Water restrictions under climate change: a Rhone-Mediterranean perspective combining 'bottom up' and 'top-down' approaches"

Sauquet et al.

Anonymous Referee #2

Sauquet and colleagues applied a scenario neutral approach to evaluate the implementation of water use restrictions and their impacts on irrigated agriculture. They applied this approach to 15 catchments in the Rhone-Mediterranean region with minimal human influence. Their methods included calibration of a hydrological model to each catchment, sensitivity analyses, assessment of exposure and clustering to identify basins with common characteristics. Strengths of this work include comparison of results regionally and identification of catchment classes, as well as high quality graphics presenting the results. Areas to for improvement include problem framing, the implementation and communication of the sustainability assessment, and explanation of the clustering process and its value. With a clearer problem framing and improved sustainability assessment I believe the scientific and practical contributions of this work would be clearer.

➔ Authors agree with this remark and the method (including the definition of sustainability) needs to be more explained.

The topic is of interest to HESS readers, and subject to major revision I believe that it would be suitable for publication.

Comments

1. The authors make a strong case for why we care about drought risk under climate change. However, the case for why we need to simulate the implementation of water use restrictions should be stronger. The main question I would like to see the authors address here is: how does the simulation of water use restrictions give us a different picture of impacts or ways to mitigate impacts than simulating streamflow alone?

➔ Water restrictions simulations complement studies on the impact of climate change on water resources availability and on water use needs. Indeed water needs can only be met first if water resources are available and second if water abstractions are allowed. Regulatory rules are pieces of the puzzle that should be examined. Roughly speaking studying water restrictions is a way to identify additional future constraints on water users. The regulatory aspects have never been deeply examined in France, perhaps due to the recent implementation of DMPs.

2. The authors thoroughly review the literature in the scenario neutral and decision scaling methods for assessing climate vulnerability in a bottom-up manner. However, the literature on robust decision making is complementary and should be included in this review. Specifically, there are a few robust decision making studies that assess the performance of existing

water management plans [e.g. Lempert and Groves, 2010; Bloom et al., 2013]. The authors should note how their work builds upon or goes beyond these prior works.

➔ Many thanks. The state of the art will be completed with literature on robust decision making.

3. The sustainability assessment is the key link between the occurrence of water use restrictions and impacts. The authors use critical thresholds as a way to measure sustainability. First, I'm not convinced that is a measure of sustainability. Is it serving as a measure of the sustainability of an agricultural economy? Or something else? Please clarify how it meets a reasonable definition of sustainability.

➔ Sustainability - like vulnerability - has no universal definition. Sustainability assessment is based on the analysis of failures or unacceptable conditions that lead to low crop yield and quality, and consequently to economic losses at such a level that the national system of compensation is initiated. In this application,

- we assumed that irrigated farming is not sustainable if restrictions during drought periods are , on average, too severe - i.e. duration with limited or suspended abstraction for irrigation above a critical threshold - to ensure enough water for crops;
- since it was not possible to compute the effect of water restrictions on crop yield and quality (no crop modelling was considered here) and on economic losses, we used 'agricultural disaster' notifications as proxies to identify the conditions that would be unacceptable/damaging for farmers activities.

This sustainability is thus indirectly related to agricultural economy (not directly related to losses expressed in euros). We change sustainability for failure analysis in the next version.

Second, it is not clear how this critical threshold was defined. The authors state that a single critical threshold is applied to all catchments. Is this reasonable given the substantial differences in elevation (and therefore temperatures)? And is the local precipitation factored into this threshold?

➔ Data are collected by the French ministry of agriculture and they are confidential. The year 2011 was the only year when the national system of compensation has been activated with available data between 1958 and 2013 and the duration of water restrictions were derived individually for each catchment and converted in anomalies $\Delta WR^*(2011)$ with respect to the benchmark value (mean over the period 1958-2013). This dispersion is due to heterogeneity in crops, in irrigation systems, in climate (precipitation, PET, temperature)… at the regional scale leading to locally differentiated sensitivity to water restrictions as well as to biases in WR modelling. Since only the year 2011 it is difficult to conclude on the origin of the dispersion (natural or non-natural). We are convinced that this information is valuable. Finally, simplifying but realistic assumptions are imposed by the lack of detail information; thus only one value was considered despite high dispersion in $\Delta WR^*(2011)$ values (Table 6): the critical threshold was set to the average $\Delta WR^*(2011)$ computed on all catchments of the region under agricultural disaster status in 2011 (6.6 10-day periods), and was used for all classes. Note that this value seems realistic: 6.6 10-day periods = 66 days with restrictions = 30% of the time between between the 1st April and the 31st October.

Lastly, do irrigators or other water users in these catchments have access to other water sources to mitigate impacts (e.g. farm ponds, groundwater)? If so, how does that influence the conclusions?

➔ More detail will be given on this aspect in section 2.1. In France 80% and 20% of water abstraction are taken from surface water and from groundwater, respectively. In the RM district 10% of water used for irrigation originate from groundwater. Irrigators may have access to small reservoirs (storage capacity usually < 1 Mm^3). There is actually a wide discussion about these hydraulic structures in France since their impacts on the ecosystem and their efficiency are not well known (Habets *et al.*: The cumulative impacts of small reservoirs on hydrology: A review. Science of The Total Environment, 643, 850-867, https://doi.org/10.1016/j.scitotenv.2018.06.188, 2018). Most of the small reservoirs are filled by surface water in winter and release water later in summer for irrigation purposes. Water restrictions are not imposed to these reservoirs but we assume here that during severe droughts most of them are empty and thus the influence of auxiliary water sources on the conclusions is limited.

4. On lines 274 to 275 the authors state that GR6J and HYDRO correctly reproduce water use restrictions but are inconsistent with observation. Do the authors mean that the GR6 and HYDRO produce consistent results, but they are incorrect (i.e. don't match observations)?

➔ There is obviously a problem with the phrasing on these lines. "Both GR6J and HYDRO simulations are globally consistent with observed WRLs (OBS). However GR6J and HYDRO results may differ from OBS (e.g. basins 9 to 11 in the Lozère department during the year 2005)."

5. On line 287 the authors state that the simulated streamflow (from GR6J) produces more accurate water use restriction simulations than the observed streamflow. This strikes me as a case where the model may be right for the wrong reasons – which casts doubt on the later results. How is this counter-intuitive result explained and what are the implications for the interpretation of the results?

➔ The discharges simulated by GR6J introduced in the WRL model lead to higher *Sensitivity* scores than those obtained with observed discharges extracted in the HYDRO database. The reasons for this unexpected result have been investigated. In particular we have compared the observed and simulated temporal variability in the time series VCN3. A "smoothing" effect in the GR6J simulations compared to observations was initially suspected. Finally no obvious difference in autocorrelation functions was found between observed and simulated time series. One reason could that the period of interest 2005-2013 – with for some basins only three years with stated water restrictions – may be too short to analyse accurately the relative performance of WRL obtained with OBS and with HYDRO, respectively.

The two scores gives a global insight on the performance of the WRL modelling framework and too much weight should not been given to the differences between scores. In this case, we should conclude that the developed WRL modelling framework leads to similar results (moderate performance in detecting stated water restrictions during the period 2005-2013) with both data sources HYDRO and GR6J. The WRL modelling framework provides an overview of the on-going drought and the drought committees are partly free to account for this information to state or to postpone water restrictions. The developed framework is a useful tool to predict water restrictions with no interference of lobbies, i.e. only based on the physical processes.

6. The authors state that the CART analysis can aid sensitivity assessment at unmodelled catchments. Please address in the conclusions if and how this classification can be helpful for water managers or other scientists.

➔ The CART algorithm creates the best homogeneous group when splitting the data using through a set of “if-then” logical conditions applied to the most relevant factors, i.e. the decision variables. The result is a decision tree with nodes separating the data into two subgroups. The decision variables known at unmodelled but gauged catchments can be introduced in the chain of rules obtained by CART to finally predict – in this application – the assignment to one of the four classes.

7. Lastly, there are some typographic errors and awkward phrasing in the manuscript and it would benefit from a thorough review. See a few examples below:

a. Line 69 use of word “predisposition” ➔ “The paper develops […] to assess the likelihood of future restrictions depending on their sensitivity, sustainability and exposure to climate deviations”

b. Line 402 “tree” should read “three” ➔ “Finally the vulnerability resulting from the combination of the three components sensitivity, sustainability and exposure”

c. Line 482 “come” should read “some” ➔ “Surprisingly negative values for ΔWR*(2011) are found for ~~come~~ some catchments of Classes 1 and 4”

d. Line 540 use of word “incited” ➔ “Water managers are thus ~~incited~~ encouraged”

References

Bloom, E., A. Draper, D. Groves, B. Joyce, M. Rayej, and D. Yates (2013), Evaluating Resource Management Strategies for Update 2013 of the California Water Plan, in World Environmental & Water Resources Congress, pp. 2391–2403.

Lempert, R. J., and D. G. Groves (2010), Identifying and evaluating robust adaptive policy responses to climate change for water management agencies in the American west, Technol. Forecast. Soc. Change, 77(6), 960–974, doi:10.1016/j.techfore.2010.04.007.

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