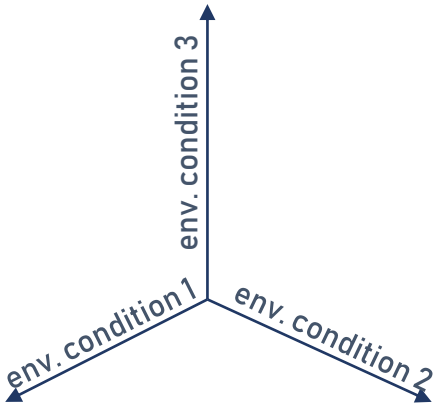
Assessment of the Climatic Connectivity of the Austrian Protected Area Network

Under the supervision of: Stefan Dullinger, Philipp Semenchuk & Dietmar Moser

Perle Charlot - 12 June 2019

Introduction

Fundamental Niche (Hutchinson, 1957)



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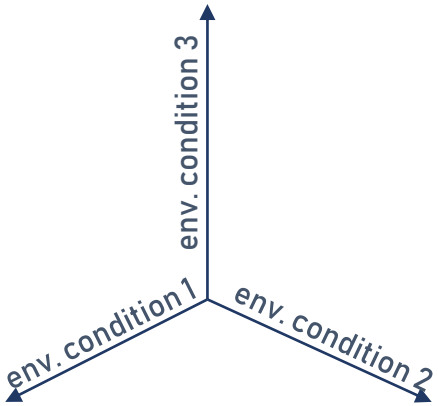

Species' geographical distribution

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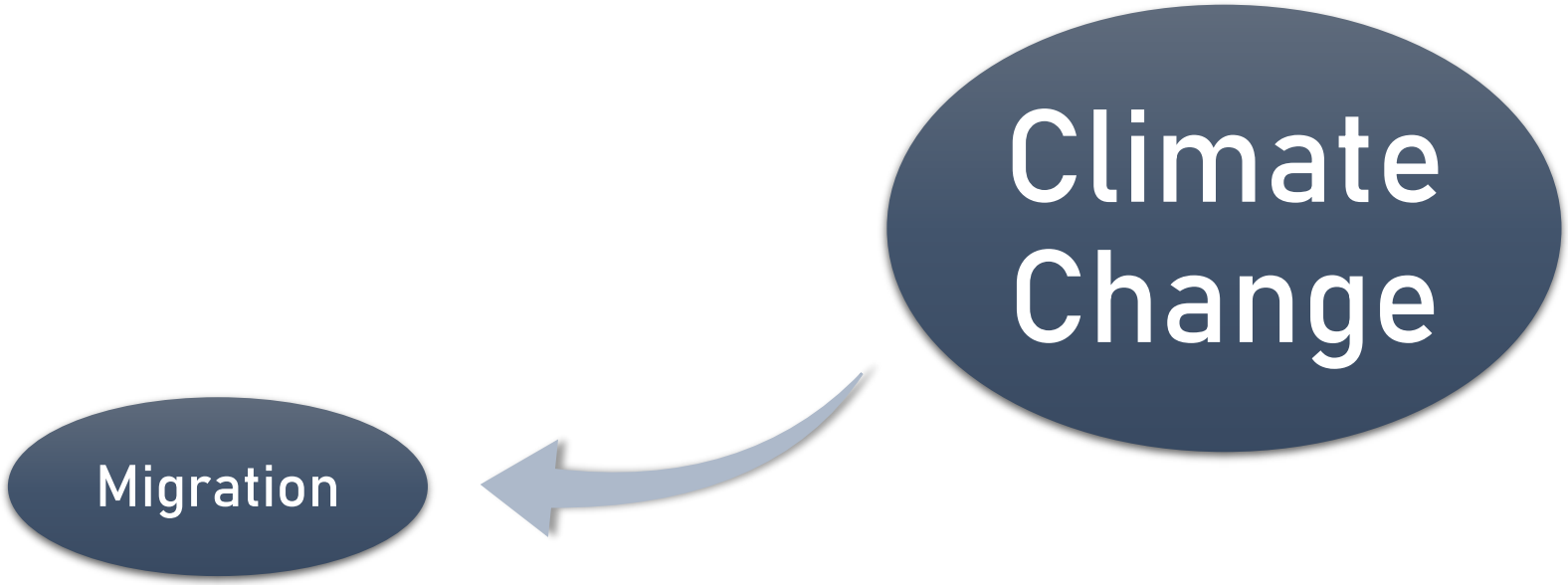

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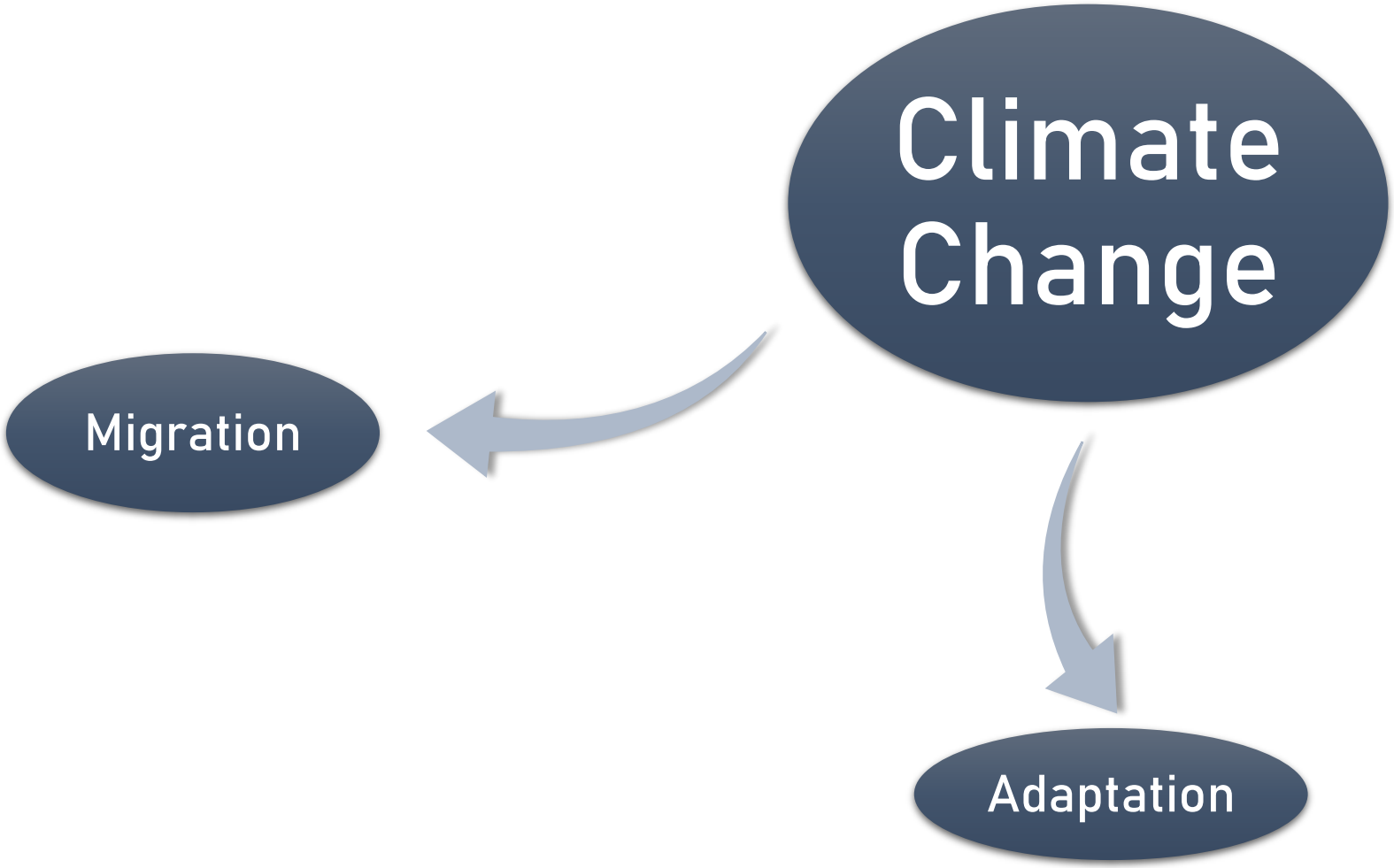

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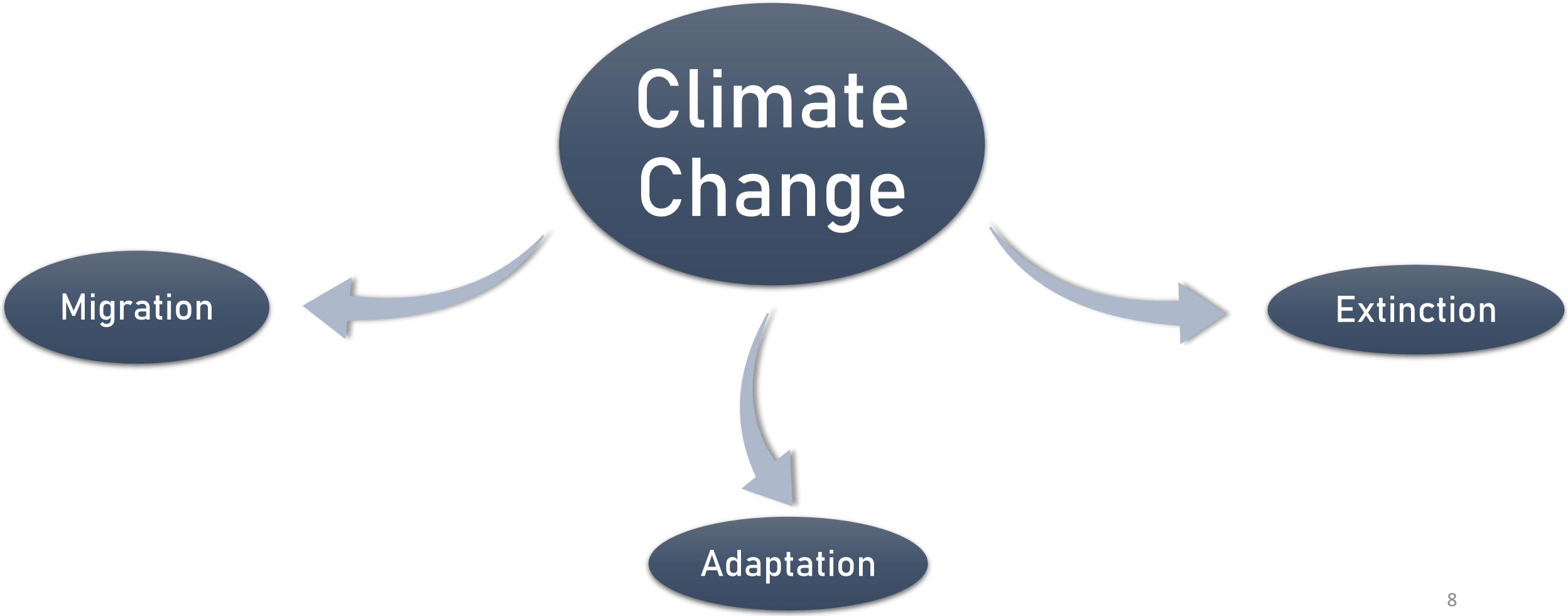

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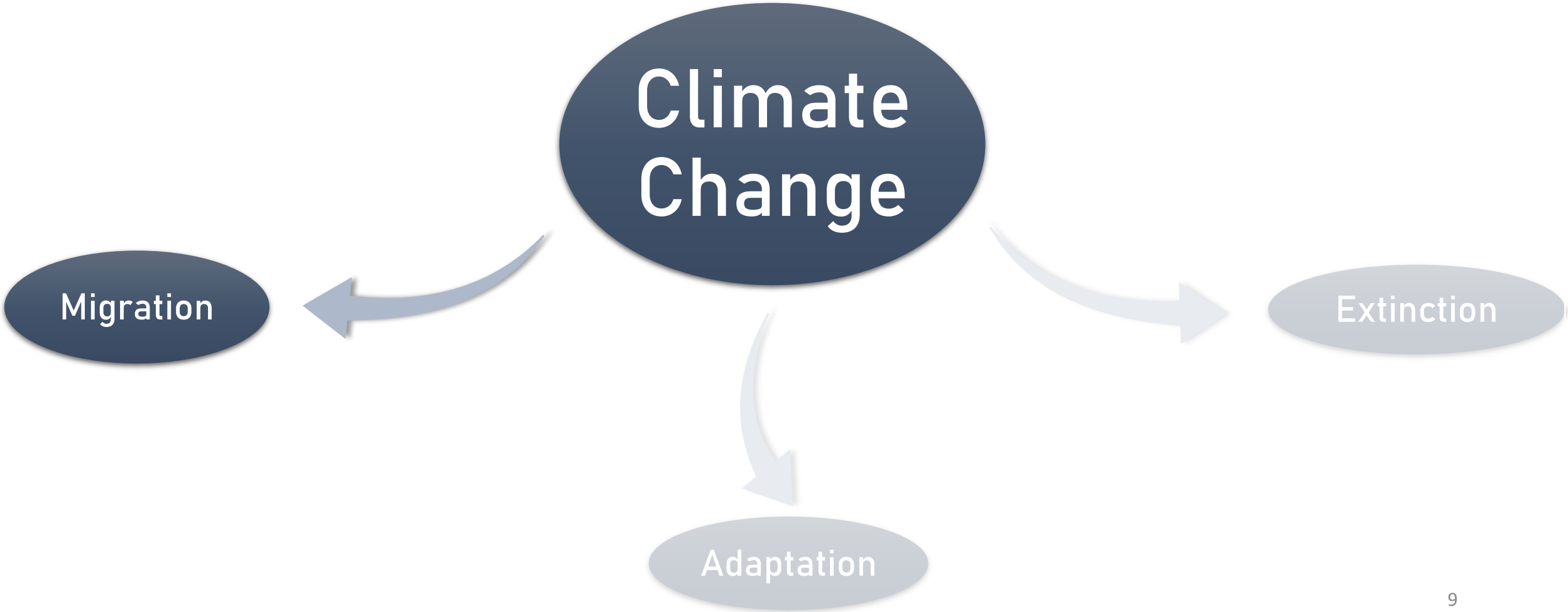

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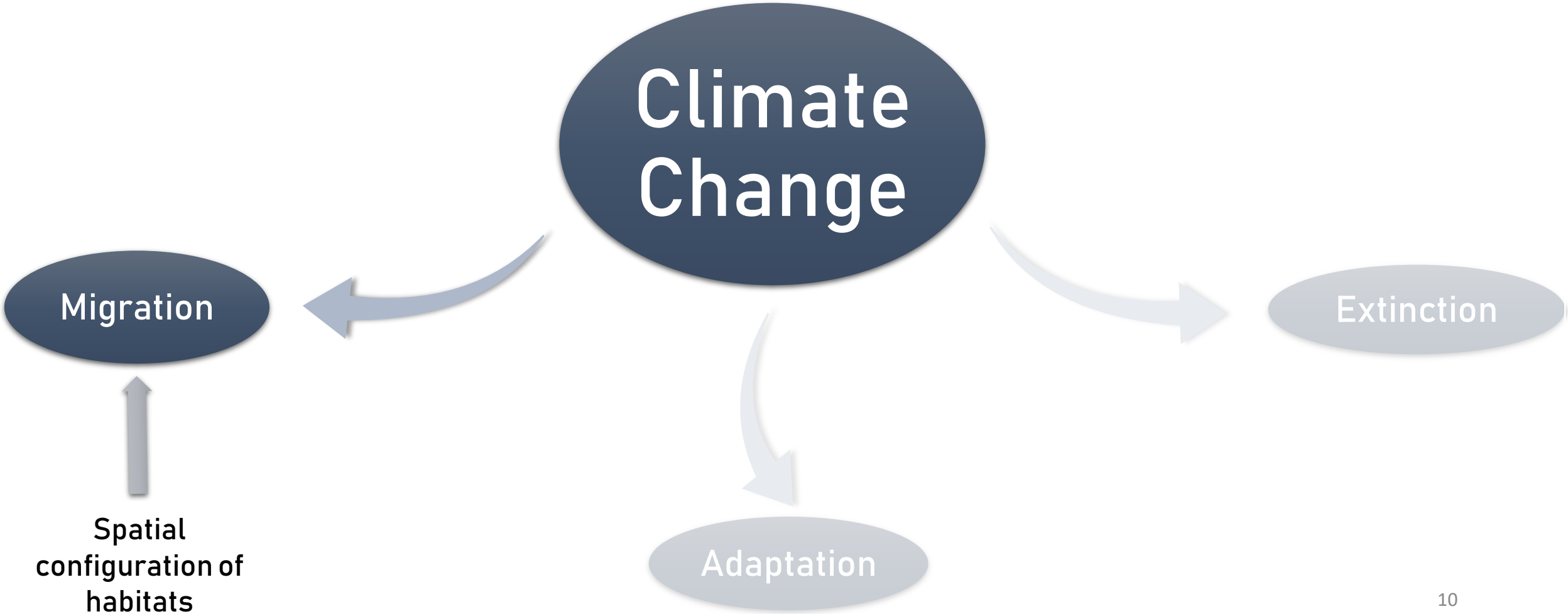
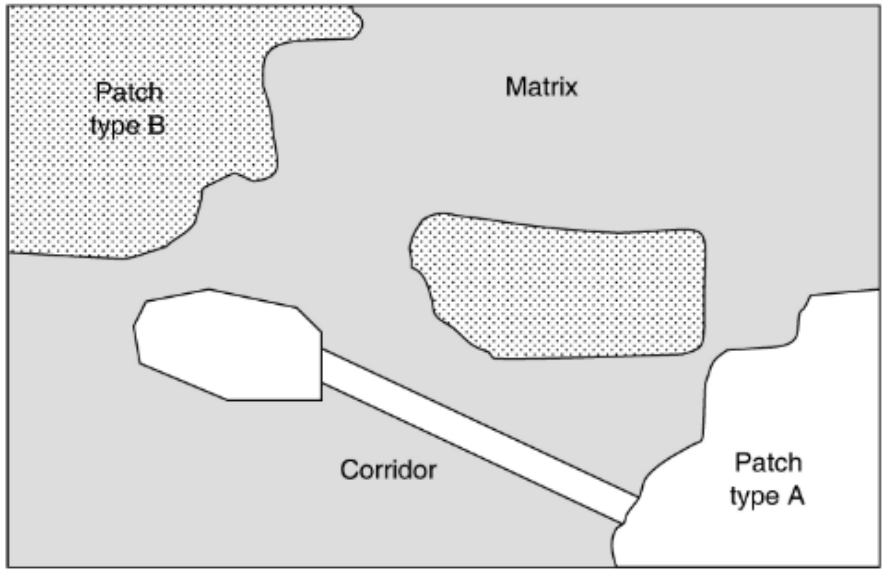


Spatial configuration of habitats



Source : Tischendorf & Fahrig. 2000. Oikos.

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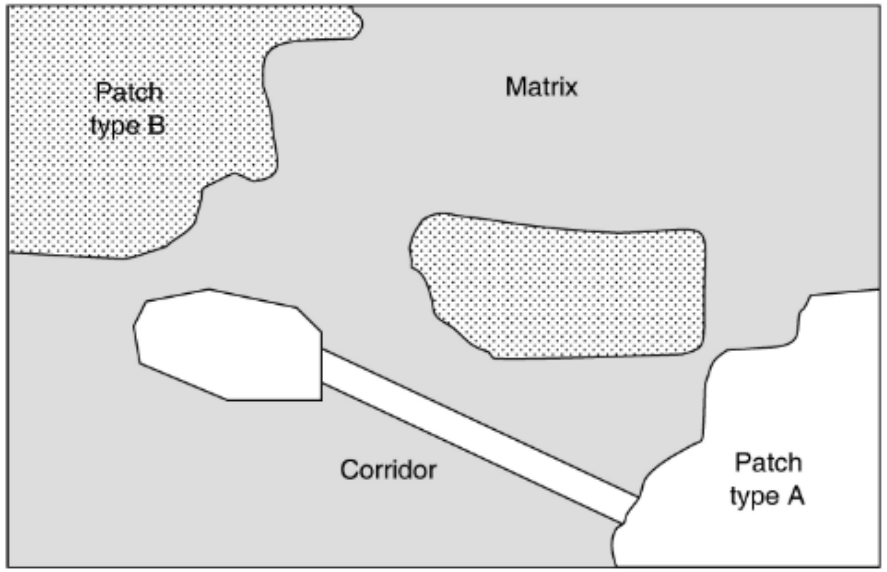

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Connectivity

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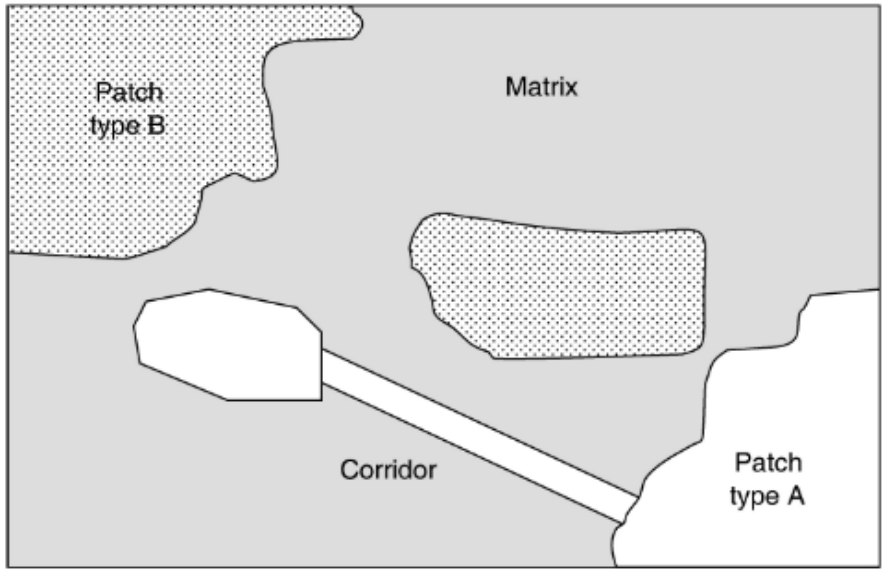

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Connectivity

Genes ⇆ Individuals

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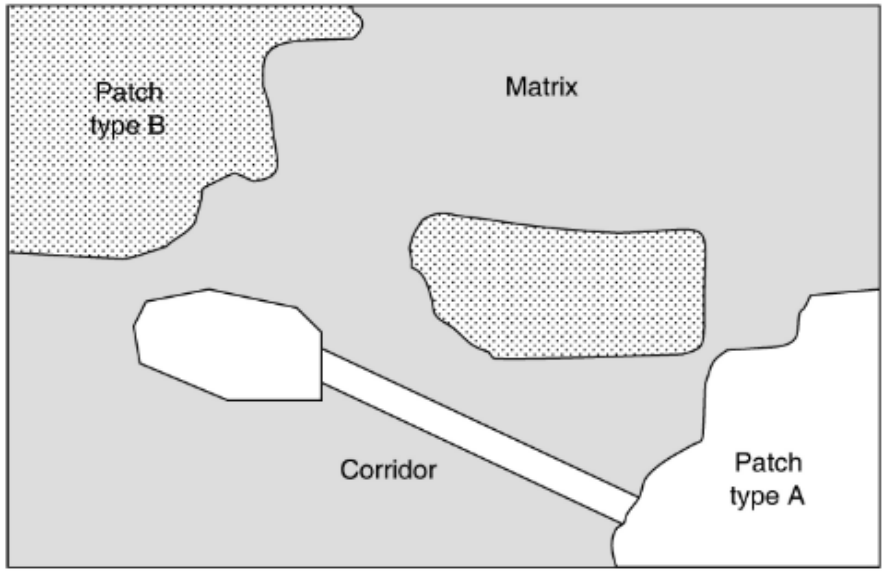

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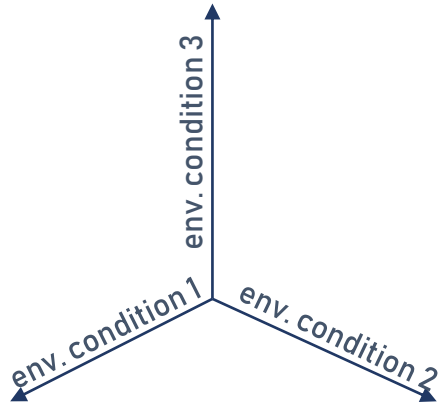
Suitable Niche



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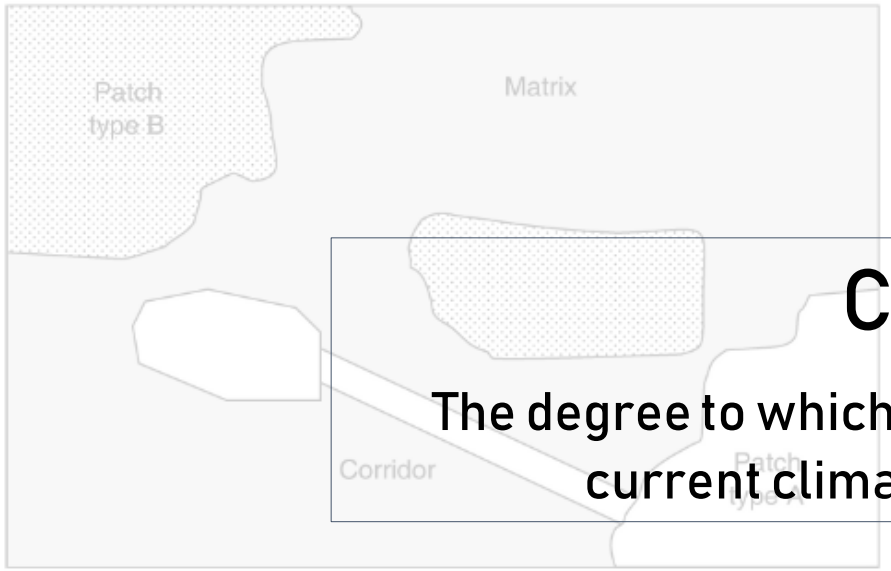

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Connectivity

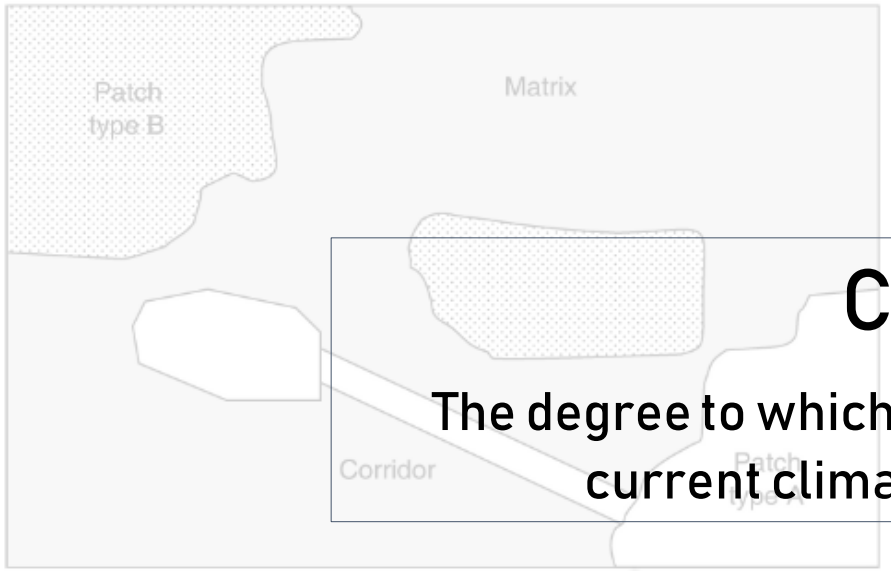
Climatic Connectivity

The degree to which habitats allow species they support to track their current climatic conditions via movement through them.

Genes ⇆ Individuals

Suitable Niche

Spatial configuration of habitats



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Connectivity

Climatic Connectivity

The degree to which habitats allow species they support to track their current climatic conditions via movement through them.

Genes ⇄ Individuals

Suitable Niche

Corridors?

Research Question

To what extent will the spatial connectivity of the current protected area network allow species to track their appropriate climate in the face of climate change?

To which degree the design of new corridors among existing protected sites could improve the climatic connectivity of the network?

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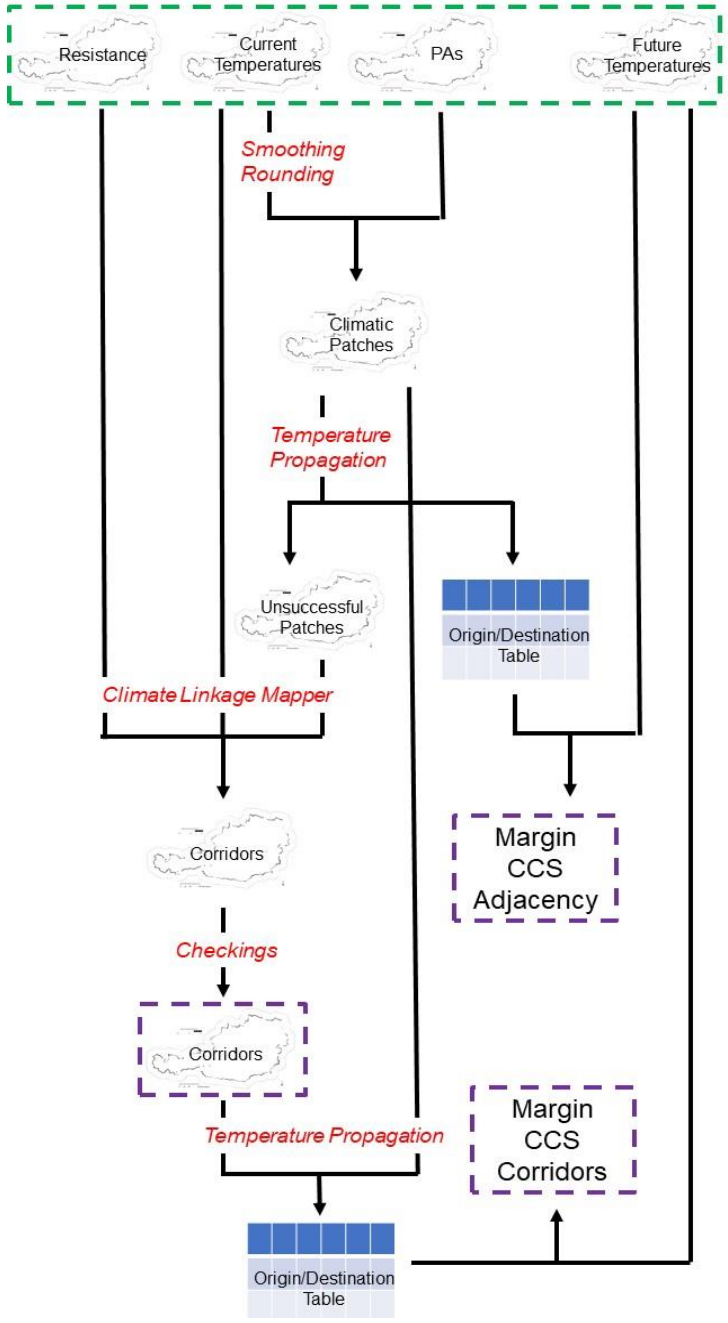
Approach :

- Temperature-analogous and temperature propagation
- Future climate projections
- Least-cost distance modelling to design corridors

(methods developed by Nuñez *et al.* (2013) and McGuire *et al.* (2016))

Methods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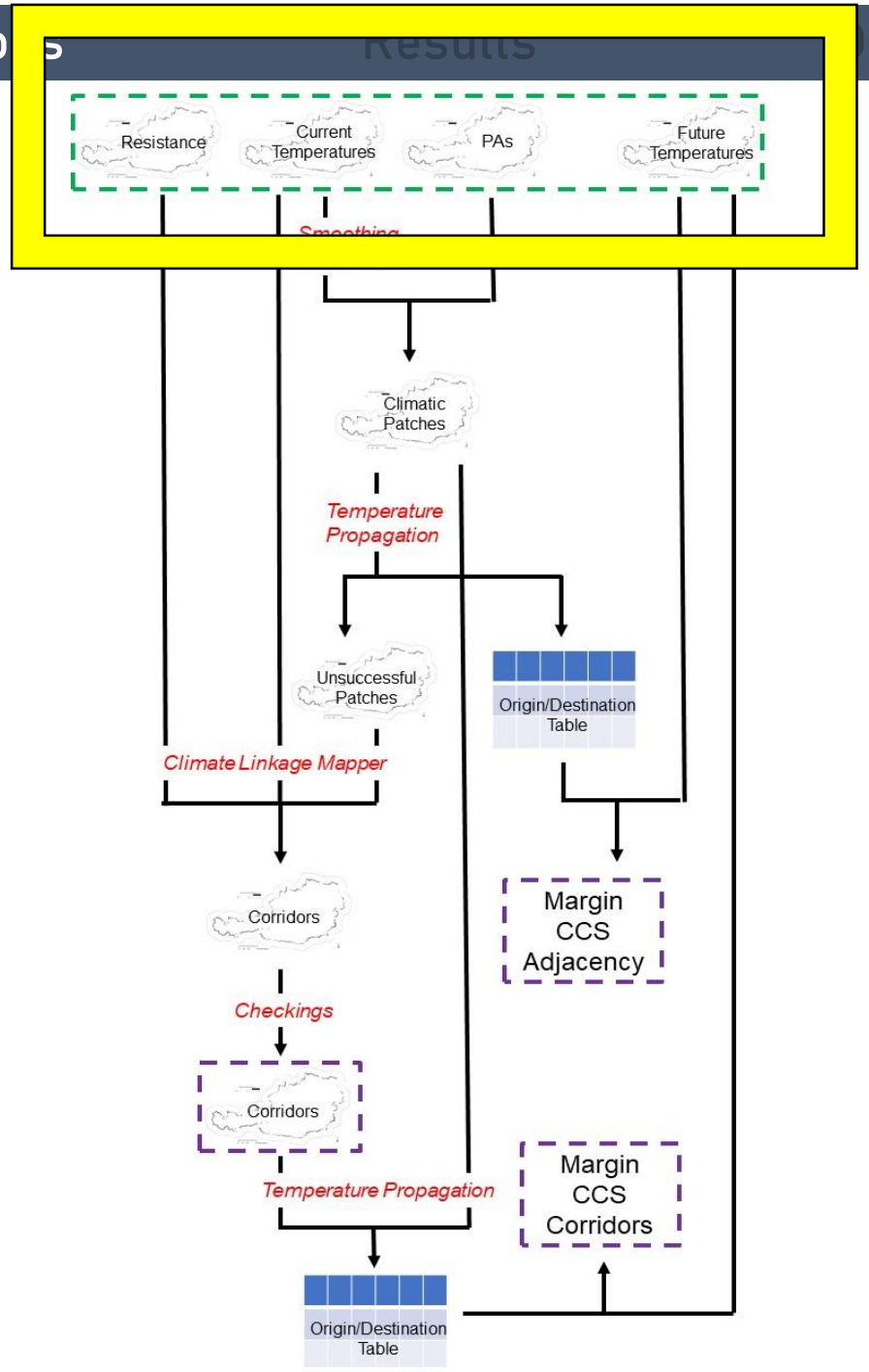
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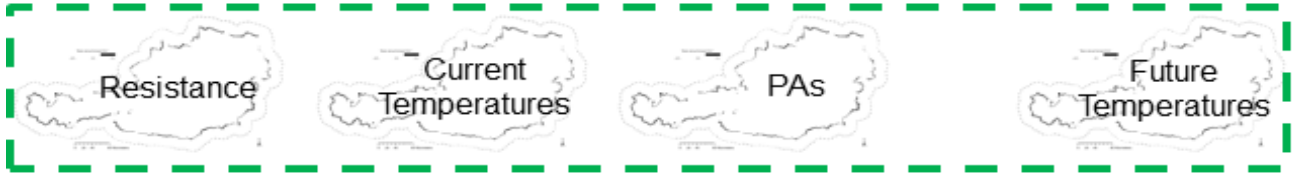
Inputs Data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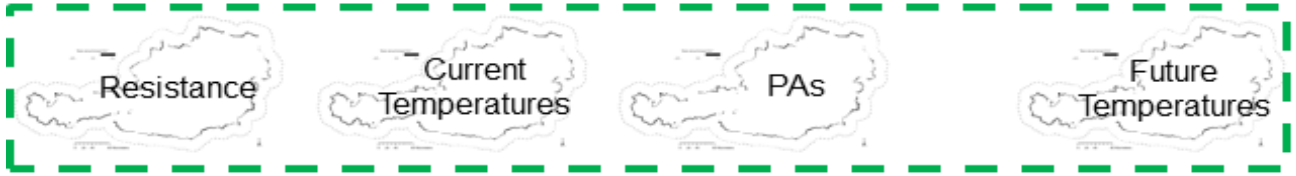

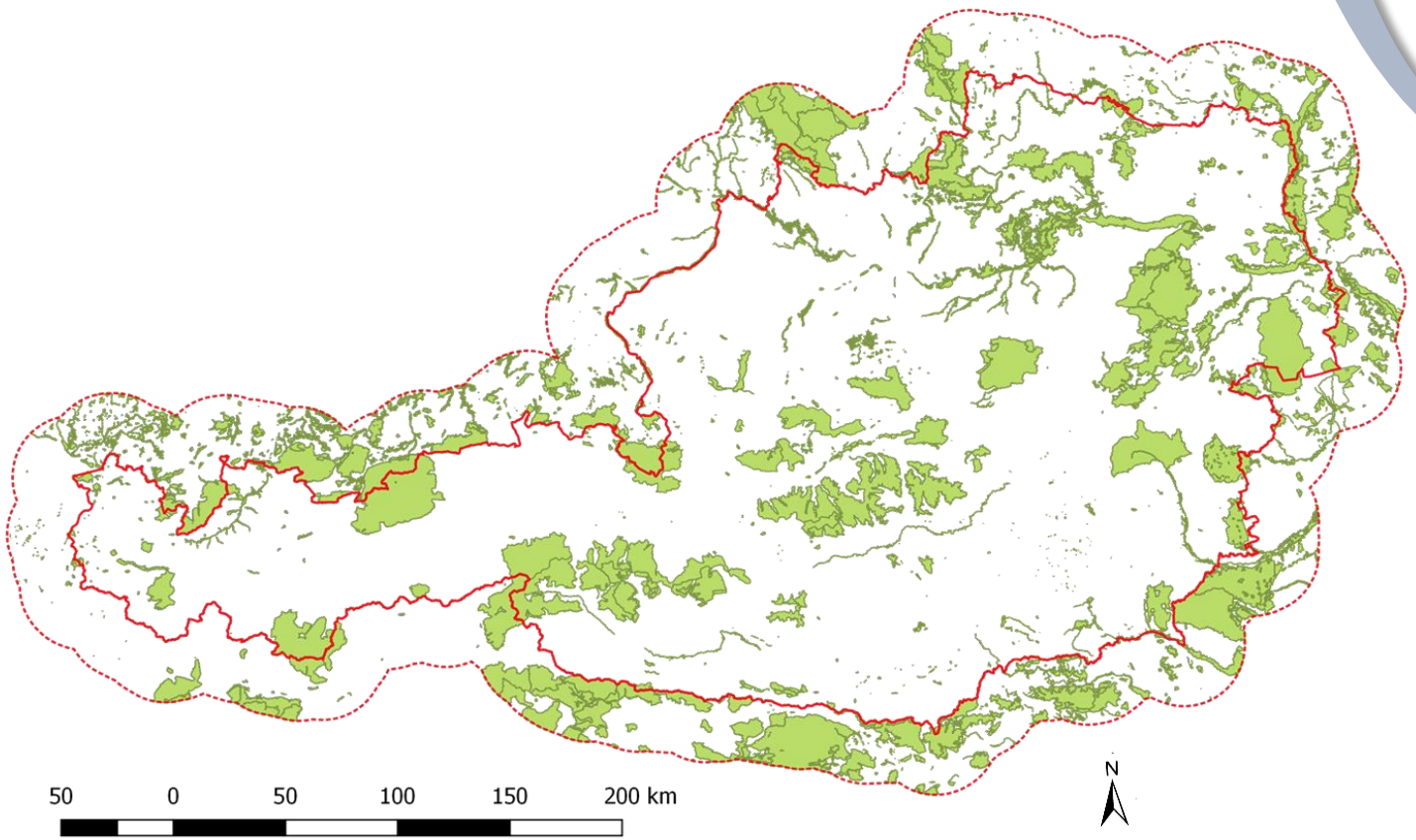

I, II, III IUCN categories + Natura 2000 = 1849 PAs = 24 960 km² (19%)

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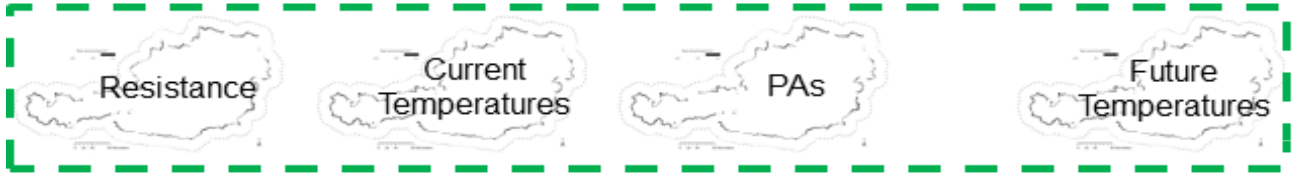
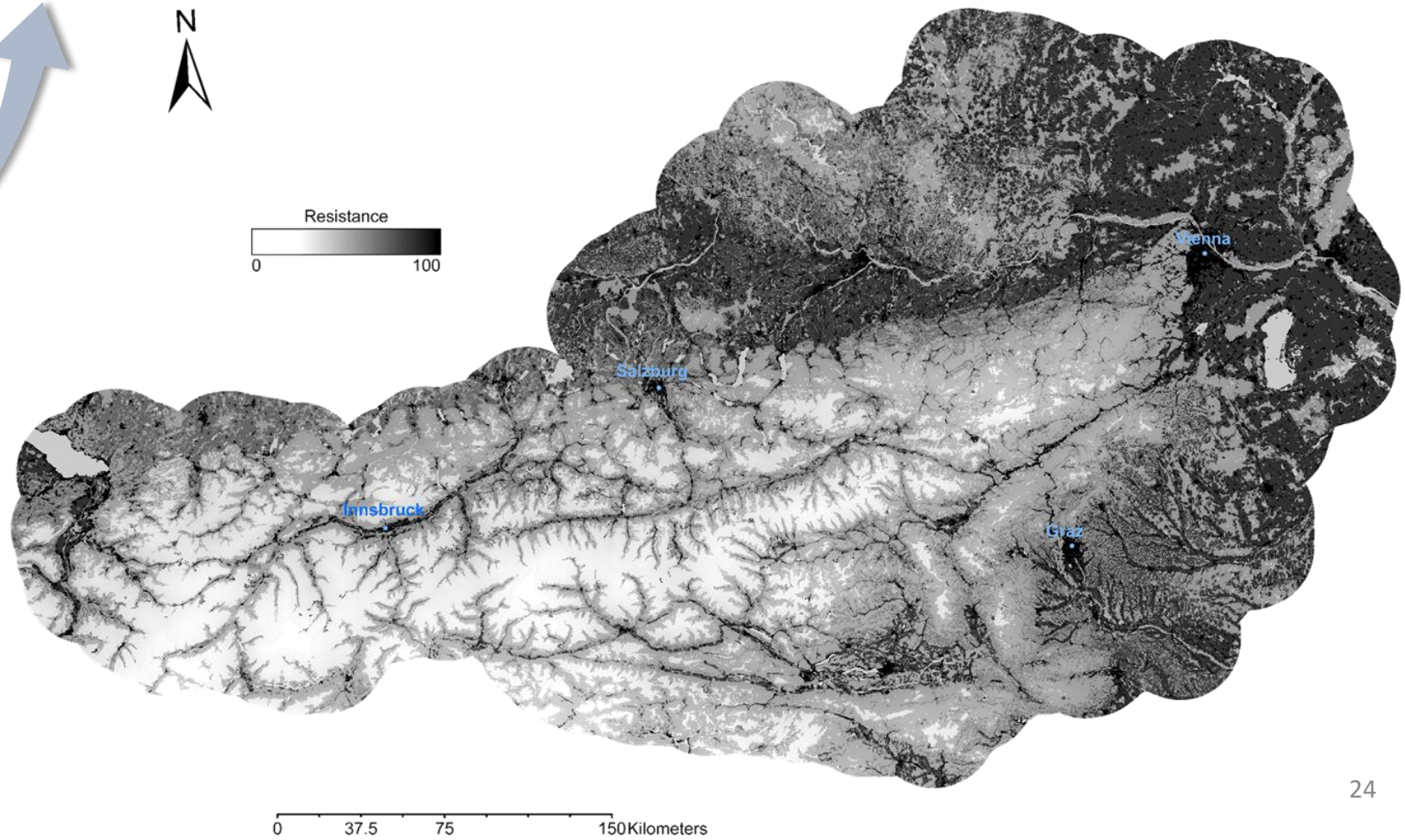


Wilderness continuum map (Plutzar *et al.*, 2013)



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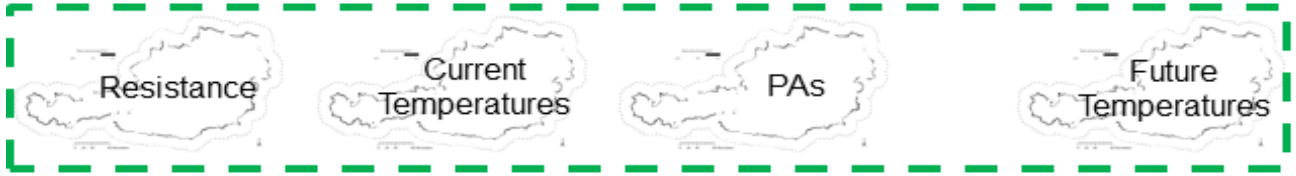
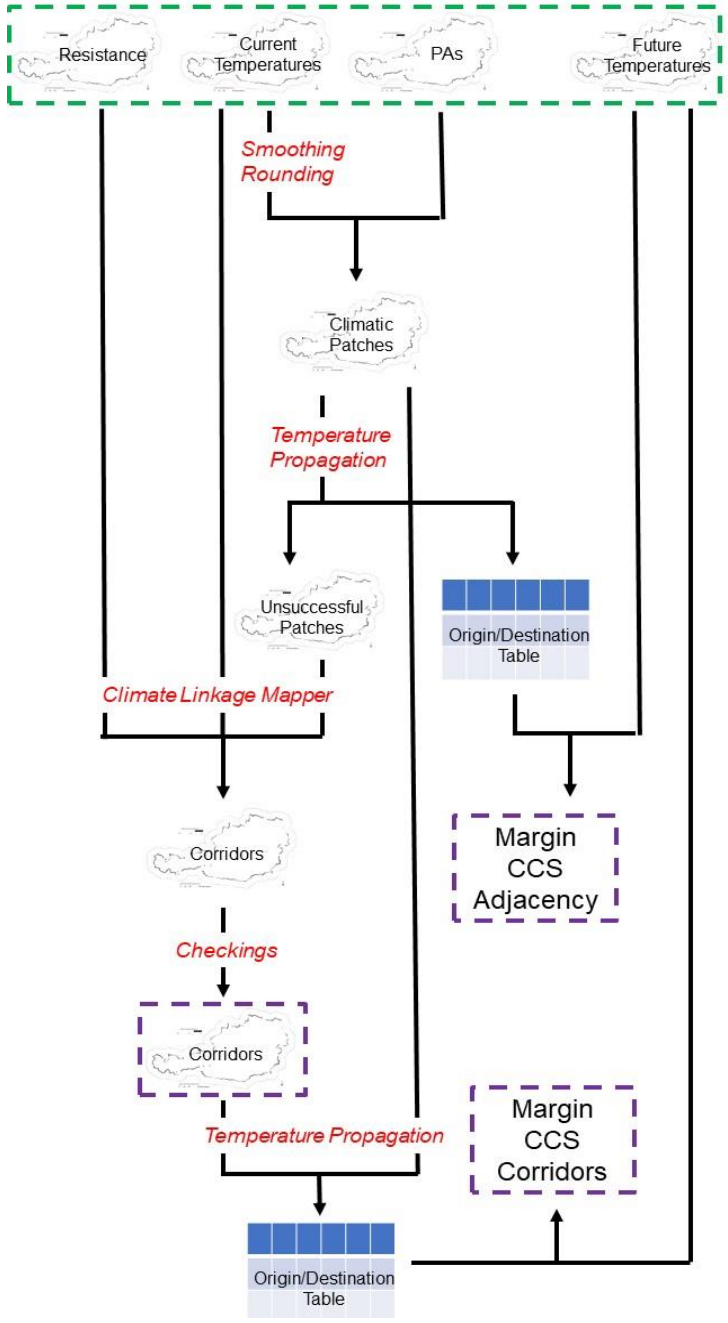


WorldClim:
Annual average temperature 1960-1990
100m resolution

EURO-CORDEX :
ALADIN-Climate Regional Climate Model
RCP2.6, 4.5 & 8.5
100m resolution
2030, 2040, 2050, 2060, 2070 & 2080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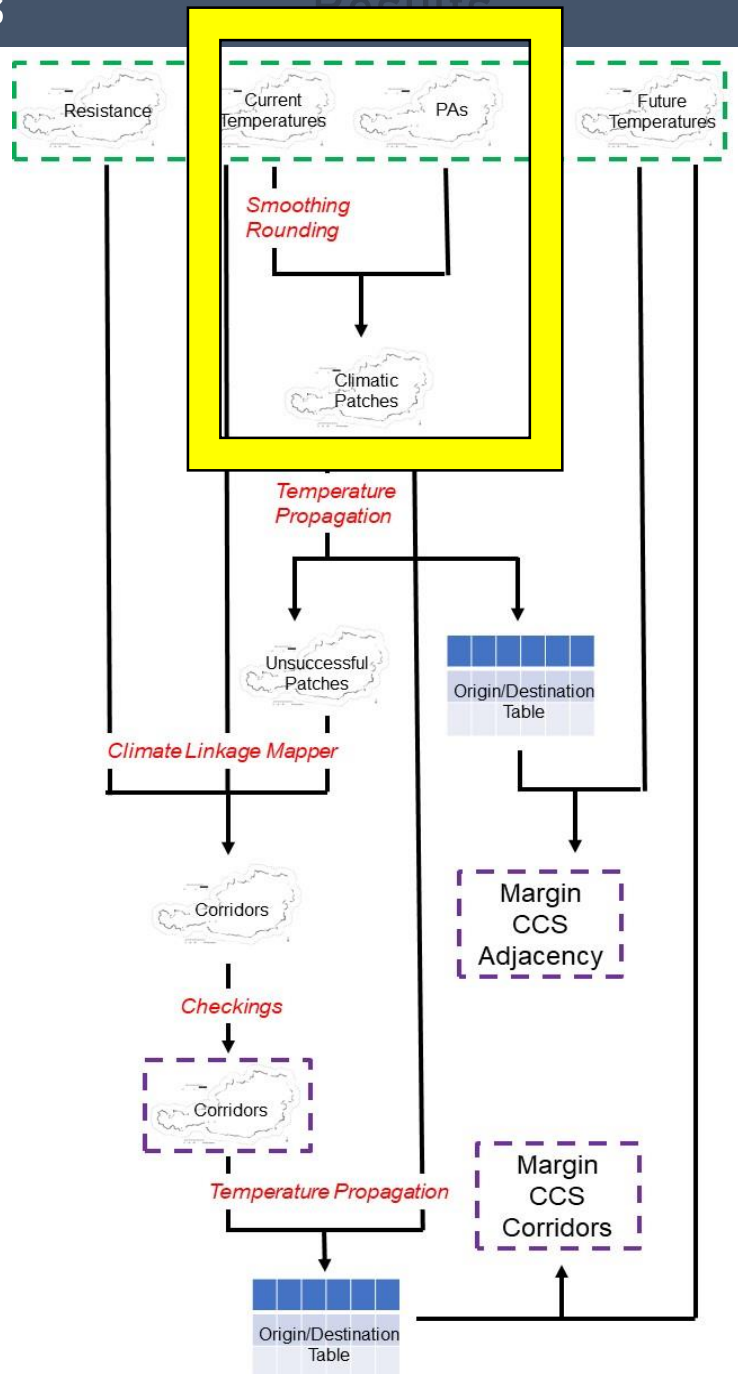
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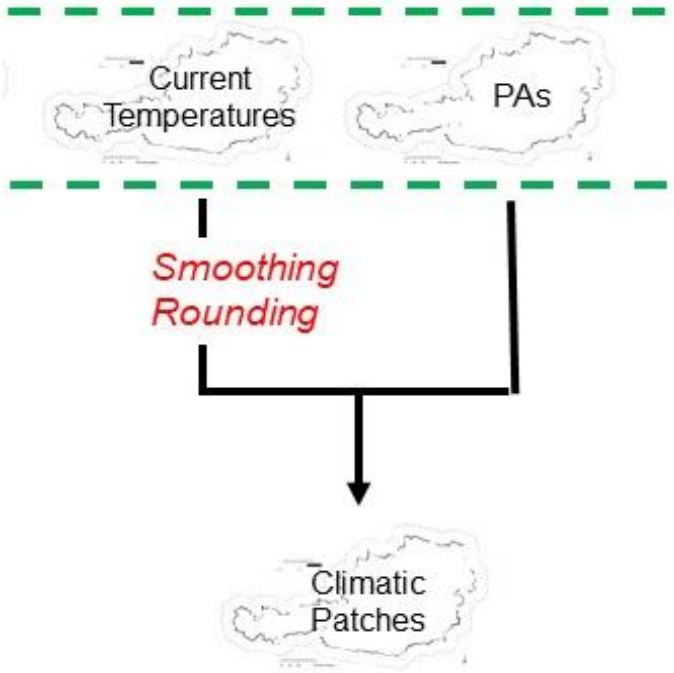
Climatic Patches Partitioning



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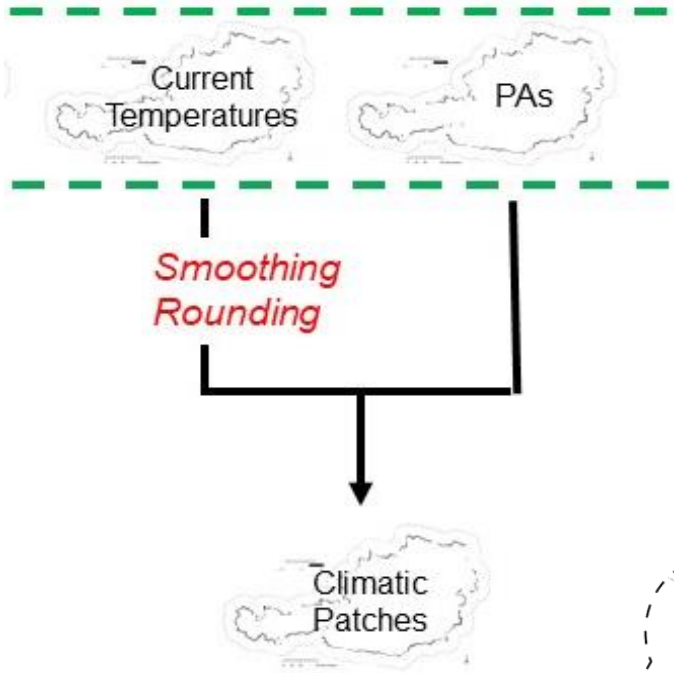
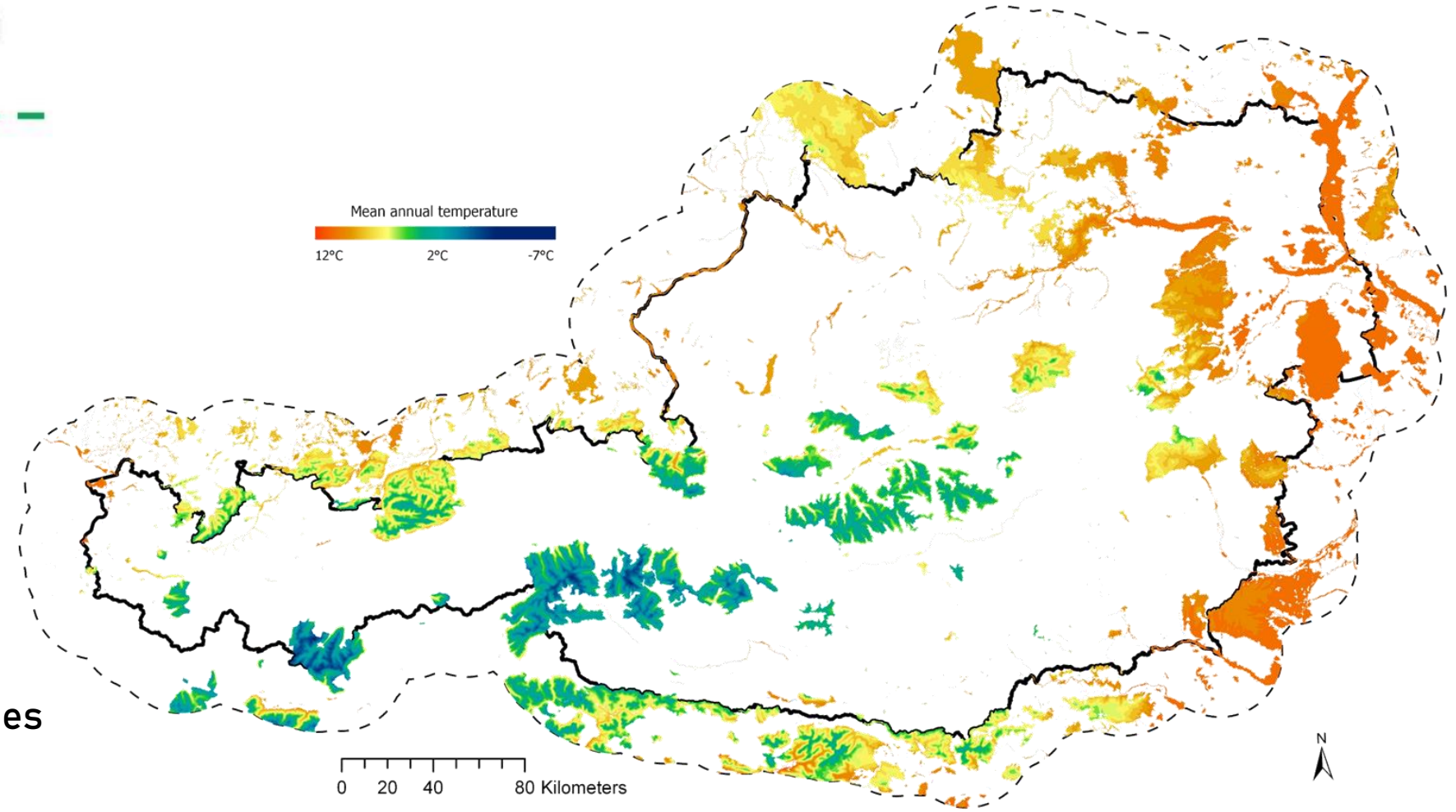
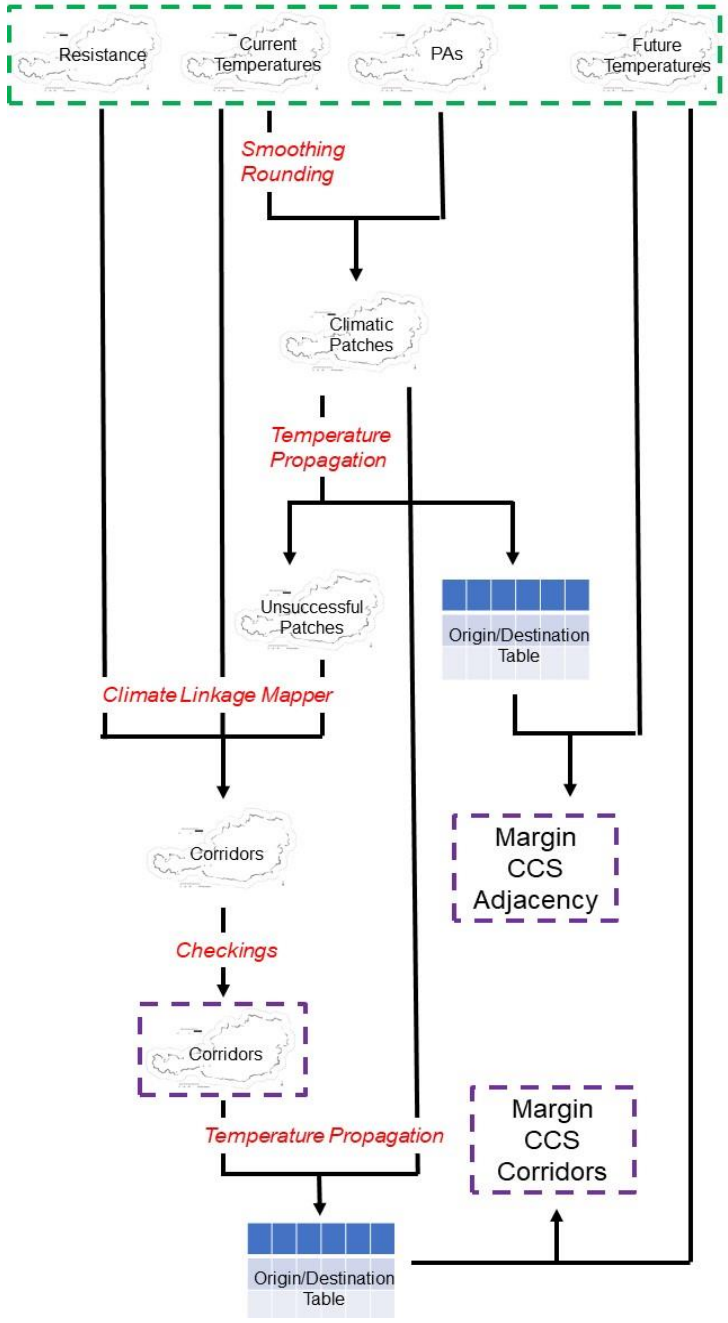




7530 homogenous patches with 1°C increment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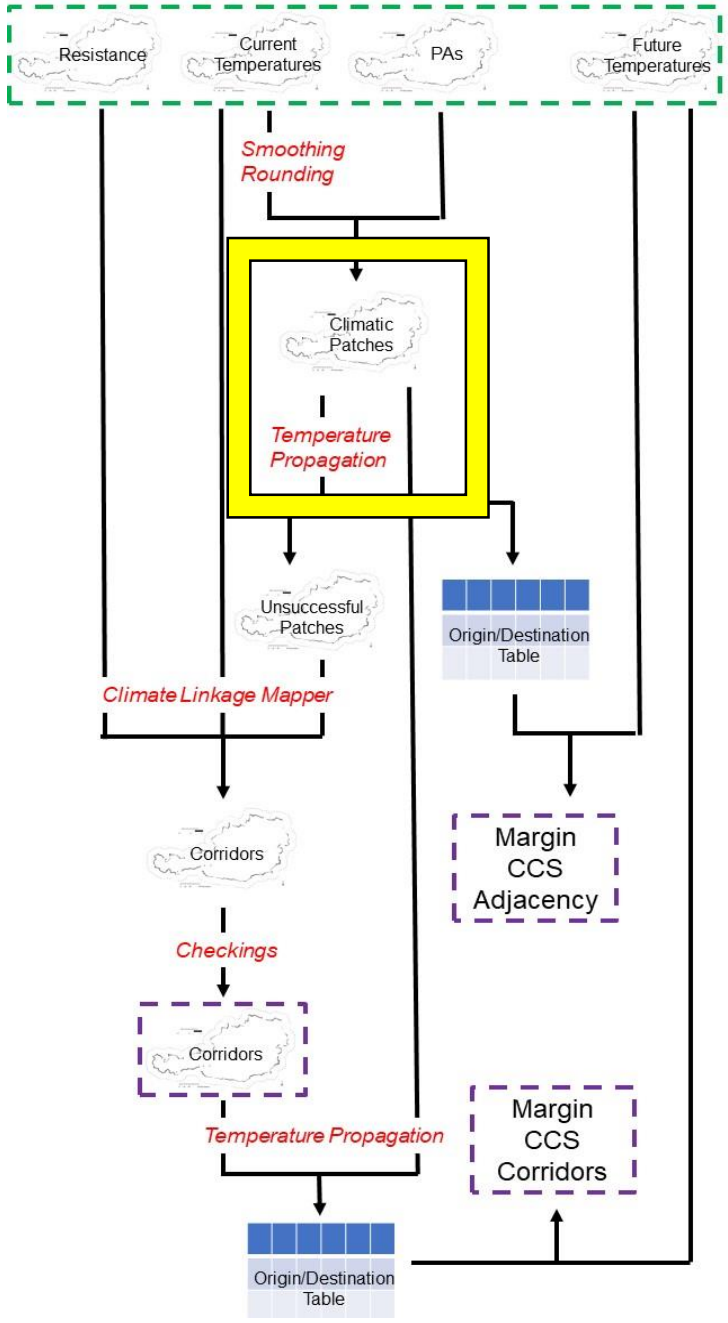
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Connecting Climate Analogous Patches

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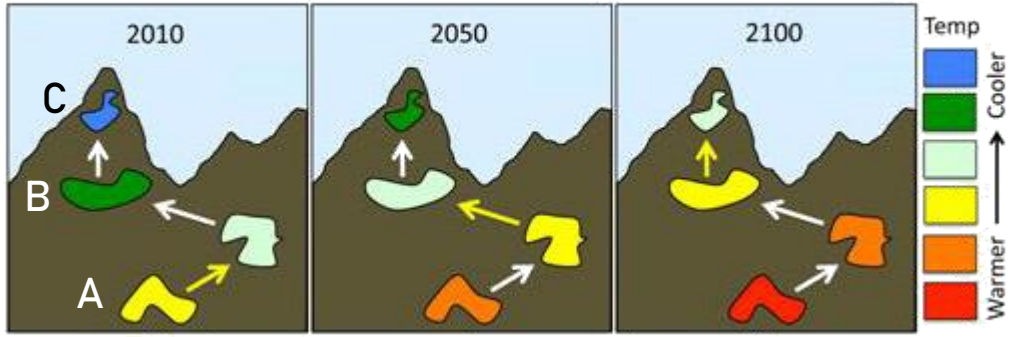

Source : Washington Wildlife Habitat Connectivity Working Group.

Migration towards future climate analogous

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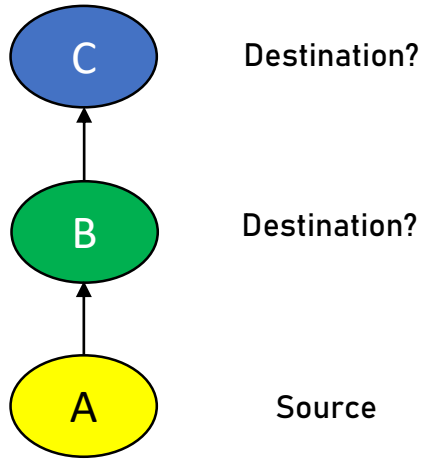

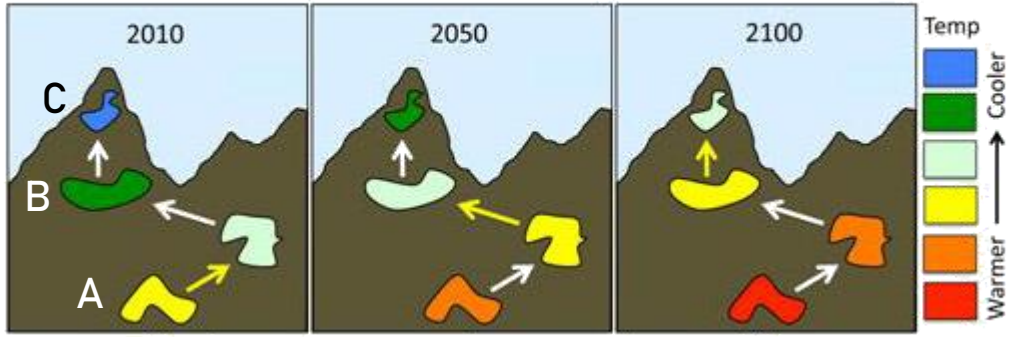

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Migration towards future climate analogous

Adapted from McGuire et al. 2016. PNAS.

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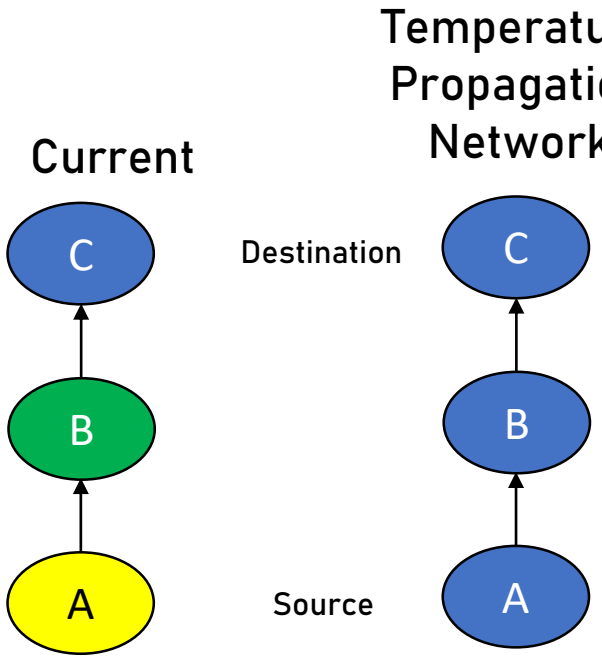

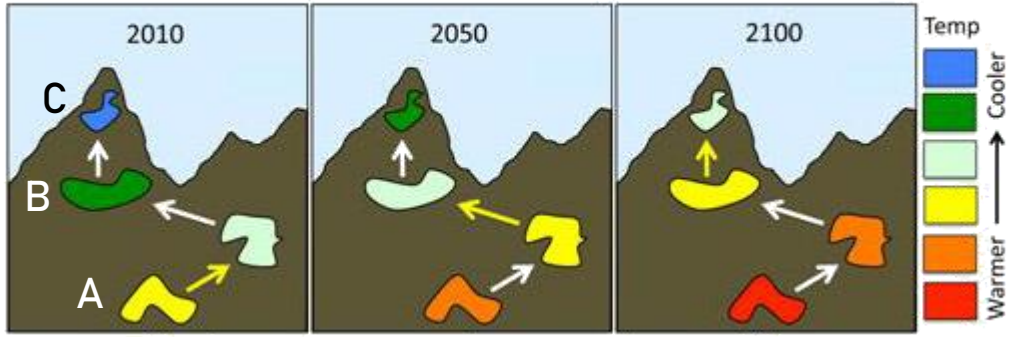

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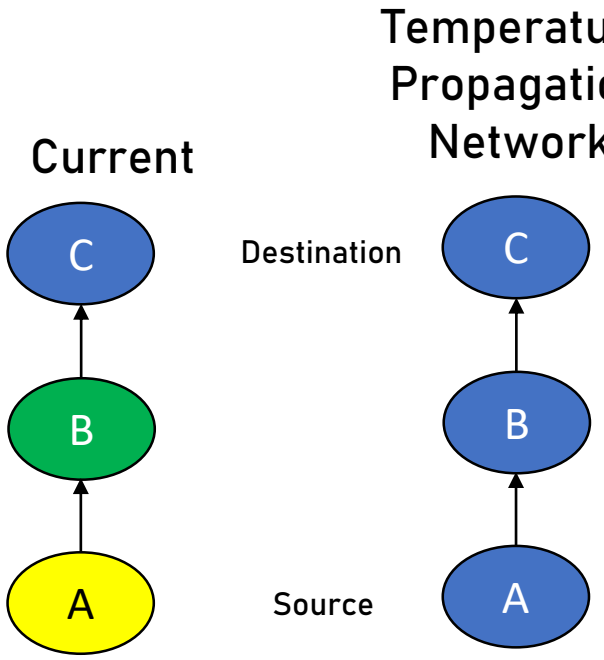

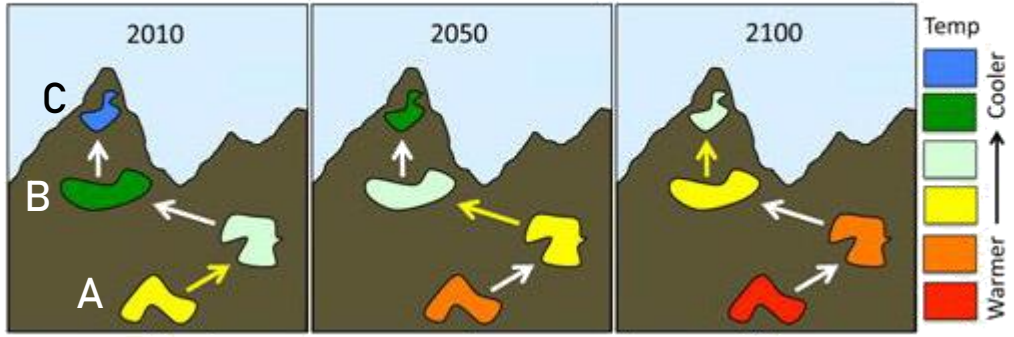

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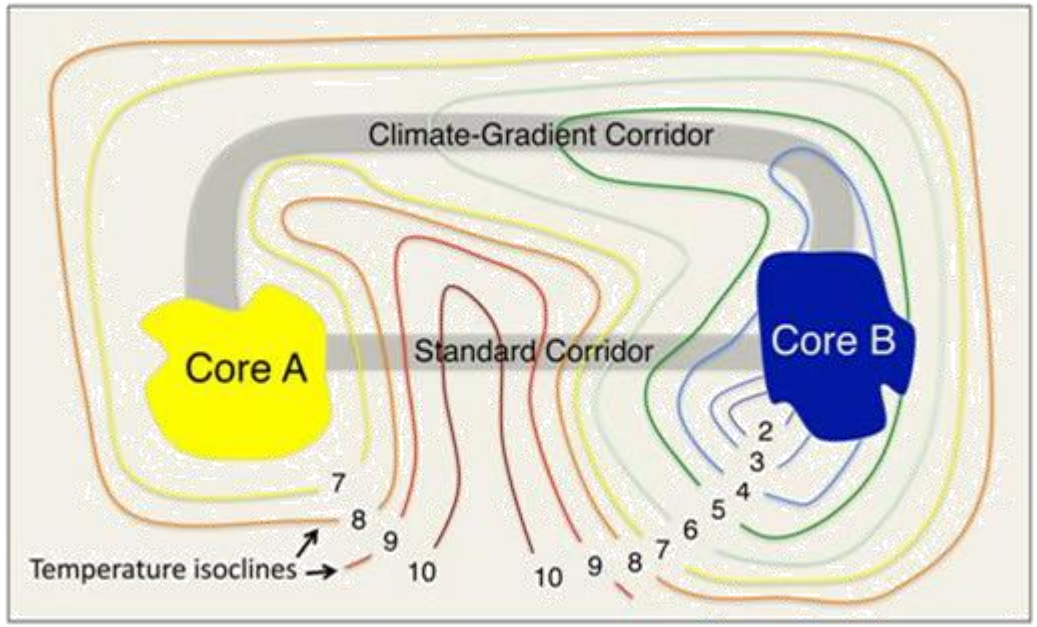

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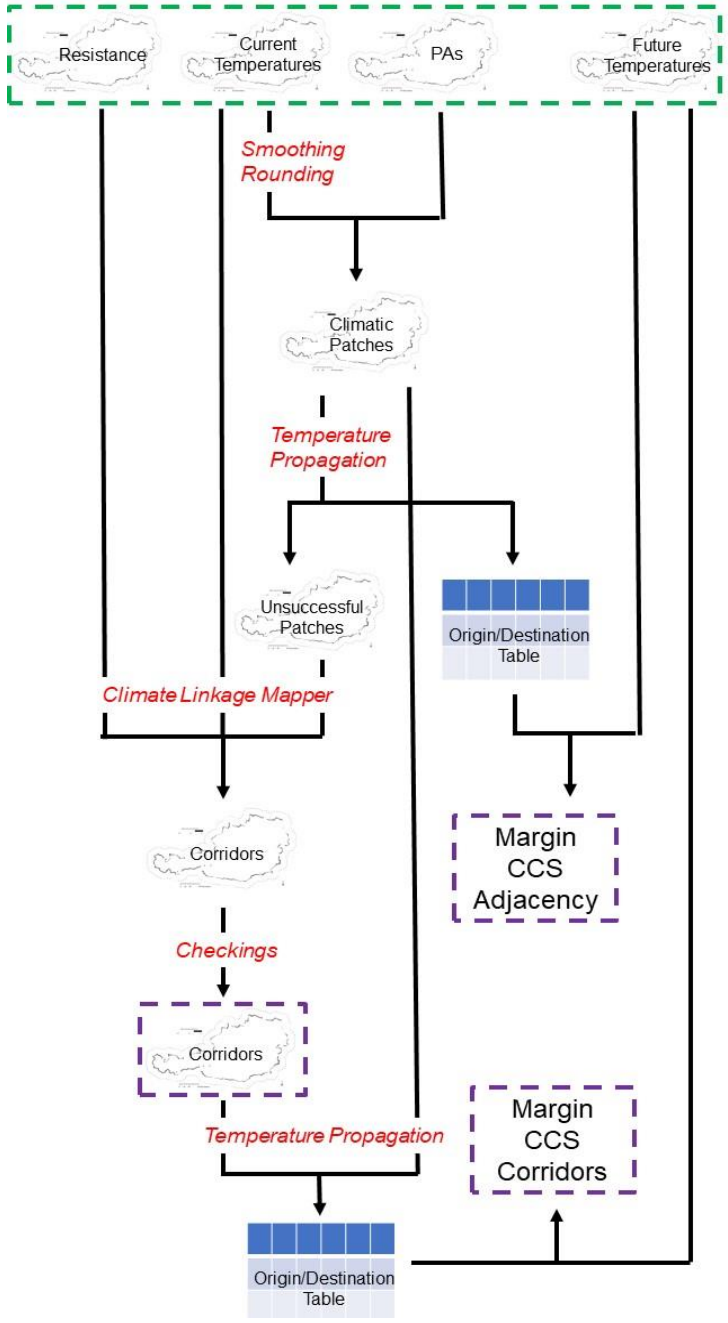
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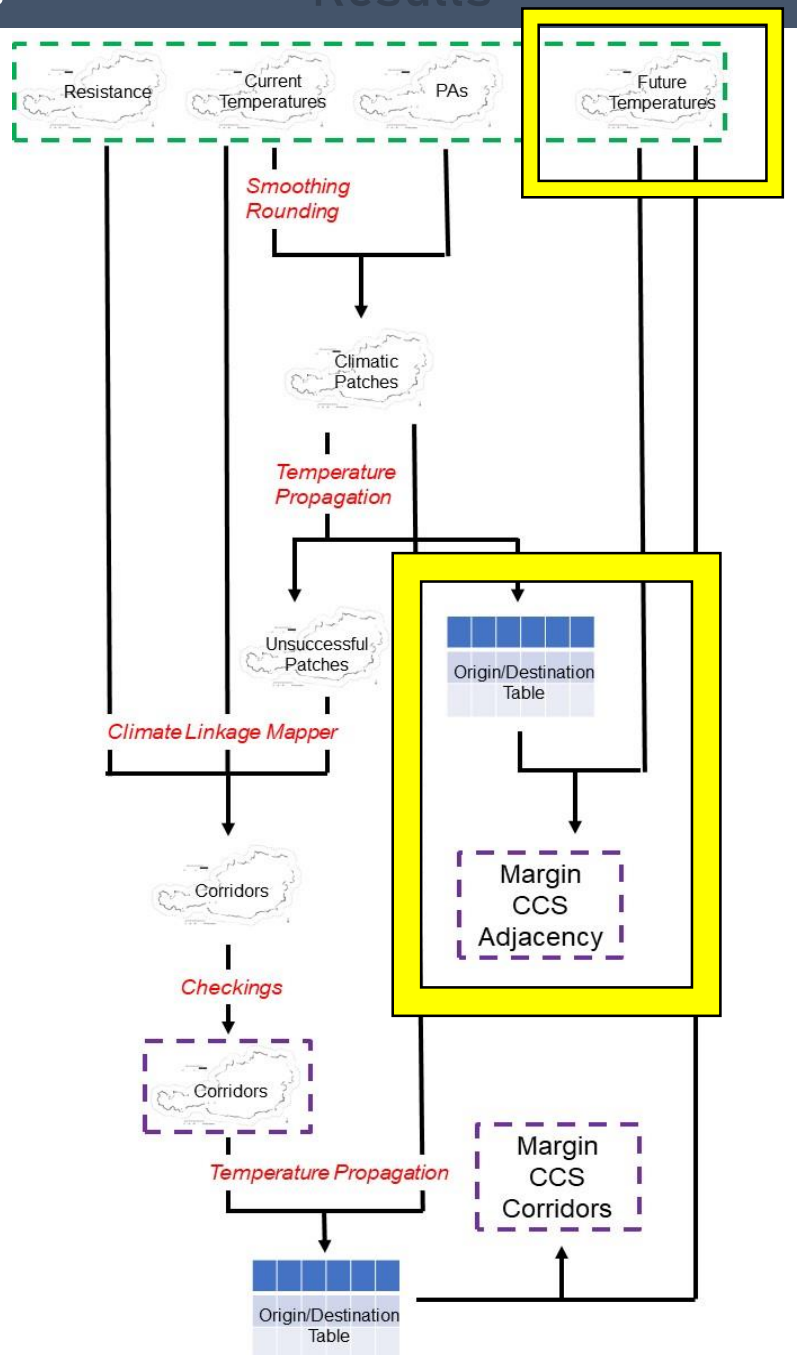
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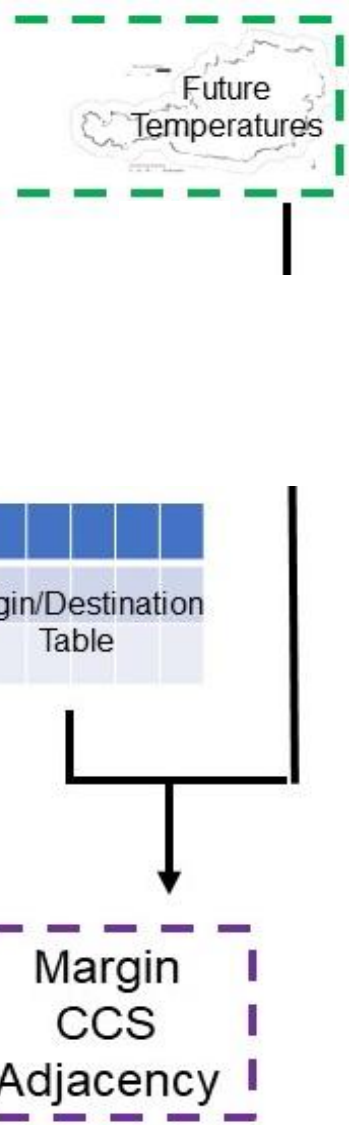
Assessing Climatic Success



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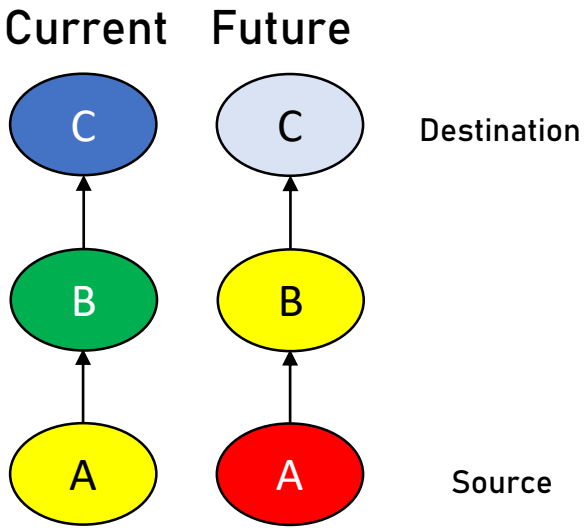

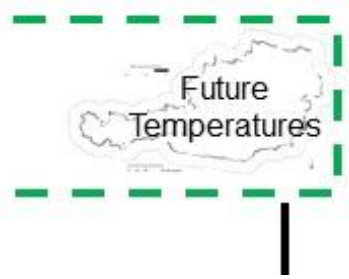

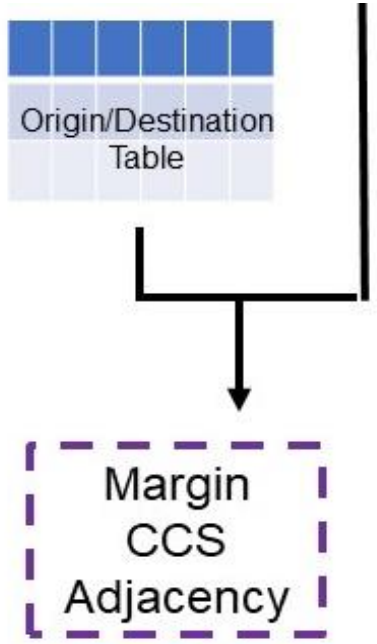

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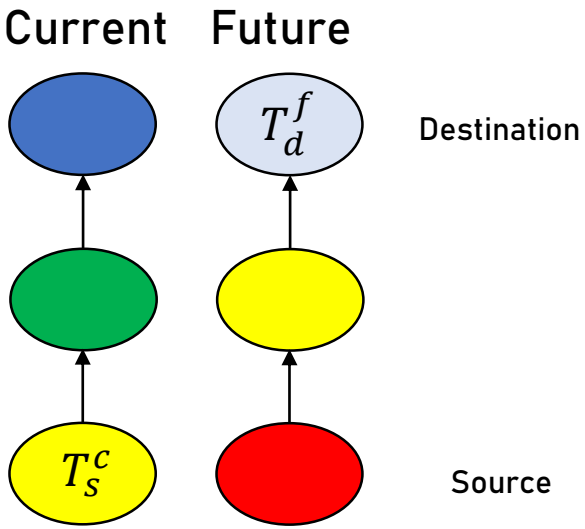
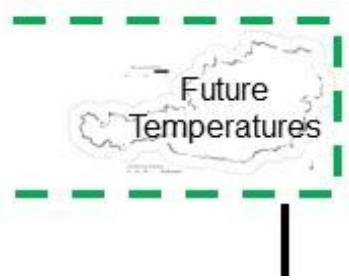
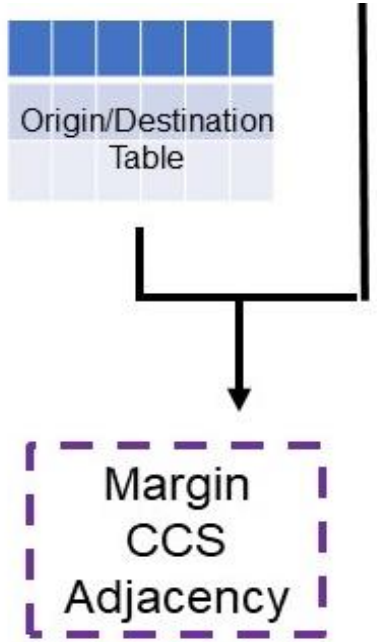


$$T_d^f \leq T_s^c$$





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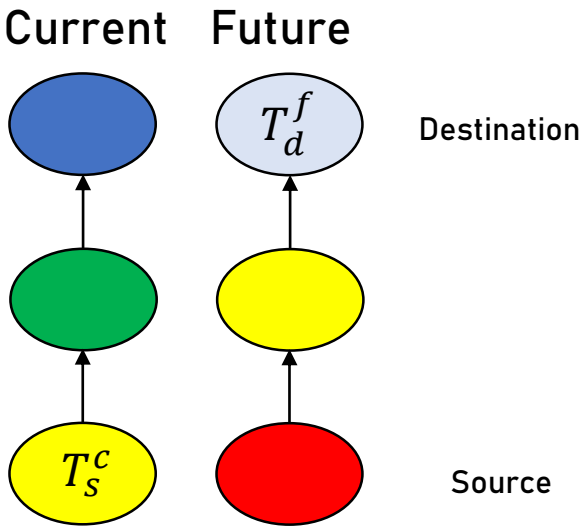
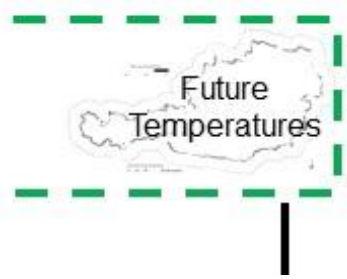
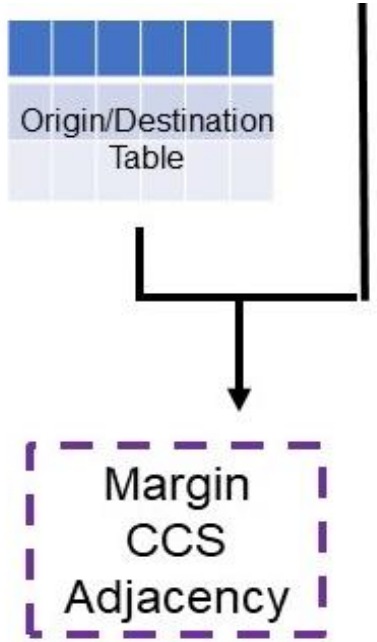


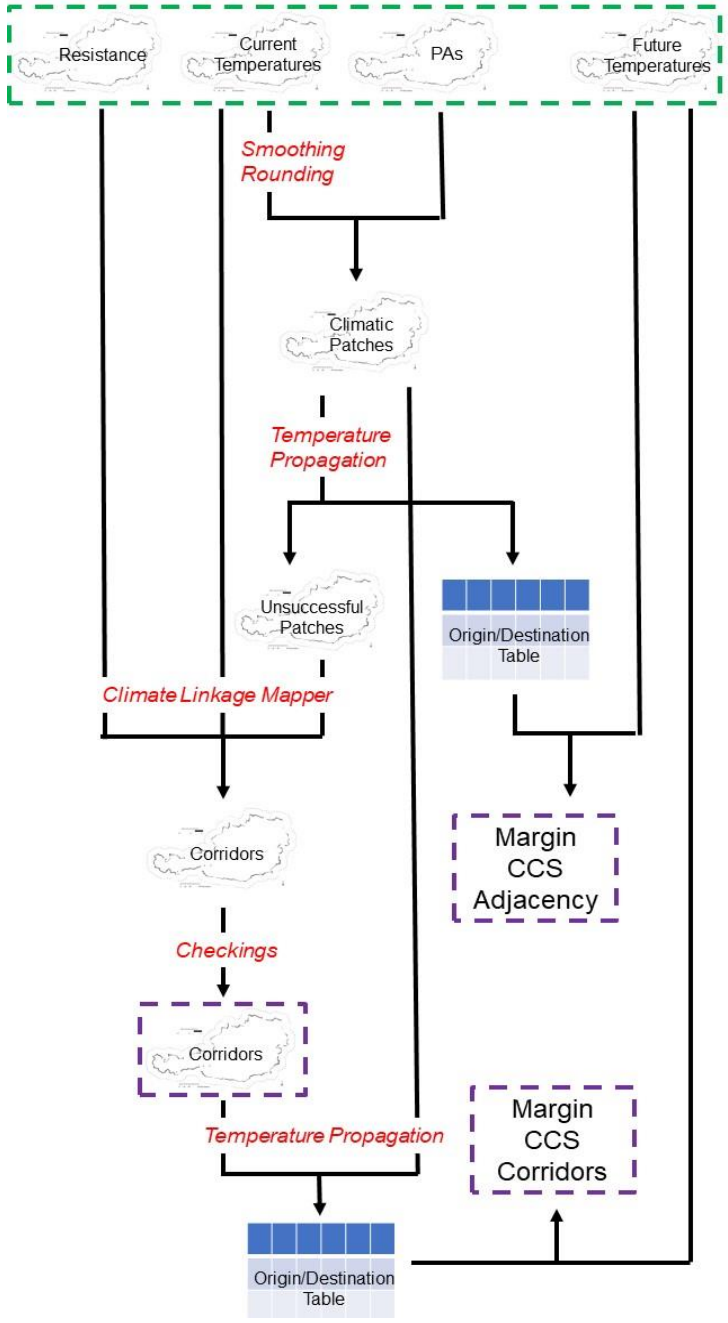
$$T_d^f \leq T_s^c$$

$$Margin_{Adj} = T_s^c - T_d^f$$

Adapted from McGuire et al. 2016. PNAS.



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Current Temperatures
PAs
Future Temperatures
Smoothing Rounding
Climatic Patches
Temperature Propagation
Unsuccessful Patches
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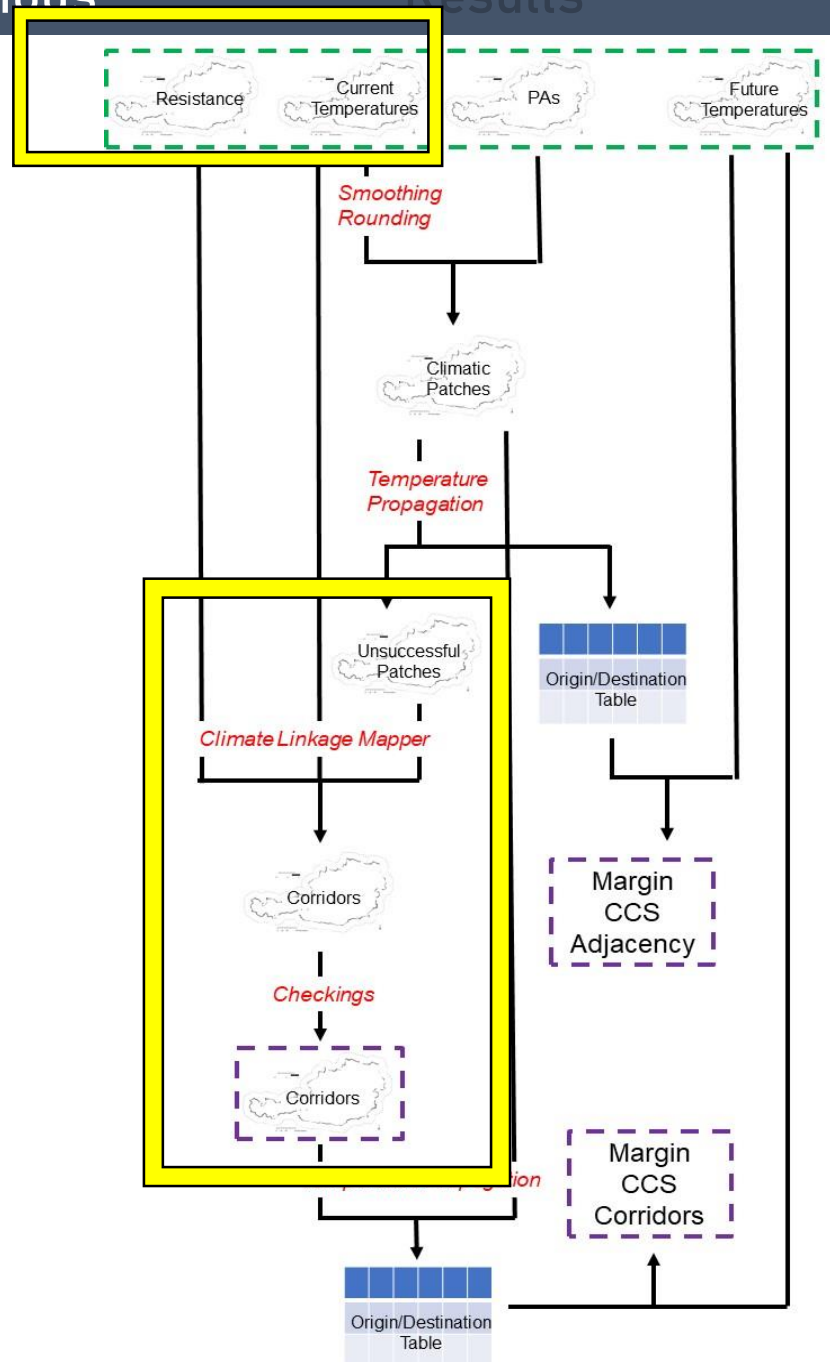
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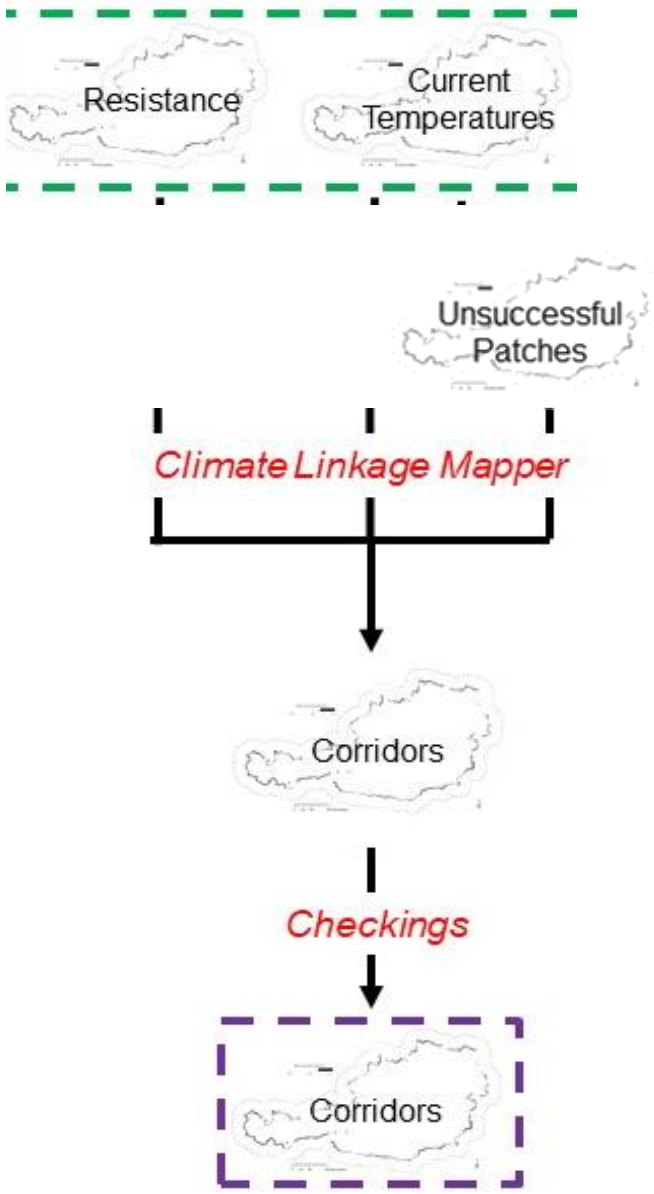
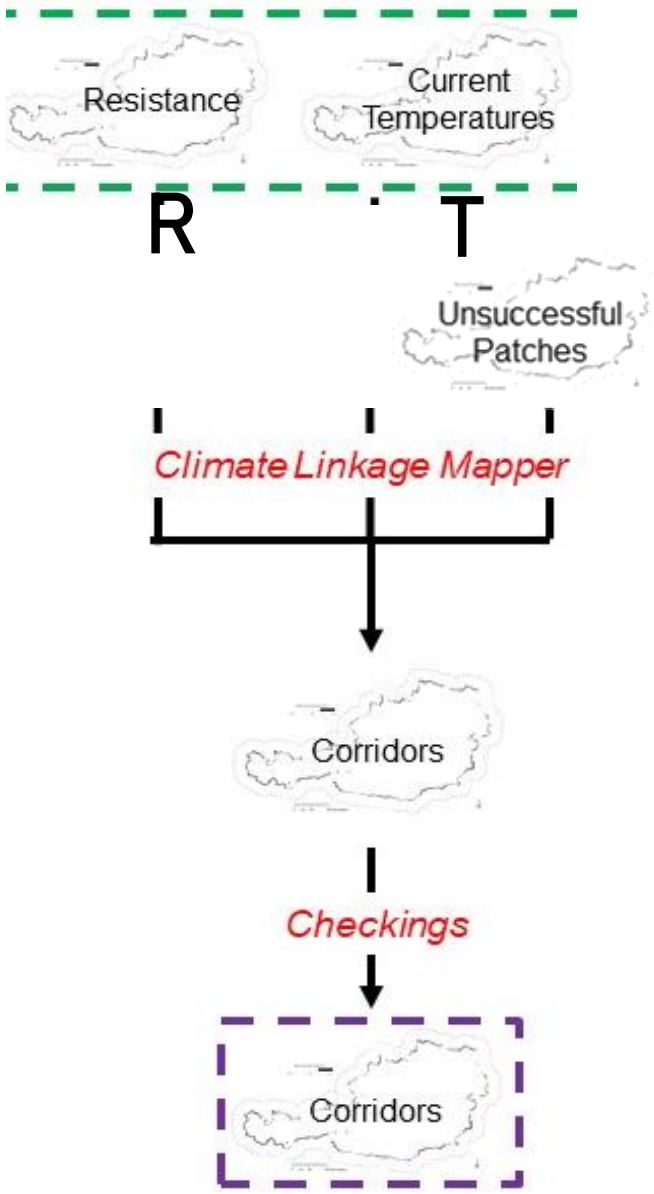
Corridor Network Design



Least cost-distance model
(Linkage Mapper Toolbox , “Climate Linkage Mapper” tool)

Corridor Network Design



Least cost-distance model
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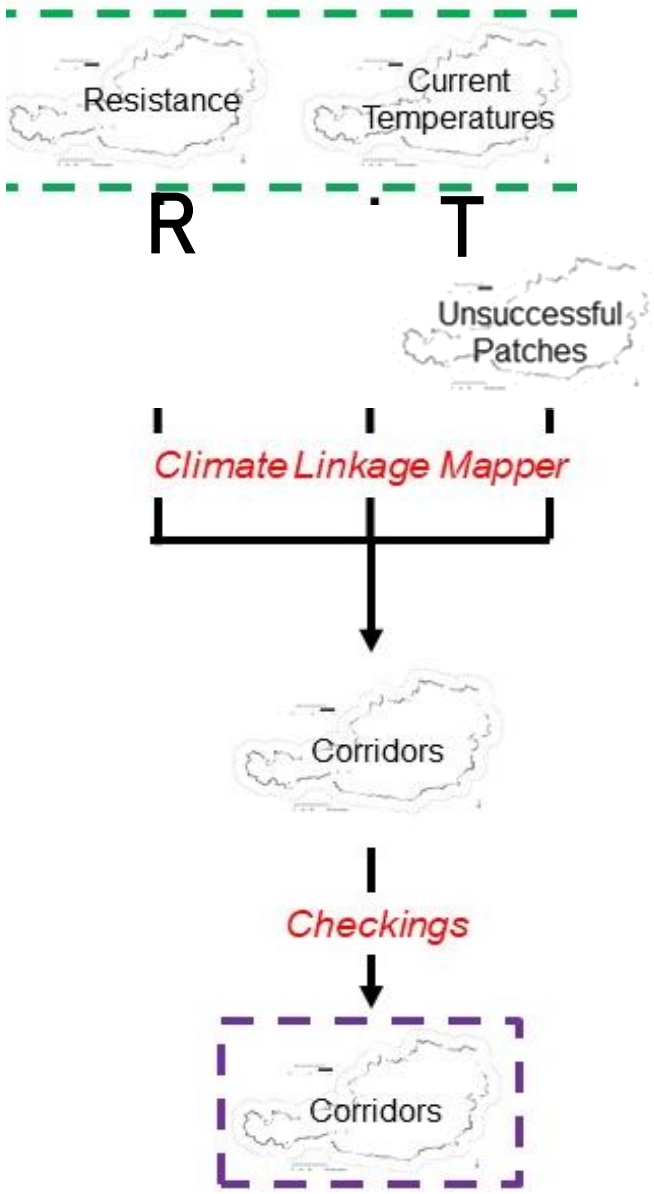
$$Cost\ distance = \left(\frac{Rfocal + Rneighbour}{2} \times Euclidean\ distance\right) + \left(temperature\ distance\ weight \times (Tfocal - Tneighbour)\right)$$

Neigh bour	Neigh bour	Neigh bour
Neigh bour	Focal	Neigh bour
Neigh bour	Neigh bour	Neigh bour

Corridor Network Design



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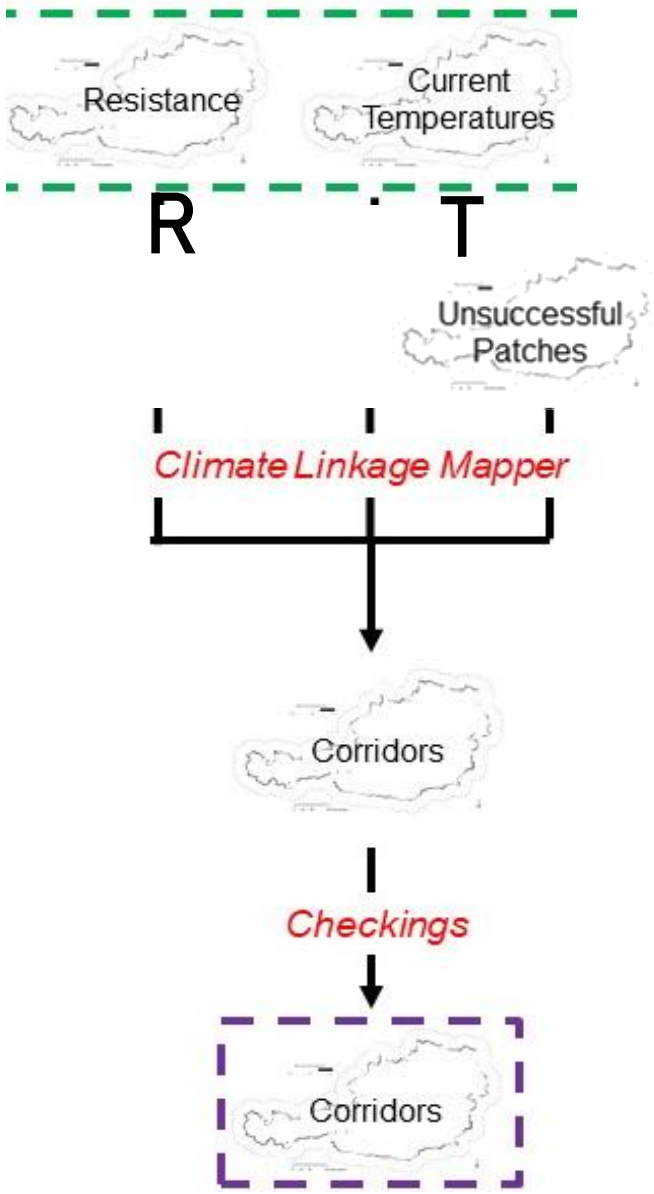
A

Cost	Cost	Cost
Cost	Cost	Cost
Cost	Cost	Cost

D

Corridor Network Design



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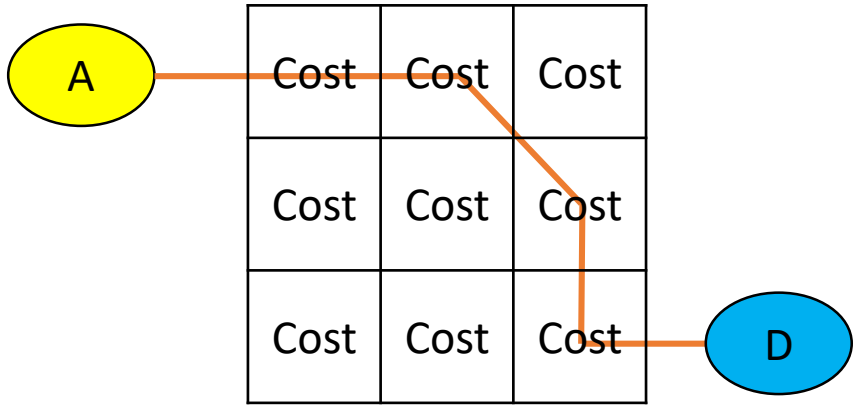
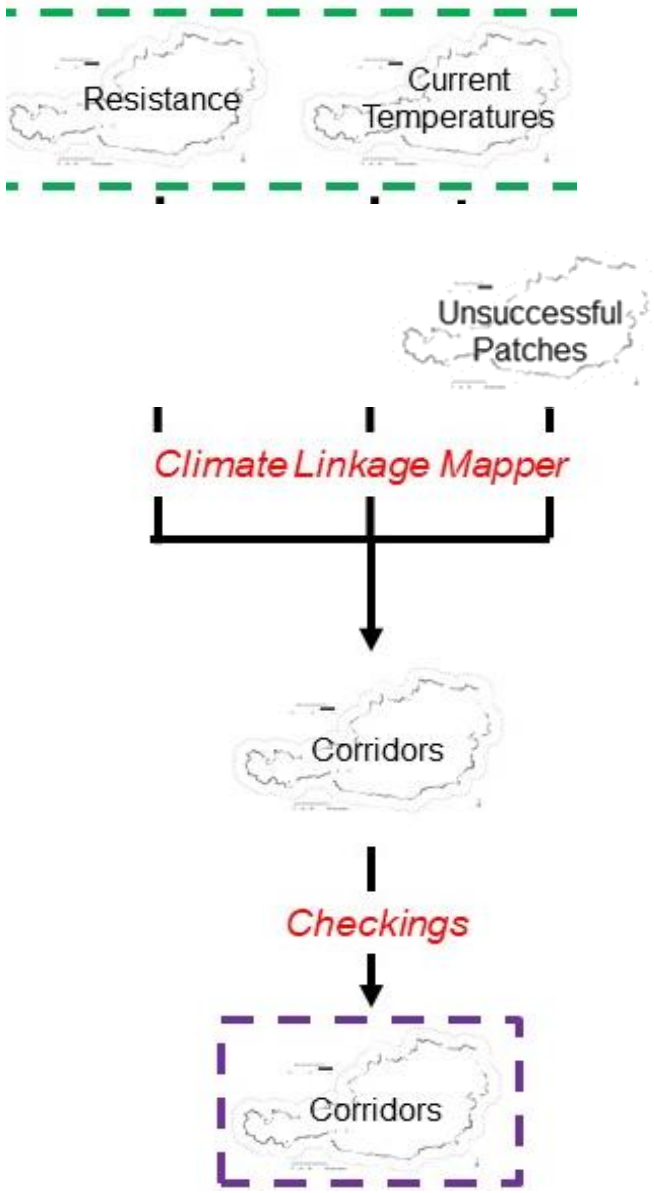
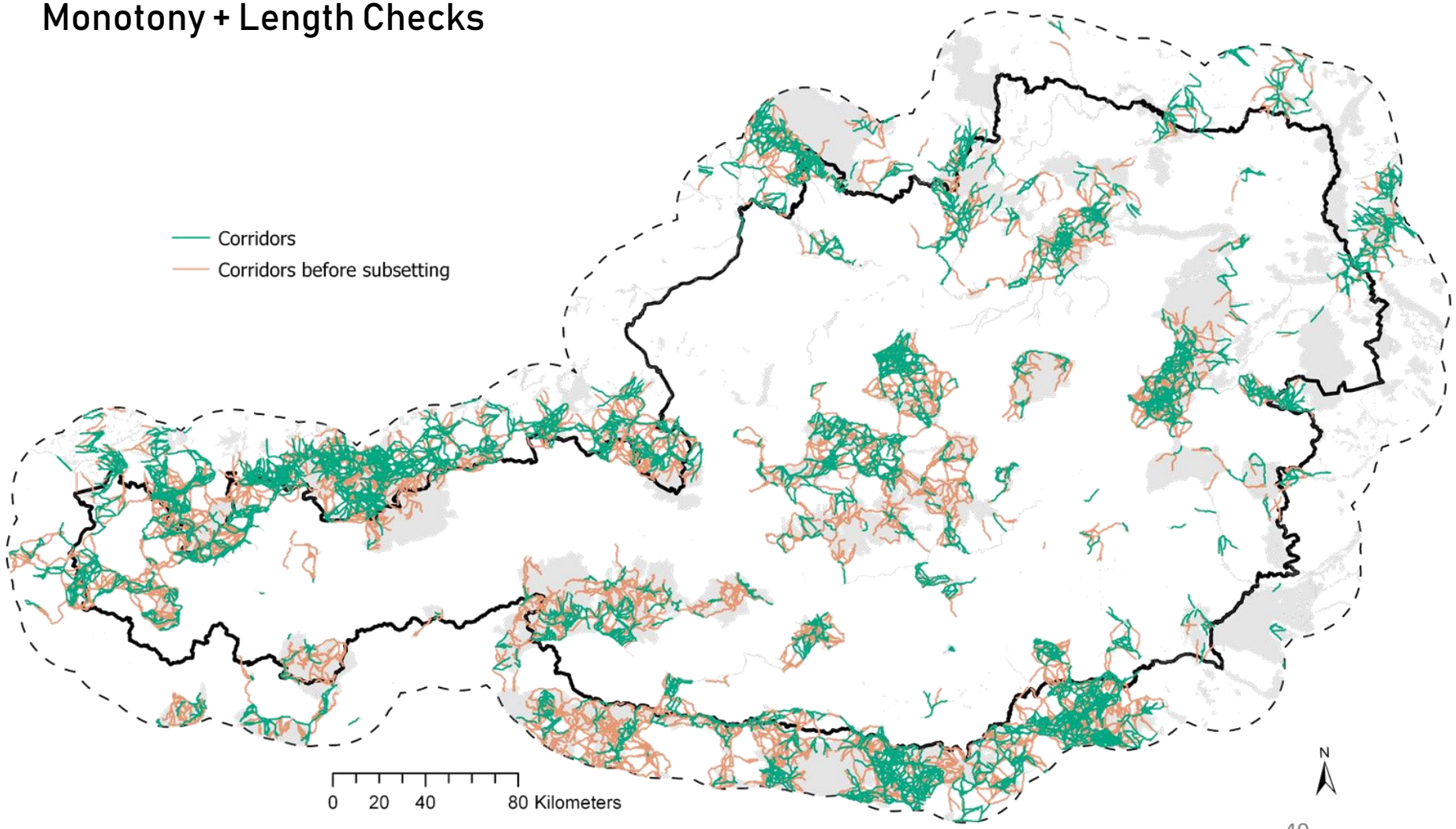
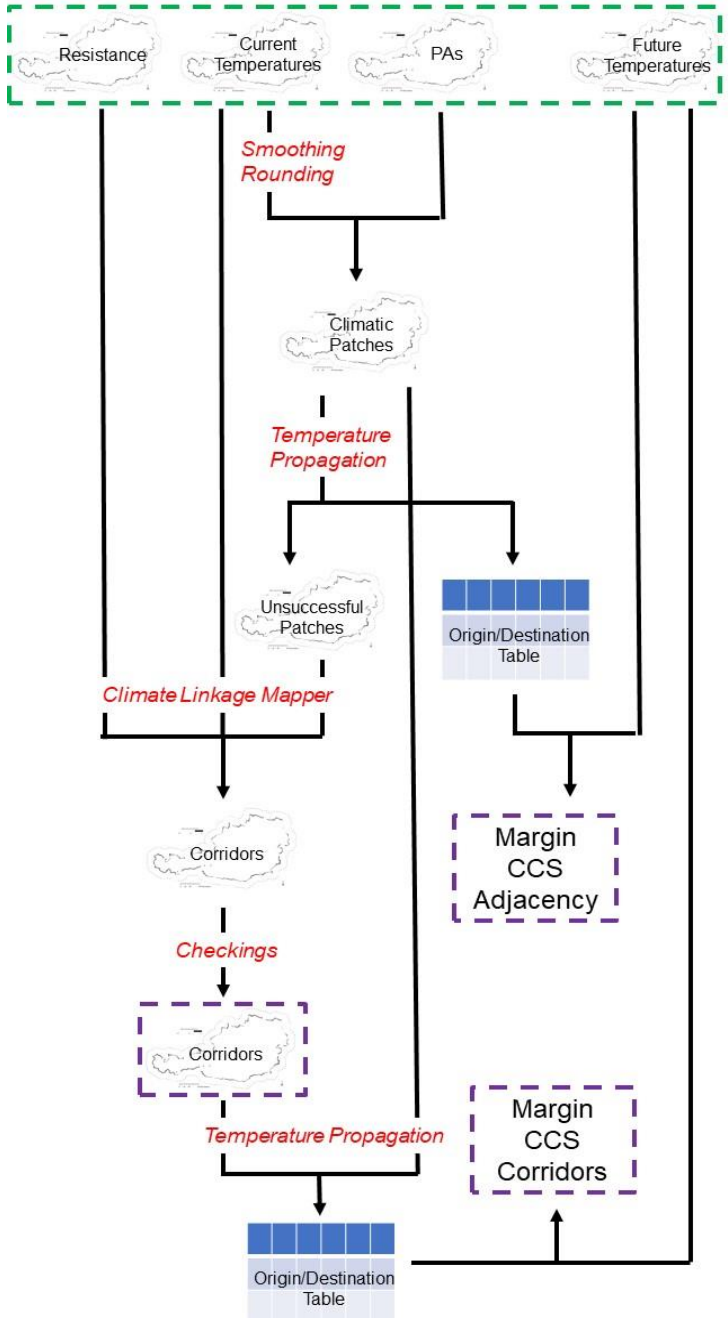


Corridor Network Design



Monotony + Length Checks

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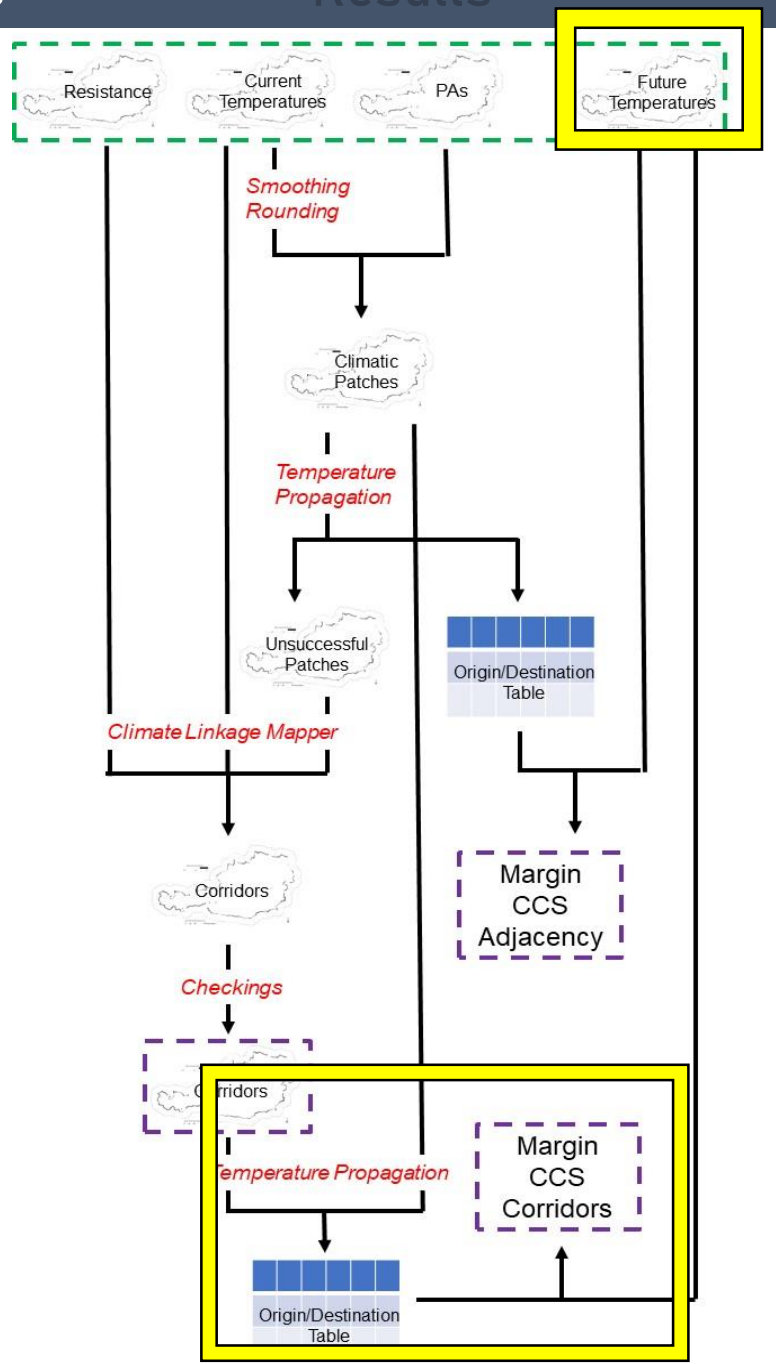
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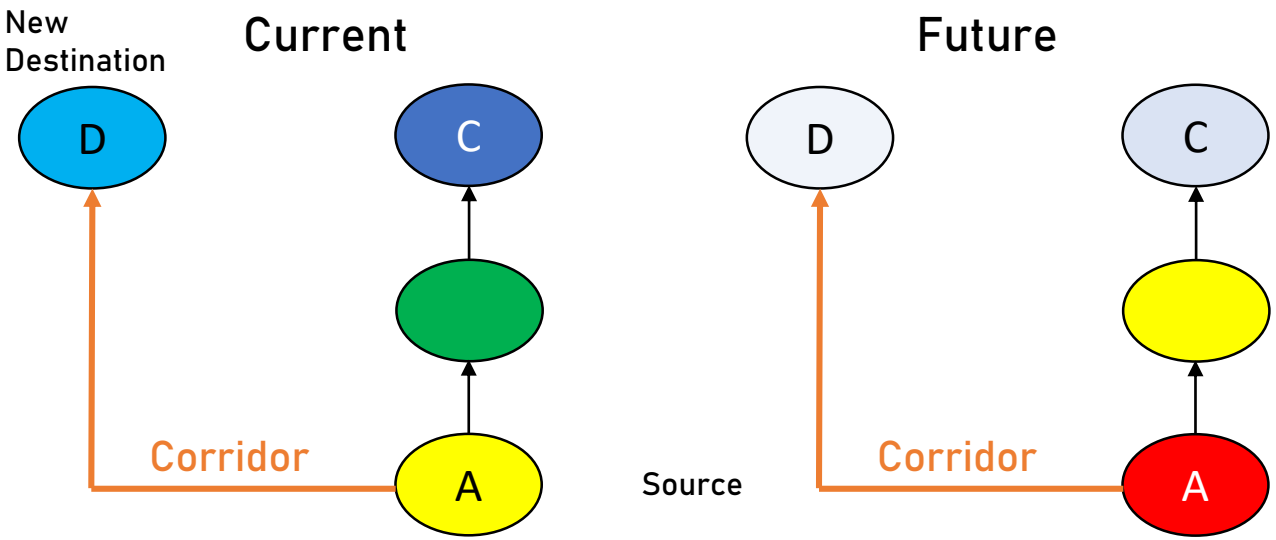
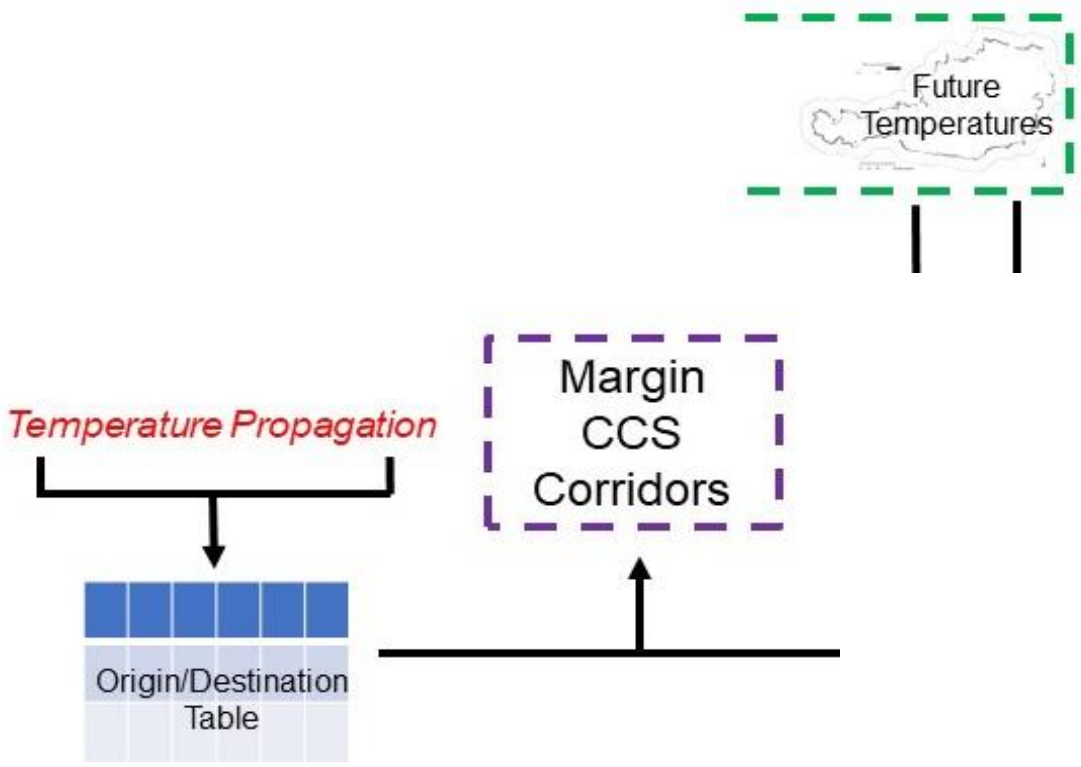
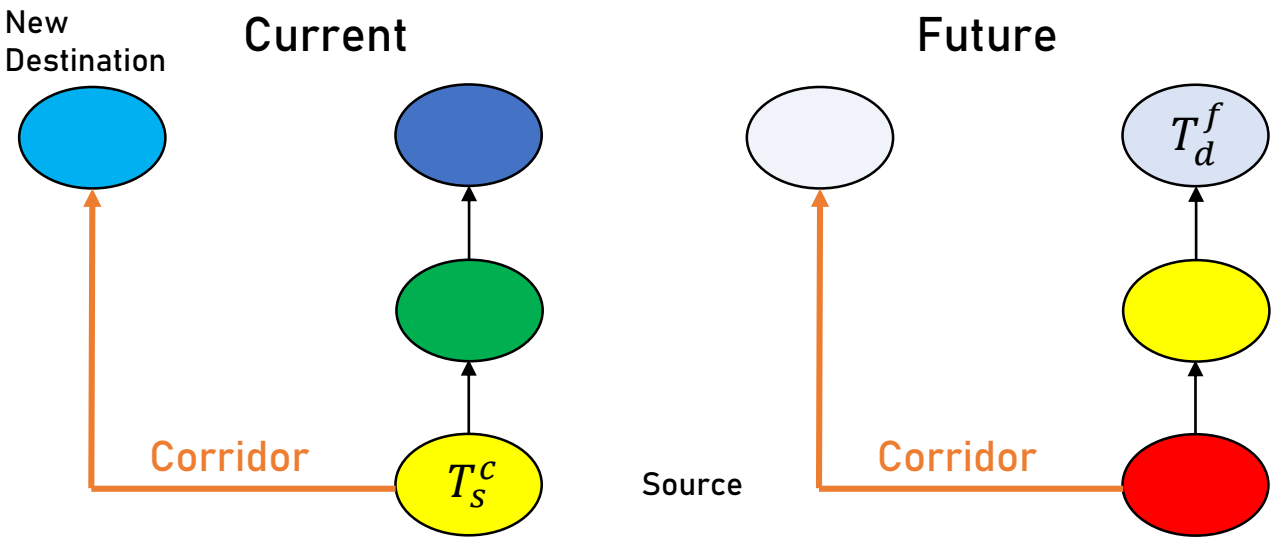
Assessing Climatic Success



$$T_d^f \leq T_s^c$$



Assessing Climatic Success



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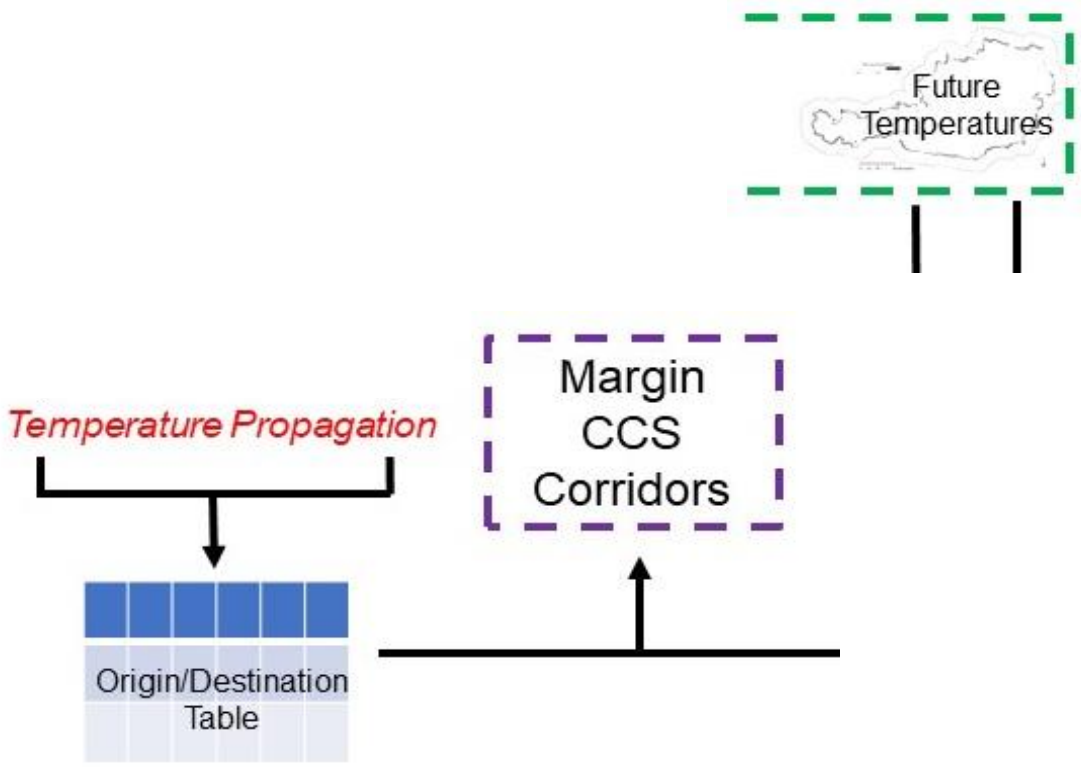

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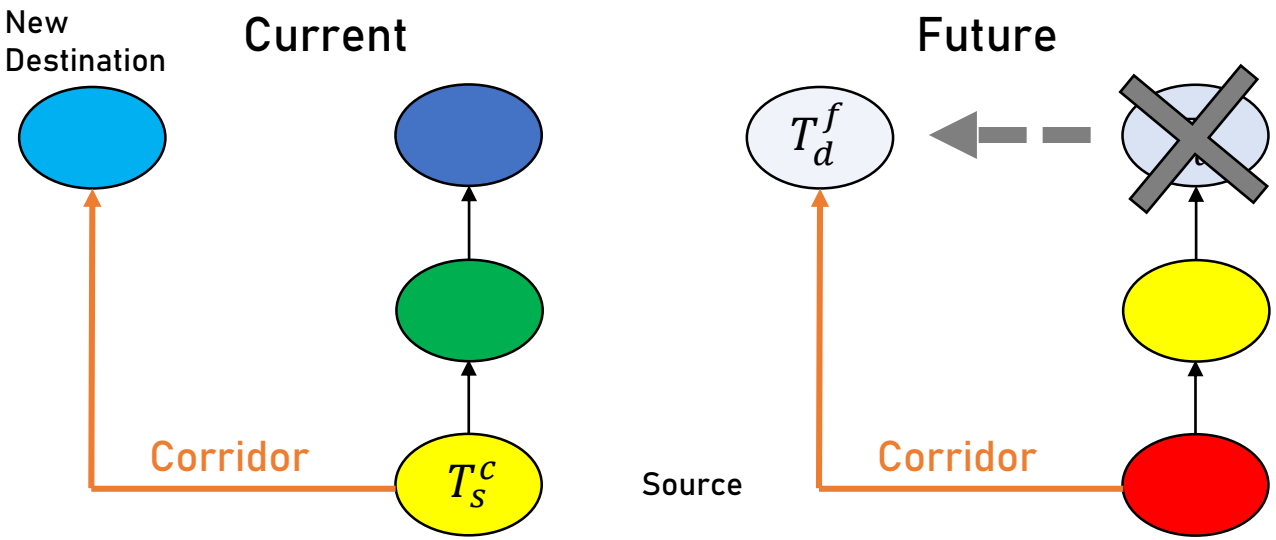
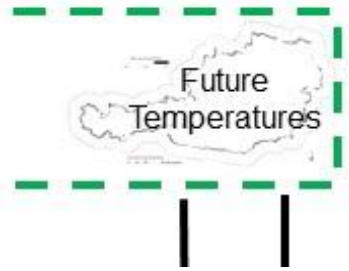
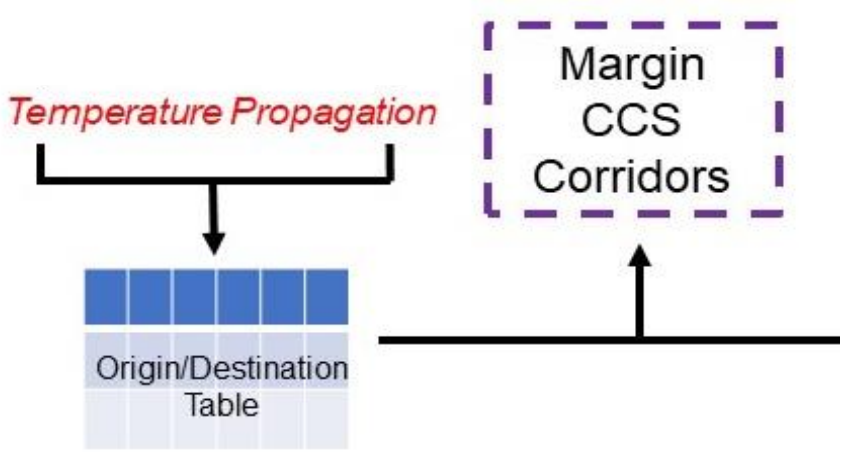




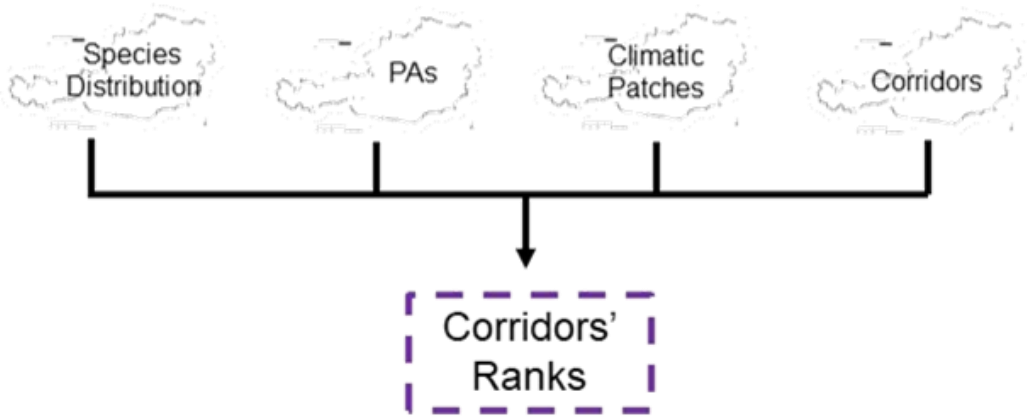


$$T_d^f \leq T_s^c$$

$$Margin_{Cor} = T_s^c - T_d^f$$

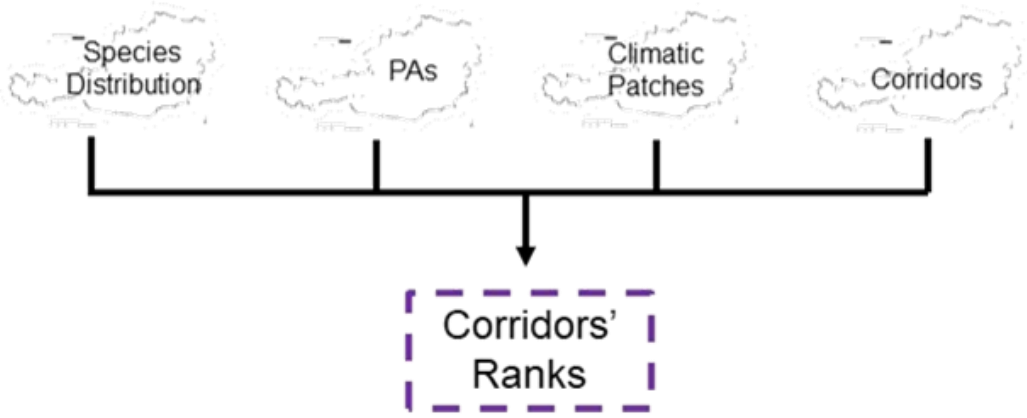
Assessing Corridor Efficiency

Assessing Corridor Efficiency



Cost, Length, Number Endemic Species → Ranks

Assessing Corridor Efficiency



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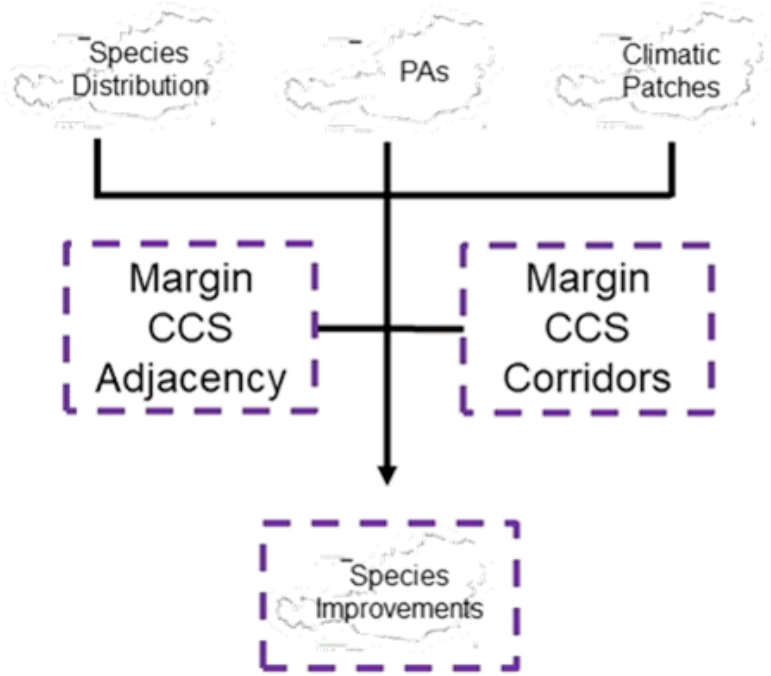

Number Endemic Species Achieving Climatic Connectivity

Results & Discussion

Climatic Connectivity Success

Figure 1: Absolute values and improvement in climate connectivity when adding corridors, as a percentage of the total protected area network area, under various climate scenarios and over time.

	Adjacency Only			Corridors			Improvement		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
2030	72	73	67	85	85	79	13	13	13
2040	66	66	64	79	78	77	13	13	13
2050	64	64	58	77	77	73	13	13	15
2060	64	62	51	77	75	63	13	13	12
2070	64	55	47	77	67	56	13	12	8
2080	64	52	38	77	64	46	13	12	8

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2060	64	62	51	77	75	63	13	13	12
2070	64	55	47	77	67	56	13	12	8
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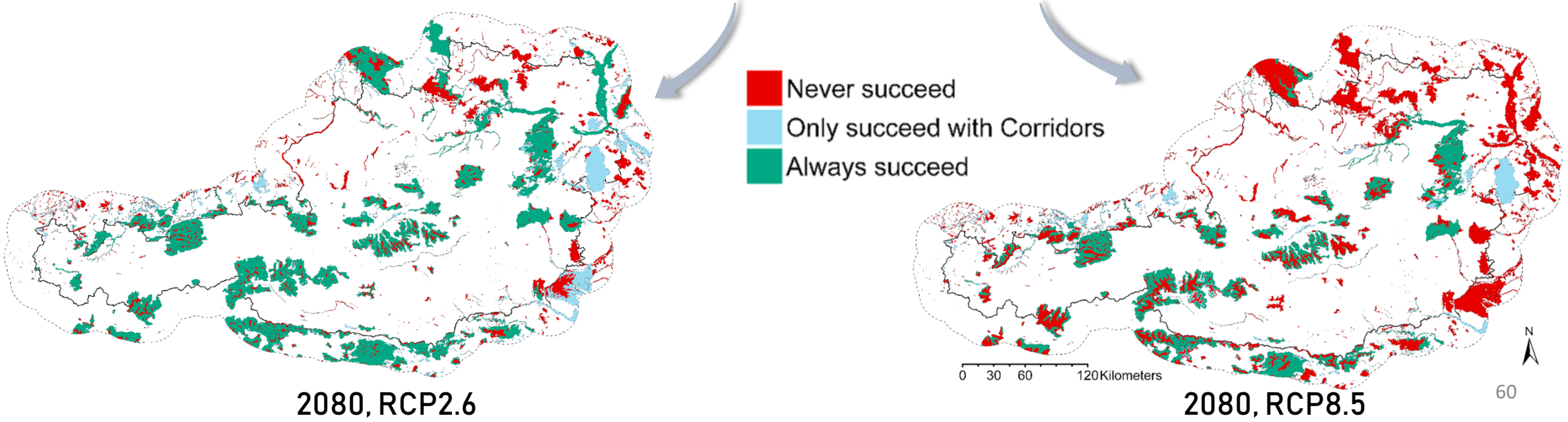

2080, RCP2.6

2080, RCP8.5

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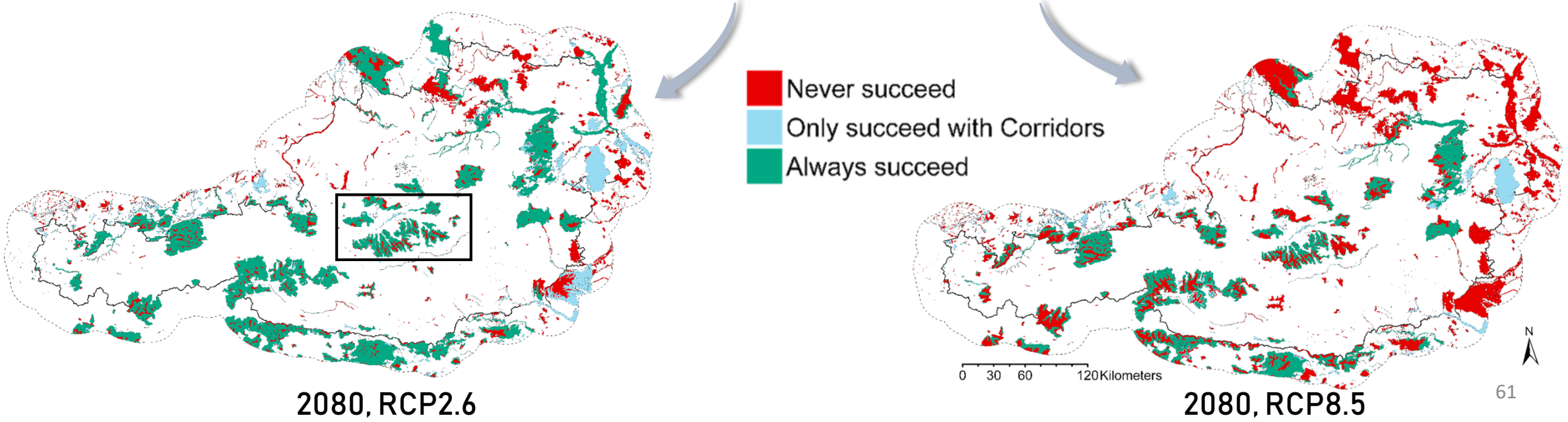

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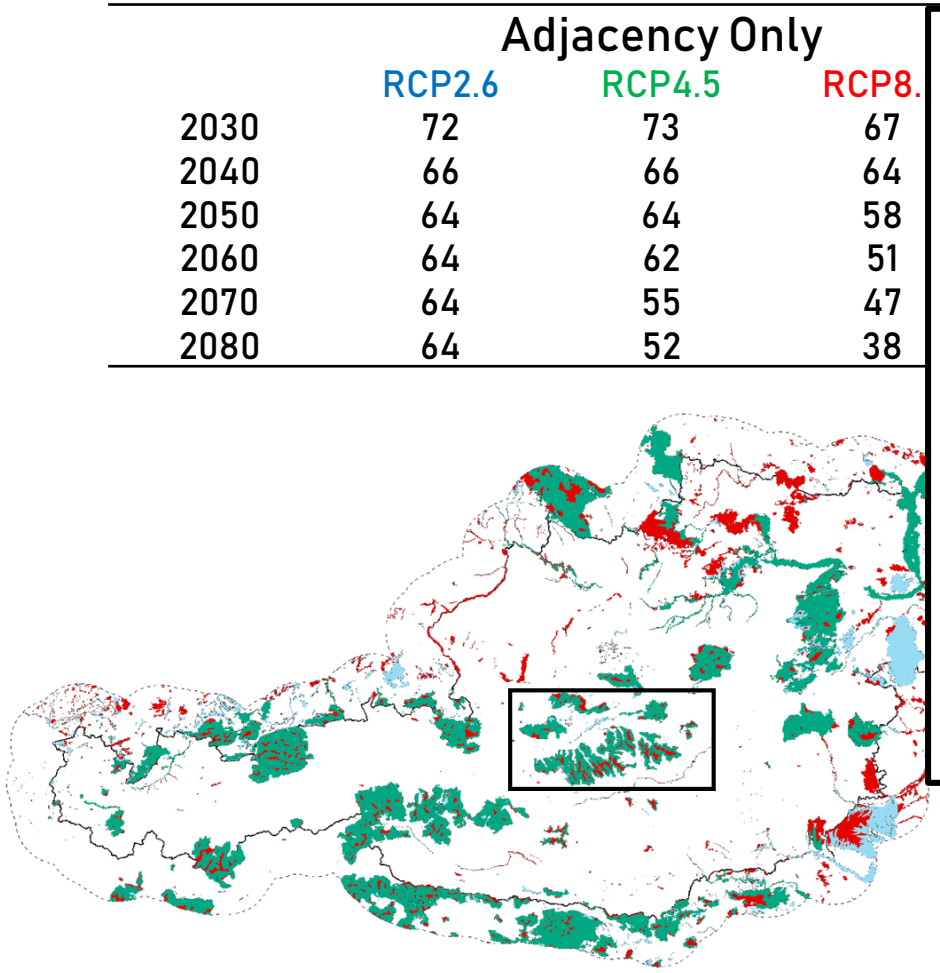
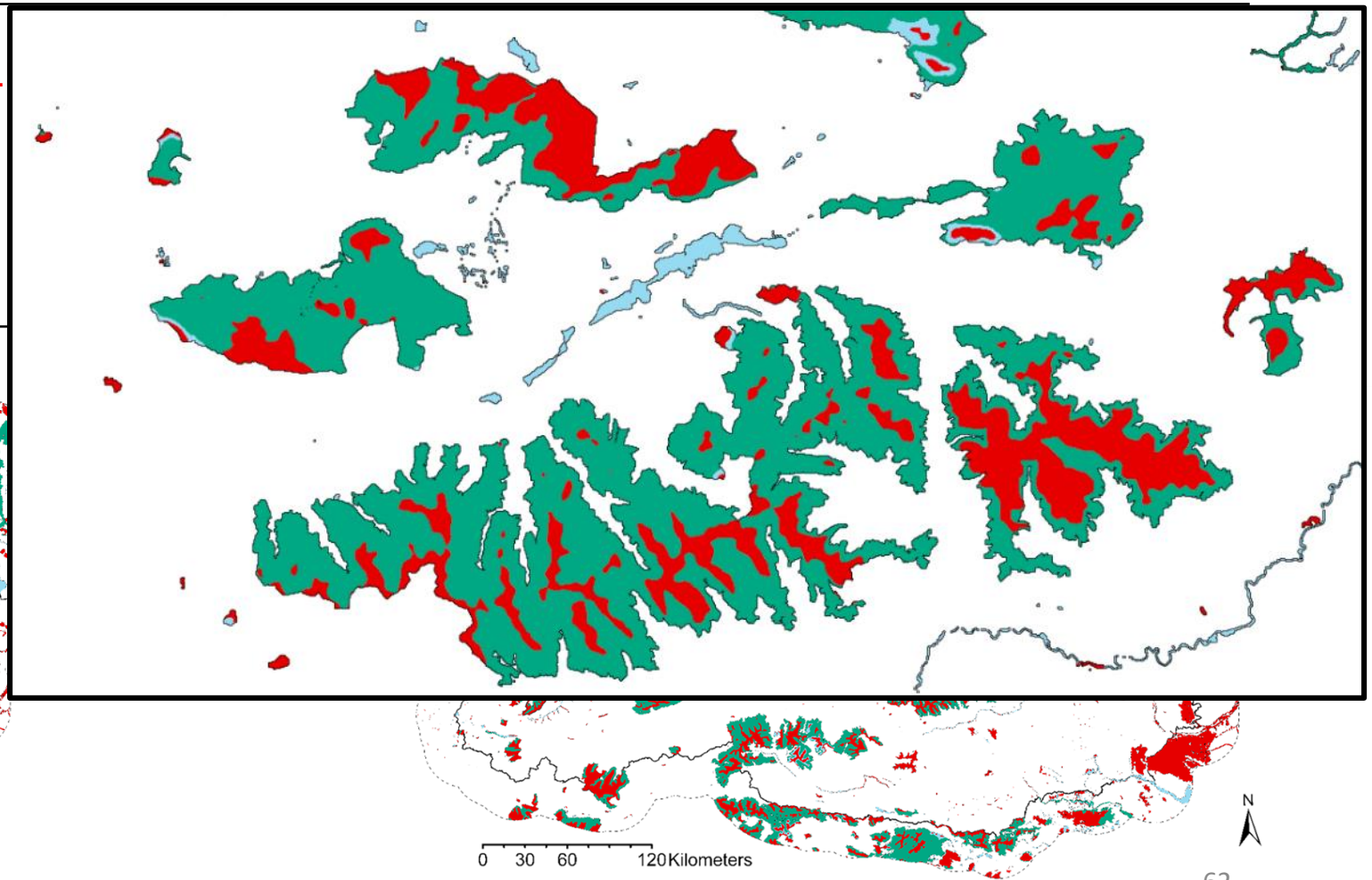
	RCP2.6	RCP4.5	RCP8.
2030	72	73	67
2040	66	66	64
2050	64	64	58
2060	64	62	51
2070	64	55	47
2080	64	52	38



2080, RCP2.6



2080, RCP8.5

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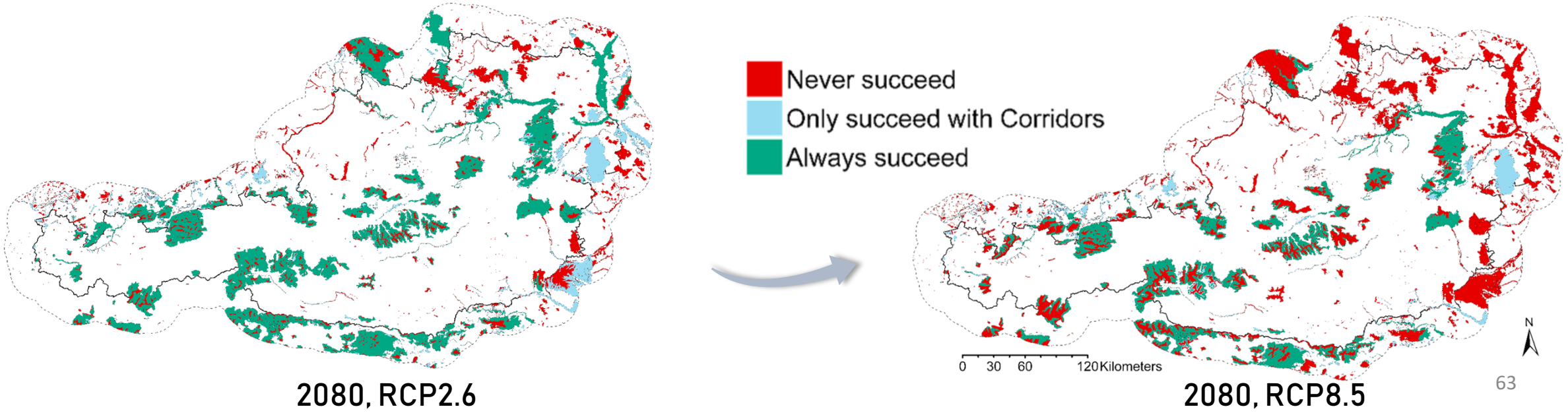

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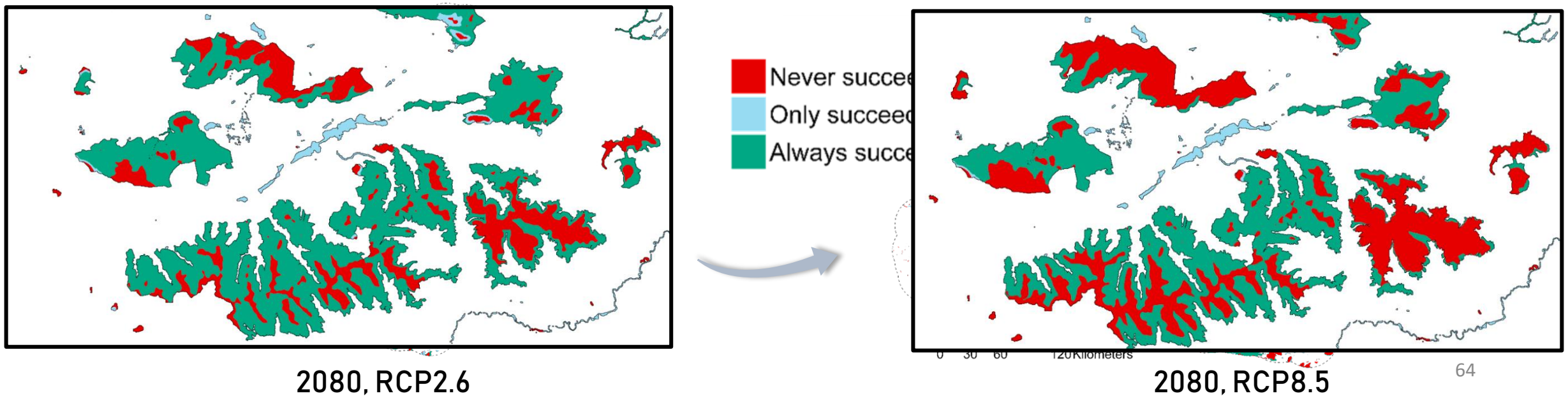


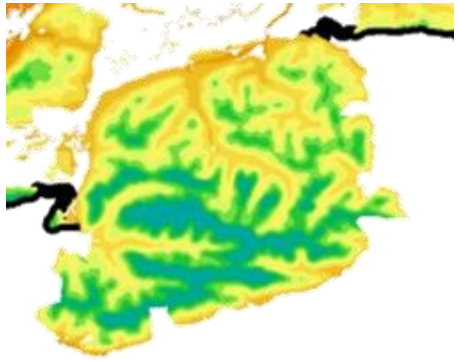
2080, RCP2.6

2080, RCP8.5

Climatic Connectivity Success

High level of climatic connectivity in Austria:

- Large internal thermal variation (mountain foothills).



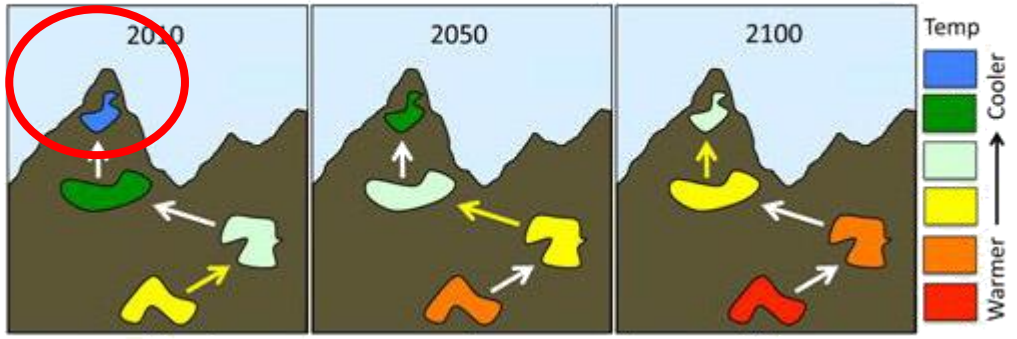
Climatic Connectivity Success

High level of climatic connectivity in Austria:

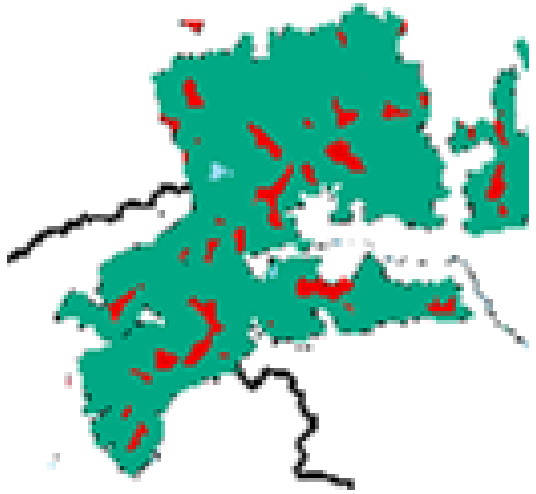
- Large internal thermal variation (mountain foothills).

Corridors have a limited potential:

- Restriction (length/monotony);
- Patches always unsuccessful by nature.



Source : Washington Wildlife Habitat Connectivity Working Group.



Climatic Connectivity Success

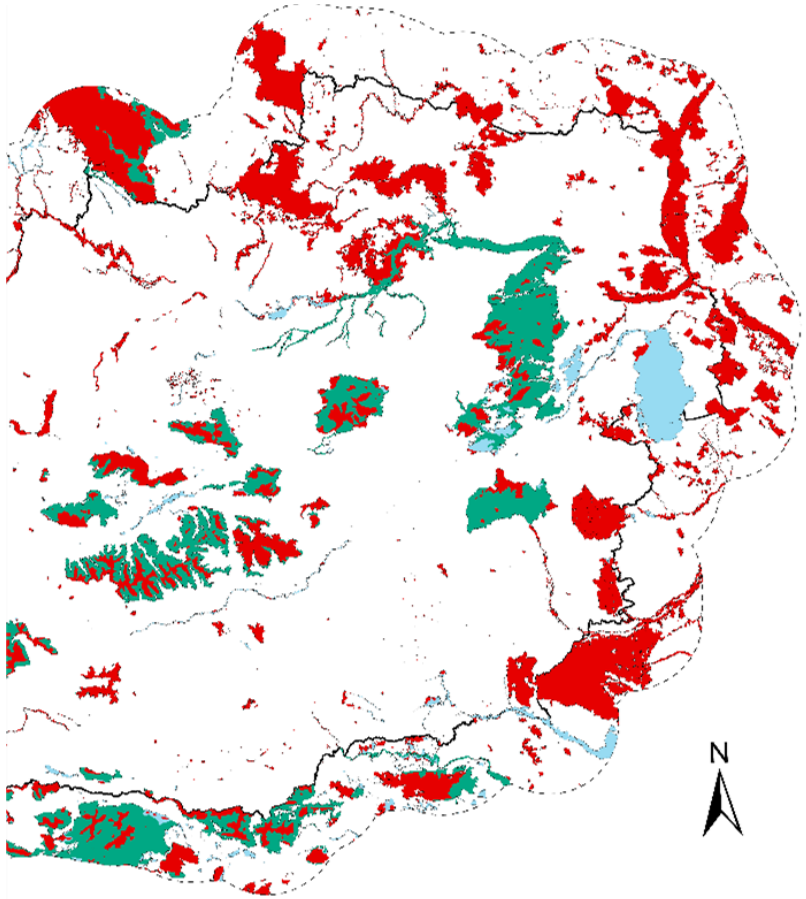
High level of climatic connectivity in Austria:

- Large internal thermal variation (mountain foothills).

Corridors have a limited potential:

- Restriction (length/monotony);
- Patches always unsuccessful by nature.

Corridors are not sufficient in case of severe climate change



RCP8.5, 2080

Corridor Efficiency

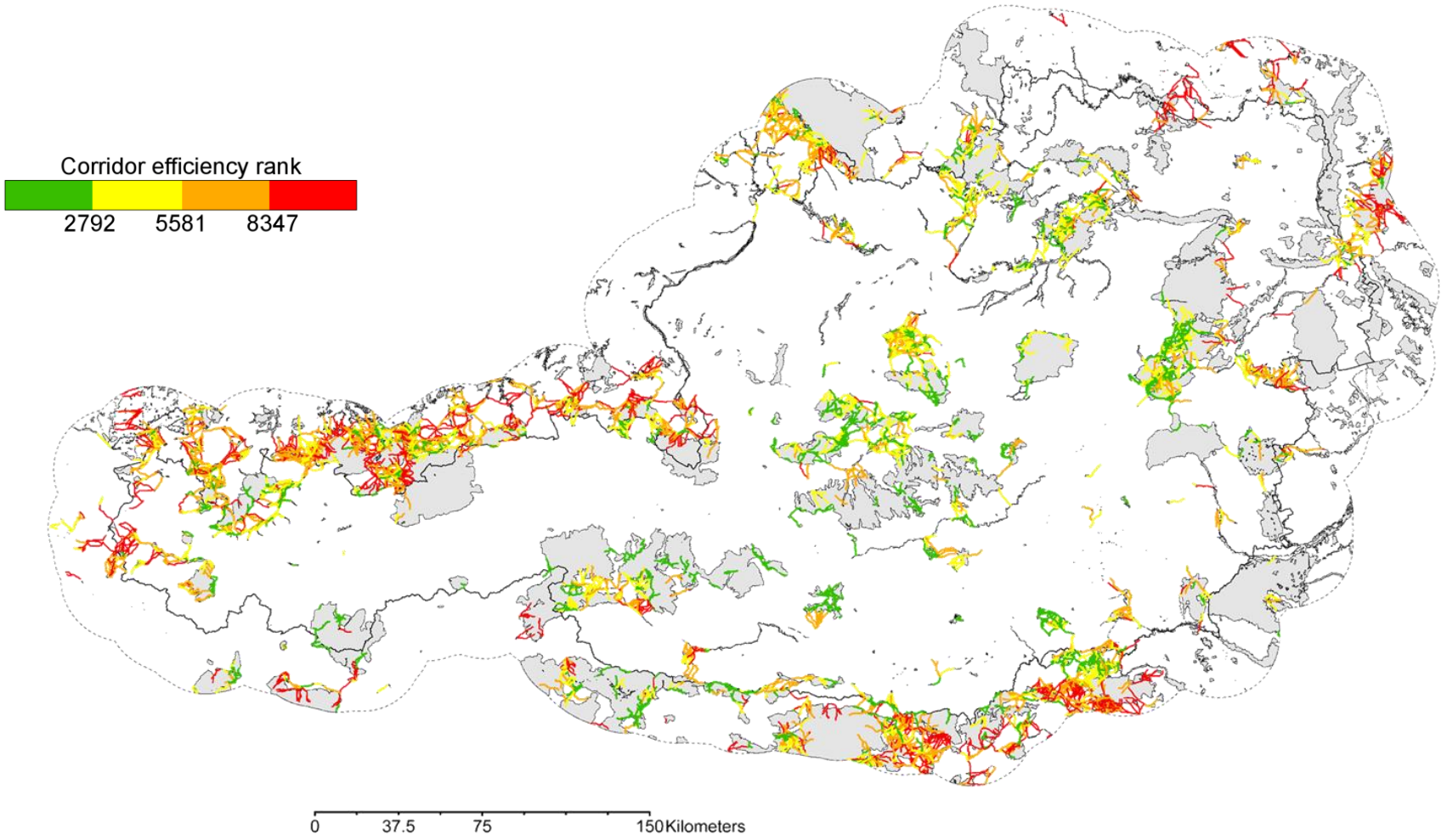


Figure 2: The efficiency of corridors, calculated based on individual rank (length, cost and maximal number of endemic species that become climatically connected to future suitable habitat via the corridor).

Corridor Efficiency

Modularity of indicators according to objectives

Corridor Efficiency

Modularity of indicators according to objectives

Corridors improvements:

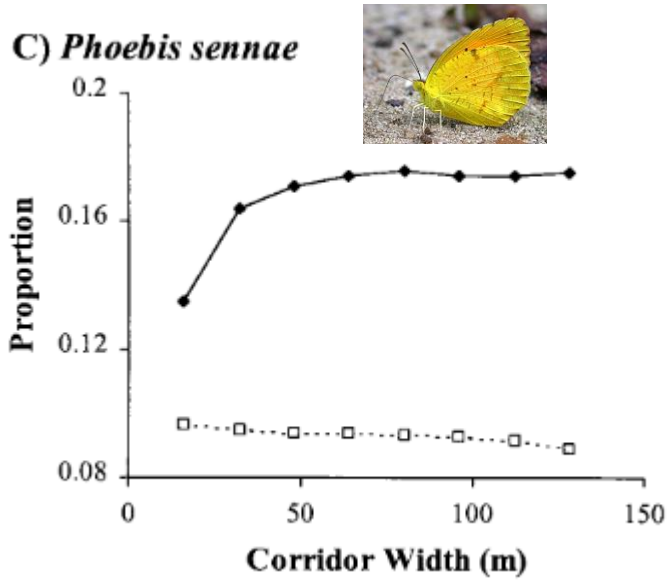
- Integrative socio-ecological approach;

Corridor Efficiency

Modularity of indicators according to objectives

Corridors improvements:

- Integrative socio-ecological approach;
- Include width.



Source: Haddad 2017. The American Naturalist.

Endemic Species and Climate Connectivity

2080, RCP4.5
23% of the PA network experience a gain

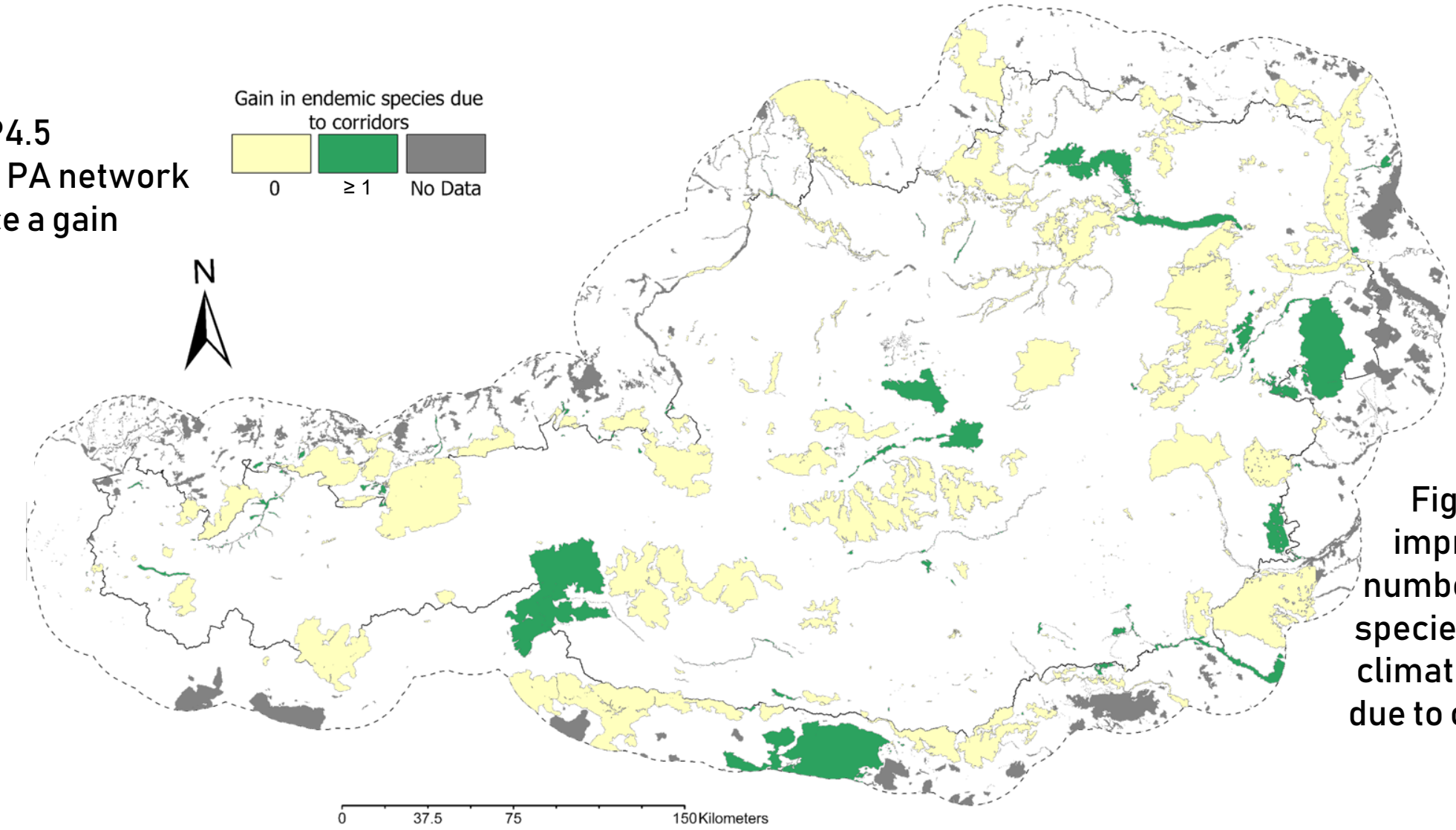
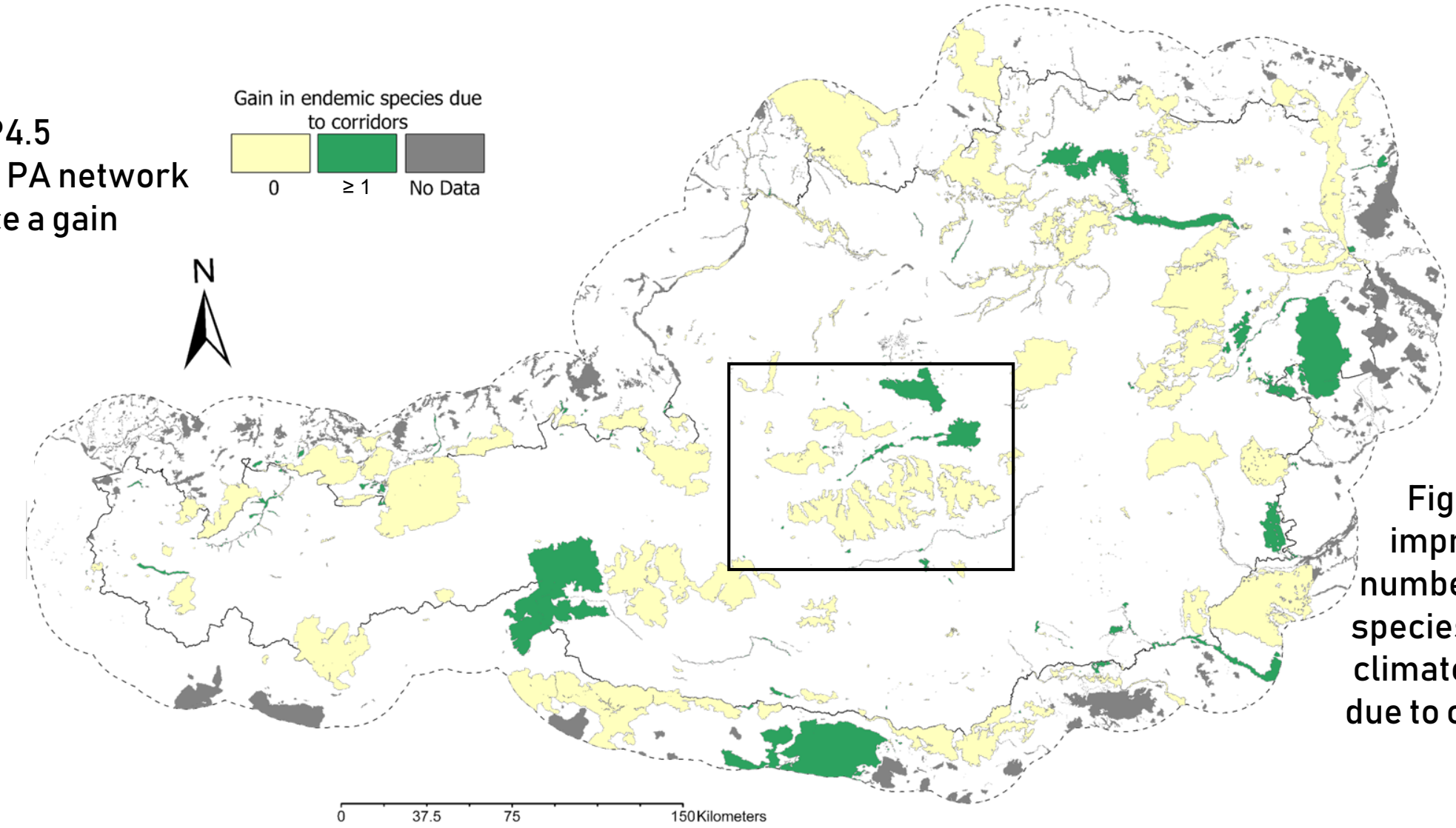


Figure 3: PAs improving their number of endemic species that achieve climate connectivity due to corridors by at least 1.

Endemic Species and Climate Connectivity

2080, RCP4.5
23% of the PA network experience a gain



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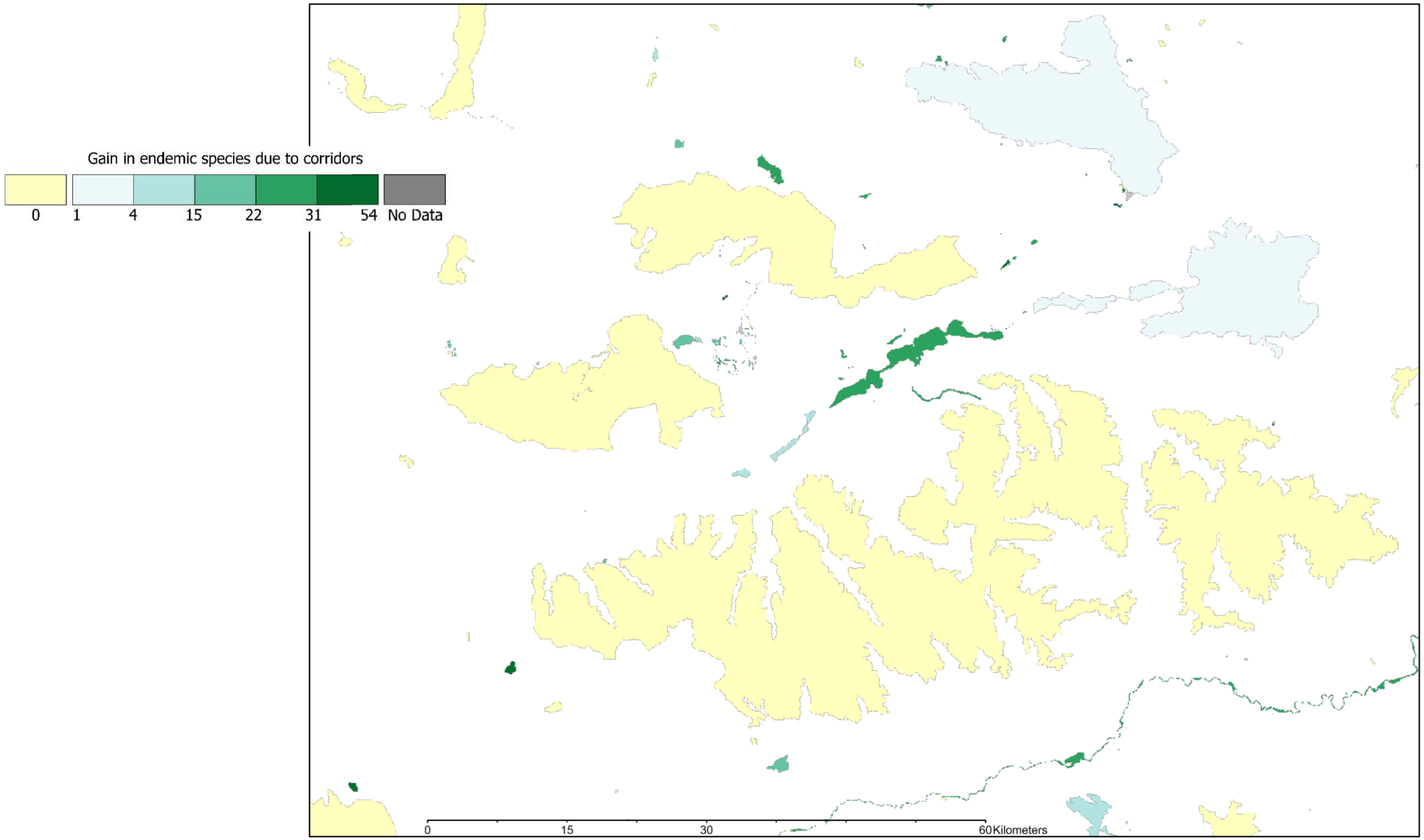
Endemic Species and Climate Connectivity



Endemic Species and Climate Connectivity

Low improvement but high impact:

- 15% & 50 endemic species;

Anonconotus italoaustriacus. © Wolfgang Wagner

.

Saponaria pumila. © Franz Hadacek

.

Campanulla pulla

Endemic Species and Climate Connectivity

Low improvement but high impact:

- 15% & 50 endemic species;
- Reduction in area of high altitude habitats.

Anonconotus italoaustriacus. © Wolfgang Wagner

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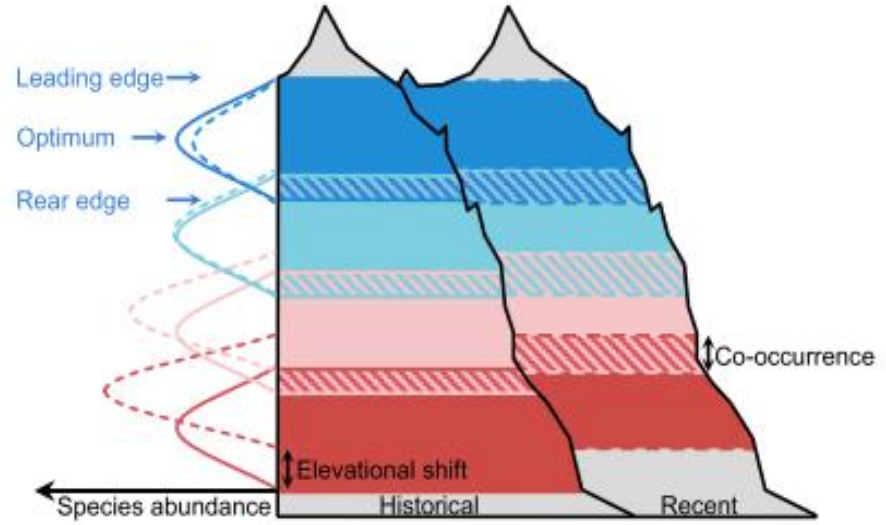

Fig. 6. Schematic illustration of elevational range dynamics of four exemplary mountain plant species. Solid and dashed curves on the left represent historical and recent species distributions, respectively. Overlapping areas of two species indicate areas of cooccurrence. Note that elevational shifts of rear edges, optima, and leading edges as well as abundance changes decrease with elevation and that areas of cooccurrence increased at all elevations.

Source: Rumpf et al, 2018. PNAS.

Model's assumptions & limitations

Model's assumptions & limitations

Mean Annual Temperature as climatic driver:

- Other predictors (minimum temperature, growing degree days, …);
- Combination of parameters.

PCA1 and PCA2 explained 66.0% and 23.3% of total variance, respectively.

Variable	PCA1 loading	PCA2 loading
MAT: mean annual temperature (°C)	-0.369	0.026
MWMT: mean temperature of the warmest month (°C)	-0.336	0.100
MCMT: mean temperature of the coldest month (°C)	-0.364	0.018
TD: difference between MCMT and MWMT (°C)	0.320	0.041
MAP: mean annual precipitation (mm, log transformed)	-0.176	-0.543
MSP: mean summer (May to Sep) precipitation (mm, log transformed)	-0.146	-0.486
MWP: mean winter (Oct to April) precipitation (mm, log transformed)	-0.140	-0.518
DD5: degree-days above 5°C (°C * days, square-root transformed)	-0.362	0.081
NFFD: the number of frost-free days (days)	-0.358	0.084
EREF: Hargreave's reference evaporation (mm)	-0.356	0.136
CMD: Hargreave's climatic moisture index (mm, log transformed)	-0.240	0.394

Source: Carroll et al, 2018. Global Change Biology.

Model's assumptions & limitations

Mean Annual Temperature as climatic driver:

- Other predictors (minimum temperature, growing degree days, …);
- Combination of parameters.

Human influences as resistance map:

- Fixed;
- Coarse for urban adapted species.

Tapinoma sessile, urban-adapted ant.
Menke et al, 2011, Urban Ecosystems.
© Tom Murray

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Model's assumptions & limitations

Mean Annual Temperature as climatic driver:

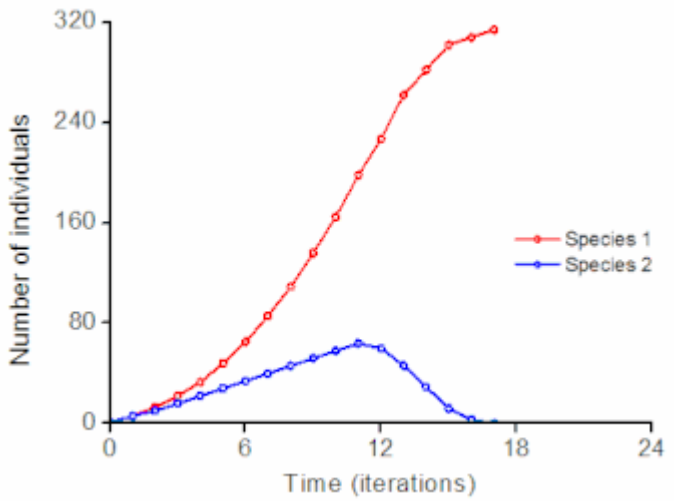
- Other predictors (minimum temperature, growing degree days, …);
- Combination of parameters.

Human influences as resistance map:

- Fixed;
- Coarse for urban adapted species.

Theoritical potential for movement:

- Unsuitable path (geographical barriers or inappropriate natural habitats);
- Population dynamics, multispecies interactions.

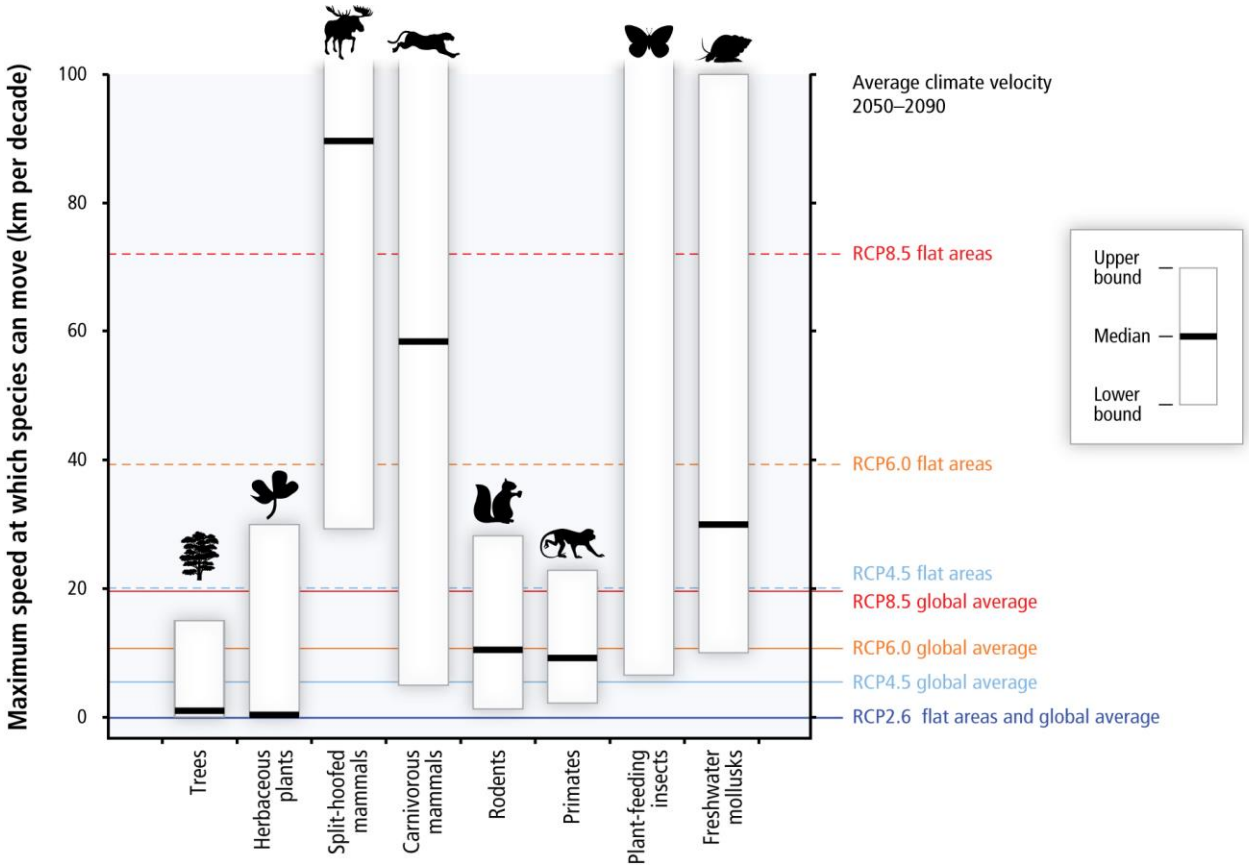


Population dynamics

Model's improvements

Speed:

- Dispersal ability;
- Climate change velocity.



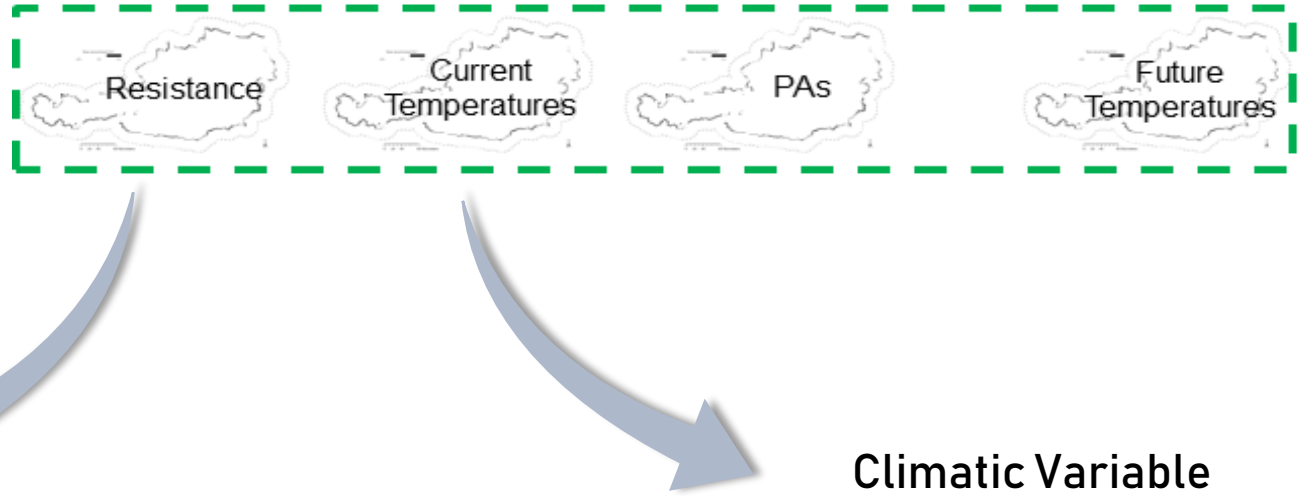
Source: IPCC, 2014, Summary for Policymakers.

Model's improvements

Speed:

- Dispersal ability;
- Climate change velocity.

Adaptability



Conclusion

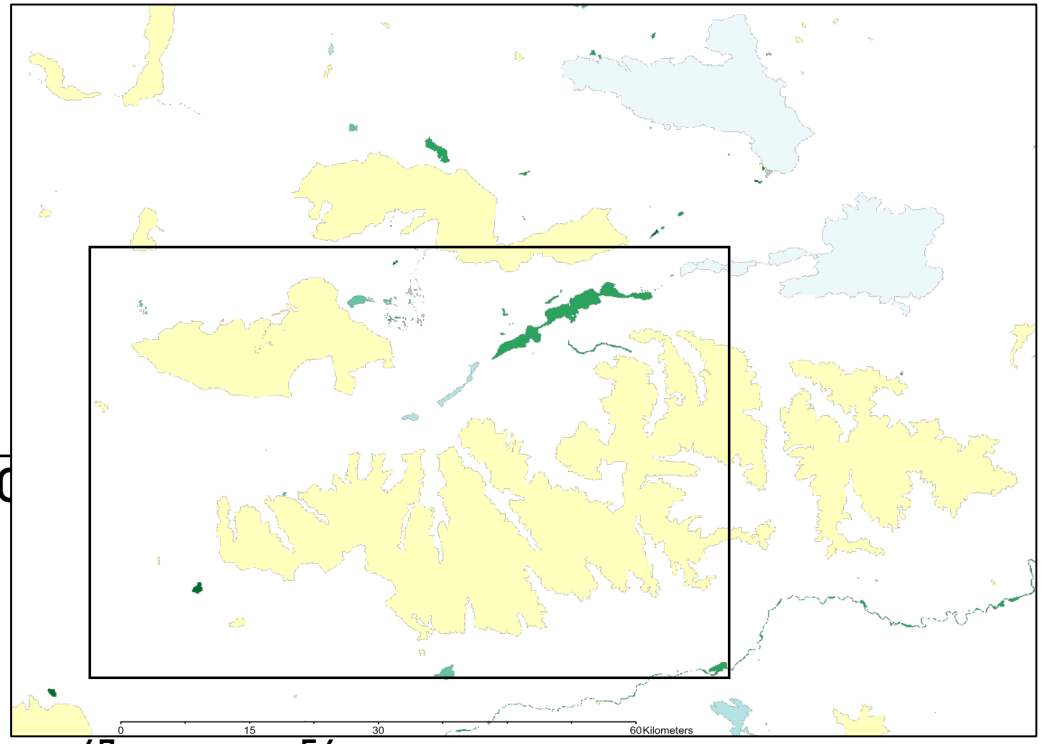
Findings:

- High climatic connectivity in Austria;

	Adjacency Only			Corridors		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
2030	72	73	67	85	85	79
2040	66	66	64	79	78	77
2050	64	64	58	77	77	73
2060	64	62	51	77	75	63
2070	64	55	47	77	67	56
2080	64	52	38	77	64	46

Findings:

- High climatic connectivity in Austria;
- Corridor still valuable in some regions.



	Adjacency Only			C		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6		
2030	72	73	67	85		
2040	66	66	64	79		
2050	64	64	58	77		
2060	64	62	51	77		
2070	64	55	47	77	67	56
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Findings:

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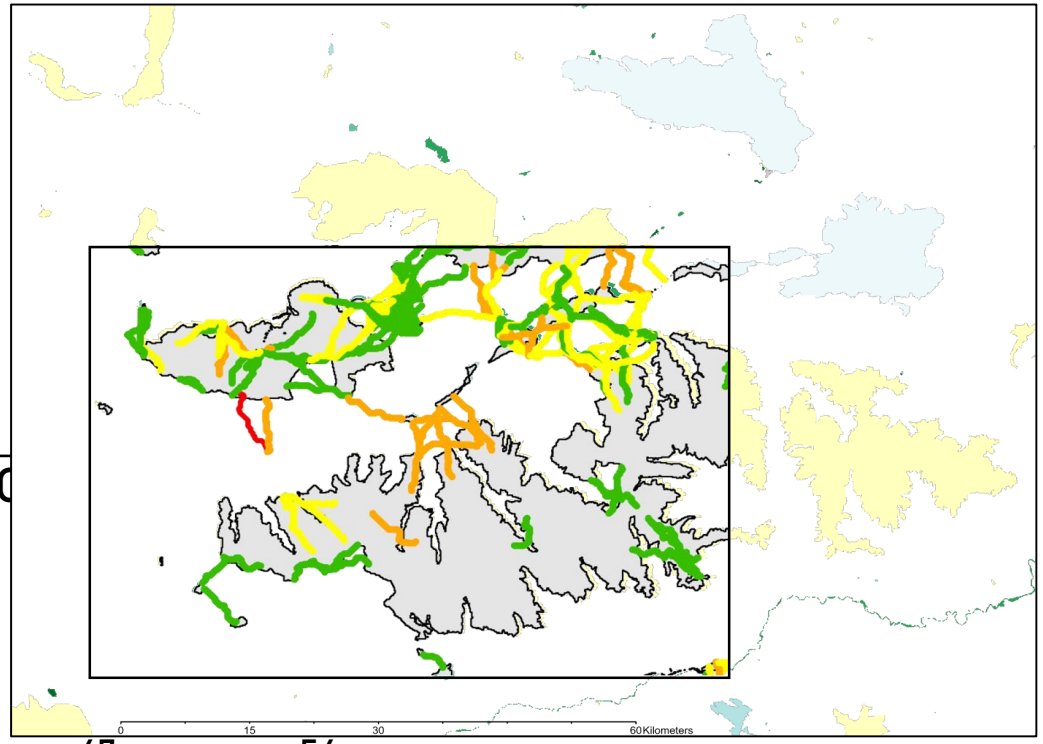


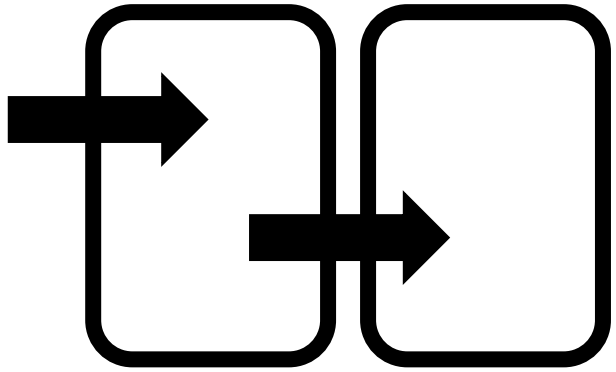
	Adjacency Only			C		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6		
2030	72	73	67	85		
2040	66	66	64	79		
2050	64	64	58	77		
2060	64	62	51	77		
2070	64	55	47	77	67	56
2080	64	52	38	77	64	46

Findings:

- High climatic connectivity in Austria;
- Corridor still valuable in some regions.

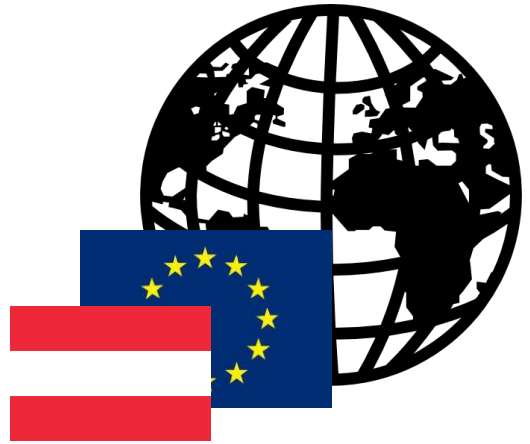
Perspectives:

- Assessment of potentiality & limitations;



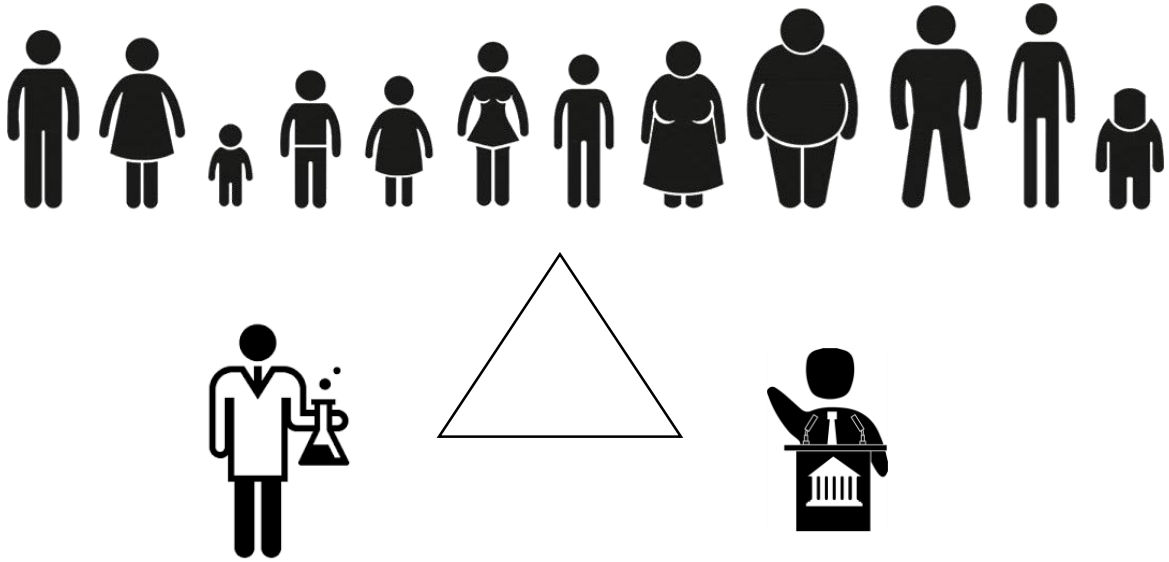
Findings:

- High climatic connectivity in Austria;
- Corridor still valuable in some regions.



Perspectives:

- Assessment of potentiality & limitations;
- Coordination in biodiversity conservation programmes.



Thanks for your attention !

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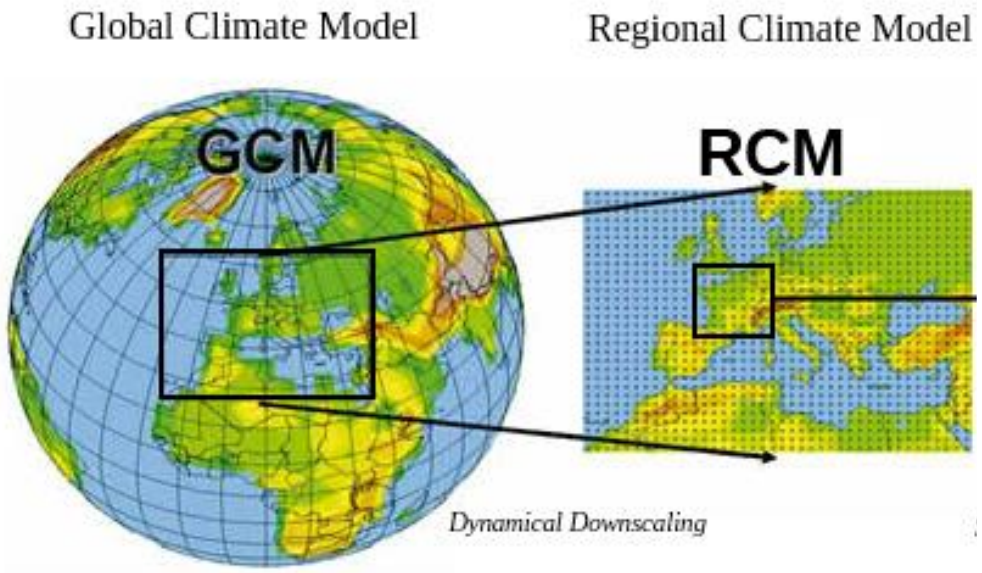
Appendices

GCM, RCM

EURO-CORDEX were again statistically downscaled to 100-m resolution using the approach described in Dullinger et al. (2012),



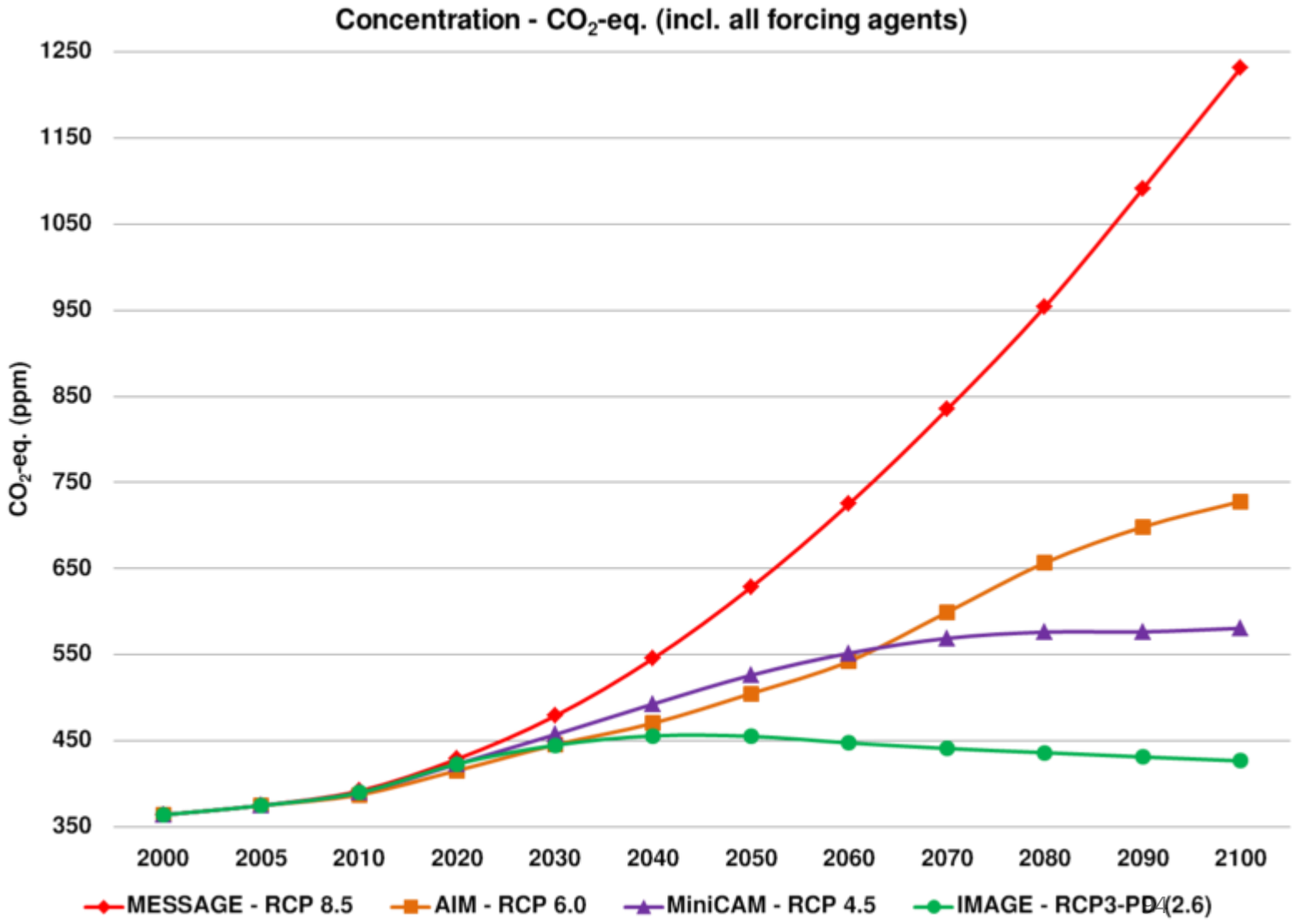
Source : www.drias-climat.fr

Dullinger S., Gattringer A., Thuiller W., Moser D., Zimmermann N.E., Guisan A., Willner W., Plutzar C., Leitner M., & Mang T. 2012. Extinction debt of high-mountain plants under twenty-first-century climate change. *Nature Climate Change*. 2(8), p. 619.

RCP Scenario

Before 2014, SRES
Now, Representative Concentration Pathway : trajectory scenario of radiation forcing by 2300

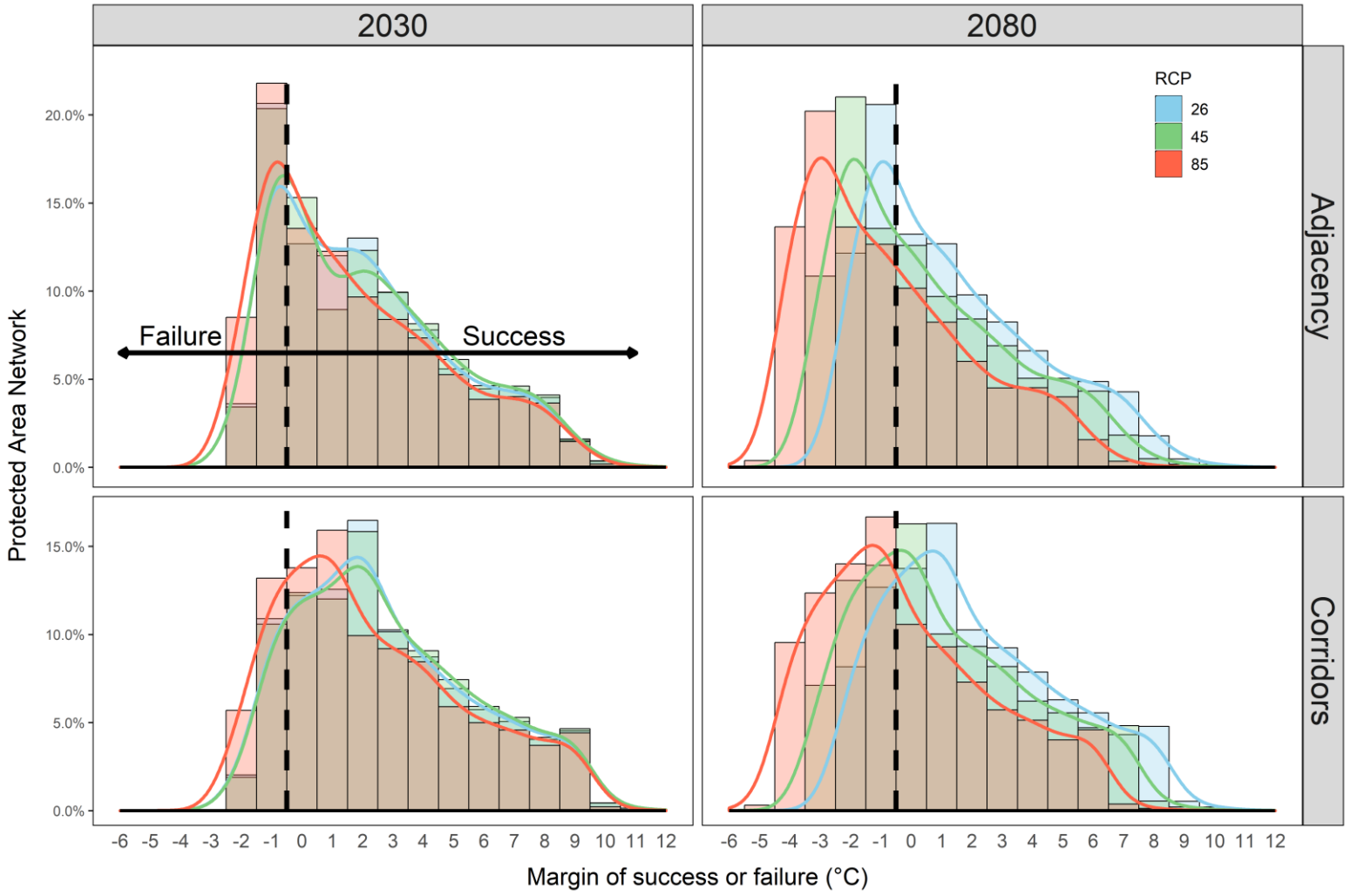
RCP 2,6 = forcing +2,6 W/m²
RCP 4,5 = forcing +4,5 W/m²
RCP 8,5 = forcing +8,5 W/m²



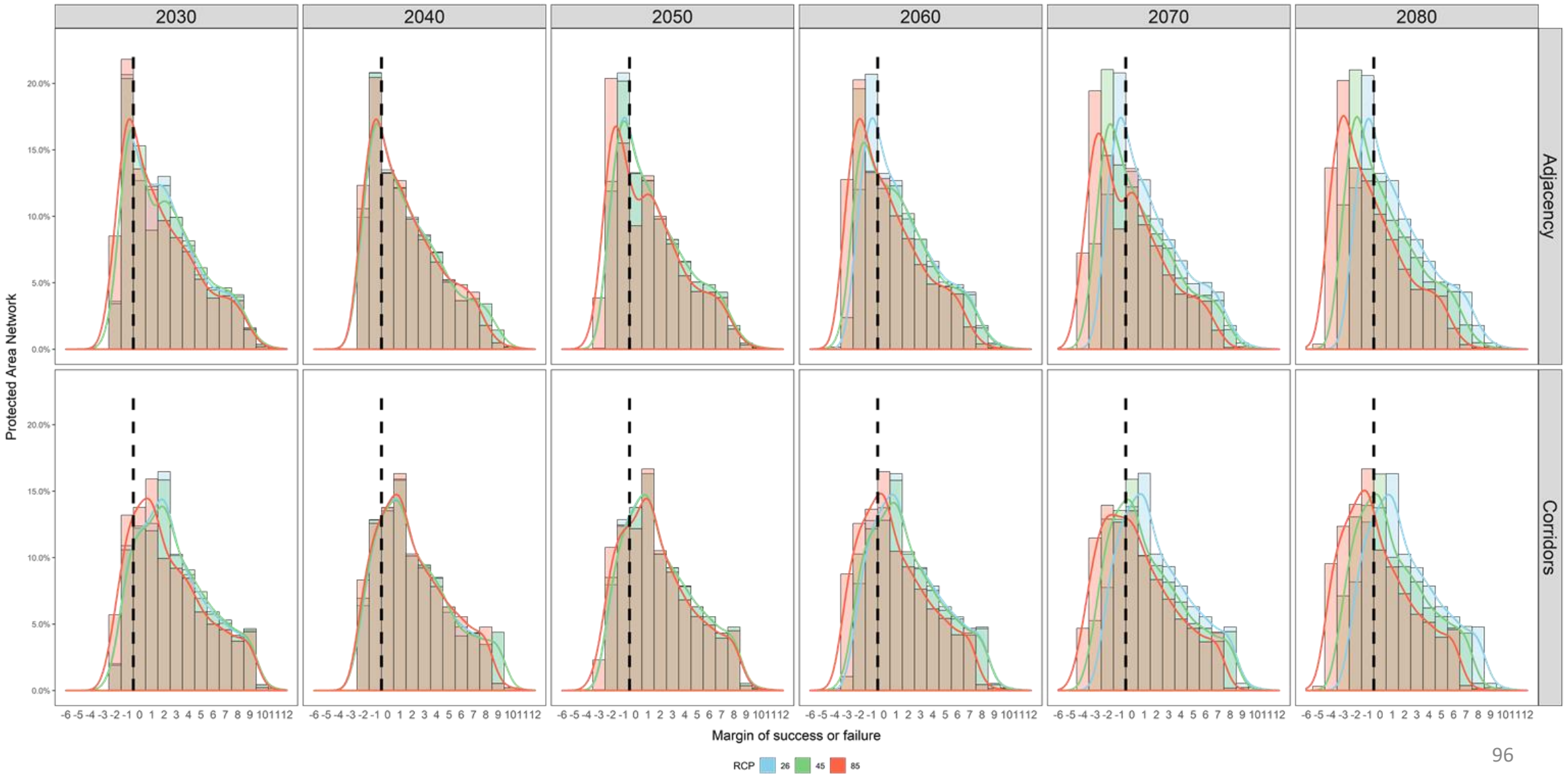
IPCC AR5 WG1 (2013), Stocker, T.F.; et al., eds., Climate Change 2013: The Physical Science Basis. Working Group 1 (WG1) Contribution to the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5), Cambridge University Press, Archived from the original on 12 August 2014

Margin CCS

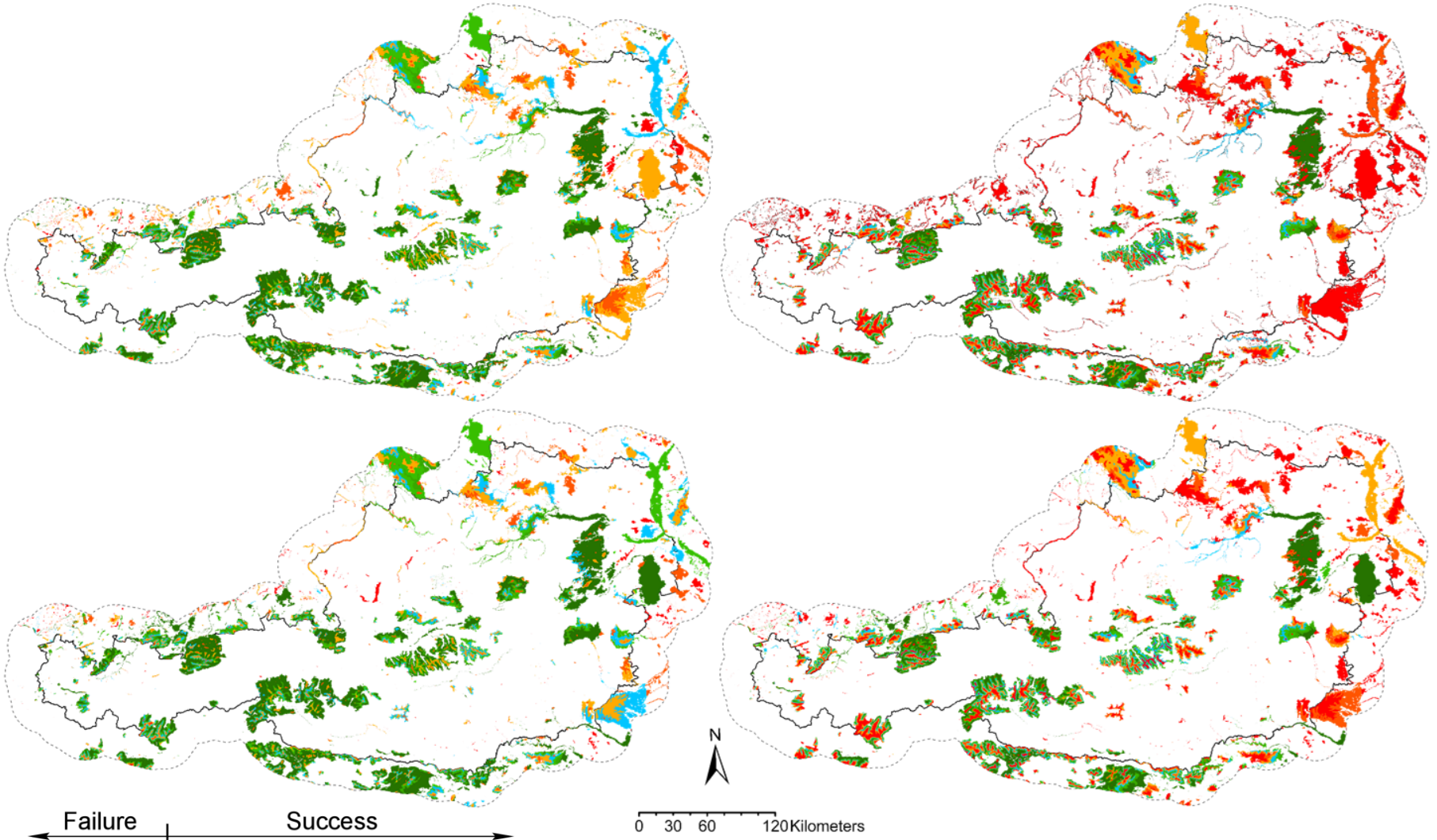
The margin of success or failure at achieving climate connectivity, given various climate scenarios, with and without corridors. The margin is defined as the difference between the current temperature of the origin patch and the future temperature of the destination patch ($Margin = Toc - Tdf$) (McGuire et al., 2016). Consequently, climate connectivity is achieved with positive margins, whereas negative margins are synonymous of failure. Margin distribution and density (A) are shown for years 2030 and 2080 under three climate scenarios (RCP2.6, 4.5 and 8.5) without ("Adjacency") and with ("Corridors") newly established corridors



Margin CCS

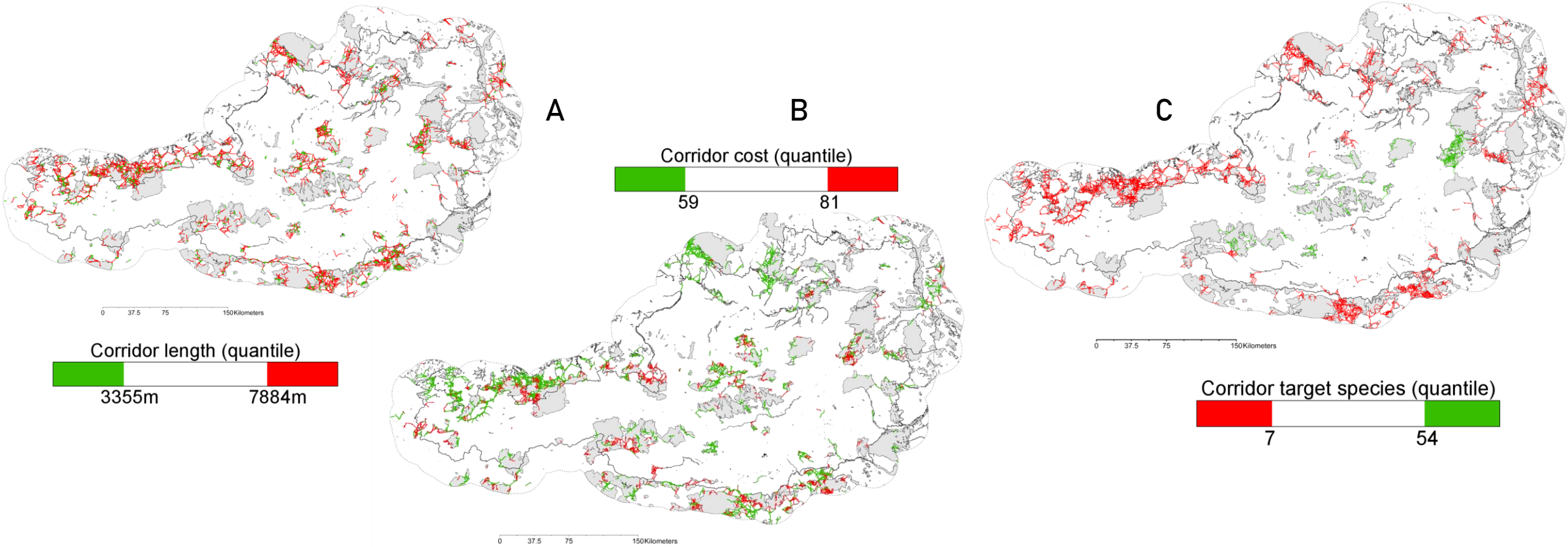

2030
2040
2050
2060
2070
2080
Adjacency
Corridors
Protected Area Network
20.0%
15.0%
10.0%
5.0%
0.0%
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12
Margin of success or failure
RCP 26 45 85

Margin CCS



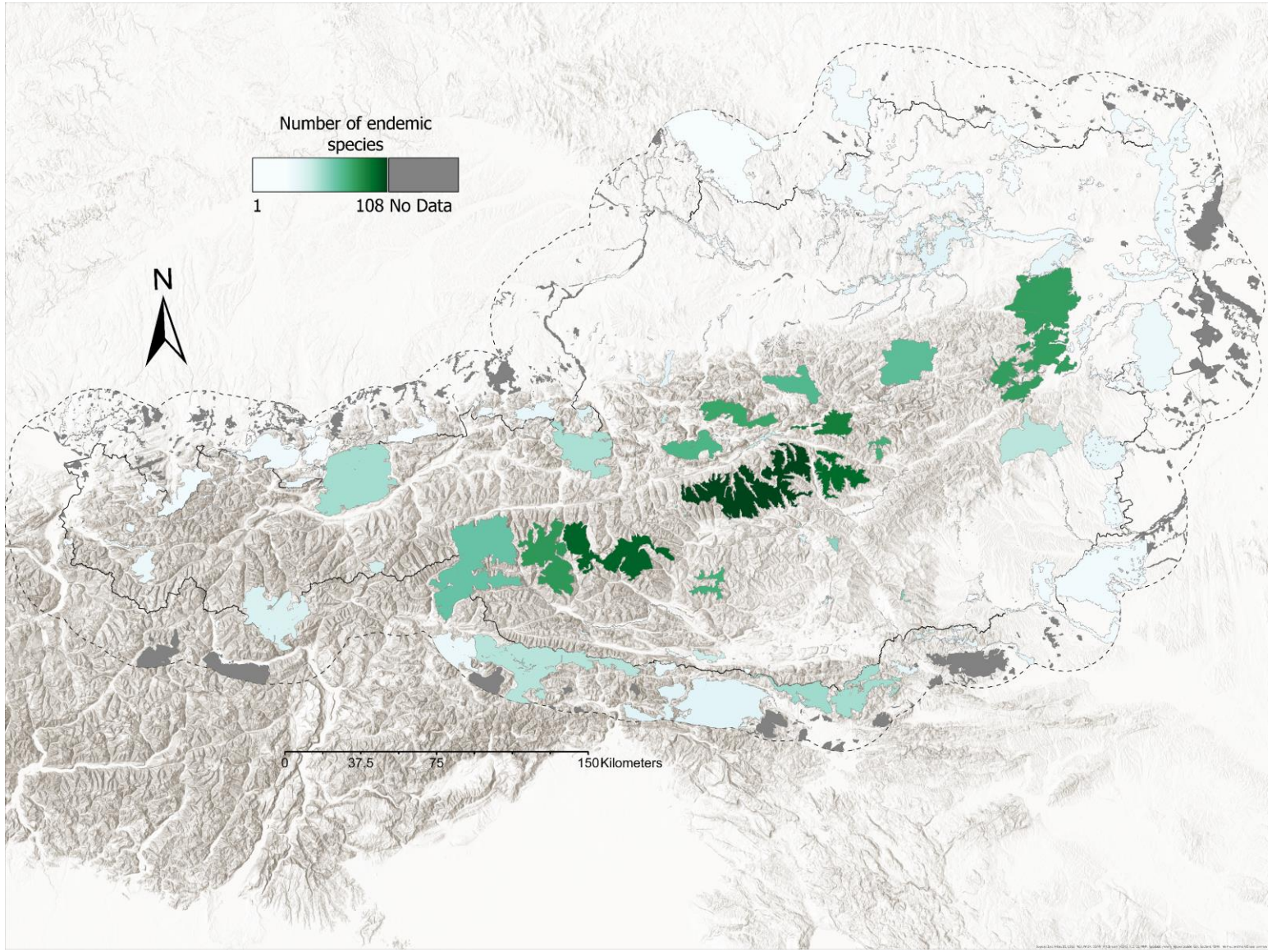
Maps of margin of success or failure at achieving climate connectivity in 2080, given the two extreme climatic scenarios (RCP2.6 and 8.5), with and without corridors. Climate connectivity is achieved with positive (green) or zero margin (blue), whereas negative margins (orange and red) are synonymous of failure.

Corridor Efficiency

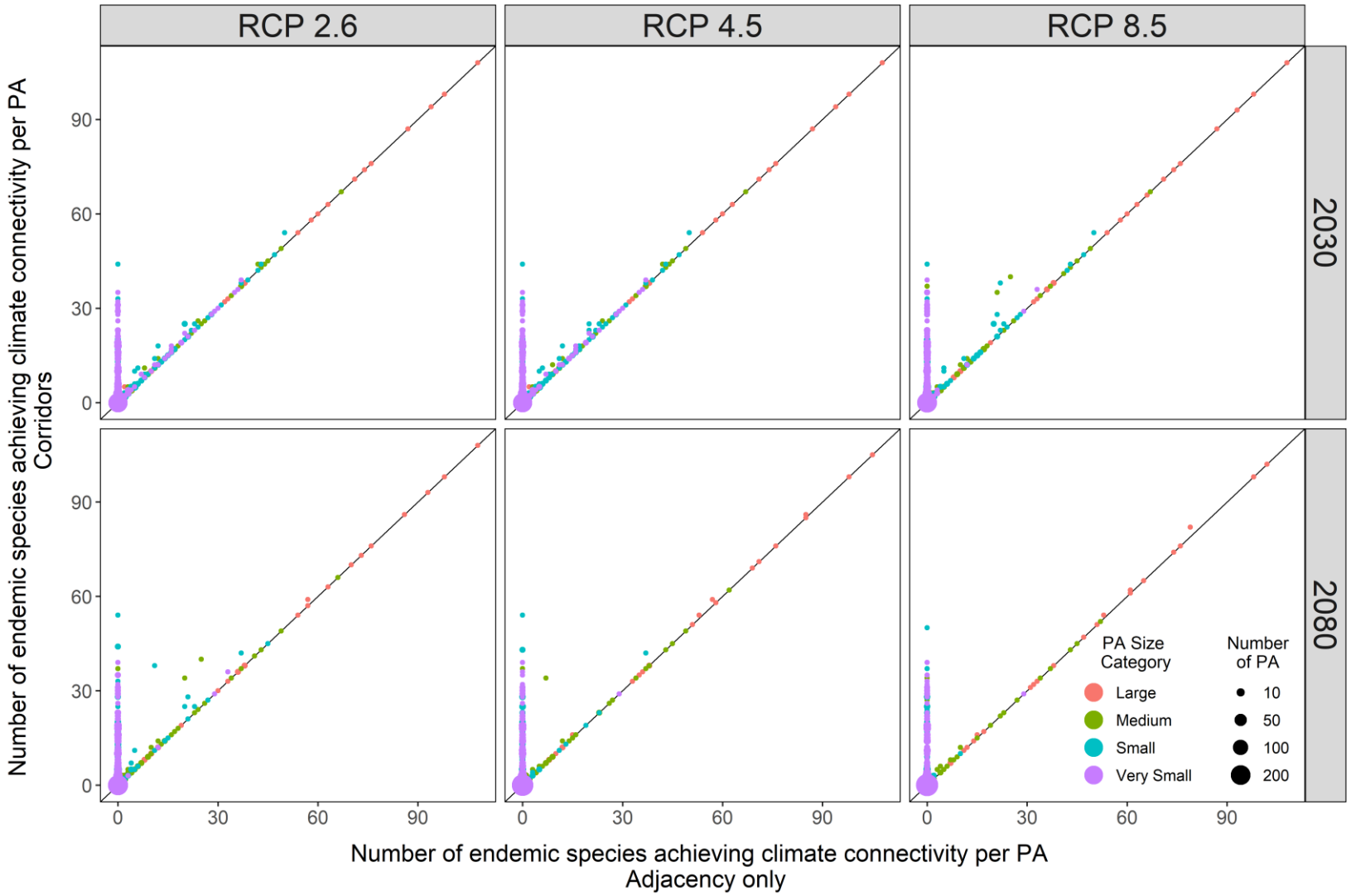


The efficiency of corridors, calculated based on their length (A), their cost (B) and the maximal number of endemic species that become climatically connected to future suitable habitat via these corridors (C).

Endemic Species Distribution

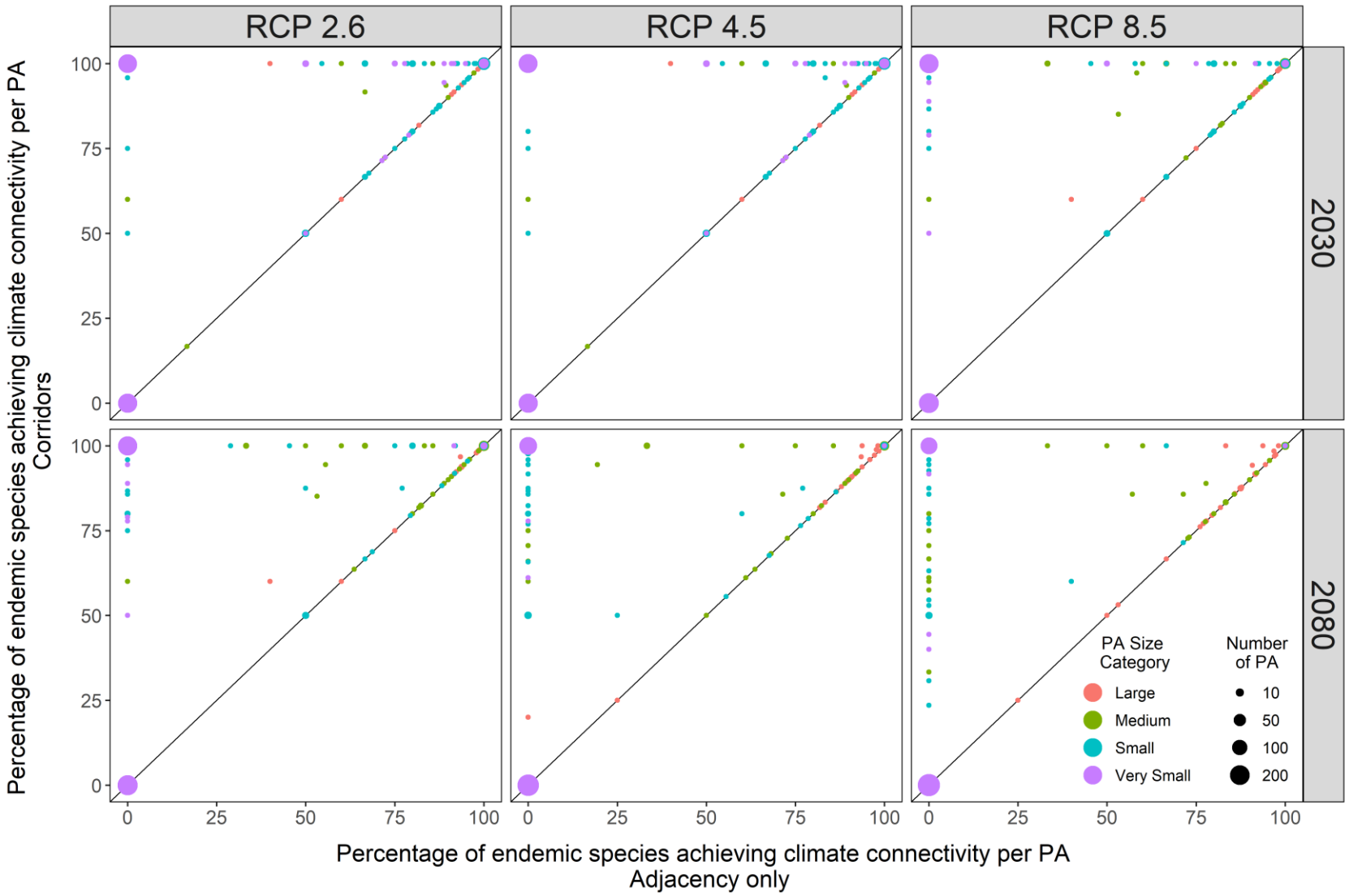


Endemic Species & PA size



Comparison of the number of endemic species per PA that achieve climate connectivity with and without corridors, according to PA size, in 2030 and 2080 and three climate scenarios. PA classification is based on logarithmic quantiles of the area, where very small PAs have an area below 0.19 km²; small PAs are comprised between 0.2 and 3.65 km²; medium PAs between 3.66 and 69.71 km²; large PAs are above 69.71 km².

Endemic Species & PA size



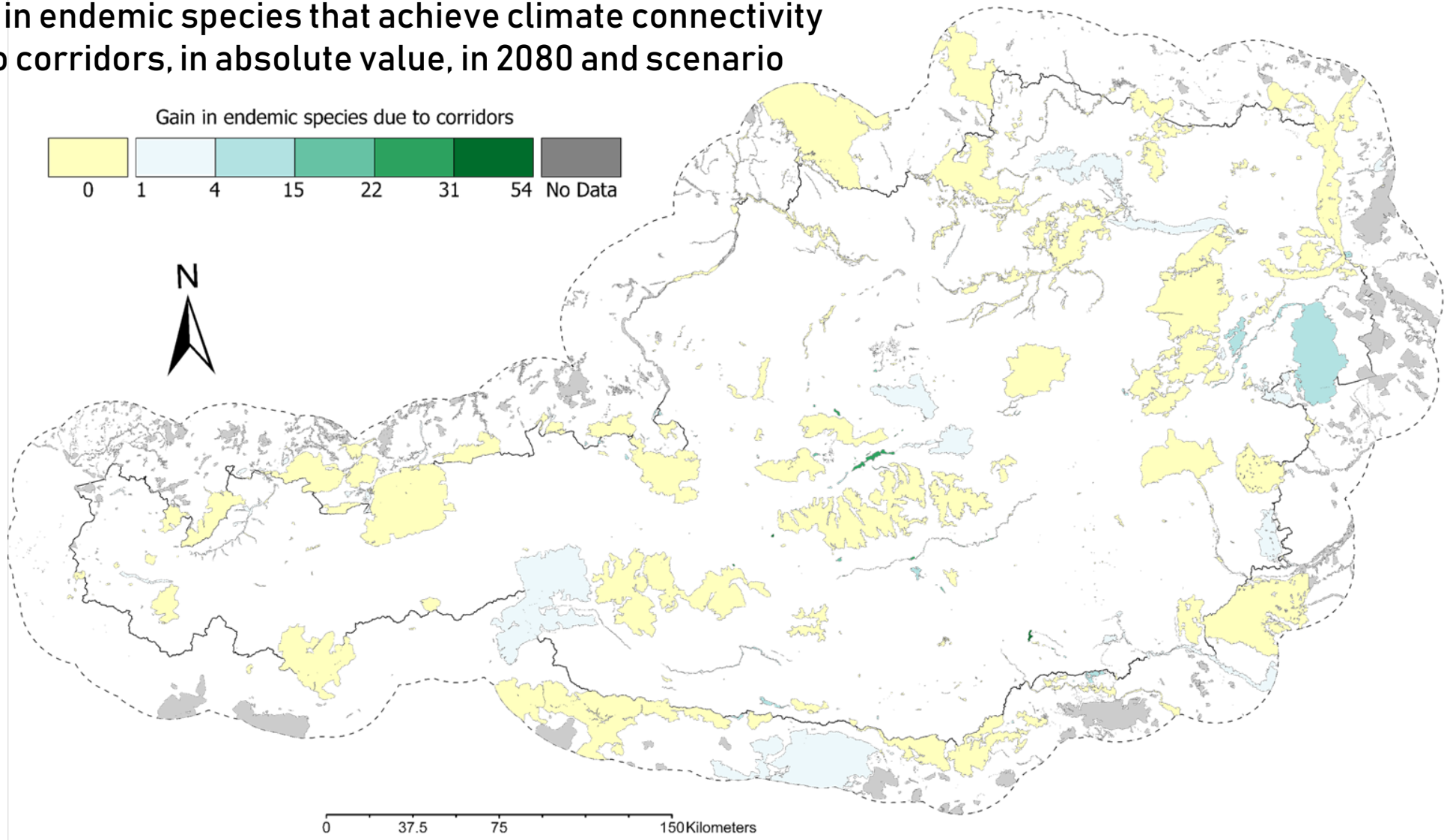
Comparison of the percentage of endemic species per PA that achieve climate connectivity with and without corridors, according to PA size, in 2030 and 2080 and three climate scenarios.

Endemic Species Gains

RCP scenario	Year	% PA network area	Number of PAs
2,6	2030	11,0	312
	2040	11,8	351
	2050	12,5	358
	2060	12,6	361
	2070	12,5	358
	2080	12,6	361
4,5	2030	11,0	312
	2040	11,8	351
	2050	12,5	354
	2060	19,2	338
	2070	17,6	307
	2080	23,0	304
8,5	2030	11,8	349
	2040	12,5	355
	2050	22,0	321
	2060	22,3	307
	2070	17,6	273
	2080	19,0	254

Endemic Species Gains

Maps of gain in endemic species that achieve climate connectivity per PA due to corridors, in absolute value, in 2080 and scenario RCP4.5



Endemic Species Gains

Maps of gain in endemic species that achieve climate connectivity per PA due to corridors, in percentage, in 2080 and scenario RCP4.5