SELECTED METHODS OF DROUGHT EVALUATION IN SOUTH MORAVIA AND NORTHERN AUSTRIA

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Abstract

Meteorological drought is frequently described in terms of drought indices, which are convenient and relatively simple to use. Two of them (i.e., the Standard Precipitation Index - SPI and Palmer´s Drought Severity Index – PDSI) were considered in the study. In order to test the performance of both indices, a case study area was defined in the southeast of the Czech Republic and northeast of Austria. Data were gathered for 45 meteorological stations with available monthly means of temperature and precipitation for period 1961-2000 within climatically homogenous region. Even after averaging of the monthly values over all 45 stations, mean values of the indices were lower than thresholds defined for extremely or severely dry conditions during some events. The spatial distribution of the drought patterns and differences between performance of both indices suggest that for the real time draught monitoring, and the assessment of climate change impacts on drought severity and duration, a "blend" of more than one drought index should to be used.

1. Introduction

Drought is the most complex and least understood of all natural hazards, affecting more people than any other hazard (Wilhite *Ed.*, 2000a). However drought has to be perceived as natural part of climate under all climatic regimes. It occurs in high as well as low rainfall areas. The frequency of droughts is commonly associated with specific climatic regions, (e.g., it is common in African Sahel or Australia and on the contrary rarely visualized in western or central Europe). However, in Central Europe drought is well noted in The paleoclimatological record as early Neolithic settlements (Kalis *et al.,* 2003) were significantly influenced by draught. In the later case so-called "green droughts" i.e. droughts associated with apparent ample yearly rainfall but reduced agricultural productivity because of the poor timing of rains (rainfall distribution in relation to crop demand) or ineffective precipitation often take place.

It should be remembered that drought has also had significant impacts on the economy and life in Eastern and Central Europe in recent decades (e.g., the results of the U.S.Country Studies Program (Smith *et al*., 1996)). Other countries, such as those of the Mediterranean region, are also strongly affected (Watson *et al*., 1997). Although the recent occurrence of droughts in these regions cannot be linked directly with human-induced climate change, estimated impacts of drought events illustrate the vulnerability of those areas to the drought episodes. Considering the projected increases in temperature over Central Europe with only a slight growth in precipitation amounts in some seasons (winter) and declines in other seasons (summer), it is very likely that the frequency of drought occurrence and its severity will increase in Central Europe in the future and the impacts associated with these events will be exacerbated. In addition, increasing demand for water and increasing pressure on other natural resources resulting from population growth, increased urbanization, and greater emphasis on environmental protection are changing the vulnerability of society to drought (McCarthy *et al*., 2001).

Drought risk directed research in the Czech Republic and Austria has been limited up to the present time. Therefore, the goal of this study is to develop drought assessement tools in the present climatic conditions. Such a study will be the basis for a more comprehensive study concentrating on an estimation of changes in drought risk and patterns of drought occurrence in the expected climatic conditions through this century, as well as real time monitoring of drought risk over the area.

2. Materials and methods

Drought differs from other natural hazards (e.g. floods, tropical cyclones and earthquakes) in several ways. First, the beginning and end of any drought is hard to determine since the effects of drought often accumulate slowly over a considerable period of time and may linger for years after the termination of the event. Second, the absence of a precise and universally accepted definition of drought, adds to the confusion about whether or not a drought exists and, if it does, its degree of severity. Therefore any realistic definition of drought must be region and application specific. Four interrelated categories of drought are usually distinguished: hydrological drought, socioeconomic drought, meteorological drought and agricultural drought. In this study only the meteorological drought will be considered. It is expressed solely on the basis of the degree of dryness (usually related to the departure of rainfall from average) and duration of the dry period. Agriculture drought links various characteristics of meteorological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil deficits etc. Any realistic definition of agricultural drought should account for the variable susceptibility of crops at different stages of crop development. Meteorological drought is frequently described in terms of drought indices, which are convenient and relatively simple to use. Two of them, the Standardized Precipitation Index (SPI) and the Palmer Drought Severity Index (PDSI), were considered in the study.

2.1. Standardized Precipitation Index

Mathematically, the SPI is based on the cumulative probability of a given rainfall event occurring at a station (McKee *et al.,* 1993). The historic rainfall data of the station is fitted to a gamma distribution, as the gamma distribution has been found to fit the precipitation distribution quite well. This is done through a process of maximum likelihood estimation of the gamma distribution parameters, α and β. In simple terms, the process described above allows the rainfall distribution at the station to be effectively represented by a mathematical cumulative probability function. Therefore, based on the historic rainfall data, an analyst can then tell what is the probability of the rainfall being less than or equal to a certain amount. Thus, the probability of rainfall being less than or equal to the average rainfall for that area will be about 0.5, while the probability of rainfall being less than or equal to an amount much smaller than the average will be also be lower (0.2, 0.1, 0.01 etc, depending on the amount). Therefore if a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event depending on the time scale. Alternatively, a high rainfall event with a high probability on the cumulative probability function is an anomalously wet event. Therefore, the SPI can effectively represent the amount of rainfall over a given time scale, with the advantage that it provides not only information on the amount of rainfall, but that it also gives an indication of what this amount is in relation to the normal. Such information helps define whether a station is experiencing drought or not. Its output is in units of standard deviation from the median based on the record length. The longer the period used to calculate the distribution parameters, the more likely you are to get better results (e.g., 50 years better than 20 years).

2.2. Palmer Drought Severity Index

The PDSI (Palmer, 1965) is based on the supply-and-demand concept of water balance equation and takes into account the role of the soil moisture. It uses a water balance model with two layers of soil. The content of the surface layer (Ss) is assumed to have a maximum of 25 mm. The content of the underlying layer (Su) has a maximum dependent on the soil type. In this model, water transfer into or out of the lower layer only occurs when the surface layer is full or empty. The water balance equation is made up of eight variables combined in four sets. The first set is made up of potential and actual evapotranspiration. The second set is made up of potential and actual recharge. The third set is made up of potential and actual runoff and the last set is made up of potential and actual loss The potential evapotranspiration for each month is calculated from the monthly temperature using a variation of Thornthwaite's Method. The seven other variables are then calculated using potential evapotranspiration and monthly precipitation. These are used to calculate four coefficients representing the normal ratio for these sets. With these coefficients calculated, a departure from the normal moisture levels, d, can be computed. The Z-index is the name given to the moisture anomaly, which represents how wet or dry it is during a given period without regard for historical trends. It is basically the moisture departure, d, adjusted by a weighing factor called the climatic characteristic and denoted by K. The original monthly PDSI relies on an empirical formula derived by Palmer in 1965 using data from nine stations. The Self-Calibrating PSDI actually adjusts the value of K necessary to obtain the correct range of PDSI values (-4.0 to +4.0). In computing the final PDSI (X), three intermediate variables are used. The variable X1 is the index for all wet spells before they become established and is always greater than zero. X2 is the index for all dry spells before they become established and is always less than 0. X3 is the index for any established spell, wet or dry. The final PDSI value is then chosen from one of these depending on the current trend.

2.3. Description of the study area

In order to test the performance of both indices the case study area was defined in the southeast of the Czech Republic and northern Austria. Monthly means of temperature and precipitation for period 1961-2000 for 45 meteorological stations within climatically homogenous region were used in the analysis. In the same time within the study region it was possible to include both intensively cultivated lowland area of South Moravia and Marchfeld regions as well as highlands in Upper Austria and in the center of the Czech Republic. The spatial distribution of the stations as well as representation of the altitude and available water holding capacity used in the study are presented at the Fig.1. Both parameters were interpolated based on the values of the 45 available stations.

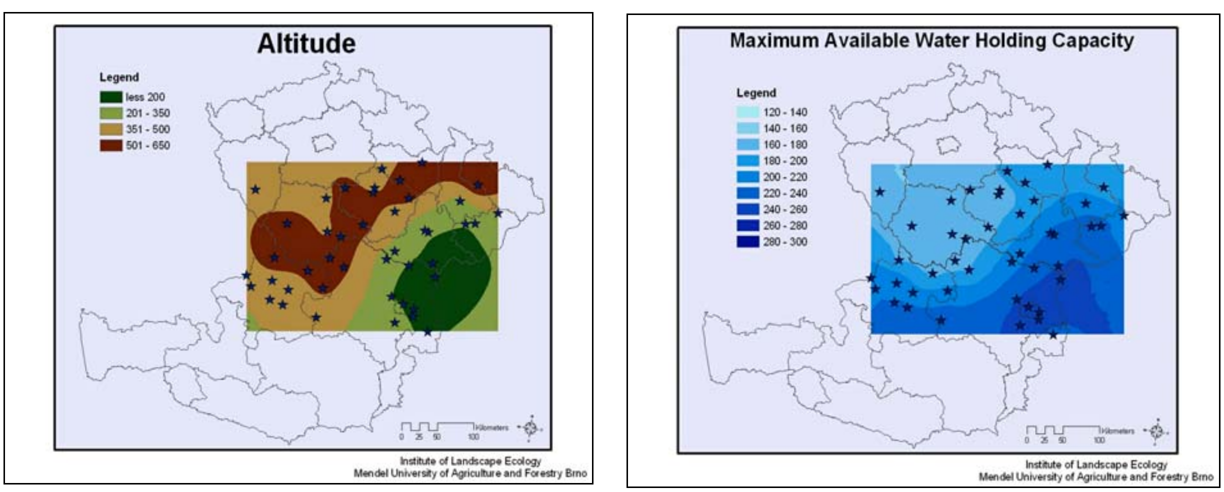
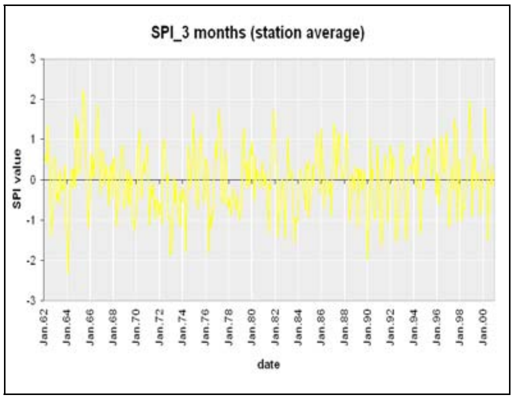


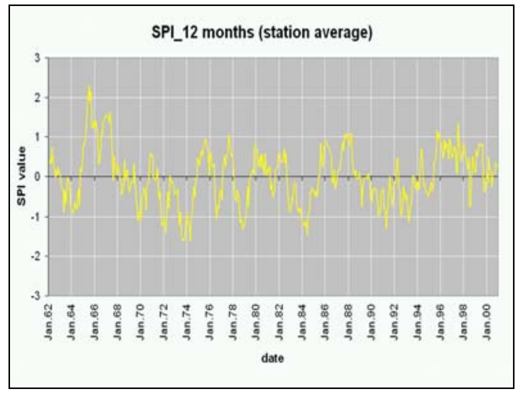
Fig. 1. Geographical location of the study area. Isolines represent altitude (a) and available soil water holding capacity (b) of the region interpolated using the individual weather stations (stars).

3. Results

The SPI was calculated for all available weather stations in the study area. The selected number of time steps was established to provide the overall picture of the frequencies of the precipitation deficiency or surplus within various time scales. As can be seen from Fig. 2a, the average of



a)



b)

Fig. 2.: Course of the SPI_3 months (a) and SPI 12_months (b) during 1962-2000 period. The value is based on mean of 45 stations in the Czech Republic and Austria

3 month SPI values are frequently smaller than the –1.0, which is considered to be a threshold below which the term "moderately dry" weather as applied by the National Drought Mitigation Centre methodology (Svoboda *et al.,* 2002).

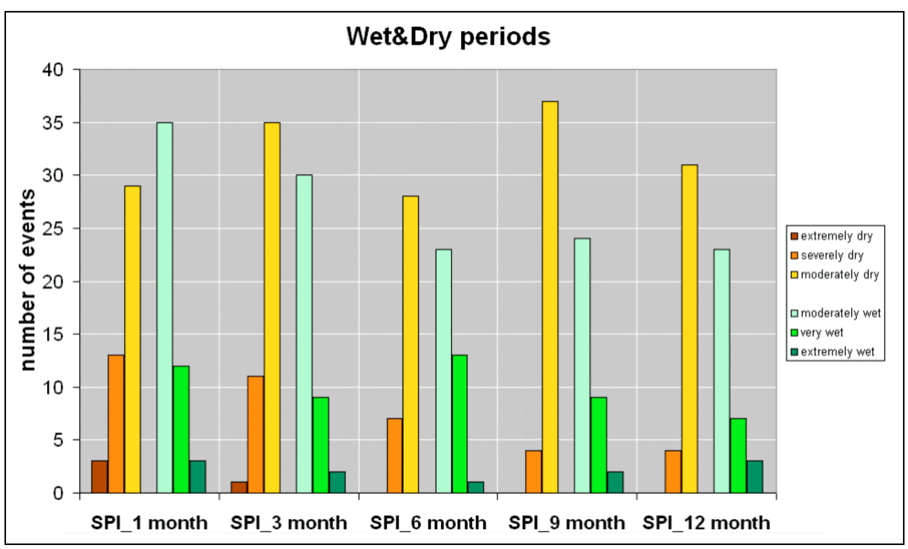


Fig. 3.: Distribution of extreme events based on the mean value of SPI (various time steps). The following SPI values are assigned to each event category: extremely dry = less than -2.00; severely dry = -1.50 to –1.99; moderately dry = -1.00 to –1.49; moderately moist = 1.00 to 1.49; very moist = 1.50 to 1.99; extremely moist = above 2.00.

The frequency and severity of dry periods decreases with the increasing time step (Fig. 2b) however pronounced periods of precipitation deficiency can be seen (e.g., during 1973-1974 or 1978). During these years significant reductions of national cereal yields were recorded over most of the Czech Republic territory (www.cso.cz, 2003). The decrease of the average occurrence of "extremely dry" (SPI < -1.5) and "severely dry" (SPI < -2.0) events with the increasing time step of SPI is well documented also at the Fig. 3. On the contrary to the decrease number of extreme dry spells the number of periods with precipitation highly above the normal has not shown any significant alteration with changing SPI time step.

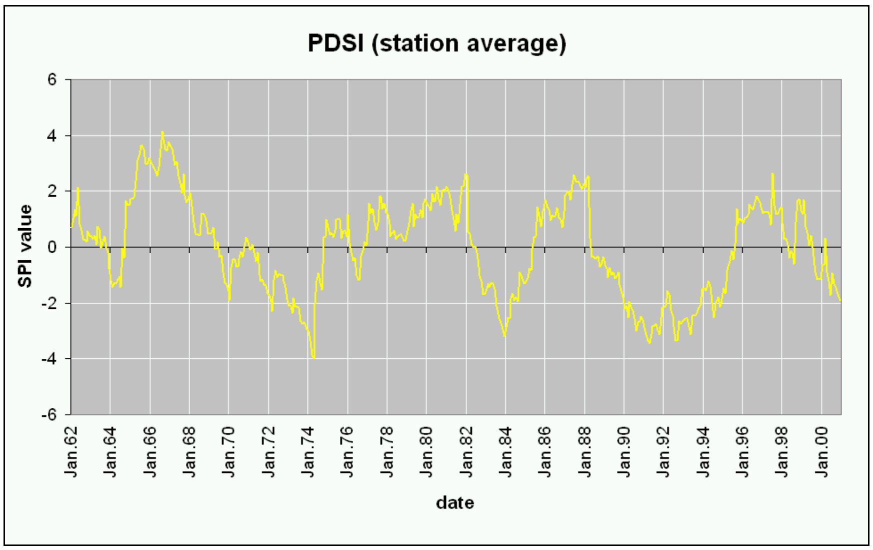


Fig. 4. Course of the PDSI during 1962-2000 time period. The value is based on mean of 45 stations in the Czech Republic and Austria

In comparison with 9- or 12-month SPI, the mean values of PDSI (Fig. 4) show much greater persistence that is most likely caused by inclusion of soil water holding capacity factor into the scheme of the index calculation. The differences between the spatial distribution of the drought episodes between the 9 month SPI and PDSI is documented in Fig. 5 and 6, which show that the PDSI signals the drought onset latter than the 9- month SPI and that the similar time lag does exist also for the drought recovery process. As the PDSI is working with a built in 9-month time step, the difference between the PDSI and 9- month SPI cannot be explained without inclusion of the soil factor into the calculations, as well as applying the water balance approach by PDSI. These two factors are the main cause of the self-calibrated PDSI higher stability as the stored soil water delays the drought onset while the necessity to recharge the soil water reservoir slows down the recovery process. Differences in the soil water holding capacities of soil profiles at individual weather stations can be used in order to explain differences in the spatial distribution of drought severity occurrence from the 9- months SPI. The latter drought index does not take into account any other difference between the stations than those caused by spatial precipitation distribution.

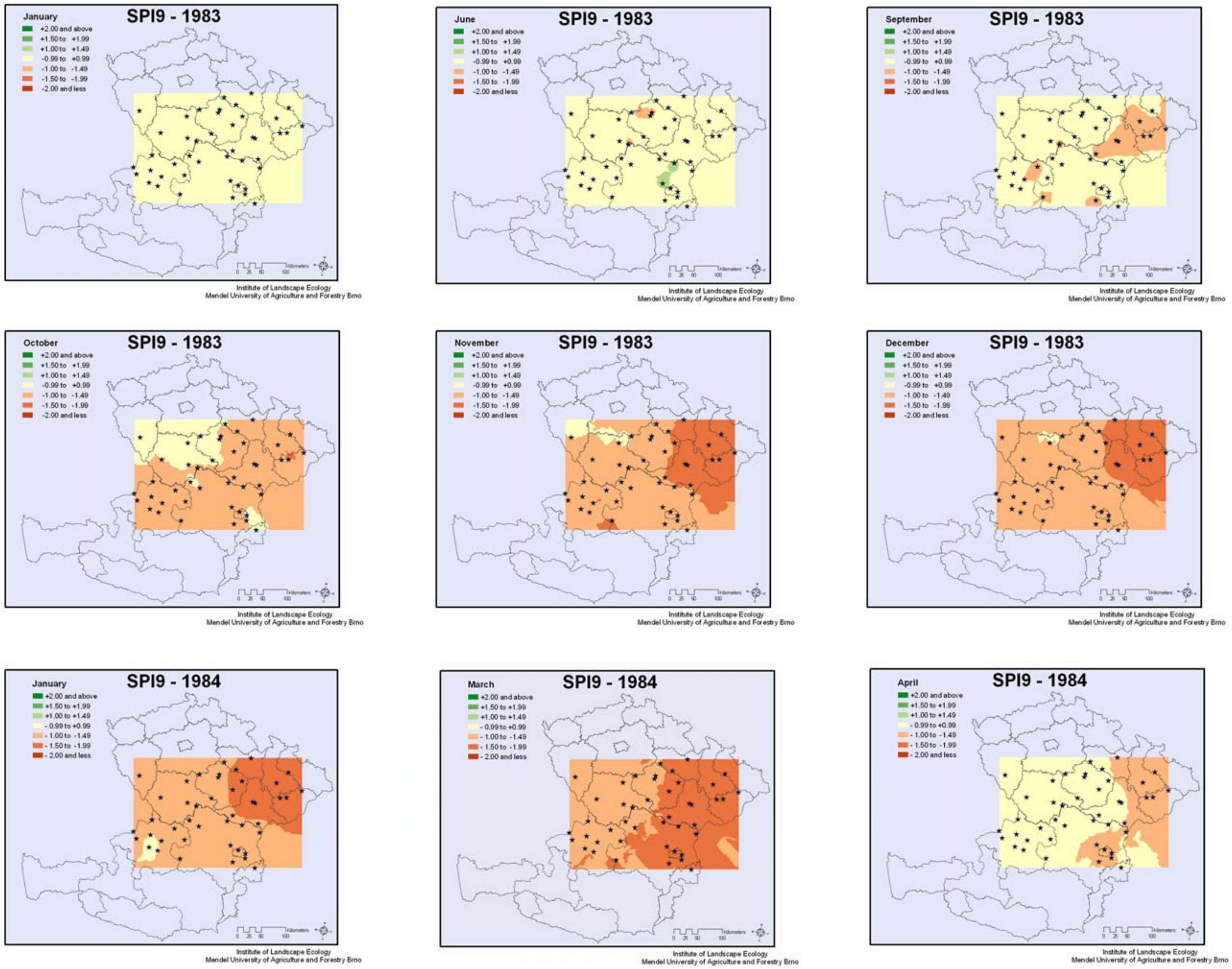


Fig. 5. Spatial distribution of the SPI 9-months values from January 1983 to April 1984 over the study area. The map was created by Kriging interpolation method.

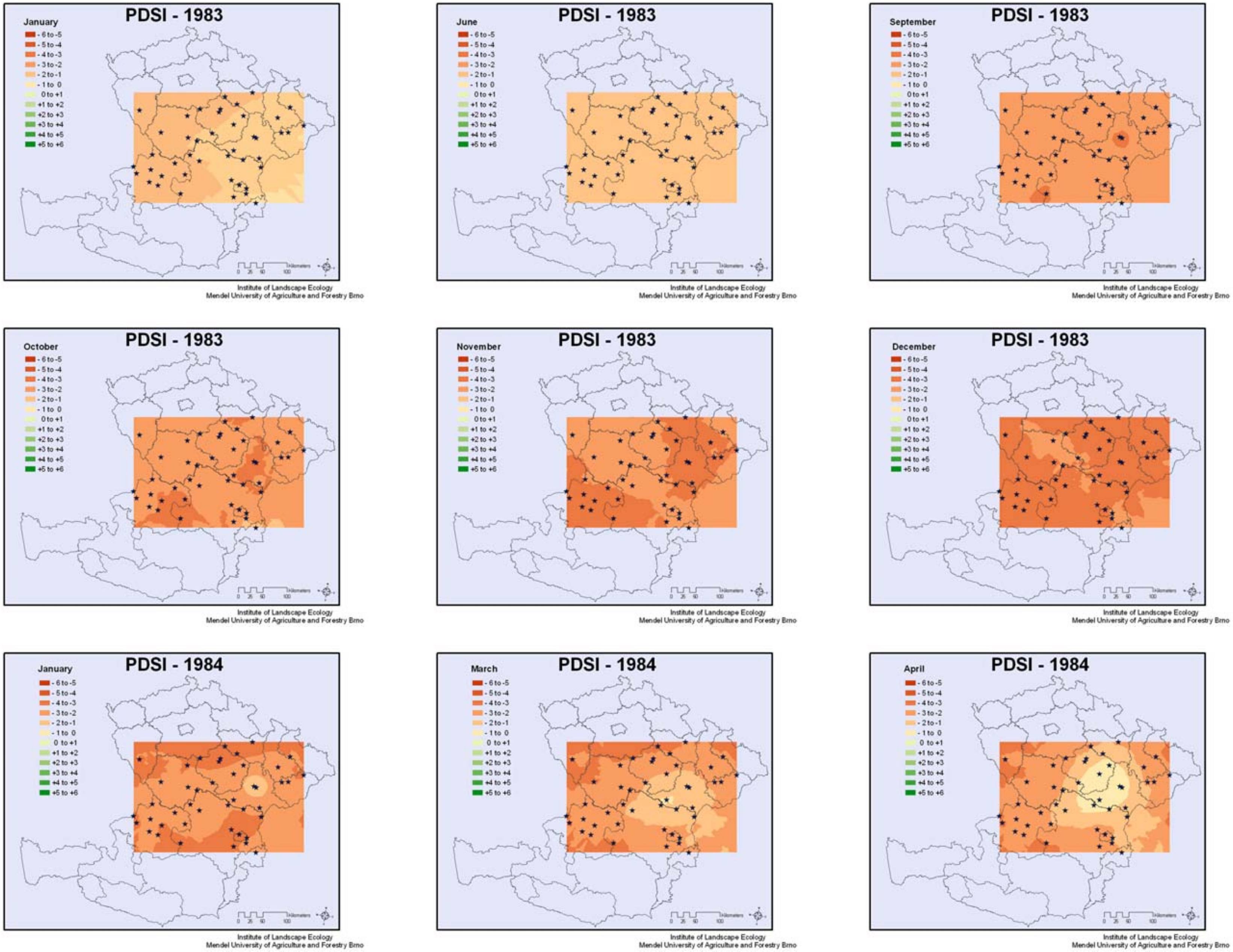


Fig. 6. Spatial distribution of the PDSI values from January 1983 to April 1984 over the study area. The map was created by Kriging interpolation method.

4. Conclusions

A new technique to objectively and reliably monitor and assess the magnitude of drought over different time scales is presented here. The Standardized Precipitation Index and the Self Calibrated version of the Palmer Drought Severity Index were tested within the selected study area. Even after averaging of monthly values over all 45 stations mean values of indices were during some events lower than thresholds defined for extremely or severely dry conditions. The spatial distribution of the drought patterns and differences between performance of both indices seems to suggest that for the real time monitoring or assessment of climate change impacts on drought severity and duration, a "blend" of more than one drought index may be to be used.

Acknowledgement

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