Integrating global species distributions, remote sensing and climate data to model change in species distributions

Remote-sensing supported global terrestrial biodiversity monitoring

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Remote-sensing supported global terrestrial biodiversity monitoring

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Others: Jeremy Malczyk (Yale U), Map of Life Team (Yale, Boulder), Dave Thau (Google)
Objective 1: Strengthen the capacity and knowledge foundations of the science-policy interface to implement key functions of the Platform:
(a) Priority capacity-building needs to implement the Platform’s work programme matched with resources through catalysing financial and in-kind support
(b) Capacities needed to implement the Platform work programme developed
(c) Procedures, approaches for participatory processes for working with indigenous and local knowledge systems developed
(d) Priority knowledge and data needs for policymaking addressed through catalyzing efforts to generate new knowledge and networking

Objective 2: Strengthen the science-policy interface on biodiversity and ecosystem services at and across subregional, regional and global levels:
(a) Guide on production and integration of assessments from and across all scales
(b) Regional/subregional assessments on biodiversity, ecosystem services
(c) Global assessment on biodiversity and ecosystem services

Objective 3: Strengthen the science-policy interface on biodiversity and ecosystem services with regard to thematic and methodological issues:
(a) One fast track thematic assessment of pollinators, pollination and food production
(b) Three thematic assessments: land degradation and restoration; invasive alien species; and sustainable use and conservation of biodiversity and strengthening capacities/tools
(c) Policy support tools and methodologies for scenario analysis and modelling of biodiversity and ecosystem services based on a fast track assessment and a guide
(d) Policy support tools and methodologies regarding the diverse conceptualization of values of biodiversity and nature’s benefits to people including ecosystem services based on an assessment and a guide

Objective 4: Communicate and evaluate Platform activities, deliverables and findings:
(a) Catalogue of relevant assessments
(b) Development of an information and data management plan
(c) Catalogue of policy support tools and methodologies
(d) Set of communication, outreach and engagement strategies, products and processes
(e) Reviews of the effectiveness of guidance, procedures, methods and approaches to inform future development of the Platform
Essential Biodiversity Variables

Examples of Candidate Essential Biodiversity Variables

<table>
<thead>
<tr>
<th>EBV Class</th>
<th>EBV Examples</th>
<th>Measurement and Scalability</th>
<th>Relevance for CBD Targets and Indicators (1,9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic composition</td>
<td>Allelic diversity</td>
<td>Genotypes of selected species (e.g., endangered, domesticated) at representative locations.</td>
<td>Targets: 12, 13. Indicators: Trends in genetic diversity of selected species and of domesticated animals and cultivated plants; RLI.</td>
</tr>
<tr>
<td>Species populations</td>
<td>Abundances and distributions</td>
<td>Counts or presence surveys for groups of species to monitor the importance for ES, over an extensive network of sites, complemented with incidental data.</td>
<td>Targets: 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15. Indicators: LPI; WBI; RLI; population and extinction risk; trends in invasive alien species; trends in climatic impacts on populations.</td>
</tr>
<tr>
<td>Species traits</td>
<td>Phenology</td>
<td>Timing of leaf coloration by RS, with in situ validation.</td>
<td>Targets: 10, 15. Indicators: Trends in extent and rate of shifts of boundaries of vulnerable ecosystems.</td>
</tr>
<tr>
<td>Ecosystem structure</td>
<td>Habitat structure</td>
<td>RS of cover (or biomass) by height (or depth) globally or regionally.</td>
<td>Targets: 5, 11, 14, 15. Indicators: Extent of forest and forest types; mangrove extent; seagrass extent; extent of habitats that provide carbon storage.</td>
</tr>
</tbody>
</table>

“Biodiversity Indicators”
Global Biodiversity Monitoring

How to achieve a globally representative and generalizable biodiversity monitoring for scientifically rigorous assessment of change?

What can remote sensing contribute?
Global Biodiversity Monitoring

I. Providing representative baselines: species distributions, communities, environment

II. Quantifying environmental change

III. Detecting, monitoring biodiversity change
Species Distributions

- Climate: 1997 - present: TRMM
- Topography: 1996: GTOP030
- Landcover future: 1992: BIOME

Hurlbert and Jetz (PNAS 2007)
Jetz et al. (Conservation Biology 2008)
ASTER GDEM V2

SRTM V4

Full global-extent 90m DEM

Blended, void-filled, multi-scale smoothed

For global derivation of terrain variables and distribution modeling
Terrain variables

Median roughness, 1km
Consensus land cover

A global 1-km consensus land-cover product for biodiversity and ecosystem modelling

Mao-Ning Tuanmu* and Walter Jetz
Heterogeneity metrics

95th percentile of EVI (MOD13Q1; 2001-05; 250m)

EarthEnv-DEM90 (3 arcsec; ~90 m)

GlobCover 2005-06 (v2.2; 23 types; 10 arcsec)

**Texture Measure**

**First-order**
- Coefficient of Variation (cv)
- Range (range)
- Skewness (skew)
- Standard Deviation (std)

**Second-order**
- Angular Second Moment (ASM)
- Contrast (CON)
- Correlation (COR)
- Dissimilarity (DIS)
- Entropy (ENT)
- Maximum (MAX)
- Variance (VAR)
- Homogeneity (HOM)

**Heterogeneity metrics** (30 arcsec; ~1 km)

**Topography-based Metrics**
- Coefficient of Variation (DEM_cv)
- Range (DEM_range)
- Skewness (DEM_skew)
- Standard Deviation (DEM_std)

**Landcover-based Metrics**
- # of landcover types (GBC_rich)
- Pielou evenness (GBC_even)
- Shannon diversity (GBC_shan)
- Simpson diversity (GBC_simp)

Species richness (BBS; 1997-2011)

GLMs & SLMs Stop & route levels

Functional diversity (diet, body size, activity time, foraging niche, habitat types)
First- and second-order texture measures calculated at ~1-km resolution

Utility for biodiversity modeling: Models built with texture measures, compared to those built with conventional metrics, generally explain more deviance in bird species richness and functional diversity across the conterminous US.
First- and second-order texture measures calculated at ~1-km resolution.

Heterogeneity metrics

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Temperature & Precipitation

Satellite-Station Data Fusion

**Temperature:**
MODIS LST (MOD11A1)

**Precipitation:**
MODIS Cloud Product
(MOD06, MOD09)

Goal: Develop daily 1km surfaces of tmax, tmin, and ppt with MODIS and climate station data (1980-2014).
Max. temperature, 1 Sep. 2010
Climate aided interpolation
Comparison of models

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cai_mod1</td>
<td>$\text{TMax} \sim f(\text{elev})$</td>
</tr>
<tr>
<td>cai_mod2</td>
<td>$\text{TMax} \sim f(\text{LST})$</td>
</tr>
<tr>
<td>cai_mod3</td>
<td>$\text{TMax} \sim f(\text{elev}, \text{LST})$</td>
</tr>
<tr>
<td>cai_mod4</td>
<td>$\text{TMax} \sim f(\text{lat}) + f(\text{lon}) + f(\text{elev})$</td>
</tr>
<tr>
<td>cai_mod5</td>
<td>$\text{TMax} \sim f(\text{lat}, \text{lon}, \text{elev})$</td>
</tr>
<tr>
<td>cai_mod6</td>
<td>$\text{TMax} \sim f(\text{lat}, \text{lon}) + f(\text{elev}) + f(\text{N_w, E_w}) + f(\text{LST})$</td>
</tr>
<tr>
<td>cai_mod7</td>
<td>$\text{TMax} \sim f(\text{lat}, \text{lon}) + f(\text{elev}) + f(\text{N_w, E_w}) + f(\text{LST}) + f(\text{LC1})$</td>
</tr>
<tr>
<td>cai_mod8</td>
<td>$\text{TMax} \sim f(\text{lat}, \text{lon}) + f(\text{elev}) + f(\text{N_w, E_w}) + f(\text{LST}) + f(\text{LC3})$</td>
</tr>
<tr>
<td>cai_mod9</td>
<td>$\text{TMax} \sim f(x) + f(y)$</td>
</tr>
<tr>
<td>cai_kr</td>
<td>$\text{CAI_{kr}}: y_{\text{var}} \sim \text{tmax}$</td>
</tr>
</tbody>
</table>
- Fusion of MODIS LST (monthly climatologies) and observations from meteorological stations (daily)

- Global MODIS data processing and testing of models for data fusion on NEX

- Current work focused on addressing data gaps in India / NW Amazon due to persistent cloud cover during June – Aug
Clouds directly affect energy and moisture transport, which in turn affect many biological processes.

Cloud dynamics can vary drastically over small spatial (~2 km) grains due to atmospheric circulation, topography.

Existing cloud products available only at relatively coarse spatial grains (8-110 km).

Here: a new MODIS-derived 1-km cloud climatology (MODCF) for use in ecological and species distribution modeling.
Cloud Cover

MOD35 Cloud Frequency (%) in February
Cloud Cover

Mean Annual Cloud Frequency (2000-14) (%)
Cloud Cover

- MODCF (%)
- PATMOS-x GEWEX (%)

Latitude

WorldClim Precip (mm)  Elevation (m)
I. Providing representative baselines: species distributions, communities, environment

II. Quantifying environmental change

III. Detecting, monitoring biodiversity change
I. Sample- and model-based Biodiversity Monitoring

Global 1km environmental layers

Global 1km Environment (static, 14/20y)
- Topography: ✔
- Land cover: Consensus ✔
- Terrain: ✔
- Radiation: in progress
- Habitat Heterogeneity: ✔
- Net primary productivity: ✔

1km Climate (daily 1980/2001-2014)
- Temperature: 2014!
- Cloud cover: close!
- Precipitation: 2014!
- Bioclimatic variables: in progress
- Extreme events: in progress

Predictions

Inference

Change in:
- Species niches
- Species distributions

1980s - 2014
II. Range-, Land-cover based Biodiversity Monitoring

1km MODIS Land cover

30m Landsat Tree cover

High-Resolution Global Maps of 21st-Century Forest Cover Change

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II. Range-, Land-cover based Biodiversity Monitoring
Thanks!