

A stylized, light-colored illustration of a plant with a central stem, several large leaves, and a cluster of small, round fruits or buds at the top, set against a dark brown background on the left side of the slide.

DROUGHT MONITORING IN THE ROMANIAN WESTERN PLAIN USING SATELLITE DATA TIME SERIES

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1. Introduction

- **MIDMURES** – Mitigation Drought in Vulnerable Area of the Mures Basin (2011-2012), financed by the CE-DGE under the development of prevention activities to halt desertification in Europe. The main goal of the MIDMURES project was to contribute to improving agricultural water saving and drought forecasting in the Mures pilot area through the combination of various technical approaches. The expected results refers to: modeling long-term agro-climatic data in order to establish the risk factors, to spot the areas with high vulnerability and provide timely drought forecasts; assessing the impact of climate changes on soil water availability for crops cultivated in the most vulnerable area of Mures River basin to drought and water scarcity, rainwater conservation in soil for optimizing water availability according to the plant needs throughout the growing season and in the period with high deficit.
- The project is one of the four pilot projects in Southern and South-Eastern Europe aiming at demonstrating technologies and management practices to improve water efficiency in water scarce areas.
- **Halting desertification in Europe** - "Development of prevention activities to halt desertification in Europe" (Reference: ENV.D2/NP/2009/200398)

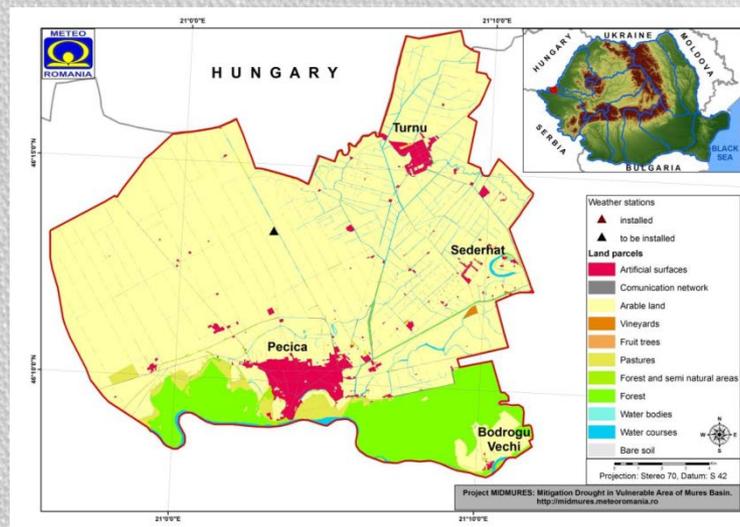
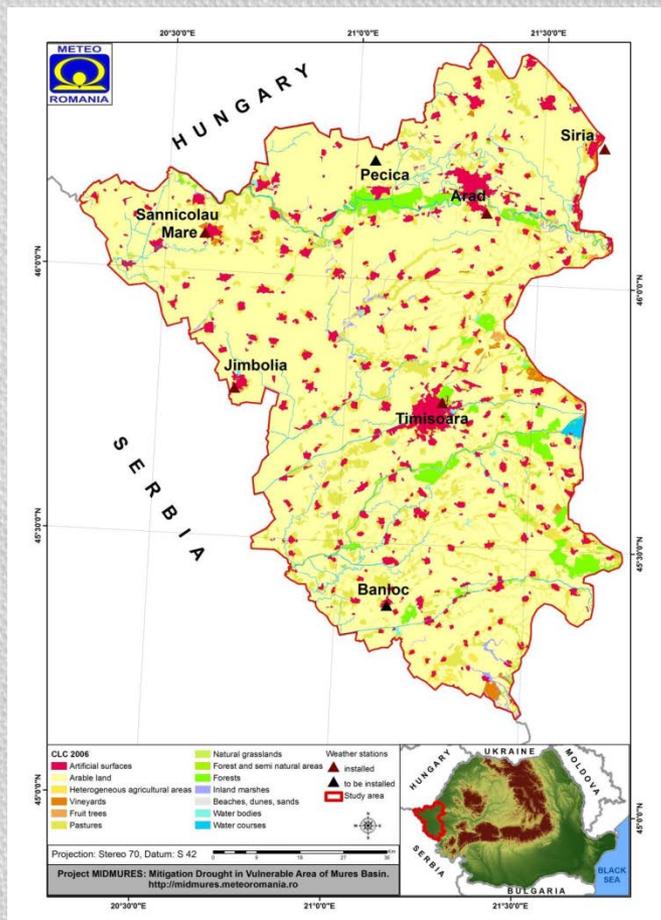
2. Data and Study area

- Western Plain occupies the western part of the country, being the eastern part of the wide plains that extend beyond the borders of Romania: the Pannonian Plain., E - West Hills, W - border with Hungary and Serbia. Western Plain is limited by the borders of Romania: the north, Ukraine to the south, Serbia and the West, Serbia and Hungary. In the eastern part is limited by the Western Hills and Western Carpathians.
- The study area is focused on agricultural region surrounding the Pecica town, in the Ier and Crac sub-basins and the Romanian downstream of Mures River (Picture 1). Mean altitude in the study area is between 100 m to 170 m with a mean slope less than 10° .
- The basin of the River Mures is shared by Romania (upstream country) and Hungary (downstream country); the river has its source in Romania and discharges to Tisza. A major trans boundary tributary to the Mures is the river Ier with its source in Romania.

Fig. 1 - Location of the study area



2. Data and Study area (cont.)



Classes	Surface (ha)
Artificial surfaces	880
Arable land	19000
Vineyards	16
Fruit trees	2.6
Pastures	500
Forest and semi natural areas	195
Forest	2680
Water bodies	11
Water courses	511
Total (2005)	23795.6

Fig. 1. b - Location of the study area

The Pecica administrative unit: main land cover / land use classes, 2006

2. Data and Study area (cont.)

- In order to see where the possibility of drought occurrence is, the temperature and precipitation charts were elaborated (Fig. 4, 5 and 6).
- the year 2000, known to be a drought year, shows a very low precipitation amount (252.0mm) and the highest annual mean air temperature value (12.2°C), comparing with the analyzing period;
- the year 2003, a similar low precipitation amount (460.6mm) can be observed correlated with the air temperature value (10.7°C).

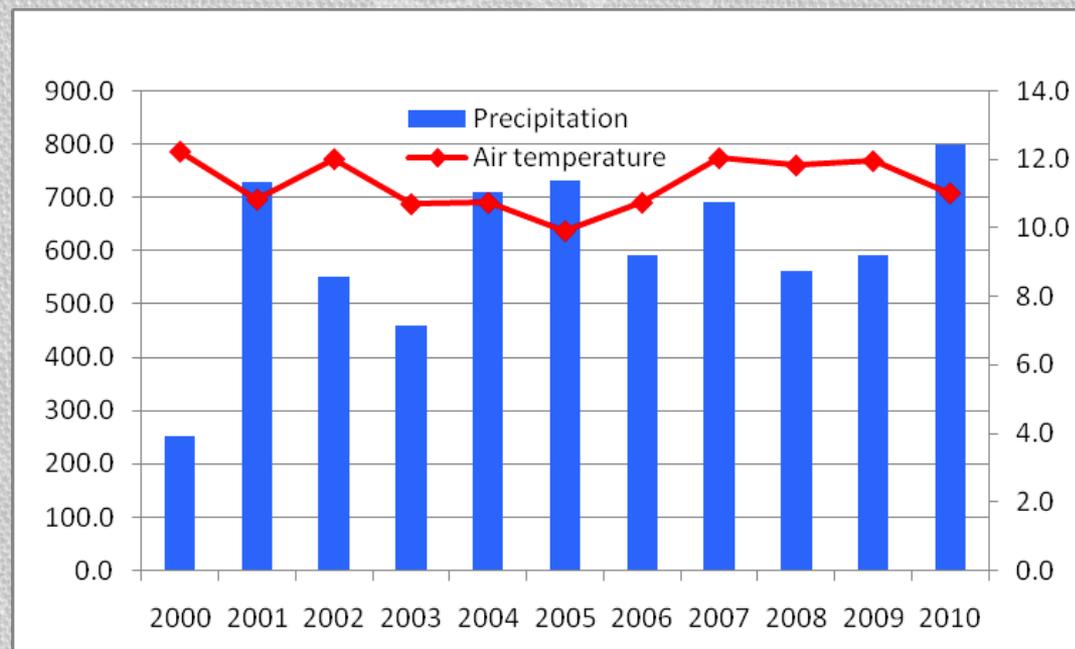
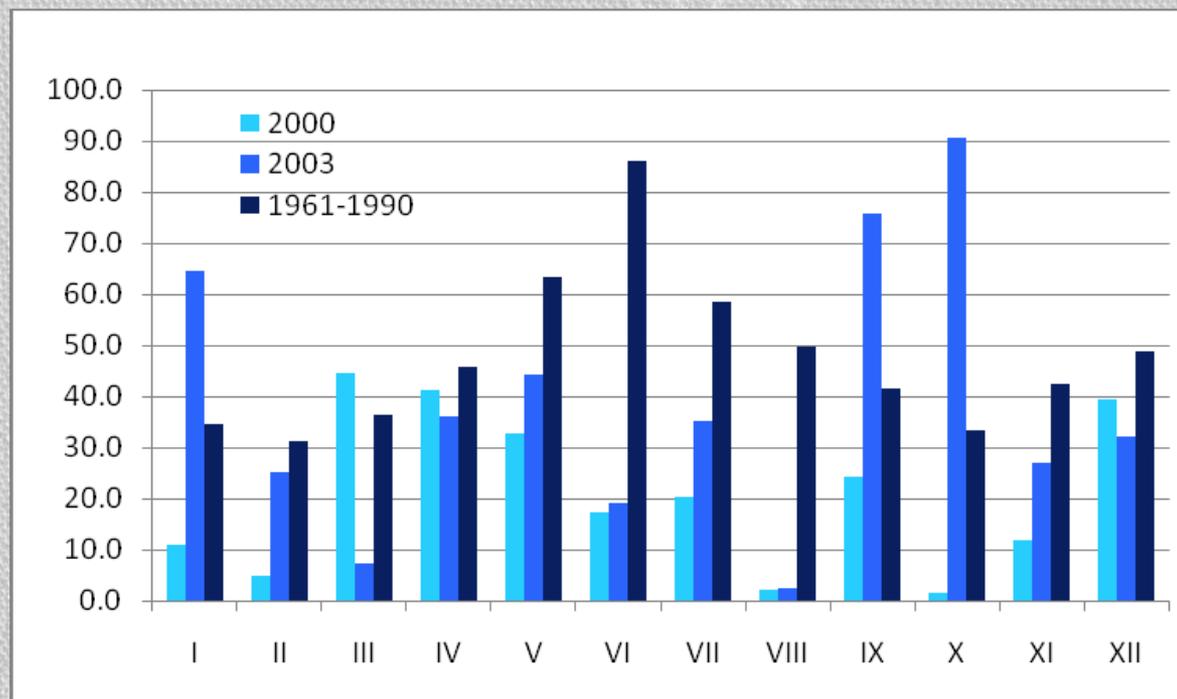


Fig. 4 - Annual precipitation and air temperature at Arad meteorological station (2000 – 2010)

2. Data and Study area (cont.)

- The monthly precipitation amounts during the years 2000 and 2003 recorded low values at the beginning of the year and also from June to August.
- The winter of the year 2000 has been extremely dry. Except the March, during the whole year the monthly precipitation amount was lower than the 1961-1990 interval.
- For year 2003 the situation is different, the winter is over or close to the normal, but the spring was also dryer than normal, but the consequences follow in a droughty year, same as 2000.
- Both years are characterized by low and extremely low precipitation during the summer time, especially in August.

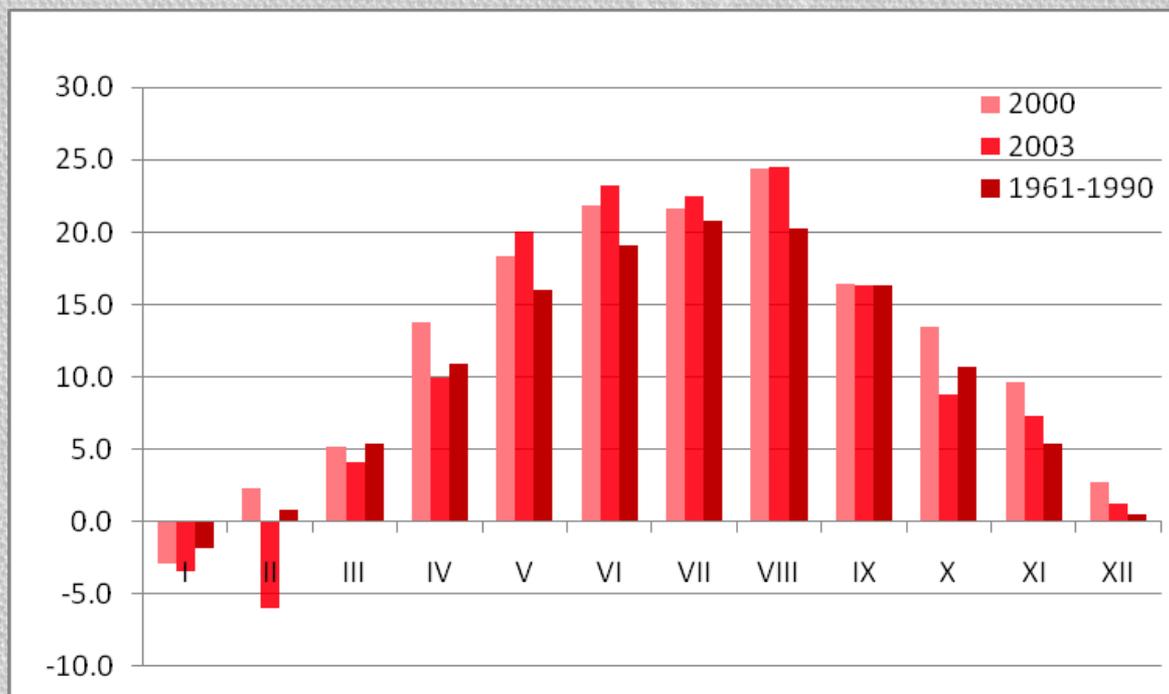
Fig. 5 - Monthly precipitation amount at Arad meteorological station



2. Data and Study area (cont.)

- Regarding the monthly air temperature, for the analyzing period at Arad meteorological station, the year 2000 recorded higher values than normal, except January and March (Fig. 7).
- For year 2003 the situation is almost the same as in year 2000 with very insignificant differences.
- The highest air temperature values are well correlated with low precipitation values which determined the 2003 as a droughty year.

Fig. 6 - Monthly air temperature mean at Arad meteorological station



2. Data and Study area (cont.)

- In order to monitor the vegetation state, the medium and high resolution satellite images have been used to obtain the dedicated vegetation indexes. These indexes are good indicators of drought and they are used also by the scientific community (European Drought Observatory).
- SPOT VEGETATION S10 product (ten day synthesis) – 1 km spatial resolution
- TERRA/MODIS Vegetation Indices 16-Day Product with 1km spatial resolution (MOD15A2) - two vegetation indices are derived from atmospherically-corrected reflectance in the red, near-infrared, and blue wavebands; the normalized difference vegetation index (NDVI), which provides continuity with NOAA's AVHRR NDVI time series record for historical and climate applications, and the enhanced vegetation index (EVI), which minimizes canopy-soil variations and improves sensitivity over dense vegetation conditions.
- TERRA MODIS Surface Reflectance product MOD09A1 and Daily Surface Reflectance (MOD09GA) with 500 m spatial resolution
- TERRA MODIS LAI/fAPAR product (MOD15A2) – 8 day synthesis, with 1 km spatial resolution.
- TERRA MODIS Land Surface Temperature/Emissivity 8-Day products MOD11A2 – 1 km spatial resolution.
- Landsat data with 30 m spatial resolution.

3. Methodology and results

- **The Normalized Difference Vegetation Index (NDVI)** is a measure of the amount and vigor of vegetation on the land surface, calculated with the following formula:

$$\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}$$

- where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively.
- NDVI values range from -1.0 to 1.0, with negative values indicating clouds and water, positive values near zero indicating bare soil, and higher positive values of NDVI ranging from sparse vegetation (0.1 - 0.5) to dense green vegetation (0.6 and above).
- Comparing current NDVI images with older ones it can monitor the positive and negative deviations that occur during the growing season of vegetation and evaluate the state's relative vegetation throughout the growing season.

3. Methodology and results (cont.)

- NDVI is an indicator of presence, density and health of vegetation compared to a pixel (1km²); the positive values are colored in shades of green to dark green and negative values are colored in shades from yellow to brown, indicating a lack of vegetation or bad health.
- Determination of the current vegetation status - by comparing a new NDVI image with the NDVI image corresponding to last year or several years ago (Fig. 7 and 8).

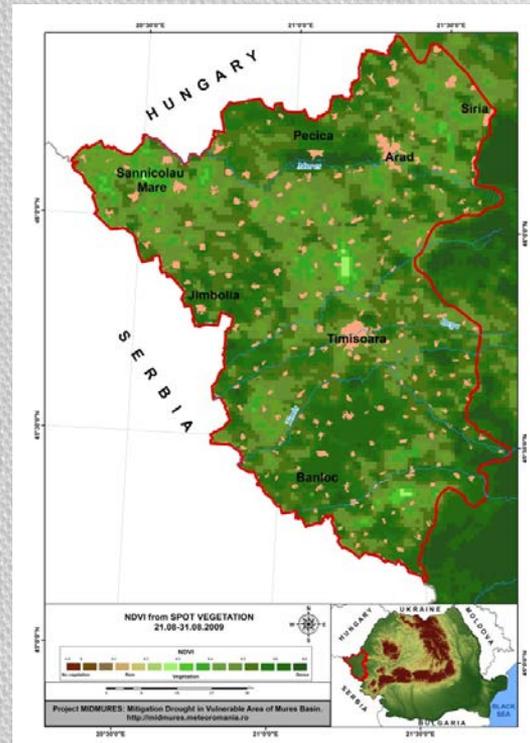


Fig. 7 - NDVI extracted from SPOT Vegetation, 21-31.08.2009

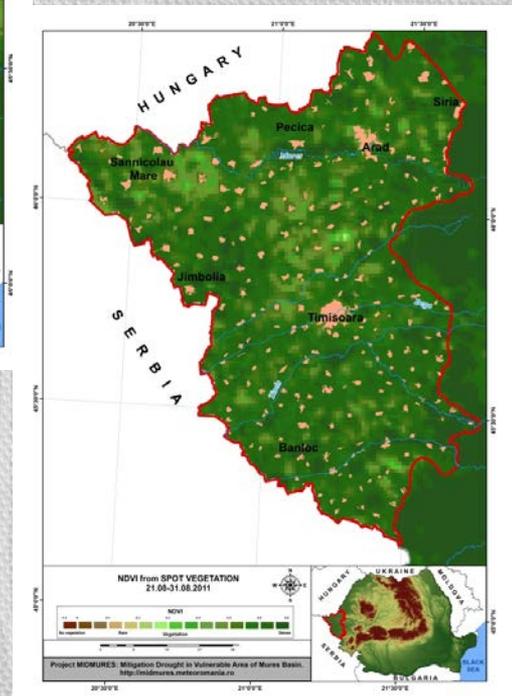


Fig. 8 - NDVI extracted from SPOT Vegetation, 21-31.08.2011

3. Methodology and results (cont.)

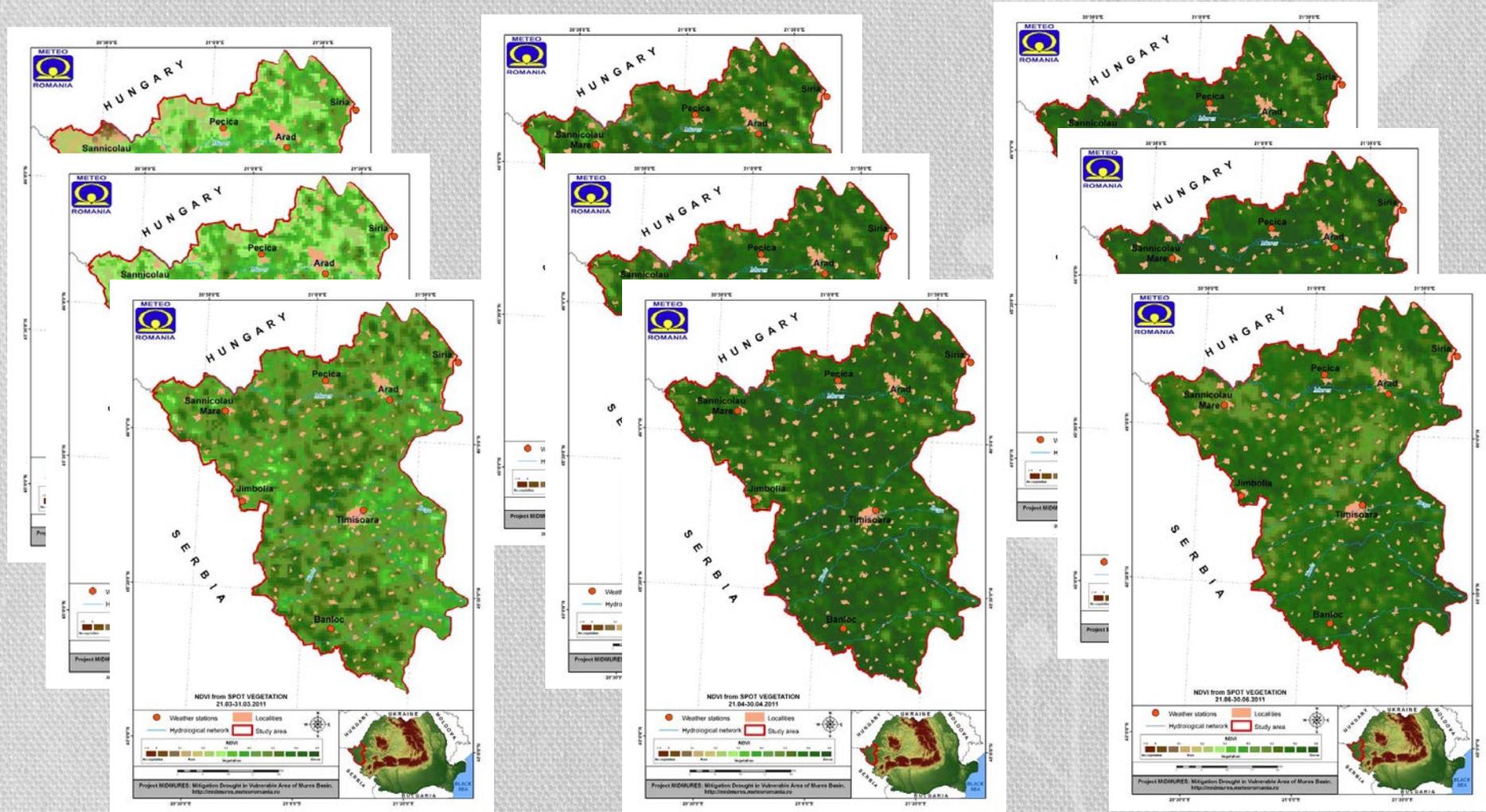


Fig. 9 - The NDVI spatial distribution - 2011 agricultural year

3. Methodology and results (cont.)

- The NDVI values can be used in correlations with various agro-meteorological parameters using datasets provided by agro-meteorological models and agro - meteorological observation platforms. The GPS measurements and crop identification on the satellite data allow to correlate the NDVI values (for different crops) with the precipitation values recorded at Arad meteorological station (Fig. 10).

Fig. 10 - The correlation between NDVI (extracted from SPOT VEGETATION) and precipitation (recorded at ARAD meteorological station)



3. Methodology and results (cont.)

- For the NDVI analysis using TERRA MODIS data there were selected four different years:
- 2000 as the drought year;
- 2003 as the year to be determined for if there was any drought occurrence or not;
- 2005 as an interval with normal climatic behavior;
- 2010 as a year with a greater level of precipitation that the average and for different vegetation phases (Fig. 12-15).
- From 6th of March to 6th of April, for year 2003 the NDVI values are low, compared to the rest, mainly because of the lack of precipitations in March (Fig. 5) which may have caused a delay of the vegetation phase start. Year 2010, on the other hand, reveals greater values due to high level of precipitations (Fig. 11).

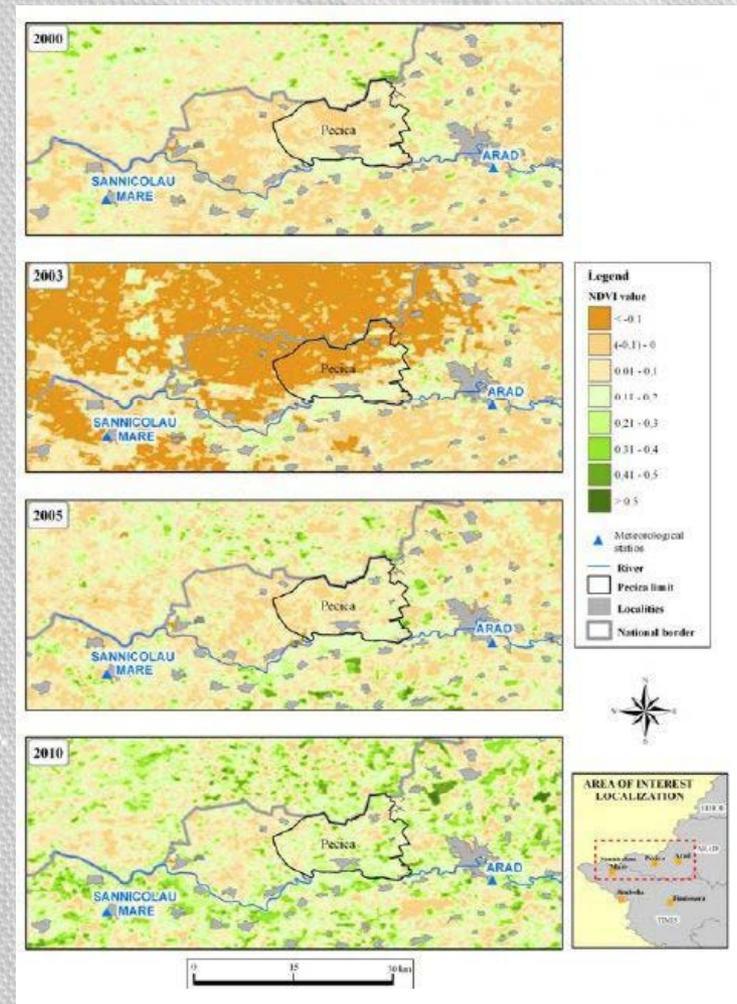


Fig. 11 - Spatial variation of NDVI values from 6th of March to 6th of April

3. Methodology and results (cont.)

- The NDVI data show a rather equal set of values between the four years, with a slight grow in 2005 and 2010 compared to 2000 and 2003 for the next periods: from 7th of April to 8th of May and from 9th of May to 9th of June (Fig. 12-13).

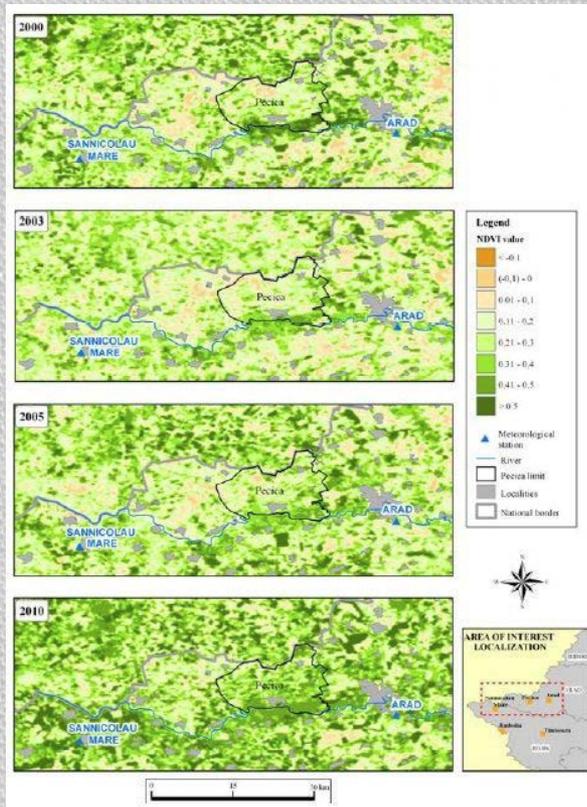


Fig. 12 - Spatial variation of NDVI values from 7th of April to 8th of May

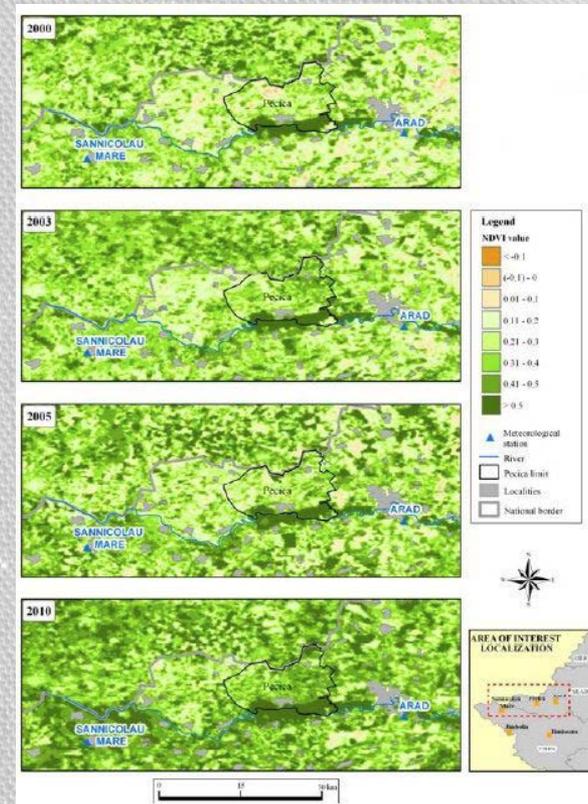


Fig. 13 - Spatial variation of NDVI values from 9th of May to 9th of June

3. Methodology and results (cont.)

- Only during the last vegetation phenophase a visible difference occurs between 2000 and 2003 on one hand and 2005 and 2010 on the other hand (Fig. 15).
- Except some wooded land along Mures (the biggest one – west of Arad) the vegetation shows the effect of low precipitation and high temperature in 2000 and 2003 (Fig. 14 and 15).
- That is why NDVI values of more than 0,3 are sparse. The compared distribution can be verified in Fig. 16.

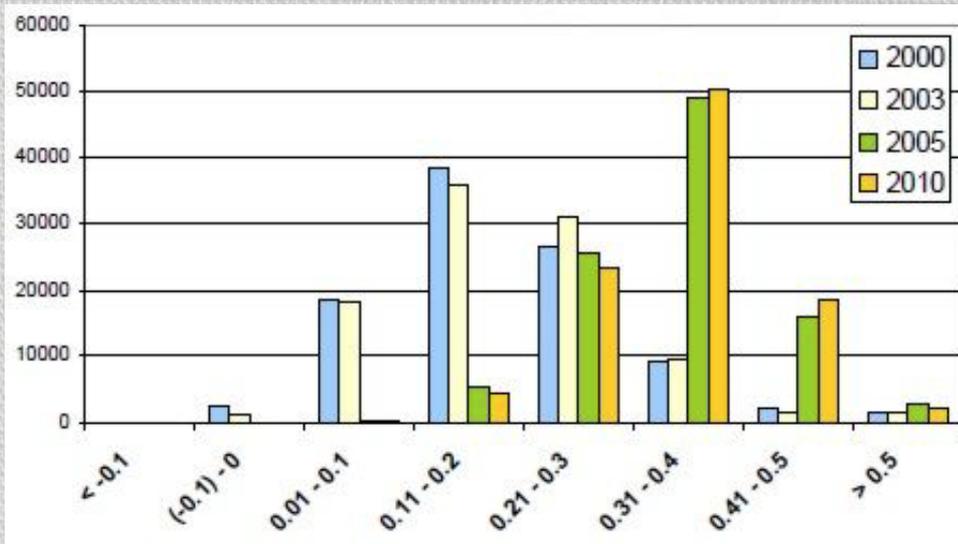


Fig. 15 - NDVI values distribution from 10th of June to 28th of August

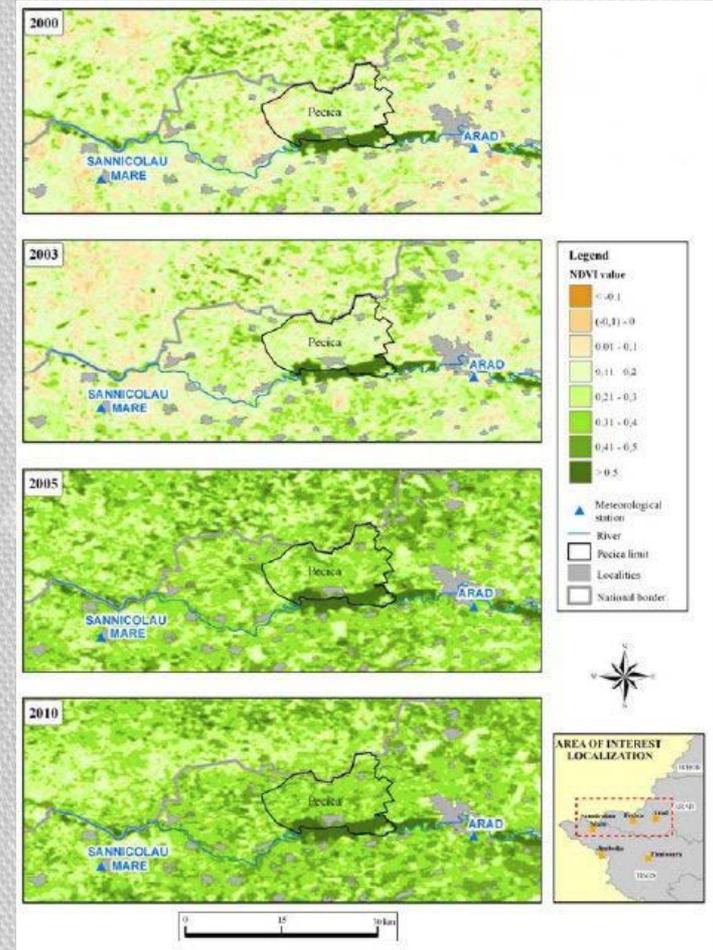


Fig. 14 - Spatial variation of NDVI values from 10th of June to 28th of August

3. Methodology and results (cont.)

- In addition to the above mentioned representation, there were calculated also the deviations from multi-annual (2000 -2010) average NDVI for the same vegetation phases (Fig. 16), which reveal the same trend as described before.

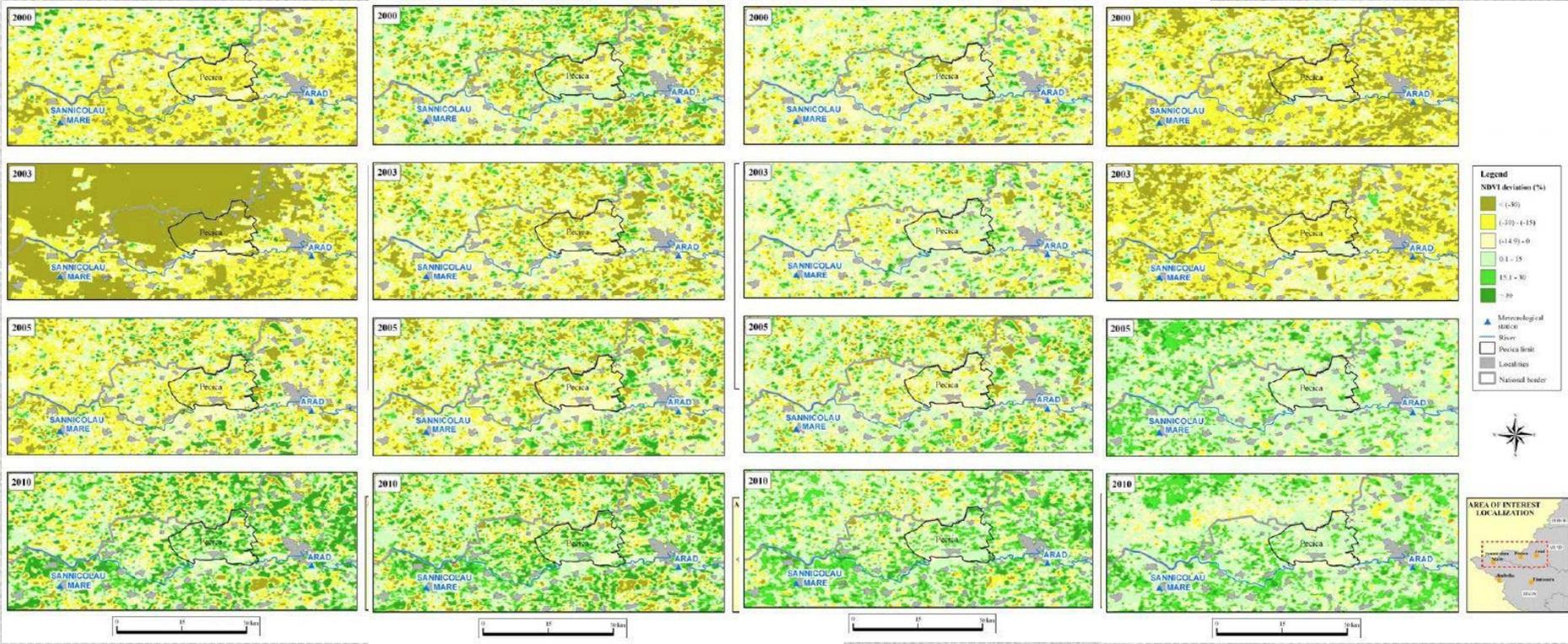


Fig. 16 - The NDVI deviation from the multi-annual average (2000-2010), from 6th of March to 6th of April (a), from 7th of April to 8th of May (b), from 9th of May to 9th of June (c), from 10th of June to 28th of August (d)

3. Methodology and results (cont.)

- Considering the geographical position of the extended test area, it was determined that it is covered at its full extent by the Row 186 Path 028 LANDSAT scene (Fig. 17).

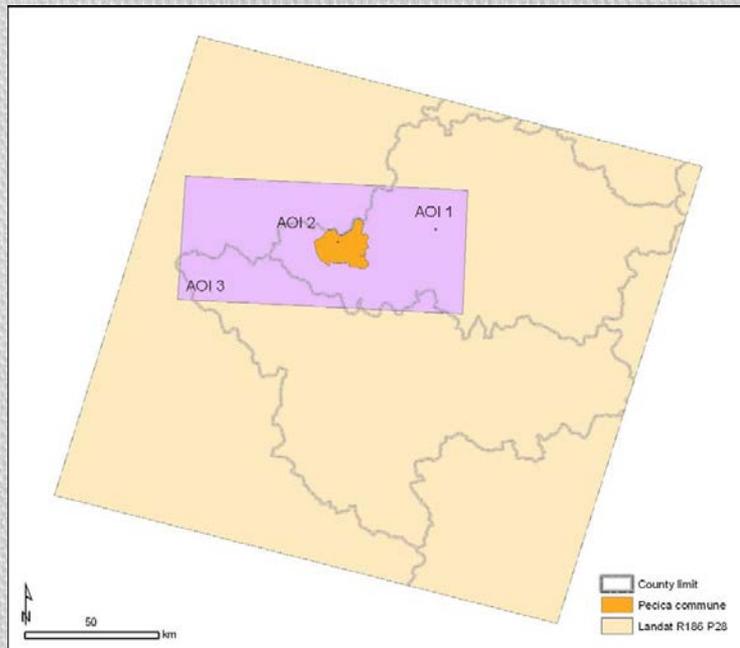


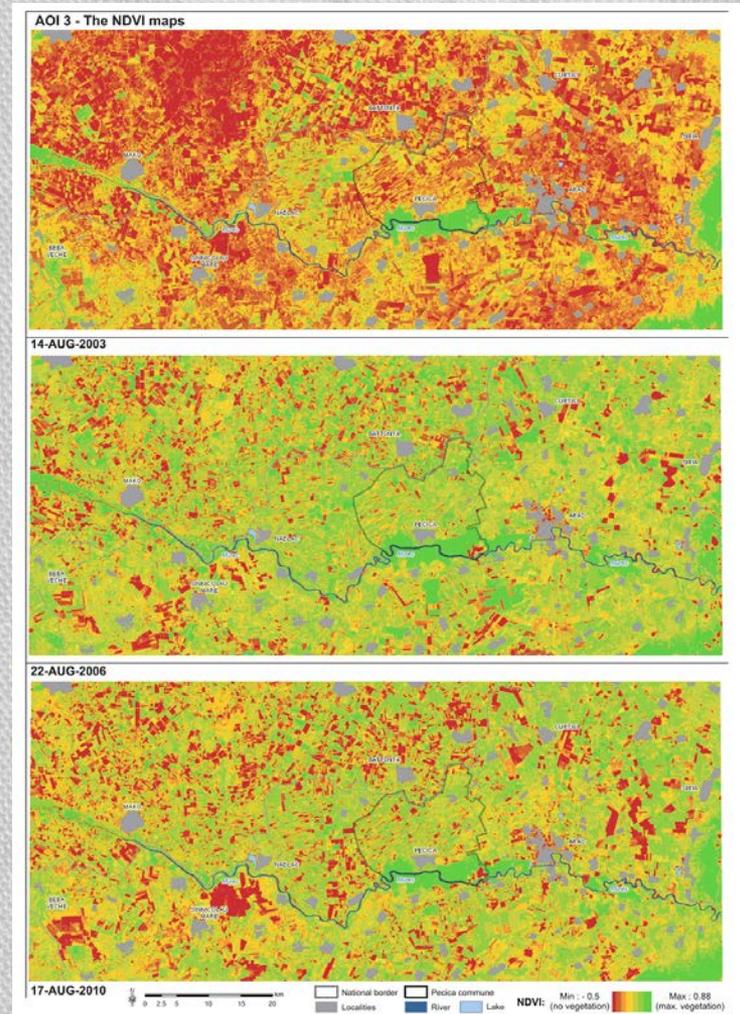
Fig. 17 - The LANDSAT image Path/Row 186/028 and the 3 areas of interest

- NDVI images from LANDSAT** were created for the years 2003, 2006 and 2010 (Fig. 19):
- ✧ • LT51860282003226MTI01, Acquisition Date: 14-AUG-2003
 - ✧ • LT51860282006234MOR00, Acquisition Date: 22-AUG-2006
 - ✧ • LT51860282010229MOR00, Acquisition Date: 17-AUG-2010

3. Methodology and results (cont.)

- Fig. 18 shows a “hot-spot”, in the center-eastern part of the image. Pecica’s administrative territory although affected by the 2003 drought has normal NDVI values in the other 2 years.
- The areas with low NDVI values doesn’t necessary mean that drought occurred there: the index’s value can be also associated with an early harvest or with the lack of vegetation due to various regions. A good example for such a situation can be found south from Mures River in the vicinity of Sinnicolau Mare when very low NDVI values were recorded in the year 2010, although not associated with drought phenomena.

Fig. 18 - The NDVI maps extracted from LANDSAT data



3. Methodology and results (cont.)

- The NDVI stretched color scale includes sometimes too much information. In order to isolate only the parts affected by drought a 2 classes classification can be applied, using a “low-vegetation” NDVI threshold (Fig. 19). For this study an NDVI value of 0.22 was used as “drought threshold“. This bi-color representation excludes the “normal” NDVI values while keeping the low ones. Areas represented in orange in Fig. 19 can be therefore associated with dry land.

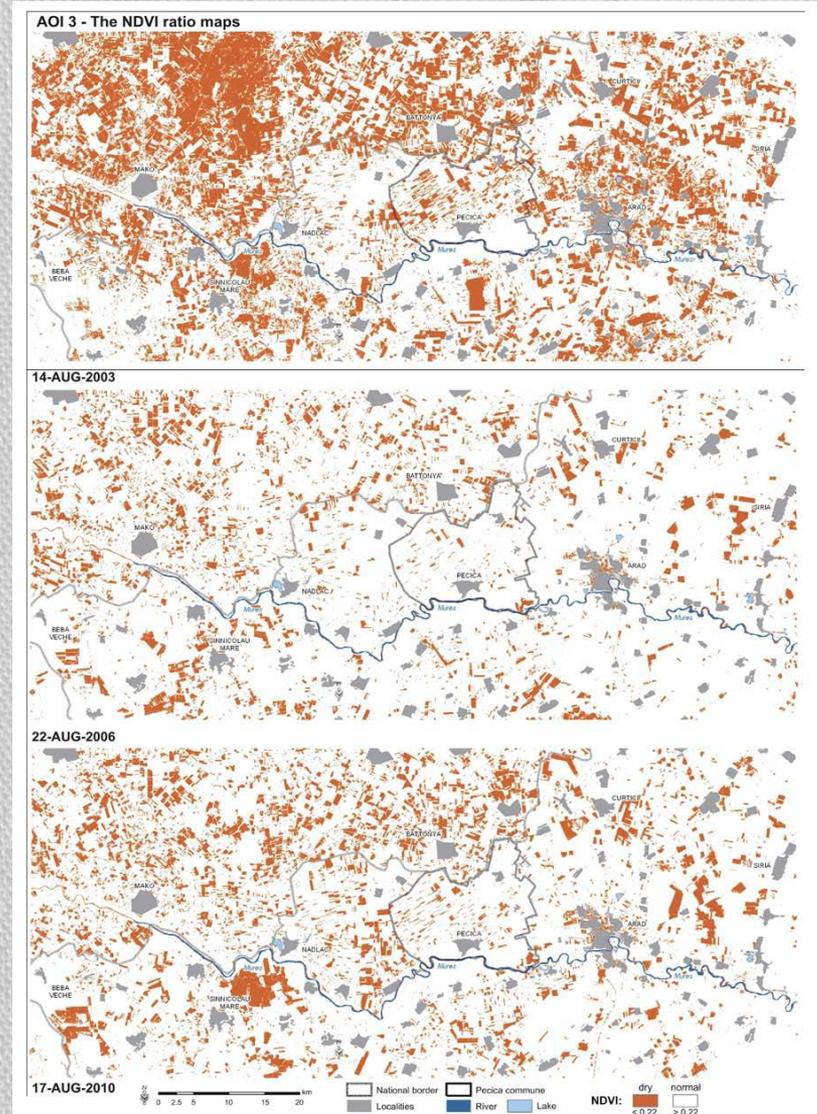


Fig. 19 - The NDVI ratio maps

3. Methodology and results (cont.)

- Another approach in evaluating the NDVI maps is by using the histograms (figure F2.20). In statistics, a histogram is a graphical representation, showing a visual impression of the data distribution. Such a data evaluation offers the possibility of a general view for the entire set of data. The NDVI histograms can be divided in 2 zones: dry and normal. The values for year 2003 are grouped in the “dry” part while for 2006 and 2010 the opposite situation is recorded.

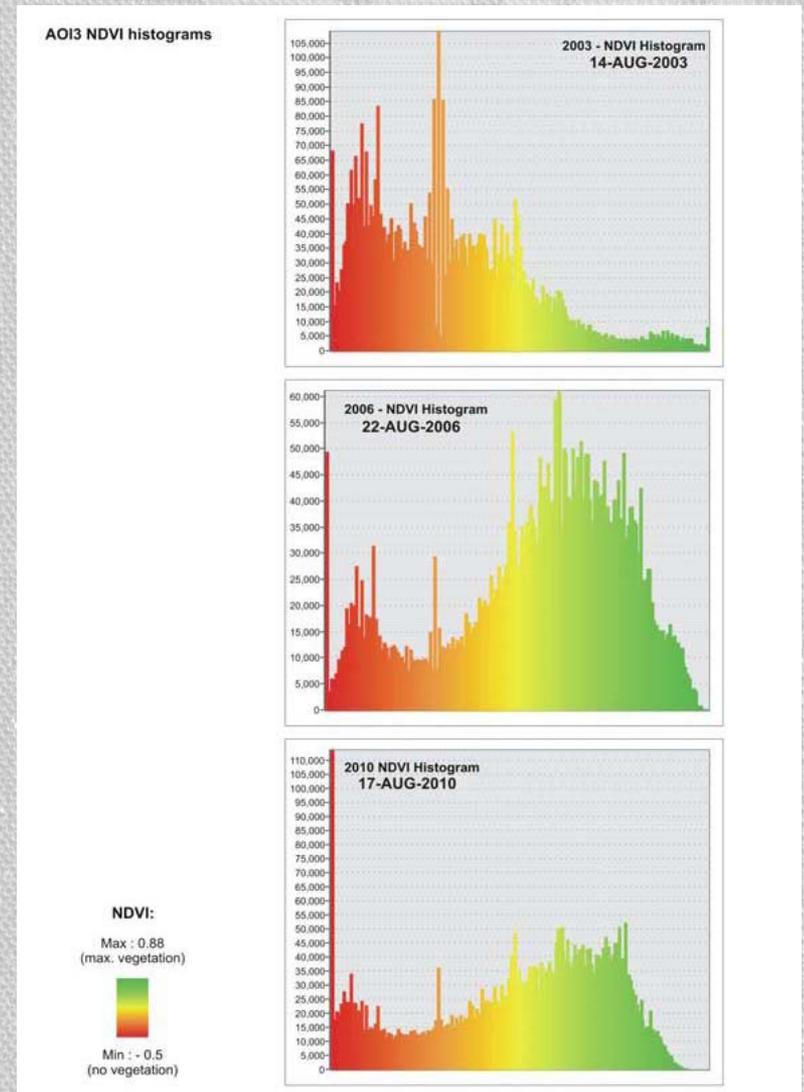


Fig. 20 - NDVI histograms

3. Methodology and results (cont.)

- A major finding on atmospheric effect minimization is the use of the difference in blue and red reflectance as an estimator of the atmosphere influence level. This concept is based on the wavelength dependency of aerosol scattering cross sections. In general the scattering cross section in the blue band is larger than that in the red band. When the aerosol concentration is higher, the difference in the two bands becomes larger. This information is used to stabilize the index value against variations in aerosol concentration levels.
- **The Enhanced Vegetation Index (EVI)** incorporates this atmospheric resistance concept as in the Atmospheric Resistant Index (ARVI), along with the removal of soil-brightness induced variations in VI as in the Soil Adjusted Vegetation Index (SAVI). The EVI additionally decouples the soil and atmospheric influences from the vegetation signal by including a feedback term for simultaneous correction.

$$EVI = G \times \frac{NIR - RED}{NIR + C_1 + RED - C_2 + BLUE + L}$$

- $L=1$, $C_1 = 6$, $C_2 = 7.5$, and G (gain factor) = 2.5.
- While the EVI is calculated similarly to NDVI, it corrects for some distortions in the reflected light caused by the particles in the air as well as the ground cover below the vegetation. The EVI data product also does not become saturated as easily as the NDVI when viewing rainforests and other areas of the Earth with large amounts of chlorophyll.

3. Methodology and results (cont.)

- The EVI values have been obtained from TERRA/MODIS data, with the same spatial and temporal resolutions as NDVI. The results are following the same trend as the NDVI considerations (Fig. 21-23).

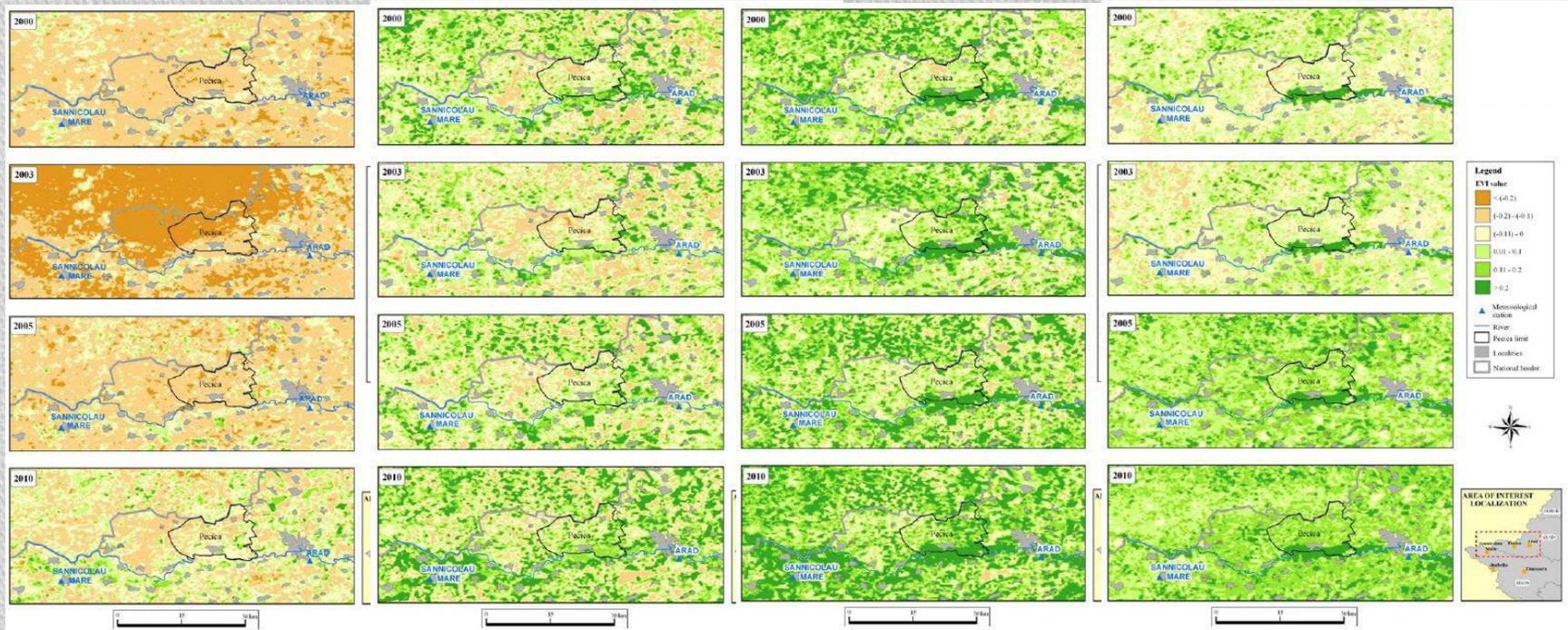


Fig 21 - Spatial variation of EVI values from 6th of March to 28th of August

3. Methodology and results (cont.)

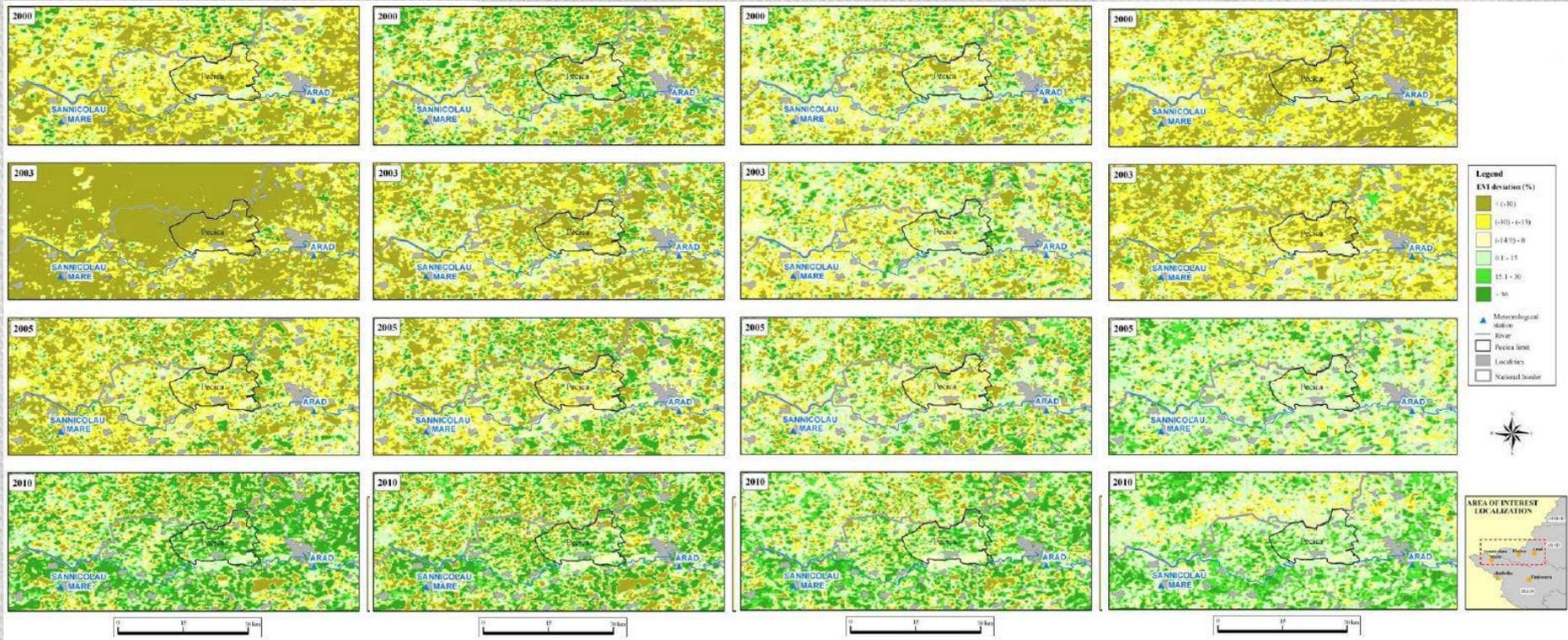


Fig 22 - The EVI deviation from multi-annual average (2000-2010), from 10th of June to 28th of August

3. Methodology and results (cont.)

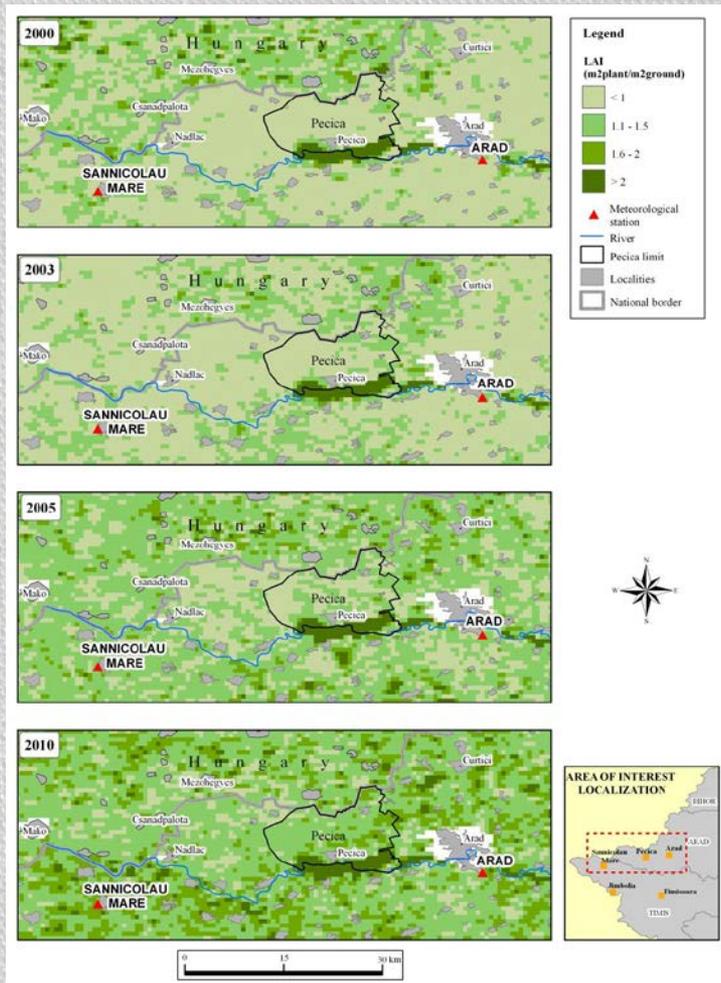


Fig. 24 - Spatial variation of LAI values

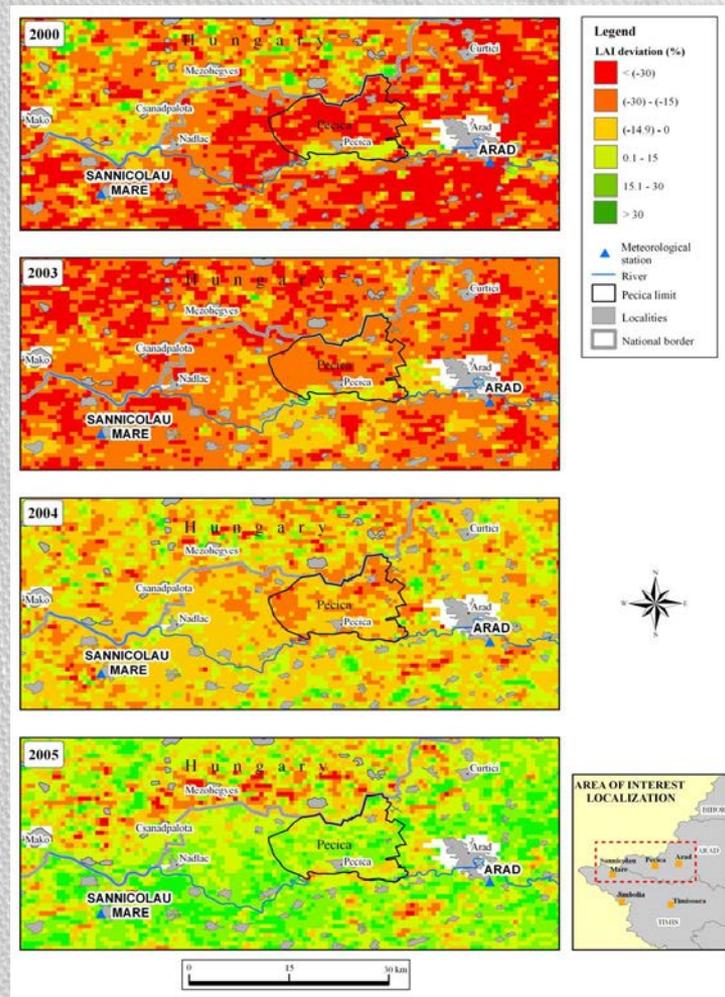


Fig. 25 - The LAI deviation from the multi-annual (2000 - 2009) average

3. Methodology and results (cont.)

- A critical period can be observed from August to October when precipitation amounts were very low and soil moisture anomalies occurred thus setting up the droughts (Fig. 27). The MODIS LAI values have been validated using the field campaigns that were carried out in the agricultural area of Pecica town. In these campaigns the LAI values were measured with specific devices (AccuPAR LP- 80). The LAI field measurements were taken for different crops like oats, sunflower, onion and watermelon.

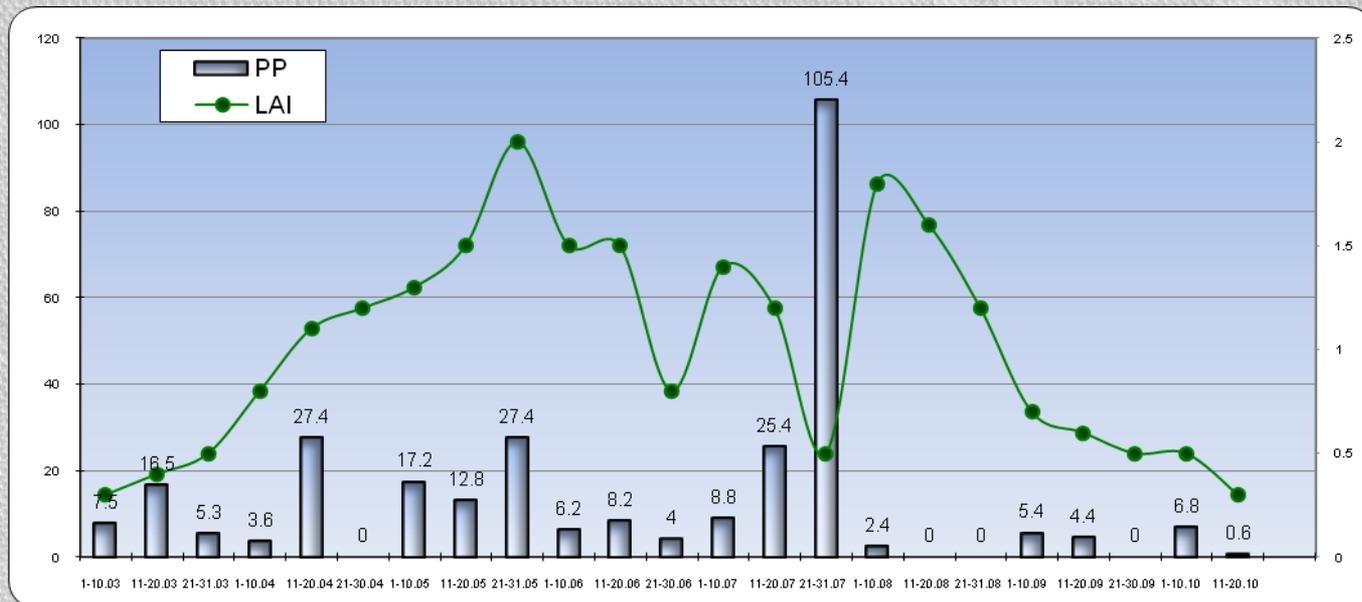


Fig. 27 - The correlation between LAI and precipitation (recorded at ARAD meteorological station)

3. Methodology and results (cont.)

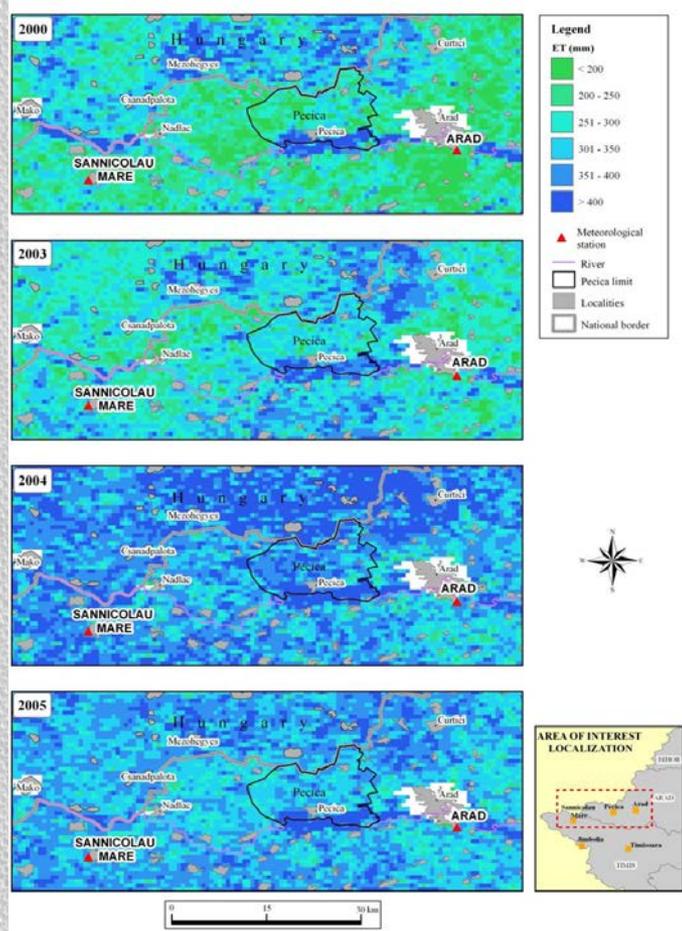


Fig. 28 - Spatial variation of ET values (6th of March – 28th of August)

WMO/EUMETSAT/FAO Satellite Products Training Course on Drought Monitoring and Applications in Agro Meteorology - Budapest, Hungary, 24-28 April 2017

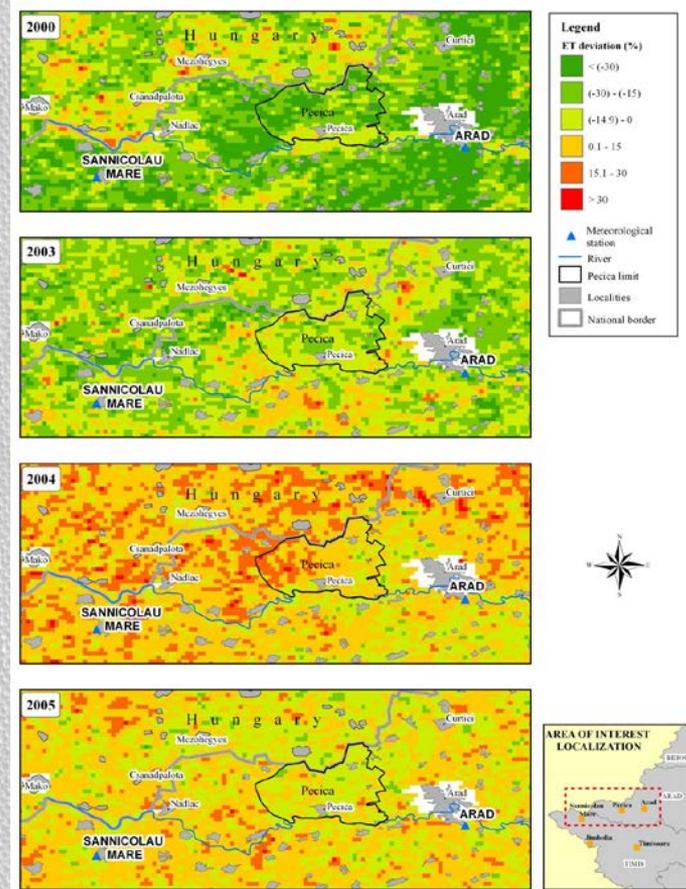


Fig. 29 - The ET deviation from the multi-annual (2000 – 2009) average (6th of March – 28th of August)

3. Methodology and results (cont.)

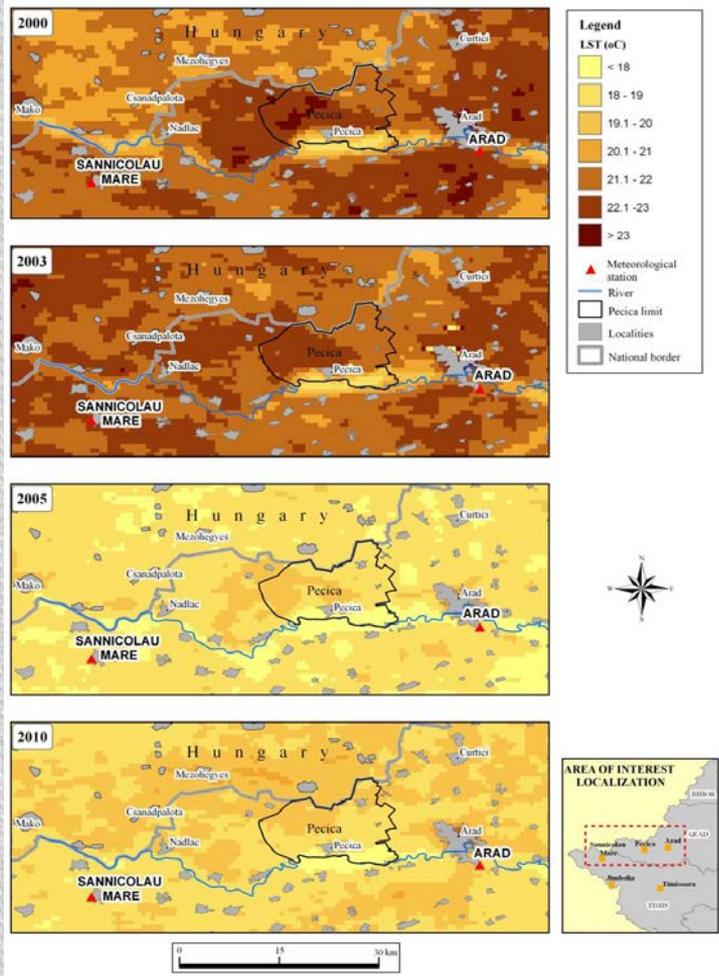


Fig. 30 - Spatial variation of LST values (6th of March – 28th of August)

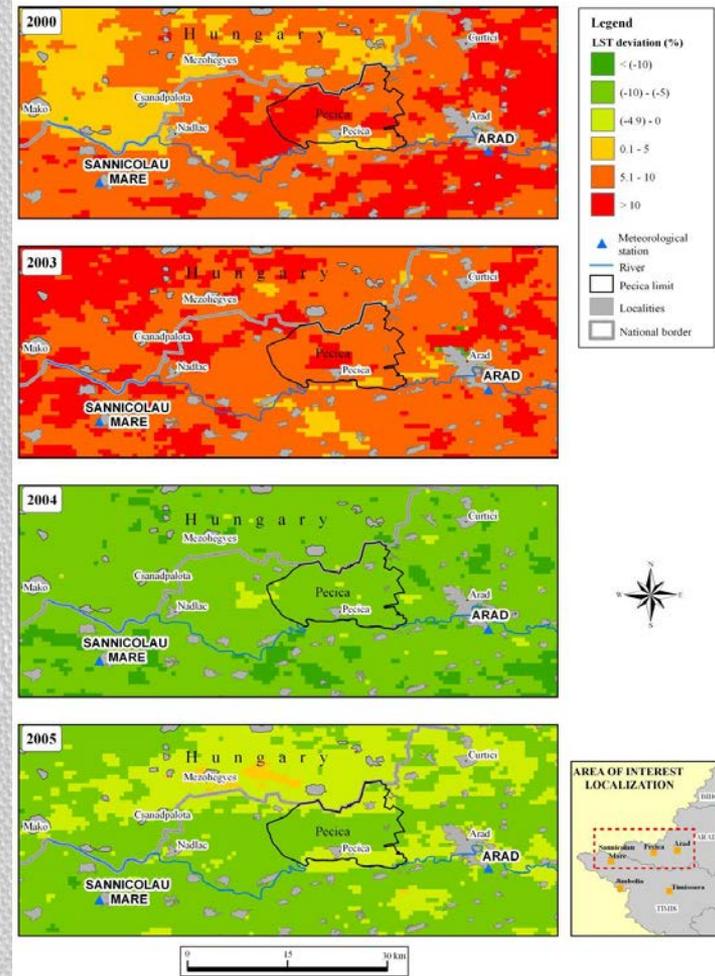


Fig. 31 The LST deviation from the multi-annual (2000 – 2009) average (6th of March – 28th of August)

4. Conclusions

- The vegetation indexes extracted from satellite images, correlated with meteorological and agrometeorological information, are good indicators of vegetation condition, in this case are relevant for monitoring the beginning, duration and intensity of drought.
- Remote sensing techniques can enhance and improve the drought analysis, especially considering the scarce availability of measured ground truth data.
- The advantage of multi-annual imagery availability allows the overlay and cross-checking of droughty, normal or rainy years.
- Intensive agricultural use was observed for Pecica commune's territory. However, the commune was also affected by the 2003 drought. The only areas not affected by drought were the ones along the Mures River.
- GIS technologies offer the possibility of crossed-analysis between various data sources such as vegetation indexes and CORINE land-cover classes. Such analysis revealed the fact that the most affected land-cover classes were the pastures and natural grasslands.
- Referring to the entire image without offering information on how NDVI reflects the behavior of various land-cover classes under drought stress.

4. Conclusions (cont.)

Table 1 - NDVI distribution per land-cover classes for the study area

Land cover (CORINE)		NDVI - 2003				NDVI - 2006				NDVI - 2010			
Code/Land classification	Area (sq. km)	Mean	Stdv	Min	Max	Mean	Stdv	Min	Max	Mean	Stdv	Min	Max
211	2525.09	0.35	0.15	-0.45	0.92	0.56	0.18	-0.58	0.93	0.52	0.20	-0.50	0.89
221	51.61	0.44	0.13	-0.29	0.93	0.60	0.15	-0.42	0.90	0.59	0.14	-0.39	0.88
222	16.34	0.51	0.16	-0.29	0.93	0.66	0.20	-0.48	0.91	0.65	0.19	-0.39	0.89
231	297.32	0.32	0.13	-0.45	0.94	0.60	0.15	-0.53	0.92	0.54	0.17	-0.50	0.90
242	71.57	0.39	0.14	-0.45	0.88	0.60	0.15	-0.52	0.90	0.55	0.17	-0.65	0.87
243	59.01	0.38	0.18	-0.28	0.92	0.60	0.19	-0.64	0.92	0.55	0.21	-0.50	0.89
311	167.85	0.77	0.17	-0.38	1.00	0.76	0.19	-0.55	1.00	0.76	0.15	-0.43	1.00
321	8.60	0.38	0.15	0.00	0.88	0.61	0.13	-0.05	0.90	0.55	0.15	-0.04	0.86
324	10.87	0.48	0.19	-0.22	0.93	0.65	0.20	-0.45	0.92	0.60	0.22	-0.44	0.89

Table 1 provides a series of statistical information on the NDVI for 9 of the most representative vegetation land-cover classes:

- ✧ 211 – Non - irrigated arable land;
- ✧ 221 – Vineyards;
- ✧ 222 – Fruit trees and berry plantations;
- ✧ 231 – Pastures;
- ✧ 242 – Complex cultivation patterns;
- ✧ 243 – Land principally occupied by agriculture, with significant areas with vegetation;
- ✧ 311 – Broadleaved forest;
- ✧ 321 – Natural grasslands;
- ✧ 324 – Transitional woodland-shrub.

4. Conclusions (cont.)

Table 2 - NDVI changes (%) per land classes for the study area

Land cover (CORINE)		NDVI % of change		
Code	Area (sq.km)	2003-2006	2003-2010	2006-2010
211	2525.09	37.19	31.64	-8.84
221	51.81	27.45	25.34	-2.91
222	18.34	22.44	21.95	-0.63
231	287.32	46.13	40.94	-9.64
242	71.57	34.81	28.80	-9.22
243	59.01	35.97	31.02	-7.72
311	187.85	-0.60	-0.76	-0.15
321	8.60	38.05	31.28	-10.94
324	10.87	27.08	20.40	-9.16

- Table 2 aggregates the raw information presented in Table 1 and illustrates the NDVI percentage change between the 3 years under analysis. For the normal years (2006 and 2010), these changes don't exceed 10%. While for 2003 they exceed 30% for a considerable number of land-cover classes. **As anticipated above, the pastures seem to be the most sensitive to drought occurrence with changes higher than 40%. The agricultural classes (CLC 211 and 243) suffer also major changes of 30%.**

<http://midmures.meteoromania.ro/>
<http://www.meteoromania.ro>

Thank you for your attention!