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SATELLITE DATA IN SUPPORT OF DROUGHT MONITORING IN GIURGIU, TELEORMAN, OLT AND DOLJ COUNTIES

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Abstract

Presently, drought can be identified and monitored using a wide range of remote sensing methods. Over the last years, drought conditions were reported in several areas located in south of the country, in Giurgiu, Teleorman, Olt and Dolj counties. This study aims at identifying the drought affected areas and the effects of the drought on vegetation, based on satellite data acquired by Landsat. Both test sites covering the counties mentioned before are of major importance for agriculture. It is estimated that the agricultural area of the Giurgiu County was of approximately 238,000 hectares in 2012. The Romanian Plain has a rich and fertile soil that is very suitable for the cultivation of grain, sunflower, and technical and medicinal plants. Dolj County is located in the most fertile region of the Oltenia Plain benefiting by favorable climatic and soil conditions. Its total arable area is about 488,000 hectares, according to 2009 statistics. The county is covered in the southern part by large sandy areas and an impressive number of lakes formed either by flooding or precipitation accumulation. Remote sensing is an important tool for drought monitoring due to its capacity to observe large geographic areas using frequent acquisitions. Moreover, remote sensing offers the possibility to study archive satellite data and therefore to make better predictions for the future. The Normalized Difference Vegetation Index (NDVI), together with information on temperature and precipitation were used for estimating the drought index. In conclusion, the early identification of drought is important for mitigation efforts, while the monitoring of the drought effects contributes to more accurate crop yield estimations.

Key words*: drought, remote sensing, satellite image, NDVI, fAPAR.*

INTRODUCTION

Drought represents an extreme phenomenon that causes an insufficient level of water necessary for the normal growth of plants. Drought can be classified as: meteorological, agricultural and hydrological. The first type of drought, the meteorological one, occurs when complete lack of rainfall lasts for a long time or precipitation falls in very small quantities. The agricultural drought appears when there is an insufficient amount of water needed for agriculture. When drought persists for a long period, the crop yield decreases significantly or it is totally compromised. Hydrological drought happens when water reservoirs (ground water, lakes) decrease substantially. Statistics show that drought occurs generally at every 10-15 years. Generally, the extreme drought years are alternating with excess years in terms of the pluviometric regime. According to the National Meteorological Administration, pluviometric deficits occurred in 2000-2003 and 2007. The aim of the present study is to identify and monitor the agricultural drought by analyzing the spectral response of vegetation, based on satellite images. The results obtained through remote sensing methods were compared with specific drought indices provided by the European Drought Observatory (EDO). The study covers the period from 2000 to 2004 and four Romanian counties affected by drought, Giurgiu, Teleorman, Olt and Dolj (Figure 1).

Figure 1. Counties affected by drought in Romania

MATERIALS AND METHODS

The materials used in this study consist of satellite images, precipitation and temperature data, and drought indices.

The satellite images have a spatial resolution of 30 m and were acquired by the Landsat mission in June 2000 and 2001, and in September 2002, 2003 and 2004. The Landsat images are available online and can be freely downloaded. The Landsat images were acquired from two adjacent orbits in order to cover the counties mentioned before (Figure 2).

But the analysis was performed over the two test areas marked in Figure 3. All the original Landsat images were cropped in order to cover the test areas (GR + TR and OT + DJ). The corresponding Universal Transverse Mercator (UTM) coordinates are shown in Table 1.

Table 1. Coordinates of the test areas

UTM	GR + TR	OT + DJ
N [m]	4,906,000	4,909,000
S [m]	4,857,000	4,860,000
E [m]	330,000	700,000
V [m]	415,000	785,000

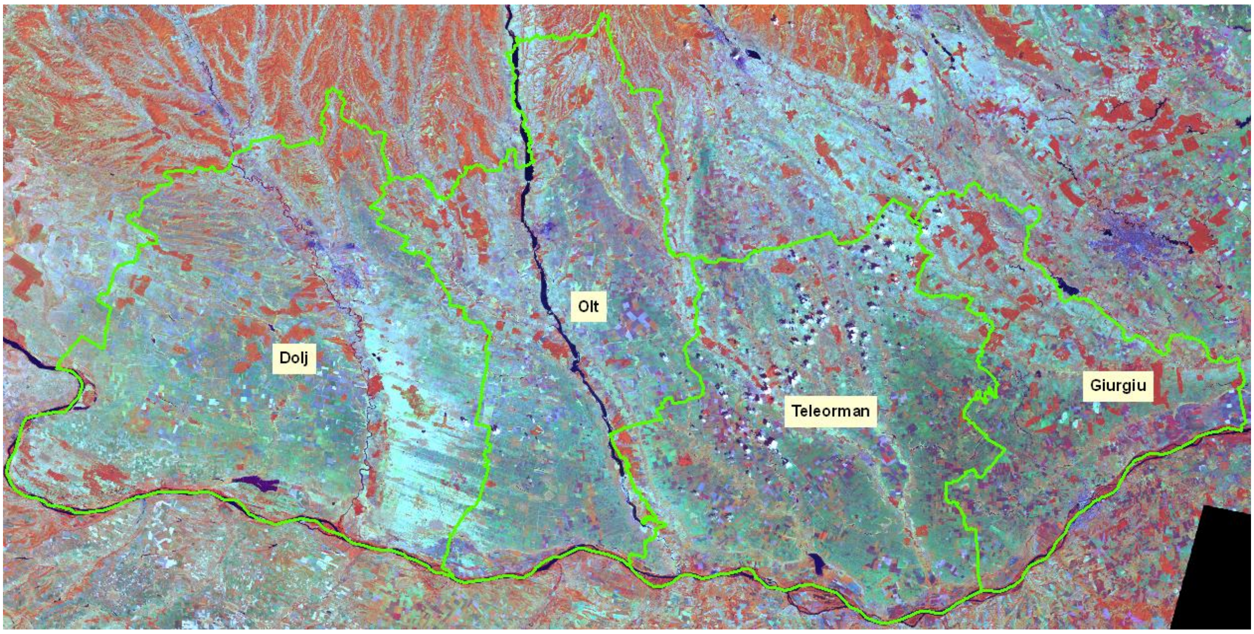


Figure 2. Counties selected for drought monitoring from 2000 to 2004 (background image Landsat ETM+)

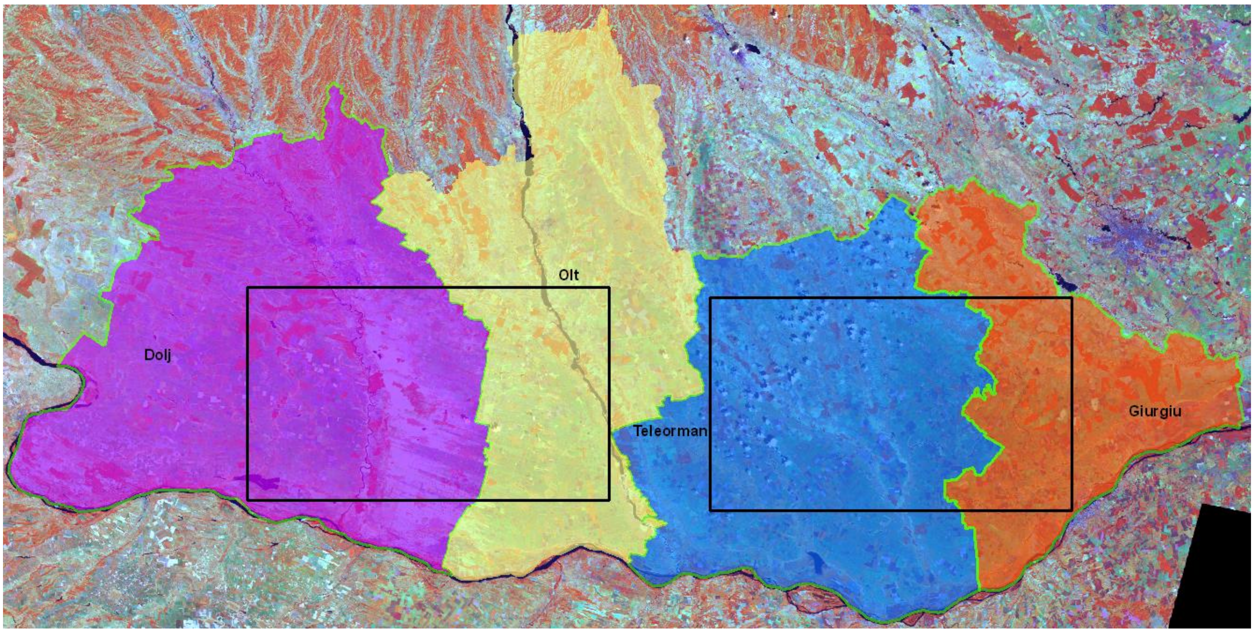


Figure 3. Test areas for a detailed analysis of the drought monitoring (background image Landsat ETM+)

Using the Landsat subset images, three remote sensing vegetation indices were computed, namely: the Normalized Difference Vegetation Index (NDVI), the Ratio Vegetation Index (RVI) and the Difference Vegetation Index (DVI). NDVI calculates the green vegetation composition, using band 4 (near-infrared) and band 3 (red) of the Landsat images (Badea, 2011). The values of this index are between -1 (no vegetation) and 1 (dense vegetation). RVI represents the ratio of the spectral response in the near infrared and spectral response in the visible red, indicating the amount of vegetation (high values mean density). DVI represents the difference between the near infrared band and the red band. It detects the amount of vegetation, but it does not offer good results when the reflected wavelengths are affected by external factors (Akkartal et al., 2004).

The data on precipitation and temperature was obtained from the website of the European Climate Assessment and Dataset (ECAD). In order to identify the extreme conditions that could lead to drought (very low amounts of precipitation and very high temperatures), the maximum temperature values were extracted.

The values for precipitation (Table 2) and for temperature (Table 3) cover a period of ten days before the satellite image acquisition date (T-10 ten days earlier, T-9 nine days earlier, T satellite image acquisition date). The average of these values was computed.

The drought indices were extracted from the datasets published by the European Drought Observatory (EDO) that aims at detecting and monitoring drought in Europe. Since droughts can be defined in different ways according to the disciplinary perspective (e.g. hydrological, meteorological, agricultural drought), and it is not possible to define a unique drought index, it is necessary to define a multidisciplinary set of indicators which monitor constantly the various environmental components that can be affected by this hazard (soil, vegetation, river flows, etc.) to obtain a comprehensive picture of the situation. These indicators are: rainfall, the Standardized Precipitation Index (SPI), the Fraction of Absorbed Photosynthetically Active Radiation (fAPAR), fAPAR anomaly, soil moisture, and soil moisture anomaly (Table 4).

The proposed combined indicator is based on the three main indices of EDO: the SPI, the soil moisture and the fAPAR. SPI-n (McKee et al, 1993) is a statistical indicator comparing the total precipitation received at a particular location during a period of n months with the long-term rainfall distribution for the same period of time at that location. In conclusion, SPI is used to characterize rain shortage. It is one of the more common drought indicators. In 2010, the World Meteorological Organization (WMO) selected it as a key meteorological drought indicator to be produced operationally by meteorological services.

fAPAR represents the fraction of the solar energy which is absorbed by the vegetation .It is proposed as drought indicator due to its sensitivity to vegetation stress (Gobron et al. 2005 and 2007). Indeed droughts can cause a reduction in the vegetation growth rate, which is affected by changes either in the solar interception of the plant or in the light use efficiency. The anomalies of fAPAR are used to characterize the consequently effects in vegetation condition (Rossi et al., 2008).

Soil moisture is one of the important variables in hydrologic, climatologic, biologic, and ecological processes because it plays a crucial role in the interactions between the atmosphere and land surface. The anomalies of soil moisture are used to characterize the effects of the rain shortage in the soil moisture.

Table 2. Precipitation values (T – satellite image acquisition date, n – number of days) - © ECAD

Test area and satellite image	Precipitation											
	T-10	T-9	T-8	T-7	T-6	T-5	T-4	T-3	T-2	T-1	T	Average
GR + TR Jun 2000	0	0	0	0	6	1	4	1	0	0	0	1.09
GR + TR Jun 2001	0	0	1	7	0	5	12	7	0	0	0	2.91
GR + TR Sep 2002	0	0	0	0	0	6	6	5	3	0	0	1.82
GR + TR Sep 2003	0	0	1	27	20	12	7	3	0	0	0	6.36
GR + TR Sep 2004	0	0	0	0	0	0	0	0	1	0	0	0.09
OT + DJ Sep 2002	0	0	0	0	0	0	0	0	5	0	0	0.45
OT + DJ Sep 2003	0	0	0	0	0	0	0	0	0	4	5	0.82
OT + DJ Sep 2004	0	0	3	0	0	0	0	0	0	0	0	0.27

Table 3. Temperature values (T – satellite image acquisition date, n – number of days) - © ECAD

Test area and satellite image	Maximum temperatures											
	T-10	T-9	T-8	T-7	T-6	T-5	T-4	T-3	T-2	T-1	T	Average
GR + TR Jun 2000	32	35	35	34	29	28	20	23	28	30	35	30
GR + TR Jun 2001	32	34	34	25	23	27	21	17	20	22	24	25
GR + TR Sep 2002	34	35	35	35	35	35	34	17	13	17	18	28
GR + TR Sep 2003	32	30	30	25	17	16	15	16	23	27	28	24
GR + TR Sep 2004	20	24	27	29	30	29	29	22	23	27	30	26
OT + DJ Sep 2002	28	29	28	28	28	28	29	28	29	29	30	29
OT + DJ Sep 2003	30	35	36	30	29	30	36	40	42	42	28	34
OT + DJ Sep 2004	32	30	28	26	22	21	22	26	19	18	18	24

Table 4. Drought indicators - © EDO

Test area and satellite	Rainfall	SPI-3	fAPAR	fAPAR anomaly	Soil moisture	Soil moisture

image						anomaly
GR + TR Jun 2000	38.36	0.46	0.29	-1.16	3.28	0.03
GR + TR Jun 2001	158.70	0.23	0.42	-0.08	3.44	0.47
GR + TR Sep 2002	57.14	1.04	0.30	0.80	3.25	-0.87
GR + TR Sep 2003	95.68	-0.69	0.21	-0.39	3.43	-0.46
GR + TR Sep 2004	46.21	-0.14	0.24	-0.02	3.72	0.27
OT + DJ Sep 2002	69.83	1.57	0.48	1.87	3.36	-0.43
OT + DJ Sep 2003	89.52	-0.33	0.08	-1.65	3.88	0.68
OT + DJ Sep 2004	40.21	0.53	0.27	-0.06	3.62	0.13

RESULTS AND DISCUSSIONS

The results obtained based on the remote sensing vegetation indices (NDVI, RVI and DVI) are similar. Their analysis indicates that Giurgiu and Teleorman were affected by drought in June 2000 and September 2003, while Olt and Dolj were affected by drought in September 2002. For each test area, the minimum, average and maximum values for the vegetation indices were computed (Table 5). The statistics are biased in the case of the satellite images acquired in September 2003 for the test area Giurgiu and Teleorman and in September 2004 for both test areas (Landsat 7 ETM+ images with Scan Line Corrector off).

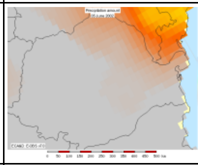
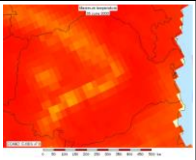
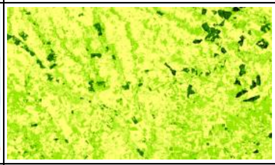
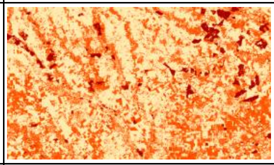
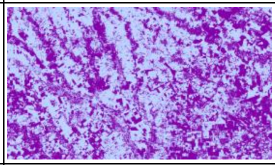
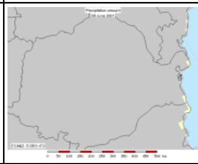
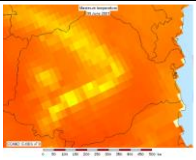
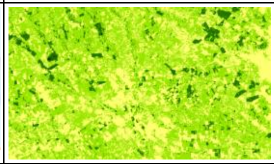
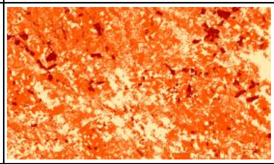
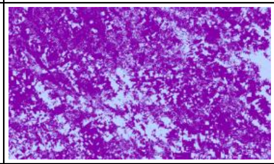
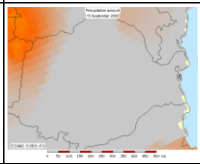
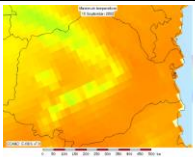
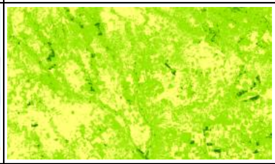
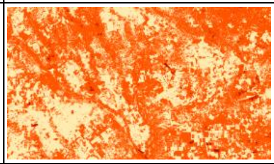
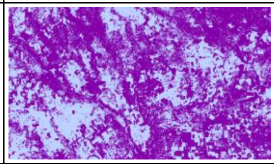
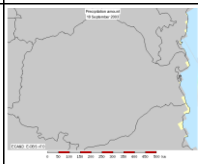
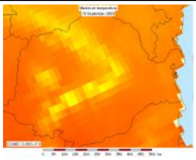
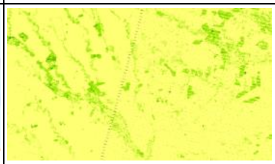
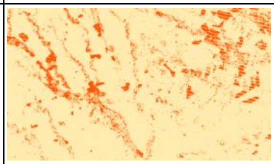
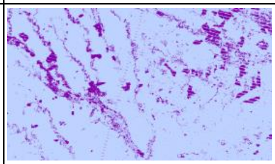
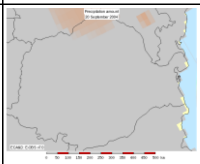
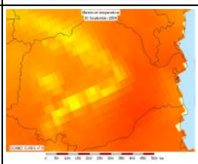
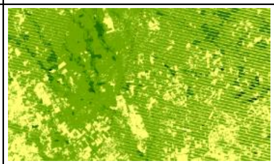
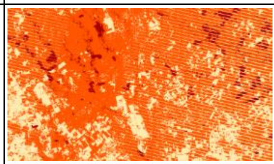
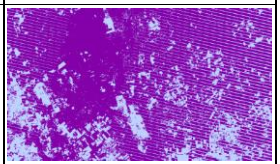
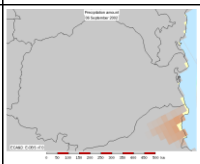
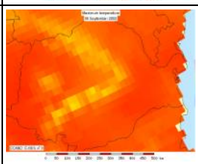
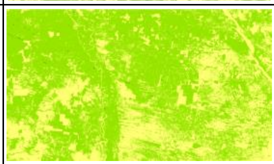
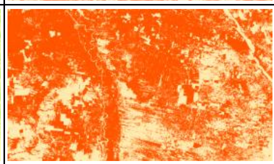
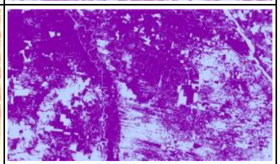
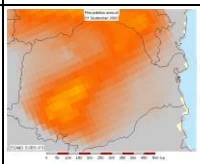
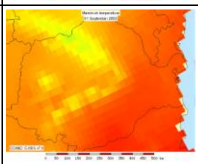
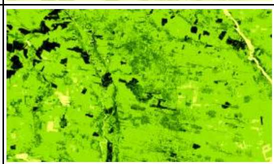
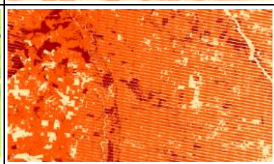
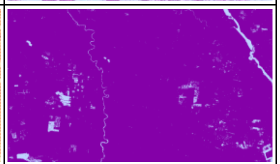
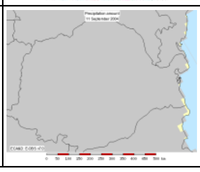
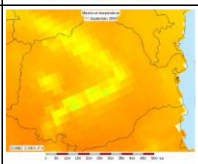
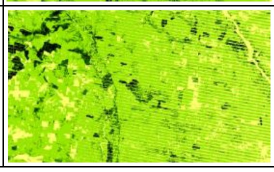
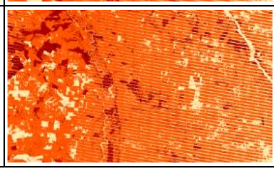
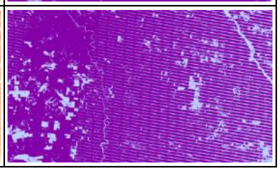
Based on the precipitation data acquired from the ECAD website, the lowest amounts of precipitation are observed in June 2000 for Giurgiu and Teleorman and also in September 2004 both for Giurgiu and Teleorman, and Olt and Dolj. Regarding the temperature data, it results that June 2000 has a higher average of maximum values in comparison with June 2001, for test area Giurgiu and Teleorman. Analyzing the values for September, 2002 was the hottest year for Giurgiu and Teleorman while 2003 was the hottest year for Olt and Dolj. In conclusion, June 2000 was a period of drought for Giurgiu and Teleorman, based on the precipitation and temperature data. This result confirms the outcomes of the vegetation indices analysis. In case of September 2002-2004, the results are not similar. However, the precipitation and temperature values cannot validate the conclusions drawn by the remote sensing analysis because these indicate only the meteorological drought, while the vegetation indices show the agricultural drought. For each satellite image and test area (Giurgiu and Teleorman, Olt and Dolj), the precipitation and temperature datasets are presented together with the vegetation indices in an overview perspective (Table 6).

Regarding the EDO drought indices, fAPAR and fAPAR anomaly clearly confirm the results from the analysis of satellite imagery for June 2000 and September 2003, for test area Giurgiu and Teleorman. These indicators also show that it was drought in September 2003, in the case of the second test area (Olt and Dolj) which has not resulted from the remote sensing analysis due to the fact that the satellite image was acquired in a rainy day (it was also raining the day before) and the vegetation indices (NDVI, RVI, DVI) were therefore biased.

Table 5. Remote sensing vegetation indices (minimum, maximum and average values)

Test area and satellite image	NDVI min	NDVI max	NDVI average	RVI min	RVI max	RVI average	DVI min	DVI max	DVI average
GR + TR Jun 2000	-0.54	0.62	0.00	0.30	4.21	1.07	-129	123	0.31
GR + TR Jun 2001	-0.48	0.56	0.06	0.36	3.55	1.20	-135	113	8.54
GR + TR Sep 2002	-0.50	0.51	0.02	0.33	3.10	1.08	-90	78	2.81
GR + TR Sep 2003	-1.00	1.00	-0.12	0.00	2.59	0.70	-133	98	-11.79
GR + TR Sep 2004	-1.00	1.00	0.09	0.00	4.95	1.13	-67	100	9.03
OT + DJ Sep 2002	-0.46	0.39	0.03	0.37	2.30	1.08	-87	66	4.14
OT + DJ Sep 2003	-0.54	0.73	0.22	0.00	5.53	1.25	-112	135	16.66
OT + DJ Sep 2004	-1.00	1.00	0.13	0.00	5.53	1.25	-65	112	13.72

Table 6. Overview perspective of the precipitation and temperature datasets, and the remote sensing vegetation indices

Image	Precipitation	Temperature	NDVI	RVI	DVI
GR + TR Jun 2000					
GR + TR Jun 2001					
GR + TR Sep 2002					
GR + TR Sep 2003					
GR + TR Sep 2004					
OT + DJ Sep 2002					
OT + DJ Sep 2003					
OT + DJ Sep 2004					

CONCLUSIONS

Remote sensing is an extremely useful tool in identifying and monitoring drought due to the fact that the satellite images cover large areas and the revisiting time is getting shorter as new satellite missions are launched.

The outcomes obtained based on the three investigated remote sensing vegetation indices, namely NDVI, RVI and DVI are similar and all of them can be used to identify the areas affected by drought. In the same time, auxiliary data such as precipitation and temperature is very useful in the analysis of the remote sensing results. The specific drought indicators computed by EDO provide critical information in determining what type of drought affects the test area. For example, the fAPAR indicator and the fAPAR anomaly are indicators of the agricultural drought. Based on these two drought indicators, the results of the remote sensing analysis could be validated.

The early identification of drought is important for mitigation efforts, while the monitoring of the drought effects could contribute to more accurate crop yield estimations.

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The ECAD precipitation and temperature data has the following citation: "We acknowledge that the E-OBS dataset is from the EU-FP6 project ENSEMBLES (http://ensembles-eu. metoffice.com) and the data providers in the ECAD project (http://www.ecad.eu). Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res., 113, D20119, doi:10.1029/2008JD10201" (http:// eca.knmi.nl/).

The drought indicators (rainfall, SPI, fAPAR, fAPAR anomaly, soil moisture, soil moisture anomaly) were obtained from the European Drought Observatory, Joint Research Center (http://edo.jrc.ec.europa.eu).

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