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Microbial evidences of abrupt shifts in dunes ecosystems after passing an aridity threshold

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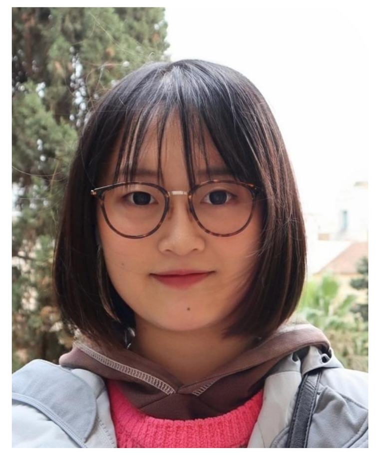

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Introduction

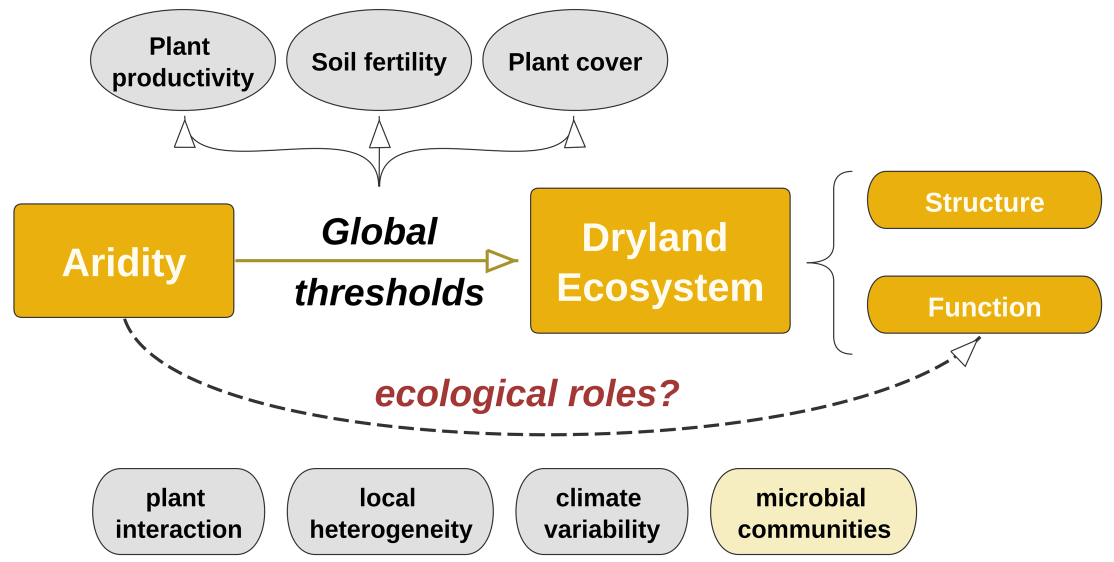

Fig.1 How aridity increasingly influence the dryland ecosystem?[1]

Global aridity thresholds

1. Vegetation decline phase: (0.54)
   - a decay in vegetation productivity and photosynthetic activity
2. Soil disruption phase: (0.69)
   - a sharp declines in soil fertility, plant nitrogen content, and biotic interactions
3. ***Systemic breakdown: (0.83)***
   - drastic reduction in plant cover

Aim

1. How does the **abundance** and **diversity** of microbial communities respond to environmental variations across threshold?
2. Is there evidence of potential regime shifts in the **community assembly** process across threshold?
3. What are the **network patterns** among communities across the systemic breakdown threshold & how do their **stabilities** differ?

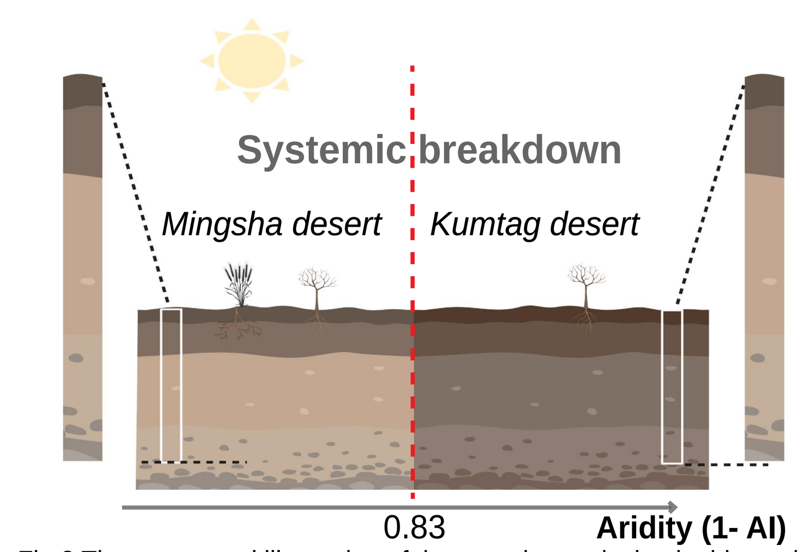

Fig.2 The conceptual illustration of the experiment design in this study

Methodology

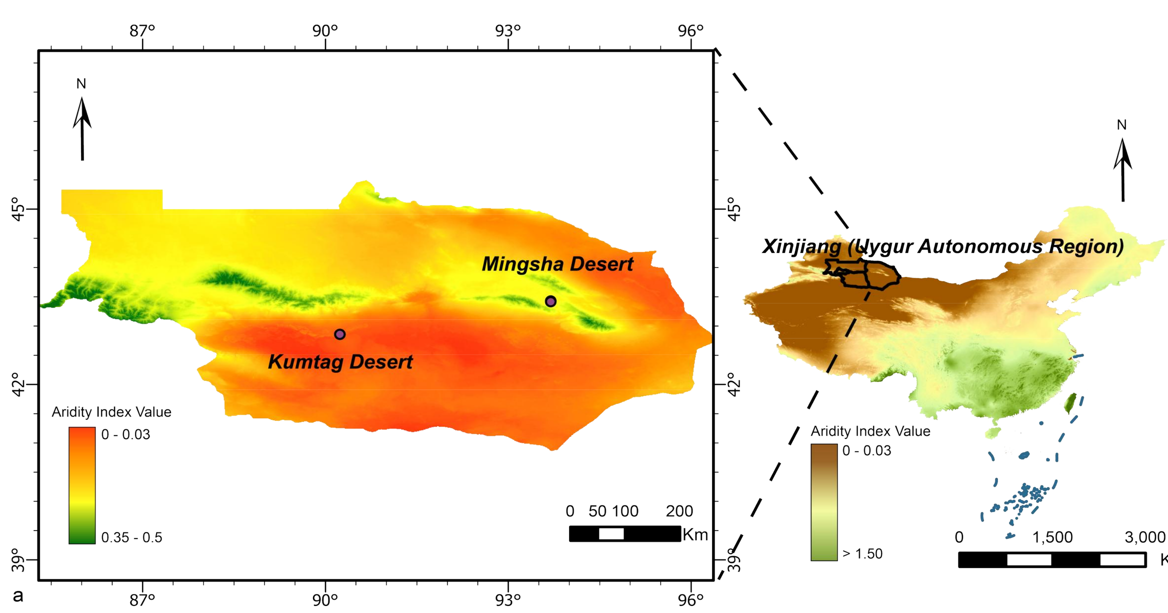

Fig.3 **Distribution of the sediment cores in two deserts across soil layers before and after the *Systemic Breakdown* aridity threshold**.

Location of the two sampling deserts which aridity is 0.73 and 0.98 respectively.

The visualization was generated by the geospatial datasets of Global Aridity Index (Global-AI) based on the Worlclim 2.1 dataset, with 30 arc-seconds resolution[2].

The aridity of this study was calculated using the 2020 annual potential evapotranspiration (PET) and 2020 annual precipitation (P) based on the UNEP equation[3].

Result

How the richness and biodiversity change across soil layers before and after the threshold?

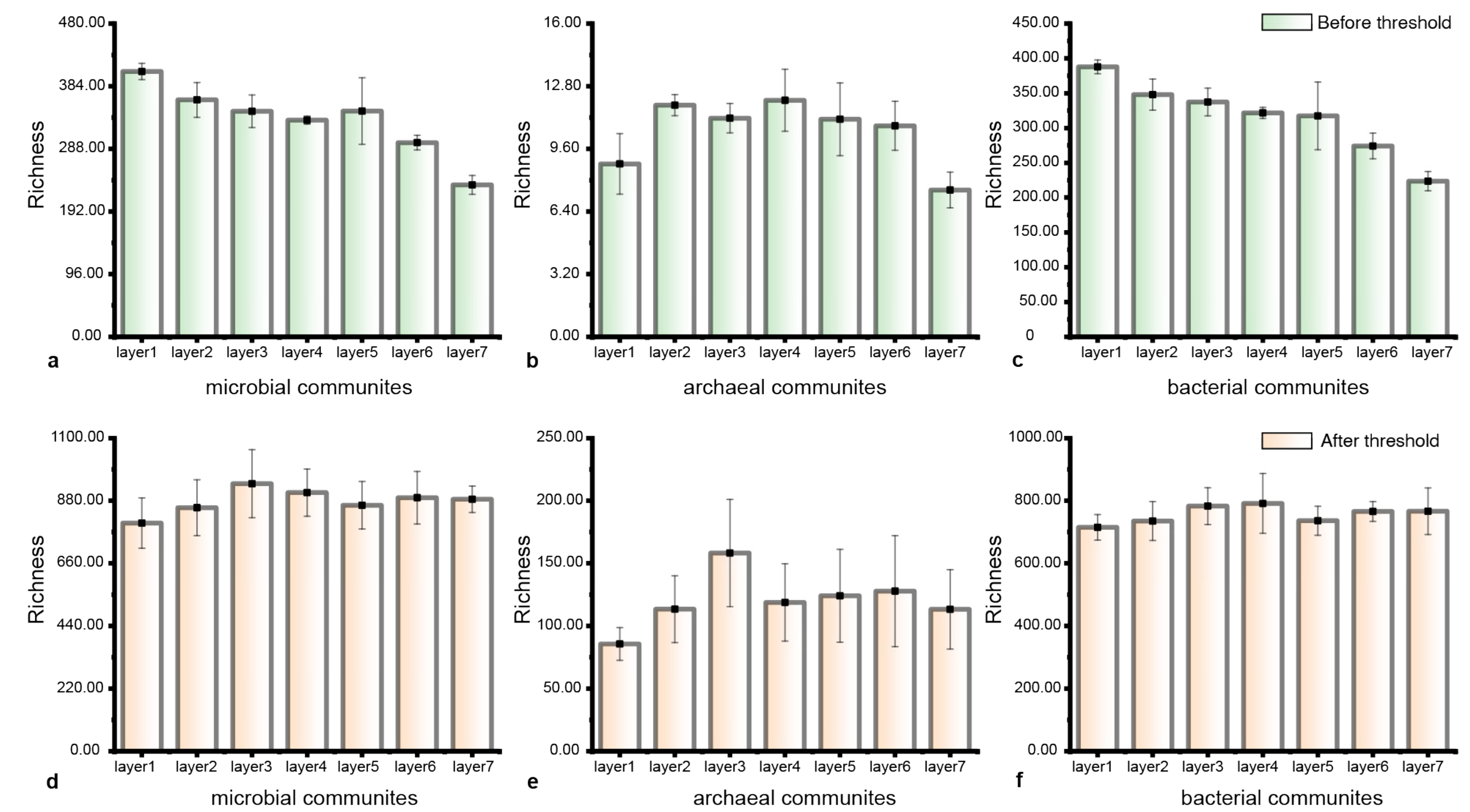

Fig.4 Richness comparison of two desert-profiles before and after the thresholds across layers among microbial communities, archaeal communities and bacterial communities. Richness was calculated by Chao1 index. Bar charts reflect mean value and standard errors for each category. The error bars on the columns represent the standard errors (SE).

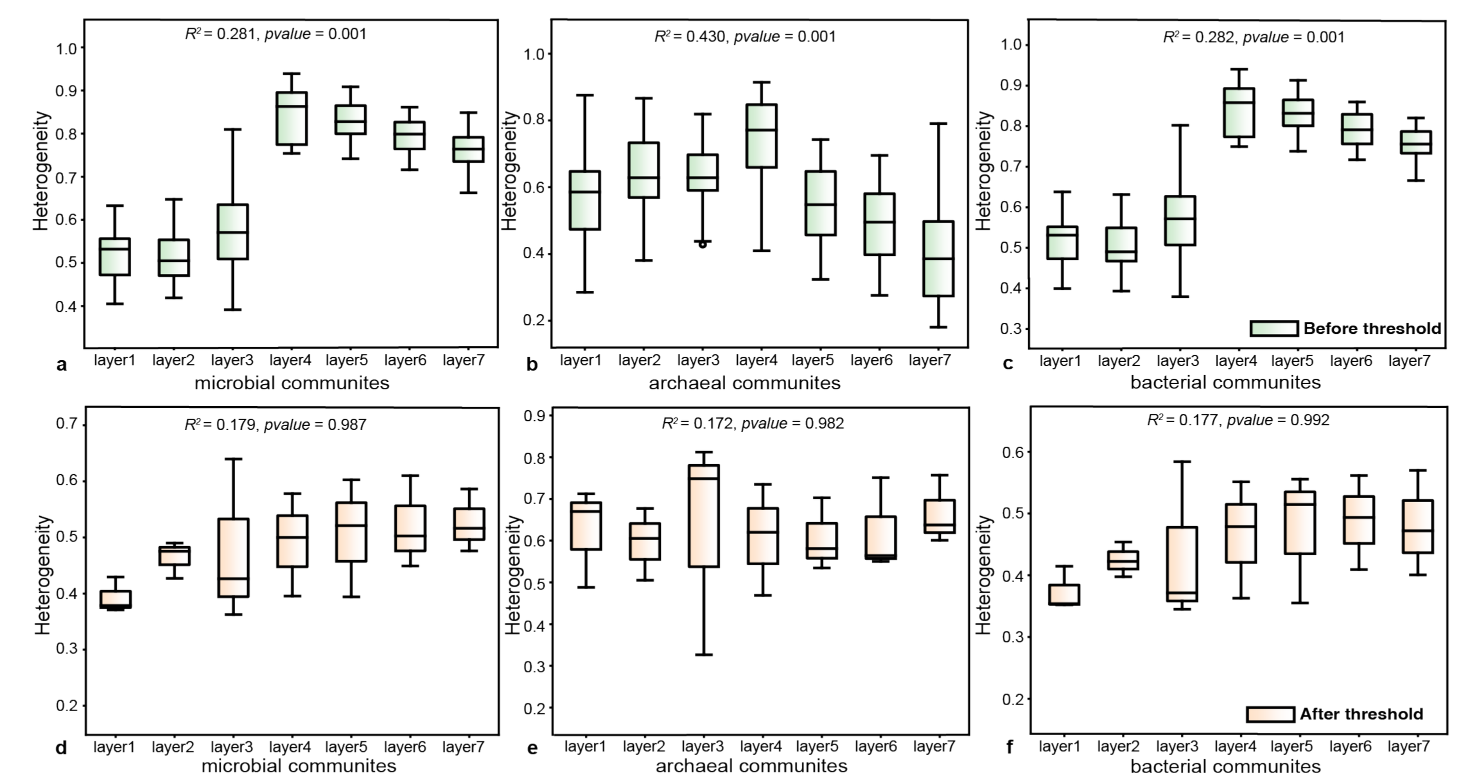

Fig.5 Heterogeneity comparison of two desert-profiles before and after the thresholds across layers. PERMANOVA P values are shown. R2, explained variances.

After passing the *Systemic Breakdown* threshold,
the microbial communities lost stratification of declining in richness; lost biodiversity, became more similar.

Any potential evidence of regime shifts in the community assembly process?

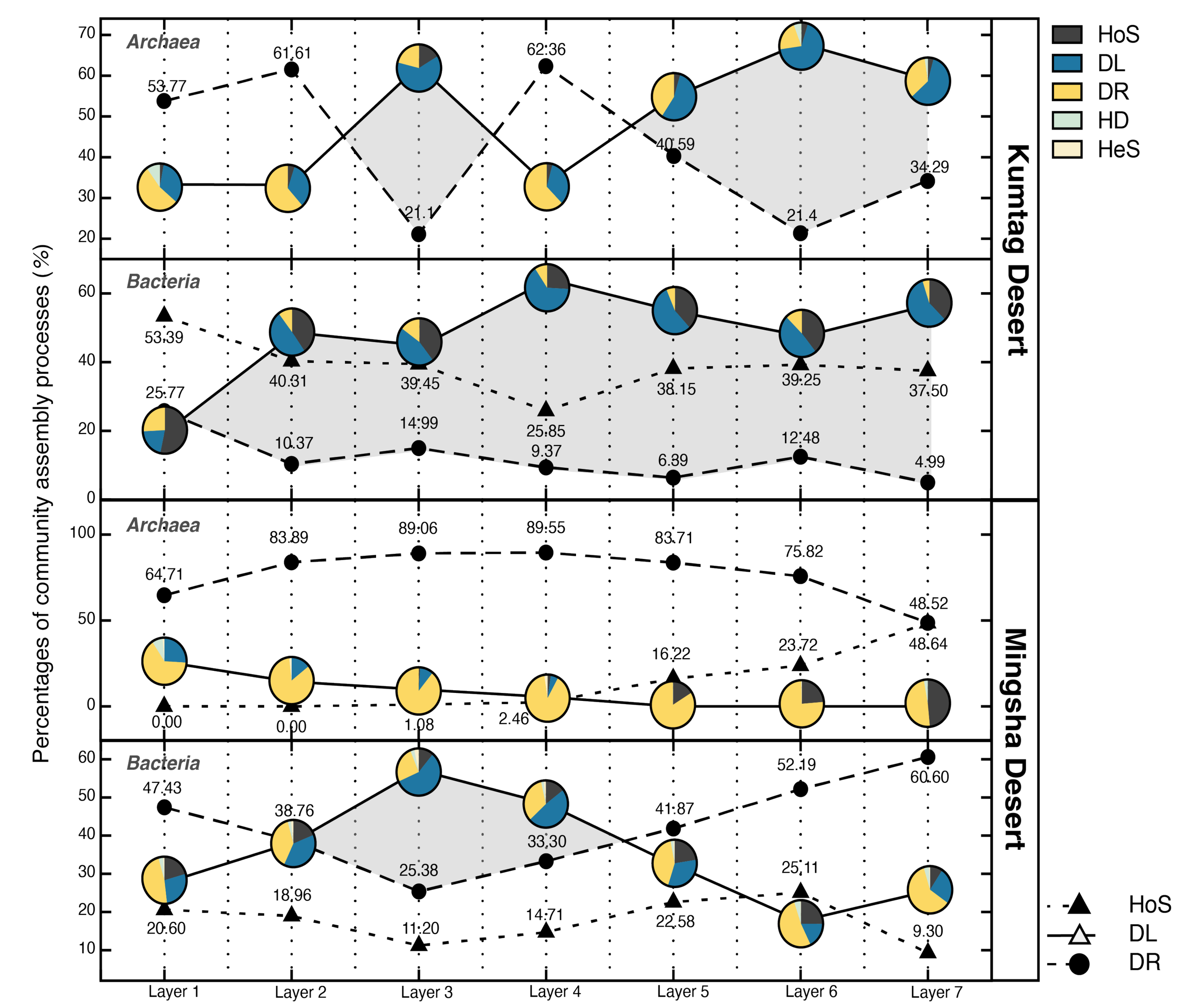

Fig.6 **The community assembly processes of bacterial and archaeal communities across soil layers before and after the threshold**. The null model analysis of the phylogenetic diversity were computed from beta Net Relatedness Index (βNRI) and modified Raup–Crick metric (RC). Under the iCAMP quantitative framework[4], community assembly processes were categorized into five processes: homogeneous selection (HoS), heterogeneous selection (HeS), dispersal limitation (DL), homogenizing dispersal (HD) and drift (DR).

After passing the *Systemic Breakdown* threshold,
the community assembly process of archeal communities became less consistent, and largely effected by dispersal limitation rather than drfit;
the community assembly process of bacterial communities were greatly influenced by Hos (homogeneous selection) and DL (dispersal limitation) across verticle layers, rather than drift.

How the co-occurrence network patterns change across threshold? and how their topological properties and stabilities varied?

After passing the *Systemic Breakdown* threshold,
the edges of the co-occurrence networks became abundant, suggesting the with-in communities' connection were stronger; the stabilities of networks were less than that before the threshold, suggesting the microbial systems were more fragile.

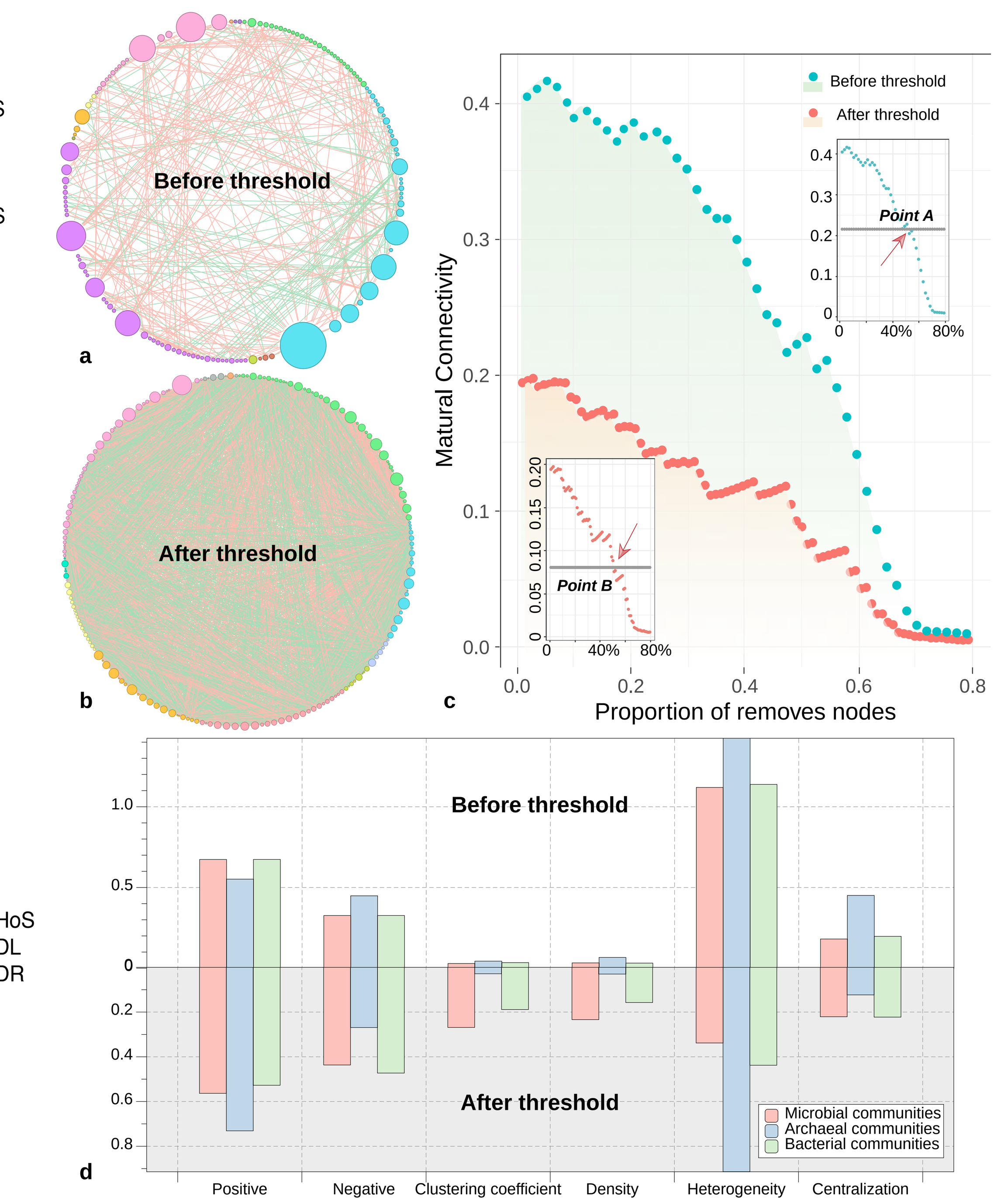

Fig.7 **Comparison of co-occurrence network, stability and topological properties before and after threshold.** In the co-occurrence networks, the node size represents for the betweenness centrality of each ASV, the node color represents for the phylum of each ASV, the edge color stands for the direction of correlation (red: positive; green: negative).
a. co-occurrence network of microbial communities before the threshold.
b. co-occurrence network of microbial communities after the threshold.
c. The network stability of microbial communities before and after thresholds.
The stability was calculated by robustness using the natural connectivity of complex networks in both the Mingsha and the Kumtag desert cores. The blue and read area with dots represent the natural connectivity variations of the tested microbial communities before and after the threshold respectively. The grey line with dots represents the natural connectivity variations of the random networks with the same number of nodes and edges as the tested network.
d. The topological properties among microbial, archaeal and bacterial communities before and after threshold, including the positive and negative relations, clustering coefficient , network density, heterogeneity and network centralization.

Reference

[1] Miguel Berdugo et al. ,Global ecosystem thresholds driven by aridity.Science367,787-790(2020).DOI:10.1126/science.aay5958
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[3] UNEP (1992) World Atlas of Desertification.
[4] Ning, D., Yuan, M., Wu, L., Zhang, Y., Guo, X., Zhou, X., Yang, Y., Arkin, A.P., Firestone, M.K., Zhou, J., 2020. A quantitative framework reveals ecological drivers of grassland microbial community assembly in response to warming. Nat. Commun. 11, 4717. https://doi.org/10.1038/s41467-020-18560-z

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