Disentangling Drivers of Changing Hydrological Extremes in Europe (1951-2020)

Pan-European impact attribution activities

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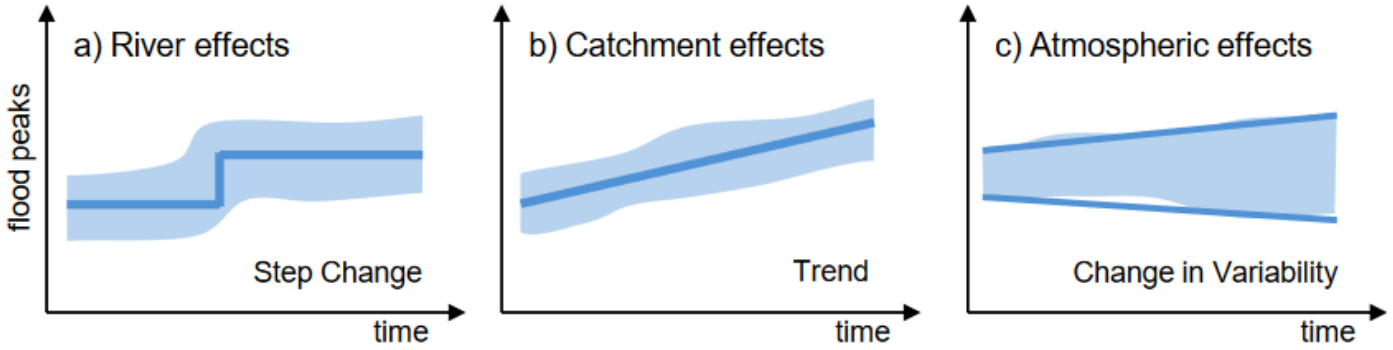
Non-stationary hydrological extremes

Concerns that a warmer world would be a world with more intense hydrological cycle, leading to more frequent and severe floods and droughts.

Different factors can drive this non-stationarity:

- Climate (climate variability, climate change)
- Socio-economic (land use changes, water management changes)

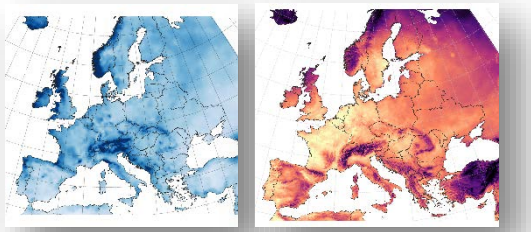


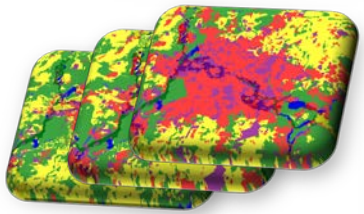
Hall, J. *et al.*: Understanding flood regime changes in Europe: a state-of-the-art assessment, Hydrol. Earth Syst. Sci., 18, 2735–2772, https://doi.org/10.5194/hess-18-2735-2014, 2014

Typical types of changes in flood peaks over decades or centuries as caused by (a) construction/removal of hydraulic structures, (b) land use change, (c) changing climate. Shaded areas represent intra-decadal variability. From Hall. et al. (2014).

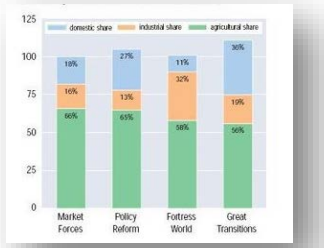
Modelling framework

Meteorological forcing

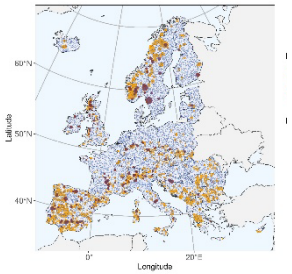




Land use

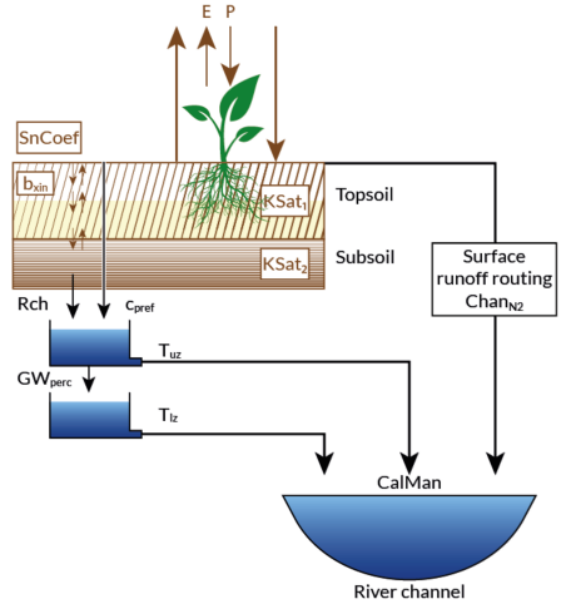


Water demand

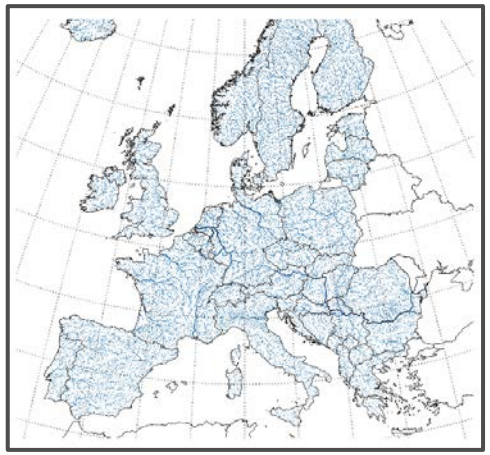


Reservoirs

LISFLOOD: Physically-based spatially distributed hydrological model



- Evapotranspiration (LISVAP)
- Soil component, groundwater storage
- Kinematic wave routing in channels and floodplains
- Lakes and dams
- Water abstraction for anthropogenic use



Pan-European simulated river flows

RtsEVA

Non-stationary Extreme value analysis

Data description paper | CC BY

HERA: a high-resolution pan-European hydrological reanalysis (1951–2020)

Aloïs Tilloy, Dominik Paprotny, Stefania Grimaldi, Goncalo Gomes, Alessandra Bianchi, Stefan Lange, Hylke Beck, Cinzia Mazzetti, and Luc Feyen

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Non-stationary Extreme value Analysis

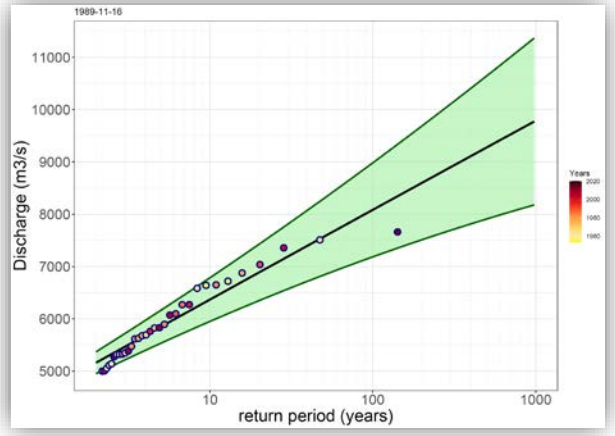
Transformed-stationary approach (Mentaschi et al., 2016):

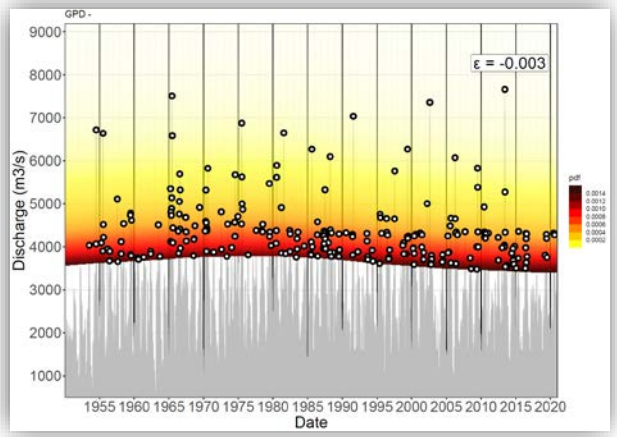
- Transforms a non-stationary time series into a stationary one, to which the stationary EV theory can be applied
- Reverse transforms the result into a non-stationary extreme value distribution

Implemented in a R package RtsEVA

- **Generalized Pareto Distribution**
- **One parameter set per time step** (shape parameter constant)

Danube @ Vienna

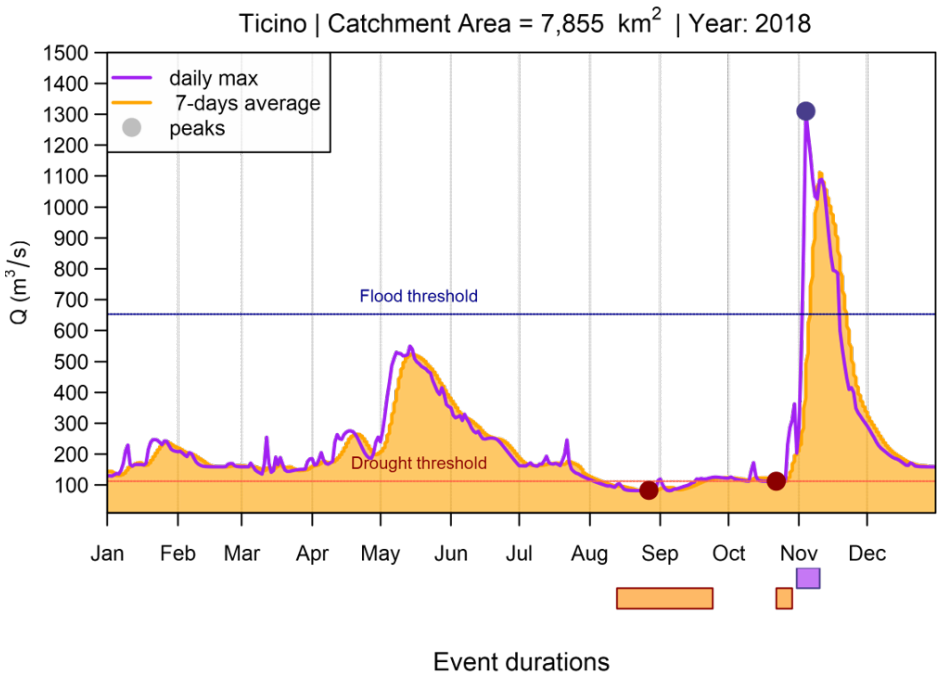




Mentaschi, L., Vousdoukas, M., Voukouvalas, E., Sartini, L., Feyen, L., Besio, G., and Alfieri, L.: The transformed-stationary approach: a generic and simplified methodology for non-stationary extreme value analysis, Hydrol. Earth Syst. Sci., 20, 3527–3547, https://doi.org/10.5194/hess-20-3527-2016, 2016.

Hydrological variables and hazard metrics

	Floods	Droughts
Variable	$Q_{max,daily}$ ($m^3.s^{-1}$)	$Q_{mean,7days}$ ($m^3.s^{-1}$)
Average number of events per year	3 events	2 events
Minimum lag time between two peaks	7 days	30 days
Season	All year	Non-frost
Transformation	none	reverse



Hazard intensity metric:
10-year Return Level

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Change attribution

Run ID	Run name	Reservoirs	Land use	Water demand	Climate
1	Historical	Dynamic	Dynamic	Dynamic	Historical
2	Static Water Demand	Dynamic	Dynamic	Static	Historical
3	Static Reservoir and Water use	Static	Dynamic	Static	Historical
4	Static Socioeconomic conditions	Static	Static	Static	Historical

Climate: TS-EVA Run 4

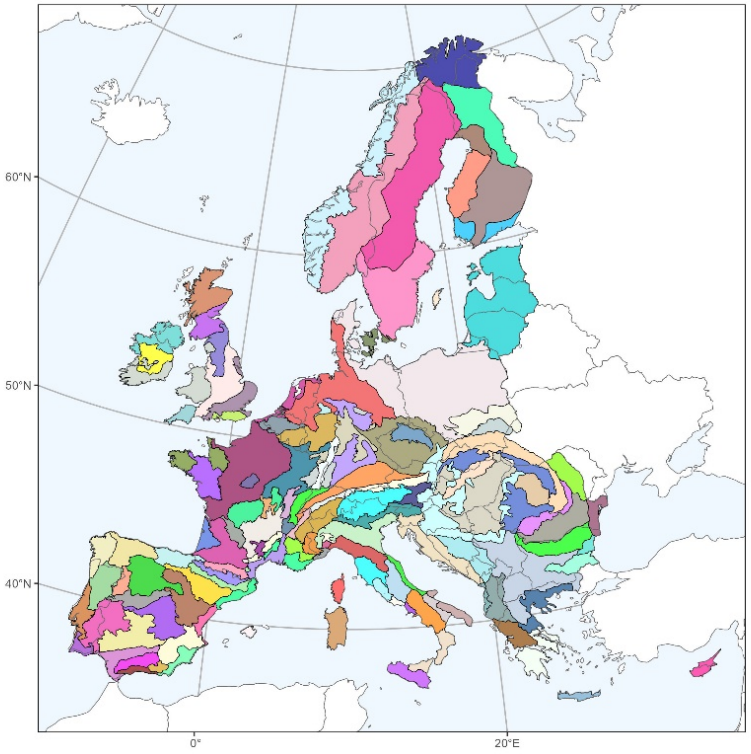
Land use: Run 3 – Run 4

Reservoirs: Run 2 – Run 3

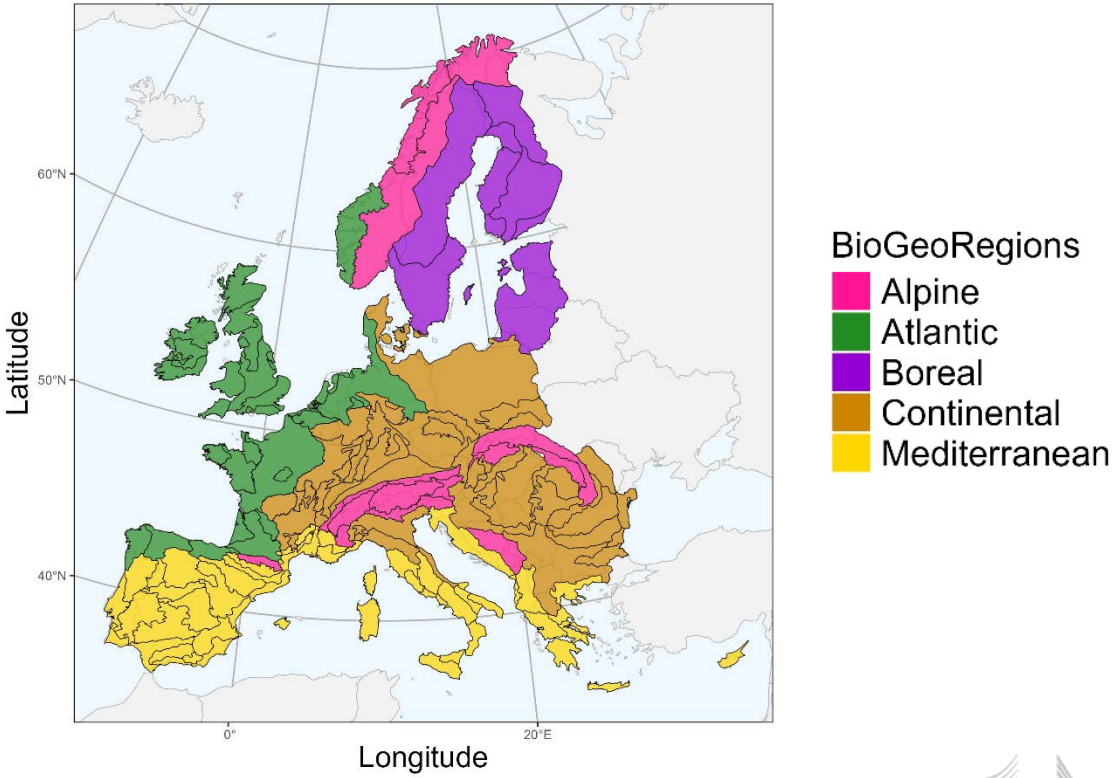
Water demand: Run 1 – Run 2

Spatial aggregation

132 European Hydro-EcoRegions (Wasson, 2007)



5 Modified European Biogeographic regions (EEA, 2016)



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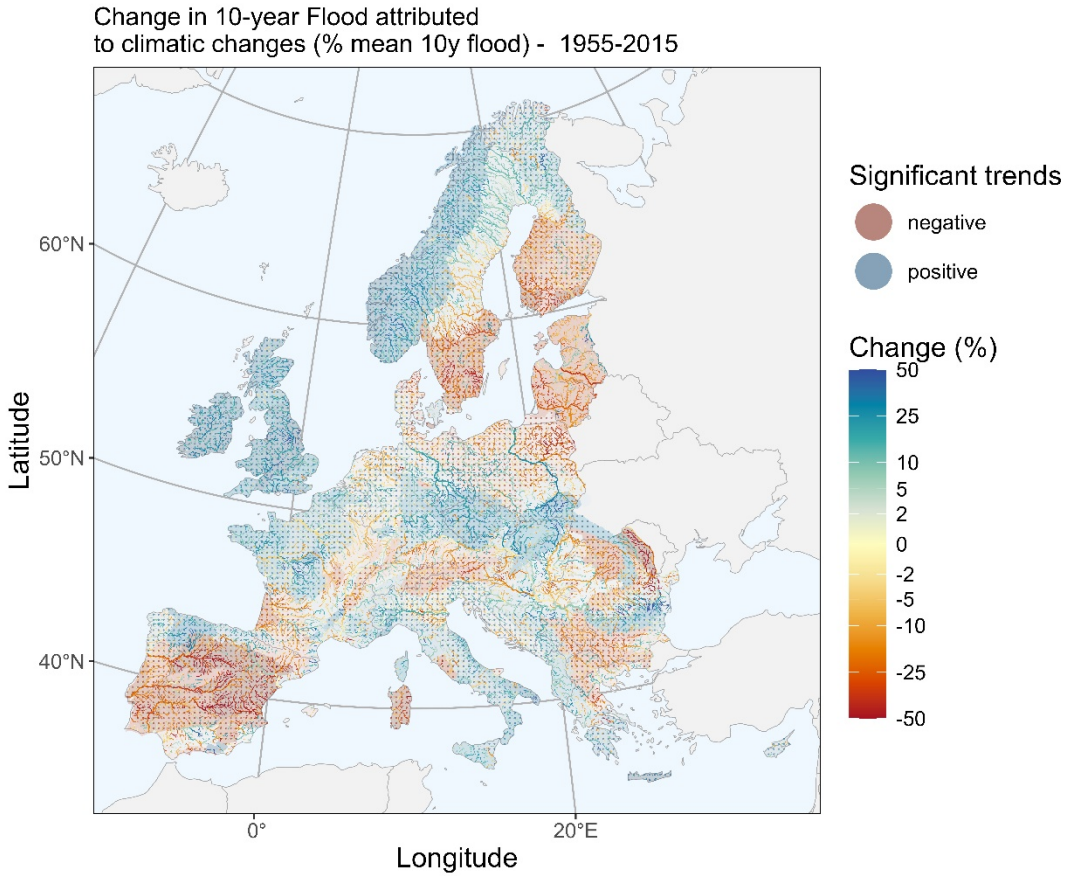
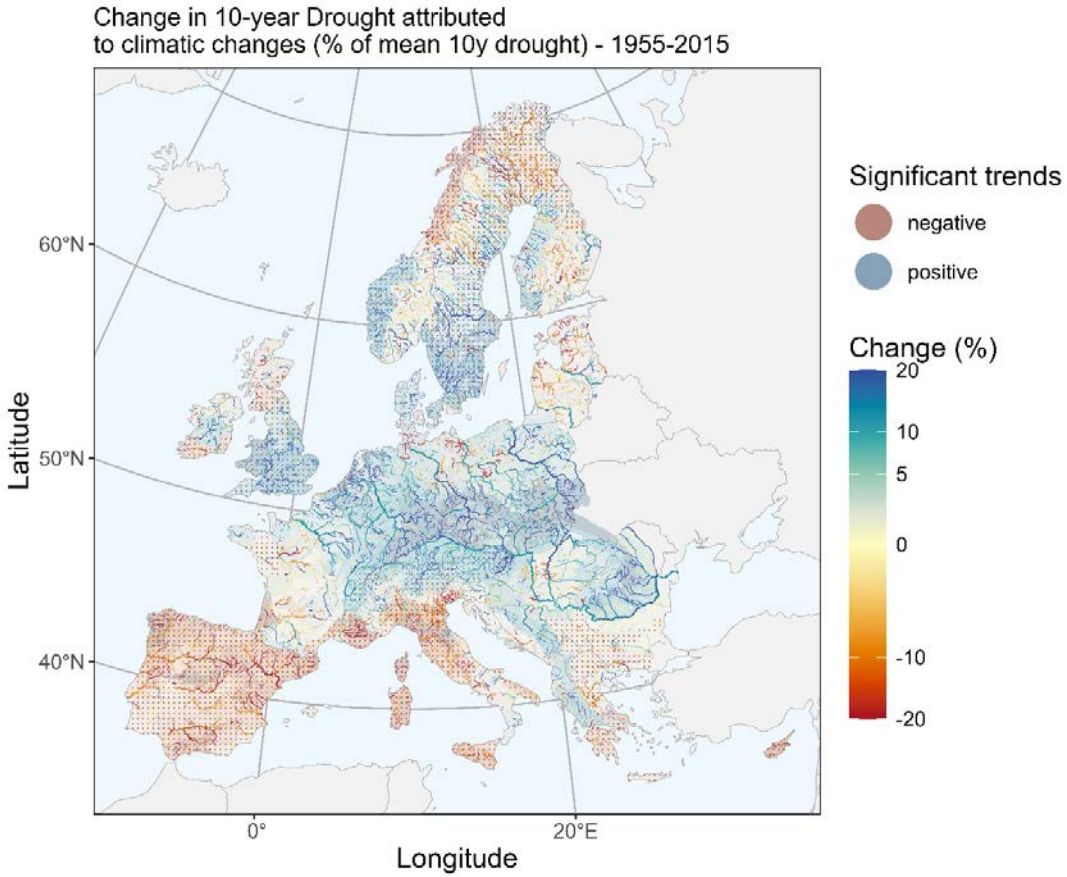
Changes driven by climate

Floods

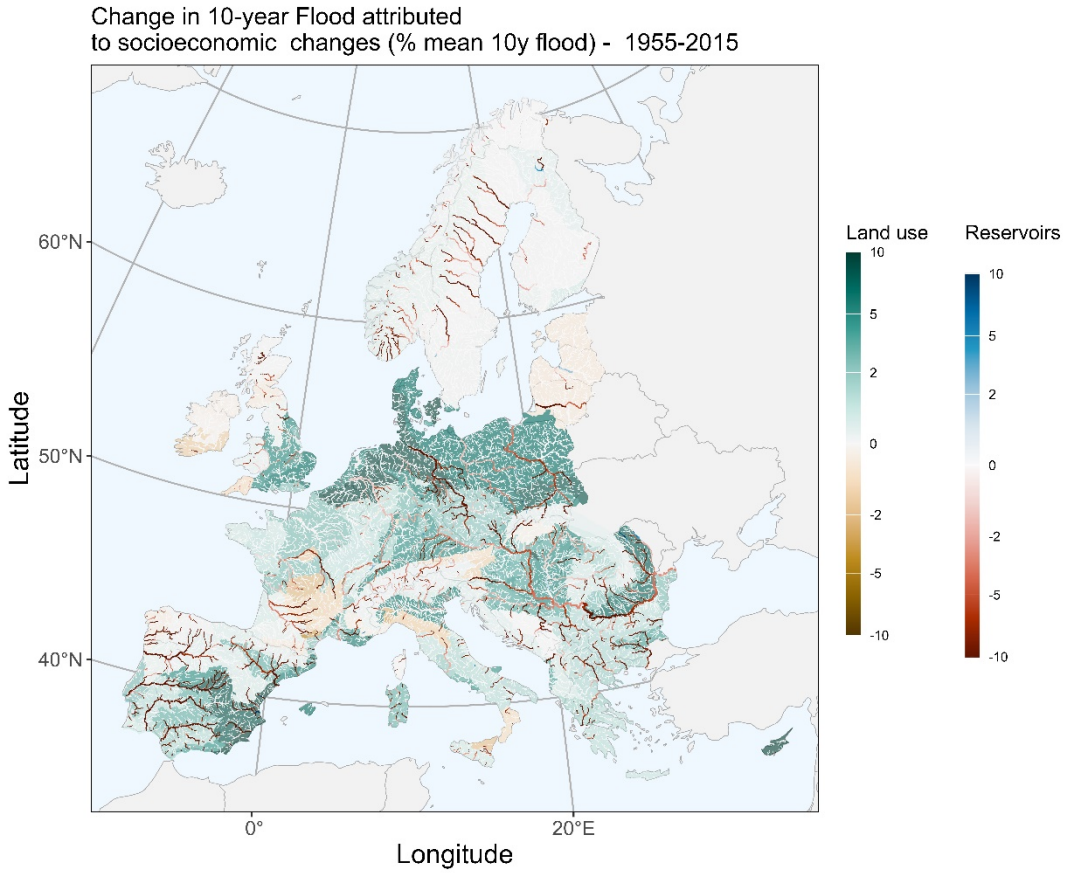


Drought (no frost)

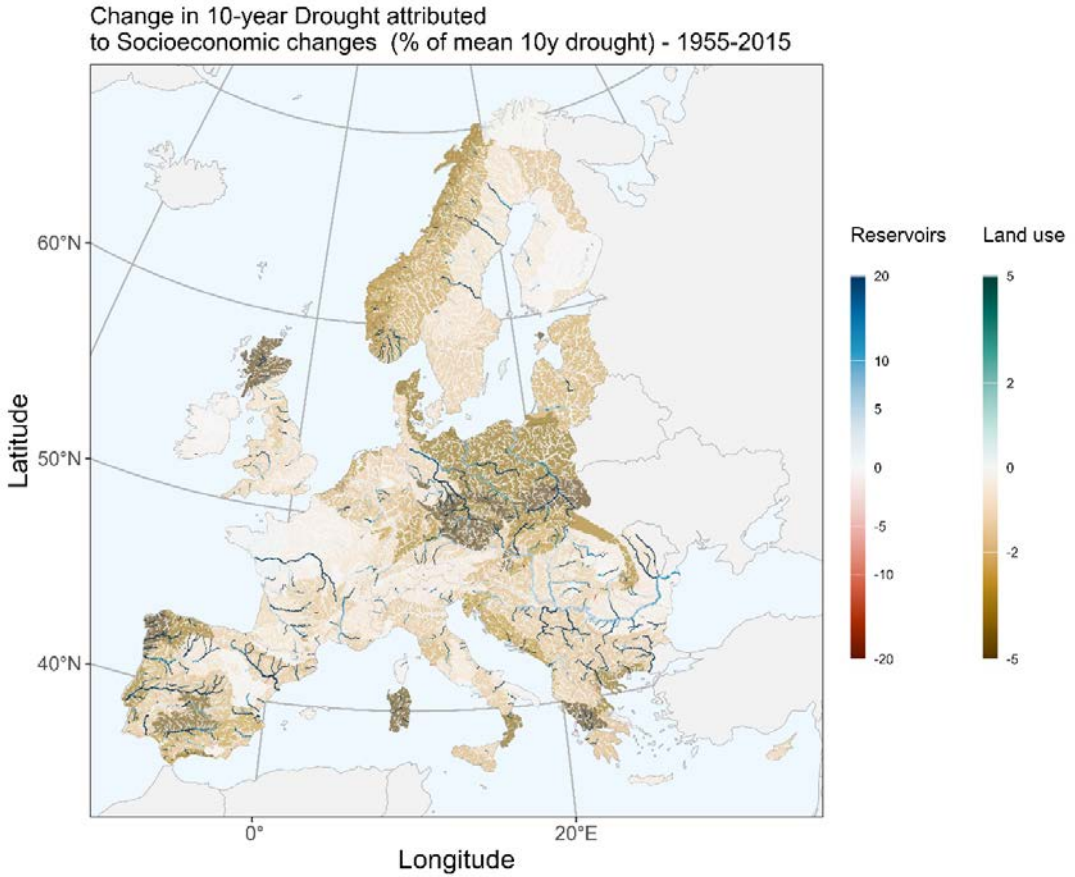


Changes driven by socioeconomic changes

Floods



Drought (no frost)



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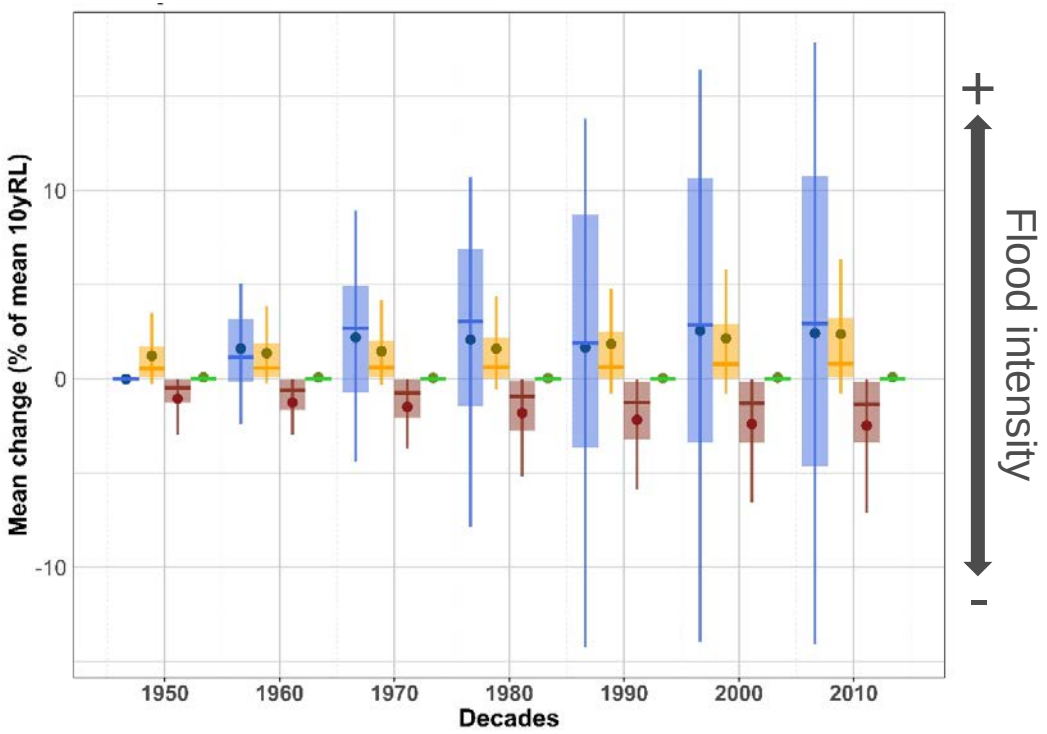
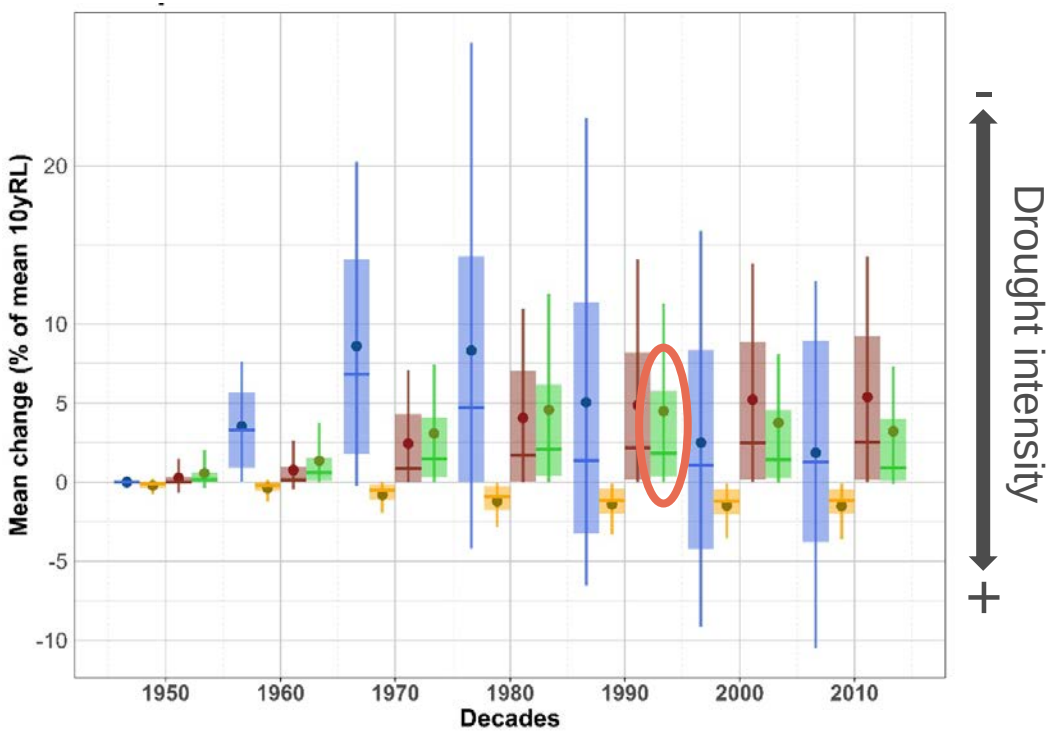
Continental level attribution

PRELIMINARY

Floods



Droughts



Drivers

- Climate
- Land use
- Reservoirs
- Water demand

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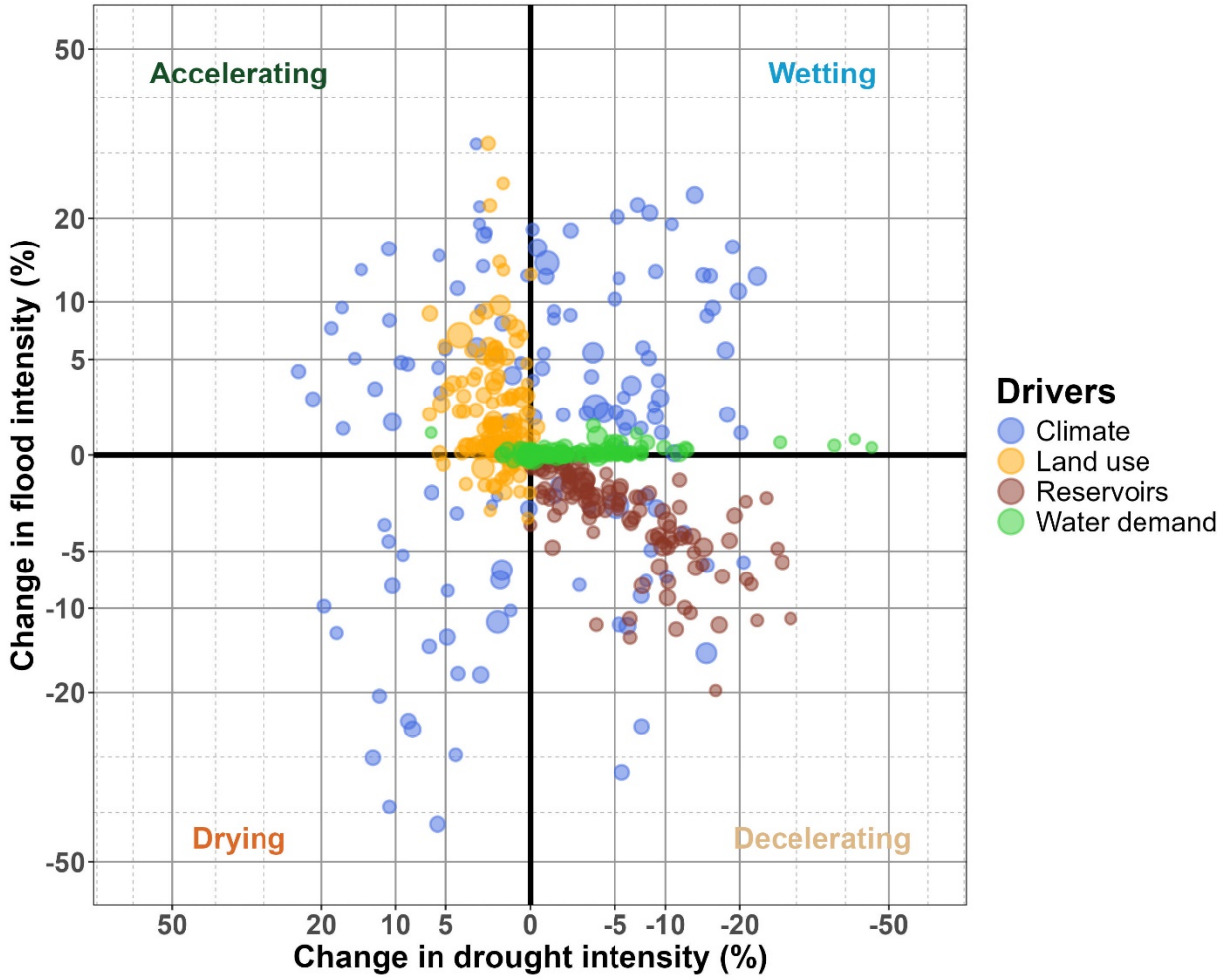
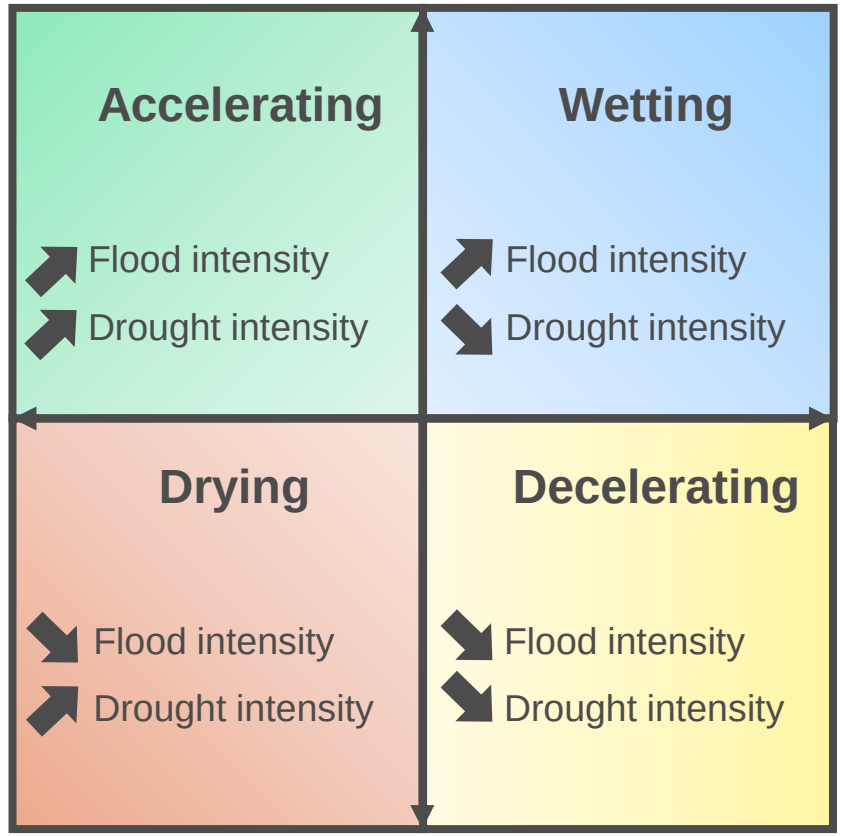
Joint analysis: four trajectories of change

Extremes reflect changes in the hydrological cycle





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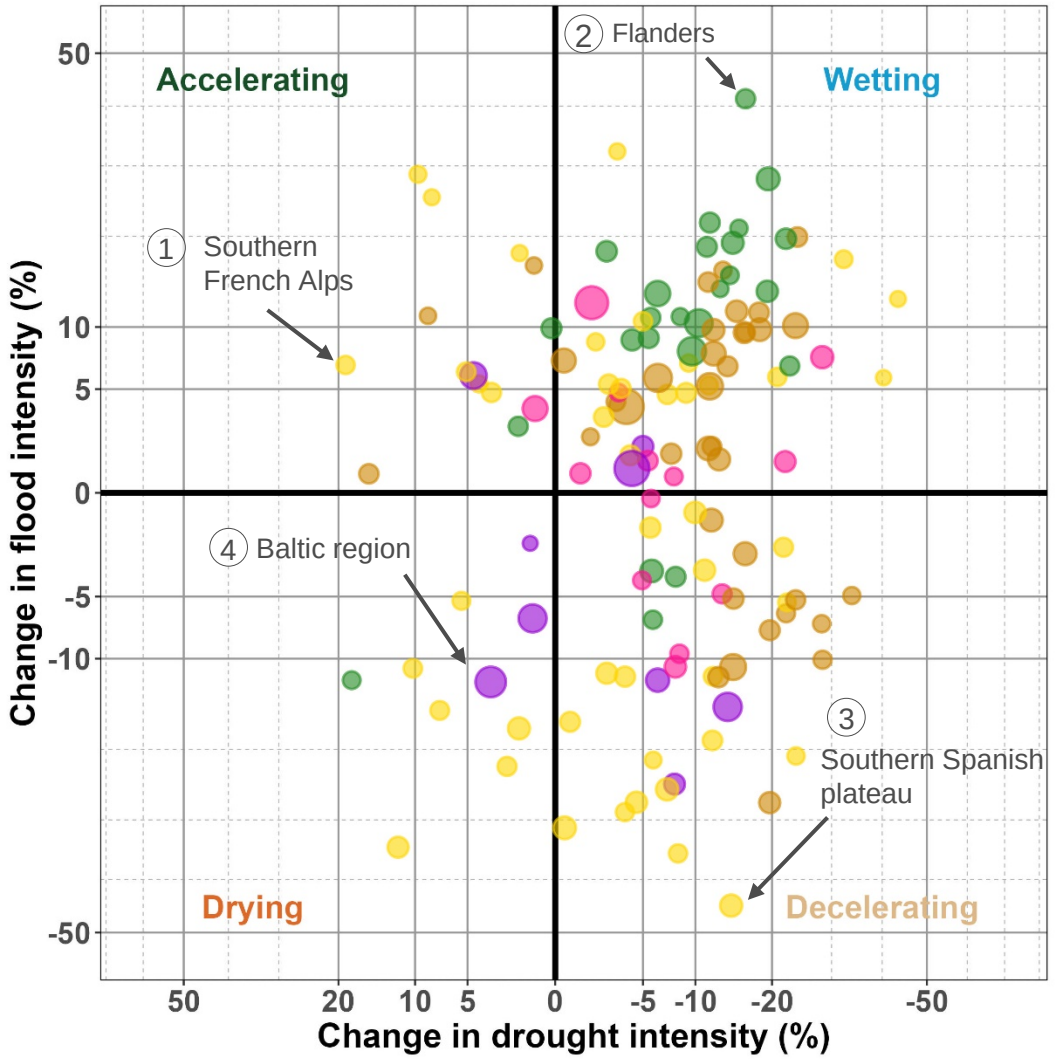
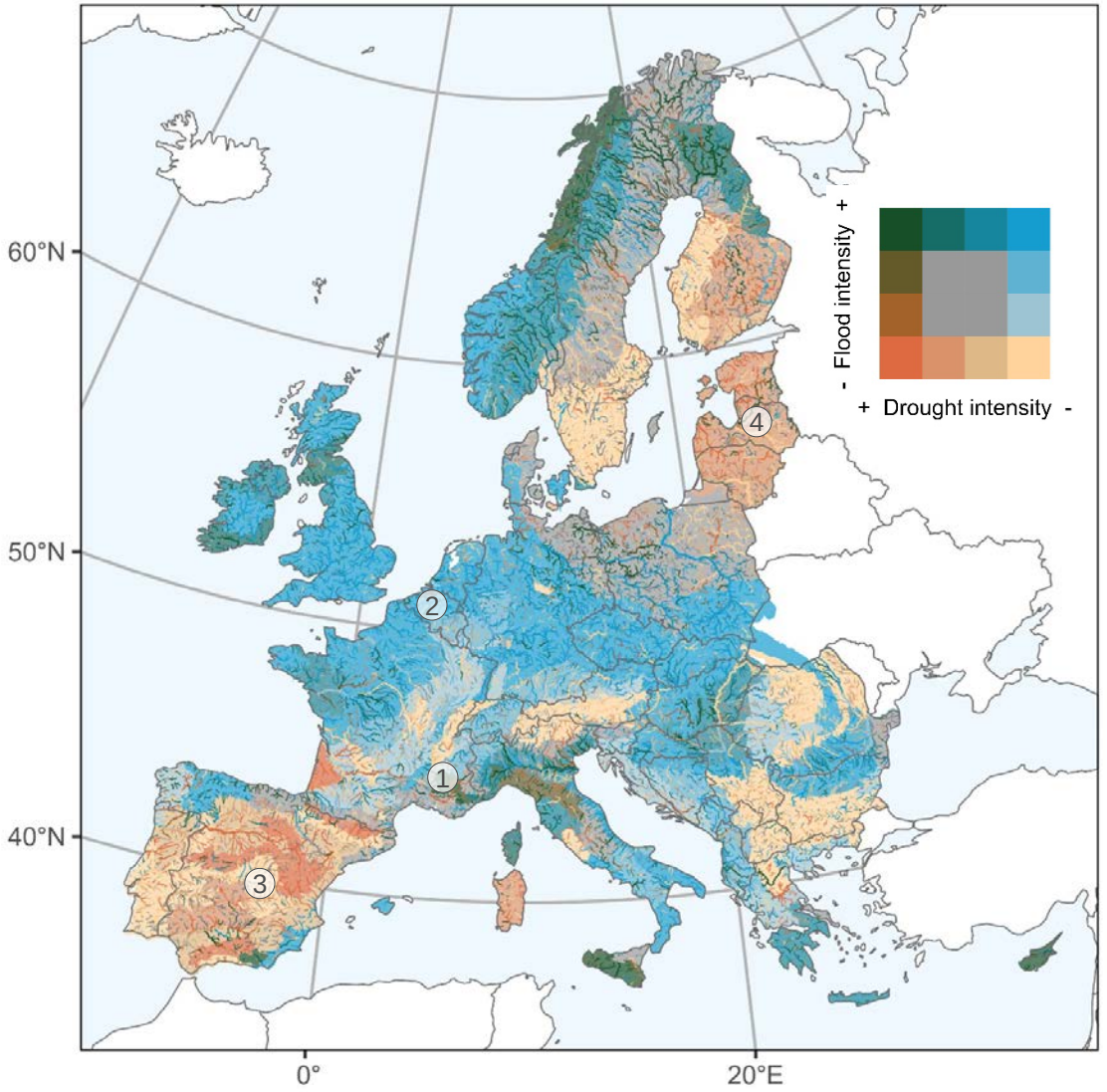
Regional trends



Regions
- Alpine
- Atlantic
- Boreal
- Continental
- Mediterranean



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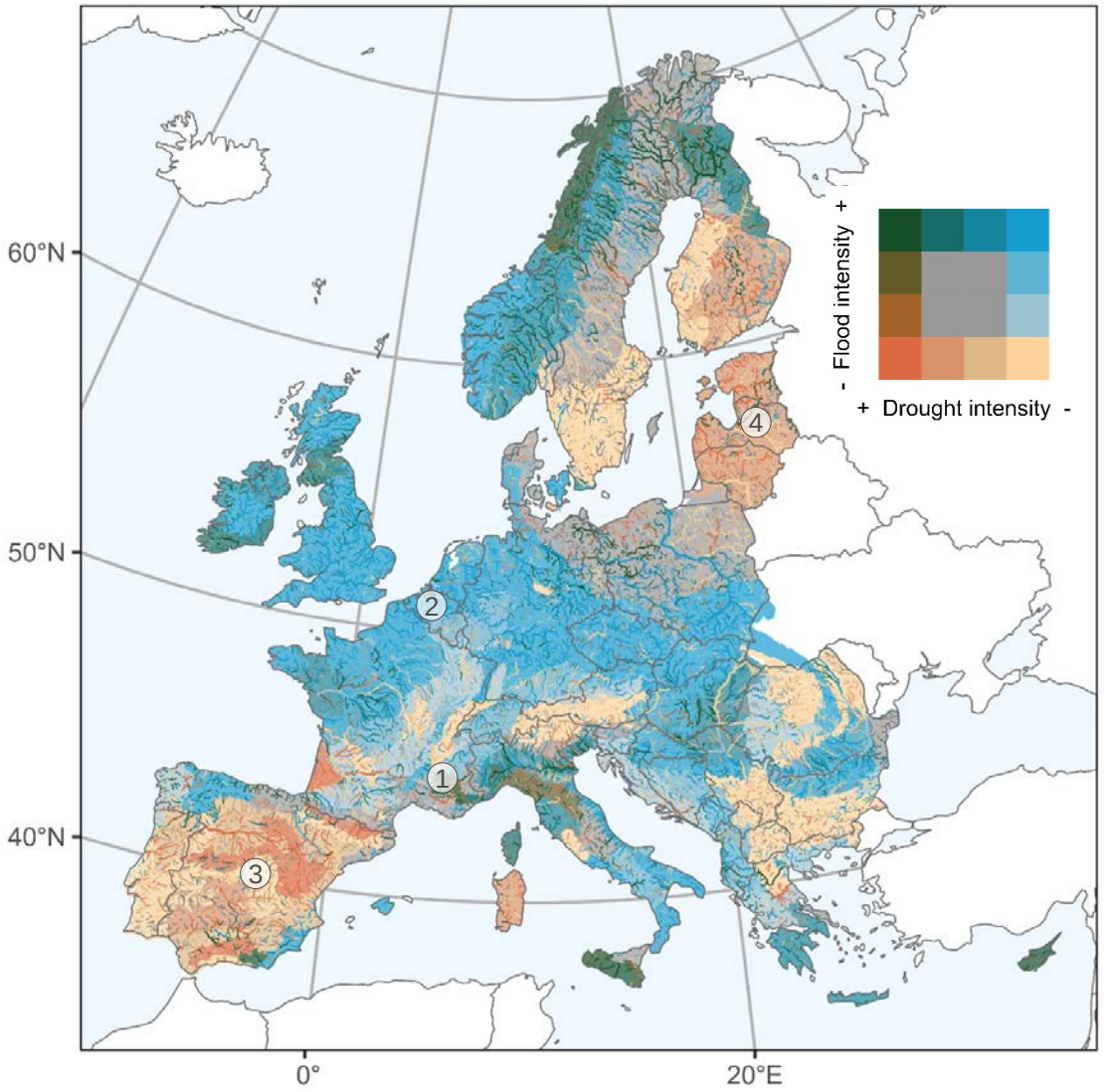
Conclusions

- A generally wetting Europe over the past 70 years
- Urbanisation and reforestation influenced flood and drought intensity
- Reservoirs have decelerated the hydrological cycle and alleviate drying patterns.
- Regional trends vs localized changes



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Thank you

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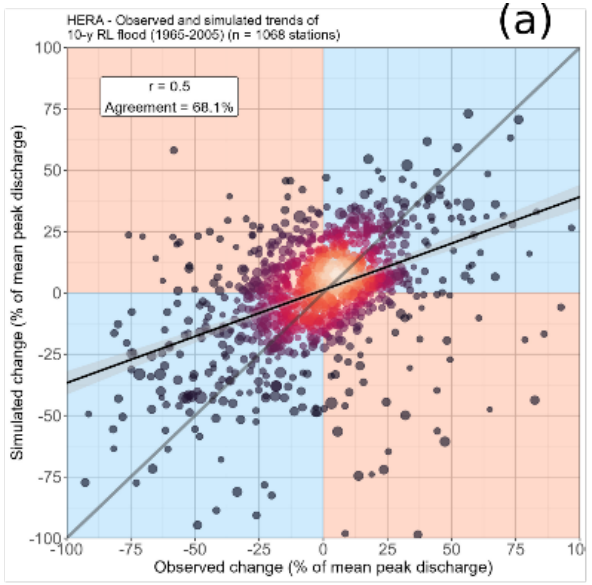
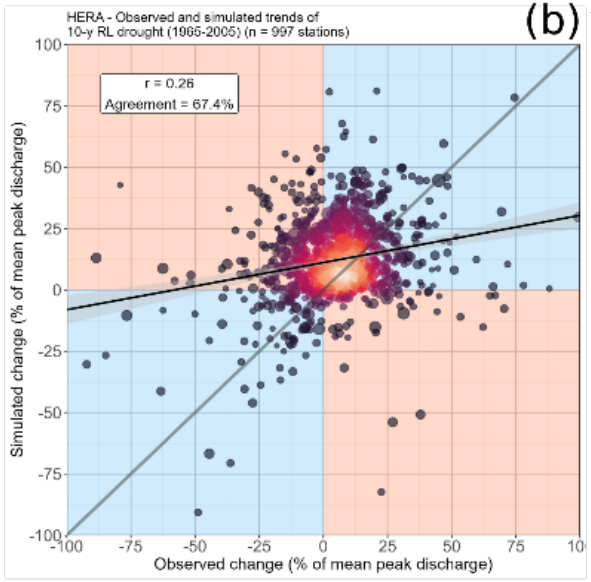
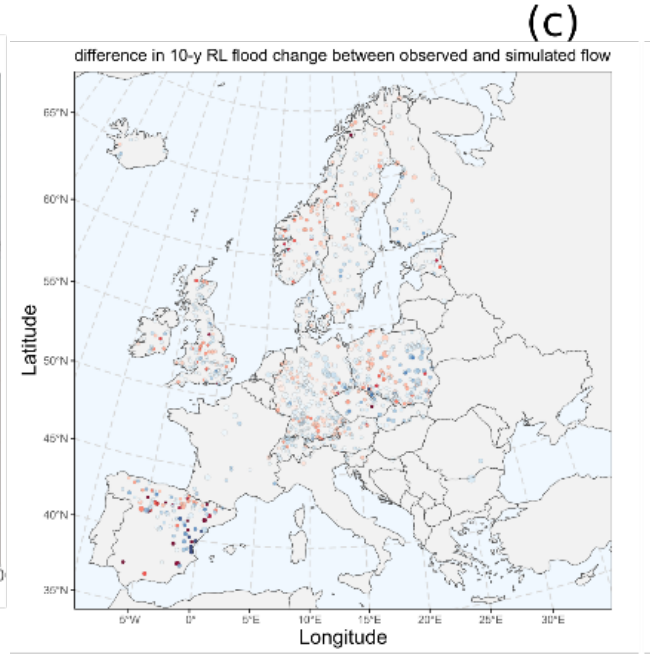
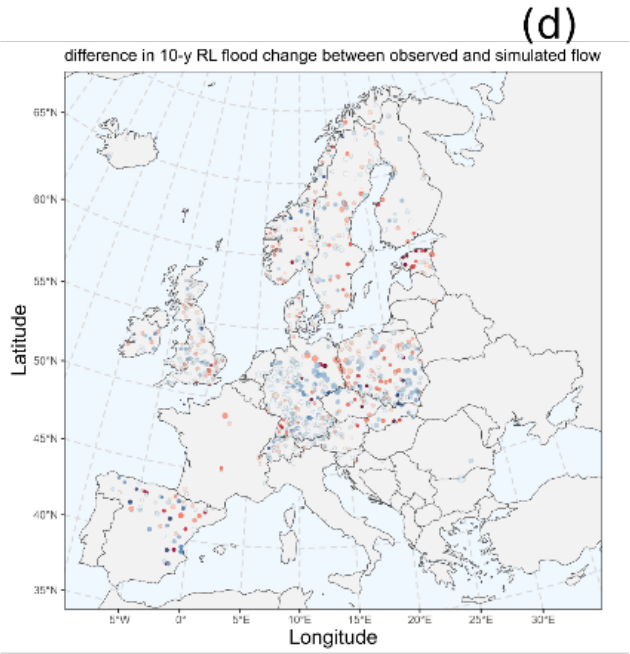
Extra slides

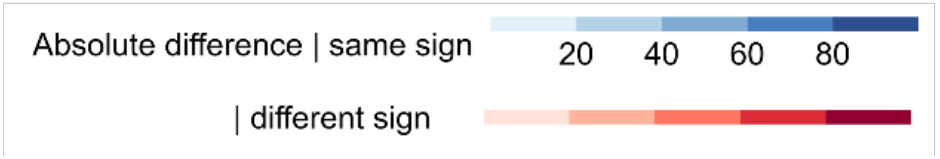
Validation











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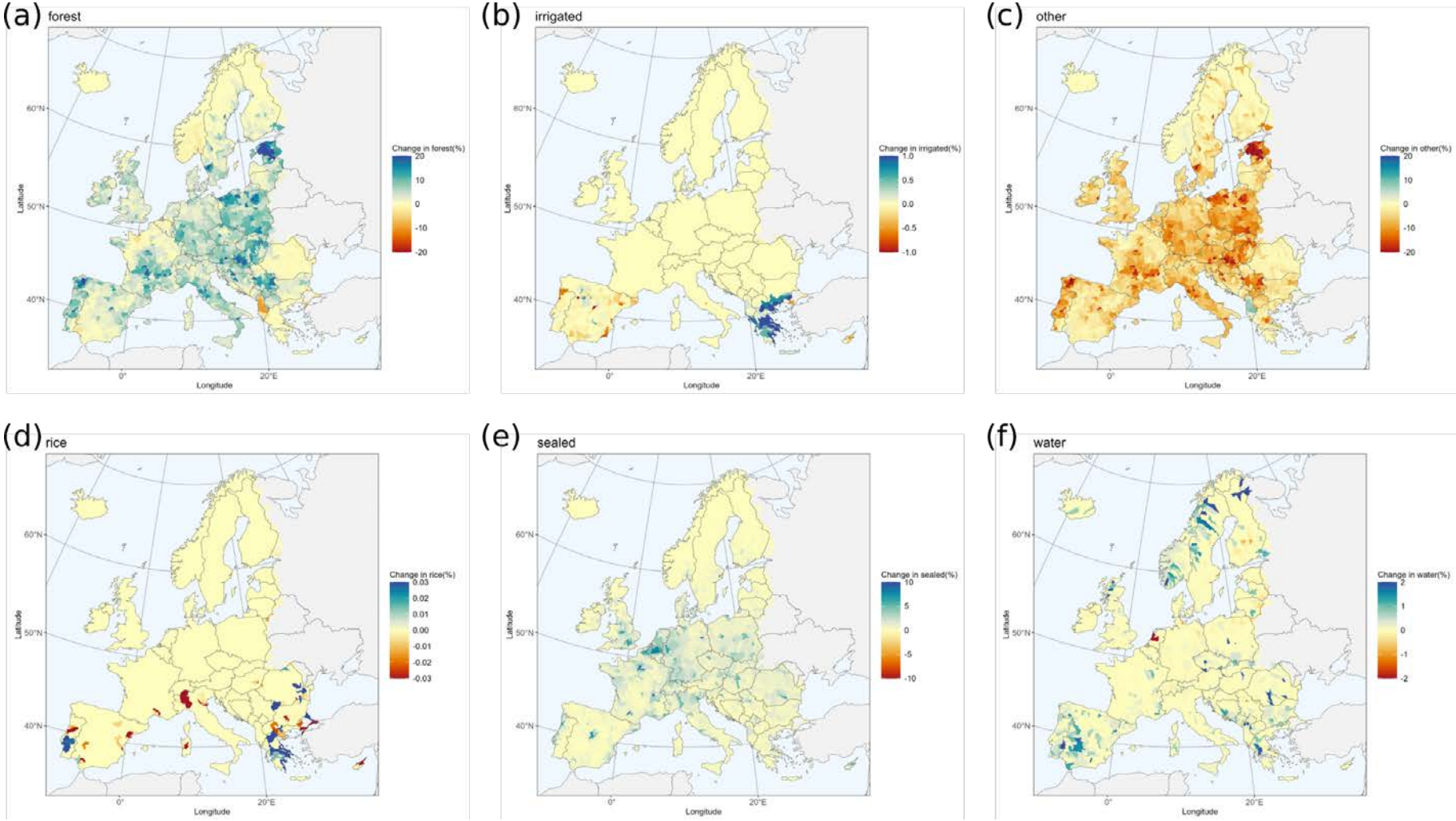
Land use changes



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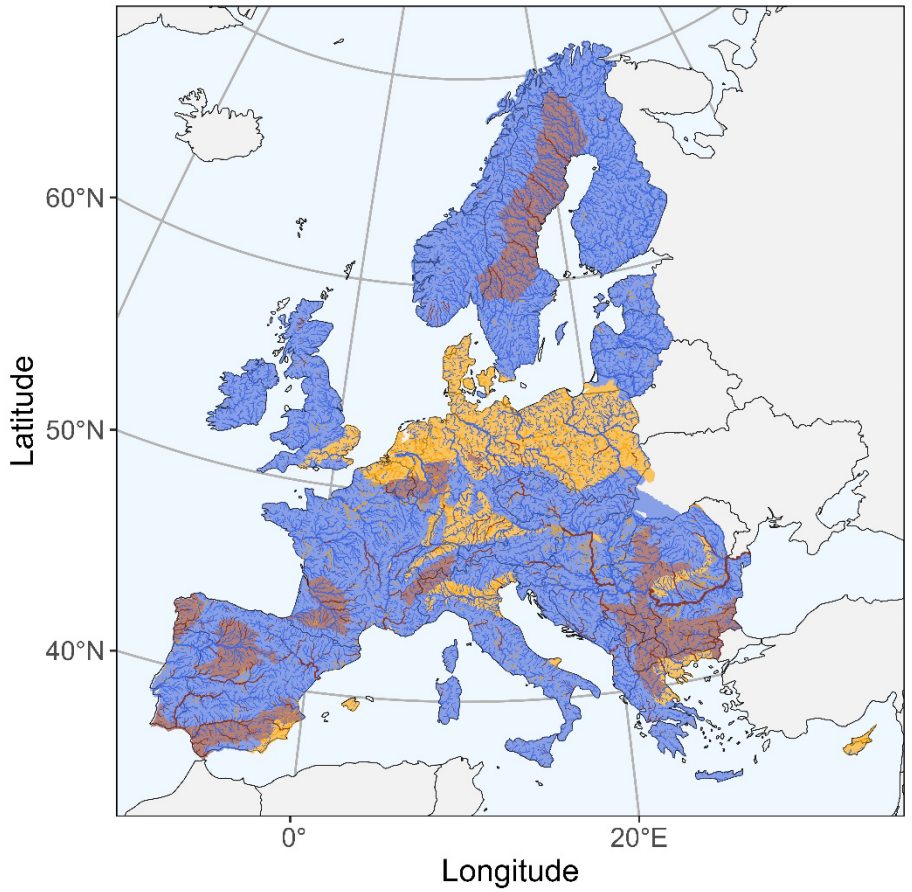
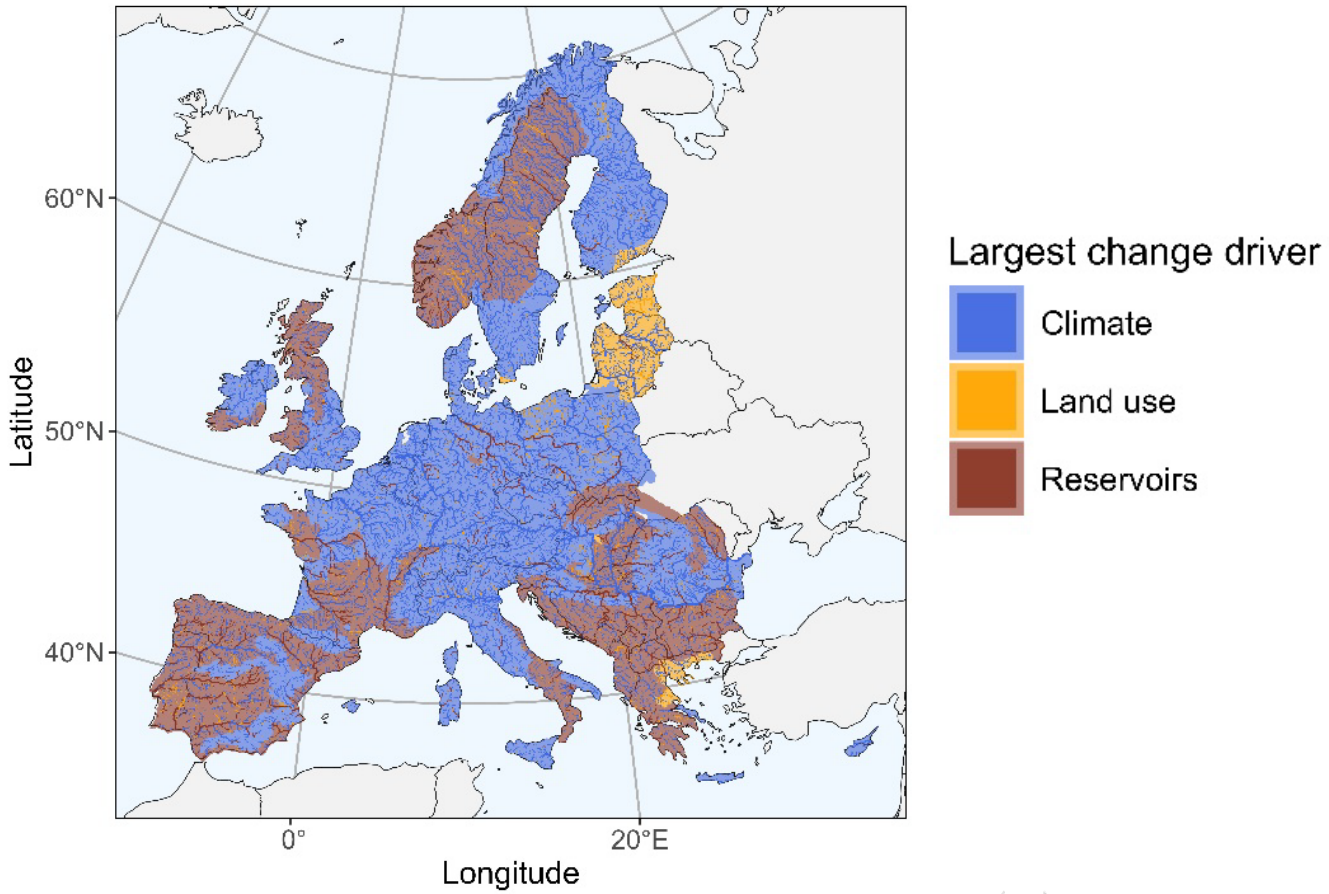
Largest driver





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