Ecosystem services and the drivers of change in a deforested area in Bangladesh: tradeoffs, livelihoods, and feedbacks

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Background

• The forest extent of Bangladesh is only about 11% (FAO, 2015) to 15% (BFD, 2015) of its total area.

• The forest area has been declining since last 100 years (Reddy et al. 2016).

• The annual deforestation rate has been ranged from 1.1% (Reddy et al. 2016) to >3% (Ahmed 2008; Sarker et al. 2011).

• However, the country has reported an increase of planted forest from 2.4 to 2.7 million ha since 1990 (Fig. 1)

Fig. 1: Bangladesh forest coverage and its change (FAO, 2015)
Background

• The plantation: principally on the roadside, inland/coastal embankments and newly accreted mud flats.

• Since 1966, Bangladesh Forest Department had been planted 0.2 million ha mangroves.

Fig. 2: Afforestation on coastal embankment (source: CDSP IV, GoB)

Fig. 3: Mangrove afforestation (source: UNDP Bangladesh)

• Natural forests, except Sundarbans, are under severe pressure from several anthropogenic and natural drivers.
Background

• The Sundarbans: located in southern coast and inter-tidal zones of Bangladesh and India.

• Bangladesh part of Sundarbans: about >6000 km².

• Declared as ‘Reserve Forest’ in 1875–1876.

• It has been always a challenge for the foresters to manage Sundarbans due to a greater dependencies of neighboring communities on it.

• More than 3.5 million people living around the Bangladesh Sundarbans are directly or indirectly dependent on the ecosystem services of the forest.

Fig. 4: Sundarbans
(source: http://www.theindependentbd.com/)
Background

• Timber, pole, firewood, food (i.e. fish, crab, honey), industrial raw materials (i.e. softwood for match industry, pulp and paper), salt, tannins and other miscellaneous products (thatching hut).

• Study on a neighboring village (Munshiganj; in 2016) suggested that Sundarbans still provide 20-32 percentage of annual livelihoods to the communities.

• Area decreased

  ➢ 1.2% between 1977 and 2000 (Giri et al., 2007).

  ➢ 5.1% between 1975 and 1989 and 4.5% between 1989 and 2000 (Islam, 2014).
Background

• Species distribution changed:
  ➢ Dieback (Top dying) diseases (Rahman, 1996; Abdul, 2014)

• Drivers of change:
  ➢ Erosion and deposition
  ➢ Cyclones
  ➢ Salinity (lowering freshwater inflow)
  ➢ Illegal logging
  ➢ Illegal encroachment (shrimp/salt farms)
US Dept of State Geographer
Image © 2019 Maxar Technologies
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1984

2019

~110 ha!
Study objectives

• Objectives:

1. To understand the historical perspectives of landuse change
2. To identify the drivers of change and their interrelationships
3. To investigate the applicability of remote sensing image for monitoring soil properties
4. To detect changes in indigenous plant biodiversity, livelihoods and public health

Monitoring soil salinity using Landsat 8

Herbs biodiversity
Study area: Shyamnagar Upazila, Satkhira District, Bangladesh

- Total area 1968.24km²
- Forest area 1622.65km²
- Non-forest area 345.59km²
- Cultivated area 251.58km²
## Study area

<table>
<thead>
<tr>
<th>Land use class</th>
<th>Settlements</th>
<th>Road</th>
<th>Villages</th>
<th>Agriculture</th>
<th>Agriaquaculture</th>
<th>Temporary settlements</th>
<th>Chuna river</th>
<th>Sundarban</th>
<th>Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil types</td>
<td>Silt and clay</td>
<td>Silt and sandy clay</td>
<td>Sandy, silt and clay loam</td>
<td></td>
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<tr>
<td>Soil salinity (ppt)</td>
<td>0.57</td>
<td>1.68</td>
<td>6.5</td>
<td>13.6</td>
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<td></td>
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<tr>
<td>Herbs diversity</td>
<td>0.60 (Shimpson)</td>
<td>0.40</td>
<td>0.26</td>
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<tr>
<td>Altitude (m)</td>
<td>5-40</td>
<td>2-5</td>
<td>0-3</td>
<td>2-6</td>
<td>0</td>
<td>&gt;0</td>
<td>0</td>
<td></td>
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</tr>
<tr>
<td>Water sources</td>
<td>Ground water, surface water, rain water and river water</td>
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</tbody>
</table>

### Land use

<table>
<thead>
<tr>
<th>Land use</th>
<th>Built-up area</th>
<th>Households</th>
<th>Crop production</th>
<th>Crop production and shrimp culture</th>
<th>Temporary households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangifera indica</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Phoenix dactylifera (1)</td>
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<tr>
<td>Albizia lebbeck</td>
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<tr>
<td>Artocarpus heterophyllus</td>
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<tr>
<td>Neolamarckia cadamba</td>
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<tr>
<td>Swietenia mahagoni</td>
<td></td>
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<tr>
<td>Cocos nucifera (2)</td>
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</tbody>
</table>

### Major plants

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Major plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dypsis lutescens</td>
<td>Mangifera indica</td>
</tr>
<tr>
<td>Azadirachta indica (3)</td>
<td></td>
</tr>
<tr>
<td>Cerbera decandra</td>
<td>Phoenix dactylifera (1)</td>
</tr>
<tr>
<td>Sonneratia apetala (2)</td>
<td></td>
</tr>
<tr>
<td>Avicennia marina (3)</td>
<td></td>
</tr>
<tr>
<td>Avicennia officinalis (6)</td>
<td></td>
</tr>
<tr>
<td>Xylocarpus moluccensis (7)</td>
<td></td>
</tr>
<tr>
<td>Xylocarpus granatum (8)</td>
<td></td>
</tr>
<tr>
<td>Cynometra raufula (9)</td>
<td></td>
</tr>
<tr>
<td>Shirakapnara indica (10)</td>
<td></td>
</tr>
</tbody>
</table>

### Medicinal plants or Herbs

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Medicinal plants or Herbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croton bonplandianus (11)</td>
<td>Croton bonplandianus</td>
</tr>
<tr>
<td>Sonchus asperifolius</td>
<td></td>
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<tr>
<td>Rhei tuberosa</td>
<td></td>
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<tr>
<td>Xylocarpus granatum</td>
<td></td>
</tr>
<tr>
<td>Xylocarpus moluccensis</td>
<td></td>
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<tr>
<td>Excoecaria agallocha</td>
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<tr>
<td>Sarcolobus globostis</td>
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</tbody>
</table>
Results:

Literature review, Kye informant interviews (15), Household survey (stratified random; target 400 (95% CI=381); completed 70)
Results:

- Poverty
  - Arable land scarcity
  - Food deficiency
  - Cyclones/Storm surge
- Technology
  - Policy/Plans
- Coastal polders
  - HYV varieties dev.
  - Agricultural extension
- Freshwater blocked
- Surgewater blocked
- Soil salinity grew

- Public health
- Social
- Economic
- Income inequality
- Local biodiversity
- Food diversity
- Salt-rich food intake
- Saline water inflow
- Liming
- Salinity grew further
- Soil property change
- Agri. Production decline
- Aquaculture extension
- Taxes/Subsidies: Shrimp

Cause → Effect
## Results

<table>
<thead>
<tr>
<th>Ecosystem service per year</th>
<th>Non-forest area</th>
<th>Forest area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish (15600 ha; 983kg/ha; $5.9/kg)</td>
<td></td>
<td>Govt. revenue ($744000+$42000 per year; 6017km²) (Uddin et al., 2013)</td>
</tr>
<tr>
<td>Crab fattening (1785 ha; 1196kg/ha; $30/kg)</td>
<td>$1864.85/ha (@30% profit)</td>
<td>$1.31/ha</td>
</tr>
<tr>
<td>Crops (7773ha; 600kg/ha; $0.4/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fodder (household survey)</td>
<td>$83/hh</td>
<td>Community livelihoods</td>
</tr>
<tr>
<td>Biomass for cooking (household survey)</td>
<td>$114/hh</td>
<td></td>
</tr>
<tr>
<td>Wild crab/fish fry collection (household survey)</td>
<td>$45/hh</td>
<td></td>
</tr>
</tbody>
</table>

$242 vs $384  
47% hh
Preliminary results: Soil salinity estimation from Landsat images

Fig.: Approach and logical flow
Result

\[ SI = \sqrt{G \times R} \]

\[ \text{Brightness} = \sqrt{G^2 + \text{NIR}^2} \]

\[ \text{NDSI} = \frac{(R - \text{NIR})}{(R + \text{NIR})} \]

\[ \text{VSSI} = 2 \times G - 5(R + \text{NIR}) \]

\[ \text{NDVI} = \frac{\text{NIR} - R}{\text{NIR} + R} \]

\[ \text{SAVI} = 1.5\frac{\text{NIR} - R}{0.5 + \text{NIR} + R} \]
Result

\begin{align*}
\text{SI} &: y = 4.34e^{0.91x}, \quad R^2 = 0.05 \\
\text{BI} &: y = 40.58e^{1.64x}, \quad R^2 = 0.68 \\
\text{NDSI} &: y = 2.90e^{3.00x}, \quad R^2 = 0.55 \\
\text{VSSI} &: y = 29.38e^{2.27x}, \quad R^2 = 0.70 \\
\text{NDVI} &: y = 2.90e^{3.00x}, \quad R^2 = 0.55 \\
\text{SAVI} &: y = 3.01e^{3.12x}, \quad R^2 = 0.57
\end{align*}
Result

$R^2 = 0.92$

$R^2 = 0.87$

Salinity class (dS/m)
- 0-2 (S1)
- 2-4 (S2)
- 4-6 (S3)
- 6-12 (S4)
- >12 (S5)

Kilometers

N
THANK YOU
References


