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Review on the doctorate thesis

titled

‚Enhancing the accuracy of process-based data-driven models for predicting drought'

by Mohammadreza Einikarimkandi

with the embedded articles

#1 'Detecting drought events over a region in Central Europe using a regional and two satellite-based precipitation datasets.'

#2 'Hydrological application and accuracy evaluation of PERSIANN satellite-based precipitation estimates over a humid continental climate catchment '

#3 'Comparison of process-based and statistical approaches for simulation and projections of rainfed crop yields'

#4 'Satellite-based soil moisture enhances the reliability of agro-hydrological modeling in large transboundary river basins'

#5 'Direct and indirect simulating and projecting hydrological drought using a supervised machine learning method'

The candidate has applied a comprehensive range of methods to simulate hydrological phenomena and characterize useful satellite data. The focus of the work is the reproduction and projection of drought. Important indicators are runoff and yields.

The methods used include various indices (SPI, RPI, JDI, WSI), distributed hydrological modeling with the SWAT 2+ rainfall-runoff model, and artificial neural networks (ANN). The author shows in various case studies that he can use the various methods in a targeted manner in cooperation with his co-authors. The introduction of the thesis summarizes the content of the case studies in publications #1 to #5, but does not discusses additional aspects. Therefore, the reviewer mainly accesses the thesis by reviewing the embedded publications #1 to #5.

The contribution of the individual publications to the scientific content of the work presented varies.

Publication #1 refers to the whole of Poland and uses the SPI to evaluate the quality of two remote sensing datasets in comparison to ground data. The focus here is on the assessment of drought on different time scales using the SPI. For the calculation of the SPI, references are given. The reviewer misses an original description of the SPI calculation by the author, information on the ranges for the parameter of the gamma distribution, on the goodness of fit and a discussion on these numbers. The core statement of publication #1 that the result of the SPI calculation depends on the data basis is

hardly surprising. However, the concrete empirical result for the satellite data sets used provides a reference point for possible subsequent applications. The methodology used can also serve as an orientation for evaluating the suitability of other satellite data sets for precipitation. Here, publication #1 has its value.

In contrast to publication #1, publications #2 and #3 refer to a much smaller area: the Welna, a sub-basin of the Oder. Publication #2 tries to build on publication #1. This time 5 different satellite data sets from the Persiann family of remote sensing based precipitation data sets are compared with ground data. In addition to Taylor diagrams, rainfall-runoff simulations are presented. Comparative information on the parameters and the goodness of fit of the gamma distributions are missing again. The motivation for SWAT 2+ model adjustments using Persian precipitation data sets, which correlate only slightly with the ground measurements, is not clear to the reviewer. The model calibration can be classified as an intermediate technical step for later model applications. In terms of content, it leads to predictably irrelevant results.

Publication #3 is consequently limited to the precipitation ground data for the area. Publication #3 focuses on the simulation and projection of agricultural yields. Results from SWAT2+ simulations are compared with the results of an ANN approach. The parameter settings for the hydrological modules are taken from publication #2. In addition, there are specifications in the parameter setting that result from a more detailed consideration of the agricultural modules. The specific changes compared to publication #2 are only described approximately. The consequences of those changes for the runoff are not considered. The parallel estimation of an ANN yield model provides potentially interesting possibilities for comparison with the SWAT 2+ estimates. However, the methodology used should not only be presented in rudimentary form and the reader should receive more support than references to other publications. The number of variables and weights, i.e. parameter values, used by the ANN should be mentioned and set in relation to the independent observations. Both models, SWAT 2+ and the ANN crop model should be trained and validated in identical time periods (2004-2011). An R2 of 0.98 for the ANN in the validation period does not suggest a rigorous validation. The described responses of the models to climate change are not very meaningful and do not provide any additional information. There is a lack of information on the variability of the mean changes. Standardization of the mean changes to the temperature change would have been helpful for classification and comparability. Overall, the parallel consideration of simulations and projections in Publication #3 with two model approaches and an additional modification of the routine for potential evapotranspiration (SWAT 2+) and the SPI (ANN) lead to a breadth of consideration that is detrimental to the depth and coherence of the analysis.

Publications #4 and #5 are much more sophisticated than publications #2 and #3. Both publications refer to the Odra river basin. In publication #4 the effect of a multi-objective calibration on the quality of the runoff simulation is convincingly presented. There does not seem to be an analogous effect on the simulation quality of the crop yields. Here, the improvement is limited to the general reduction of the mean error. For maize, however, the goodness of fit of the model improves. Unfortunately, the discussion of the results remains superficial again. More in-depth studies on this issue would be desirable. The use of the SWI index as an interface between simulation results and satellite data is innovative. A more explicit description of the procedure, illustrated with examples, would be appropriate.

Publication #5 is the author's best work. It is innovative, clearly structured and not overloaded in its orientation. The performance indicators are explicitly described. However, the presentation of the ANN shows the shortcomings already mentioned in publication #3. Validation and testing of run off simulations were carried out analogously to publication #3. Again, the validation measures outperform those for calibration, which should have been discussed and motivate a more rigorous

approach. The differences between the direct and indirect ANN modeling of the SRI are remarkable. They suggest that the integration of structural elements into ANN modeling improves model quality.

The results of the projection contrast with the results of the SWAT 2+ modeling and deserve further in-depth analysis. In particular, the question arises as to whether the demonstrated goodness of fit of the ANN procedures can be translated into an analogous projection quality.

Overall, the author's work in the publications #1 to #5 pursue a variety of analytical directions. The author brings together a broad spectrum of modeling techniques in the sense of the respective task. However, the large number of analytical directions goes at the expense of a transparent and comprehensive presentation of the methodology pursued and the depth of analysis. The reader is still expected to carry out a great deal of reference follow up in order to access the presented results.

Nevertheless and beside the deficits mentioned, I certify that the doctoral dissertation of Mohammadreza Einikarimkandi meets all the requirements for doctoral theses as specified in the Act of 20 July 2018 – Law on higher education and science (consolidated text of 10 March 2023, Polish Journal of Laws 2023, item 742, as amended). I recommend that the doctoral committee proceed with awarding the scientific degree of doctor to Mohammadreza Einikarimkandi .

To support reproduction of the results and future work, the thesis should definitely be supplemented by an online repository. This should contain the data used for each article and the necessary scripts that are required.

Frank Wechsung 2.7.2024