Remote Sensing Data Analyses for the Study of Drought

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Abstract. Droughts are normal climate episodes, but they are also among the most expensive natural disasters. Knowledge about timing, severity and extension of drought can aid in planning and decision-making. There are several possibilities of drought monitoring based on ground measurements, hydrological and climatological data. Another possibility is to use remote sensing data. Evaluation of secondary events, such as vegetation condition, serve for the examination of primary reason - the drought. The climate of Romania territory allows a quite high risk of drought. The continental climate with long periods of high pressure can cause a lack of precipitation for a month or two. In this paper an experiment is described with the use of SPOT satellite decadal vegetation data for detection of drought. By evaluating an eight-year time series of NDVI (Normalized Differential Vegetation Index), the possibility of monitoring of drought with a rather simple approach is presented. The result potential map of drought stress have been validated by comparing them with the land use/land cover map and not only the occurrence of drought in years 2000 and 2003 was confirmed, but also the dynamics of vegetation development during the vegetation period can be studied for different places of the country.

Keywords: drought monitoring, vegetation condition index

1 Introduction

Used with conventional methods of drought monitoring, the satellite data are successful in early detection and monitoring of drought and its impact on crops and pastures in countries such as China, Greece, Mongolia, Brazil and others [2]. There have also been developed operational systems, for example the Department of Agriculture in USA offers drought monitoring products all over the world, involving robust statistical methods based on a combination of several indices [7]. In our study only a part of this complex approach has been used, the method developed by Kogan [4] in which the so-called VCI - vegetation condition indices are used in combination with temperature indicators. However, only the VCI have been used in our study in order to simplify the process. Daily SPOT satellite Végétation data with a geometrical resolution of 1km serve as input into the model. The last SPOT generation satellite, SPOT 5, is equipped with a new type of sensor. SPOT satellites are known for their high-resolution imagery easily used for developing ortophotomaps and high-resolution thematic maps or even for DEM generation using photogrametic methods. Considering the need of data with higher temporal resolution covering the whole globe, the new generation of satellites carry the so called VI (vegetation instrument) with a swathe of 2250 km able to scan the whole globe every day. With its four channels it can derive various secondary products. They are suited especially for mapping the vegetation over vast regions, and for global change studies [6]. The raw data are geometrically and atmospherically corrected and geo-referenced by provider, and also, for long periods analysis, the so called decadal (10 days) syntheses are available. The original data are spoiled by clouds and weather fluctuations. In order to avoid this phenomenon as much as possible short-time syntheses are generated. Nevertheless the cloudy parts are still presented, but are assigned specific values. Annual time series can show us the differences in vegetation amounts by comparing the values of the same place, at different times within a year and also the years with each other. Simply comparing the annual curves with the average one, the years much under the average can be pointed out. These are probably the years of drought. There are two main difficulties: 1. the data availability period is not long enough to draw some really reliable conclusions, 2. short-term high frequency weather fluctuation can not be completely removed, allowing miss-interpretation of the results due to erroneous values. Various agricultural field covers of several years are included here. All these influences ought to be removed as much as possible from data by taking into account only the period lasting from early April to early November (1. 04. - 1.11). Also the values connected to clouds are removed. The most important step is the temporal smoothing of the data using linear regression in a moving the temporal window [5]. With such pre-prepared NDVI decadal values the next steps are accomplished. First comes the computation of VCI indices. The average curve and the differences related to it are evaluated accordingly. The method itself and the interpretation of results comply with three basic environmental lows regarding the behavior of ecosystem [3].

1. The law-of-minimum holds that the primary production is proportional to the amount of the most limiting growth resource and becomes the lowest when one of the factors is at the extreme minimum.
2. Each ecosystem depends on environmental factors. These factors have a maximum and a minimum, causing the ecosystem varies within the range of tolerance.
3. The principle of carrying capacity, which distinguishes between ecosystem differences and stratification. Thus, every pixel is evaluated separately during the processing.

This is only one small part of complex monitoring method presented by Kogan [4], [2], but the results show that even with this particular part, the vegetation stress caused by drought can be successfully detected and monitored.

2 Method and Results

2.1 Point-vice analyzes

The smoothing procedure and the fixing of all possible pitfalls had to be provided at first only in one point and in time domain. Also the difficulties connected to the behavior of values in different places have had to be examined. For this purpose test areas have been chosen the in the Arges River basin in southern Romania. According to the high-resolution land use/land cover map three test locations have been chosen. One containing summer crops (maize, sunflower), one containing winter crops (first of all cereals), and one with grasslands in the basins mountainous part, see fig. 1.

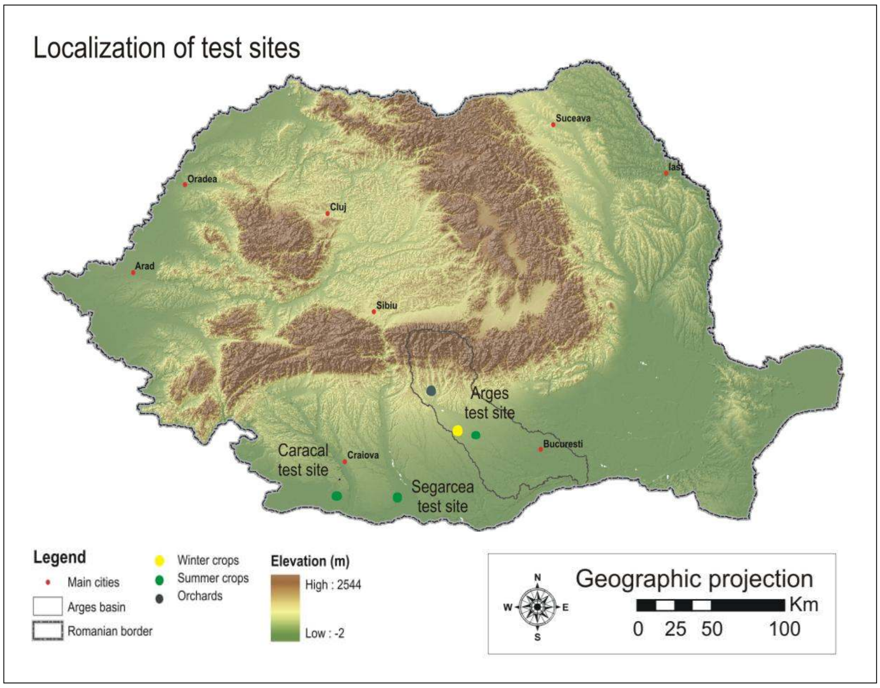

Fig. 1: The test sites - agricultural fields with various kinds of crops have been picked up according to land use/land cover map within the experimental Arges River basin.

For each test zone the NDVI values for each decade have been derived. Using moving the temporal window and with linear regression these data have been smoothed. The average value of these linear functions has always been taken as a result. This is a very simple approach. However the resulting curve is smoothed well and is comparable to the other years. In fig. 2 the smoothing procedure is sketched.

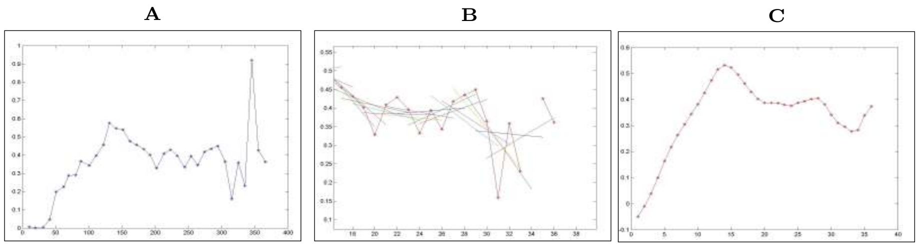

Fig. 2: The smoothing procedure is provided by moving temporal window of 7 decades. In **A** the original annual curve of NDVI values can be seen. Applying the least-square regression and the conditions for high values, the outliers are excluded. The final NDVI value is computed as average of these particular results (**B** and **C**).

The next problem is based on the fact that by comparing the years with each other it is possible that there is a trend caused for example by the growing of vegetation. Small differences caused by a long-term fluctuation of the climatic conditions in a particular place can be presented as well. By using the multiyear NDVI minimum and maximum the values are forced into the same range, and are quantitatively comparable afterwards. This product is called **Vegetation Condition Index** [4].

$$\mathrm{VCI} = 100(\mathrm{NDVI} - \mathrm{NDVI}_{\mathrm{min}})/(\mathrm{NDVI}_{\mathrm{max}} - \mathrm{NDVI}_{\mathrm{min}}) \qquad (1)$$

In fig. 3 the co-plot of VCI annual curves of the 1998-2005 decadal values can be seen. The difference between winter and summer crops is clear. The summer crops have a more marked dispersion of values, and the drought years 2000 and 2003 are easily distinguished. Also the different behavior of these two dry years can by seen. According to [1] a severe drought which affected all the crop types occurred in 2000. On the other hand the drought of 2003 started in June and had impact first of all on summer crops. The co-plot of VCI curves and, consequently, the co-plot of differences regarding the linear-regression-in-time values (fig. 4) confirm the results connected to the cereal yield, temperature and precipitation studies [1].

2.2 Processing of test area

After the study was provided for the chosen test locations, the algorithm was supposed to be applied for the whole Romania. However, in this step, more practical problems appeared. First there is a problem of quite huge computational

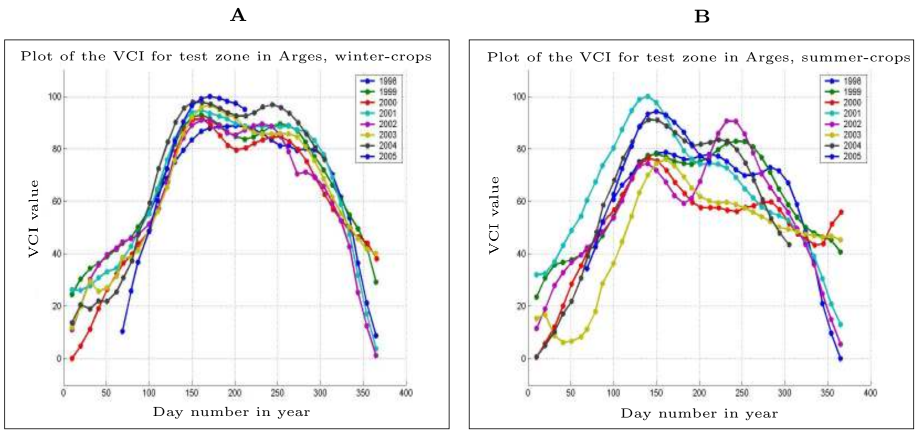

Fig. 3: Co-plot of annual VCI curves for winter crops **A** and summer crops **B**. High dispersion and sink of years 2000 and 2003 are clear. Winter crops are much less sensitive for weather fluctuation.

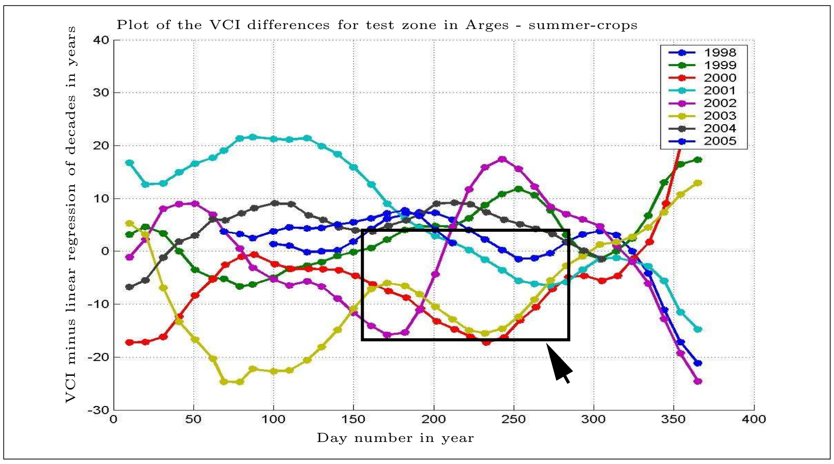

Fig. 4: Differences between original decadal value and linear time regression for the summer crops. The temporal dynamics of the drought years 2000 and 2003 can be studied here.

efforts. Secondly, there are the strongly affected image parts, in wintertime being even 5 decades of cloudy decadal values. Their values are of course excluded from computation, but the interpolation gives irrealistic results afterwards, and the evaluation of VCI is completely erroneous. For this purpose the computation of VCI has been restricted only to the vegetation period.
Only a small crop of the original scene has been processed. First the data were smoothed, VCI indices were computed for each year and the differences from the average value in this case were evaluated. These differences already promise the first piece of information about the behavior of drought in the space domain. Applying the certain threshold, the potential map of drought stress can be made. Thus, with regard to the first environmental law, which postulates separate approaches of different ecosystems, a direct applying of the constant threshold is not entirely correct. Nevertheless, in fig. 5 the differences for the 23rd decade (mid-August) can be seen. The drought years as well as the various extends and degrees of impact severity are clear. In fig. 6 the potential map of the 23-rd decade, 2000 drought is presented. The extend of the red region which is significantly below the average corresponds almost exactly to a cultivated region.

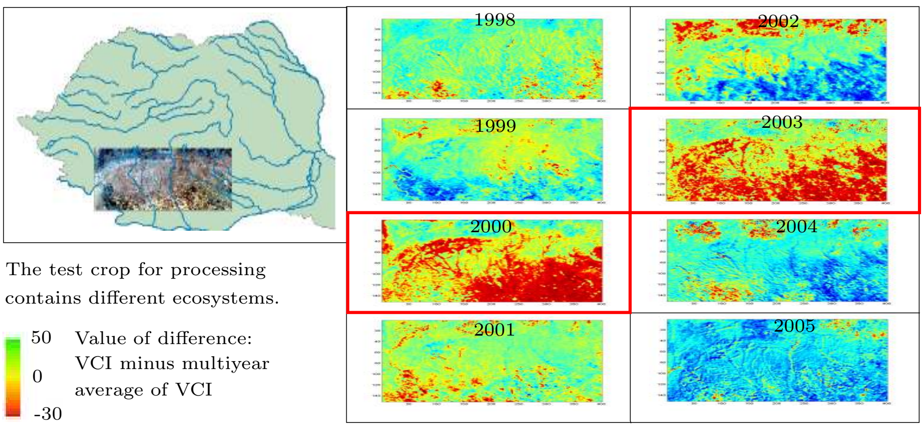

Fig. 5: The results of processing the crop area are shown. The differences related to the multi-year average clearly show correlation with the drought years 2000 and 2003. The red color means that VCI is for more then 10 lower than average. Differences are evaluated for mid-August.

3 Conclusion

In this study only a small part of the complex theory used for drought monitoring was applied. However, the drought years have been successfully detected and the temporal and spatial dynamics of the phenomena have been studied. After

Differences - potential map of ecological stress caused by drought.

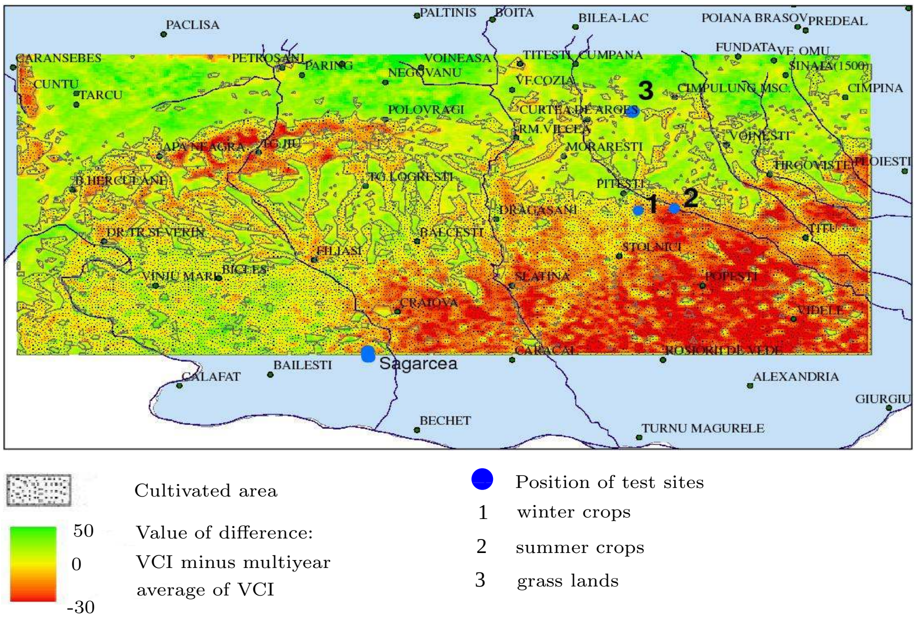

Fig. 6: Georeferenced differences can show the spatial pattern of stress impact. The position of the test points also corresponds to a little different behavior of the winter crops. Evident impact is on the cultivated area.

verifying the results and the optimalization of processing we can hold that even this simple method can serve for detecting of drought. In order to apply the original method presented by Kogan [4], not only the vegetation condition has to be evaluated, but also the soil surface temperature. The thermal band remote sensing data are used to solve this problem.

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