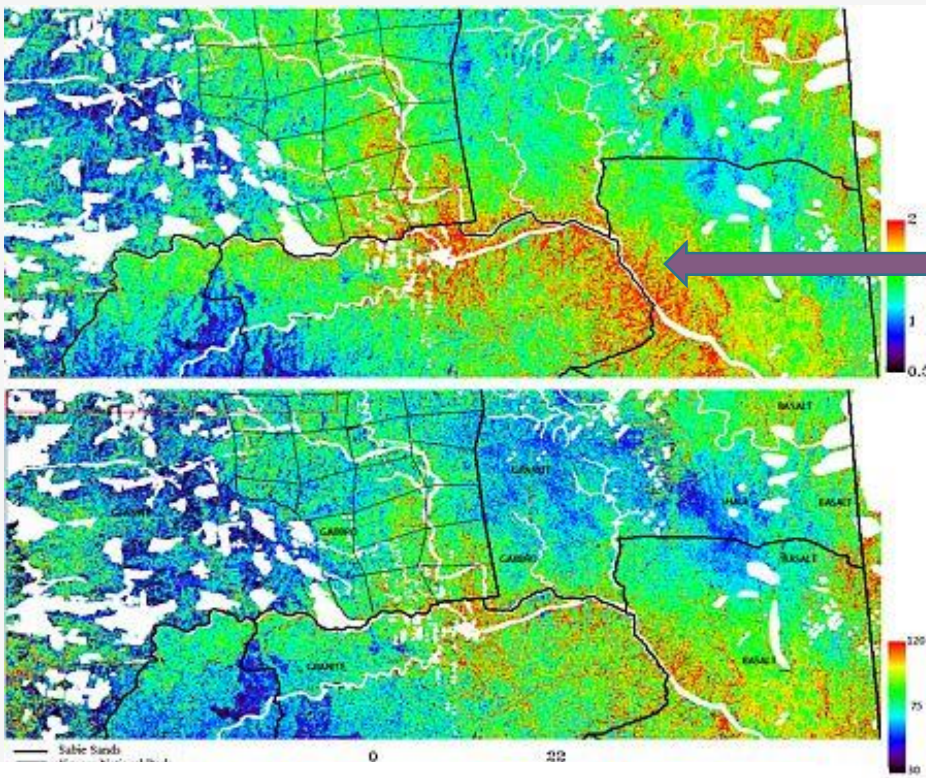
Geophysical Research Letters

Intercomparison of satellite sensor land surface phenology and ground phenology in Europe

CONTINUOUS RS-EBVs

PLANT TRAITS



Leaf nitrogen (top) and canopy nitrogen (bottom) in savanna South Africa (Kruger NP to Sabi Sands). Red edge band of RapidEye

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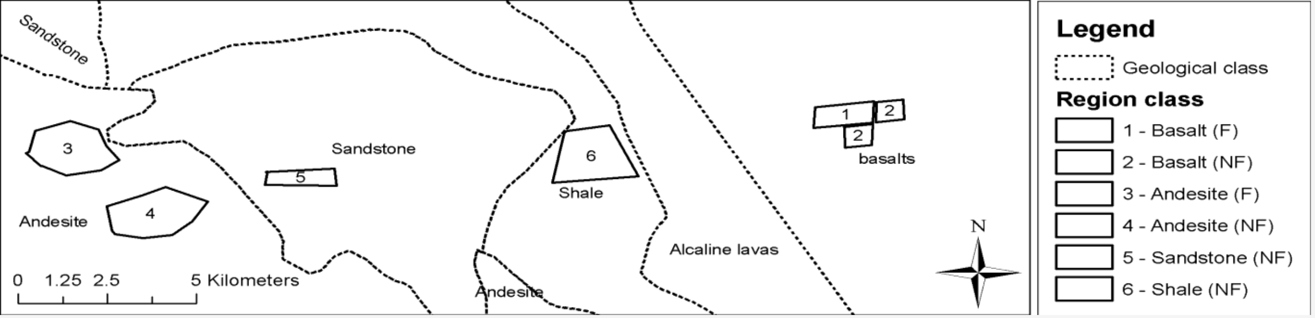
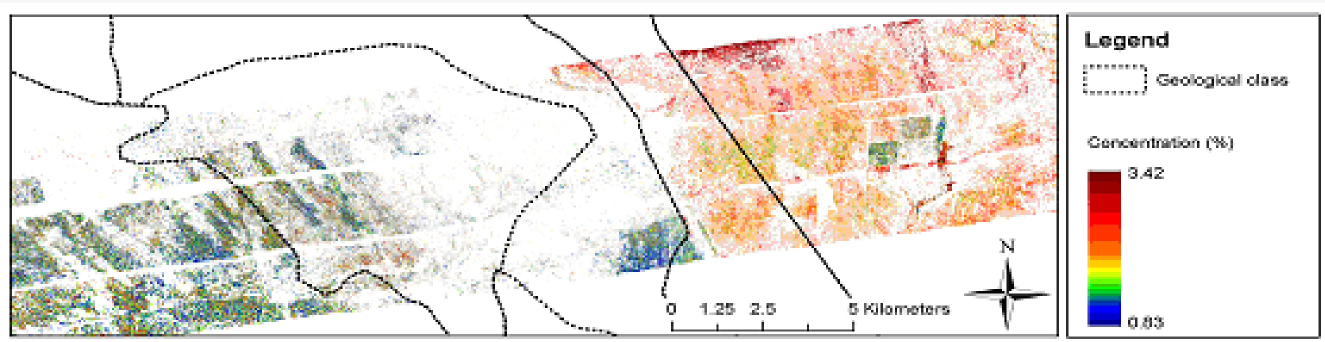
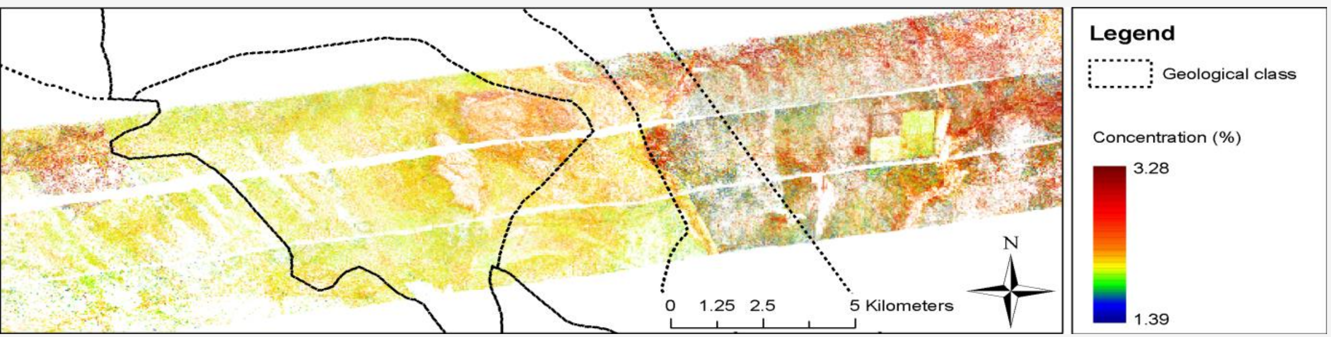
Ramoelo A, et al (2012) JAG 19, pp: 151-162)



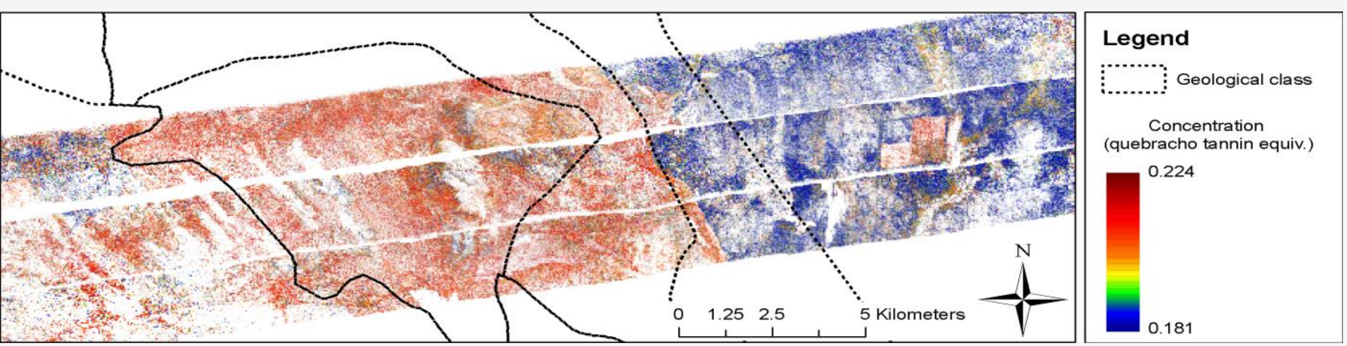
Geology



Foliar nitrogen grasses



Foliar nitrogen mopane

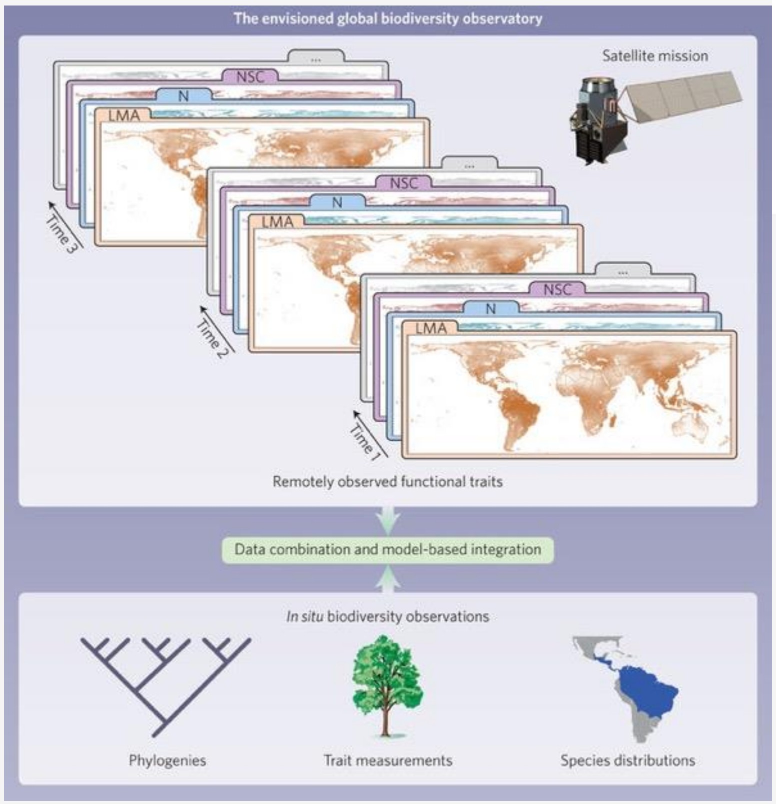


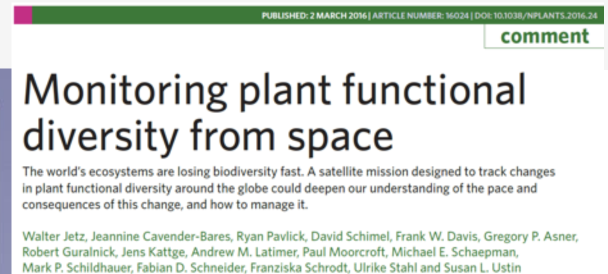
Tannin mopane

Skidmore et al RSE. (2010)

CONTINUOUS RS-EBVs

ECOSYSTEM FUNCTION




PUBLISHED: 2 MARCH 2016 | ARTICLE NUMBER: 16024 | DOI: 10.1038/NPLANTS.2016.24

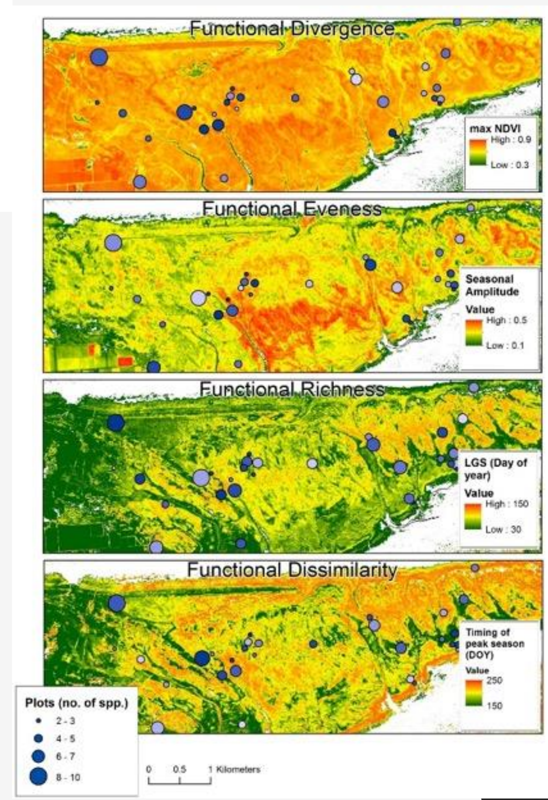
comment

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, Jeannine Cavender-Bares, Ryan Pavlick, David Schimel, Frank W. Davis, Gregory P. Asner, Robert Guralnick, Jens Kattge, Andrew M. Latimer, Paul Moorcroft, Michael E. Schaepman, Mark P. Schildhauer, Fabian D. Schneider, Franziska Schrodt, Ulrike Stahl and Susan L. Ustin

ESA Innovator Project
RS for EBV



CATEGORICAL RS-EBVs

- Subjective: Expert input
- Separate entities (classes) – challenge to define
- Categorical (nominal, ordinal or dichotomous)
- Closer to biodiversity indicators
  Requires ancillary data

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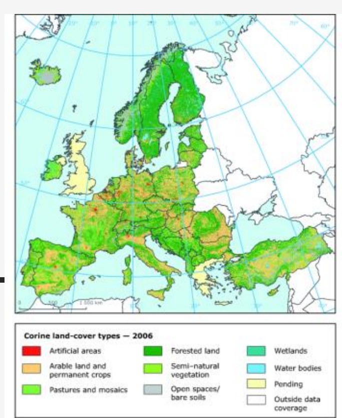


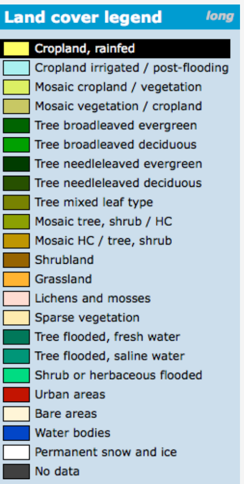
CATEGORICAL RS-EBVs

LAND COVER

The ESA Land Cover CCI

A consistent set of global Land Cover products at 300m

3 **consistent global LC** maps for epochs **2000**, **2005** and **2010**



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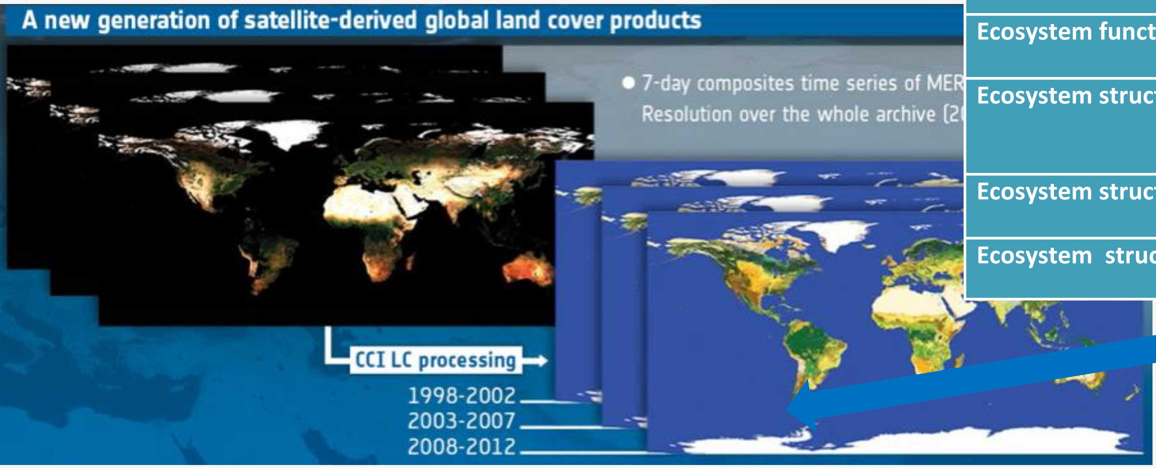
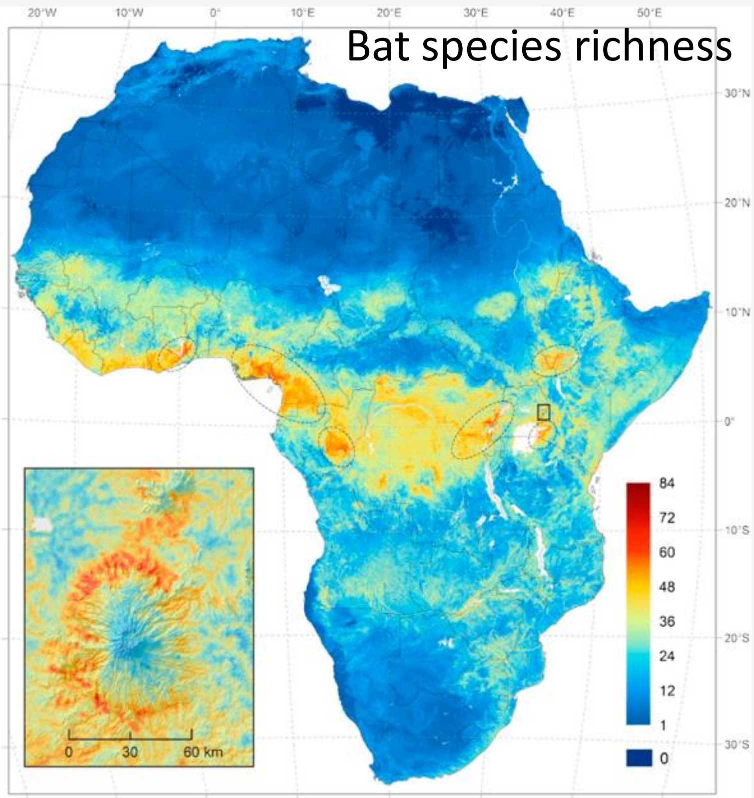
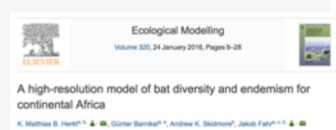


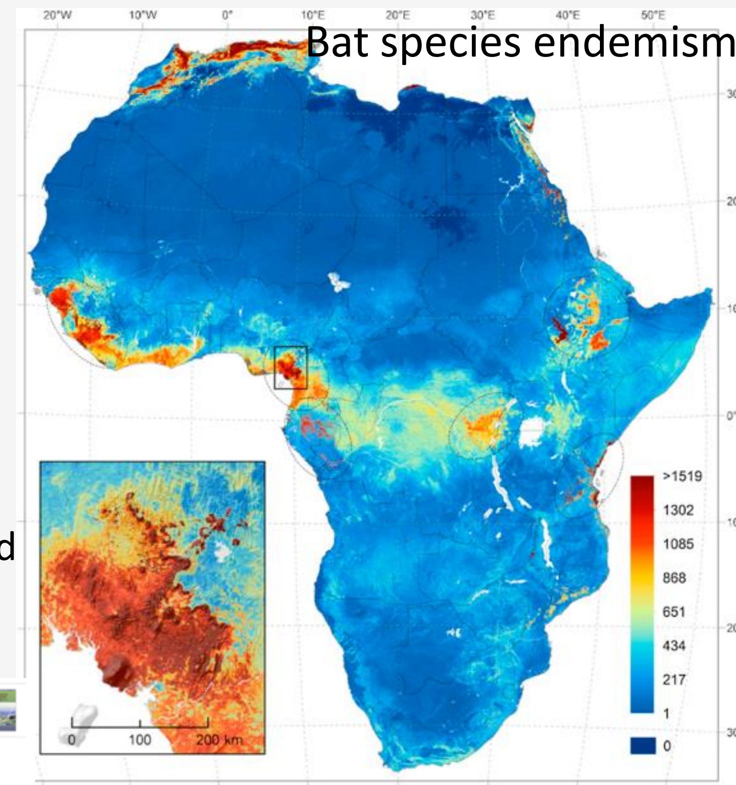
CATEGORICAL RS-EBVs

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

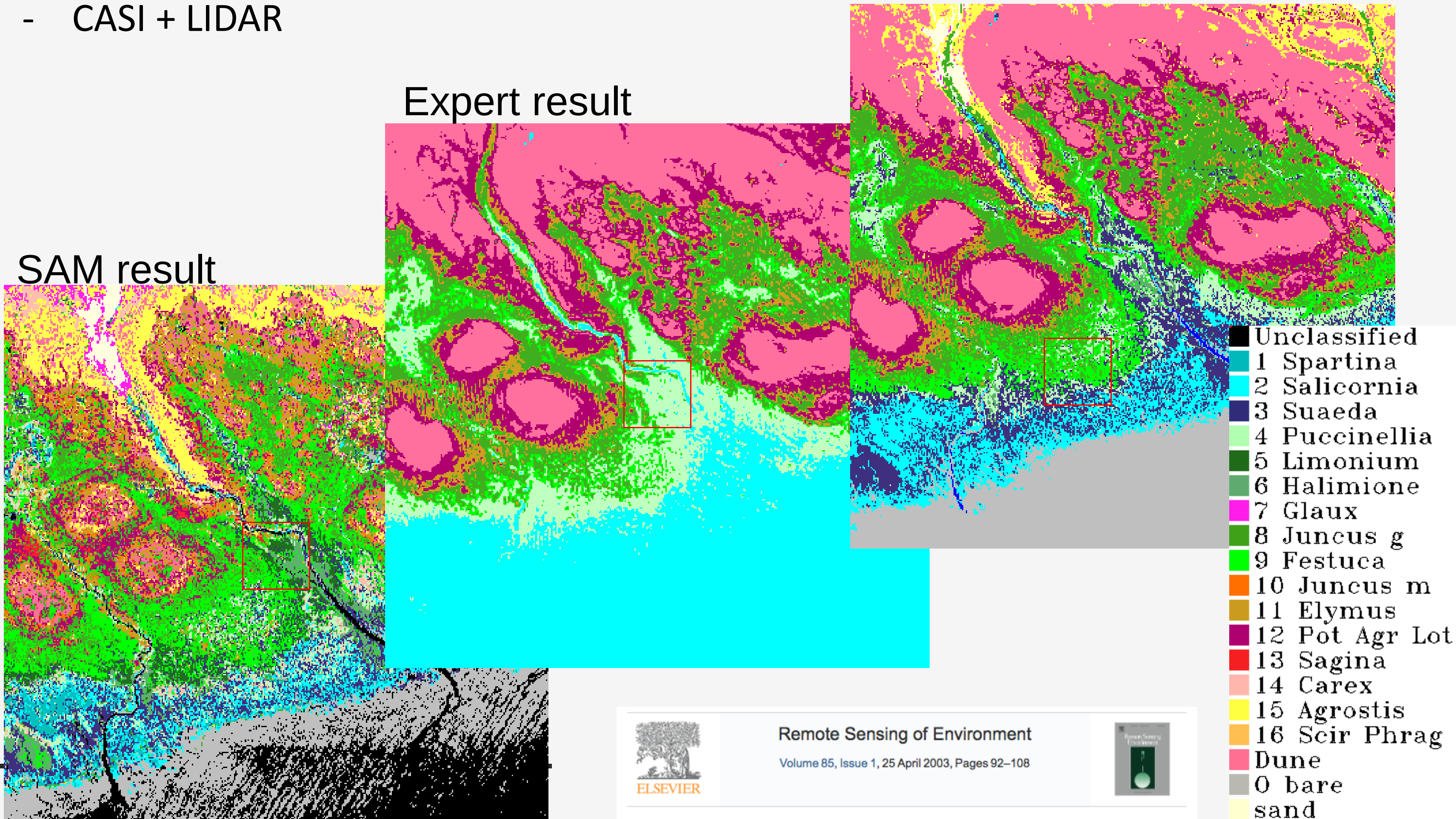

Ecological Modelling
Volume 320, 24 January 2016, Pages 9–28
A high-resolution model of bat diversity and endemism for continental Africa
K. Matthias B. Herkt, Günter Barnikel, Andrew K. Skidmore, Jakob Fahr



CATEGORICAL RS-EBVs

SPECIES ABUNDANCE IN A DUTCH SALTMARSH

- CASI + LIDAR



Remote Sensing of Environment
Volume 85, Issue 1, 25 April 2003, Pages 92–108

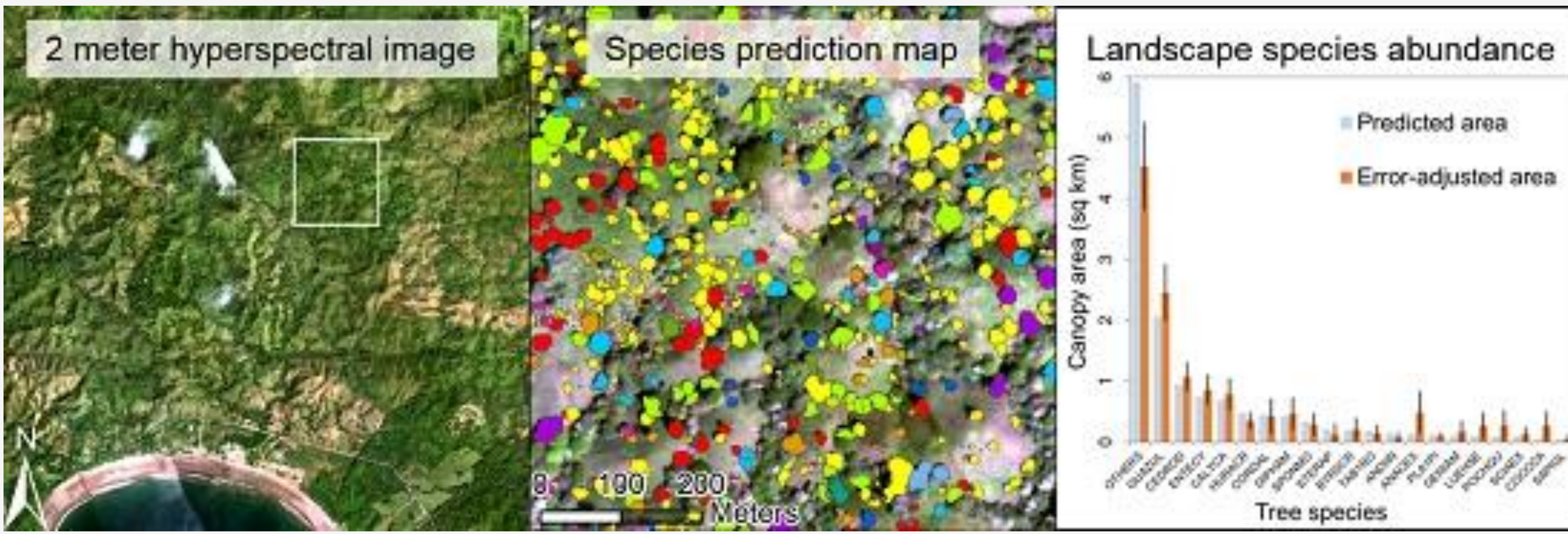
Spectral discrimination of vegetation types in a coastal wetland

K.S. Schmidt, A.K. Skidmore

CATEGORICAL RS-EBVs

SPECIES ABUNDANCE IN A TROPICAL AGRICULTURAL LANDSCAPE

- CAO: airborne hyperspectral @ 5m
- Trees identified by LIDAR ht
- Tree species classified by support vector machine (SVM)



Open Access Article

Tree Species Abundance Predictions in a Tropical Agricultural Landscape with a Supervised Classification Model and Imbalanced Data

by Sarah J. Graves, Gregory P. Asner, Roberta E. Martin, Christopher B. Anderson, Matthew S. Colgan, Leila Kalantari and Stephanie A. Bohlman

Remote Sens. **2016**, *8*(2), 161; doi:10.3390/rs8020161
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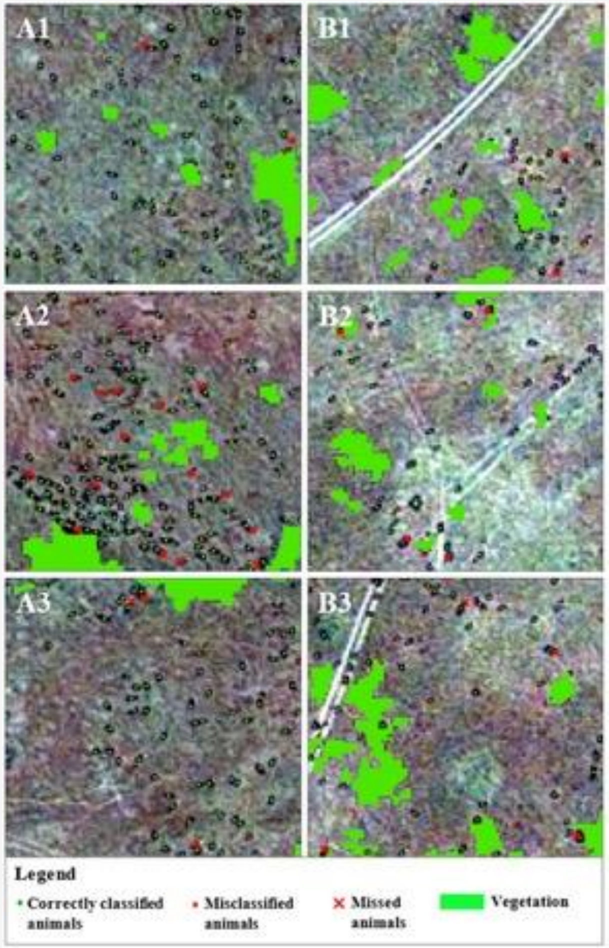
Cited by 5 | Viewed by 810 | PDF Full-text (5505 KB) | HTML Full-text | XML Full-text | Supplementary Files

CATEGORICAL RS-EBVs

ANIMAL SPECIES ABUNDANCE

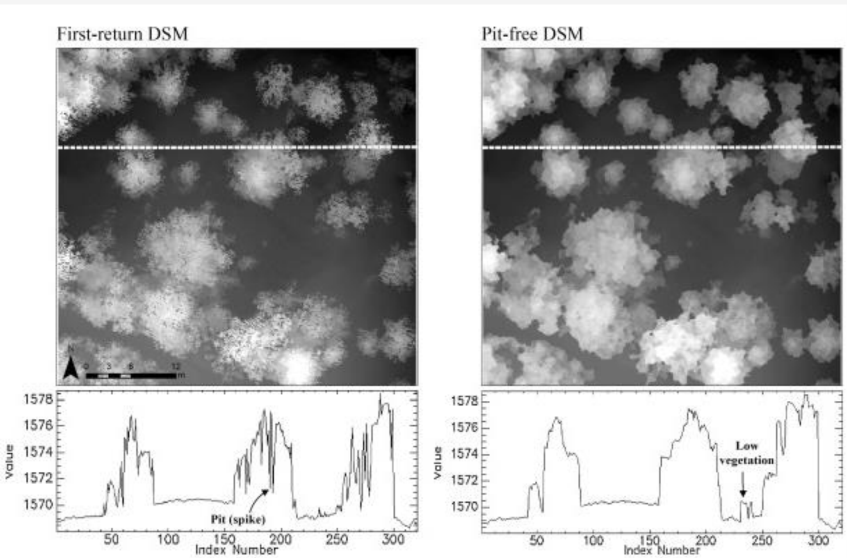
- Very high resolution instruments directly observe large or gregarious animals



Yang Z, et al (2014) Spotting East African Mammals in Open Savannah from Space. PLoS ONE 9(12)

GLOBAL BIODIVERSITY OBSERVING SYSTEM

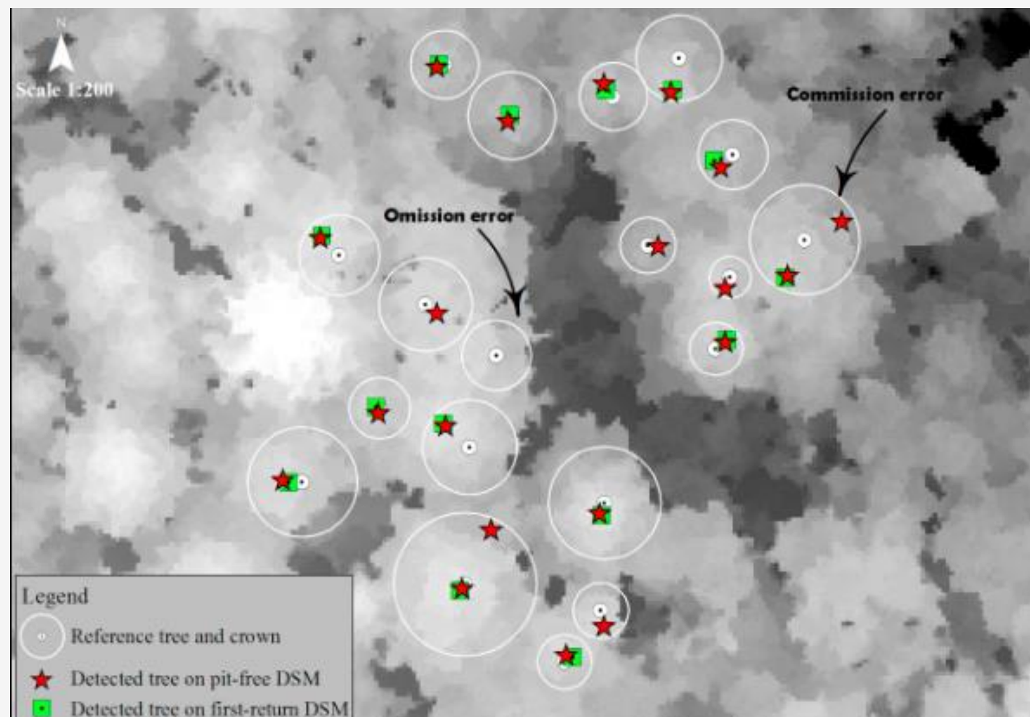
SOLUTION – HIGHER SPATIAL RESOLUTION USING LIDAR



International Journal of Applied Earth Observation and Geoinformation
Volume 52, October 2016, Pages 104–114

Generating spike-free digital surface models using LiDAR raw point clouds: A new approach for forestry applications

Anahita Khosravipour[a], Andrew K. Skidmore[a], Martin Isenburg[b]



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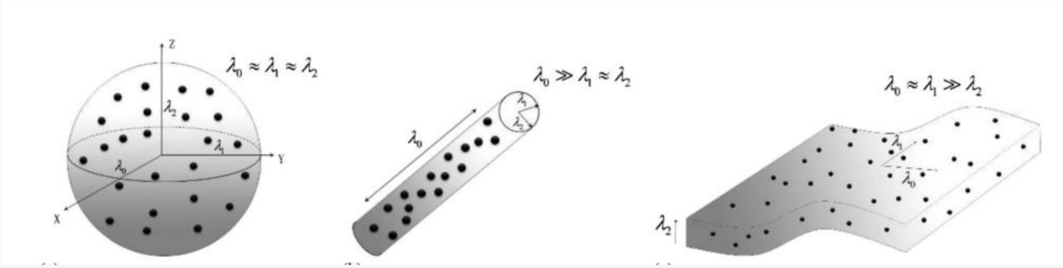
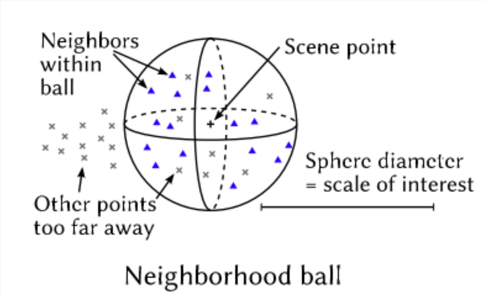
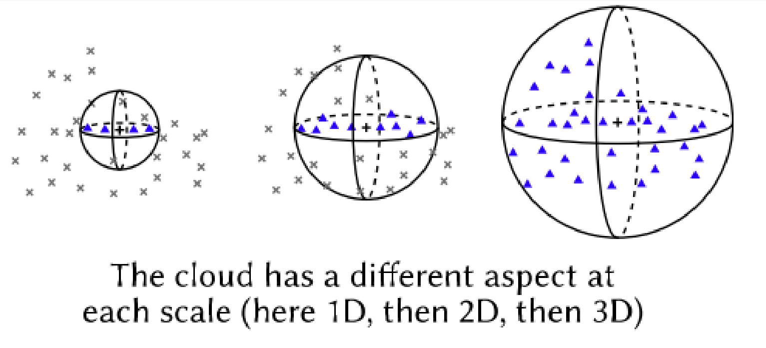
SOLUTION – HIGHER SPATIAL RESOLUTION USING LIDAR

- Dimensionality feature which label objects as different shapes (Linear, surface, random representing leaf, ground, branch)
- When we use different radius, the dimensionality of the single point can be different.







http://ezproxy.utwente.nl:2084/science/article/pii/S0303243416300873

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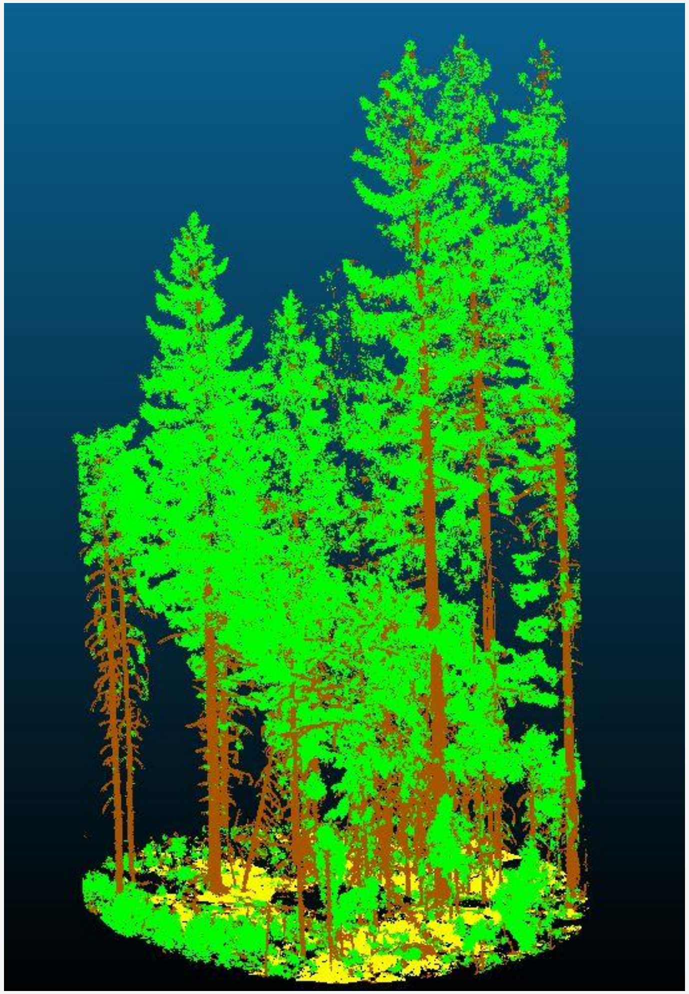
SOLUTION – HIGHER SPATIAL RESOLUTION USING LIDAR



http://ezproxy.utwente.nl:2084/science/article/pii/S0303243416300873

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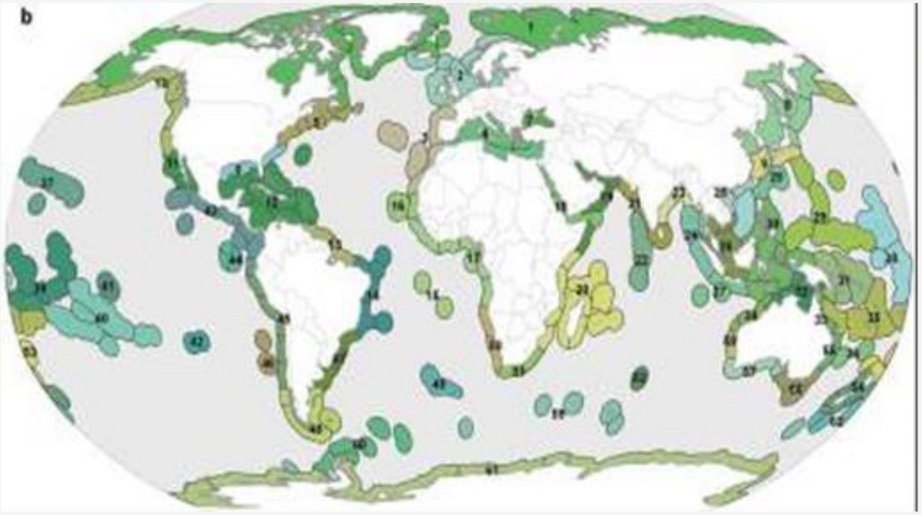
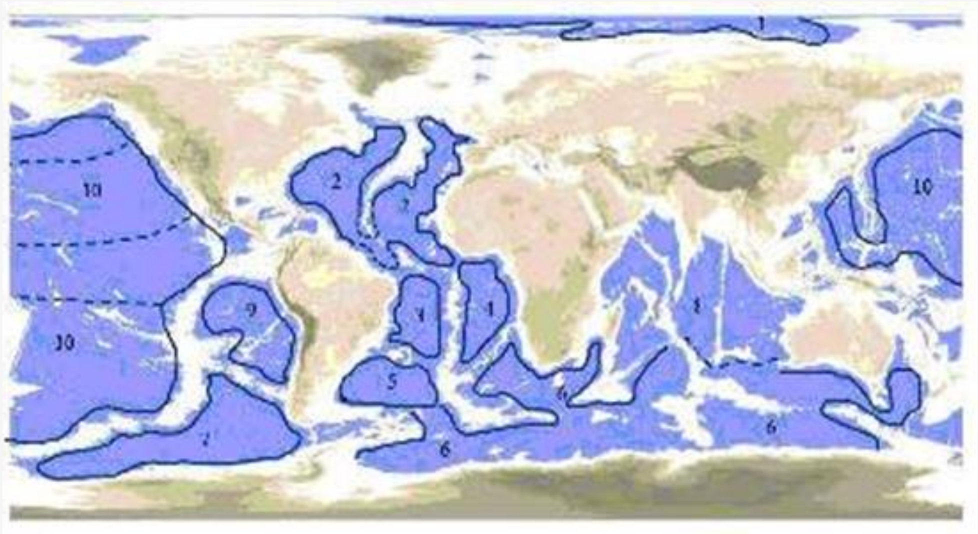
SOLUTIONS – TERRESTRIAL AND OCEANS





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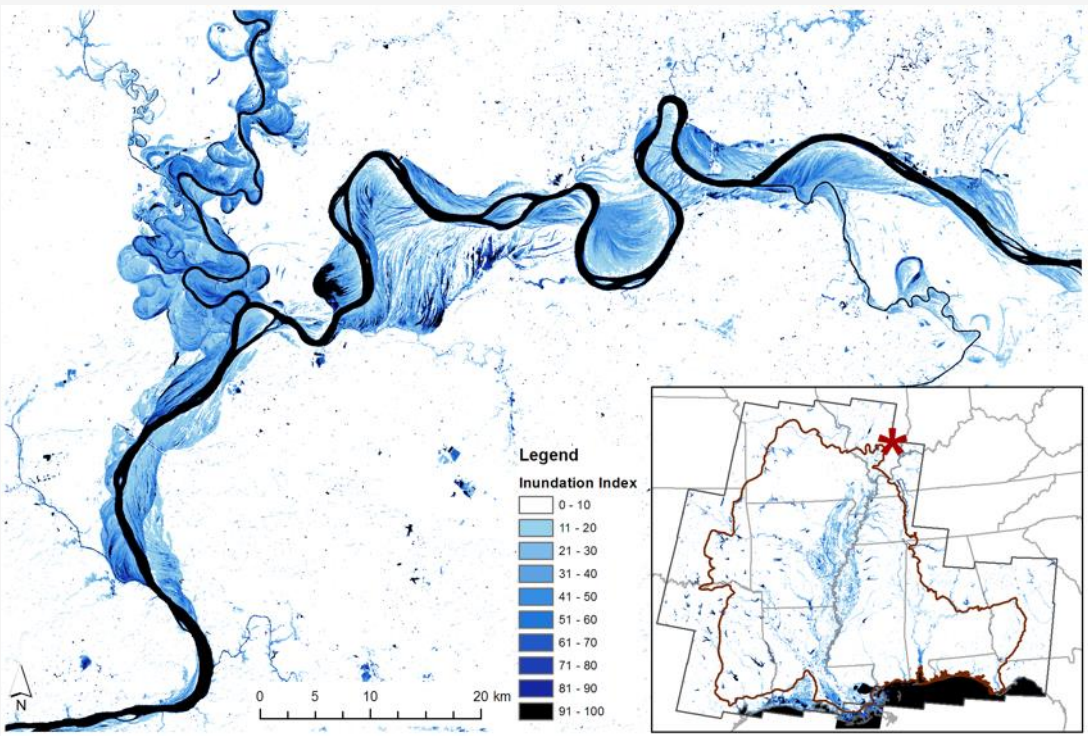
SOLUTIONS - GLOBAL SURFACE WATER - JRC



LETTER

doi:10.1038/nature20584

High-resolution mapping of global surface water and its long-term changes

Jean-François Pekel[1], Andrew Cottam[1], Noel Gorelick[2] & Alan S. Belward[1]

The location and persistence of surface water (inland and coastal) is both affected by climate and human activity[1] and affects climate[2,3], biological diversity[4] and human wellbeing[5,6]. Global from reservoir filling, although climate change[14] is also implicated. Loss is more geographically concentrated than gain. Over 70 per cent of global net permanent water loss occurred in the Middle East

River Research and Applications

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Research Article

Landscape Scale Assessment of Floodplain Inundation Frequency Using Landsat Imagery

Y. Allen

First published: 18 December 2015 Full publication history

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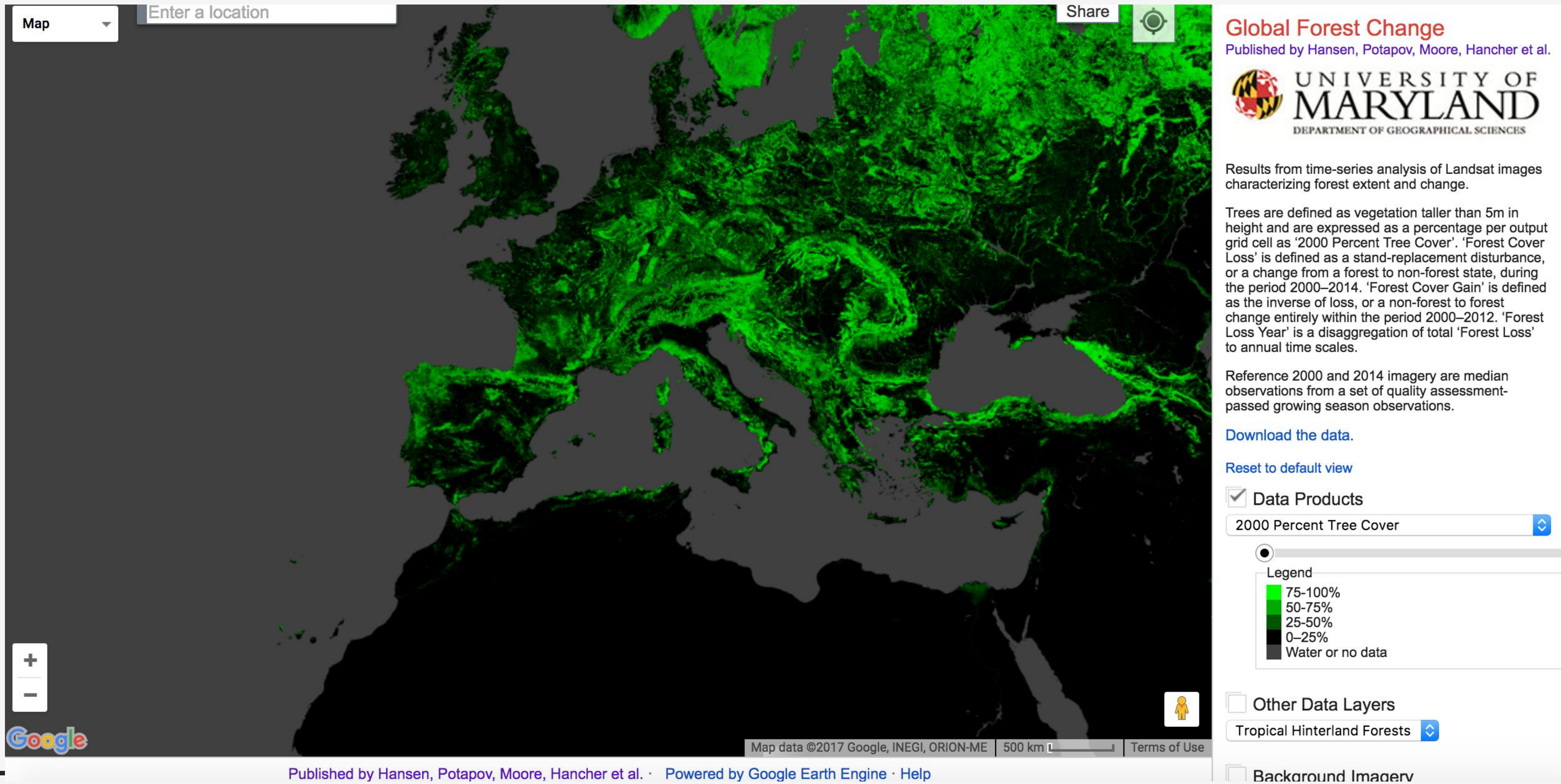
SOLUTIONS – FOREST COVER



https://earthenginepartners.appspot.com/science-2013-global-forest

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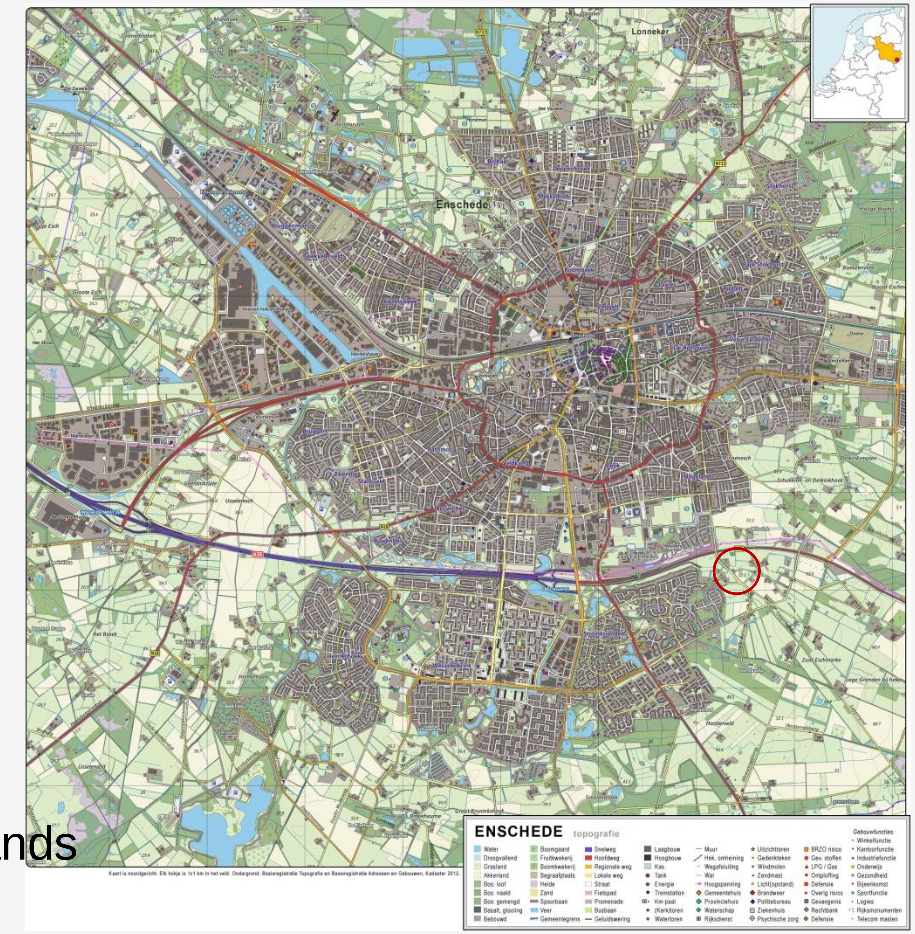
ACCURACY



Netherlands

Dutch topographic map 1:25000

Aerodata International 10 cm air photo + Hansen Forest 2000 Landsat 7

JRC Forest Map 2006 23m (FMAP2006)

IRS-P6 LISS-III

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-i
http://forest.jrc.ec.europa.eu/download/data/google-earth-overlays/
http://earthenginepartners.appspot.com/science-2013-global-forest

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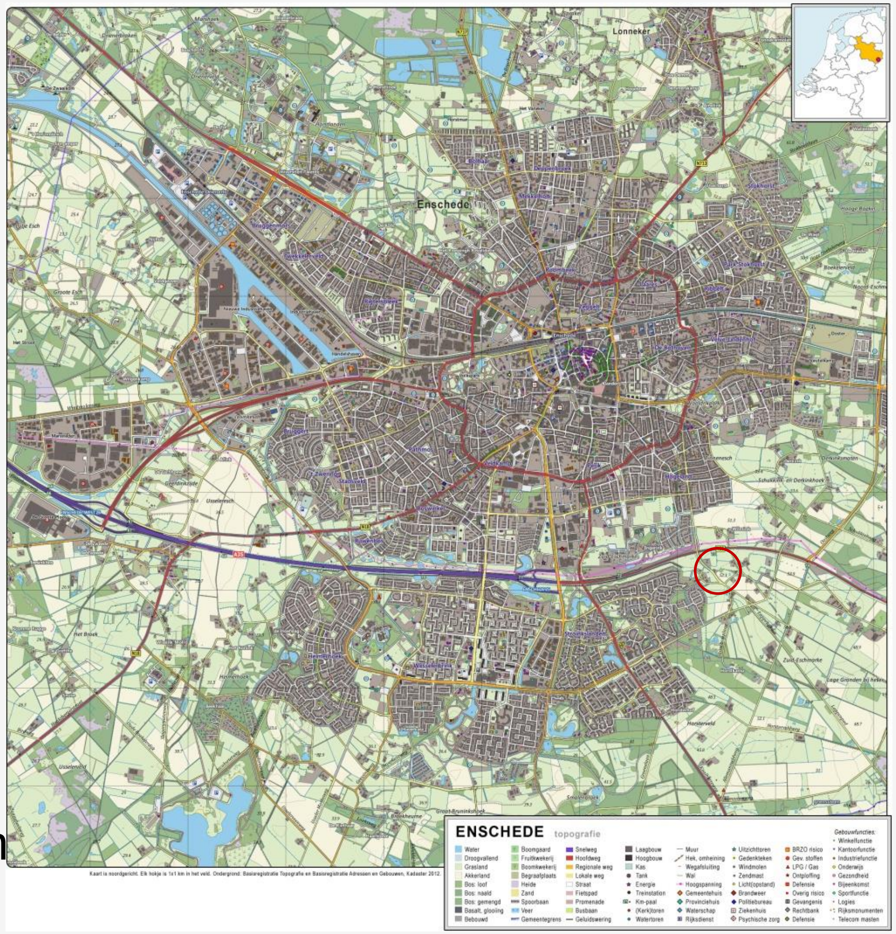
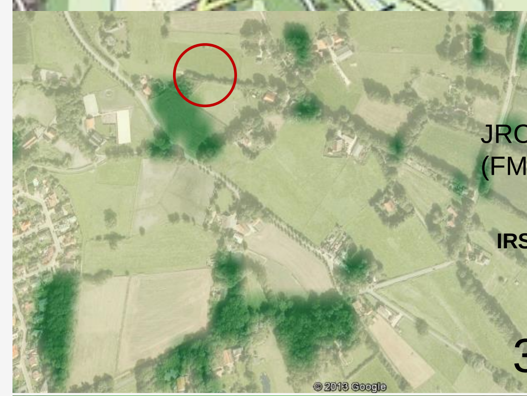
ACCURACY



Netherlan

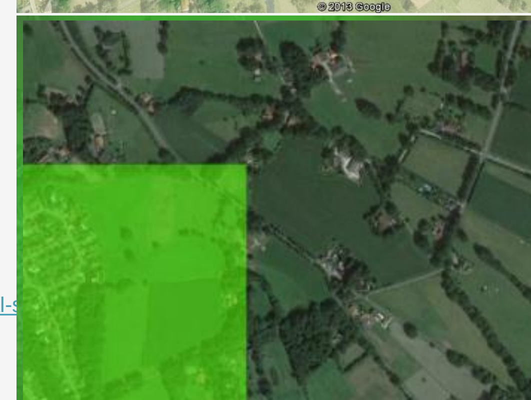
2.5 m



JRC Forest Map 2006 (FMAP2006)

IRS-P6 LISS-III

30 m



1 km global vegetation height

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-s
http://forest.jrc.ec.europa.eu/download/data/google-earth-overlays/

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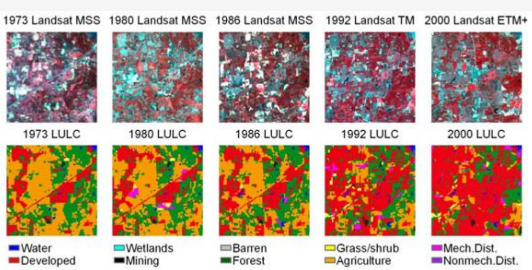
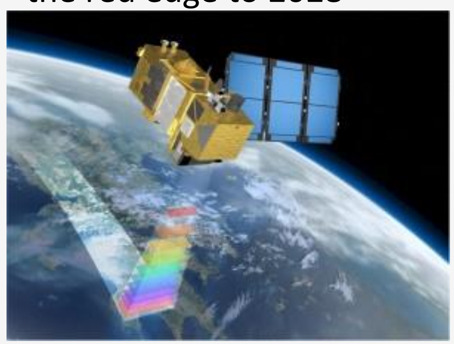
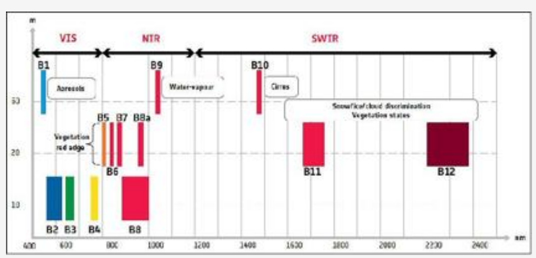
SOLUTION: PROGRESS IN SATELLITES AND IMAGE PROCESSING TECHNIQUES

Landsat – systematic and global acquisition for next 25 years

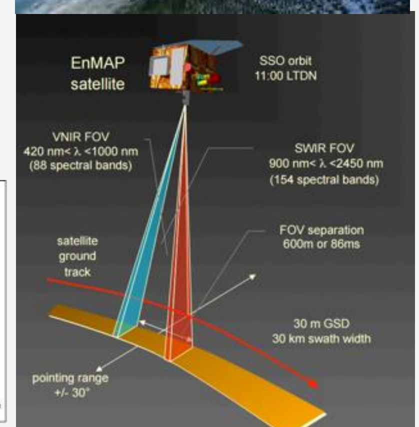


Sentinel-2 – systematic global acquisition including the red edge to 2028

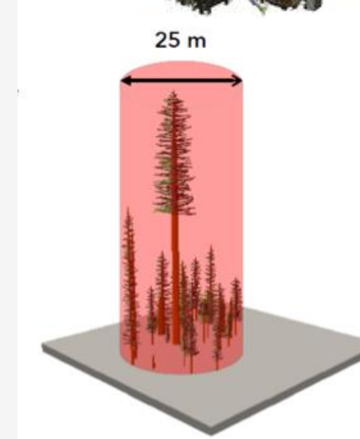




EnMAP- Environmental mapping and analysis program



GEDI – Global Ecosystems Dynamics Investigation LiDar



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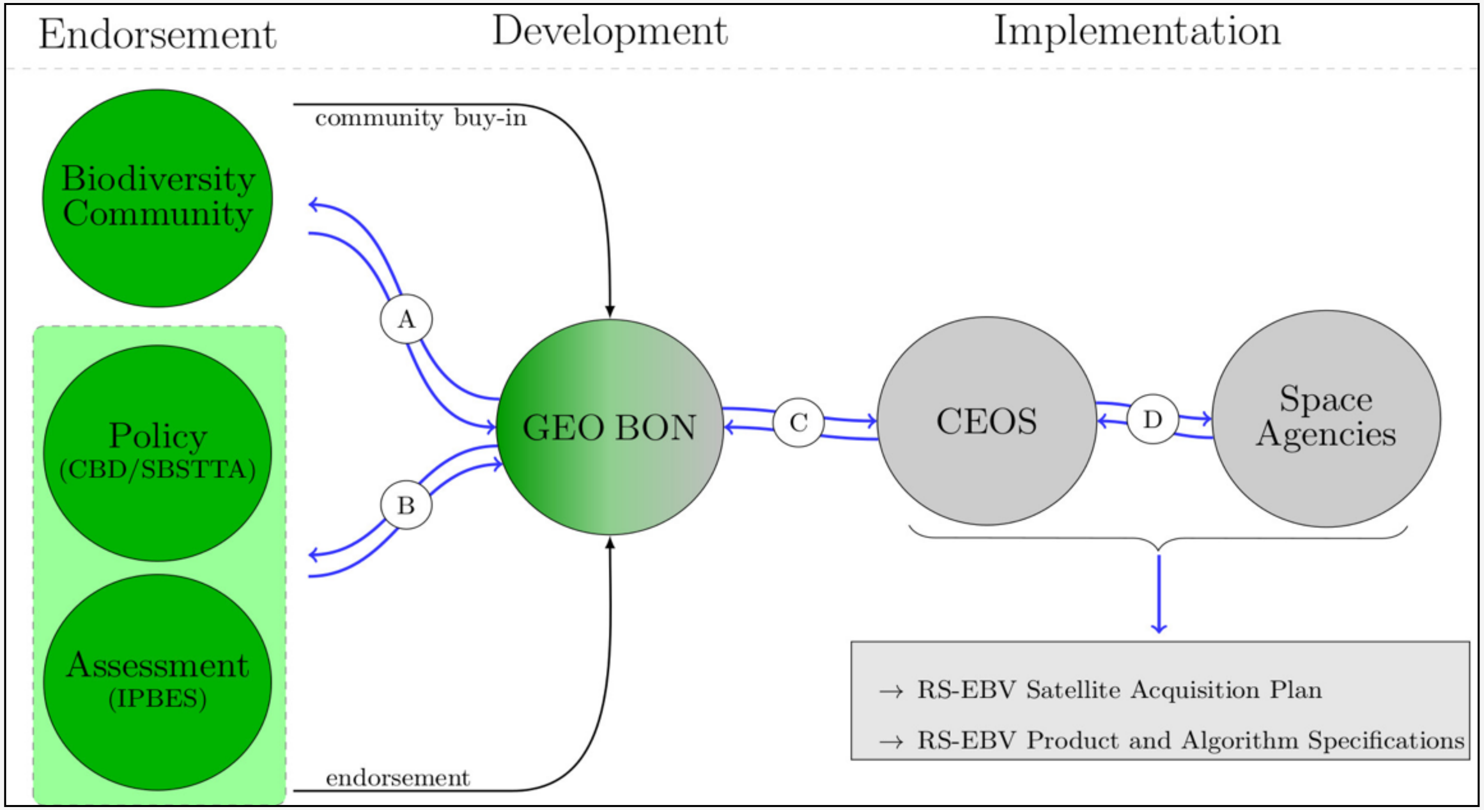

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RANKING OF EBVS

- 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

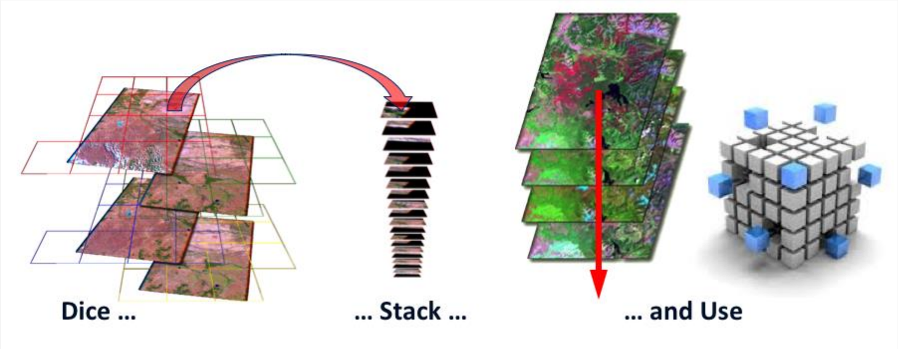
- Land cover P=1 F=1 I=1 S=2
- Fire Disturbance P=1 F=1 I=1 S=2
- Other Disturbance P=2 F=2 I=2 S=3

*based on TOPC (Terrestrial Observation Panel for Climate)

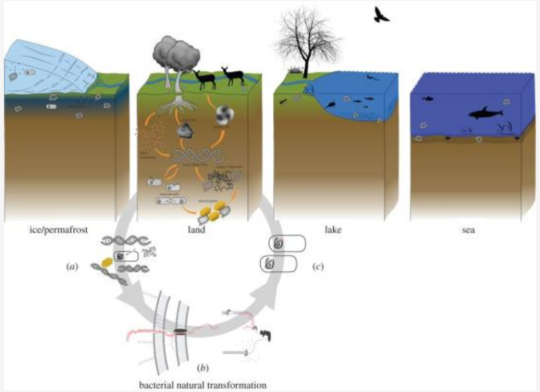
New connections:

linking remote sensing with

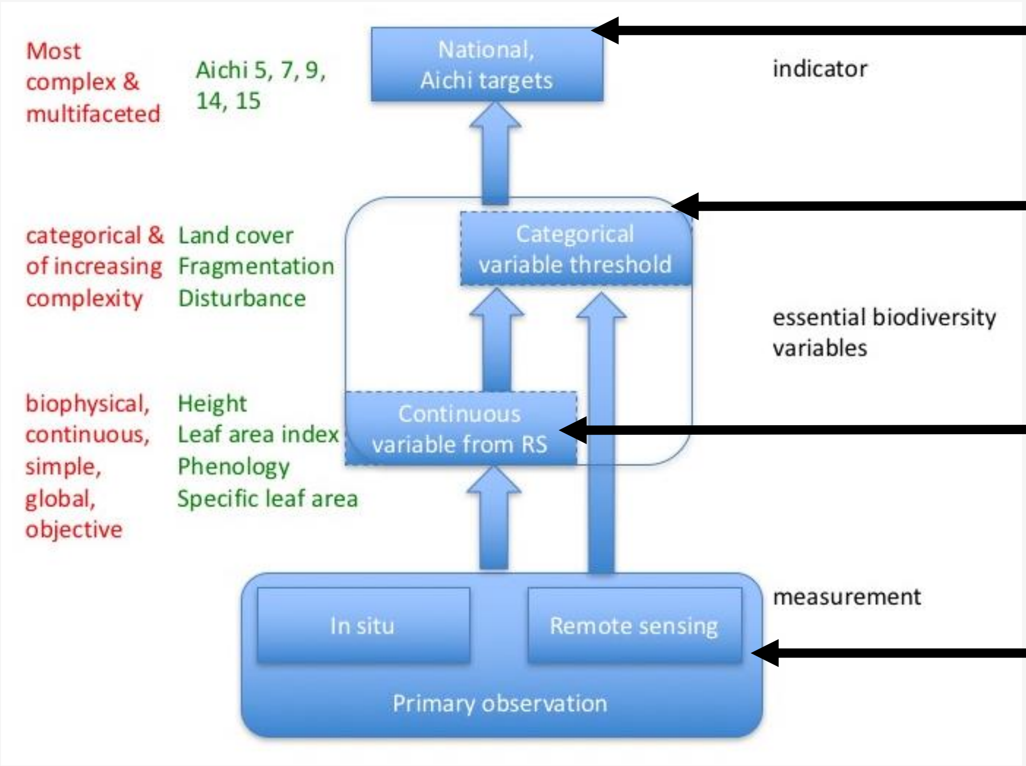
- Data cube and data sharing (DIAS)
  - Opportunities for H2020 e.g. EuroGEOSS



- eDNA and metagenomics (in situ data & functional ecology)



CONCLUSIONS



Policy level

EBV requiring ecological expertise and class thresholds

EBV most suited for direct retrieval from remote sensing

Measurements