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NOVEL RIVER ECO-HYDROLOGICAL SYSTEMS PROJECTED FOR EUROPE

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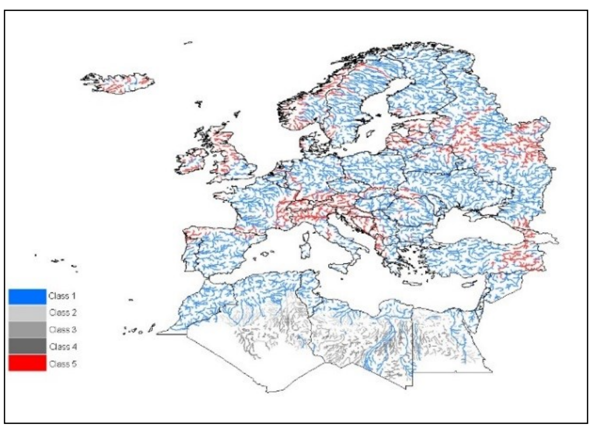
Topic of this work Future flows in rivers throughout Europe were computed for different combinations of climate models and socio-economic scenarios for a baseline (1961-1990) and for the future (2050s). Sets of indicators describing all ecologically-relevant facets of river flow regime were derived. Eco-hydrological regime types were defined using classification techniques applied to these indicators. Projected future flow alterations (2050s) for major European rivers were mapped in terms of eco-hydrological types and compared with maps for the baseline situation. It was found that for many river reaches their regime would remain broadly similar (in the same class), for other reaches the regime would alter to be more similar to another class. For some reaches the eco-hydrological regime would change to a novel form not currently seen in Europe, with the potential to create new river ecosystems.

Research question (or operational application) It is widely acknowledged that changing hydro-climatological conditions associated with changing socio-economics will impact the global hydrological cycle with implications for human use of water resources and for aquatic ecosystems and the services they provide to mankind. Studies like the Millennium Ecosystem Assessment show that many water-dependent ecosystems are being degraded or lost. River restoration requires reference conditions to set-up appropriate outcome targets, which traditionally relate to past ecological state. However, under changing water availability, whether due to water use or climate, reverting to such reference conditions may be too restrictive as it does not take into account the natural variability of the system, nor its evolution. The study aims to identify baseline river ecosystem types and to assess how they may evolve in the context of changing climate and socio-economic conditions across Europe. In turn, this could contribute to identifying appropriate target conditions.

Originality of this work There are few studies addressing future ecologically relevant flow regimes and most focus on a limited number of sites and/or a limited geographical extent, and are often descriptive rather than quantitative. This study is one of the few: (i) to provide pan-European geographical coverage, (ii) to use a detailed (given the geographical extent) river network based on 33,368 cells with a 5' x 5' resolution, (iii) to consider explicitly a set of ecologically-relevant hydrological indicators (i.e. all facets of the flow regime), and (iv) to consider not just climate-induced change, but combined climate and socio-economic pressures.

Data and / or method Eleven sets of modelled monthly flow series were generated using different combinations of climate data inputs and socio-economic scenarios by running the continental-scale water model WaterGAP 3.1 (Water – Global Assessment and Prognosis; University of Kassel; 5' x 5' grid). Climate inputs included observed historical climate data (1961-1990) and projected future climate data for 2040-2069 ('2050s') from two GCMs, IPSL-CM4 ('IPCM4') and MIROC3.2 ('MIMR'). Model runs were as follows: Baseline, historical naturalised flows (i.e. no water usage) for 1961-1990; five model runs for each GCM representing future flows under various water usage conditions (naturalised flows ('Natural') and four socio-economic scenarios representing extreme possible future for the pan-European area). A subset of the WaterGAP cells was selected corresponding to all major European rivers and their tributaries thus totalling 33,368 cells. Monthly flow statistics, thereafter referred to as Monthly Flow Regime Indicators (MFRIs), were derived for all 11 modelled flow series. They include 14 metrics capturing all aspects of the flow regime: timing, magnitude, frequency of extremes, etc. For each model run independently, all cells (i.e. 33,368) were grouped based on similarity of MFRIs using cluster analysis (CA). CA was done in two stages: hierarchical clustering followed by non-hierarchical clustering (k-means). Each identified class represents a hydrological type, the specific set of ecologically significant flow metrics of which is assumed to represent an ecological type, therefore referring to the class as an eco-hydrological type.

Main results Five classes were identified for the Baseline, seven for both IPCM4 and MIMR 2050s runs. Each cell was colour-coded according to its river type derived from CA, then mapped (Figure 1 shows the river types for the Baseline and for IPCM4 2050s). The number of cells changing river types from Baseline to 2050s runs are as follows: (i) a majority of cells do not change river type (c. 55% for IPCM4 and c. 60% for MIMR); (ii) some cells shift to an existing Baseline river type (c. 15% for both IPCM4 and MIMR); (iii) some cells shift to a new river type (c. 30% for IPCM4 and c. 20% for MIMR). The broad patterns in term of class shifts are: most of northern Europe and northern Africa is unchanged; there is a roughly southwest-northeast-southeast belt (including Spain, France, south of the UK, etc.) where rivers change to a novel eco-hydrological type; the remainder changes to an existing river type (for example, class 5 expands in Norway).



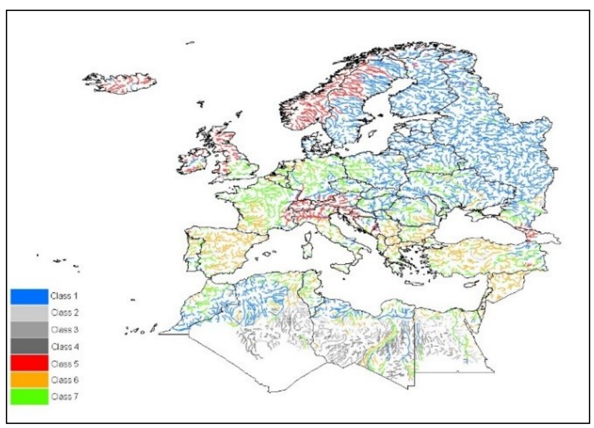


Figure 1 Left, Baseline k-means 5 classes; Right, IPCM4 Natural 2050s k-means 7 classes

Discussion The implications of changing from one eco-hydrological type to another may differ depending on species or ecosystem services being considered, or on which aspect of the flow regime is changing (e.g. lower flow variability benefits macrophytes but higher magnitudes may be detrimental). For rivers changing toward an existing type, their ecology may change to reflect that type, although there are other controls beside hydrology that need to be considered (e.g. water temperature, water quality). Further research is on-going to relate the current and future eco-hydrological typology to observed biological data (e.g. broad-scale fish species richness). The findings provide guidance for setting appropriate flow targets for restoration and conservation under the Water Framework Directive.