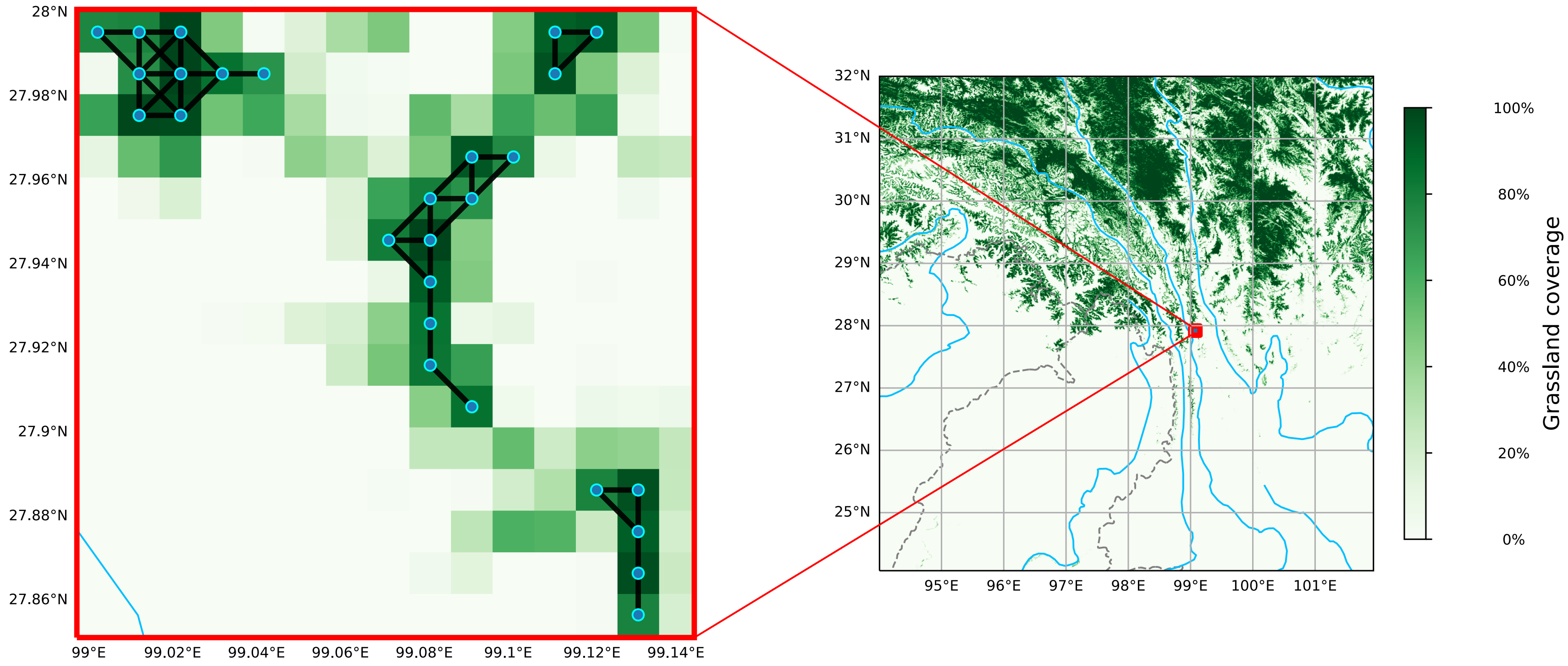
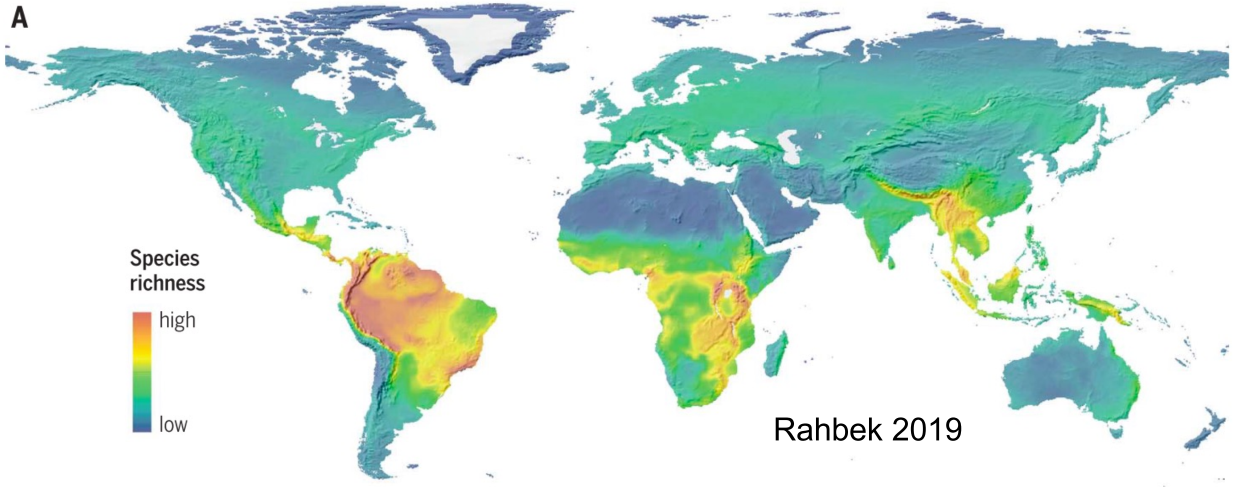


Using graph-based metrics to assess the effect of landscape topography on diversification

Victor Boussange, Loïc Pellissier, and Yaquan Chang

ECBC Amsterdam 2021

Large-scale geographical patterns of species diversity

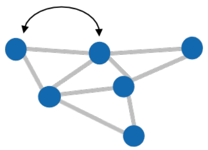


Mountains represent **25 % of land area, but 85% of the world's species** of amphibians, birds and mammals, many entirely restricted to mountains (Rahbek 2019)

Topological constraints **Habitat heterogeneity**

Underlying mechanisms?

First principles modelling approach



Graph representation of the landscape

$$m\partial_t v = \sum_i F_i$$

Eco-evolutionary individual based model

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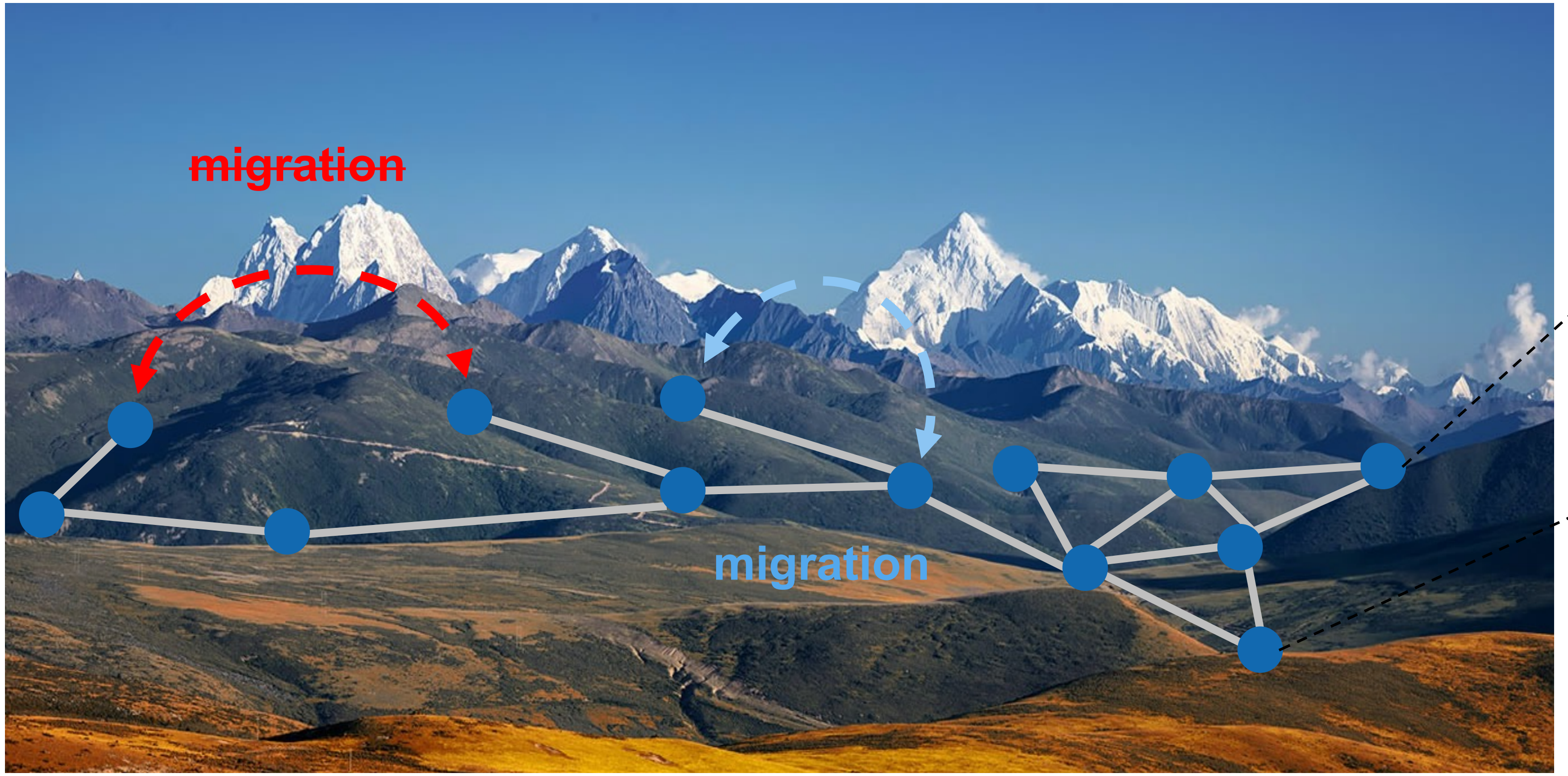
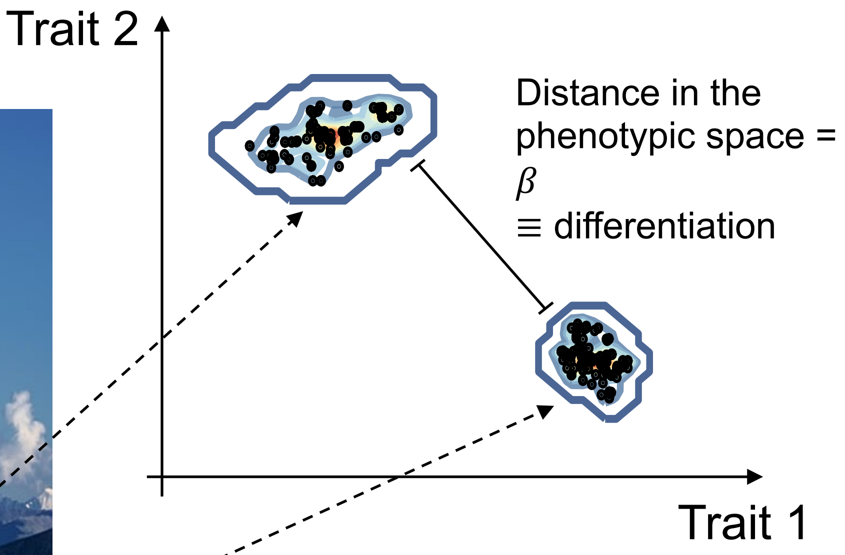
Capturing complex connectivity patterns with graphs

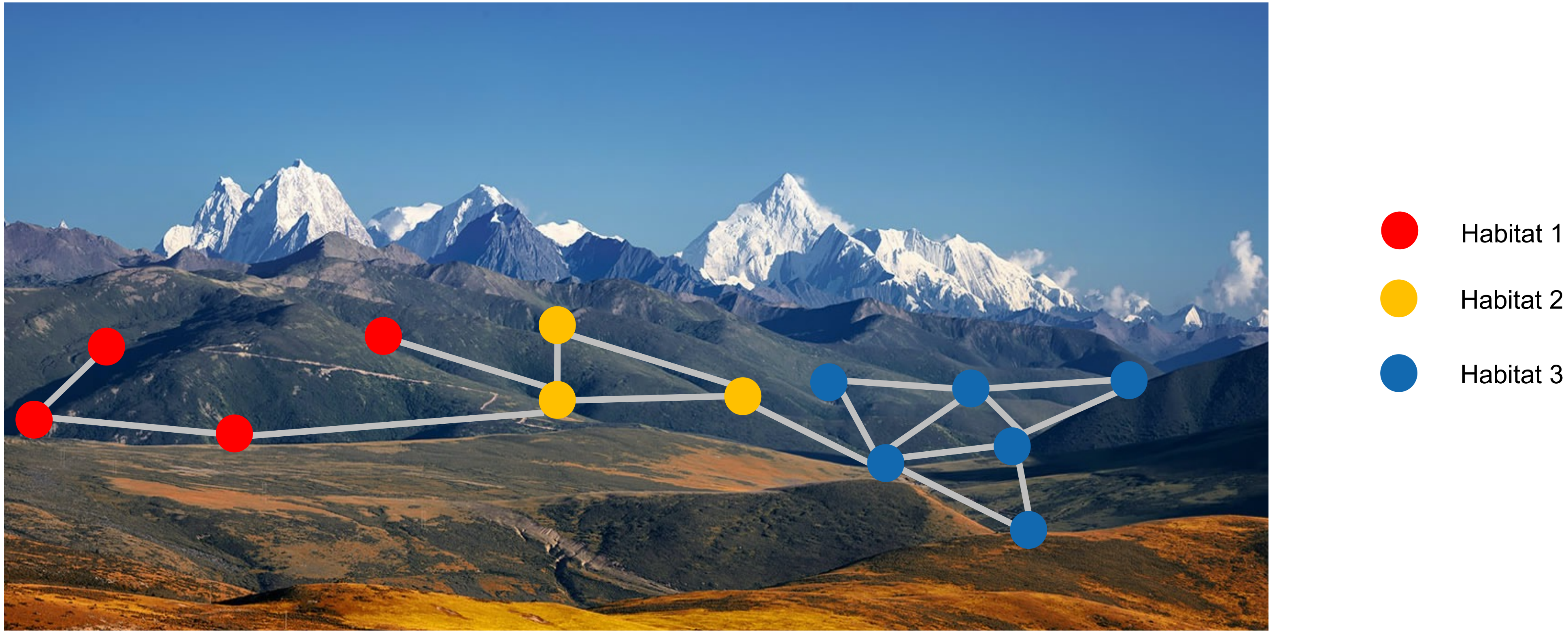
Graphs, to capture dispersal patterns
➔ Geometric constraints





Capturing habitat heterogeneity with graphs

Graphs, to capture
environmental heterogeneity



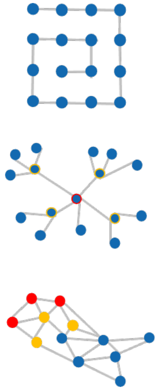
Graph-based eco-evolutionary model

Numerical simulations & **Analytical results**

$$
\begin{aligned}
L\phi(\nu_t^{(i)}) = & \int_{\mathcal{X}} \Big\{ b_i(\mathbf{x})(1-\mu)(1-m)(\phi(\nu_t^{(i)} + \delta_{\mathbf{x}}) - \phi(\nu_t^{(i)}))\Big\} \nu_t^{(i)}(d\mathbf{x}) \\
& + \int_{\mathcal{X}} \Big\{ \mu(1-m) \int_{\mathcal{X}} b_i(y)(\phi(\nu_t^{(i)} + \delta_z) - \phi(\nu_t^{(i)}))\mathcal{M}(\mathbf{x}, y)dy \Big\} \nu_t^{(i)}(d\mathbf{x}) \\
& + \iint_{\mathcal{X}} \Big\{ \frac{1}{K}(\phi(\nu_t^{(i)} - \delta_{\mathbf{x}})) - \phi(\nu_t^{(i)}))\nu_t^{(i)}(dy)\, \nu_t^{(i)}(dx) \Big\} \\
& + \sum_{j \neq i} \frac{a_{i,j}}{d_j} \int_{\mathcal{X}} \mu m \Big\{ \int_{\mathcal{X}} b_j(y)(\phi(\nu^{(j)} + \delta_{\mathbf{x}}) - \phi(\nu^{(j)}))\mathcal{M}(\mathbf{x}, y)dy \Big\} \nu_t^{(j)}(d\mathbf{x}) \\
& + \sum_{j \neq i} \frac{a_{i,j}}{d_j} \int_{\mathcal{X}} \Big\{ b_j(\mathbf{x})(1-\mu)m(\phi(\nu^{(j)} + \delta_{\mathbf{x}}) - \phi(\nu^{(j)}))\Big\} \nu_t^{(j)}(d\mathbf{x}).
\end{aligned}
$$

↓

- **Characteristic length**
- **Heterogeneity in degree**
- **Environmental assortativity**



Mechanisms

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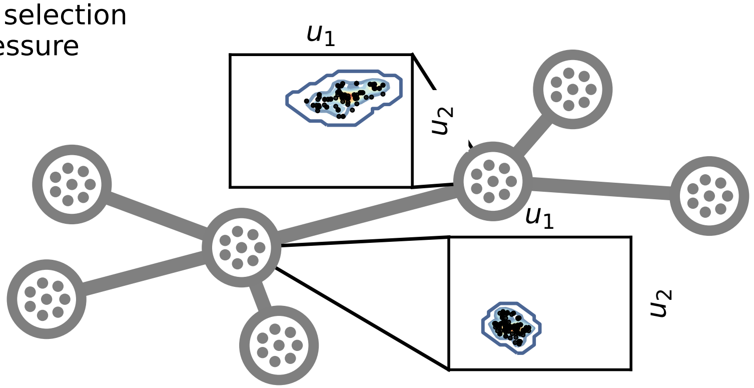
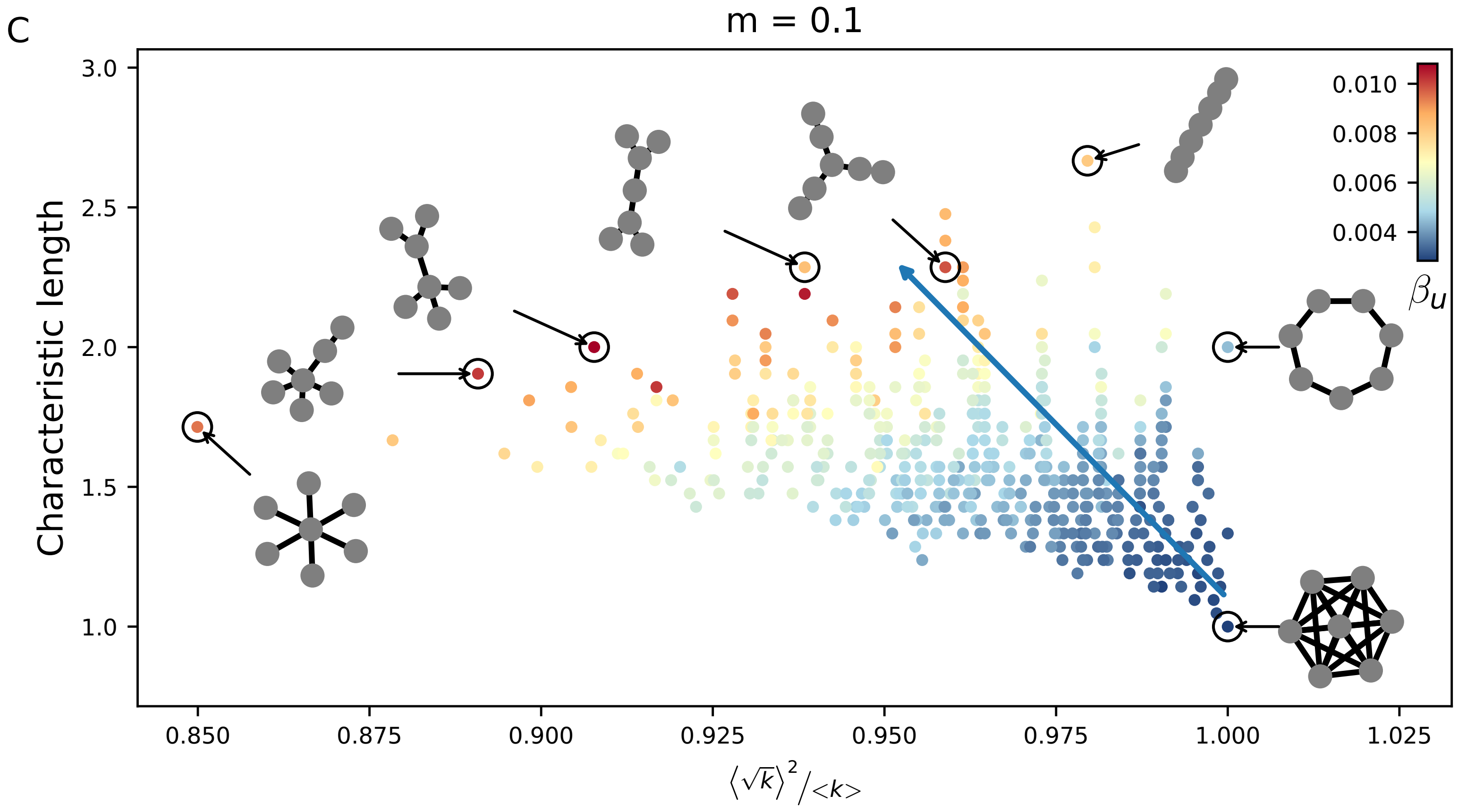
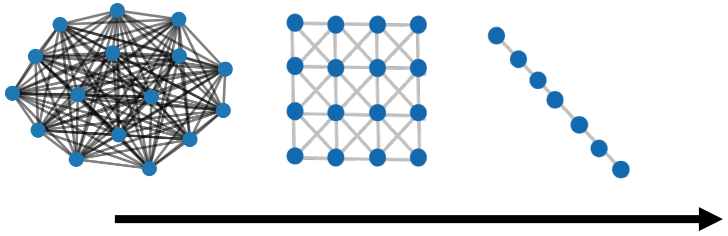
Experiment #1 – Effect of topology on differentiation

Setting (1):
no selection
pressure





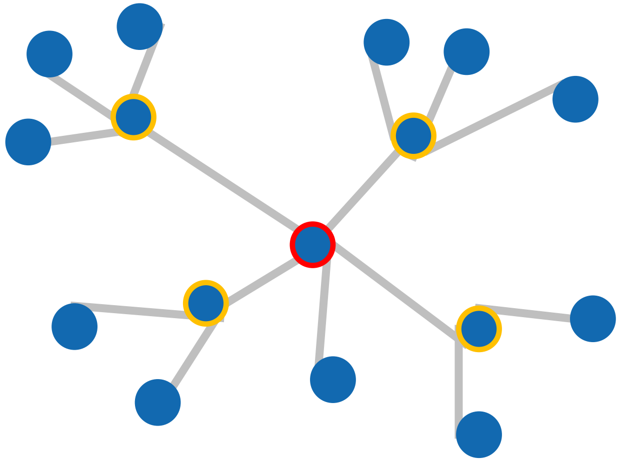
Characteristic length and heterogeneity in degree explain 88% of diversity variation



Characteristic length
~ landscape dimensionality

average shortest path between all pairs of nodes in the graph

Nodes with relatively high degree



High influx of migrants

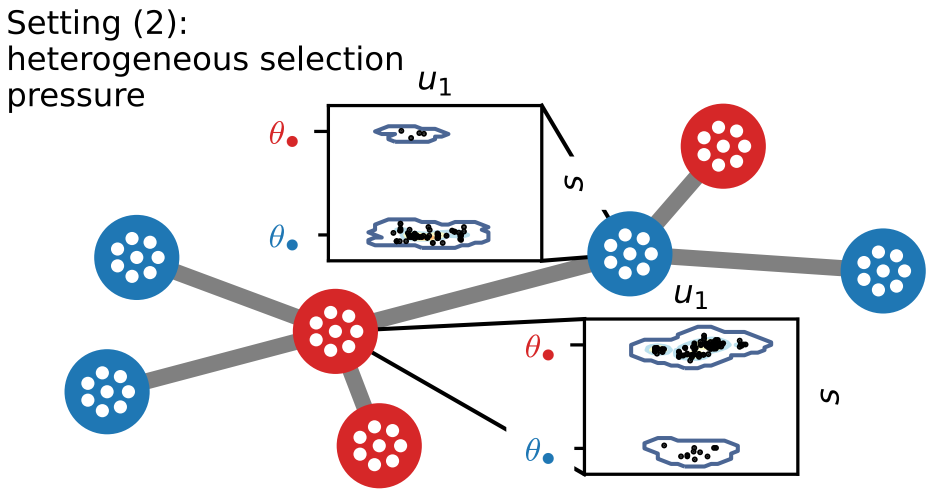
↓

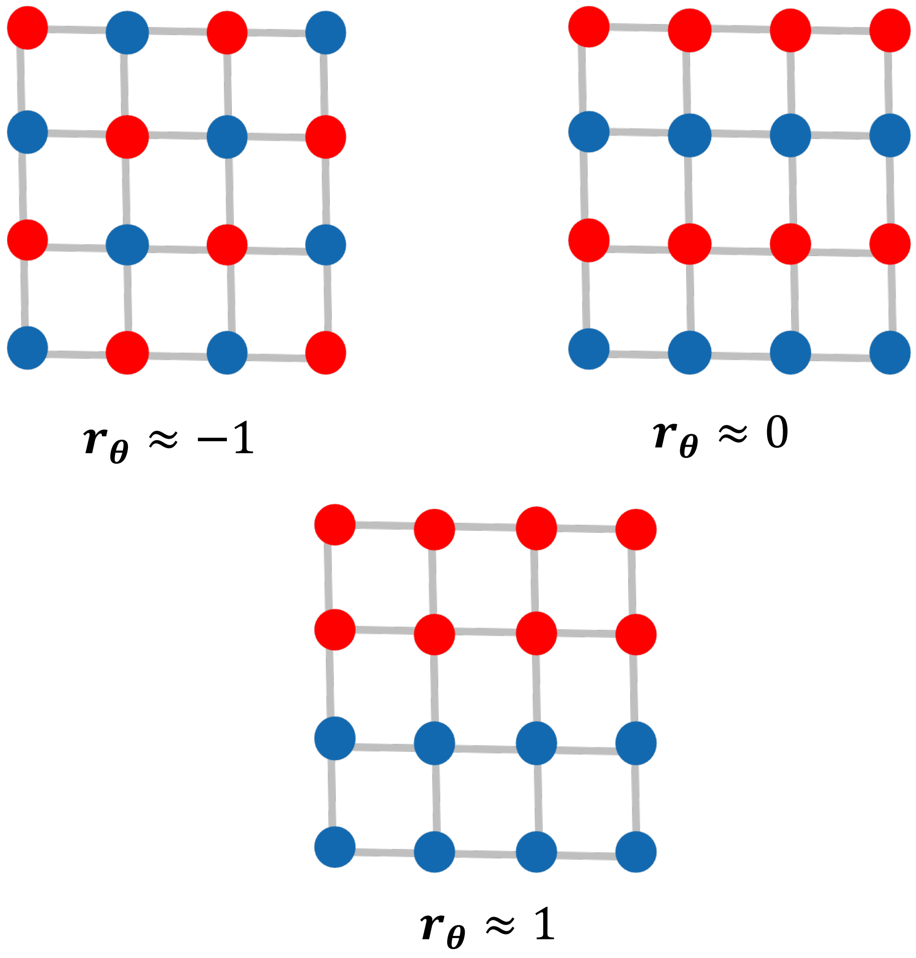
Increased competition

↓

Higher death rate → Bottlenecks
Barriers to dispersal

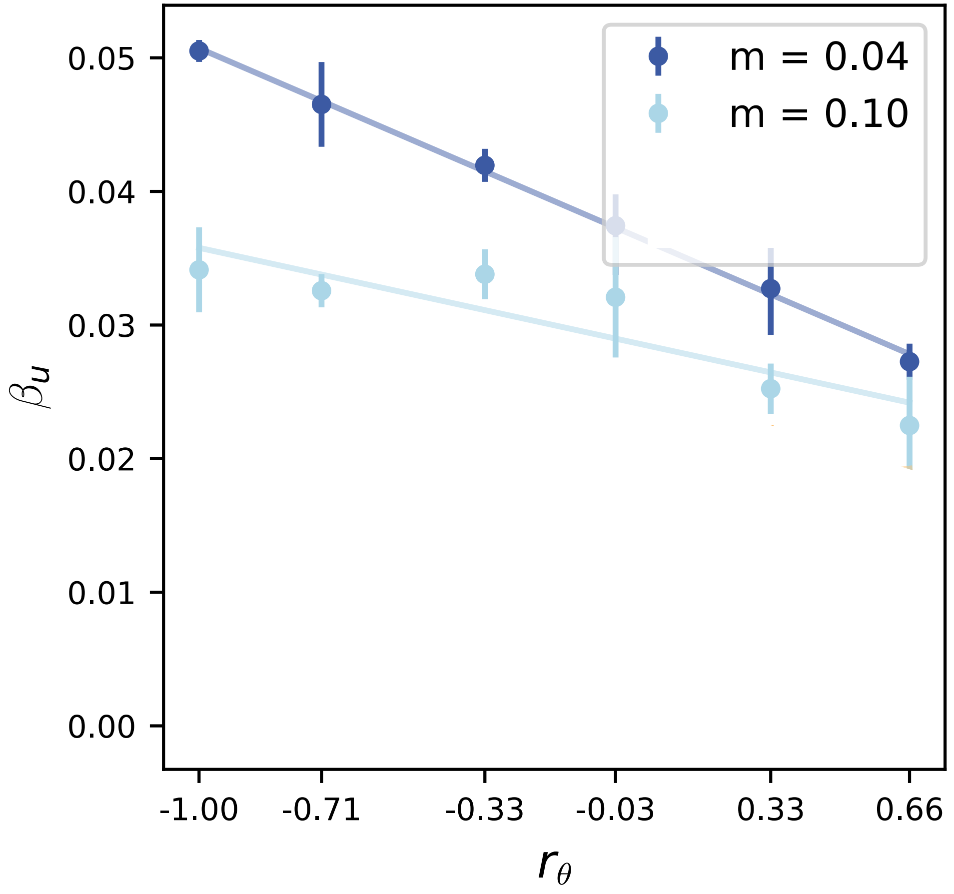
Experiment #2 – Effect of topology on adaptive differentiation

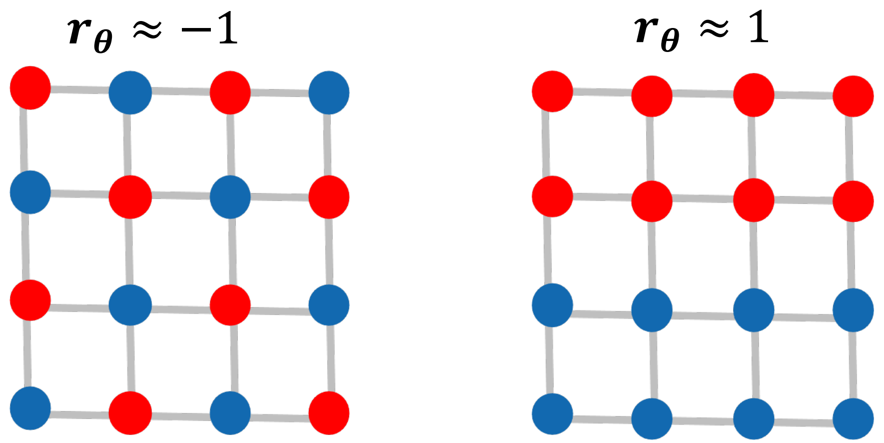




Environmental assortativity r_θ ~Environmental spatial autocorrelation

Experiment #2 – Effect of environmental assortativity on neutral differentiation





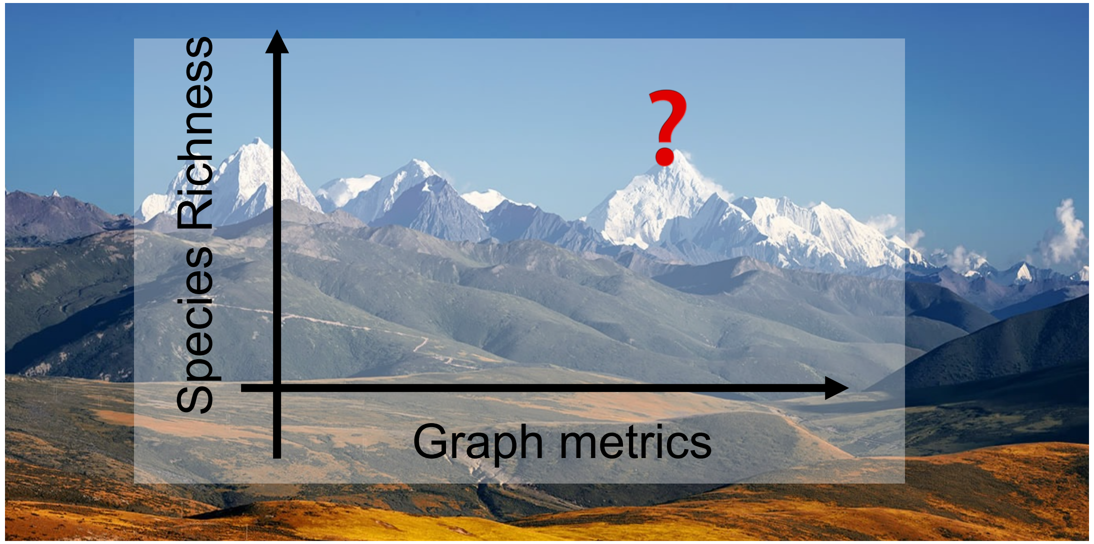
Higher environmental isolation at **low** migration rate

Higher environmental isolation at **high** migration rate

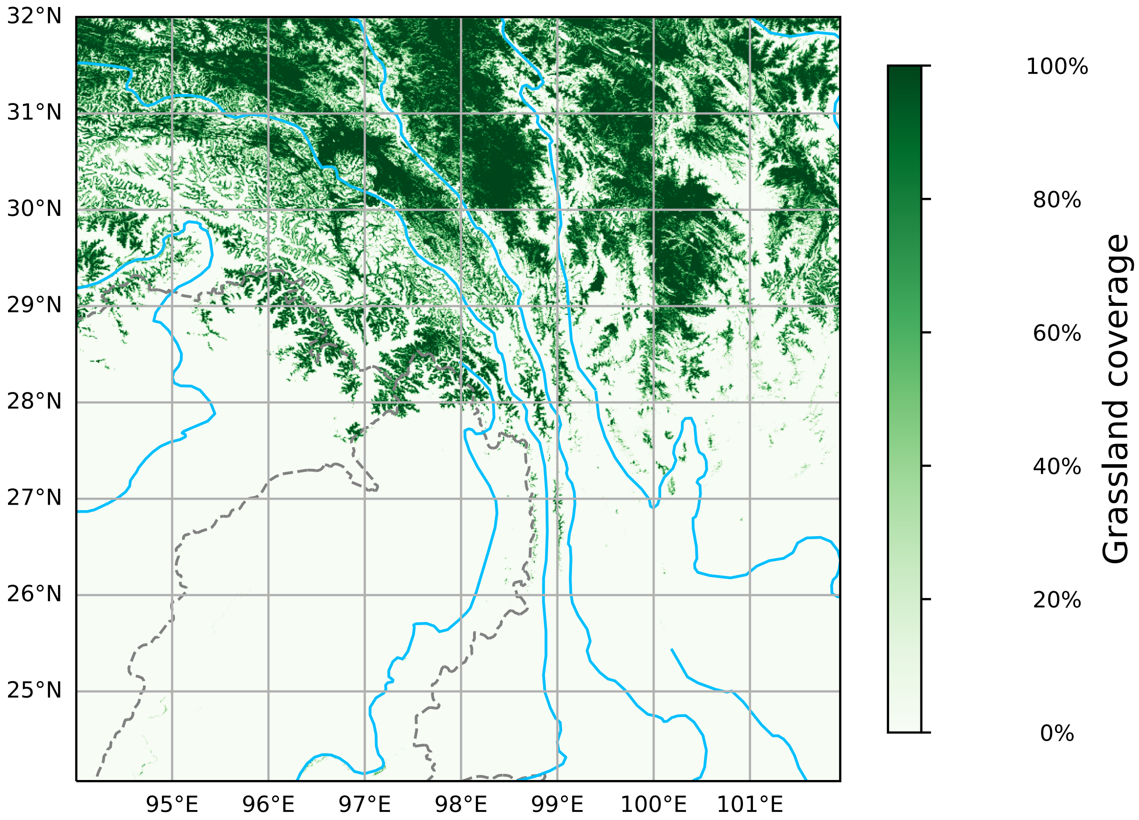
Boussange, V., & Pellissier, L. (2021). Topology and habitat assortativity drive neutral and adaptive diversification in spatial graphs. *BioRxiv*.

In revision @ **Communications Biology**

Theory validation and application



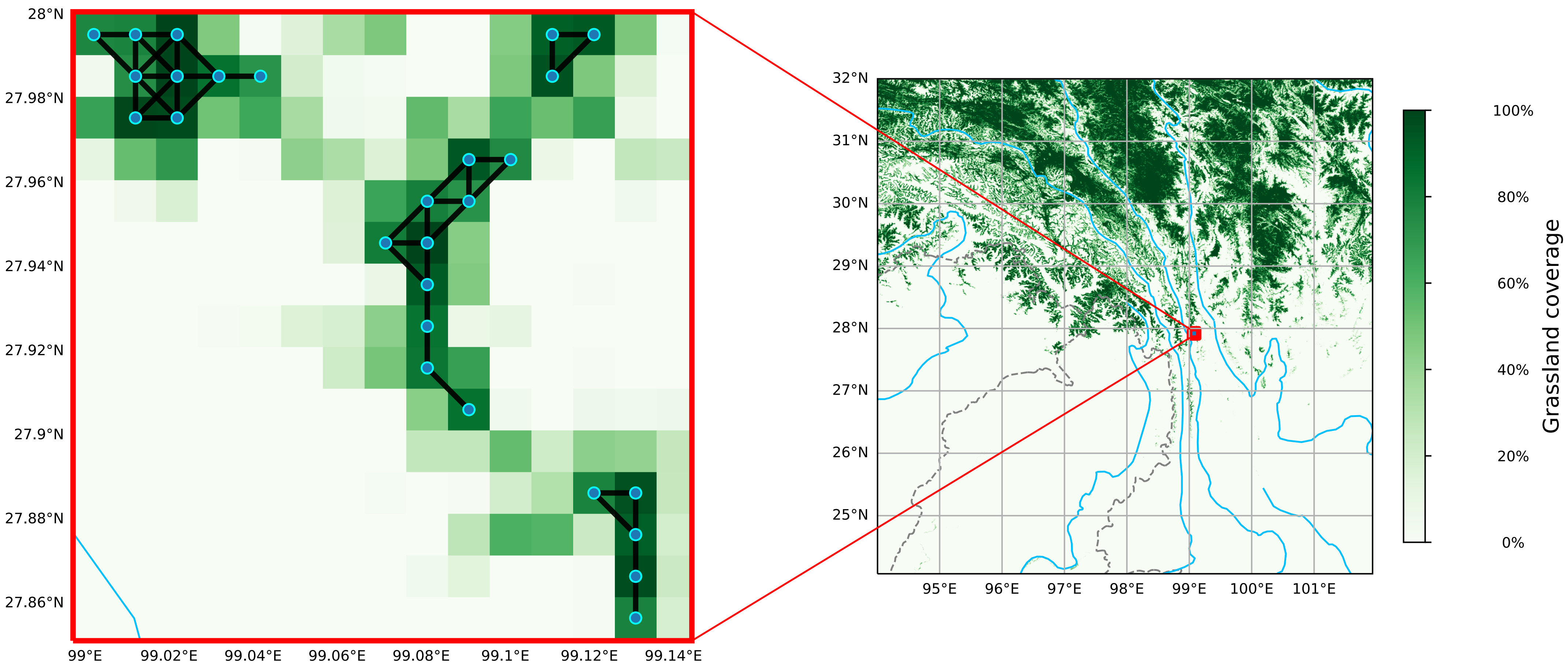
→**Project real landscapes on graphs**



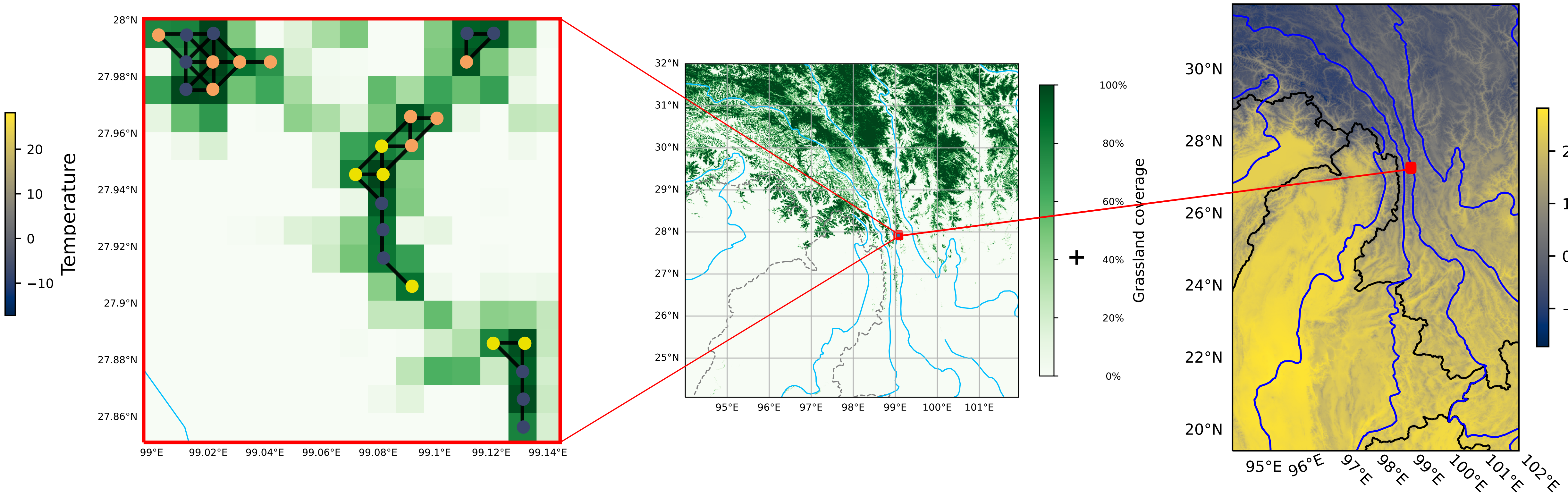
A global map of terrestrial habitat types, M. Jung et al. 2020

spatially explicit characterization of 47 terrestrial habitat types at 0.01° resolution, as defined in the (IUCN) habitat classification scheme

Graph representation

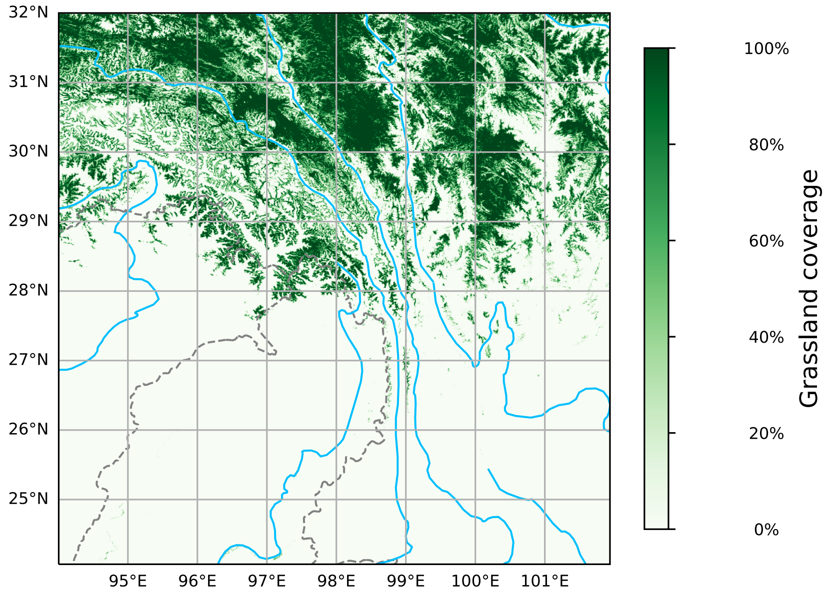


Graph representation with environmental conditions

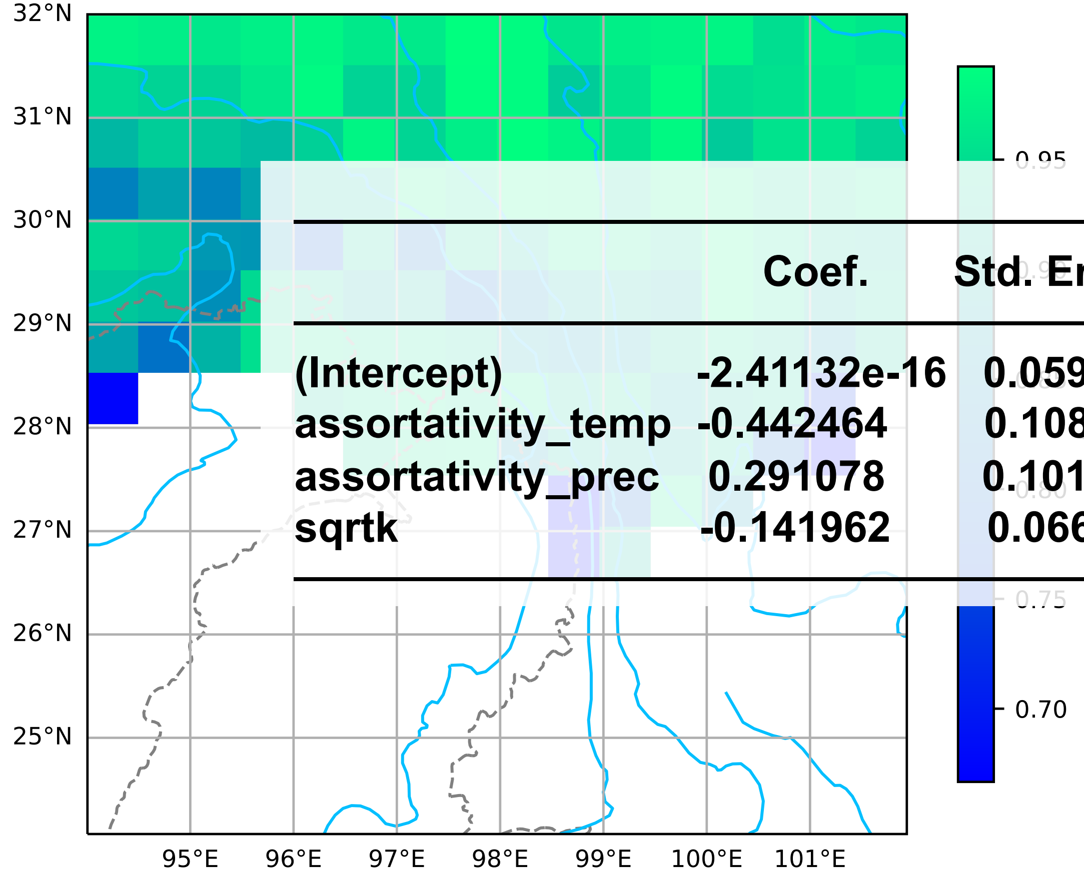


Systematic mapping of graph-based metrics

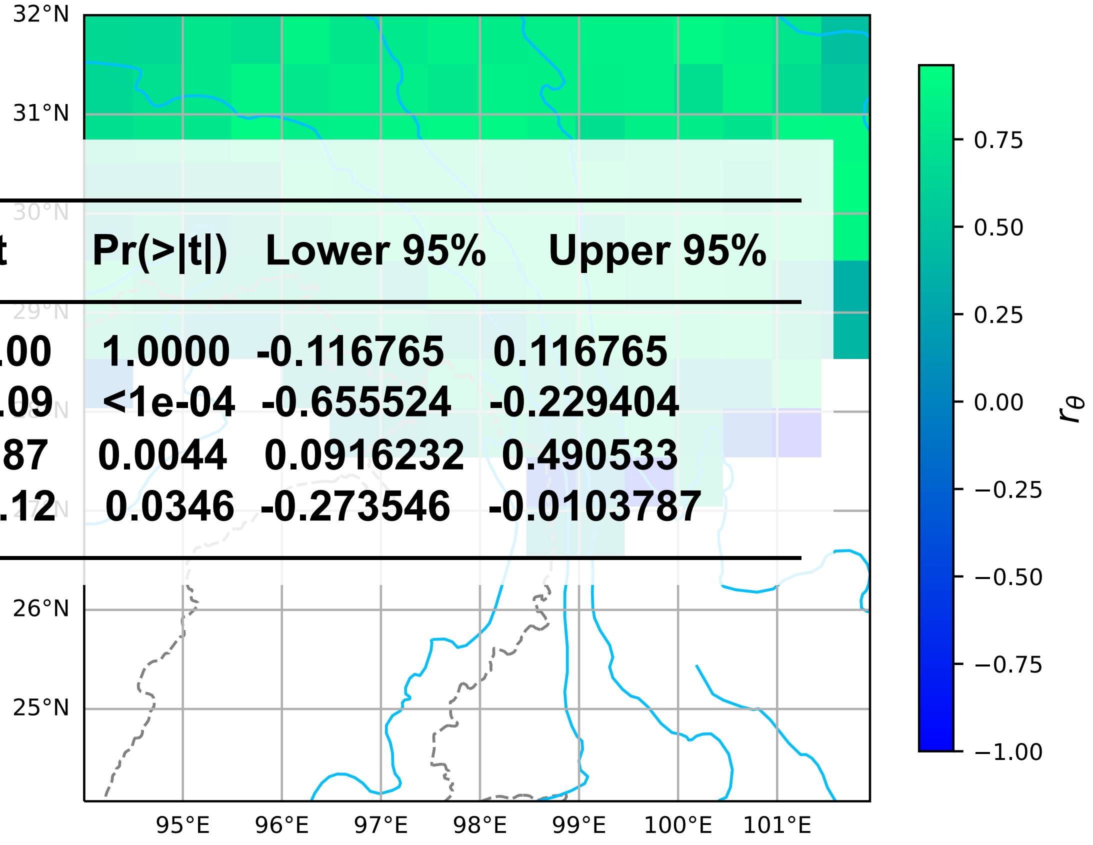
- Compute metrics for all graphs within window 0.25° x 0.25°
- Average
- Reproject on map with pixel size 0.25° x 0.25°
- Correlate with empirical data



Heterogeneity in degree



Temperature assortativity



	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	-2.41132e-16	0.0592843	-0.00	1.0000	-0.116765	0.116765
assortativity_temp	-0.442464	0.108175	-4.09	<1e-04	-0.655524	-0.229404
assortativity_prec	0.291078	0.101268	2.87	0.0044	0.0916232	0.490533
sqrtk	-0.141962	0.0668082	-2.12	0.0346	-0.273546	-0.0103787

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Acknowledgements

Loïc Pellissier

Yaquan Chang

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Thanks!
(looking for a position next year ☺)

Check out my personal website

to discover more
about my research