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Hydrology and Earth System Sciences
Discussions
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Interactive comment on "Vegetation vulnerability to drought on southeastern Europe" *by* Patrícia Páscoa et al.

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1. Frequency, duration and spatial extent of drought conditions over the study area were considered, but the severity level was not analyzed, which would have been a valuable contribution to this work. Impacts of drought on vegetation vary according to both duration and severity of drought, and the authors did not account for acknowledge this gap in their study. The consideration of severity should would greatly improve this work and the value of the method presented. However, it is acknowledged that this type of research would be complex. If the authors do not choose to add a severity component to the analysis, then at a minimum, they should discuss this gap, state why it was not considered and summarize the limitations of the specific drought conclusions that can be drawn from these results.

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Discussion paper

Response: We acknowledge that the level of severity was not assessed separately, however the effect of severity is indirectly included. The existence of a linear relation between NDVI and SPEI, as assessed by the correlation analysis, points to the simultaneous occurrence of extreme NDVI anomalies and SPEI values. Therefore, for the cases when the correlation is positive, we expect that NDVI anomalies and SPEI values decrease simultaneously. Moreover, it should be noted that we also included the analysis of a severe drought event to study in more detail the impacts on vegetation. In fact, the drought event of 2000/2001 was chosen precisely because it was found to be the most severe in the period 1960-2013, as stated by several authors (Spinoni et al., 2013, Ionita et al. 2016). The study of this drought event showed that severe droughts affect vegetation in areas usually not affected by droughts. This is already stated in the data and methods section.

An analysis of the effect of different classes of severity should be performed on a pixel basis, in order to discard differences arising from different geographical locations. We believe this analysis would require longer time series in order to capture drought events of different severity classes on the same location (pixel). The NDVI dataset used in this work is not long enough to perform such analysis. This statement will be included in the manuscript.

2. The paper contains many long sentences that are somewhat difficult to read and interpret the key points that are trying to be made. Suggest dividing many of the longer sentences into shorter, more precise sentence to improve the readability of the manuscript.

Response: We have made a serious effort to accommodate this requirement. Therefore, several longer sentences will be split in two shorter sentences in the final version of the paper, as follows:

Line 185: The number of months with SPEI values below -0.84 was also computed and mapped for the same time period. This allowed assessing the spatial extent of the drought episode at various time scales and the overlapping of vegetation under stress conditions.

Line 234: The Carpathian Mountains generally present a lower concordance than the remaining area, and it also presents a lower number of low NDVI anomalies (Fig.6). A higher agreement is found in the central area in May, in the northeastern area in June and in the south in July (Fig.7).

Line 298: By analysing the period from May to October, it was possible to identify significant negative correlations at high altitudes in the Carpathians, and also the moment these negative correlations tend to disappear, around in July. This coincides with the emergence of significant positive correlations at lower altitudes.

Line 304: The negative correlations obtained here for the month of June at high altitudes point to a positive effect of dryness on the vegetation activity. The subsequent signal change in the month of July may be a response to the increasing temperature coupled to the decrease in precipitation, and an indicator of water stress, even though at shorter time scales the correlation at high altitudes is mostly non-significant.

Line 338: In any case, all land cover types present an area of negative correlations in June which increases with altitude, and likewise, all land cover types present an area of positive correlations in July which decreases with altitude. These results are in agreement with previous results obtained in the Carpathians by Sidor et al., 2015, and on areas situated at lower altitudes by Baumbach et al. (2017).

Section 120: What does 'status map' refer to here? Briefly explain what it is.

Response: This dataset provides information regarding the presence of clouds, cloud shadows, or ice, at each pixel, which is referred to as the status map. Pixels identified as snow cover by the status map were excluded, as well as NDVI values below 0.1, since they do not represent vegetation. A brief description of the status map will be included in the manuscript and the last sentence of the section will be changed in order to make more clear that NDVI values below 0.1 are unrelated to the status map. Section 130: State the numerical ranges of the SPEI and corresponding drought severity levels for each range.

Response: The severity classification used in this work was proposed by Agnew (2000). The limits and probability of occurrence of each class will be included in the new version of the manuscript, on Table 2. Theoretically, SPEI has no limits, although the probability of occurrence of extreme values is extremely rare, since this index is normally distributed. The information attached will be added in order to clarify this aspect and based on this classification, a threshold of -0.84 was established to identify the drought events (20% of the probability distribution function and a return period of 1 in 5 years).

Section 135: Briefly explain how the SPEI value threshold representing drought was selected from the data for this study.

Response: As mentioned in the previous comment, the threshold was chosen based on the normal distribution function. The meteorological data does not influence the choice of the thresholds, since the resulting index is standardized and therefore these thresholds always correspond to the same probability of occurrence.

Section 210: The negative correlations and different relationship results for needle-leaved forest is not surprising given their primarily evergreen nature and fairly consistent NDVI response across the growing season. There is minimal NDVI fluctuation across the year because of their evergreen status and minimal NDVI often occur during drought compared to other vegetation types with a more pronounced, seasonal NDVI cycle This may be worth noting somewhere in the paper as this vegetation type appears to have consistently different results in the study.

Response: We agree with reviewer about the less marked vegetative cycle of NDVI over needle-leaved forest. Several works pointed out the different response of this vegetation type to drought events (Gouveia et al., 2009, 2012, 2017, Vicente-Serrano et al., 2013). The knowledge about this behaviour lead us to compute the annual cycle of NDVI for the different land cover types over the region (Figure 1, bottom right panel). Additionally, we opted to perform the correlation analysis on monthly NDVI, as our aim is to analyse the inter-annual variability of NDVI and therefore assess the inter-annual response of vegetation to extreme events, namely drought events.

However, and with the aim of clarifying this issue a reference to the less marked vegetative cycle of needle-leaved will be added on the Section Discussion and Conclusions in the next version of the paper.

Section 220: What does "intense" refer for "intense negative NDVI: : :." Do you extremely negative? Consider using a different term here.

Response: The expression will be changed in order to clarify this issue as follows:

'The relationship between drought severity and the NDVI was also assessed by counting the number of months characterised by simultaneous occurrence of extremely negative NDVI anomalies and negative SPEI.'

The thresholds used to consider the NDVI anomaly as extremely negative is -0.025 and this threshold is clearly mentioned on the Data and Methods Section.

Section 240 (and throughout paper): Suggest using a different phrase than "period of highest vegetation activity", which is somewhat vague. Possible use a phrase such as "peak of growing season" or "peak of vegetated phase of plants".

Response: We acknowledge the reviewer's point of view. Throughout the text, the expression 'highest vegetation activity' does not corresponds to a single month but refers to the period in which the vegetation is photosynthetically more active and therefore prone to be more affected by adverse conditions. Therefore, we agree with the reviewer that a more appropriate terminology should be used ("growing season") and several changes will be made on the new version of the document.

Section 250: Considerable discussion of the SPEI results for the longer time intervals

(6 months+) are presented here and in other parts of the paper, but only minimal discussion of the short time periods (e.g., 1 and 3-month SPEI). Why? This contradicts an earlier statement in the paper where the authors state that the longer period produced similar results and the longest periods would not be presented other than one representative longer time interval, yet the shorter periods are only minimal presented and discussed. Consider adding some discussion about the short SPEI time period results to the paper.

Response: We understand the reviewer's concern, as in the first version of this work we decided to discuss the results only in the last section of the manuscript (on Discussion and Conclusions section). On the other hand, our statement about the results related with time scales of 9 and 12 months aims to highlight that these results do not add additional information to the results obtained with the time scale of 6 months.

Nevertheless, we agree with the reviewer that the discussion of the results should indeed include more details about the shorter time scales (1 to 3 months). Therefore, we will add a short statement about this issue on Results and more detailed information on Discussion and Conclusions section.

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Drought classification	SPEI range	Return period
Moderate	-0.84<SPEI	1 in 5 years
Severe	-1.28<SPEI	1 in 10 years
Extreme	-1.65<SPEI	1 in 20 years

Table – Drought classes and corresponding range of SPEI values and return period, as proposed by Agnew (2000) and used in this work.

Fig. 1. Drought classes and corresponding range of SPEI values and return period, as proposed by Agnew (2000) and used in this work.