Review of Törnos and Menzel "Characterizing droughts under current and future climates in the Jordan River region" by A.F. Van Loon

In this paper the authors calculated the SPI of the Jordan River region for different time scales and correlated this to the NDVI-index. They concluded that the 6-month SPI best describes drought in the region and subsequently used this index to estimate the difference between current and future conditions. They found that drought duration and severity are projected to increase in the region. Model results showed that also the irrigation demand is projected to increase.

General comments

The research presented in this paper is in my opinion not very novel, but it might be important for the region and in that respect deserves a publication in HESS. My main comment to this paper is that the authors are quite blunt in their statements and interpretation of the results. The manuscript requires major rewriting before it can be published.

Primarily more explanation is needed on the link between meteorological drought and vegetation. For example the relation between SPI and NDVI is not further investigated by looking at time series.

The authors should do more analysis with the data they have, for example, using the modelling results and looking at the correlation between SPI and soil moisture anomalies (by using a soil moisture drought index, the threshold level method or the method described in Sheffield and Wood (2007)) and between soil moisture anomalies and NDVI.

In the climate change analyses the authors compare the future period with the control period, but they fail to do the comparison between the control period and the observations. In the Discussion section a study is mentioned that shows that the precipitation in the GCMs is underestimated, but this only concerns averages. There is no mention about extremes. I advise the authors to include the observations in the comparison in Figure 6.

The results of this research should be substantiated by more references.

Specific comments

Abstract:

p.5876, l.9: inter-annual variation of NDVI? the SPI was correlated with monthly NDVI

p.5876, l.10-11: assuming that NDVI is a good proxy for agricultural drought, which is not the case because other influences play a role as well and irrigation is already applied in the region (see p.5889).

Introduction:

p.5876, l.21-22: Reformulate the definition of drought to something like "Drought is an extended period with water deficits, often related to a lack of precipitation". And discuss the different drought types meteorological drought, soil moisture or agricultural drought and hydrological drought already here instead of mentioning them only on page 5877.

p.5877, l.4-5: Cite papers that give an overview of drought indices and discuss the pro's and con's of the various indices. Examples are: Mishra and Singh (2010) and Sheffield and Wood (2011).

p.5877, l.11-12: The SPI has been recommended by the WMO for characterizing meteorological drought. SPI is not recommended for agricultural drought. You need to be much more careful which drought type you are studying. You should be aware of the discussion about using a meteorological drought index like SPI as proxy for soil moisture and hydrological anomalies. Several studies pointed out that great caution is needed in using these meteorological drought indices for drought related to soil moisture and water resources (see for example Teuling et al. 2013).

p.5877, l.20-24: This is a too simple statement. It should be something like: "Some studies have shown that in some cases SPI can be used as proxy for soil moisture drought and hydrological drought, since in the end the hydrological cycle is mainly driven by precipitation and the catchment acts as a low-pass filter." In the Discussion section, you should come back to this issue and discuss that other factors than precipitation play a role in the development of soil moisture drought and hydrological drought as well.

p.5877, l.29 – p.5878, l.1: Correlation does not show "how" vegetation responds to drought, it shows that there is a certain relationship between the two variables, but it does not explain the causes of this relationship. Correlation therefore does not directly "support the performance of the drought index".

p.5878, l.10-13: Again you should refer to the discussion about using indices based on precipitation for agricultural drought. It might well be that in the southeastern Mediterranean region precipitation is the dominant factor and soil moisture droughts and hydrological droughts are only caused by a precipitation deficit, but it should be discussed why other factors can be neglected, e.g. snow accumulation, evapotranspiration, non-linear transformation of the drought signal in the subsurface.

p.5878, l.13: "a drought index based on precipitation alone is appropriate for the southeastern Mediterranean region" > appropriate for what? to characterize agricultural drought? to predict biomass of vegetation?

p.5879, l.6-13: The objectives of this study are not very clear and not well linked. What is the overall objective? How do the separate parts contribute to that objective? In which way do the focus points that are mentioned contribute to the objective?

Materials and methods:

p.5879, l.22-23: The assumption that land use has not changed and will not change in the future should be substantiated by literature and discussed in the Discussion section.

p.5879, l.26: The fact that this study focuses on agricultural drought should be mentioned in the Introduction section. And: even though this study focuses on agricultural drought it would be very useful to include natural vegetation in the analysis, especially shrubland, because that allows for a comparison between the response to drought of natural vegetation and crops. Since the arid region is mainly covered with shrubs this is relevant to interpret the results of the effects of climate change in this region (as given in Fig. 6).

p.5881, l.14: Unclear how the "most appropriate" SPI timescale is identified. This is not straightforward. Explanation is needed on why linear correlation is used.

p.5882, l.2: Why was the relation between SPI and NDVI only studied per land use class and not also per climate region as was done for the climate change analyses?

p.5883, l.11-12: Is this model calibrated? How are the parameters of the model estimated?

p.5884, l.10-12: From the range in Fig.2 it cannot simply be concluded that "vegetation develops more slowly and reaches a lower maximum" during drought years. The consistency in the temporal information is completely lost. For this conclusion time series of dry and wet years should be studied separately.

p.5884-5885: Can you exclude that the good correlation between SPI6 and NDVI is caused by seasonal variation in both precipitation and crop growth independent of drought occurrence?

p.5885, l.5-7: Be careful with the use of the significance. Significant results do not necessarily mean good results. Not-significant results do indicate bad results and the difference between significant and not-significant results can be used as a source of information.

p.5885, l.15-18: This is a very blunt statement. A negative correlation does not necessarily mean that the "shorter time scales are not capable of addressing agricultural drought" and a positive correlation does not necessarily indicate that "vegetation responds to precipitation accumulated over several months and that response is delayed". To prove this some more analyses are needed, like the correlation between precipitation anomalies (SPI) and soil moisture anomalies and between soil moisture anomalies and vegetation (NDVI). Additionally, some example time series should be shown.

p.5885, l.22: It is not about "performance", only the relationship has more variation.

p.5885, l.24: What could be the reason that the "6 month SPI best explains the interannual variability of NDVI"? This is a very long timescale, which can surely not only be due to the reaction time of soil moisture to precipitation. Please elaborate on this.

p.5886, l.9: Convective rainfall events are not well simulated by GCMs. If this is the reason there should also be a clear difference between seasons and months.

p.5886, l.23-24: Why not aggregated per land use type like in the previous analyses? It would increase the consistency if you would do both throughout the research.

p.5886, l.25-28: Also include SPI characteristics for the observations and compare with the modelled control period.

p.5887: Fig.6b does not give delimited drought events, but number of months with negative SPI.

p.5887, l.28: The pattern with "more vegetation" in Fig. 7a is not consistent with the NDVI map in Fig.2a.

p.5888: Include the correlation between SPI and NDVI and model results.

Discussion:

Include more references.

p.5889, l.25-27: Why can the model be considered plausible? You can get the right results for the wrong reason.

Conclusions:

p.5890, l.12: Why are the results also "relevant for arid and sub-humid regions in general" No comparison with literature is done.

p.5890, l.23-27: These are non-funded generalisations. I suggest to take these lines out.

p.5890, l.27: The arid-region was mainly covered by natural scrubland, which was not taken into account in the analysis.

Technical corrections

p.5877 l.2: "characteristics of soil moisture **and** drought" > "characteristics of soil moisture drought"

p.5877 l.14: "the calculation **realizes** the fit..." > choose another verb

p.5879, l.6: "a drought index, which ..." > "a drought index that ..."

p.5879, l.16: "preparedness for drought" > "drought preparedness plans"

p.5879, l.25: "**remains** dry" > choose another verb

p.5885, l.3: do not use the word "superior" in this context. Just say that the correlation between SPI6 and NDVI is more positive than the shorter timescales.

p.5885, l.20-21: "the value favors slightly the 6 month SPI" > rephrase

p.5886, l.28: "projections" > "models"

p.5887, l.24: "in general" > "in most of the area"

p.5889, l.24: "potential erroneous" > "potential errors"

Fig.1: indicate countries

References:

Mishra, A. K., and Singh, V. P.: A review of drought concepts, Journal of Hydrology, 391, 202–216, doi: 10.1016/j.jhydrol.2010.07.012, 2010.

Sheffield, J., and Wood, E. F.: Characteristics of global and regional drought, 1950-2000: Analysis of soil moisture data from off-line simulation of the terrestrial hydrologic cycle, Journal of Geophysical Research-Atmospheres, 112, 21, doi: 10.1029/2006JD008288, 2007.

Sheffield, J., and Wood, E.: Drought; Past Problems and Future Scenarios, Earthscan, London, UK, Washington DC, USA, 2011.

Teuling, A. J., Van Loon, A. F., Seneviratne, S. I., Lehner, I., Aubinet, M., Heinesch, B., Bernhofer, C., Grünwald, T., Prasse, H., and Spank, U.: Evapotranspiration amplifies European summer droughts, Geophysical Research Letters, DOI: 10.1002/grl.50495, 2013.