ECOPOTENTIAL: Remote sensing for ecosystems

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www.ecopotential-project.eu

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improving future ecosystem benefits through earth observations

Ecosystems are seen as “one physical system” with their environment, with strong geosphere-biosphere-hydrosphere interactions

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ECOPOTENTIAL in a nutshell

• Focus on a **network of Protected Areas**

• Identify relevant **ecosystem services** and focus on supporting **ecosystem functions/processes**

• Generate **EO data products** to characterize ecosystems state and changes

• Collect existing **in-situ** data and identify data gaps

• Quantify **changes** in the ecosystems

• Build **models** capable of assimilating EO and in-situ data, capable to include uncertainty estimates

• Estimate the **future state** of ecosystems

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ECOPOTENTIAL in a nutshell

- Build knowledge **with relevant stakeholders**: PA staff, environmental managers, etc.

- Define **policy options** and the requirements of future protected areas

- Make all results **available to the community**, contributing to GEO/GEOSS (GEO ECO, GNOME) through a Virtual Laboratory Platform

- Produce **dissemination material** at multiple levels

- Develop a **pan-European view** starting from the information gained at PA level

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Working in partnership with 23 Protected Areas in Europe and beyond

Ecosystem types:
Mountains
Arid/semi-arid
Coastal/marine

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Representativeness of ECOPOTENTIAL PAs

Spatial analysis is focused on:

• Terrestrial and Coastal Ecosystems (no „marine only“ ecosystems)
• European Continent (without Greenland)
• National Parks (NP)
• UNESCO Man and Biosphere Reserves (MAB)
• Natural UNESCO World Heritage Sites (WHS natural)

Data Sources are:

• World Database on Protected Areas (IUCN and UNEP-WCMC 2016)
• Database on National Designated Areas (EEA 2016)
• Additional literature and web search

Hofmann, Beierkuhnlein et al, 2016, in prep 2017

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Ecosystem services in mountain protected areas
Perceptions of respondents

Results of the questionnaire sent to PA managers/staff with the collaboration of ECOPOTENTIAL partners working in each PA

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Synthesis report based on results from questionnaires to PA staff

• The Ecosystem Service (ES) approach is used little in PA management.
  – Lack of knowledge
  – Lack of ES included in formal goals and policy frameworks relevant for PAs
    (Ecosystem preservation and tourism/recreation are the main formal goals of PAs)
  – Respondents were positive to the ES approach and identified a range of important ES provided by their PAs

• The use of EO tools in the management of PAs is overall low but has (eco)potential to be enhanced.

• There are good cases of use of EO tools in particular PAs and a strong willingness to share experiences.

• A range of training resources, as well as software and hardware tools, are required for the PAs to be able to effectively apply the technical tools provided by ECOPOTENTIAL: access to data is often good, but lack of capacity to analyse and use the data.

• PAs requested more knowledge on how to use of EO tools and Remote Sensing data for management in particular, in relation to their formal goals.
What do we study in the Protected Areas:

Current state of Protected Areas from Remote Sensing

Ongoing changes in the ecosystems and environment of the ECOPOTENTIAL Protected Areas

Future projections on the state of the ecosystem in the ECOPOTENTIAL Protected Areas

Narratives related to stakeholder needs: The Storylines

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Narratives for an integrated approach with stakeholders: The ECOPOTENTIAL storylines

• Focus on given Protected Area(s) and identify the main Ecosystem Services of interest and the functions/processes supporting them

• Identify indicators for the state of the ecosystem and of ecosystem processes (DPSIR SoE), for the most important control factors on the ecosystem, for the main (human-induced) pressures (DPSIR Pressures)

• Identify the most critical/endangered/fragile ecosystem components and identify indicators of the impacts/response of ecosystem structure, functions and services (DPSIR Impacts)

• Identify, retrieve, collect and possibly extend the data base (in situ and Remote Sensing) for the above indicators and the relevant Essential Variables

• Identify societal and management responses (DPSIR Responses) and develop conservation and management policy options

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An arid/semi-arid storyline

Spatial-temporal dynamics of savanna ecosystems as a life support system to wildlife and livestock production in and around Kruger National Park (A. Ramoelo, CSIR, SA)

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Ecosystem property needed to keep / improve the service</th>
<th>Supporting ecosystem characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecotourism</td>
<td>Species abundance and diversity e.g. presence of wild animals (Elephants, Rhino, Buffalo, Lion, Leopards etc),</td>
<td>Healthy state of open grasslands and woodland habitats and vegetation diversity</td>
</tr>
<tr>
<td>Grazing and Browsing resources (wild and domesticated animals)</td>
<td>Grass and tree foliage or cover</td>
<td>Quality and quantity grass and leaves for grazing and browsing respectively</td>
</tr>
<tr>
<td>Woody resources (energy and timber)</td>
<td>Woodland components (trees)</td>
<td>Quantity and species of trees</td>
</tr>
<tr>
<td>Water</td>
<td>Vegetation productivity, soil quality</td>
<td>Vegetation cover, low alien species cover</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Driver of change</th>
<th>Indicator</th>
<th>Method [reference] (type)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>Burnt area – frequency of fires</td>
<td><a href="http://www.afis.co.za/">http://www.afis.co.za/</a></td>
</tr>
<tr>
<td>Grazing activities</td>
<td>Biomass and quality</td>
<td>Ramoelo et al. (2012; 2015) (R)</td>
</tr>
<tr>
<td>Elephant tree pushovers</td>
<td>Tree cover (%)</td>
<td>Wessels et al. (2011), Mathieu et al. (2013), Naidoo et al. (2014) (R,M)</td>
</tr>
<tr>
<td>Fuel wood collection</td>
<td>Tree cover (%) or woody biomass (tons/ha)</td>
<td>Mathieu et al. (2013), Naidoo et al. (2014), Mograbi et al. (2015) (M)</td>
</tr>
<tr>
<td>Bush encroachment</td>
<td>Tree cover (%)</td>
<td>Naidoo et al. (2014) (R)</td>
</tr>
<tr>
<td>Land use – settlement and agriculture</td>
<td>Land cover or use</td>
<td>National Land Project – SA (R)</td>
</tr>
</tbody>
</table>
An arid/semi-arid storyline

Spatial-temporal dynamics of savanna ecosystems as a life support system to wildlife and livestock production in and around Kruger National Park (A. Ramoelo, CSIR, SA)

<table>
<thead>
<tr>
<th>DPSIR Type</th>
<th>Indicator Variable</th>
<th>Nearest Essential Variable (and originating typology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>Herbaceous biomass (g/m²)</td>
<td>Above ground biomass (ECV)</td>
</tr>
<tr>
<td></td>
<td>Leaf nitrogen (%)</td>
<td>Ecosystem function (EBV)</td>
</tr>
<tr>
<td></td>
<td>Tree biomass (ton/ha)</td>
<td>Above ground biomass (ECV)</td>
</tr>
<tr>
<td></td>
<td>Tree cover (%)</td>
<td>Habitat structure (EBV)</td>
</tr>
<tr>
<td></td>
<td>Habitat structure/type</td>
<td>Habitat structure (ECV)</td>
</tr>
<tr>
<td></td>
<td>Vegetation productivity – LAI</td>
<td>LAI (ECV)</td>
</tr>
<tr>
<td></td>
<td>Precipitation dynamics - Drought</td>
<td>Precipitation (ECV)</td>
</tr>
<tr>
<td></td>
<td>Landscape diversity index</td>
<td>Land cover (ECV)</td>
</tr>
<tr>
<td></td>
<td>Water and carbon fluxes</td>
<td>Evapotranspiration, soil moisture, carbon fluxes (ECV)</td>
</tr>
</tbody>
</table>

Link with Essential Variables

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A mountain storyline

high-altitude environments as a life-support system to wild herbivores
(S. Imperio, T. Bargmann)

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Ecosystem property needed to keep / improve the service</th>
<th>Supporting ecosystem characteristics</th>
</tr>
</thead>
</table>
| Sustainable tourism (GPNP, HNP) / hunting (HNP) | • Traditional landscape  
• Biodiversity  
• Presence of flagship species (Alpine ibex, chamois, wild reindeer) | • Floristic, arthropod and avian diversity  
• Wild ungulates distribution and abundance  
• Disturbance regimes |
| Habitat for rare and/or endemic species and/or of cultural value | • Micro-habitat diversity  
• Low human disturbance rates (tourism, pollution, land management) | • Species and community population dynamics  
• Phenology  
• Precipitation and temperature regimes  
• Disturbance regimes |
| Food production | • Cattle (GPNP), sheep (HNP)  
• Wild meat production (reindeer, grouse, fish) | • Gross primary production  
• Plant forage value |
| Water provision | • Soil moisture  
• Water budget | • Precipitation and temperature regime  
• Soil water content  
• Evapotranspiration |
| Carbon balance/storage | • Carbon cycling between soil, vegetation and atmosphere | • CO₂/CH₄ exchanges  
• Soil organic carbon  
• Resilience to extreme events and to soil freeze–thaw cycles |

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A coastal storyline

the Wadden Sea: improving coastal lagoon benefits under multiple pressures (G. El Serafy, H. Hummel, A. Ziemba)

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A marine storyline

the Pelagos sanctuary
(V. Drakou, L. Pendleton, W. Appeltans)

Southern Right Whales in Valdes Peninsula, captured with WorldView3 images from Digital Globe – © British Antarctic Survey/Digital Globe

Fin Whale observed in the Pelagos Sanctuary – Photo ©: F. Bendinoni – Thetis Research Institute

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A freshwater storyline

An ESS approach for the sustainable management of Lake Ohrid
(S. Giamberini, O. Tasevska, I. Baneschi)

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An emerging thread: ongoing changes in PAs

Meteo-climatic drivers from gridded and local data

LC/LU, vegetation, turbidity, chlorophyll-a and other info from Remote Sensing

In situ data on ecology/biology/pop.dyn./geomorphology/hydrology/water

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Example of PA changes: the Gran Paradiso National Park

Grided meteo-climatic datasets
E-OBS: 0.25°, EURO4M: 0.05° (only prec)
HISTALP, OI (Piedmont): 0125°

Model outputs and reanalyses
CMIP5, EURO-CORDEX,
ERA-Interim/Land and 20CRv2, MERRA, NCEP

Local meteo-climatic datasets
about 30 temperature sensors
2 meteo stations

Satellite products
e.g. snow: Global SWE, AMSR-E
vegetation, NDVI, LC/LU

Water/carbon fluxes and phenology
eddy covariance
flux chambers

Ecosystem and population dynamics
ibex, chamois, vegetation, biodiversity

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Spatial-temporal dynamics of savanna ecosystems as a life support system to wildlife and livestock production in and around Kruger National Park (A. Ramoelo, CSIR)

<table>
<thead>
<tr>
<th>SoE</th>
<th>Indicator</th>
<th>Method [reference] (type)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution of grazing and browsing resources in the semi-arid</td>
<td>amount of grass per unit area (biomass)</td>
<td>empirical techniques [Ramoelo et al. 2015] (M)</td>
</tr>
<tr>
<td>environments</td>
<td>percentage of nutrients in dry matter (leaf N (%))</td>
<td>empirical techniques [Ramoelo et al. 2012; 2015] (M)</td>
</tr>
<tr>
<td></td>
<td>percentage of tree cover per unit area (%)</td>
<td>field, LiDAR and SAR empirical techniques [Mathieu et al. 2013, Naidoo et al. 2014, Urbazaev et al. 2015] (M)</td>
</tr>
<tr>
<td></td>
<td>above ground woody biomass per unit area (ha) &amp; woody volume as biomass</td>
<td>field, LiDAR and SAR empirical techniques [Mathieu et al. 2013, Naidoo et al. 2014] (M)</td>
</tr>
<tr>
<td></td>
<td>proxy</td>
<td></td>
</tr>
<tr>
<td>Water and carbon fluxes</td>
<td>Measurement of soil moisture, evapotranspiration, carbon fluxes</td>
<td>eddy covariance and/or chamber techniques (I)</td>
</tr>
</tbody>
</table>

Figure 2: Time series of mean annual biomass data based on 500m spatial resolution MODIS data (2001 – 2015).

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## PA changes: Selected RS variables

<table>
<thead>
<tr>
<th>Type of ecosystem</th>
<th>RS variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountains</td>
<td>NDVI</td>
</tr>
<tr>
<td></td>
<td>Snow cover (duration)</td>
</tr>
<tr>
<td></td>
<td>Gross primary production</td>
</tr>
<tr>
<td>Coastal/marine</td>
<td>Chlorophyll a concentration</td>
</tr>
<tr>
<td></td>
<td>Sea Surface Temperature</td>
</tr>
<tr>
<td></td>
<td>Total suspended solids</td>
</tr>
<tr>
<td>Arid ecosystems</td>
<td>NDVI</td>
</tr>
<tr>
<td></td>
<td>Soil moisture</td>
</tr>
<tr>
<td></td>
<td>Tree cover density (%)</td>
</tr>
</tbody>
</table>
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Future projections

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Scale mismatch: the downscaling-impact chain

5 CMIP5 GCMs, RCP4.5, RCP8.5
Total precipitation annual mean 1951–2007

Euro-CORDEX – 11 km – 5 members

Specific eco models for each PA

Stochastic downscaling for prec
Interpolation with orography correction for temp

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## PAs and weather variables

<table>
<thead>
<tr>
<th>PA</th>
<th>Ecosystem function; vegetation dynamics</th>
<th>Model</th>
<th>Variables</th>
<th>Spatial resolution</th>
<th>Temp. resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camargue</td>
<td>marsh hydrology</td>
<td>locally developed hydro model</td>
<td>Precipitation, Evapo-transpiration</td>
<td>1 degree obtained by aggregating CORDEX runs at 0.11°</td>
<td>Monthly</td>
</tr>
<tr>
<td>Wadden Sea</td>
<td>state of the lower trophic levels of the marine ecosystem</td>
<td>DELFT3D including NPZD</td>
<td>Wind, Radiation, Precipitation, Temperature (air) boundary conditions for the local ocean model</td>
<td>0.11° nominal from CORDEX runs</td>
<td>3 hours</td>
</tr>
<tr>
<td>Curonian Lagoon</td>
<td>state of the main trophic levels in the lagoon ecosystem</td>
<td>hydro + NPZD locally developed + ECOSIM</td>
<td>Temperature, Precipitation, Snow cover</td>
<td>0.11° nominal from CORDEX runs</td>
<td>3 hours</td>
</tr>
<tr>
<td>Hardanger vidda</td>
<td>reindeer population dynamics</td>
<td>locally developed models</td>
<td>Precipitation, Temperature, Snow cover</td>
<td>1 km obtained by different downscaling methods 0.11°</td>
<td>Daily</td>
</tr>
<tr>
<td>Gran Paradiso</td>
<td>Alpine grassland dynamics, ungulate population dynamics</td>
<td>locally developed models + soil models</td>
<td>Precipitation, Temperature, Snow cover</td>
<td>250 meters from downscaling temperature and precipitation</td>
<td>Daily</td>
</tr>
<tr>
<td>Gran Paradiso</td>
<td>State of the alpine lake ecosystems</td>
<td>locally developed NPZD models</td>
<td>Precipitation, Temperature, Snow cover</td>
<td>250 meters from downscaling temperature and precipitation</td>
<td>Daily</td>
</tr>
<tr>
<td>Gran Paradiso</td>
<td>spatial biodiversity distribution</td>
<td>locally developed model</td>
<td>Temperature</td>
<td>90 meters obtained by downscaling e-Obs from 2006 and/or future scenarios from WorldClim</td>
<td>Daily and/or climatology</td>
</tr>
<tr>
<td>Kruger</td>
<td>biomass distribution; animal distribution; fires small-scale dynamics and interaction between geomorph. and vegetation</td>
<td>correlation models</td>
<td>Temperature, Precipitation, Wind, Temperature</td>
<td>0.11° daily</td>
<td></td>
</tr>
<tr>
<td>Negev</td>
<td></td>
<td>LP, IML, EcoHyd</td>
<td>Precipitation</td>
<td>5 meters downscaling with the meteo version, active only when it rains</td>
<td>Hourly</td>
</tr>
</tbody>
</table>

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Thanks for your attention