Linking Essential Biodiversity Variables from space for Wetland conservation and management

J.K. Garg
Senior Fellow
TERI School of Advanced Studies, New Delhi 110070

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TERI School of Advanced Studies, New Delhi 110070

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Essential Biodiversity Variables (EBVs) are defined as the derived measurements required to study, report, and manage biodiversity change, focusing on status and trend in elements of biodiversity. They provide the first level of abstraction between low-level primary observations and high-level indicators of biodiversity (GeoBon).

Criteria for Essential Biodiversity Variables - An ideal EBV should be

- able to capture critical scales and dimensions of biodiversity
- biological
- a state variable (in general)
- sensitive to change
- ecosystem agnostic (general - to the degree possible)
- technically feasible, economically viable and sustainable in time
What are wetlands .......

Ramsar uses a broad definition of wetlands, including lakes and rivers, swamps and marshes, wet grasslands and peatlands, oases, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans.
Wetland – the components

Hydrology

Biology

Catchment

Chemistry

Physical Habitat

Sociocultural interrelationships

“Wetland Triangle”

Hydrophytic Vegetation

Water and Soils Support Plants

Wetland Hydrology

Water Makes Soils Hydric

Hydric Soils

Soils Retain Water
Wetland ecosystems highly productive and rich repository of biodiversity than any other ecosystem.
Major Threats faced by wetland ecosystems

- Urbanization and landuse changes
- Conversion to agriculture
- Hydrologic alterations
- Deteriorating Water Quality
- Eutrophication
- Invasive species
- Global Climate Change

Leading to significant losses in biodiversity
Many of wetlands (especially Ramsar sites, and bird sanctuaries, under the legal jurisdiction of Forest Departments in South Asian countries and elsewhere)

Many wetlands are forested (e.g. Sundarbans in India and Bangladesh)
Wetland Conservation and Management

Huge requirement of temporal field and geospatial data

Geospatial datasets/images

- Wetland
  - Structural components
  - Habitat Types
- Catchment
  - Land use
  - Road/rail network
  - Settlements
  - Drainage
  - Slope
  - Geomorphology
  - Soils
  - Etc

In-situ measurements

- WQ/hydrology
  - BOD
  - DO
  - pH
  - Calcium
  - Total hardness
  - Magnesium
  - Alkany
  - Phosphate
  - Trophic state
  - Water Balance
- Flora
  - Macrophytes
    - % cover in littoral zone
    - number of species
    - Shannon diversity
    - no. of rare species
    - % area under exotic species
  - Phytoplanktons
    - total density
    - Shannon diversity
    - % blue green algae
    - % other algae species
- Fauna
  - No. of Taxa
  - Mean No. of Individual Per taxon
  - % contribution of dominant taxon
  - Shannon diversity

Socio-economic data and cultural ethos
Regional
Large Scale Spatial Resolution

High
1:1000000
1:250000
1:50000
1:25000
1:10000
1:5000
> 1m
5m
10m
25m
50m
500m

AWiFS
LISS IV
LISS III
Cartosat
Oceansat

National
State
District
Local

Scales and Satellite Data

Small scale Spatial Resolution
Low
1:1000000
1:250000
1:50000
1:25000
1:10000
1:5000
> 1m
5m
10m
25m
50m
500m

LISS IV
LISS III
AWiFS
Oceansat

IP* Implementation Plan

India RS satellites provide unique opportunity + international RS satellites
Candidate EBVs amenable to Remote Sensing
(More applicable to forests and forested wetlands/catchments)

<table>
<thead>
<tr>
<th>EBV Class</th>
<th>Candidate RS-EBV</th>
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</thead>
<tbody>
<tr>
<td><strong>Species populations</strong></td>
<td>Species distribution</td>
</tr>
<tr>
<td><strong>Species populations</strong></td>
<td>Species abundance</td>
</tr>
<tr>
<td><strong>Species traits</strong></td>
<td>Phenology</td>
</tr>
<tr>
<td><strong>Species traits</strong></td>
<td>Plant traits (e.g., specific leaf area, leaf nitrogen content)</td>
</tr>
<tr>
<td><strong>Community composition</strong></td>
<td>Taxonomic diversity</td>
</tr>
<tr>
<td><strong>Community composition</strong></td>
<td>Functional diversity</td>
</tr>
<tr>
<td><strong>Ecosystem function</strong></td>
<td>Productivity (e.g., NPP, LAI, FAPAR)</td>
</tr>
<tr>
<td><strong>Ecosystem function</strong></td>
<td>Disturbance regime (e.g., fire, inundation)</td>
</tr>
<tr>
<td><strong>Ecosystem structure</strong></td>
<td>Habitat structure (e.g., height, crown cover and density)</td>
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<tr>
<td><strong>Ecosystem structure</strong></td>
<td>Ecosystem extent and fragmentation</td>
</tr>
<tr>
<td><strong>Ecosystem structure</strong></td>
<td>Ecosystem composition by functional type</td>
</tr>
<tr>
<td>Variable</td>
<td>Information Need/EBVs</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Spatial information</td>
<td>Inventory and monitoring&lt;br&gt;Structural components/ habitat types&lt;br&gt;Aq. veg/weeds extent</td>
</tr>
<tr>
<td></td>
<td>Aquatic vegetation type</td>
</tr>
<tr>
<td>Water quality Variable</td>
<td>Pollution sources/waste outfalls</td>
</tr>
<tr>
<td></td>
<td>Thermal pollution</td>
</tr>
<tr>
<td></td>
<td>Phytoplankton/algal blooms/Chlorophyll</td>
</tr>
<tr>
<td></td>
<td>Turbidity/sediment load</td>
</tr>
<tr>
<td></td>
<td>Oil pollution</td>
</tr>
<tr>
<td></td>
<td>Pollutant species</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Habitat diversity</td>
</tr>
<tr>
<td></td>
<td>Fragmentation</td>
</tr>
<tr>
<td></td>
<td>Habitat-biotic assemblages etc.</td>
</tr>
<tr>
<td>Catchment characteristics</td>
<td>Land cover, soils, landforms, hydrologeomorphology, etc.</td>
</tr>
<tr>
<td>Action Plan for</td>
<td>Integration and criteria based action plan generation</td>
</tr>
<tr>
<td>Conservation &amp; Management</td>
<td></td>
</tr>
</tbody>
</table>
Inventories of Indian Wetlands

AQUATIC ENVIRONMENT

WETLANDS ECOSYSTEMS

- Wetlands cover about 8-10% of world’s land surface.
- Wetlands are a big source of GHGs acting as sources as well as sinks (Methane, Nitrous oxide, Carbon dioxide). Wetlands contribute about 22% of global methane budget.
- Carbon pool contained in wetlands is estimated to amount up to 230 Gt out of a total of about 1943 Gt.
- Methane is considered as the most significant GHG due to its Global Warming Potential (GWP) which is 21 times higher than carbon dioxide and with a greater volume of emissions than any other gas except CO₂.

Wetlands and Remote sensing

Broadly, RS provides information/inputs on:
- Wetland occurrence
- Wetland inventory (type-wise)
- Seasonal changes in water spread
- Areas under aquatic vegetation (emergent)
- Structural component of wetlands/habitat diversity
- Wetland degradation
- Turbidity
- Estimation of period of biological activity & biogeochemical cycling
- Surrounding vegetation cover and land use
### Type-wise Distribution of Wetlands in India

Source: SAC 2011

<table>
<thead>
<tr>
<th>Wetland Category</th>
<th>Total Wetland Area (ha)</th>
<th>% of Wetland Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake/Pond</td>
<td>729532</td>
<td>4.78</td>
</tr>
<tr>
<td>Ox-bow lake/Cut-off meander</td>
<td>104124</td>
<td>0.68</td>
</tr>
<tr>
<td>High altitude wetland</td>
<td>124253</td>
<td>0.81</td>
</tr>
<tr>
<td>Riverine wetland</td>
<td>91682</td>
<td>0.60</td>
</tr>
<tr>
<td>Waterlogged(Natural)</td>
<td>315091</td>
<td>2.06</td>
</tr>
<tr>
<td>River/Stream</td>
<td>5258385</td>
<td>34.46</td>
</tr>
<tr>
<td>Reservoir/Barrage</td>
<td>2481987</td>
<td>16.26</td>
</tr>
<tr>
<td>Tank/Pond</td>
<td>1310443</td>
<td>8.59</td>
</tr>
<tr>
<td>Waterlogged(Man-made)</td>
<td>135704</td>
<td>0.89</td>
</tr>
<tr>
<td>Salt pan(Inland)</td>
<td>13698</td>
<td>0.09</td>
</tr>
<tr>
<td>Lagoon</td>
<td>246044</td>
<td>1.61</td>
</tr>
<tr>
<td>Creek</td>
<td>206698</td>
<td>1.35</td>
</tr>
<tr>
<td>Sand/Beach</td>
<td>63033</td>
<td>0.41</td>
</tr>
<tr>
<td>Intertidal mud flat</td>
<td>2413642</td>
<td>15.82</td>
</tr>
<tr>
<td>Salt Marsh</td>
<td>161144</td>
<td>1.06</td>
</tr>
<tr>
<td>Mangrove</td>
<td>471407</td>
<td>3.09</td>
</tr>
<tr>
<td>Coral Reef</td>
<td>142003</td>
<td>0.93</td>
</tr>
<tr>
<td>Salt pan(Coastal)</td>
<td>148913</td>
<td>0.98</td>
</tr>
<tr>
<td>Aquaculture pond</td>
<td>287232</td>
<td>1.88</td>
</tr>
<tr>
<td>Sub-total</td>
<td>14705015</td>
<td>96.36</td>
</tr>
<tr>
<td>Wetlands (&lt;2.25 ha)</td>
<td>555557</td>
<td>3.64</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15260572</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

**Type-wise Distribution**

**swamp/marsh**
Wetland component EBVs

Legend:
- Submerged Vegetation
- Scrubland
- Plantation
- Open Water
- Grass Beds
- Floating Vegetation
- Exposed soil with scanty grass

Wetland structural components extracted using LISS IV imagery
# Wetland’s health EBVs

<table>
<thead>
<tr>
<th>WQP’s</th>
<th>Algorithm</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chl-a ($\mu$g/L)</td>
<td>$54.658 + 520.451<em>B2 –1221.89</em>B3 + 611.115<em>B4 – 198.199</em>B5</td>
<td>Lim et al., (2015)</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>$1.195+14.45*B4</td>
<td>Carpintero et al., (2013)</td>
</tr>
<tr>
<td>Trophic State</td>
<td>$10 \times [6-(2.04 -0.68\ln(\text{Chl-a})/\ln2)]$</td>
<td>Carlson (1977)</td>
</tr>
</tbody>
</table>

*Note

**Landsat 8 OLI**

Band 2 Blue(B2)   (0.45 – 0.51)
Band 3 Green(B3)  (0.53 – 0.59)
Band 4 Red(B4)    (0.64 – 0.67)
Band 5 NIR(B5)    (0.85 – 0.88)

**Chattisgarh**

- Kota
- Bilaspur
- Bilha
- Matsuri Tahsils

Area: $2853 \text{ km}^2$
Area dotted with ponds
Spatial variation in TSI based on Chl-a
Lotic Ecosystems

\[ MNDWI = \frac{\text{Band 3} - \text{Band 6}}{\text{Band 3} + \text{Band 6}} \]

\[ AWEI_{nsh} = 4 \times (\text{Band 3} - \text{Band 6}) - (0.25 \times \text{Band 5} + 2.75 \times \text{Band 7}) \]

SWIR 1 Band Reflectance

![Image of Lotic Ecosystems with SWIR 1 Band Reflectance](image)
Variation in Chlorophyll-a Concentration

In situ:

- May 2016:
  - 18.2 µg/L
  - Cal: 17.66 µg/L

- Oct 2016:
  - 34.23 µg/L
  - Cal: 65.3 µg/L

- May 2017:
  - 16.6 µg/L
  - Cal: 10.5 µg/L

Calculated:

- May 2016:
  - 16.7 µg/L

- Oct 2016:
  - 15.7 µg/L

- May 2017:
  - 30.2 µg/L

Map showing Chl-a Concentration (µg/L) for May 2016, Oct 2016, and May 2017.
Variation in turbidity values

In situ: 62.4 NTU  Cal: 33.05 NTU

In situ: 6.75 NTU  Cal: 19.14 NTU

In situ: 56.7 NTU  Cal: 93.9 NTU

In situ: 40.9 NTU  Cal: 29.2 NTU

In situ: 69.4 NTU  Cal: 78.34 NTU

In situ: 19.2 NTU  Cal: 24.16 NTU
Land use land cover in buffer zone of Bhindawas wetland

FCC of wetland buffer zone for various years
Waterfowl in the Bhindawas Wetland – Ramsar candidate

- Chest-nut Bee-eater
- Pheasant Tailed Jacana
- Black Headed Ibis
- Grey Heron
- Cormorants
- White Throated Kingfisher
- Northern Shoveller
- Red wattled lapwing
- Cormorants
- Black Headed Ibis
- Swamp Hen
- Black Winged Stilt
Land use land cover maps of Wetland buffer zone

Land use land cover maps for wetland buffer zone
Landscape Fragmentation EBV in forested wetland catchment

(Blue colour indicates Renuka wetland) (Thakur, 2018).
Action Requirement (Tentative)

If $DI = \text{Moderate AND TSI = Eutrophic}$
AND
$DI = \text{Low AND TSI = Eutrophic}$

If $DI = \text{Moderate AND TSI = Mesotrophic}$

Improve water holding capacity

If $DI = \text{High AND TSI = Eutrophic}$

Biophysical parameters should be regulated

Removal of Vegetation/Dredging

Otherwise AND If description = national park/sanctuary

No Action required

Deeper Beel

Variation in diversity metrics in Deeper Beel in different years

|-------|------|------|------|------|------|

Dissection Index of Deeper Beel
Action Plan for Deeper Beel

- Biophysical parameters should be regulated
- Improve water holding capacity
- No action required
- Removal of vegetation/Dredging
Research carried out so far has proved utility of remote sensing and GIS in inventorying, monitoring and assessment of health of Wetland Ecosystems. For ‘wise use’ of wetlands following are the needs:

• Use of Landscape Ecological Approach for Conservation and Restoration of Wetlands.

• Development of metrics/indicators/EBVs for assessment of health of wetland and its catchment integrity.

• Development of socio-cultural indicators (metrics) for assessing the impact on health of wetlands (of people directly or indirectly dependent on wetlands).
Selected References

Thanks for your patience