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Satellite products for drought monitoring and agro-meteorological applications. 24-28 April 2017

VEGETATION AND SOIL MOISTURE ASSESSMENTS BASED ON MODIS DATA TO SUPPORT REGIONAL DROUGHT MONITORING

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János Bolyai Research Scholarship of the Hungarian Academy of Sciences

Drought is almost a natural phenomenon on continental climate areas – such as Hungary – that is also provided with historical records (Réthly 2009).

Increasingly extreme precipitation events and pattern are today the main effects for the variability of drought (in addition the increasing temperature) – Regional climate models predict a combined trend of higher average temperatures and less precipitation (first of all in Summer) for the Carpathian Basin – This makes the region vulnerable to future droughts.

Dry seasons in Spring and in Autumn are getting stable from 1901 (< 1 mm/day)

20^{th} century: only 5 years had less than 200 mm precipitation than in their previous year in Hungary.
21^{st} century: we know already 4 years (less than two decade…) in similar situation („twin years”: 2010 and 2011). Max. and min. precipitation in consecutive years.

Unfortunatelly these facts generally gets rarely on the national, or regional spatial plannings, territorial developments.
But for mitigation of agricultural management problems caused by extremity, this sector must have informations from sensitivity and state of vegetation, or soil moisture – monitoring can do it.

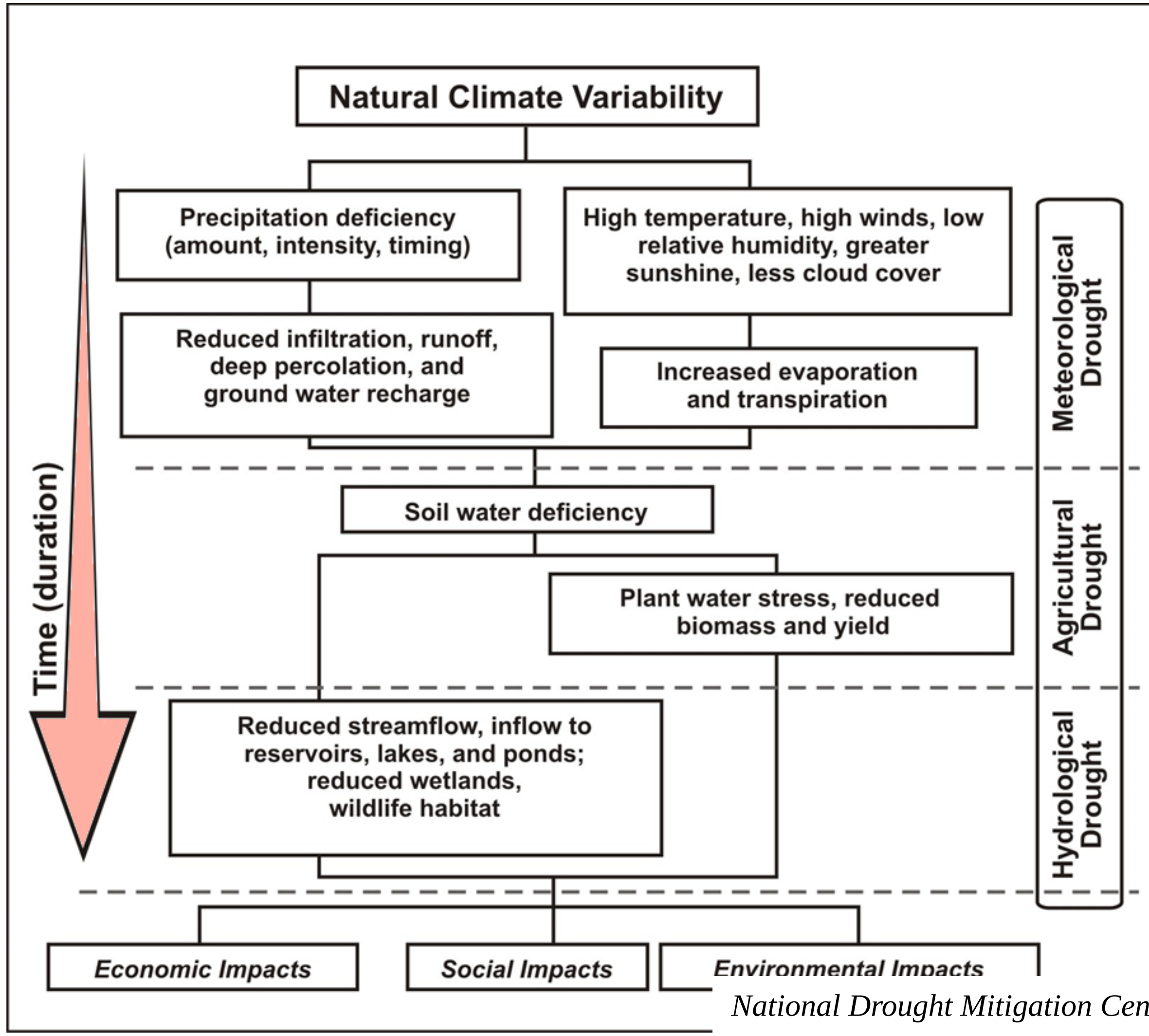
BUT; drought is a complex phenomena that require large amounts of data to study them.

Drought

Hard to define; -when does it start? -what numbers do we mark it with?

-it can be interpreted by region

Good news: measurement network of precipitation, temperature, soil moisture are permanently growing and their data integrate to the drought monitoring.



National Drought Mitigation Center

BUT unfortunatelly point scale informations often aren’t useful for operative management of agriculture practice.

Spatio-temporal monitoring of water supply changes

Free data

High temporal resolution

Real time

Free products

Large area (regional scale)

MODIS based drought assessment (version 5, L3)
(national, regional and local scale)

MOD09A1
Surface Reflectance 8-Day 500m

MOD13A1 Vegetation Indices 16-Day 500m

MOD13Q1 Vegetation Indices 16-Day 250m

MOD11A Land Surface Temperature and Emissivity Daily 1 km

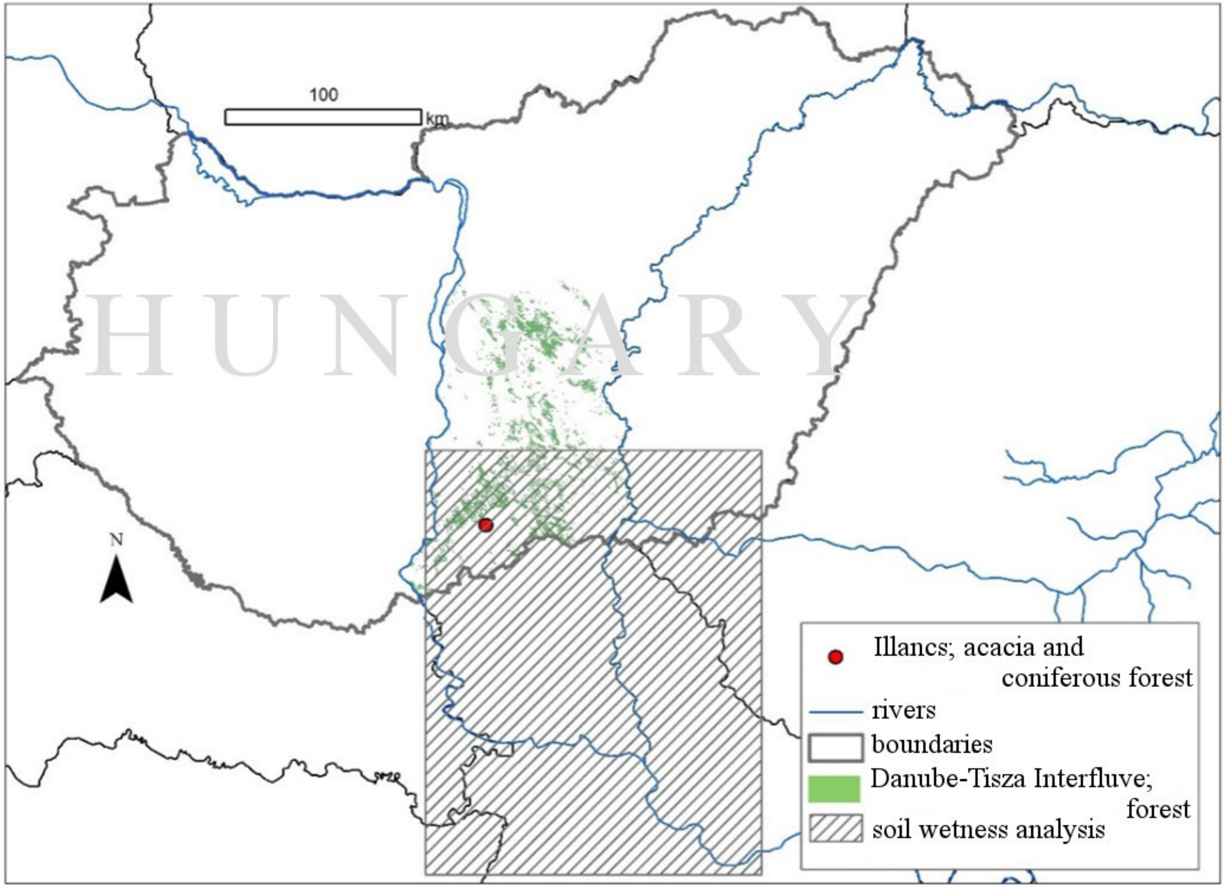


Image pre-processing - Only the best quality cells were kept.
VI detailed Quality Control: cells with inaccurate values, which were mainly caused by cloud cover and shadow, aerosols.

+ project transformation + study area

bit	*Long name*	*Value*	*Key*
0–1	**MODLAND_QA**	**00**	VI produced, good quality
		01	VI produced, but check other QA
2–5	**VI usefulness**	**0000**	Highest quality
		0001	Lower quality
		0010	Decreasing quality
		0100	Decreasing quality
6–7	**Aerosol quantity**	**00**	Climatology
		01	Low
8	**Adjacent cloud detected**	**0**	No
9	**Atmosphere BRDF**	**0**	No
10	**Mixed Clouds**	**0**	No
11–13	**Land/Water Flag**	**000**	Shallow ocean
		001	Land (Nothing else but land)
		010	Ocean coastlines and lake shorelines
		011	Shallow inland water

Generally 75 % is rate of the valid pixels in the country (based on MOD13A1).

Lots of images – f.i. MOD09 images from 2000 to 2014 in vegetation period, it means 358 images; ***Automatic pre-processing and analysis; Softwares: QGIS (Python), GDAL, MODIS Reprojection Tool, LDOPE Tools, SAGA GIS, GRASS GIS, R, Modis Calculate Mean Tool, ArcGIS (Python)***

Drought index

$$NDDI = (NDVI - NDWI) / (NDVI + NDWI)$$

$$NDVI = (NIR_{858\ nm} - R_{645\ nm}) / (NIR_{858\ nm} + R_{645\ nm}),$$

$$NDWI = (NIR_{858\ nm} - SWIR_{2130\ nm}) / (NIR_{858\ nm} + SWIR_{2130\ nm}),$$

R: Red, NIR: near-infrared, SWIR: middle-infrared

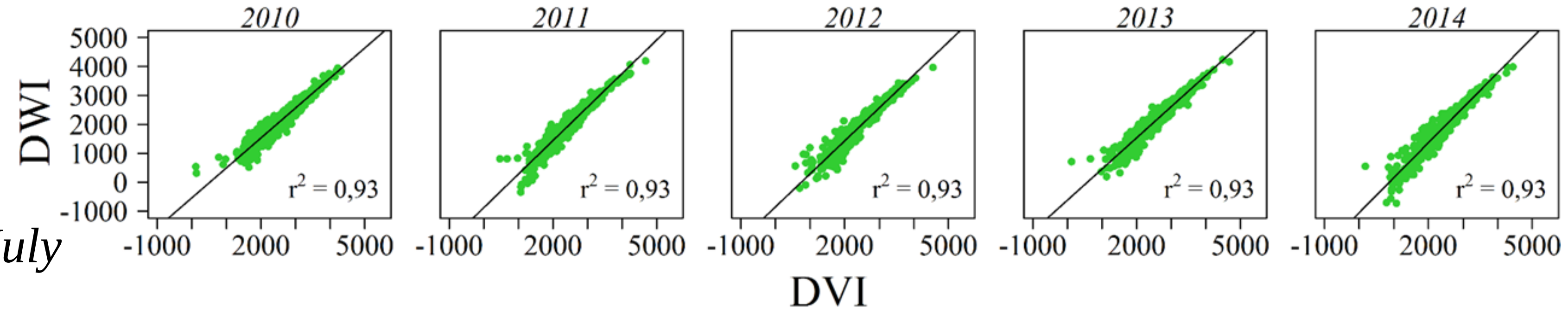
Reflectance is increasing when water content is decreasing

$$DDI = DVI - DWI$$

$DVI = NIR_{858\ nm} - R_{645\ nm}$, $DWI = NIR_{858\ nm} - SWIR_{2130\ nm}$

Plain study area: no problem without normalization

More simple version; less statistical problem



In July

The connection validates DWI and NDWI, they are suitable to analyse of the vegetation response to drought .

EVI = G·((NIR–R) / (NIR+C_1·R+C_2·$B_{469\ nm}$+L))

L: canopy background adjustment; C_1, C_2: the coefficients of the aerosol resistance term; G: gain factor; B: Blue

minimizing atmospheric effects and soil-brightness induced variations.

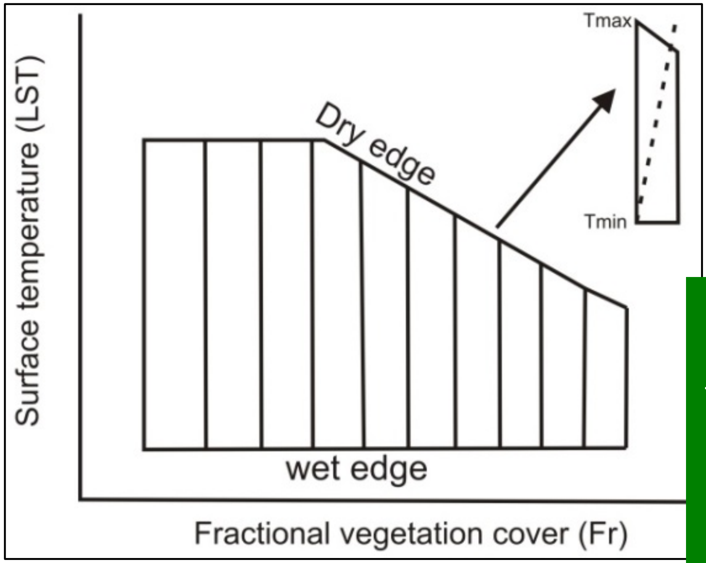
$$PAI = \frac{\left[\sum_{i=apr}^{aug} T_i\right] / 5}{\sum_{i=oct}^{aug} (P_i * w_i)} * 100 * k_t * k_p * k_{gw}$$

Pálfai Drought Index as a reference data

Annual index; calculated from temperature, precipitation and groundwater data with correction factors.

Soil moisture index; SMI = T_s / VI

T_s: surface temperature; VI: **(NDVI-$NDVI_{min}$)/($NDVI_{max}$-$NDVI_{min}$)**



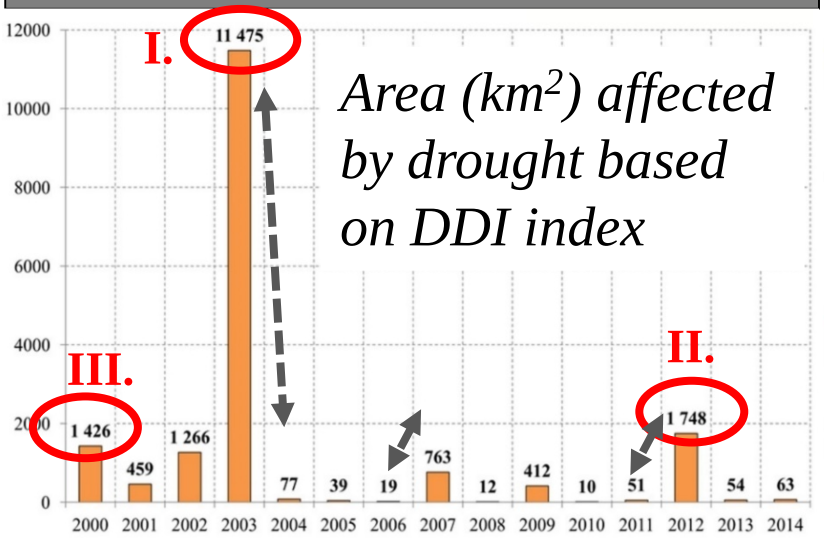
We suppose thet it's linear connection between surface temperature and soil moisture in one vegetation category.

F_r maps: LST_{min} = 1 and LST_{max} = 0 SMI value; because of 10 F_r classes we have 10 SMI maps . We need to merge them to have a daily SMI map.

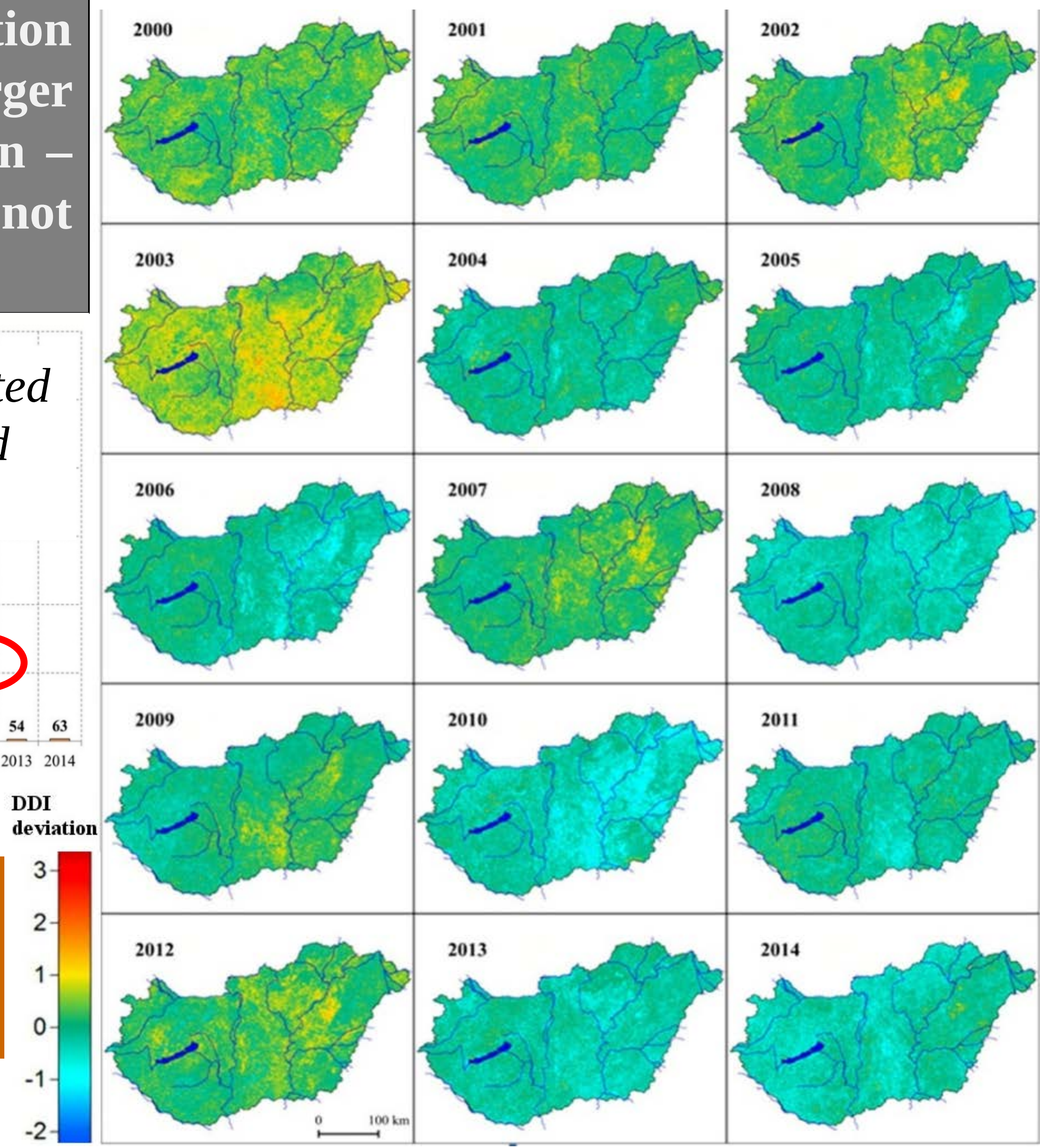
Relationship between LST, soil moisture and vegetation fraction (VICENTE et al. 2004;)

DDI, NDDI, NDWI (2000-2014)

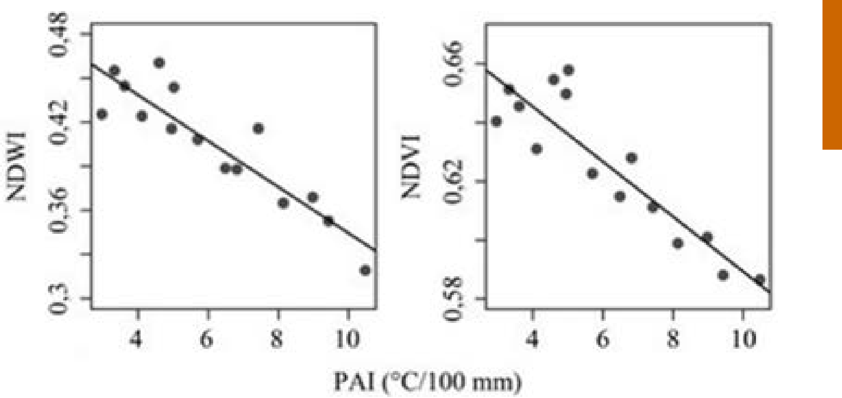
It is a drought if the deviation from the index mean is larger than the standard deviation – we think it's a change, not variability.



No drought: from 2004 to 2006, 2008, 2010, 2011, 2013, 2014.



First of all NDVI and NDWI show statistical significant connection with the reference data (PAI).



Relationship between the spectral indices and the PAI using linear regression

Water indices show more sensitive the drought events than vegetation indices.

Some problems:

DDI and NDDI show drought in 2001, but PAI doesn't.

2013. is a drought year based on PAI values, but it isn't after DDI.

NDVI and NDWI show a larger deviation from PAI in 2005 and 2013.

	Index	*PAI (Hungarian Plain)*	*PAI (whole country)*	*All cereals [kg/ha]*
MOD09A1	DDI	**0.87**	**0.81**	0.67
	NDDI	**0.85**	0.77	0.65
	DWI	**0.81**	0.75	0.79
	NDWI	**0.90**	**0.80**	**0.80**
	DVI	0.60	0.62	0.69
	NDVI	0.78	0.71	0.72
MOD13A1	EVI	0.63	0.67	**0.81**

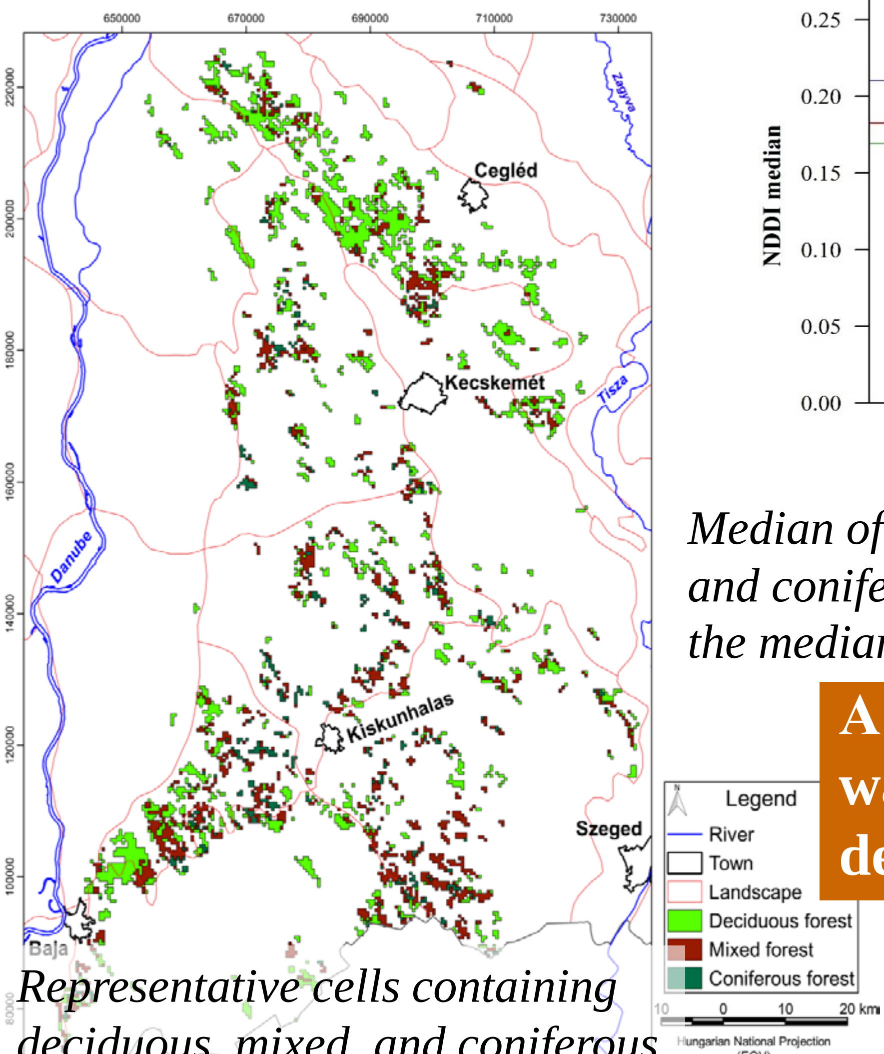
vs.

Effects of land cover heterogenity

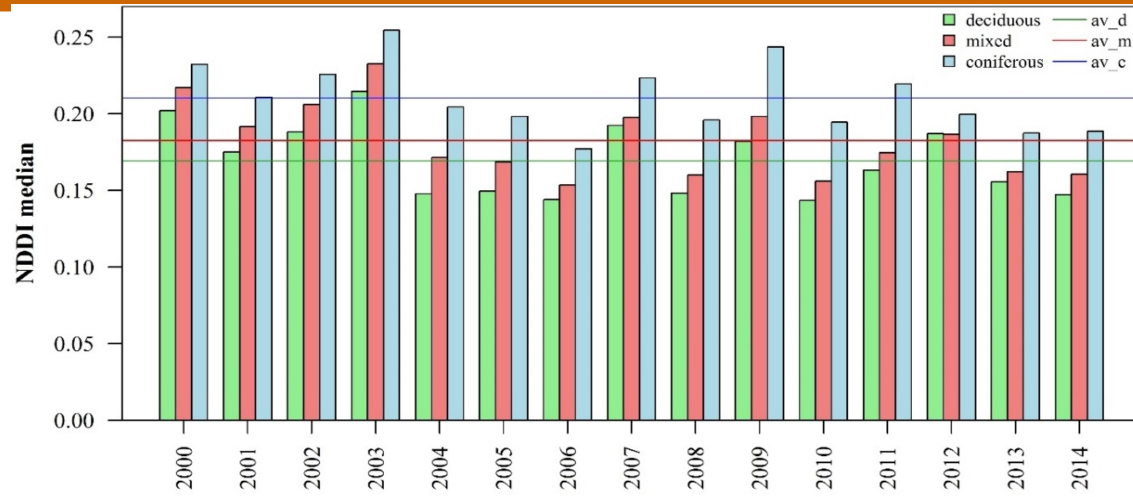
(urban areas, water surfaces, forests and green spaces)

Performance comparison of indices according to values of the correlation coefficients (r^2) in July coefficient of determination

Forest vegetation: the chlorophyll and VWC of trees are highly sensitive to drought conditions – good indicators.
Multi-year fluctuations; it may be possible to detect short-term effects of climate change on drought conditions via vegetation changes.



Representative cells containing deciduous, mixed, and coniferous forests in the study area in 2012.

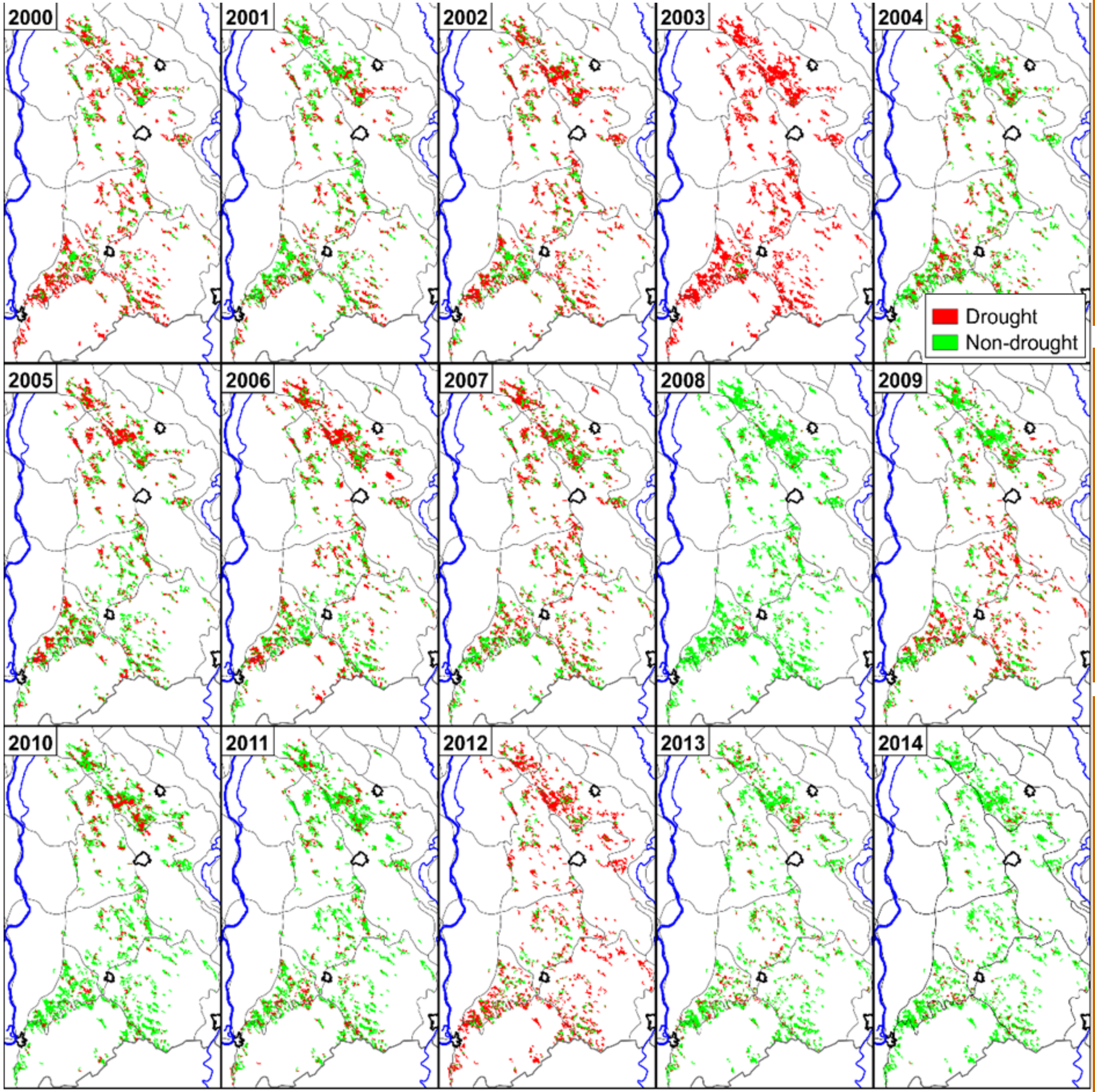


Median of NDDI in the examined years for deciduous, mixed, and coniferous forests. Coloured lines indicate the average of the medians as the drought threshold limit

A pixel was representative if ⅔ of its area was dominated by the same land cover: deciduous, coniferous, mixed forest.

CLC datasets; 2000, 2006, 2012.
49% of the forests of 2012 has the same cover as from 2000.

Reclassification of standardized NDDI values into drought (positive deviations from reference average) and non-drought classes (zero or negative deviations) for the three 5-year periods.



Growing season NDDI averages, standardized and reclassified into drought and non-drought categories

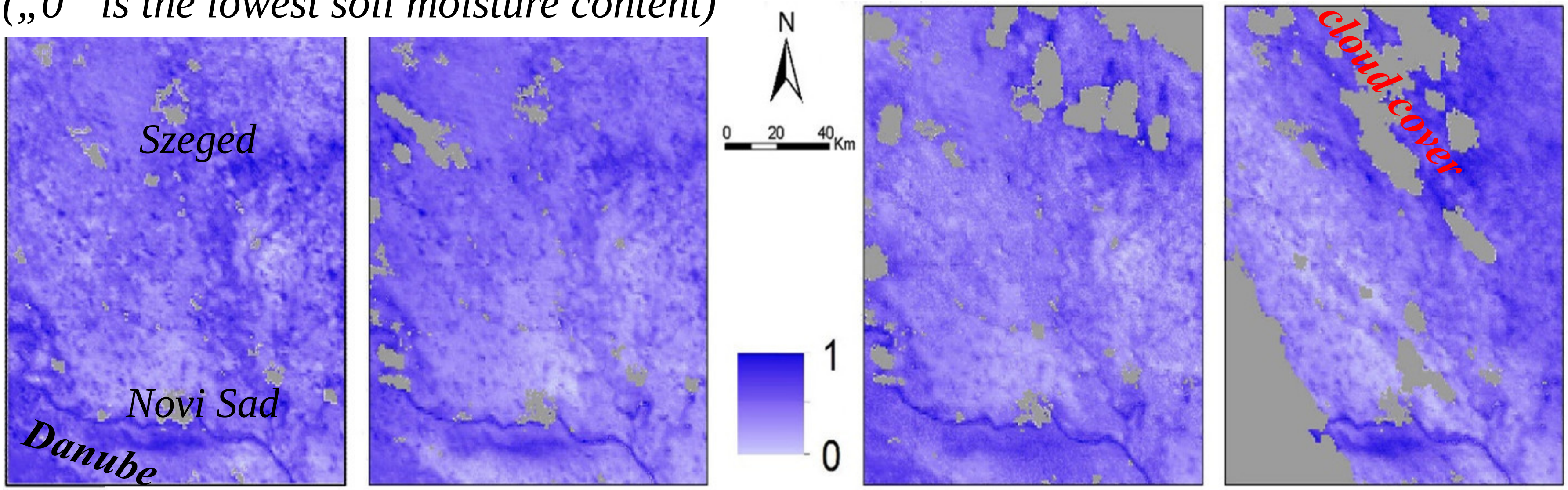
The results suggest that black locust and poplar forests are more sensitive to drought than pine forests.

The period 2000-2005 stands out. The following periods reflect less intensive drought conditions. 2007, 2009, 2012 were drought years as well.

Drought estimation with SMI

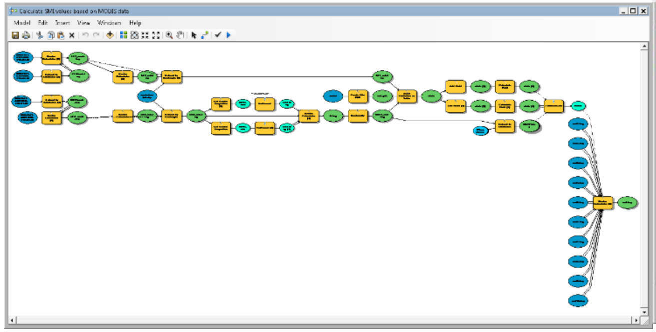
MOD11 (LST) + MOD13 (VI) products in 2015. 1 km, daily resolution SMI maps with good QA parameters.

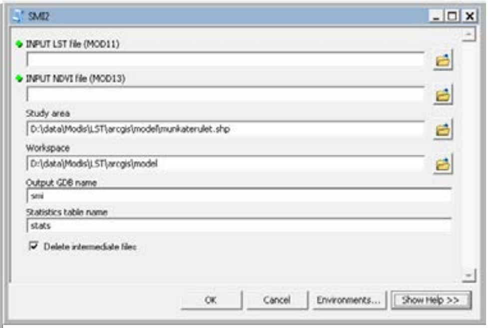
Calculated SMI maps of the study area for four selected days („0” is the lowest soil moisture content)



13.03.2015. 22.03.2015. 31.03.2015. 03.04.2015.

Relative differences in moisture content: rivers and its environment, sandy area, forest area are very showy.
The lowest SMI in Novi Sad and Bács-Kiskun and Békés county.



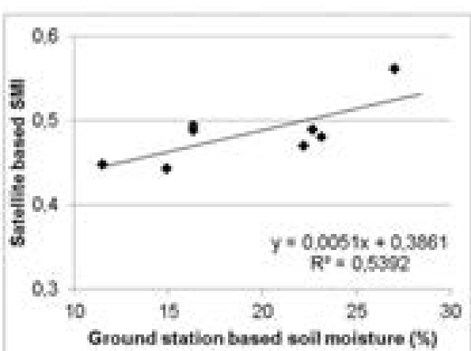


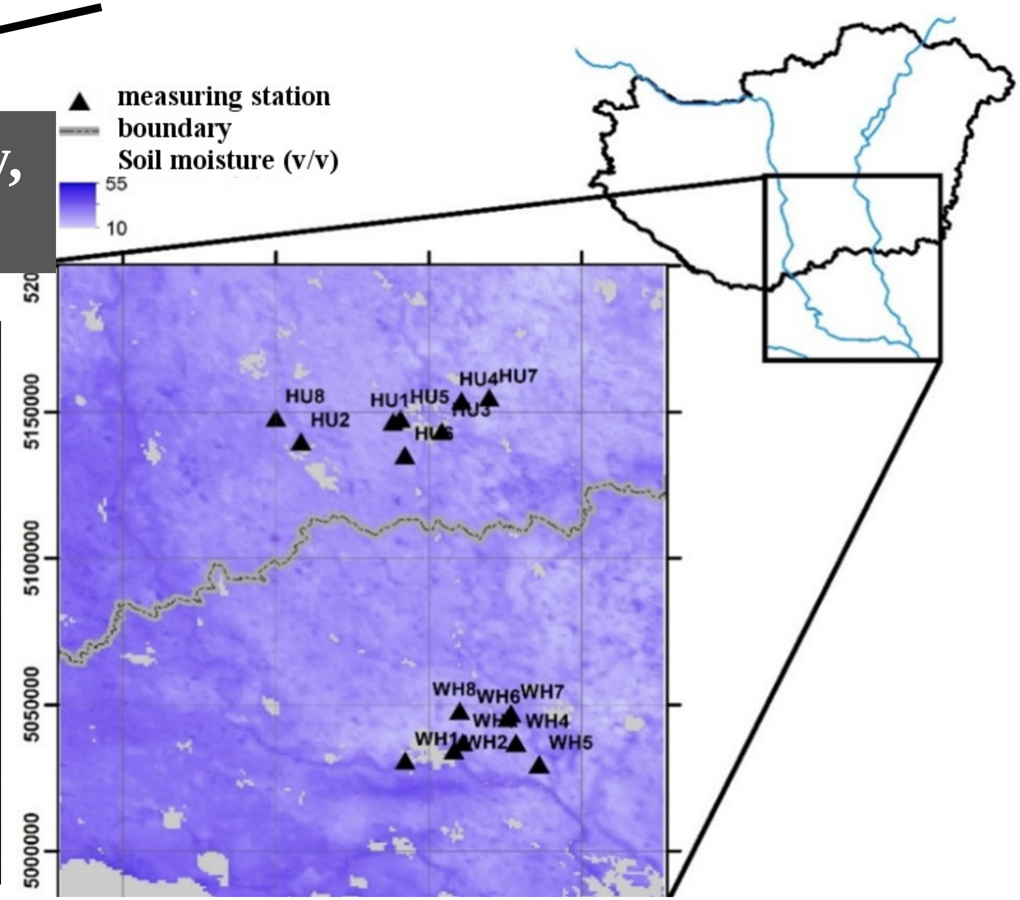
Automatic SMI processing

Connection between field soil moisture meter data and multispectral SMI index value. → 16 station on the field.
Determination coefficients (r^2) value: 0.1–0.95.

We made maps which days have min. 0.4 determination coefficient value – it is a significant connection. 82 days from 305 days in 2015.

Because of -geometric heterogenity, -pixel heterogenity, -measuring methods (surface vs. subsurface), -delayed effect





Soil moisture map of the study area on 11 March 2015

Some conclusions

NDWI, NDVI and NDDI achieve the requirements to practical application on the base of statistical connection with Pálfai Drought Index.

NDWI is more sensitive than NDVI.

Successful drought monitoring can only be achieved when we are able to accurately delineate vegetation cover (NDWI, NDVI).

EVI based yearly biomass production is in connect with drought index values, but so it is not operative. We can evaluate the events in the past.

One of the most important parameter of drought (and climate change) is the soil moisture. We can solve the expansively and constantly measuring only with remote sensing. We have to develop the field measurement network.

Forecasting based on spectral indices could help to water management in a drought monitoring system (MODIS, VIIRS, LANDSAT, Sentinel). The heavily droughted areas could be dinamically located.

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Thanks!

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