Spatial dependence of vegetation recovery after drought events and the spatiotemporal characteristics

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Background

Wide-spread vegetation drought impacts can result in a regional decrease in **ecosystem resilience.** The spatial dependence of the **post-drought vegetation recovery,** i.e. the extent to which events co-occur at multiple locations simultaneously, can shed a light on the processes affecting the co-occurrence of recovery.

In our study, we identify **the spatial dependence of vegetation recovery** after a drought. Thereby we explain the underlying mechanisms and patterns which could support recovery forecasting in the future.

Methods

1. Extraction of **drought events** and the associated timing of different stages (*Fig. 1a*)
2. Apply **event synchronization** (ES) on three different stages which are related to the dynamics of the vegetation recovery (*Fig 1b,c*).
3. The ES results in different metrics which characterizes the spatial drought and recovery dynamics (*Fig. 1d, Fig. 2, Fig. 3*).
4. With this information and additional spatial drought characteristics we apply **k-means clustering** (*Fig. 1e, Fig. 4a*).
5. The **hydro-meteorological and geographical characteristics** are compared between the clusters to explain the spatial recovery dynamics (*Fig. 4b-e*).

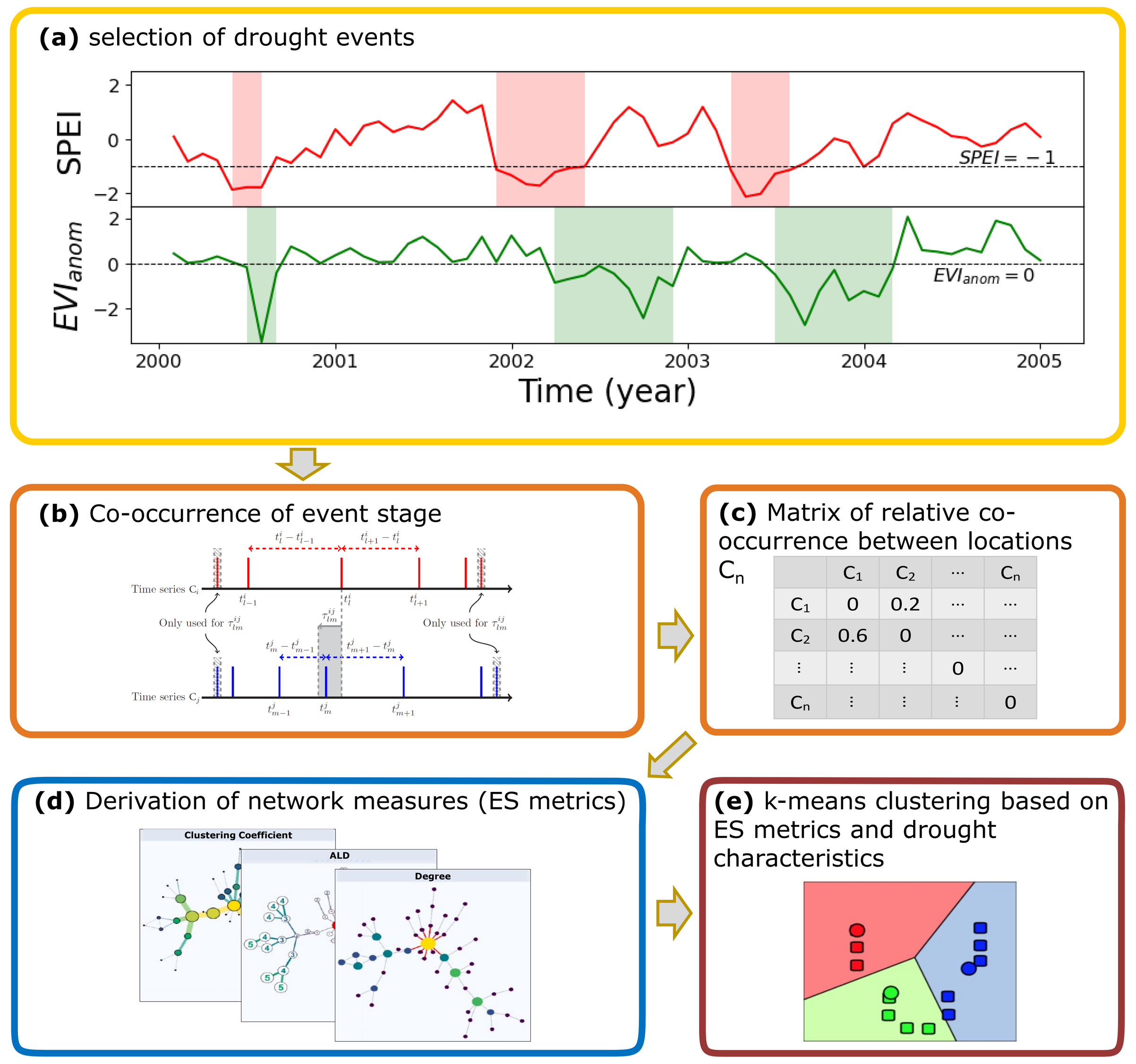

Figure 1: *Workflow illustrating the ecological drought event assessment*
Images retrieved from: (b) Odenweller & Donner (2020); (d) Muthuvel & Sivakumar (2024); (e) Wikipedia 'k-means clustering', Weston.pace

Synchronicity of the end of drought recovery

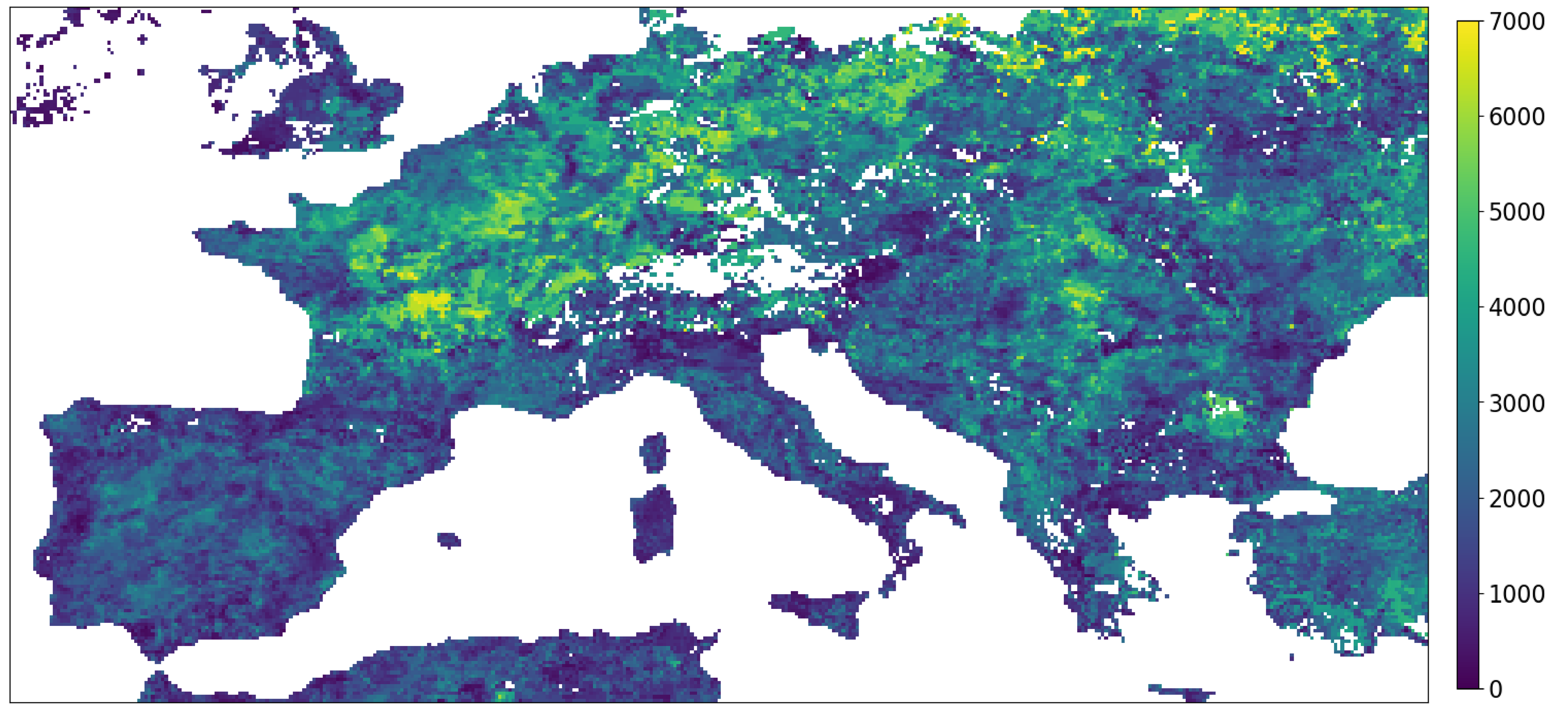

***Figure 2**: The strength of connectedness (degree centrality), represented by the number of locations that significantly co-experience events.*

Dependence explained by level of synchronicity

Based on the synchronicity of events, multiple relations of connectedness can be derived. Together they explain the level of dependence. E.g.:

- Propagation potential, representing source and sink regions where events generally occur first or are lasts when co-occurring with other locations.
- The average distance of all the linking locations.
- Local clustering coefficient: taking all the locations that are connected to one location, then the proportion of these locations that are interlinked. Indicating cells that are forming groups.

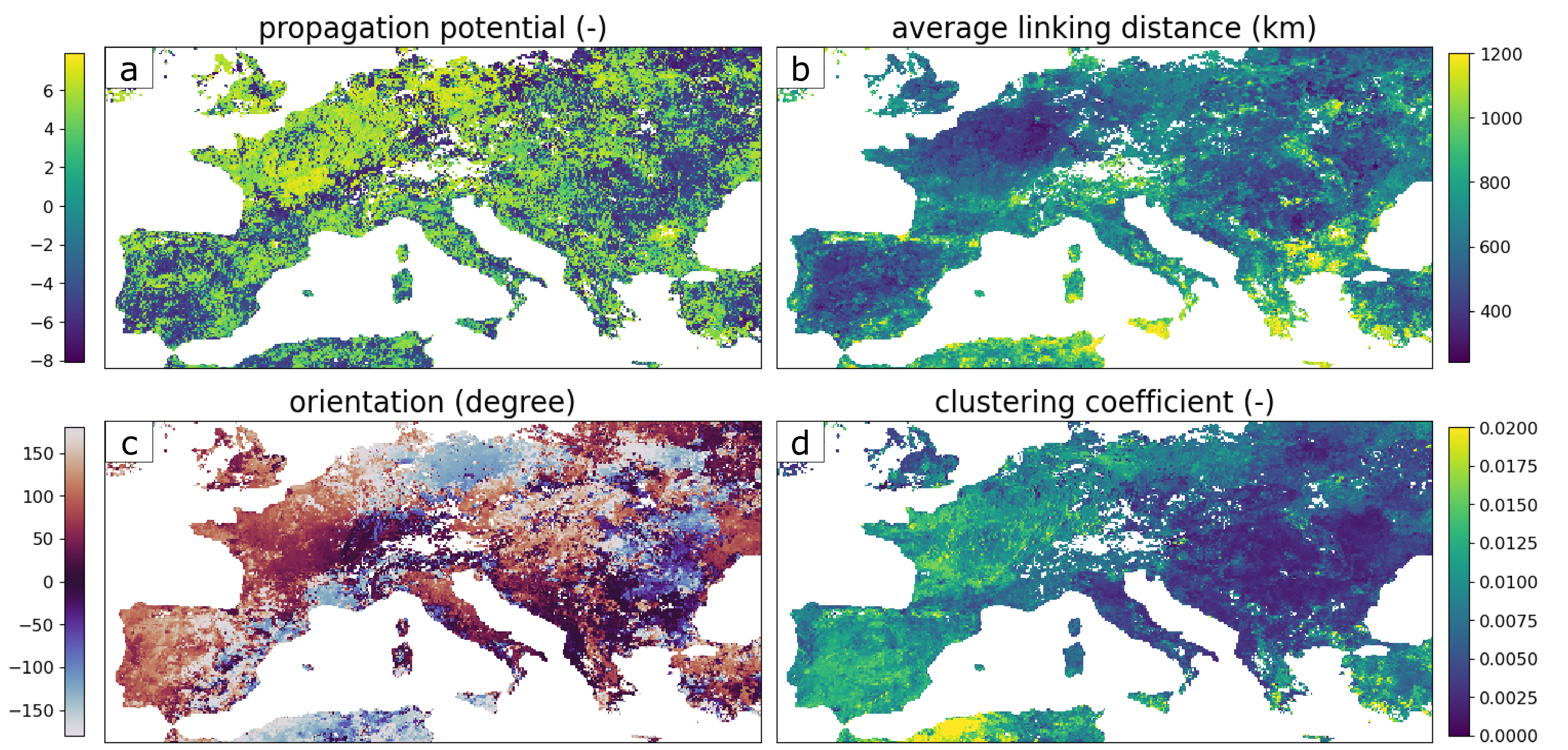

***Figure 3**: Event synchronization measures of the start of the recovery: (a) average linking distance (ALD); (b) propagation potential; (c) the mean orientation of all significant links; (d) the local clustering coefficient; and (e) detail of the source and sink regions.*

Clustering of synchronicity and drought characteristics

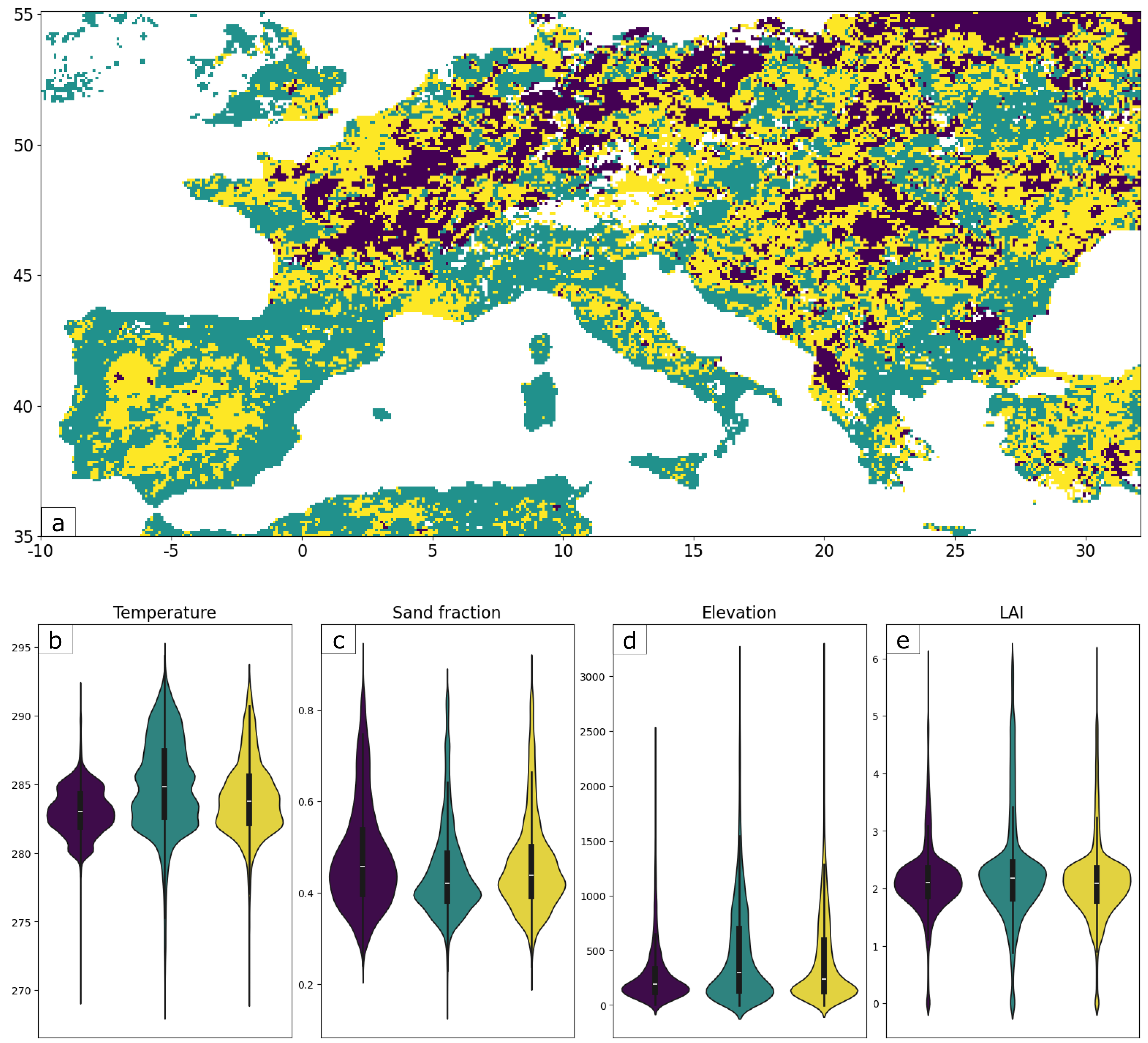

***Figure 4**: (a) Clustering based on event synchronization metrics and drought characteristics, and the spread of different hydro-meteorological and geographical variables in each cluster. Shown here: (b) median annual temperature; (c) sand fraction; (d) elevation; and (e) median leaf area index (LAI) of high vegetation.*

Conclusions

- Different drought recovery stages have similar **connectedness patterns** (*Fig. 2*).
- Multiple **event synchronization** metrics provide insights into the dynamics of the recovery phase of vegetation (*Fig. 3*).
- The **grouped recovery characteristics** are moderately different in their average annual temperature, whereas many hydro-meteorological and geographical have little variance (*Fig 4*).
- For recovery forecasting the **spatial information** is regarded subordinate compared to **temporal dynamics** when compared to other research *(Schwalm et al., 2017)*.

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