Climate change reflected in dynamics of vegetation

Using satellite vegetation index

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Climate and vegetation

The plant community in an area is the most sensitive indicator of climate.

Climate, more than any other factor, controls the broad-scale distributions of plant species and vegetation. Rapid climate change over the next century is likely to lead to major changes in the distribution of plants and thus in biomes and habitats.
Climate and vegetation

<table>
<thead>
<tr>
<th>Scales of interactions (Monteith, 1981)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biome</td>
</tr>
<tr>
<td>Community</td>
</tr>
<tr>
<td>Individual</td>
</tr>
<tr>
<td>Component</td>
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<tr>
<td>Component</td>
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</tbody>
</table>

- Biome: Global climate
- Community: Local climate
- Individual: Microclimate
- Component: Epicclimate
- Component: Endoclimate

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Climate and vegetation

• Vegetation dynamics like growth, reproduction, and winter rest, competition for nutrients, water, and light are strongly influenced and determined by climate variables.

• A scientific discipline, which is able to link vegetation dynamics with climate variables, is phenology.
  ➢ Phenology is the study of the timing of recurrent biological processes such as budburst, flowering, fruit ripening and leaf fall.
Phenology

**Traditional phenology**
- Ground based
- Dates of phenological phases
- Based on visual observation
- Species-level
- Local

**Land surface phenology**
- Satellite based
- Dates of critical values of vegetation indices
- Based on satellite observation
- Ecosystem level
- Areal

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Detectable climate change

Increasing temperature

Phenological observations

Global Temperature, 1880 - 2014

Budbreak of the horse chestnut in Geneva 1808–2017

Training course on the use of satellite products...
Some results on the basis of traditional plant phenological observations

- **International Phenological Gardens (1957- )**

- **Menzel (2000):**
  - She found, that only 27% of the trends of the spring records are significant (14% at the 0.01 level, 13% at the 0.05 level; 73% were not significant) owing to high interannual variability and the short length of the time series.
  - Moreover, not all trends of the spring events are in the same direction.
    - 73% of them have a negative sign (22% significant, 51% not significant records)
    - 27% have a positive sign (5% significant and 22% not significant records).
Some results on the basis of traditional plant phenological observations

COST Action 725 and PEP 725

coordinate the collection of in-situ phenology observations and expand existing observing networks.

• Different species show different sensitivity to climatic variables, therefore the impact of climate change on the vegetation as a whole can be detected with several difficulties using long time data series from the same places.
Remote sensing in phenological studies

Remote sensing phenology, the use of satellites to track phenological events can complement or substitute ground observation networks. Satellites provide a unique perspective of the planet and allow for regular, even daily, monitoring of the entire global land surface.

Obviously remote sensing data are not the traditional phenological phases but they are reflectance (ρ) in different spectral channels. The status of the vegetation is in close connection with its reflectance especially in the near infrared and red spectrums.
The aim of our research was to study the response of vegetation to climate change.

- Retrieve land surface phenological data from satellite observations
- Comparing traditional phenological observation data with land surface phenological data
- In our study we used the “Enhanced Vegetation Index” (EVI) to characterize the status of the vegetation.
  - (Huete et al., 2002; Zhang et al, 2003; Liang and Schwartz;,, 2009; De Beurs and Henebry, 2010)
Material 1

Sample area: IKLAD

(5 km x 5 km) covered by different agricultural and native plants

This size of sample area was chosen, because it is small enough, that the variability of EVI at a given time derives from the inhomogeneity of vegetation rather than different climatic conditions and large enough to represent the inhomogeneity of vegetation in a typical Central-European rural area.
Satellite data:

Enhanced Vegetation Index (EVI) from MODIS placed at Terra and Aqua satellites (NASA, LP DAAC, 2011)

The MODIS Vegetation Index algorithm operates on a per-pixel basis and relies on multiple observations over a 16-day period to generate a composited Vegetation Index both from Terra and Aqua satellites overlapped with 8 days.

We got **high resolution** (250m x250m pixels) composite data with 8 day frequency for an eleven years period (2003-2013).
# Material 3

Plants: Traditional observations

- Within the same sample area in 2011 and 2012

<table>
<thead>
<tr>
<th>Plant</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>locust (<em>Robinia pseudacacia</em>)</td>
<td>native plants</td>
</tr>
<tr>
<td>poplar (<em>Populus spp</em>)</td>
<td></td>
</tr>
<tr>
<td>sessile oak, (<em>Quercus petraea</em>)</td>
<td></td>
</tr>
<tr>
<td>winter wheat (<em>Triticum aestivum</em>)</td>
<td>agricultural plants</td>
</tr>
<tr>
<td>maize (<em>Zea Mays</em>)</td>
<td></td>
</tr>
<tr>
<td>sunflower (<em>Helianthus annuus</em>)</td>
<td></td>
</tr>
</tbody>
</table>

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The site of the traditional observations were identified by pixel-level (250m x 250m)
The EVI values of those pixels were analysed.
Methods

• Spatial average and variation coefficient of high resolution EVI data is used to characterize of the vegetation dynamics.

• Temporal variation in EVI data are modelled using piecewise sigmoid models. Each growth cycle is modelled using two sigmoid functions: one for the growth phase, one for the senescence phase (Zhang et al. 2003).

• To identify the land surface phenological transition dates, the rate of change in the curvature of the fitted logistic models is used for each year.

• Specifically, transition dates correspond to the times at which the rate of change in curvature in the EVI data exhibits local minima or maximums.
Spatial and temporal variability of EVI

• Filtering

In spite of the serious data processing and filtering done by NASA a further checkup process was applied to avoid data, which are irrelevant to natural vegetated surface. This process should have been done for wintertime data, from middle of December until the end of February. During this period of the year negative values of EVI were omitted as well as too high values. This latter means for example in wintertime sometimes EVI value exceeded 0.9, because of snow and ice.
Spatial variability

In wintertime the spatial variability of EVI is extremely high and the years are very different.

The variation coefficient sharply reduced when the growing season starts.

Annual course of spatial variability of EVI within the sample area

From March to the end of November the average CV% of EVI is 32.2%.

During this period there is a time course as well.

In springtime when different species at different time revived the size of inhomogeneity is larger than in summertime when all species are lively, CV% decreases from about 35% to 25%. Later, during senescence, that process also has a different rate for each species, the CV% increases again from 25% up to 44% in average.
Temporal Variability

of EVI values is analyzed by the annual course of the spatial average of EVI

\[ EVI = \frac{U}{1 + e^{a+bx} + c} \]

The upper and lower polynomial enveloping curves fitted for the maximal and minimal values of EVI at a specified time show the inter-annual variability of the vegetation development.
Temporal Variability

- The maximum of the maxima of the spatially averaged EVI was **0.53 in 2006**, while the minimum of the maxima was **0.39 in 2012**.

These results support the views that limiting factor of biomass accumulation in the Carpathian Basin is the lack of precipitation.

*Cumulative precipitation and temperature at the meteorological station Aszód for the years 2006 and 2012*
Dynamics of vegetation development

- It is characterized by the yearly course of the spatially averaged EVI values, which is modelled by logistic functions.

\[ EVI = \frac{U}{1 + e^{a + bx}} + c \]

From a mathematical viewpoint the logistic curve has the advantage that it has sharp points can be related to the changes of the vegetation status. These points are the time, when the changes of the curvature have local minima or maxima.

Annual course of spatial average of EVI at the sampling area Iklad in 2011.
Land surface phenological (LSP) data

To identify the land surface phenological transition dates, the rate of change in the curvature of the fitted logistic models is used for each year.

Specifically, transition dates correspond to the times at which the rate of change in curvature in the EVI data exhibits local minima or maximums.
Rate of change in the curvature of the fitted logistic models

F1 - the start of the season
F2 - maximum greenness begins
F3 - greenness begins to decrease
F4 - notes the beginning of dormancy

Increasing period of EVI

Decreasing period of EVI
Land surface phenological dates in different years

the onset of greenness increase (F1),
the onset of greenness maximum (F2),
the onset of greenness decrease (F3), and
the onset of greenness minimum (F4).

BUT

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The length of growing season calculated by the difference of landscape phenological phases F4 and F1

\[ y = 2.6455x - 5103.5 \]

\[ R^2 = 0.4042 \]

Significant (5%)
EVI values on pixel level

2012

Native trees

EVI

8 days periods

locust
poplar
oak
FL loc
FL pop
FL oak

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EVI values on pixel (species) level

Agricultural plants

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Conclusions

• Land surface phenology based on EVI is suitable to evaluate the vegetation dynamic of the season.
• Traditional phenology is more sophisticated but it is difficult to integrate.
• EVI values for native plants (trees) can be modeled by logistic curves.
  • Flowering time relating to EVI is plant specific
• EVI values for agricultural plants show different shape (not logistic).
  • The maximum EVI is around flowering and then the decreasing phase has rather convex curvature.
Thank you for your attention!