Optimizing Reservoir Water Management in a Changing Climate

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1 Data collection and processing

The following sets of data have been collected to perform this study: meteorological data, climate models data, historical reservoir water levels, water use in both watersheds, observed runoff data, land use, reference values for crops water demands.

Historical data for daily precipitation is obtained from the Iberia01 dataset (IB01) (Herrera et al., 2019) which is an observational gridded dataset for daily precipitation and temperature based on a network of stations in the Iberian Peninsula for the period 1971–2015 at 0.1° resolution. Daily values of precipitation are, adjusted by using the linear-scaling approach (Lenderink et al., 2007), which is based on the differences between observed and the IB01 simulated values on a monthly bias correction.

Climate model results are obtained from the regional high-resolution EURO-CORDEX program (Jacob et al., 2014) using a 0.1° resolution grid and considering two representative concentration pathways emission scenarios (RCP4.5 and RCP 8.5), for the period 2021 to 2100, and a control simulation corresponding to the 1971-2000 climate. The ensemble consists of a set of global models, used to force different regional models with approximately the same topographic forcing. From a group of three global models (CM5, CM5A, EC-Earth) and five regional climate models (CCLM4, HIRHAM5, WRF33, RACMO22E, RCA4), an ensemble of eight global and regional models are used (CM5_CCLM4, CM5_RCA4, CM5A_RCA4, CM5A_WRF33, ECEARTH_CCLM4, ECEARTH_HIRHAM5, ECEARTH_RACMO22E, ECEARTH_RCA4). These where selected based on their higher capability to represent actual biophysical conditions of the study area for the reference period (1971- 2000) (Soares et al., 2015). Bias correction of precipitation is performed using a quantile mapping algorithm following Piani et al. (2010).

2 Methods

2.1 Rule curves

The definition of the rule curves for the two reservoirs is based on the analysis of historical water uses, future expected consumption, and the future inflows estimated by hydrological modelling using the results from climate models. Historical analysis of water uses for human consumption shows a relatively stable monthly pattern, associated with a stable population in the region, as well as the efficiency of the water treatment and distribution systems. Thus, the same pattern is assumed for the future urban supply. Future agriculture water demands are estimated using the FAO water production function, following the methods described in (Steduto et al., 2012). As for irrigation water needs, in the Monte Novo (MN) basin all irrigated area is considered dedicated to olive groves, and for the Vigia (VG) basin a weighted average of water needs for olive groves and vineyards is considered, since these crops represent most of the irrigated area.

The rule curves are designed to ensure water availability for human consumption - priority use - seeking to optimize the supply for irrigation, as well as observing the importance of anticipating the quantification of water availability for the entire duration of each irrigation campaign.

The following assumptions are taken for storage in the reservoirs at the beginning of each month:

A. For irrigation, the storage volume ensures the supply to the entire irrigation campaign, which starts in the beginning of March and ends at the end of September.
B. One year of average evaporation is included as losses and is therefore accounted within the storage reserves.
C. For urban supply the storage volume ensures water reserves of one year for the MN reservoir and two years for VG.
D. For Ecological Flows twelve months for the VG reservoir and six months for MN

The rule curves for MN and VG reservoirs are represented in Figure SM1 in percentage relative to the storage volume at the normal pool level (NPL).

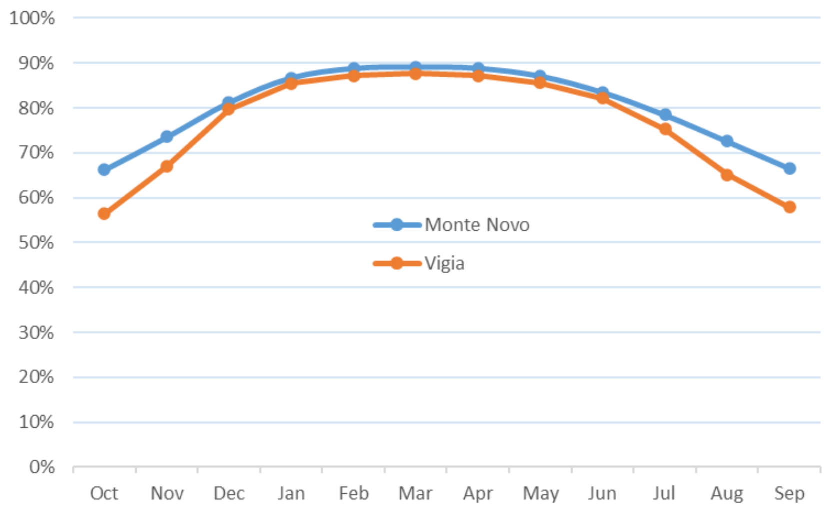

Figure SM1 – Rule curves for the MN and VG reservoirs

2.2 Hydrological modelling

The HEC-HMS Modelling System (Bartles et al., 2022) is used, applying the soil-moisture accounting model (SMA), which is appropriate for continuous, long-term simulations, simulates both wet and dry weather behaviour, and is sensitive to different crops and soil types.

Data from the nearest downstream hydrometric station is used to perform an initial calibration to assess overall model performance and to set the initial parameter input ranges. Additional refinement calibration for the MN and VG watersheds is performed by estimating the runoff from the reservoirs' water balance for the period 1994-2004 (hydrologic years). Simulations are performed on a daily time scale.

Future inflow to the two reservoirs is estimated by hydrological modelling, using the mentioned bias corrected climate models' results for the period 2021-2100.

2.3 Calibration and validation of the hydrological model

The performance of the HEC-HMS model after calibration is assessed by quantitative statistics in addition to the graphical techniques. We have used three quantitative statistics: Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), and ratio of the root mean square error to the standard deviation of measured data (RSR). The calibration for both watersheds is done in the period between 1994-2004. Validation for the hydrological modelling is done by estimating the reservoirs water balance using the inflows obtained in modelling and comparing with the observed values for the water level in each reservoir in the period 2004-2015.

The summary of the calibration and validation results is displayed in Table SM1. Using the performance ratings defined by (Moriasi et al., 2007) for streamflow evaluation, we can say that the results for the MN and VG watersheds are very good in all three parameters.

Table SM1 – Calibration and validation results for the two watersheds

	CALIBRATION		VALIDATION	
	MN	VG	MN	VG
NSE	0.844	0.917	0.924	0.821
PBIAS	0.03%	4.10%	0.00%	0.07%
RSR	0.395	0.287	0.276	0.423

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