Estimation of past forest cover changes over last 150 years: Case studies from the Swiss Alps and the Polish Carpathians

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Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Background

- over the past decades **agricultural land** in Europe has **declined** and forest area has expanded considerably
- recent trends of **land abandonment** have been most **pronounced in marginal areas** like mountains (agriculture and economical inefficient)
- the **potential upper tree line** was **shifting upward** as a consequence of global warming (e.g. the Alps)

- studies conducted so far on forest cover change in the Swiss Alps and the Polish Carpathians were either (1) **local case studies** restricted in their **spatial extent**, (2) based on **forest statistics** and **not spatially explicit**, or (3) looked only at **recent changes**

- **spatially accurate large-scale and long-term reconstructions of forest cover changes** are lacking for both mountain regions and the extent, spatial or temporal variation and underlying **driving forces** of the forest cover change trends are still insufficiently understood
Study Area

Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Study area

Polish Carpathians
AREA: 20’000 sqkm
Alt range 200-2500

Swiss Alps
AREA: 10’000 sqkm
Alt range: 250-4000
The aim of this part of project is to assess influence of different drivers like land use and/or climate change on forest cover changes over the last 150 years in the parts of two European mountain ranges: the Swiss Alps and the Polish Carpathians.
Database: forest cover

Data (the Polish Carpathians)
- Second Austro-Hungarian military survey maps (~1850, scale 1:28 800)
- Polish topographic maps (1930s, 1:100 000)
- Polish topographic maps (1970s, 1:25 000)
- Landsat satellite data (2011, spatial resolution 30 m)

Data (the Swiss Alps)
- Dufour Map (~1850, scale 1:25,000 – 1:50,000)
- Siegfried Map (edition 1880 and 1940, scale 1:25,000 – 1:50,000)
- Landeskarte der Schweiz (1970s, 1:25,000)
- Landeskarte der Schweiz (2012, 1:25,000)
### Database: factors/drivers

#### Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)

<table>
<thead>
<tr>
<th>FOREST</th>
<th>PL</th>
<th>CH</th>
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</thead>
<tbody>
<tr>
<td>forest cover</td>
<td>forest cover 1860s</td>
<td>forest cover 1850s</td>
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<tr>
<td></td>
<td>forest cover 1930s</td>
<td>forest cover 1880s</td>
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<td>forest cover 1970s</td>
<td>forest cover 1940s</td>
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<td>forest cover 2011</td>
<td>forest cover 2010</td>
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<td>forest cover change 1850s-1880s</td>
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<td>forest cover change 1930s-1970s</td>
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<tr>
<td></td>
<td>forest cover change 1970s-2011</td>
<td>forest cover change 1940s-2010</td>
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</tbody>
</table>

#### FACTORS/DRIVERS

<table>
<thead>
<tr>
<th>Source PL</th>
<th>Source CH</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM DEM (90 m)</td>
<td>DHM10</td>
</tr>
</tbody>
</table>

**Environmental factors**

- **topography**
  - altitude
  - slope
  - norhness
  - eastness

- **climate**
  - Mean values for temperature (1850s-2010(11))
  - CARPAT CLIM
  - WORLD CLIM, CRU, DAYMET
  - Mean values for precipitation (1850s-2010(11))
  - Mean annual DDsum (1850s-2010(11))

**Socio-economic factors**

- **population**
  - number of people
  - number of households
  - age (different categories)

- **agriculture**
  - number of farms
  - number of animals (different types: cows, pigs, sheep, goats etc)
  - farming area (cropland/pasture)

- **economy**
  - number of employees by sector

- **accessibility**
  - railroad (yes/no)/main road (yes/no)
  - distance to settlements

**Context**

- **forest composition and configuration**
  - forest spatial pattern
  - distance to forest
  - forest maps (for analysis points of time)

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Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Methods – units and models

- Carpathians communes (CC list): 234
- Cities and villages about 1862: 2084
- Cities and villages 2008: 2048

statistical models (General Linear Models; GLMs)

- Communities: 199
- Districts: 15
- Cantons: 5
Results

1850-1930
1930-1970
1970-2011

Forest cover 1850-2011

- 1850
- 1930
- 1970
- 2011

- Forest (no change)
- Deforestation
- Forest increase
- Non-forest

[Graph showing percentage changes over time]
Results

1850-1880

persistent loss
increase

1880-1940

1940-2012

trajectories and implications (FORECOM)
Results

Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Results

Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Results (the Polish Carpathians): Forest cover change communes and R²

<table>
<thead>
<tr>
<th>single models</th>
<th>min. elevation [m]</th>
<th>slope degree [°]</th>
<th>northness</th>
<th>eastness</th>
<th>distance to forest [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>change of forest proportion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1860s-1930s</td>
<td>0,23</td>
<td>0,33</td>
<td>0,22</td>
<td>0,22</td>
<td>0,25</td>
</tr>
<tr>
<td>1930s-1970s</td>
<td>0,24</td>
<td>0,02</td>
<td>0,02</td>
<td>0,03</td>
<td>0,25</td>
</tr>
<tr>
<td>1970s-2011</td>
<td>0,24</td>
<td>0,13</td>
<td>0</td>
<td>0,05</td>
<td>0,25</td>
</tr>
</tbody>
</table>

| net forest increase | | | | | |
| 1860s-1930s       | 0,25              | 0,64            | 0,2       | 0,24     | 0,25                 |
| 1930s-1970s       | 0,25              | 0,26            | 0,09      | 0,15     | 0,25                 |
| 1970s-2011        | 0,25              | 0,24            | 0         | 0,16     | 0,25                 |

| forest increase [%] | | | | | |
| 1860s-1930s       | 0,24              | 0,47            | 0,19      | 0,23     | 0,25                 |
| 1930s-1970s       | 0,24              | 0,11            | 0,06      | 0,1      | 0,25                 |
| 1970s-2011        | 0,24              | 0,05            | 0,04      | 0,01     | 0,25                 |

| net forest decrease | | | | | |
| 1860s-1930s       | 0,08              | 0,25            | 0,02      | 0,21     | 0,25                 |
| 1930s-1970s       | 0                 | 0,04            | 0         | 0,03     | 0,25                 |
| 1970s-2011        | 0,11              | 0,59            | 0,07      | 0,19     | 0,25                 |

| forest decrease [%] | | | | | |
| 1860s-1930s       | 0,08              | 0               | 0,05      | 0,02     | 0,25                 |
| 1930s-1970s       | 0,11              | 0,31            | 0,09      | 0,13     | 0,25                 |
| 1970s-2011        | 0,03              | 0,25            | 0,01      | 0,09     | 0,25                 |

<table>
<thead>
<tr>
<th>whole model</th>
<th>change of forest proportion</th>
<th></th>
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<tr>
<td>1860s-1930s</td>
<td>0,03</td>
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<td>1930s-1970s</td>
<td>0,02</td>
<td></td>
</tr>
<tr>
<td>1970s-2011</td>
<td>0,14</td>
<td></td>
</tr>
</tbody>
</table>

| net forest increase | |
| 1860s-1930s | 0,66                          |
| 1930s-1970s | 0,26                          |
| 1970s-2011  | 0,59                          |

| forest increase [%] | |
| 1860s-1930s | 0,52                          |
| 1930s-1970s | 0,14                          |
| 1970s-2011  | 0,28                          |

| net forest decrease | |
| 1860s-1930s | 0,29                          |
| 1930s-1970s | 0,05                          |
| 1970s-2011  | 0,32                          |

| forest decrease [%] | |
| 1860s-1930s | 0,42                          |
| 1930s-1970s | 0,44                          |
| 1970s-2011  | 0,09                          |
Results (the Polish Carpathians): Forest increase and slope degree

1860s-1930s

1930s-1970s

1970s-2011

Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Results (the Polish Carpathians): Forest decrease and slope degree

1860s-1930s
1930s-1970s
1970s-2011
Results (the Polish Carpathians): Change in forest proportion and elevation

- **1860s-1930s**
  - Forest increase [%] vs. min. elevation [m]
  - Data points indicating increasing forest cover at higher elevations.

- **1930s-1970s**
  - Forest increase [%] vs. min. elevation [m]
  - Data points showing a more varied trend with both increases and decreases.

- **1970s-2011**
  - Forest increase [%] vs. min. elevation [m]
  - Data points indicating a trend towards stabilization or slight decreases at higher elevations.
Results (the Polish Carpathians): forest cover and elevation

Forest cover changes in mountainous regions – drivers, trajectories and implications (FORECOM)
Results (the Swiss Alps): Forest increase

Model: GLM (binomial) stepwise, sample: 10’000 non-forest pixels at t1

Target variable: forest gain (yes/no)

Explanatory variables: exposition (northness/eastness), *altitude*, *slope*, *distance to forest edge* at 1st time step, *distance to settlement*

![Bar chart showing Adjusted R² values for different time periods: OM-sieg1st (1850-1880), sieg1st-sieglast (1880-1940), sieglast_today (1940-2010).]
Results (the Swiss Alps): Forest decrease

Model: GLM (binomial) stepwise, sample 10’000 forest pixels at t1
Target variable: forest gain (yes/no)
Explanatory variables: exposition (northeness/eastness), altitude, slope, distance to forest edge at 1st time step, distance to settlement

![Bar chart showing forest decrease over different periods](chart.png)
Results (the Swiss Alps): forest cover

Model: GLM (binomial) stepwise, sample 10’000 of all pixels
Target variable: forest (yes/no)
Explanatory variables: exposition (northeness/eastness), altitude, slope, forest cover at previous time step
Conclusions

• net forest cover increase have been observed for both study areas and across almost all periods
• long-term studies help to identify hot-spots of change and persistency (spatial) and periods of change and stability (temporal)
• forest-transition -> different stories at regional and locale scales

• relatively, topography and context information do not significantly contribute to the explanation of forest cover decrease or increase
Thank you for your attention!