Climate change reflected in dynamics of vegetation

Using satellite vegetation index

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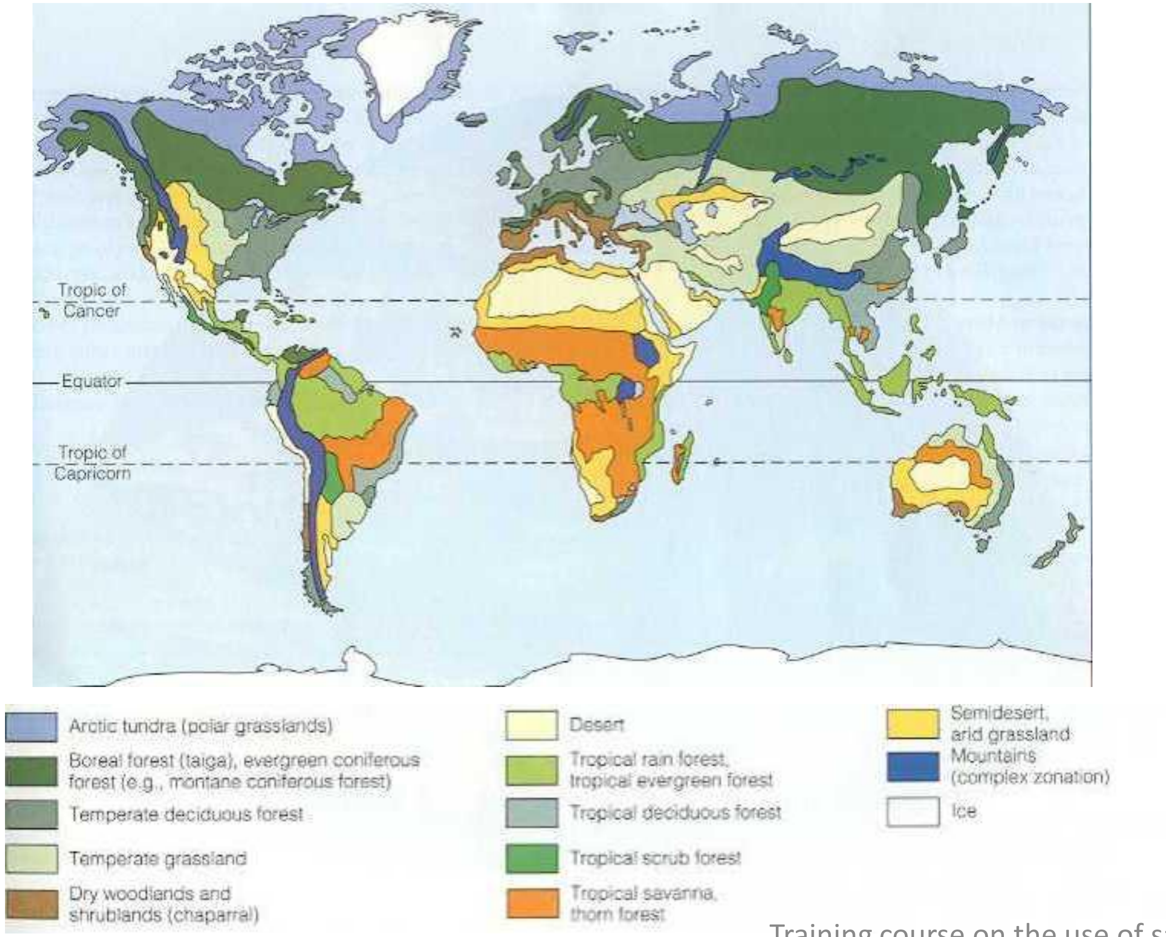
Climate and vegetation

Biomes in the Earth



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

Scales of interactions (Monteith, 1981)		
Biome	⟷	Global climate
↑		
Community	⟷	Local climate
↑		
Individual	⟷	Microclimate
↑		
Component	⟷	Epiclimate
		Endoclimate

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

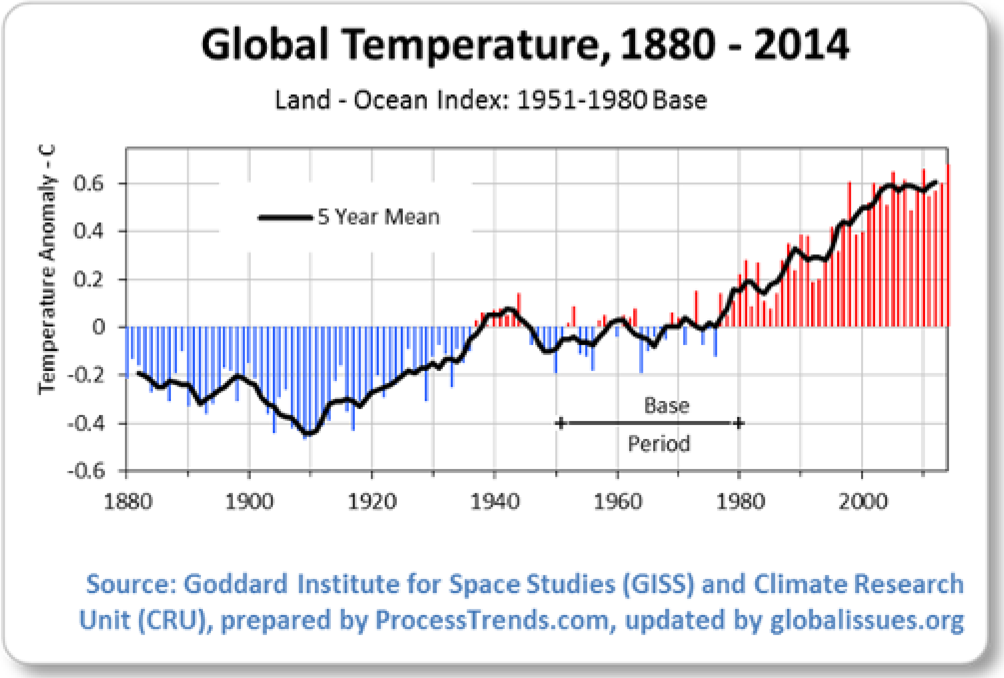
- Dates of phenological phases
- Based on visual observation
- Species-level
- Local

Land surface phenology
Satellite based

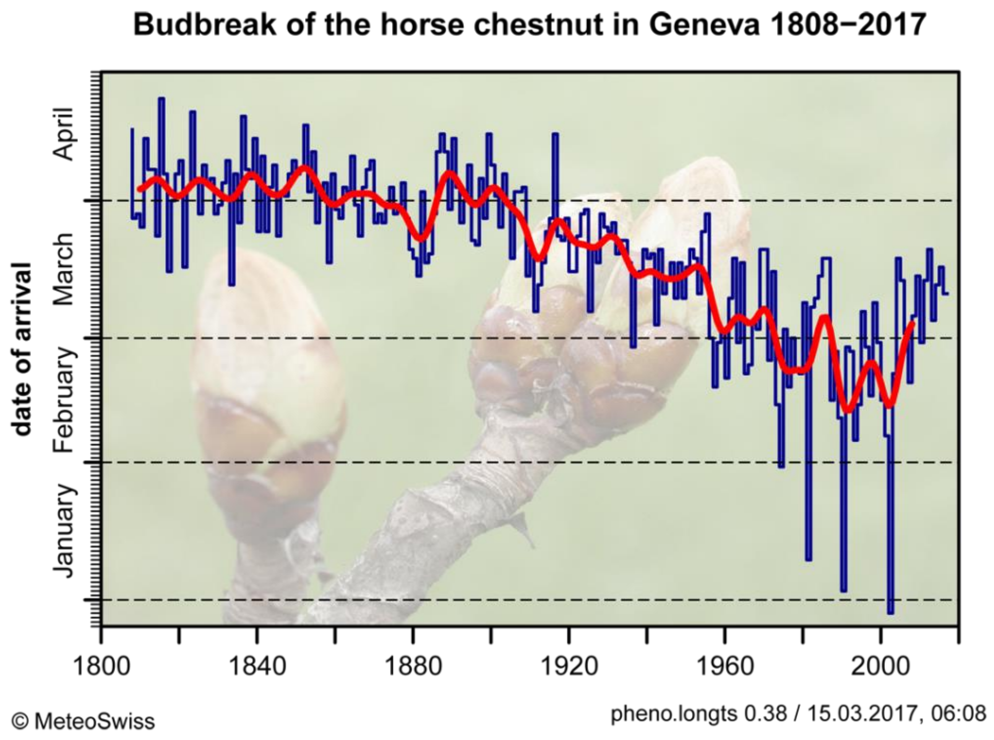
- Dates of critical values of vegetation indices
- Based on satellite observation
- Ecosystem level
- Areal

Detectable climate change

Increasing temperature



Phenological observations



Some results on the basis of traditional plant phenological observations

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

- *Menze*l (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.

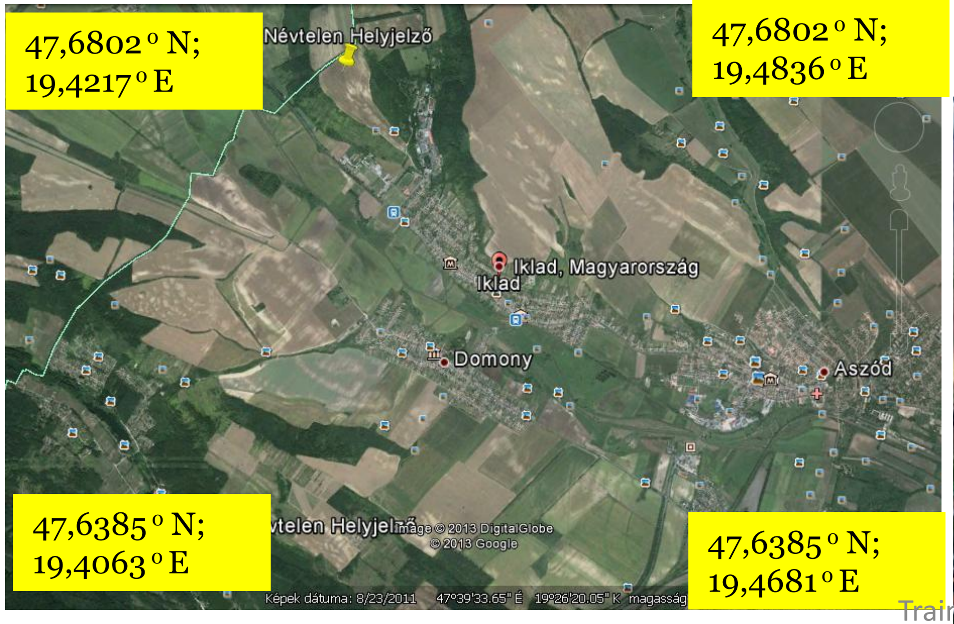
  - (*Huete et al*., 2002; *Zhang et al, 2003; Liang and Schwartz*;, 2009; *De Beurs* and *Henebry, 2010)*

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.




Slovensko
(Slovakia)
Magyarország
(Hungary)
Znojmo
Hodonín
Trenčín
Prievidza
Košice
Humenné
Michalovce
Uzhhorod
(Ужгород)
Mukacheve
(Мукачево)
Rožňava
Trnava
Nitra
Wien
Bratislava
Liesing
Salgótarján
Miskolc
Vynohradiv
(Виноградів)
Nyíregyháza
Eger
Hajdúnánás
Satu Mare
Carei
Vác
Győr
Sopron
III. kerület
Budapest
X. kerület
Jászberény
Debrecen
Kapuvár
Monor
Marghita
Érd
Cegléd
Szombathely
Zalău
Székesfehérvár
Oradea
Aleşd
Zalaegerszeg
Csongrád
Békéscsaba
Beiuş
Szentes
Nagykanizsa
Kiskunhalas
Kaposvár
Varaždin
Szeged
Mecsekjánosi
Baja
Arad
Koprivnica
Mohács
Pécs
Subotica
Kikinda
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Sombor
(Суботица)
(Кикинда)
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Sesvete
(Сомбор)
Timişoara
Lugoj
Hunedoara
Osijek
Sisak
Caransebeş
Novi Sad
Zrenjanin
Novska
Slavonski
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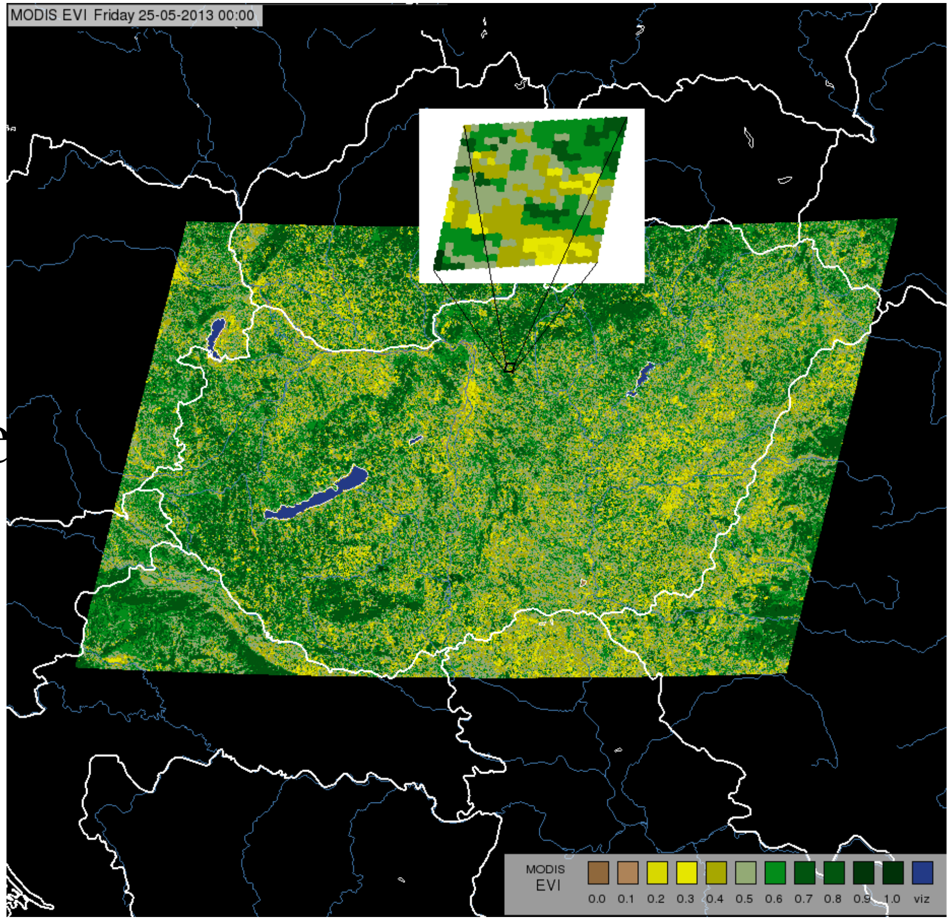
Material 2

Satellite data:

Enhanced Vegetation Index (EVI) from MODIS placed at Terra and Aqua satellite (*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

locust (*Robinia pseudacacia*);
poplar (*Populus spp*);
sessile oak, (*Quercus petraea);*
winter wheat (*Triticum aestivum*);
maize (*Zea Mays*);
sunflower (*Helianthus annuus*);

native plants

agricultural plants

Material 4

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

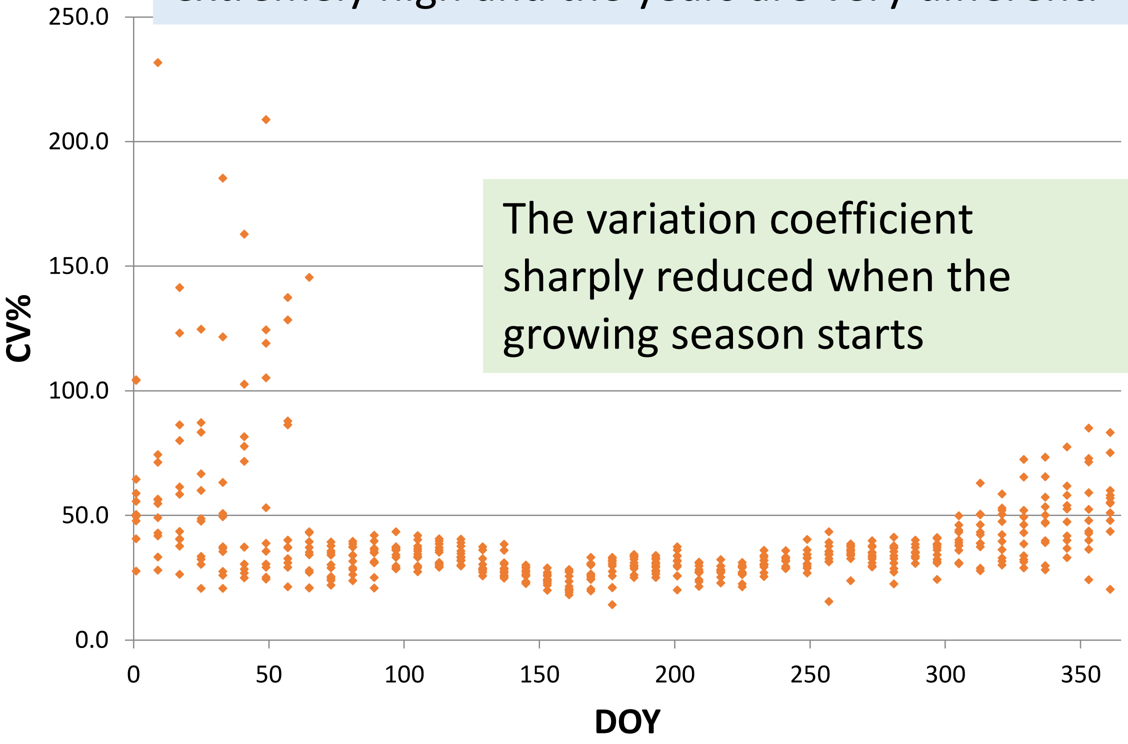
- Filtering

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

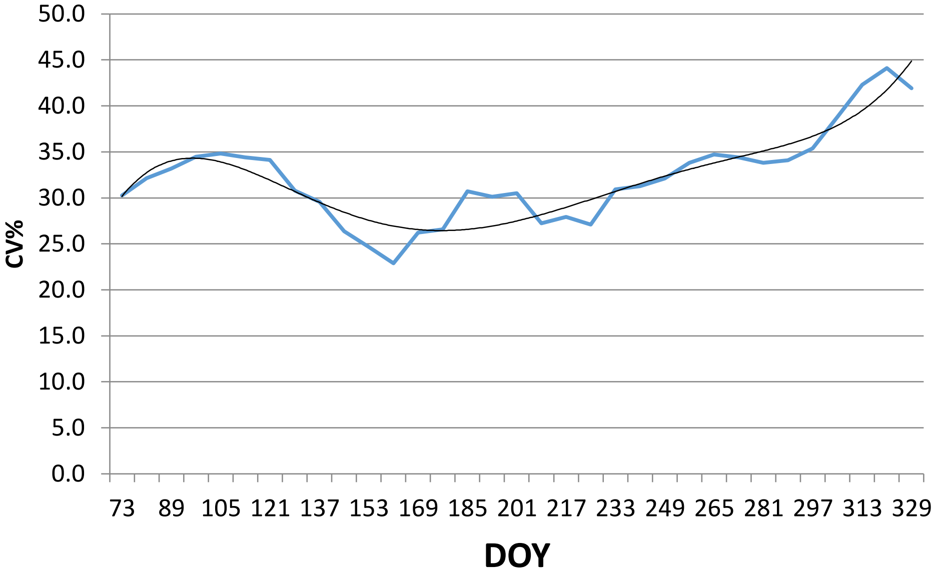


Annual course of spatial variability of EVI within the sample area

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.

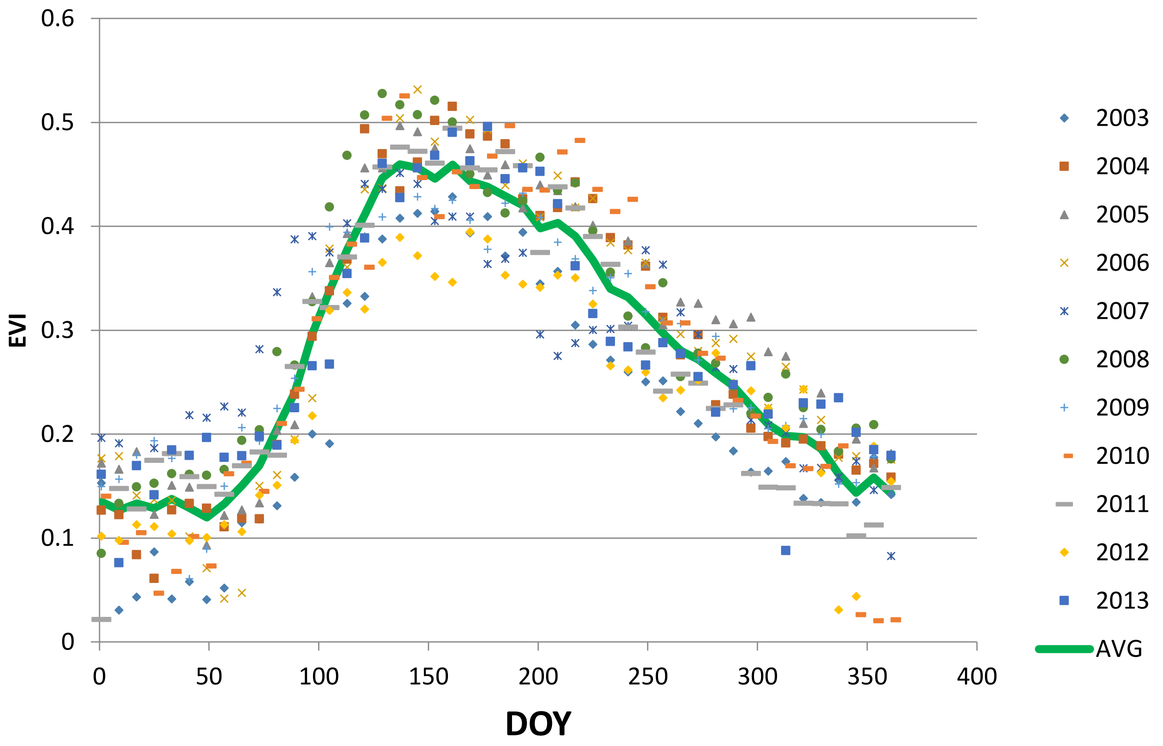
In springtime when different species at different time revived the size of inhomogeneity is larger than in summertime when all species are lively, CV% decreases from about 35% to 25%. Later, during senescence, that process also has a different rate for each species, the CV% increases again from 25% up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



The mean spatial variability CV% of EVI during the growing season

Temporal Variability

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

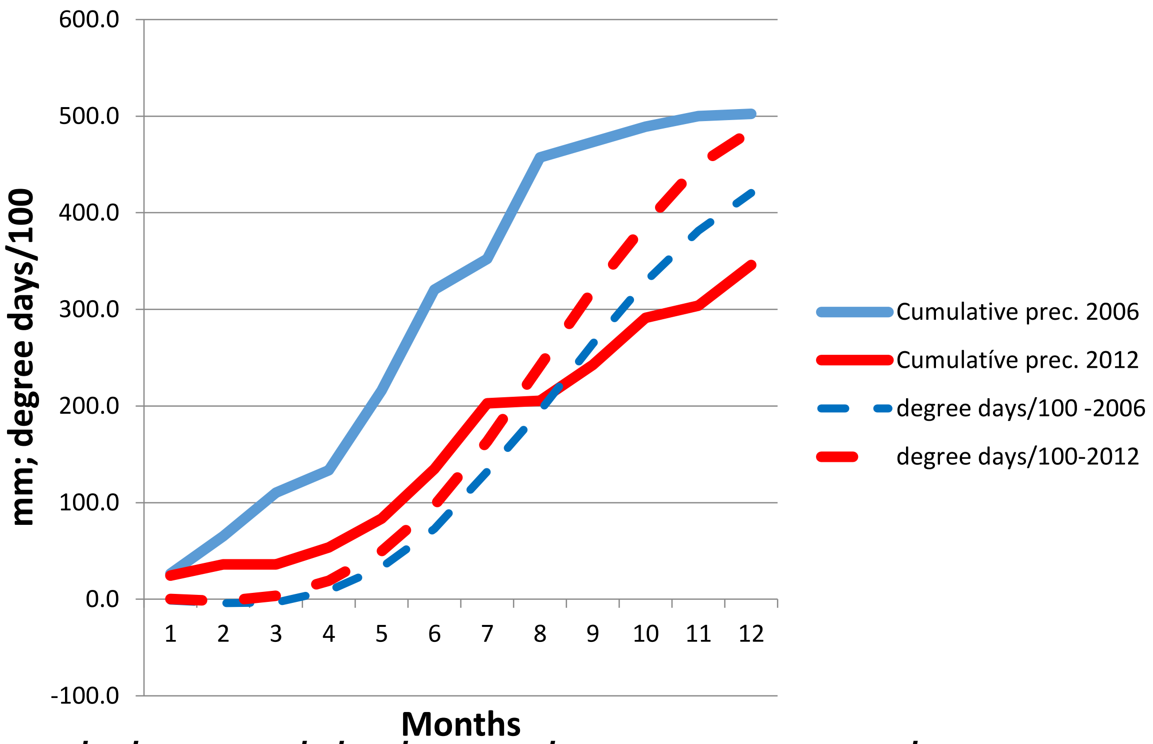


$$EVI = \frac{U}{1+e^{a+bx}} + c$$

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**.

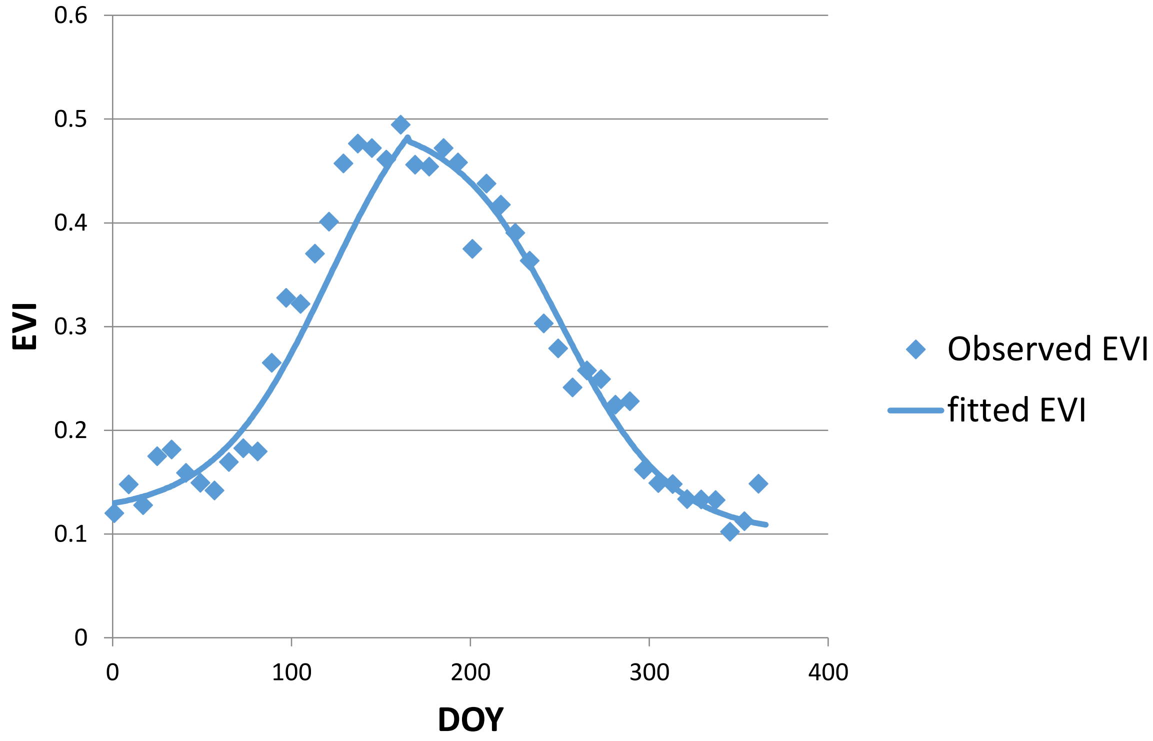


Cumulative precipitation and temperature at the meteorological station Aszód for the years 2006 and 2012

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

Dynamics of vegetation development

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



Annual course of spatial average of EVI at the sampling area Iklad in 2011.

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

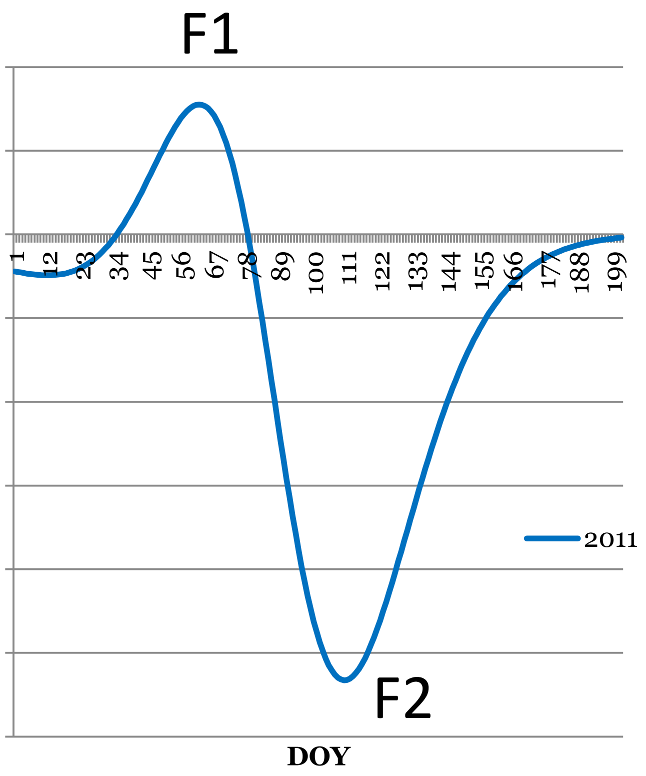
From a mathematical viewpoint the logistic curve has the advantage that it has sharp points can be related to the changes of the vegetation status. These points are the time, when the changes of the curvature have local minima or maxima.

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



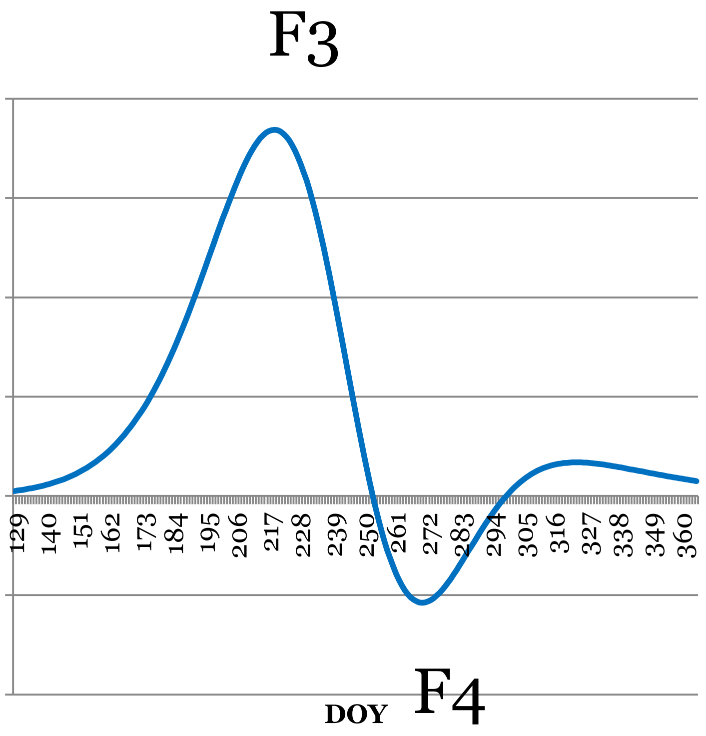
Increasing period of EVI

F1- the start of the season

F2- maximum greenness begins

F3- greenness begins to decrease

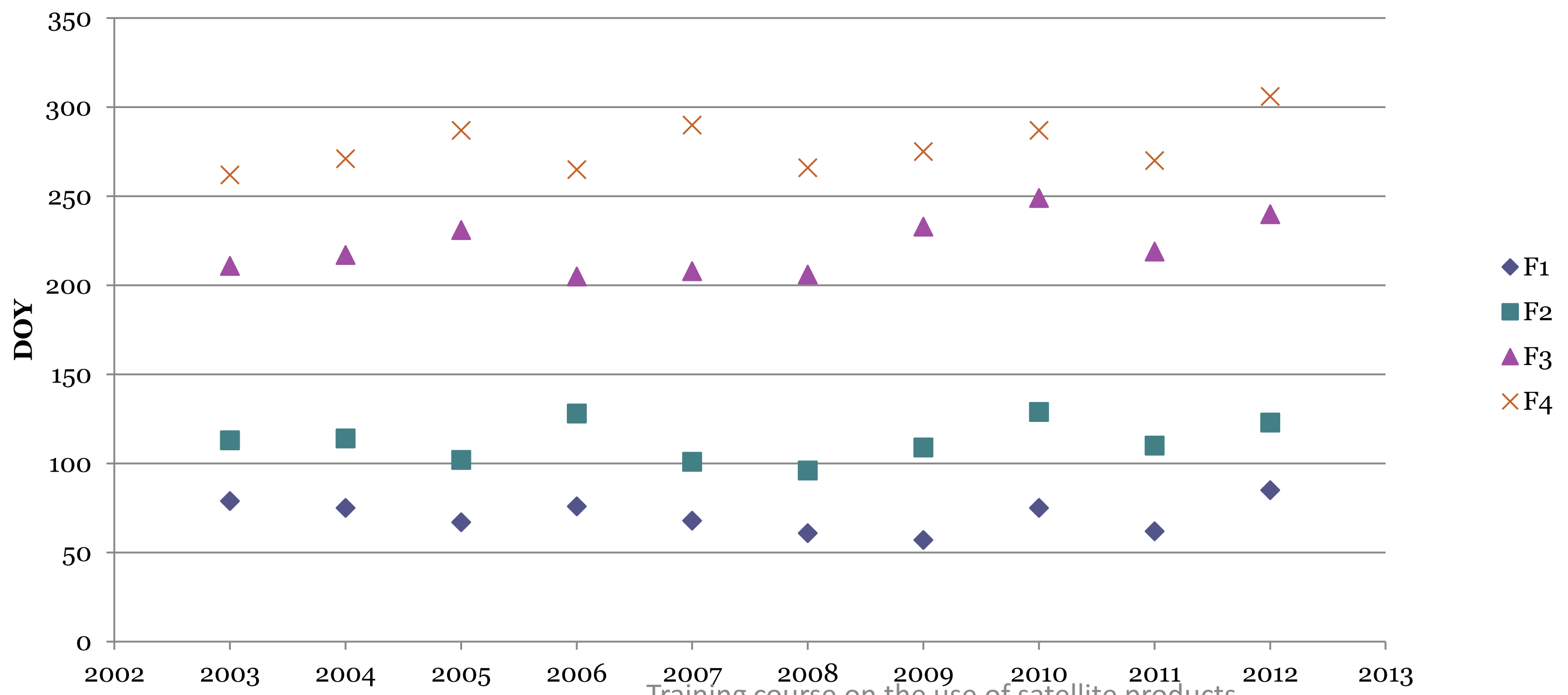
F4- notes the beginning of dormancy



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).

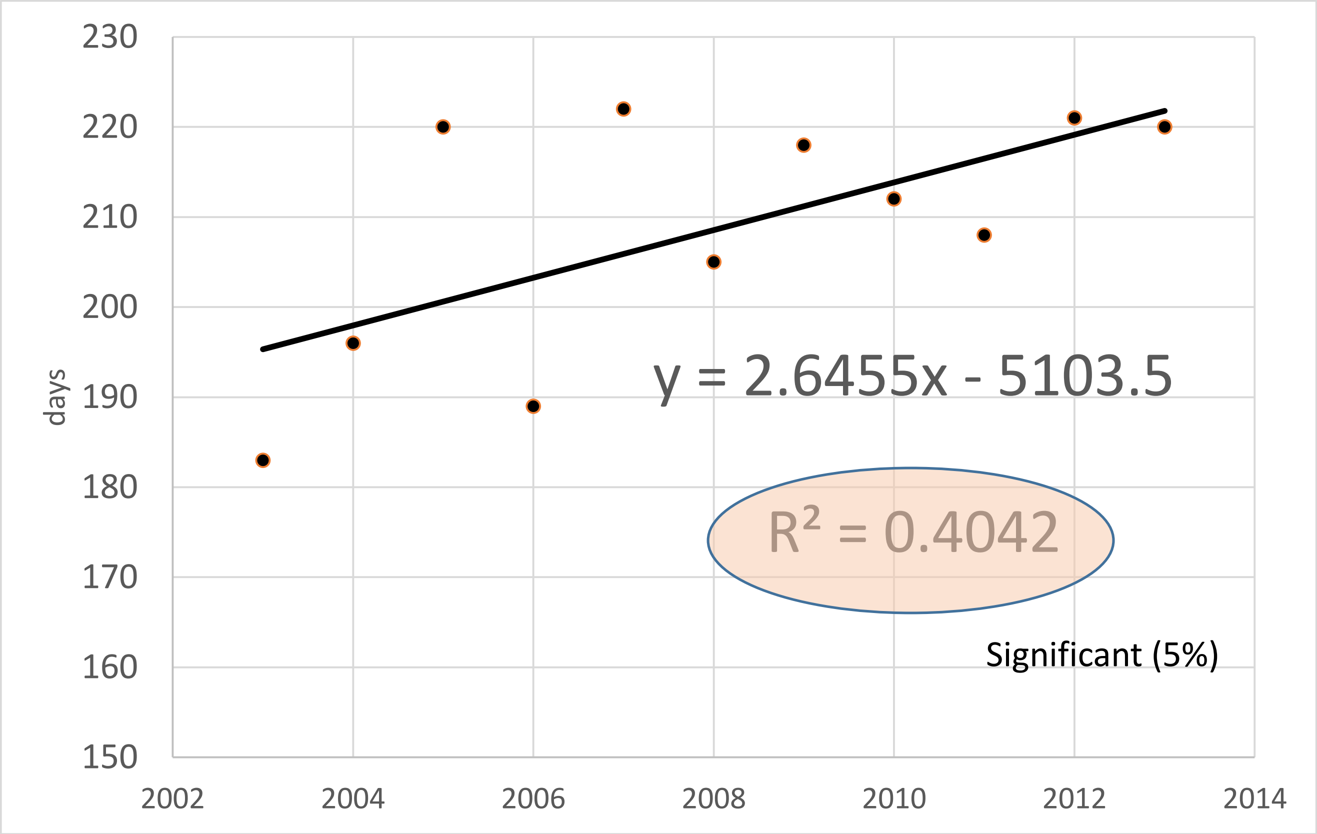


Trend?

No significant trend.

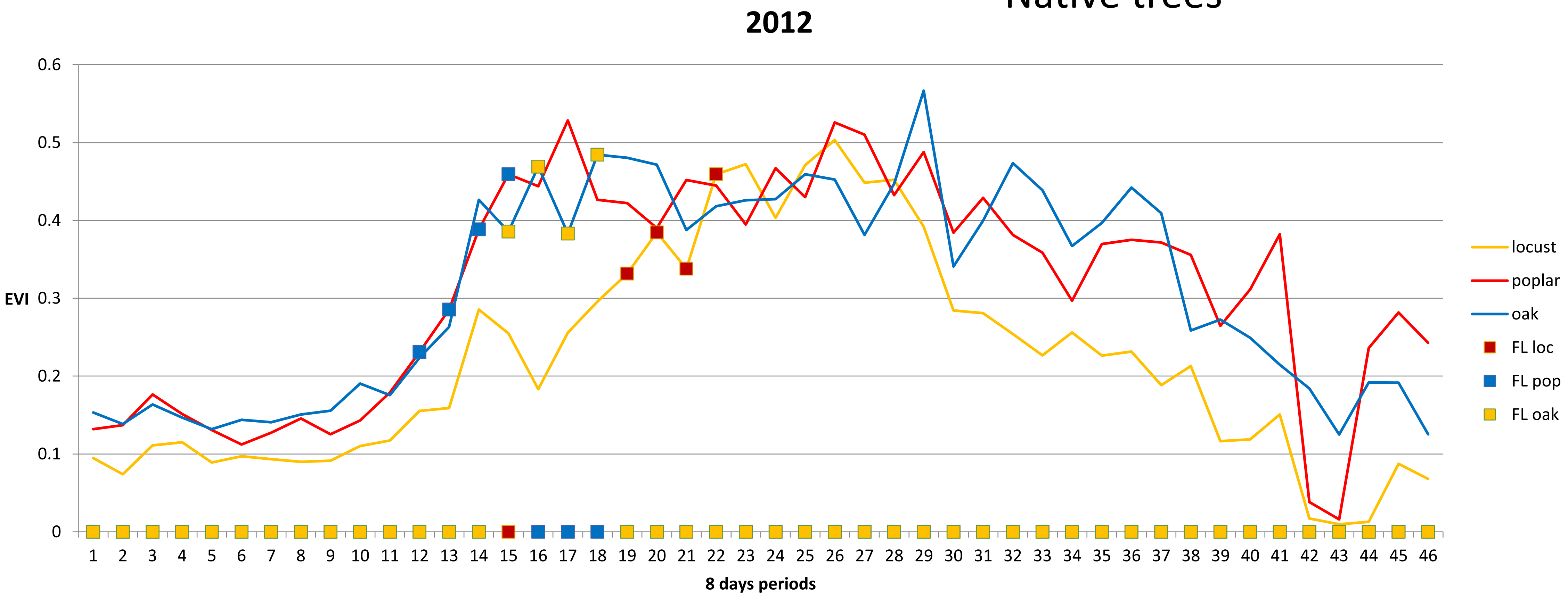
BUT

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



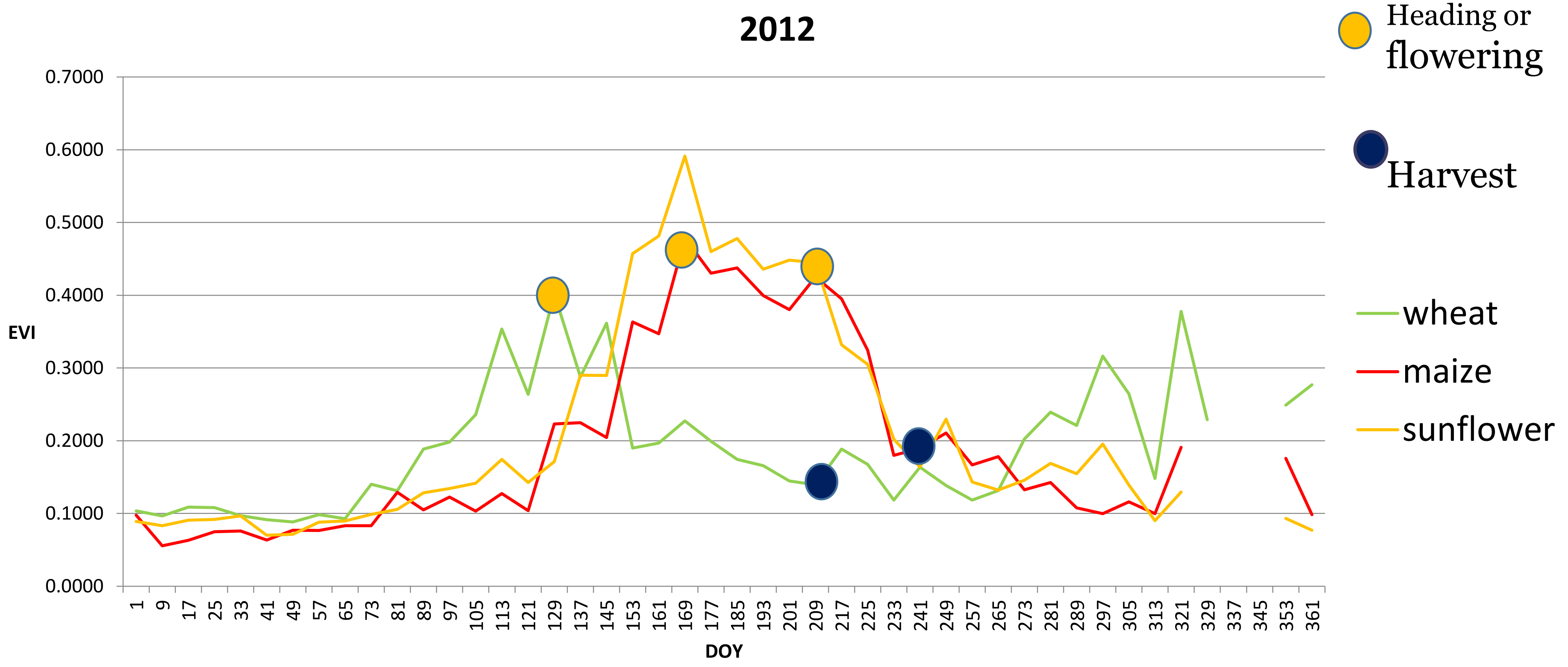
EVI values on pixel level

Native trees



EVI values on pixel (species) level

Agricultural plants



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!