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**LEUVEN**

# Church forests in Ethiopia

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

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# Suggested citation

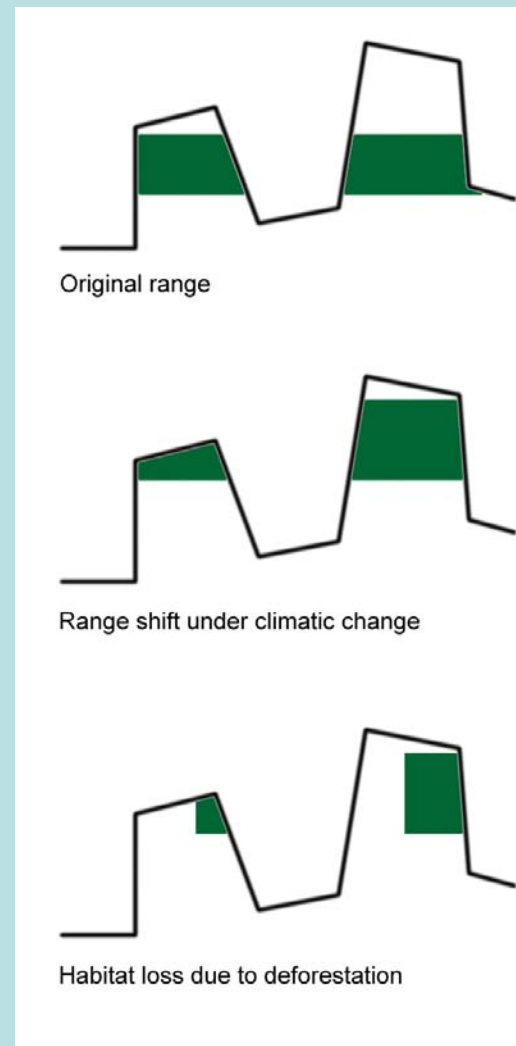
Aerts R., Pankhurst R., Van Overtveld K., November E., Hermy M. and Muys B. 2008. Historical deforestation patterns and the conservation value of church forests in the northern Ethiopian highlands. International Conference *Mountain Forests in a Changing World. Advances in Research on Sustainable Management and the Role of Academic Education*. UNI BOKU Vienna, April 2-4, 2008. Book of abstracts, p. 14

See also

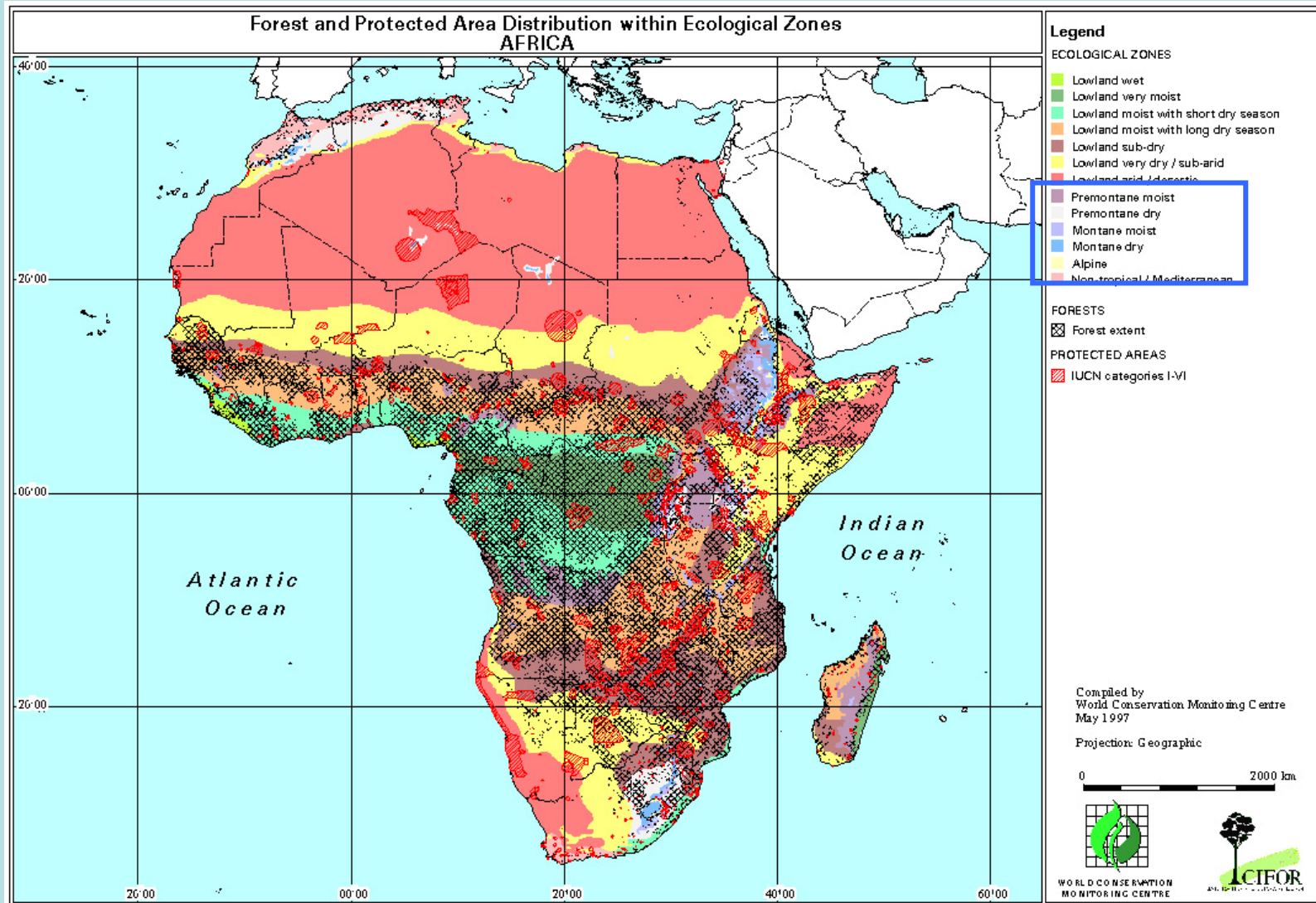
<http://www.biw.kuleuven.be/lbh/lbni/forecoman/eng/publications.asp#1>

# Mountain forest plants

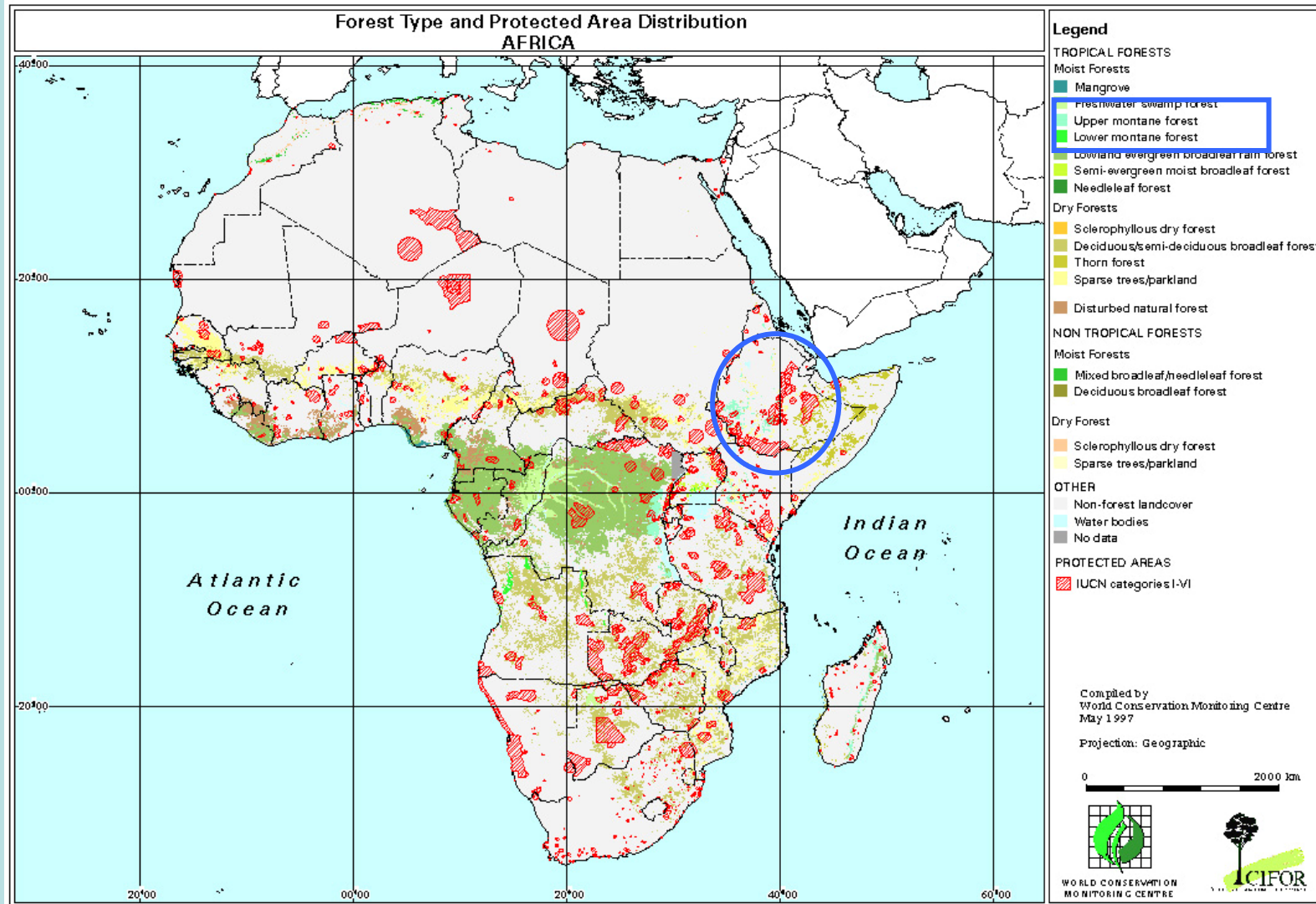
- Limited capacity for migration
  - Altitudinal gradients limit species ranges
  - Physical barriers against dispersal
- Natural *islands* of biodiversity
  - Diversity ~ island size
- Vulnerability to species loss increases
  - Effects of climatic change
  - Effects of habitat fragmentation
- Conservation
  - Large fragments
  - Small habitat patches
  - Relictual vegetation



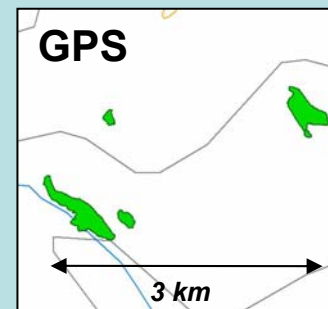
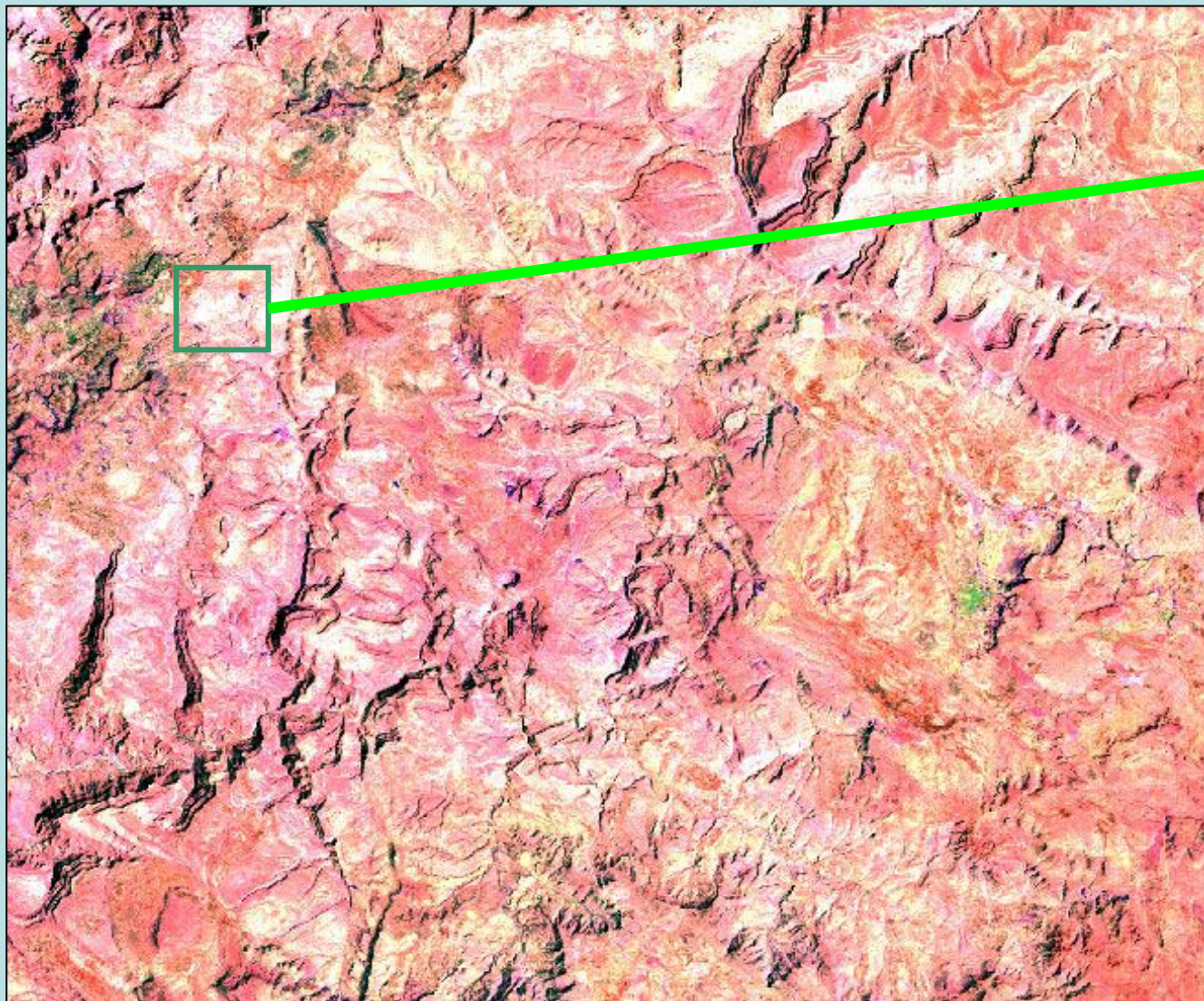
# Ecological zones in Africa: (pre)montane zones in Ethiopia



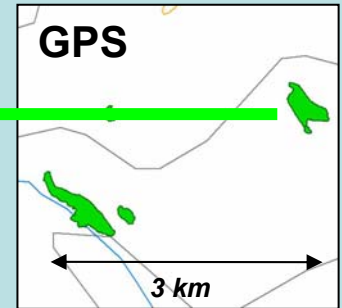
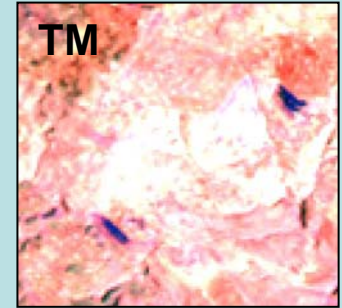
# Ethiopia: where have the mountain forests gone?



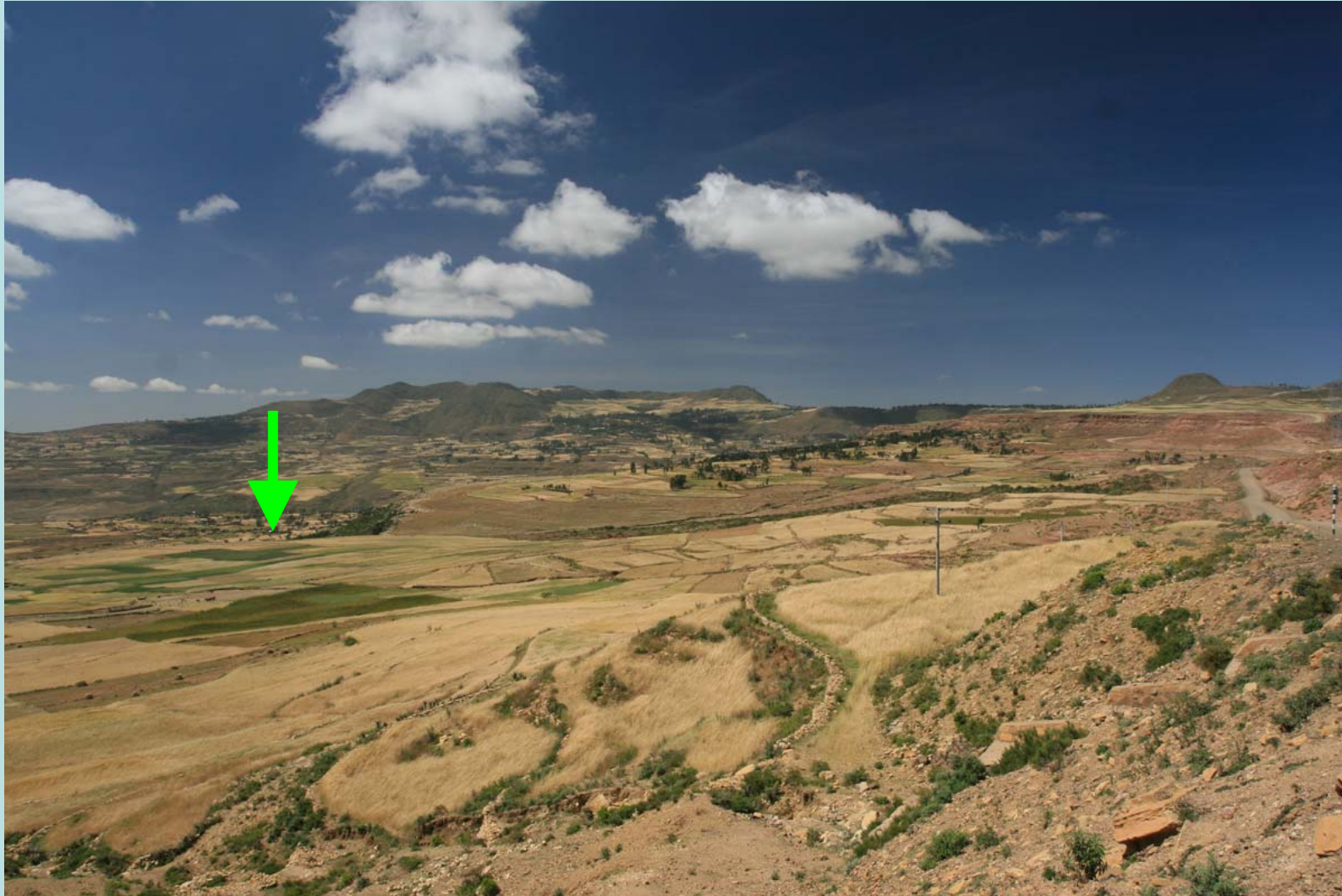
# Northern highlands of Ethiopia: Landsat TM - blue is forest



# Forest fragments: church forests...



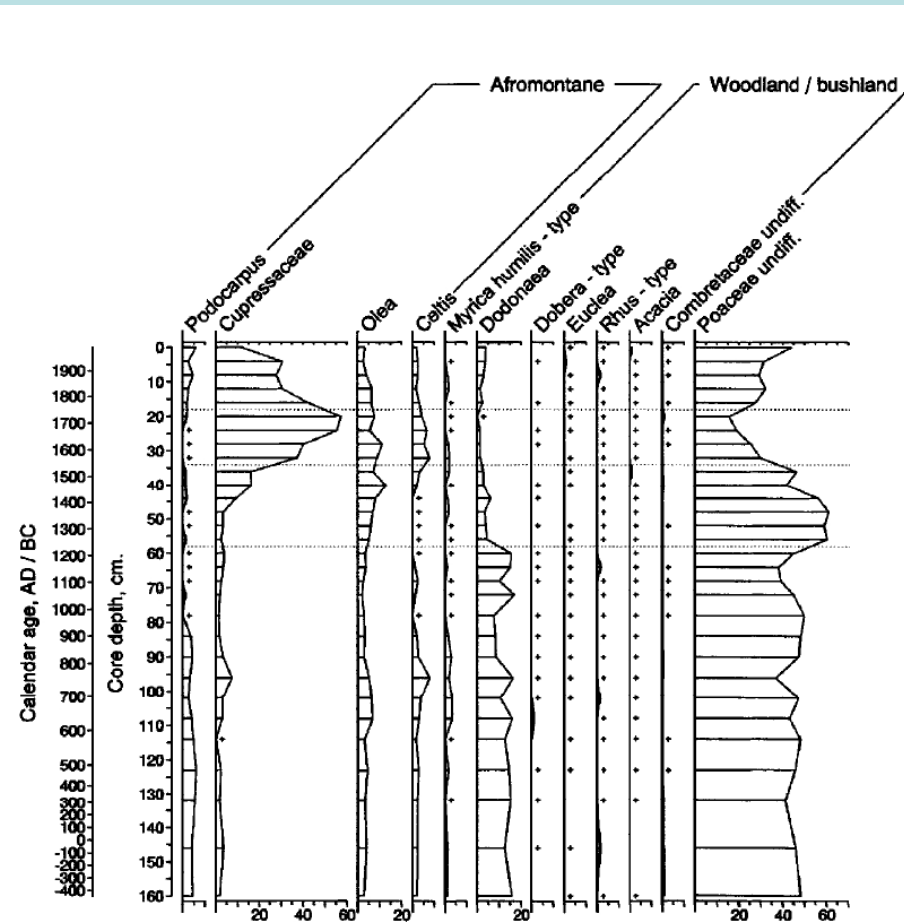
# ...in a matrix of cropland and degraded semiarid savanna





# Historical plant communities

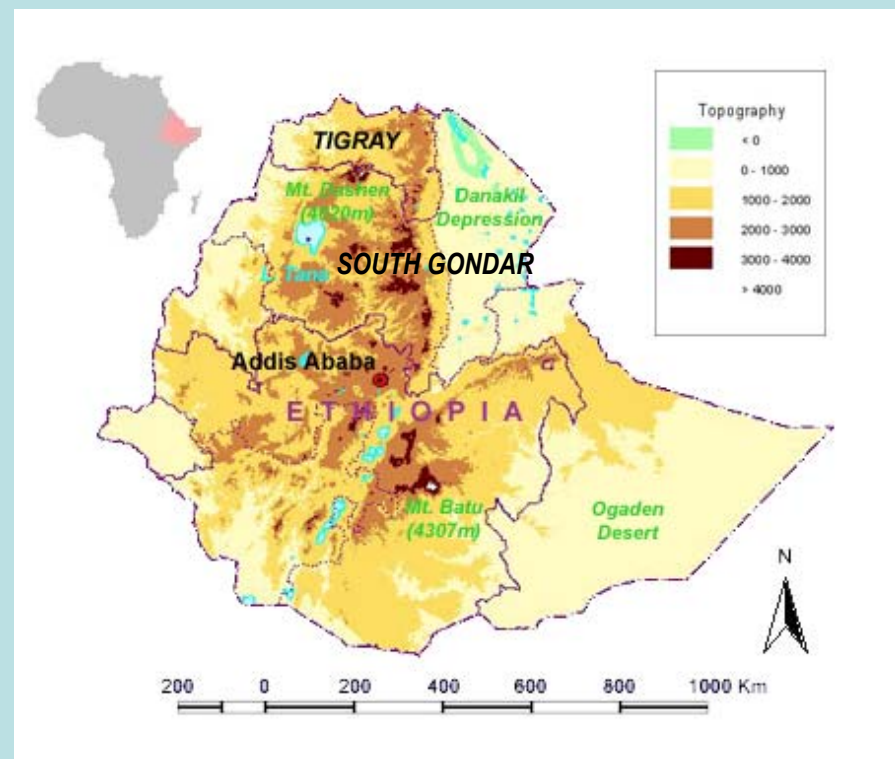
- Until 2500 years ago
  - Undifferentiated or dry monodominant Afromontane forest (Friis 1992)
  - *Juniperus procera* with *Afrocarpus falcatus* (Pencil cedar-Yellowwood)
- 500 BC
  - Forest clearance
  - *Dodonaea* and *Rumex*
- 1200-1400 AD
  - Grass and frequent fires
- 1400-1700 AD
  - Secondary forest
  - *Juniperus* with *Olea* and *Celtis*



Percentage pollen and chlorophyte algal stratigraphy of Lake Hayk core HYK99-1. Darbyshire et al. (2004) The Holocene 13(4):537-546 (DOI:10.1191/0959683603hl644rp)

# 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)



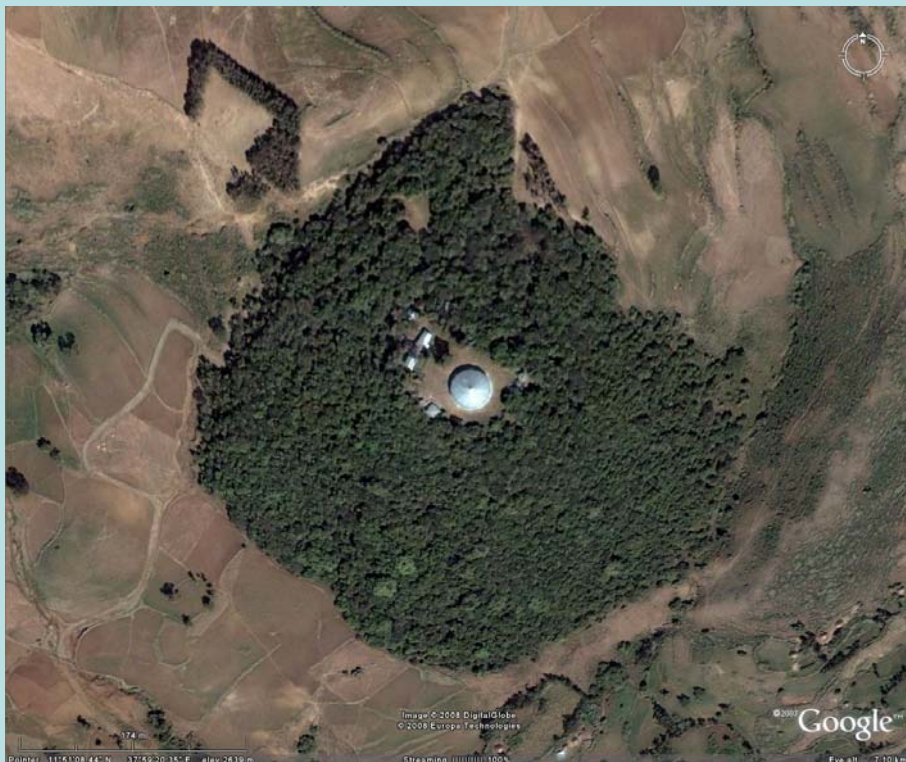
# Example: Debre Tabor



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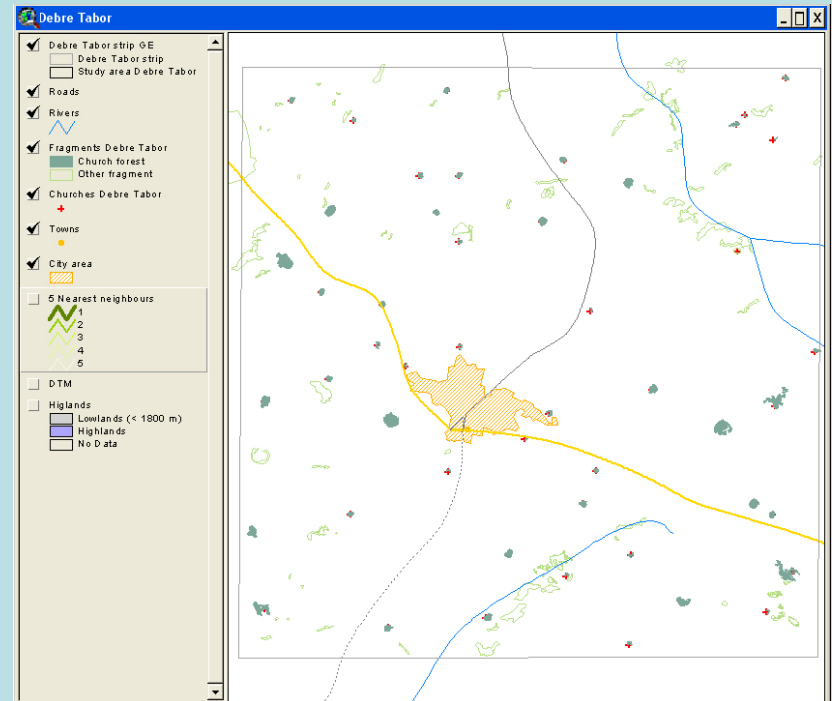
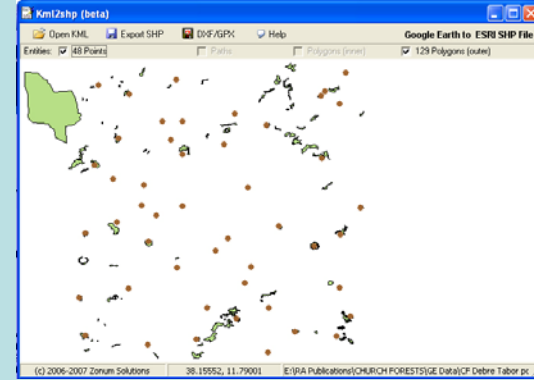
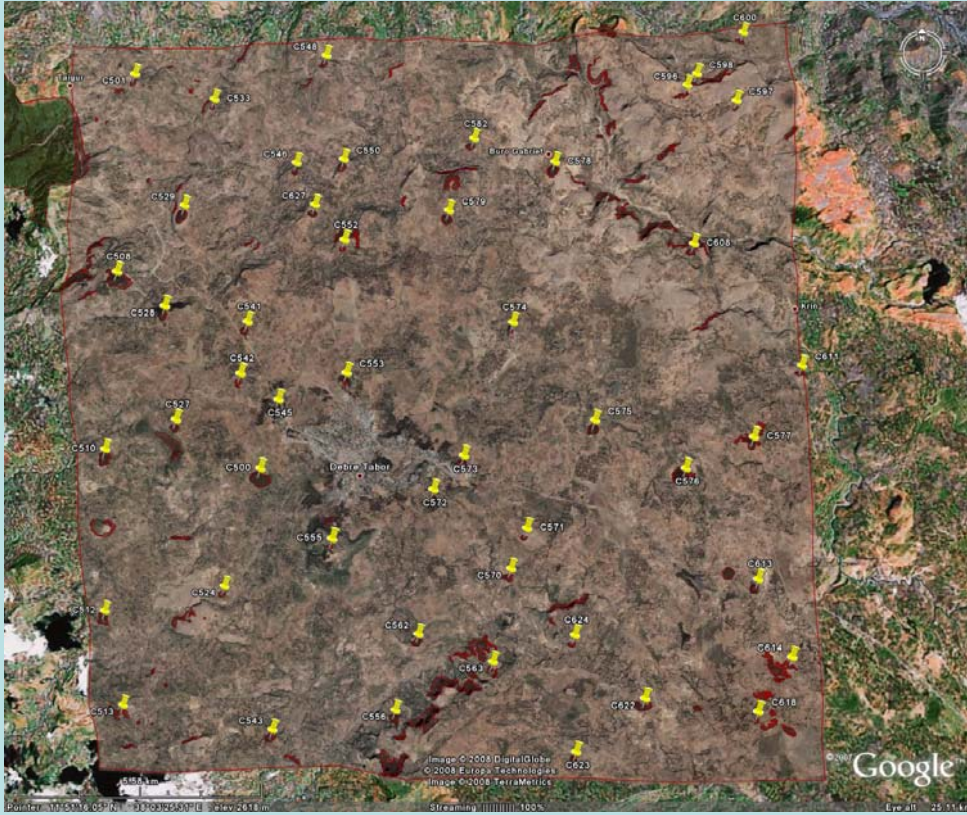


# Example: Debre Tabor



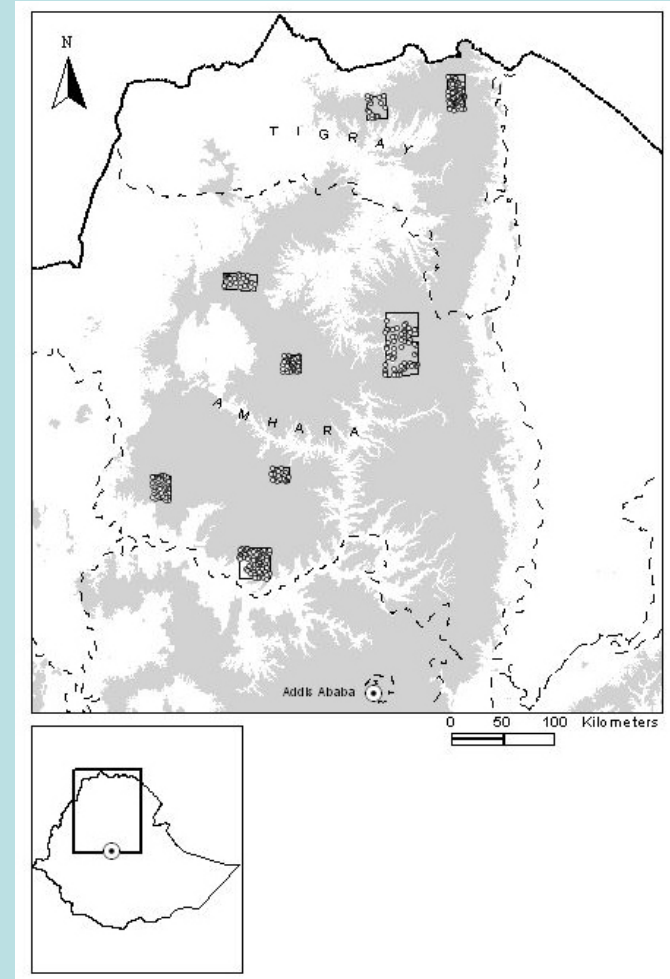


# GE > KML2SHP > ArcView GIS



# 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 ( $m/m^2$ ; PAR; 0.02 for a circle with  $r = 100\text{ m}$ )
    - Shape index ( $\sim P/\sqrt{A}$ : 1 circle;  $>1$  more complex shapes)
    - Fractal dimension ( $\sim 2\ln P/\ln A$ : 1 simple – 2 complex)
  - Isolation
    - Nearest neighbor distance (m)
  - Configuration
    - Aspect (via overlay with DTM)
    - Slope ( $^\circ$ )
    - Church to patch centroid distance (m)



# Results

	North ( <i>n</i> = 155)	South ( <i>n</i> = 239)	<i>P</i>
Mean patch size (ha)	2.81 (0.69)	2.26 (0.31)	0.271
Mean patch core area (ha)	0.59 (0.18)	0.32 (0.14)	0.238
Patch density (patches per ha)	0.43 (0.11)	0.46 (0.08)	0.801
Edge density (m/ha)	342 (55)	317 (43)	0.727
Core index (%)	23 (12)	5 (10)	0.308
Forest index (%)	0.18 (0.10)	0.31 (0.08)	0.346
<b>Mean perimeter:area ratio (m/m<sup>2</sup>)</b>	<b>0.066 (0.003)</b>	<b>&gt; 0.048 (0.002)</b>	<b>&lt; 0.001</b>
<b>Mean shape index</b>	<b>1.65 (0.04)</b>	<b>&gt; 1.4 (0.03)</b>	<b>&lt; 0.001</b>
<b>Mean fractal dimension</b>	<b>1.38 (0.01)</b>	<b>&gt; 1.33 (0.01)</b>	<b>&lt; 0.001</b>
Patch isolation (m to nearest neighbor)	1993 (92)	1887 (74)	0.329
<b>Aspect</b>	<b>F(NW&gt;SE; P&lt;0.05)</b>	<b>F(NW=SE; P&gt;0.05)</b>	
<b>Slope (°)</b>	<b>8.3 (0.5)</b>	<b>&gt; 4.7 (0.4)</b>	<b>&lt; 0.001</b>
<b>Church-patch centroid distance (m)</b>	<b>66 (6)</b>	<b>&gt; 36 (5)</b>	<b>&lt; 0.001</b>

# 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



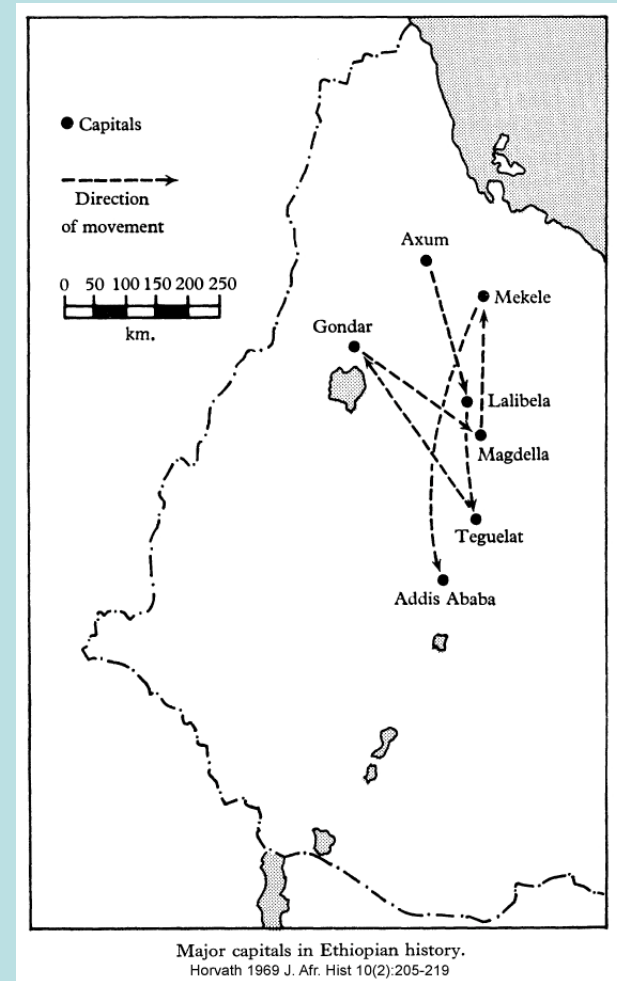
Typical southern church forest

# Discussion

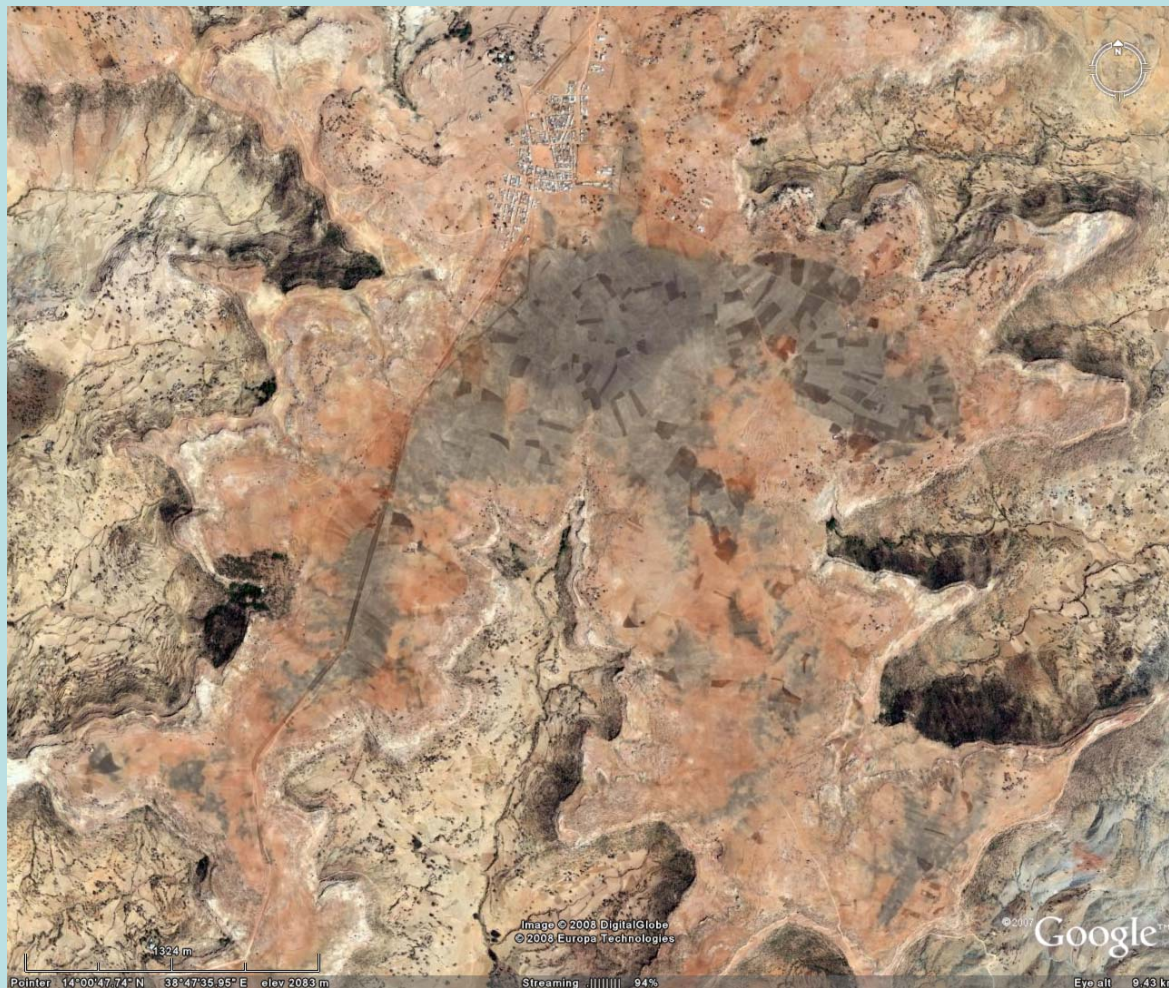
- Shape, not size, reflect historical deforestation pattern
- North: church forest protected remnant forest patches after large scale deforestation of the landscape (thus, on steep, drier slopes)
- South: church forests protected designated forest patches in a forested landscape, prior to large scale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



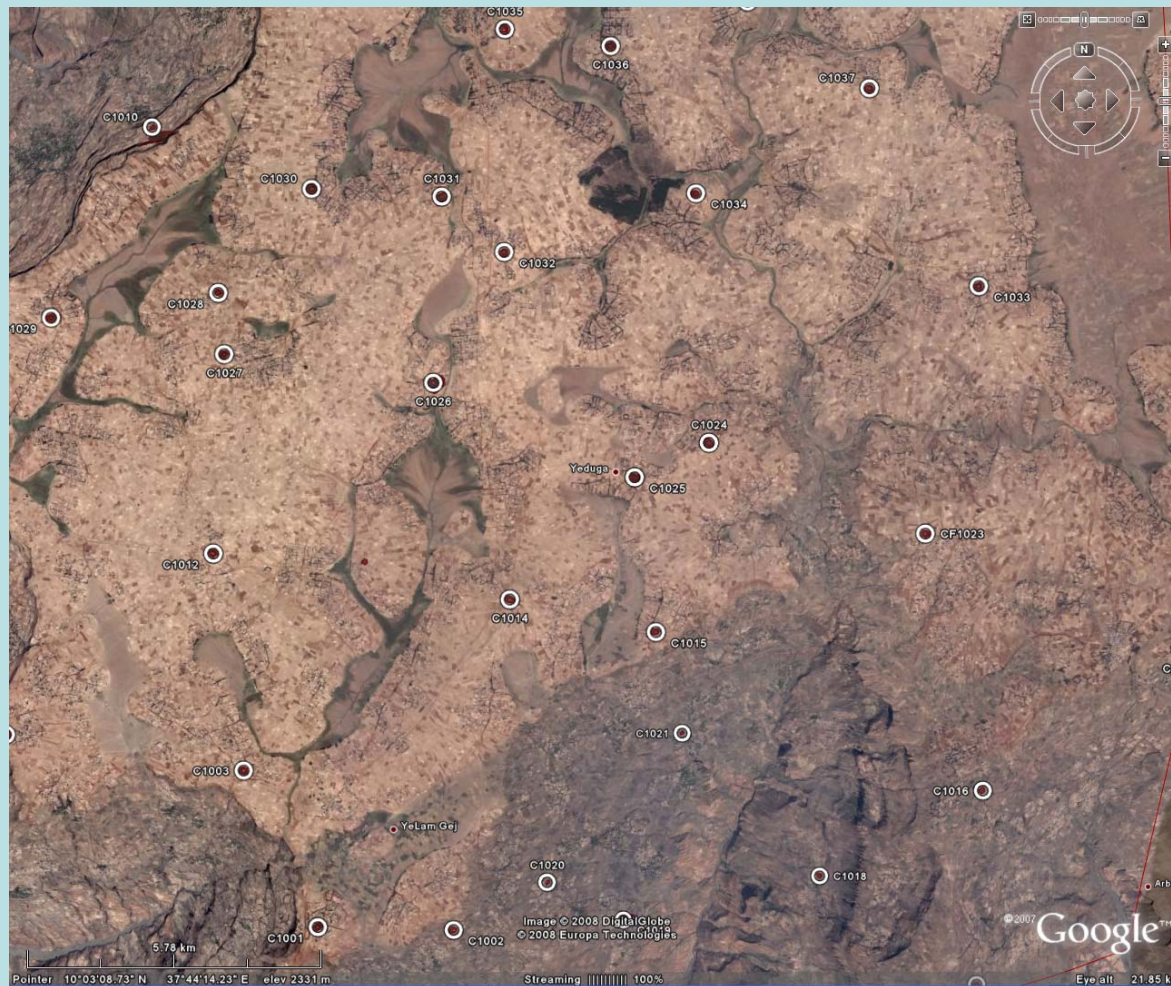
# Discussion



Northern forests on NW slopes (Axum)



# Discussion



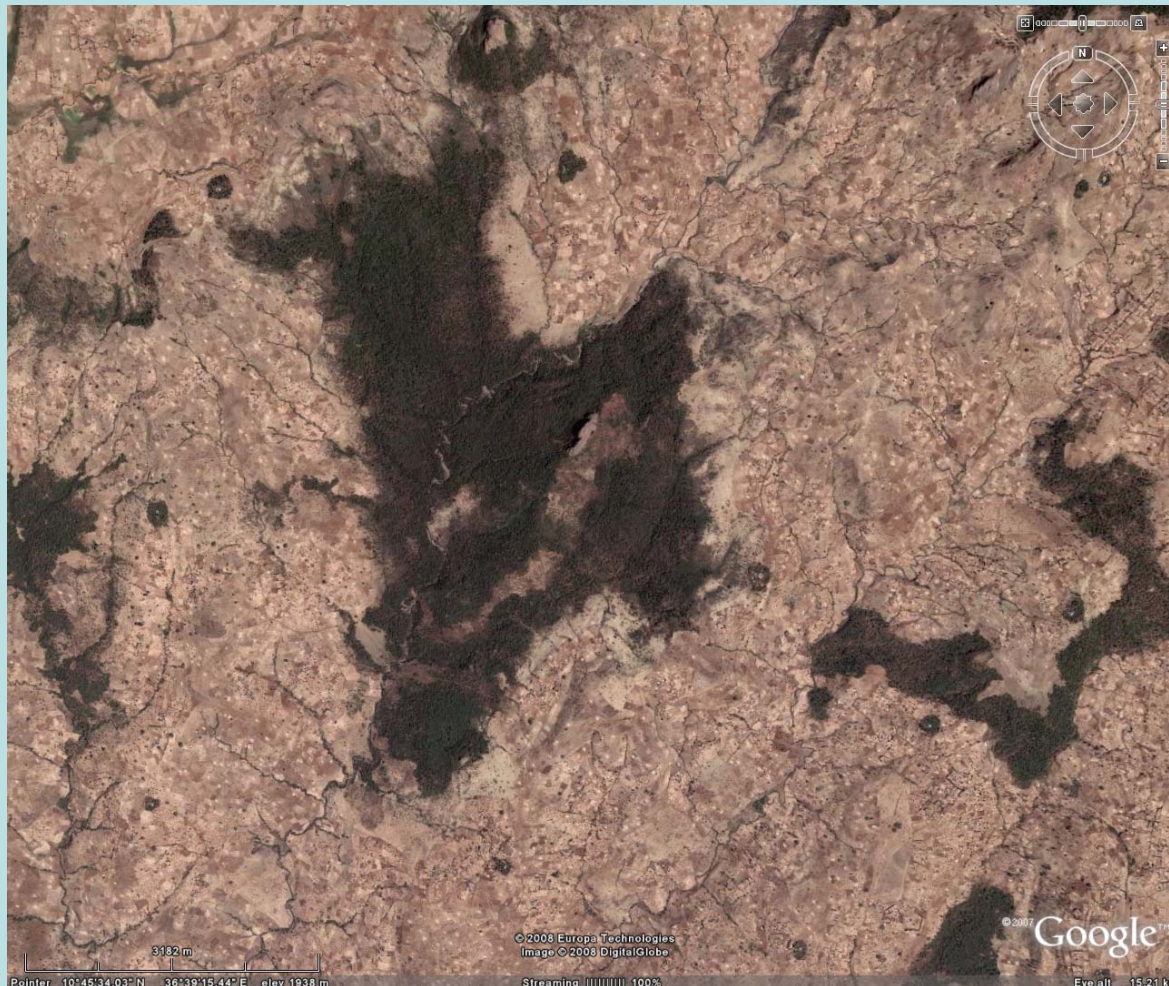
Southern forests, regularly spaced (Debre Markos)

# Discussion



Southern forests: churches on 3 x 3 km<sup>2</sup> grid

# Discussion



Southwestern forests: 3 x 3 km<sup>2</sup> 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%)