Church forests in Ethiopia

The conservation value of church forests is linked to historical deforestation patterns

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See also
http://www.biw.kuleuven.be/lbh/lbnl/forecoman/eng/publications.asp#1
Mountain forest plants

- Limited capacity for migration
  - Altitudinal gradients limit species ranges
  - Physical barriers against dispersal
- Natural *islands* of biodiversity
  - Diversity ~ island size
- Vulnerability to species loss increases
  - Effects of climatic change
  - Effects of habitat fragmentation
- Conservation
  - Large fragments
  - Small habitat patches
  - Relictual vegetation
Ecological zones in Africa: (pre)montane zones in Ethiopia
Ethiopia: where have the mountain forests gone?
Northern highlands of Ethiopia: Landsat TM - blue is forest
Forest fragments: church forests...
...in a matrix of cropland and degraded semiarid savanna
Historical plant communities

- Until 2500 years ago
  - Undifferentiated or dry monodominant Afromontane forest (Friis 1992)
  - *Juniperus procera* with *Afrocarpus falcatus* (Pencil cedar-Yellowwood)

- 500 BC
  - Forest clearance
  - *Dodonaea* and *Rumex*

- 1200-1400 AD
  - Grass and frequent fires

- 1400-1700 AD
  - Secondary forest
  - *Juniperus* with *Olea* and *Celtis*
Forest plant communities today

- **North (Central Tigray)**
  secondary forest
  [Aerts et al. 2006: 10 forests]
  - Moist Afromontane forest with *Faidherbia*, *Celtis* and *Pterolobium*
  - Dry Afromontane forest with *Olea*, *Acacia* and *Combretum*
  - Shrub savanna with *Acacia* and *Echinops*

- **South (South Gondar)**
  degraded primary forest
  [Alemayehu Wassie 2007: 28 forests]
  - Afromontane forest with *Juniperus*, *Olea* and *Maytenus*
What is conserved in church forests?

• Conservation value and management
  – depend on what is actually conserved in church forests
  – e.g. conservation (primary forest) vs. restoration (secondary forest)
• Not all church forests are the same
  – not necessarily “the original forest vegetation” (often said so)
• Remarkable difference between north and south
  – Is this also reflected in fragment area and spatial allocation?
    (cfr. “larger fragments or better connectivity = better conservation”)
  – If so, is this a general trend (more and larger fragments in the south)?
• Things to know to solve this question:
  – Where are the forests in the highlands?
  – What are the forest sizes and how much forest is really left?
    (forest cover is usually estimated at 4%)
  – What are the spatial characteristics of the forests?
Methods: Google Earth/GIS

- Northern highlands
- 8 sample blocks
- 0.5 million ha
- High-resolution satellite images (pixel resolution 0.8 m)
- Detected and digitized all 394 church forests
- (There were more churches than church forests – not all churches have old forest)
Example: Debre Tabor
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Spatial analysis

- Fragment and landscape metrics (Arcview GIS: Spatial Analyst, Patch Analyst)
  - Area
    - Patch area (ha)
    - Patch core area (ha; 50 m internal buffer from edge and church)
  - Density
    - Patch density (patches per ha)
    - Edge density (m/ha)
    - Core index (%)
    - Forest index (%)
  - Shape
    - Perimeter-area ratio (m/m²; PAR; 0.02 for a circle with r = 100 m)
    - Shape index (~P/√A: 1 circle; >1 more complex shapes)
    - Fractal dimension (~2lnP/lnA: 1 simple – 2 complex)
  - Isolation
    - Nearest neighbor distance (m)
  - Configuration
    - Aspect (via overlay with DTM)
    - Slope (°)
    - Church to patch centroid distance (m)
## Results

<table>
<thead>
<tr>
<th></th>
<th>North (n = 155)</th>
<th>South (n = 239)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean patch size (ha)</td>
<td>2.81 (0.69)</td>
<td>2.26 (0.31)</td>
<td>0.271</td>
</tr>
<tr>
<td>Mean patch core area (ha)</td>
<td>0.59 (0.18)</td>
<td>0.32 (0.14)</td>
<td>0.238</td>
</tr>
<tr>
<td>Patch density (patches per ha)</td>
<td>0.43 (0.11)</td>
<td>0.46 (0.08)</td>
<td>0.801</td>
</tr>
<tr>
<td>Edge density (m/ha)</td>
<td>342 (55)</td>
<td>317 (43)</td>
<td>0.727</td>
</tr>
<tr>
<td>Core Index (%)</td>
<td>23 (12)</td>
<td>5 (10)</td>
<td>0.308</td>
</tr>
<tr>
<td>Forest index (%)</td>
<td>0.18 (0.10)</td>
<td>0.31 (0.08)</td>
<td>0.346</td>
</tr>
<tr>
<td>Mean perimeter:area ratio (m/m²)</td>
<td>0.066 (0.003)</td>
<td>&gt; 0.048 (0.002)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Mean shape index</td>
<td>1.65 (0.04)</td>
<td>&gt; 1.4 (0.03)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Mean fractal dimension</td>
<td>1.38 (0.01)</td>
<td>&gt; 1.33 (0.01)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Patch isolation (m to nearest neighbor)</td>
<td>1993 (92)</td>
<td>1887 (74)</td>
<td>0.329</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aspect</th>
<th>F(NW&gt;SE; P&lt;0.05)</th>
<th>F(NW=SE; P&gt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (°)</td>
<td>8.3 (0.5)</td>
<td>&gt; 4.7 (0.4)</td>
</tr>
<tr>
<td>Church-patch centroid distance (m)</td>
<td>66 (6)</td>
<td>&gt; 36 (5)</td>
</tr>
</tbody>
</table>
Results

• Northern forests
  – More complex shape (PAR, SI, FD)
  – On steeper slopes
  – More on NW slopes
  – Ex-centric churches (churches at the edge)

• Southern forests
  – Simple shape, often circular, often with a radius of ~100m
  – On small mountain tops
  – Church central
  – Almost on a regular grid in the landscape
Results

Typical northern church forest

Typical southern church forest
Discussion

- Shape, not size, reflect historical deforestation pattern
- North: church forest protected remnant forest patches after large scale deforestation of the landscape (thus, on steep, drier slopes)
- South: church forests protected designated forest patches in a forested landscape, prior to large scale deforestation
- Results consistent with ‘roaming capitals of Ethiopia’
Discussion

- ‘Old capitals’: Axumite period
  - Large deforestation prior to arrival of Christianity
  - Churches were established in deforested land
  - Church forests protected ‘what was left’
  - Mainly secondary forest
- ‘Newer capitals’: Gondarine period
  - Colonization of the land
  - Church as a means to control the land
  - Regular pattern of regular churches
  - More likely to represent primary forest
Discussion

Northern forests on NW slopes (Axum)
Southern forests, regularly spaced (Debre Markos)
Discussion

Southern forests: churches on 3 x 3 km² grid
Southwestern forests: 3 x 3 km² grid and remnant of the original forest
Conclusion

- Historical deforestation patterns
  - Linked to historical development of the highlands
- Church forests have different origins
  - North and northeast: conservation after fragmentation
  - South and southwest: conservation before fragmentation
- Differential conservation status requires differential management
- Conservation of primary species a focus in the SW
- Restoration of primary species in secondary forest a focus in the NE
- Forest expansion needed in all regions: fragments very small (2.5 ha) and forest cover too low (0.2%)