FEN Master's Defense

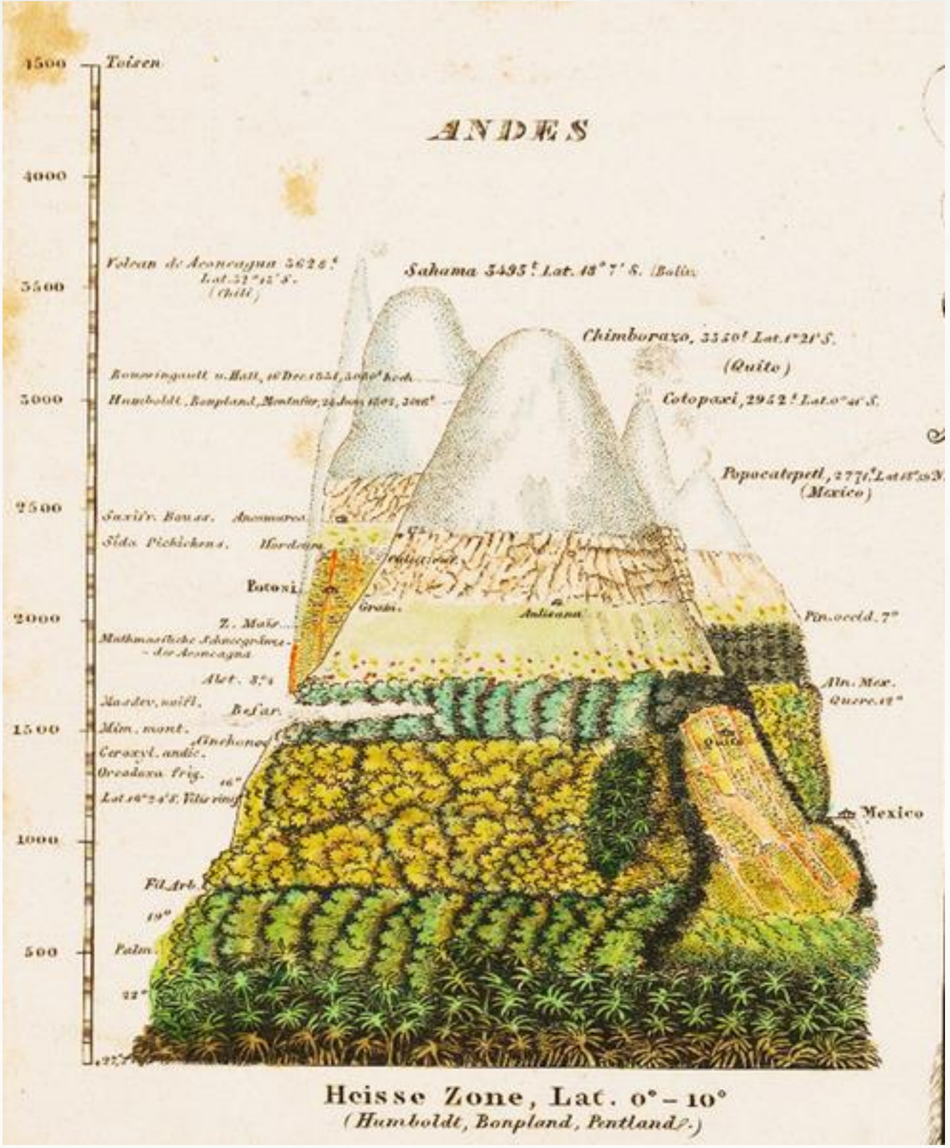
Global tree distribution disequilibrium dynamics:

View of land-use transformation and paleoclimate anomaly

Presenter: Pengcheng LAI

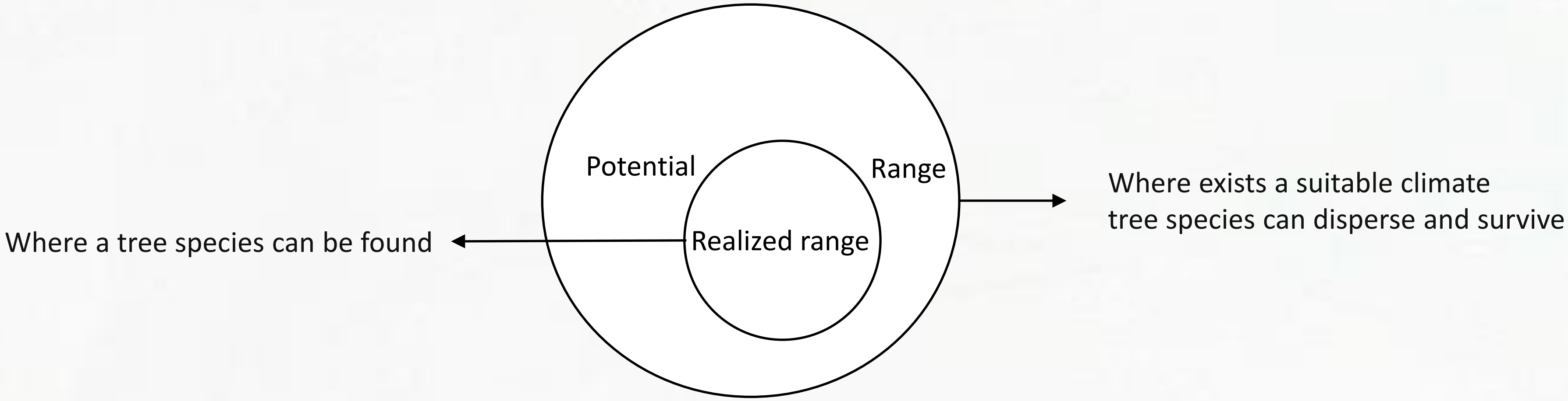
Supervisor: Josep M. Serra-Diaz, AgroParisTech

Academic referent: Jean-Claude Gégout, AgroParisTech



Berghaus,1845

Climatic disequilibrium:



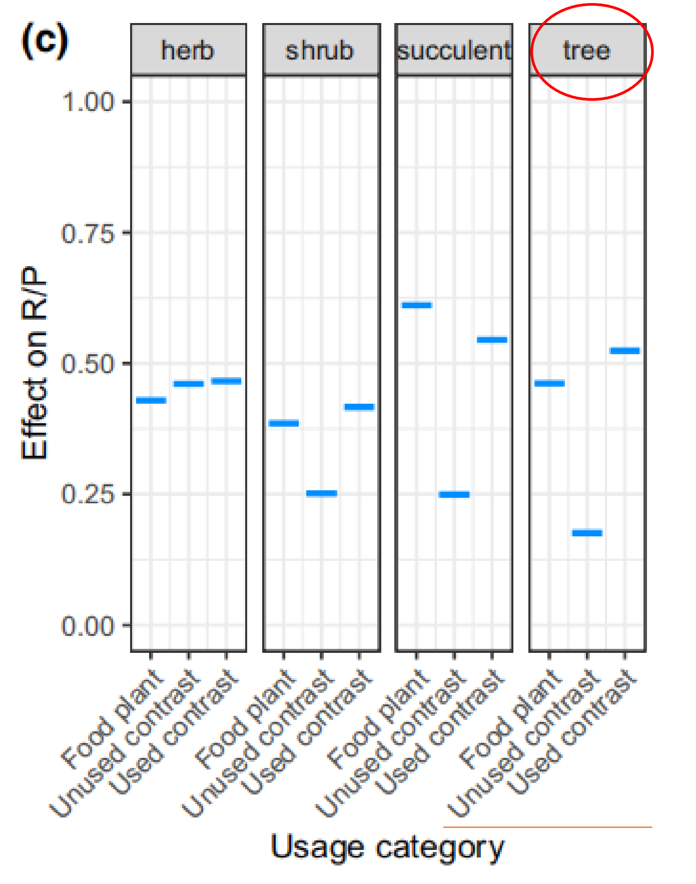
Importance:

Understanding tree species distribution is a critical conservation priority in ecosystem restoration and the post-2020 goals for biodiversity protection.

Impact of paleoclimate

Ginkgo digitata, Muséum national d'Histoire naturelle

Impact of human activities



Flower *et al.*, 2021

Question:

A） What is the global tree disequilibrium status quo across seven major biogeographical realms?

Hypothesis:

a) Potential ranges of global tree species are potentially wide unfilled.

Question:

B） Do land use changes in critical prehistorical and historical periods and paleoclimate anomalies drive current tree disequilibrium?

Hypothesis:

b) Present-day tree species distribution is co-influenced by the current climate, current land use, paleoclimate change, and (pre-)historical land-use change.

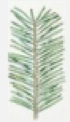
1. Calculation of Rang unfilling:

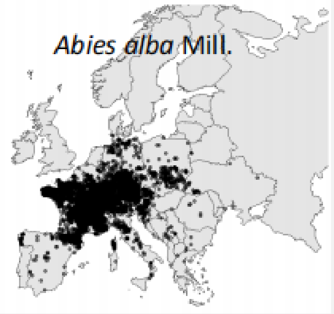
Species selection

- > 57000 global tree species
- 51620 accepted species
- 29166 species with ≥ 10 unique records (57%)
- 19041 species included in the final analysis

Occurrence compilation

GBIF



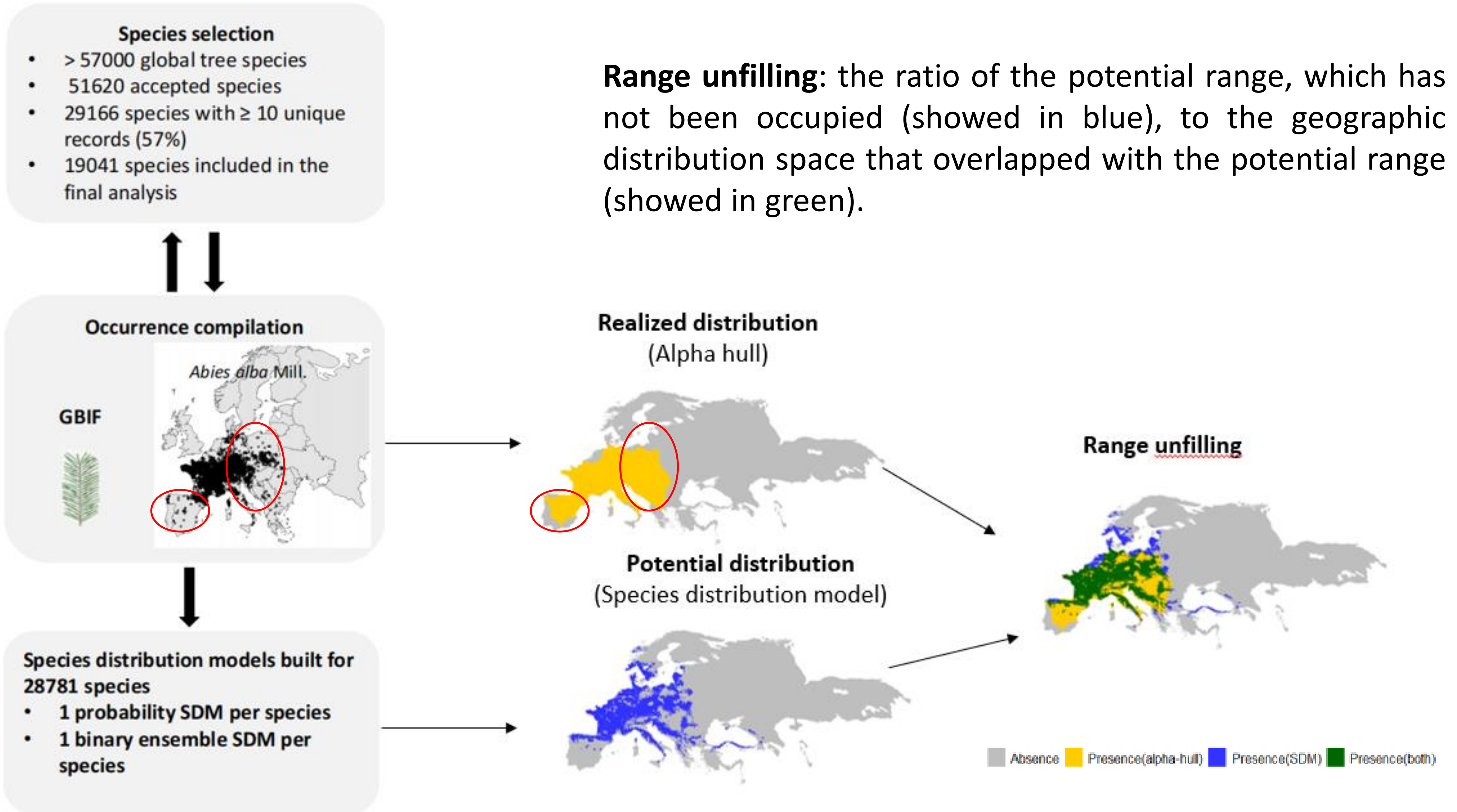


Species distribution models built for 28781 species

- **1 probability SDM per species**
- **1 binary ensemble SDM per species**

1. Calculation of Rang unfilling:

Range unfilling: the ratio of the potential range, which has not been occupied (showed in blue), to the geographic distribution space that overlapped with the potential range (showed in green).



2. Simulation of drivers: A. Paleoclimate change

Past climate change

- Late Miocene (Miocene, 11.6 – 7.2 mya)

  Pound *et al*., 2011

- Last Glacial Maximum (LGM, ~ 21 kya)

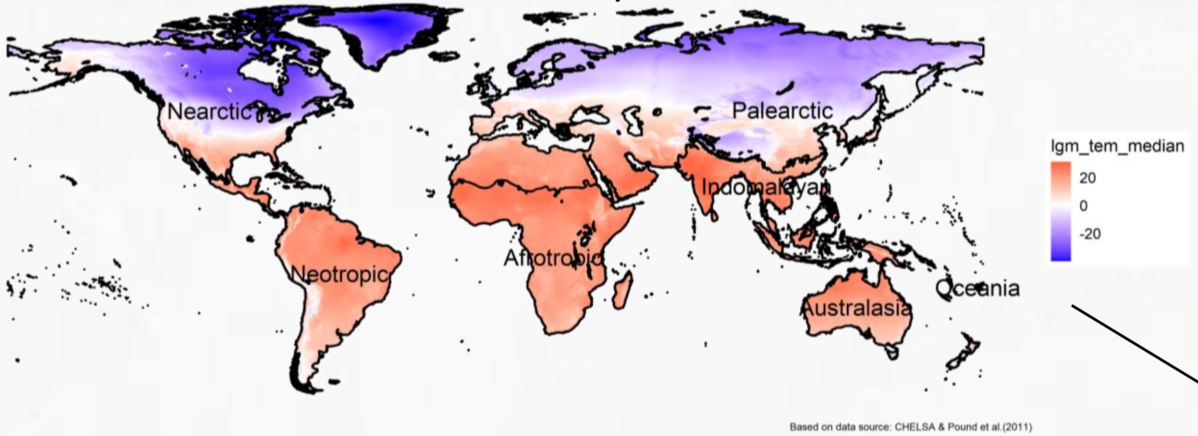
  Karger *et al*., 2021

Temperature anomaly

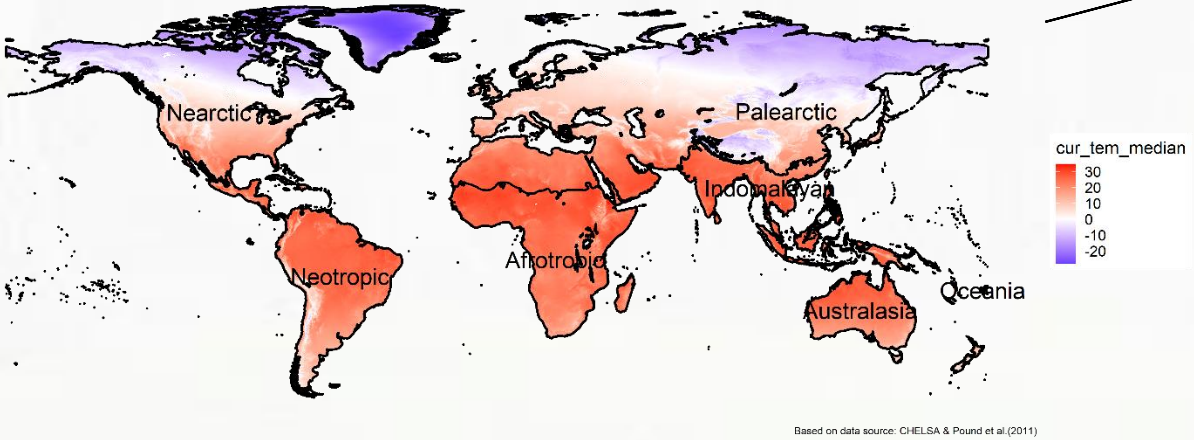
Precipitation anomaly

2. Simulation of drivers: A. Paleoclimate change

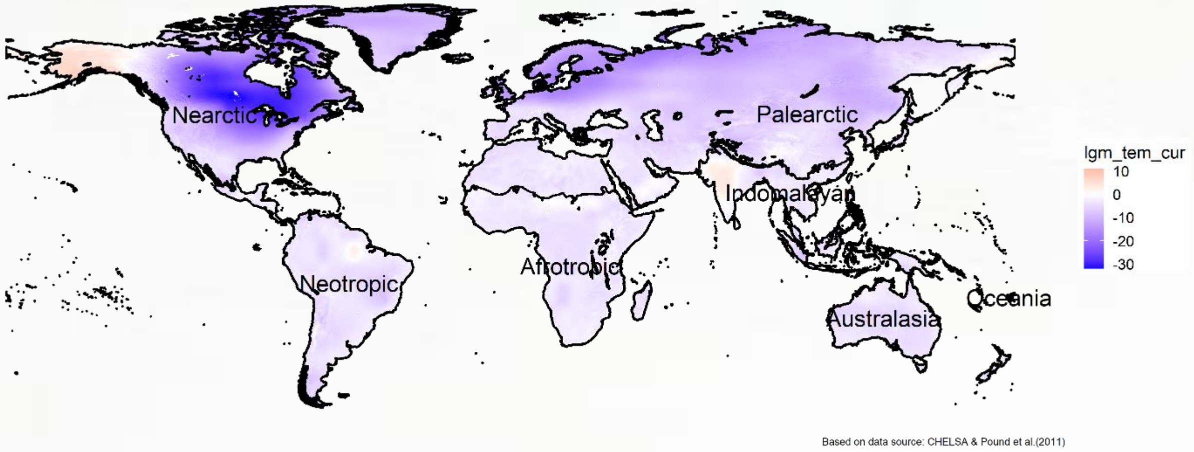
LGM temperature



Current temperature(1981-2010 average)



LGM temperature anomaly



2. Simulation of drivers: B. Land use transformation

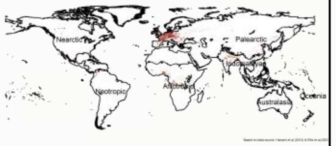
Land-use transformation

- Early agricultural era (EAE, 10,000 BCE - 1 CE)
- Agricultural era (AE, 1 CE - 1500 CE)
- Era of discovery (ED, 1500 CE - 1850 CE)
- Era of post-first industrial revolution (EPFIR, 1850 CE - 1950 CE)
- Era of post-second industrial revolution (EPSIR, 1950 CE - 2013 CE)

Ellis *et al.*, 2021

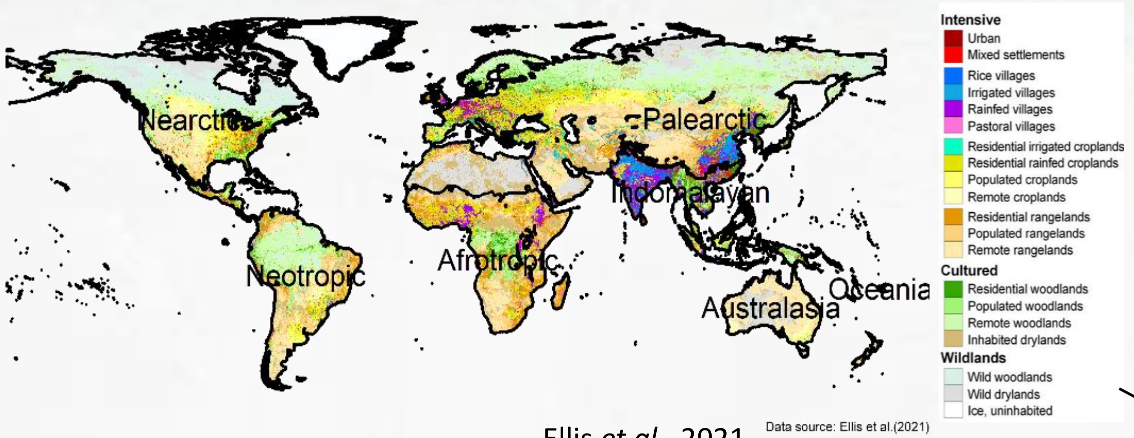
Human pressure change

Tree cover alternation



2. Simulation of drivers: B. Land use transformation

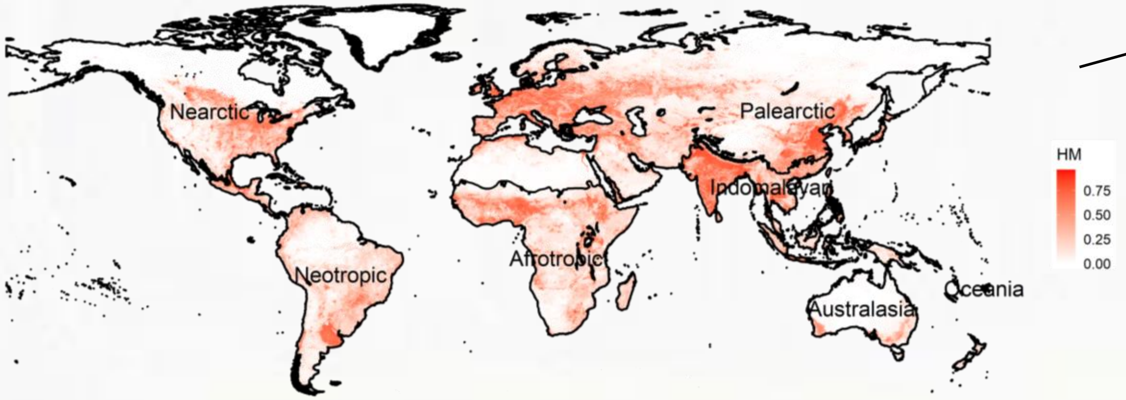
Land use in the year 2016



Ellis *et al.*, 2021

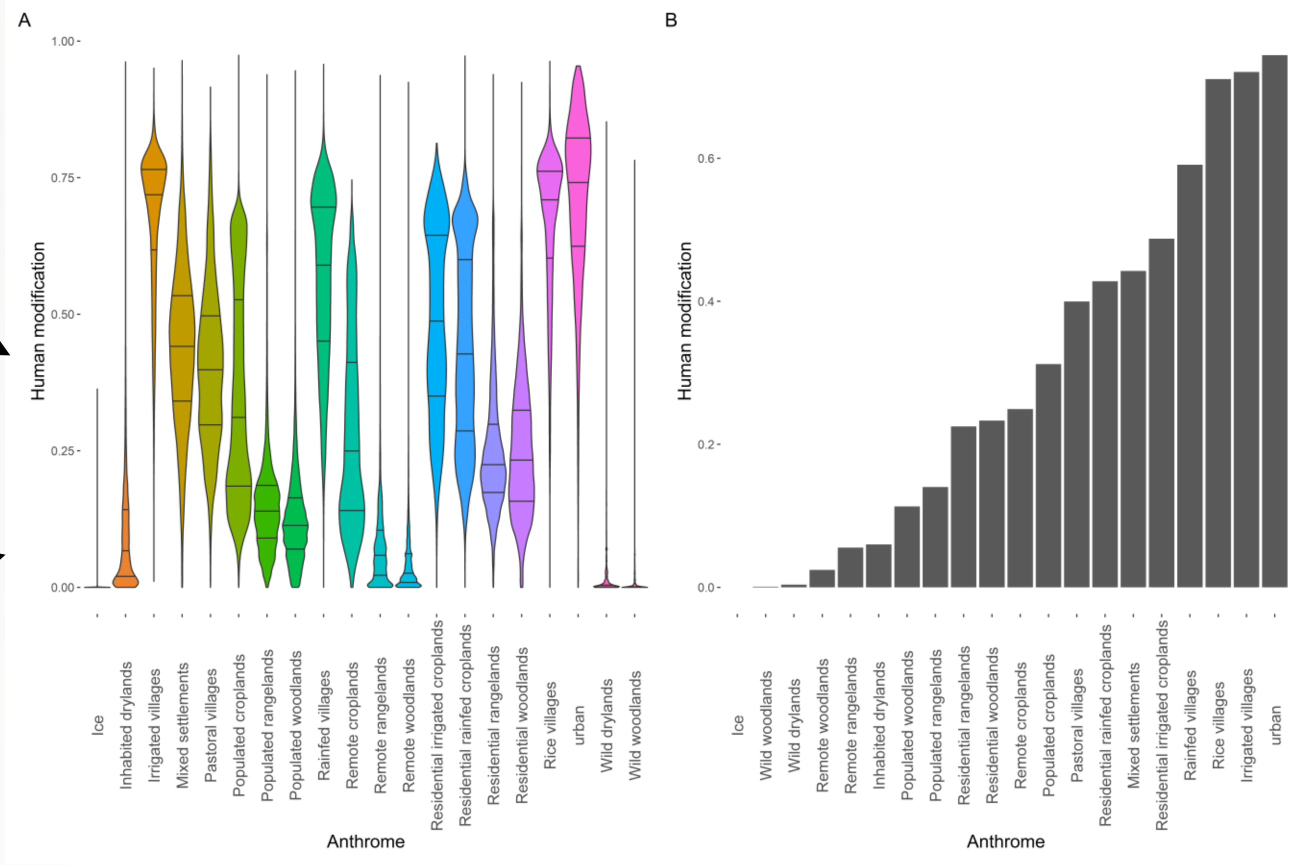
Step a:

Human modification in the year 2016



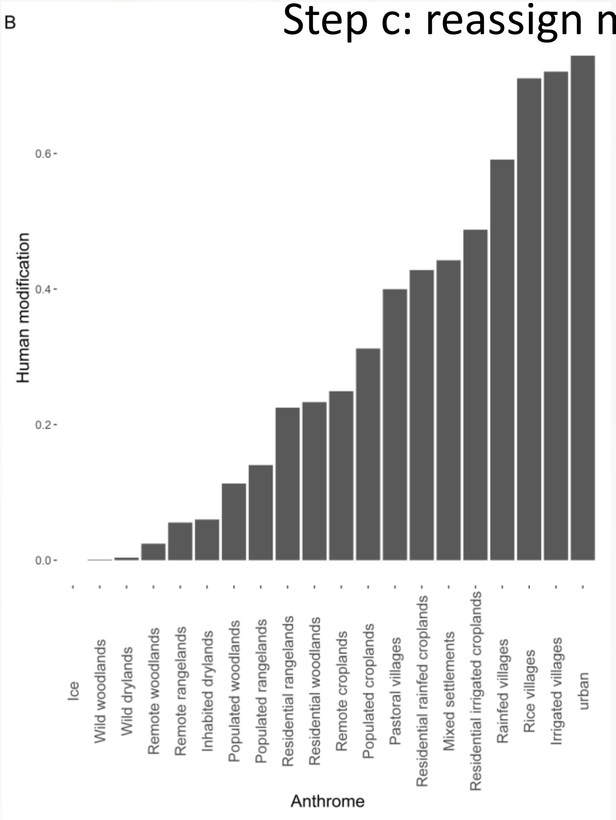
Kennedy *et al.*, 2019

Step b: calculation of median values of HM in each land use type

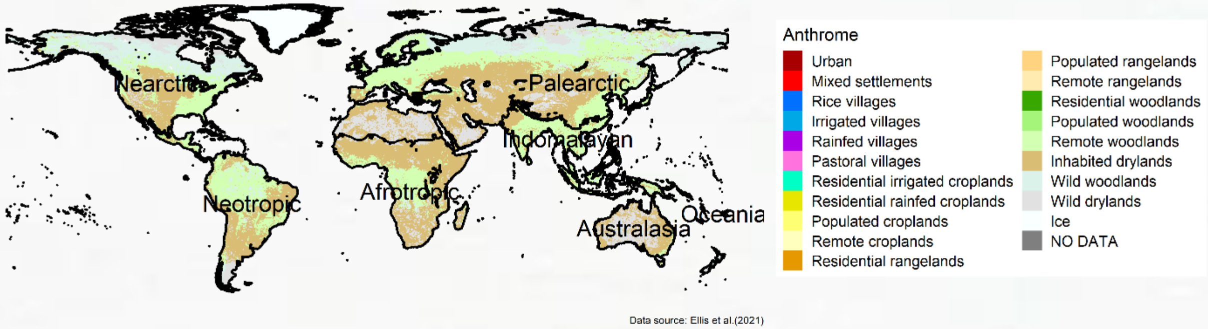


2. Simulation of drivers: B. Land use transformation

Step c: reassign median HM

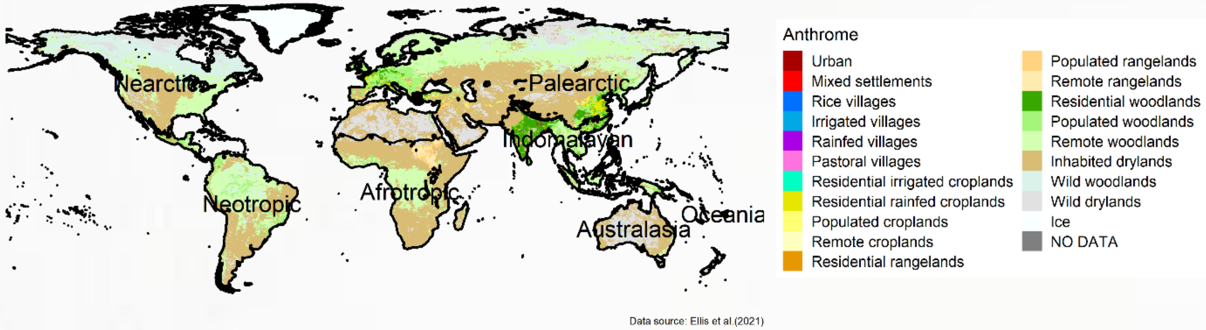


Land use in the year 10,000 BCE

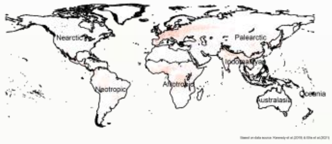


Step d: calculation of HM alternation for EAE

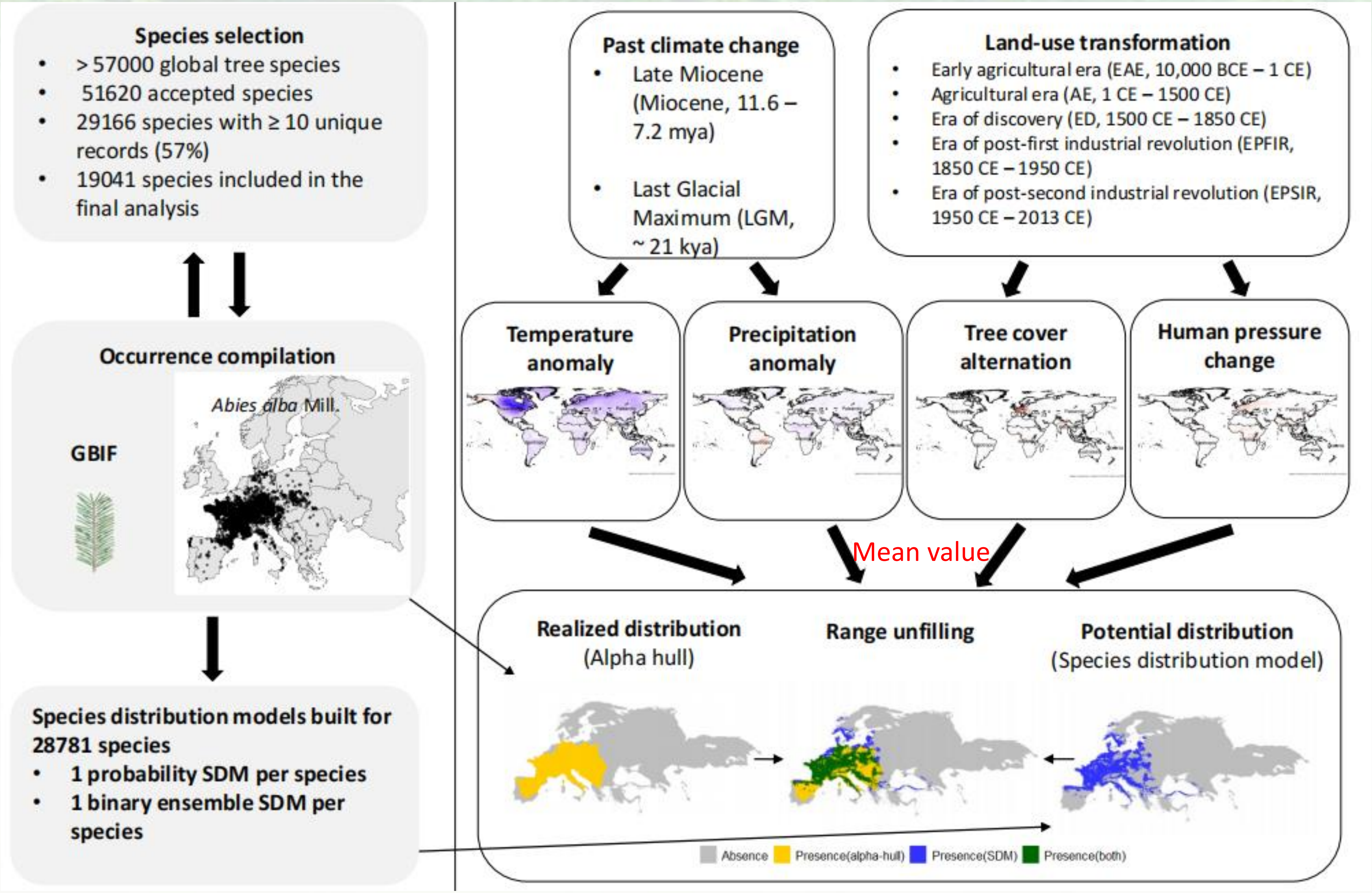
Land use in the year 1 CE



Human pressure change



Ellis *et al.*, 2021


Species selection
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GBIF
Abies alba Mill.
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Past climate change
• Late Miocene (Miocene, 11.6 – 7.2 mya)
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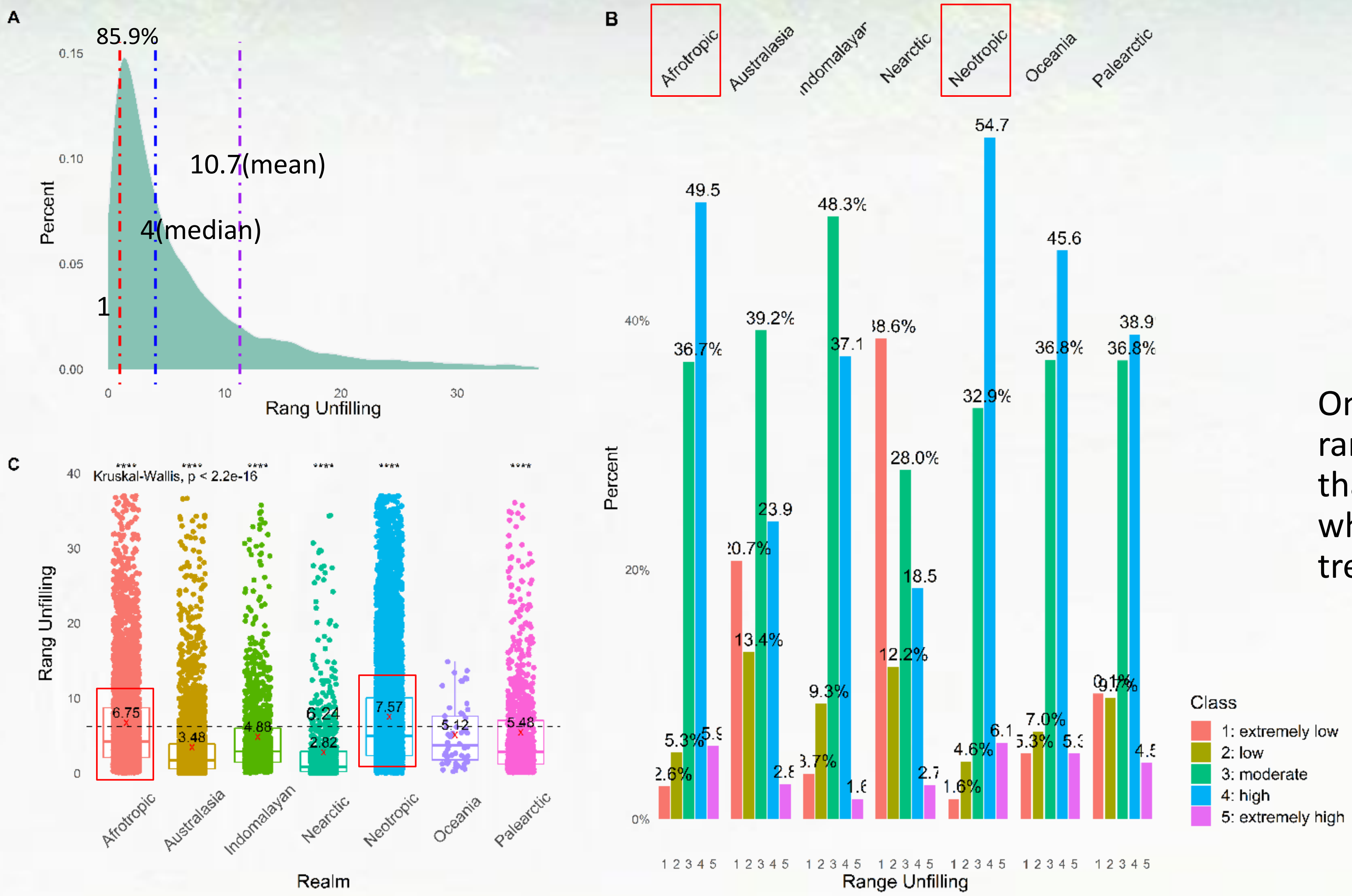
Land-use transformation
• Early agricultural era (EAE, 10,000 BCE – 1 CE)
• Agricultural era (AE, 1 CE – 1500 CE)
• Era of discovery (ED, 1500 CE – 1850 CE)
• Era of post-first industrial revolution (EPFIR, 1850 CE – 1950 CE)
• Era of post-second industrial revolution (EPSIR, 1950 CE – 2013 CE)
Temperature anomaly
Precipitation anomaly
Tree cover alternation
Human pressure change
Mean value
Realized distribution (Alpha hull)
Range unfilling
Potential distribution (Species distribution model)
Absence
Presence(alpha-hull)
Presence(SDM)
Presence(both)

RESULT



On average, species' potential ranges are 10.7 times larger than their geographic ranges, while the median RU of global tree species is 4.

FIGURE 1 Range unfilling was classified into five RU classes: extremely low (class 1, $0 < RU \leq 0.5$), low (class 2, $0.5 < RU \leq 1$), moderate (class 3, $1 < RU \leq 4$), high (class 4, $4 < RU \leq 37$), extremely high (class 5, $37 < RU$).

RESULT

TABLE 1 Results of the generalized linear mixed models of Range Unfilling.

	Rang unfilling	
Predictors	*Estimates*	*P Value*
Intercept	1.46 (0.43 – 2.49)	**0.005**
TC	0.00 (-0.00 – 0.00)	0.549
HM	-0.75 (-0.76 – -0.75)	**<0.001**
TC-EPSIR	0.01 (0.01 – 0.02)	**<0.001**
HM-EPSIR	4.76 (4.76 – 4.76)	**<0.001**
TC-EPFIR	0.01 (0.01 – 0.01)	**<0.001**
HM-EPFIR	0.50 (0.50 – 0.51)	**<0.001**
TC-ED	-0.01 (-0.02 – -0.01)	**<0.001**
HM-ED	2.02 (2.02 – 2.02)	**<0.001**
TC-AE	-0.04 (-0.04 – -0.04)	**<0.001**
HM-AE	-3.28 (-3.28 – -3.28)	**<0.001**
TC-EAE	0.00 (-0.00 – 0.00)	0.083
HM-EAE	-1.06 (-1.06 – -1.06)	**<0.001**
MAP	0.11 (0.11 – 0.12)	**<0.001**
MAT	-0.01 (-0.02 – -0.01)	**<0.001**
LGMPA	0.00 (0.00 – 0.00)	**0.025**
LGMTA	-0.15 (-0.15 – -0.15)	**<0.001**
MPA	0.00 (0.00 – 0.01)	**<0.001**
MTA	0.00 (0.00 – 0.00)	**0.004**
Random Effects		
σ^2	1019.30	
$\tau_{00\ realm}$	1945.23	
ICC	0.66	
N_{realm}	7	
Observations	19041	
Marginal R^2 / Conditional R^2	0.000 / 0.656	

Land use variables

Climate variables

Tree cover change during the era of post-first indusrtical revolution (1850 CE - 1950 CE)

Human modification change during the era of discovery (1500 CE - 1850 CE)

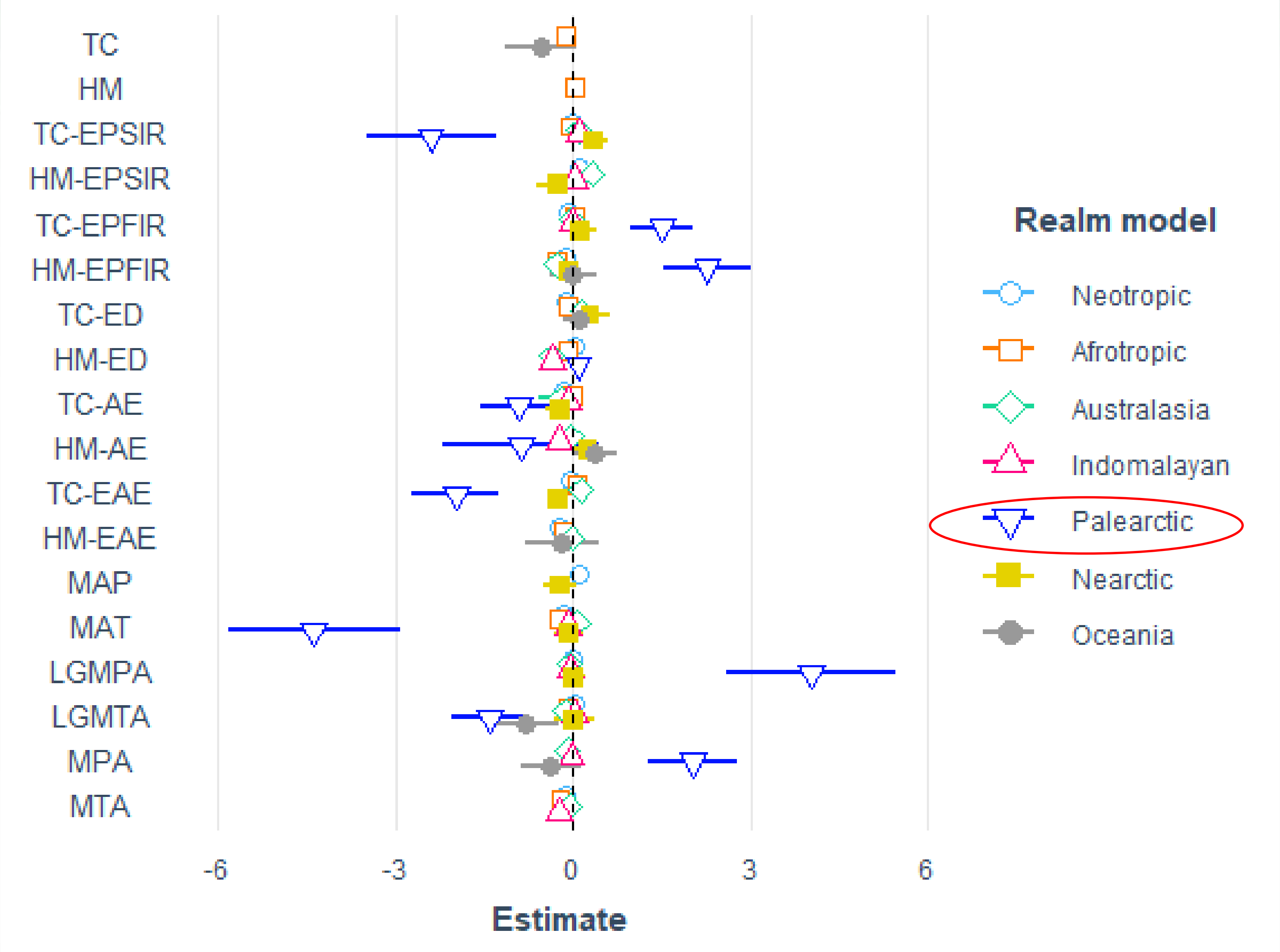
LGM temperature anomaly

1. Land-use transformation and paleoclimate anomaly with current land use and present-day climate can explain the 65.6% variance of range unfilling.

2. The intensified human activities negatively impacted RU in the early eras of human society, whereas the opposite effects happened since the era of discovery.

3. Extensive deforestation has hampered tree species from filling their potential range more in the early stages. In contrast, the increase of tree cover during the post-industrial era, due to conversing from inhabitable drylands to intensive anthromes, has a positive effect on RU.

4. LGM temperature anomaly has reduced climatic disequilibrium with the higher temperature difference between the LGM and current to fill more of their potential ranges.



RU of tree species in the Palearctic was significantly affected by land-use transformation in the early agricultural era and after the post-industrial revolution, current temperature, LGM precipitation anomaly, and Miocene precipitation anomaly

FIGURE 2 Results of Generalized linear model: Regression coefficients (estimates) of the relationships between predictors and range unfilling for seven major realms. Continuous predictors were standardized to allow comparison.

1. Global tree species are widespread unfilled, with species' potential ranges that have not been occupied 10.7 times larger than their geographic ranges.

2. Current tree species distribution is co-shaped by present-day human pressure, current climate, and to a greater extent, legacies of prehistorical and historical anthropogenic impacts and paleoclimatic change.

3. Over recent centuries, the dramatic negative effect of intensified land-use conversion on tree species distribution recalls the urgent need to protect key biodiversity areas.

Reference:

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- Ellis, E., Gauthier, N., Klein Goldewijk, K., Bird, R., Boivin, N., Diaz, S., . . . Watson, J. (2021). People have shaped most of terrestrial nature for at least 12,000 years. *Proceedings of the National Academy of Sciences, 118*, e2023483118. doi:10.1073/pnas.2023483118
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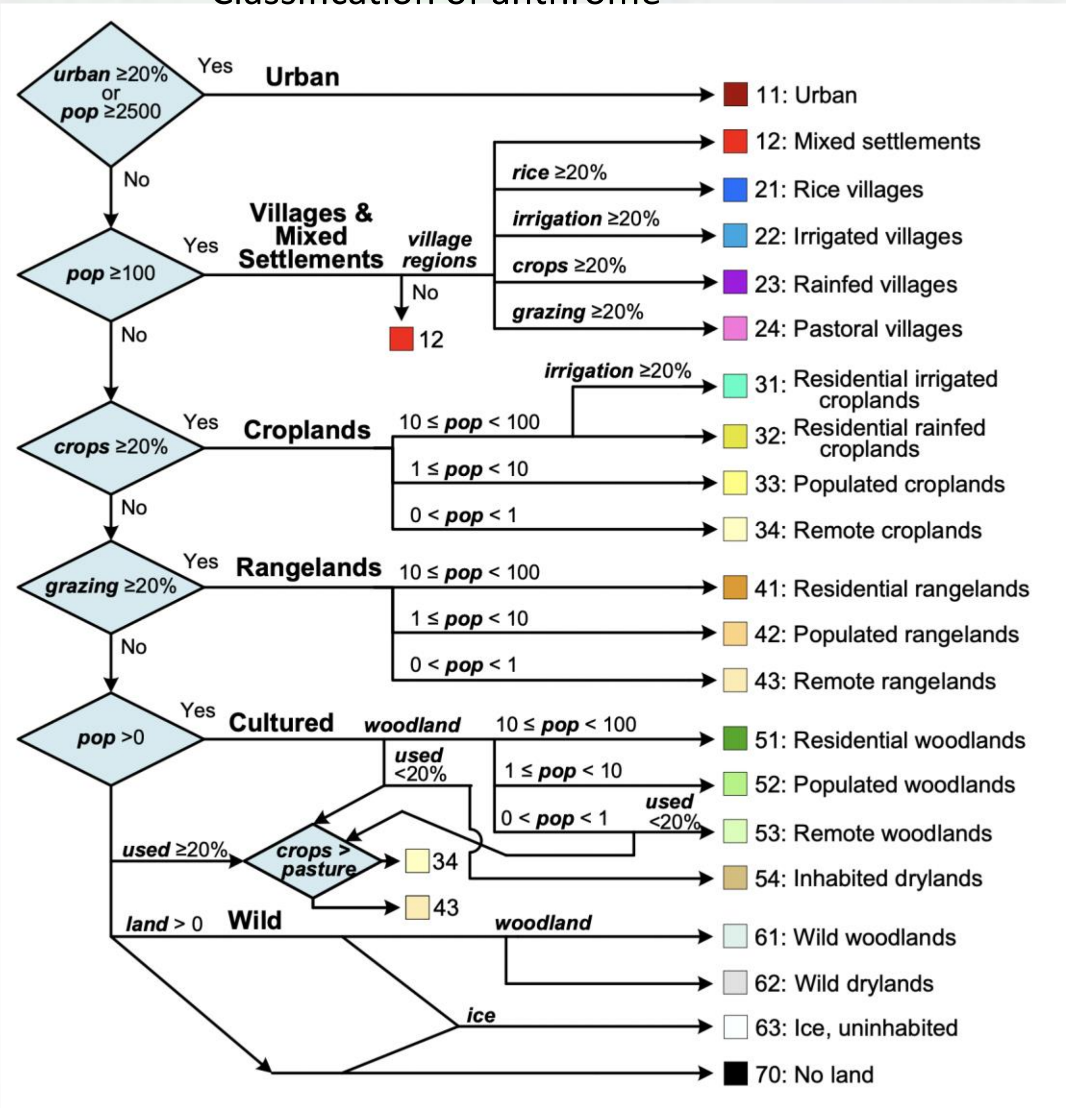
- Karger, D. N., Nobis, M., Normand, S., Graham, C., & Zimmermann, N. (2021). *CHELSA-TraCE21k v1.0. Downscaled transient temperature and precipitation data since the last glacial maximum*.
- Kennedy, C., Oakleaf, J., Theobald, D., Baruch-Mordo, S., & Kiesecker, J. (2019). Managing the middle: A shift in conservation priorities based on the global human modification gradient. *Global Change Biology, 25*. doi:10.1111/gcb.14549
- Pound, M., Haywood, A., Salzmann, U., Riding, J., Lunt, D., & Hunter, S. (2011). A Tortonian (Late Miocene, 11.61–7.25 Ma) global vegetation reconstruction. *Palaeogeography Palaeoclimatology Palaeoecology - PALAEOGEOGR PALAEOCLIMATOL, 300*, 29-45. doi:10.1016/j.palaeo.2010.11.029
- Seliger, B. J., McGill, B. J., Svenning, J. C., & Gill, J. L. (2021). Widespread underfilling of the potential ranges of North American trees. *Journal of Biogeography, 48*(2), 359-371.
- Svenning, J. C., & Skov, F. (2004). Limited filling of the potential range in European tree species. *Ecology Letters, 7*(7), 565-573.

Thank you for your listening!

Questions?

Complementary Information:

Classification of anthrome

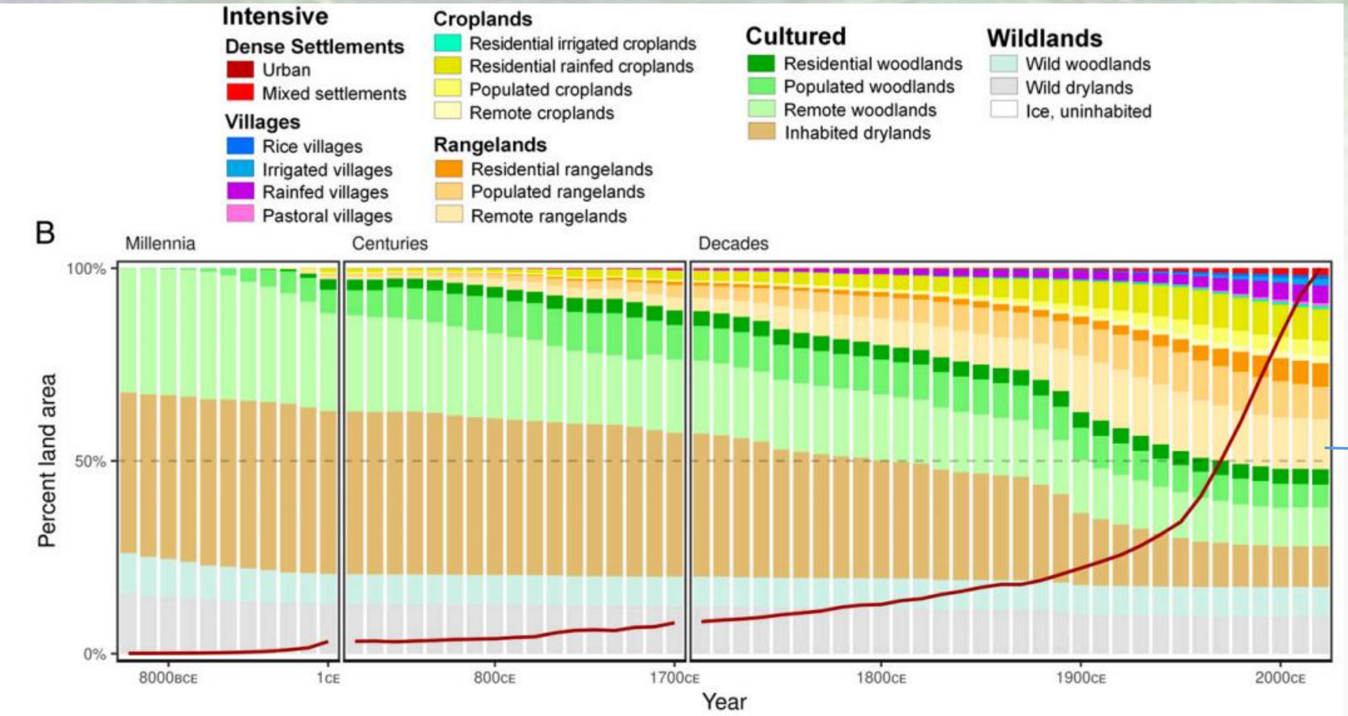


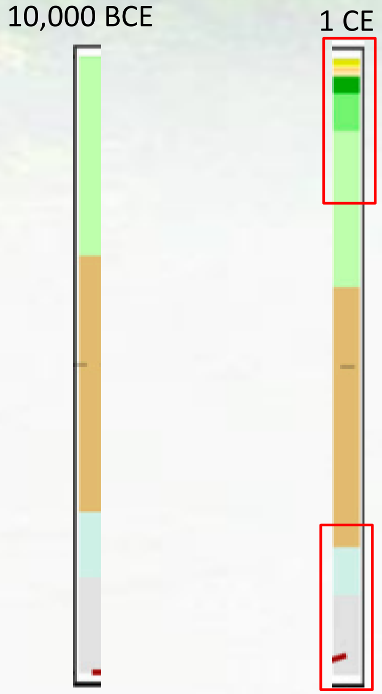
Ellis *et al.*, 2020

TABLE 2

Regression coefficients (showed confidence interval) of the relationship between predictors and range unfilling for seven major realms. Continuous predictors were standardized to allow comparison. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

	Neotropic	Afrotropic	Australasia	Indomalayan	Palearctic	Nearctic	Oceania
TC		-0.13 **					-0.53
		[-0.23, -0.04]					[-1.13, 0.08]
HM		0.04					
		[-0.05, 0.13]					
TC-EPSIR	0.01	-0.07	0.10 *	0.10	-2.40 ***	0.36 **	
	[-0.04, 0.06]	[-0.16, 0.02]	[0.00, 0.19]	[-0.00, 0.19]	[-3.48, -1.31]	[0.12, 0.59]	
HM-EPSIR	0.11 **		0.32 ***	0.04		-0.26	
	[0.04, 0.17]		[0.20, 0.43]	[-0.09, 0.17]		[-0.61, 0.09]	
TC-EPFIR	-0.10 ***	0.02	-0.04	0.00	1.52 ***	0.12	
	[-0.15, -0.04]	[-0.08, 0.13]	[-0.16, 0.07]	[-0.13, 0.14]	[0.99, 2.04]	[-0.16, 0.40]	
HM-EPFIR	-0.11 **	-0.28 ***	-0.28 ***		2.27 ***	-0.05	0.01
	[-0.18, -0.04]	[-0.41, -0.15]	[-0.45, -0.12]		[1.54, 3.00]	[-0.25, 0.14]	[-0.38, 0.41]
TC-ED	-0.14 ***	-0.09 **	0.16			0.29	0.10
	[-0.18, -0.09]	[-0.15, -0.03]	[-0.04, 0.36]			[-0.05, 0.63]	[-0.17, 0.38]
HM-ED	0.03	-0.08	-0.36 ***	-0.34 ***	0.09		
	[-0.03, 0.10]	[-0.20, 0.04]	[-0.55, -0.17]	[-0.46, -0.21]	[-0.05, 0.24]		
TC-AE	-0.17 ***	-0.02	-0.21	-0.07	-0.92 **	-0.22	
	[-0.21, -0.12]	[-0.11, 0.07]	[-0.57, 0.15]	[-0.18, 0.05]	[-1.57, -0.28]	[-0.46, 0.01]	
HM-AE			-0.03	-0.24 ***	-0.87	0.25 *	0.39 *
			[-0.21, 0.15]	[-0.34, -0.13]	[-2.18, 0.43]	[0.04, 0.46]	[0.03, 0.74]
TC-EAE	-0.06 *	0.07 *	0.13 *		-1.97 ***	-0.26 ***	
	[-0.11, -0.01]	[0.01, 0.13]	[0.02, 0.24]		[-2.71, -1.23]	[-0.41, -0.12]	
HM-EAE	-0.24 ***	-0.14 **	-0.02				-0.18
	[-0.31, -0.17]	[-0.23, -0.06]	[-0.13, 0.10]				[-0.78, 0.43]
MAP	0.10 ***					-0.21	
	[0.06, 0.14]					[-0.48, 0.07]	
MAT	-0.15 ***	-0.22 ***	0.08	-0.09 *	-4.37 ***	-0.07	
	[-0.19, -0.10]	[-0.35, -0.10]	[-0.07, 0.23]	[-0.16, -0.01]	[-5.82, -2.92]	[-0.33, 0.18]	
LGMPA	-0.02		-0.06	-0.05	4.01 ***	0.01	
	[-0.06, 0.03]		[-0.17, 0.04]	[-0.13, 0.04]	[2.59, 5.44]	[-0.20, 0.22]	
LGMTA	0.01	-0.08	-0.13 **	0.04	-1.39 ***	0.02	-0.81 **
	[-0.03, 0.06]	[-0.19, 0.04]	[-0.22, -0.04]	[-0.06, 0.14]	[-2.02, -0.75]	[-0.32, 0.36]	[-1.39, -0.23]
MPA			-0.10	-0.03	2.02 ***		-0.37
			[-0.22, 0.03]	[-0.12, 0.07]	[1.26, 2.77]		[-0.87, 0.14]
MTA	-0.12 ***	-0.22 ***	-0.06	-0.25 ***			
	[-0.16, -0.07]	[-0.32, -0.11]	[-0.17, 0.05]	[-0.35, -0.14]			
N	8924	3790	2943	1182	930	798	47
Pseudo R^2	0.03	0.03	0.03	0.11	0.31	0.09	0.43



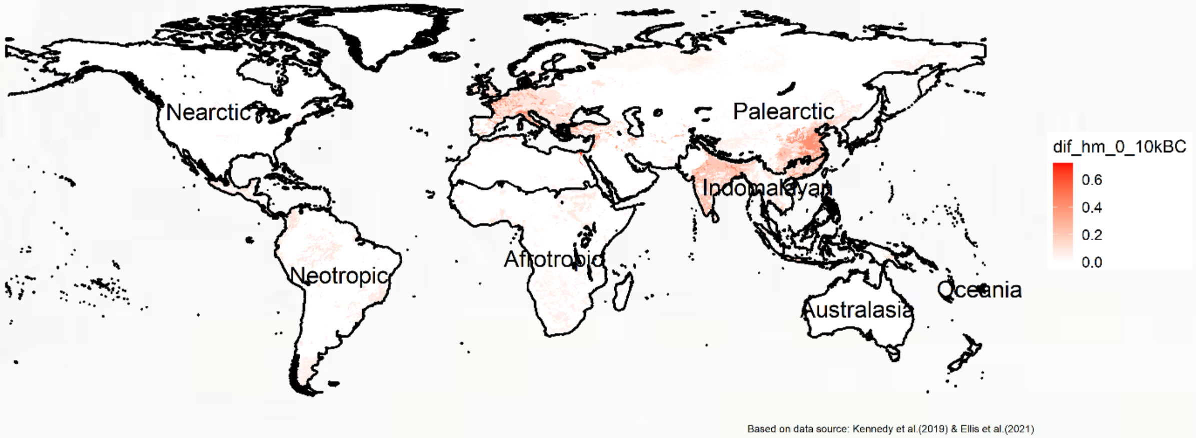


Effect of land-use change (GLMM)

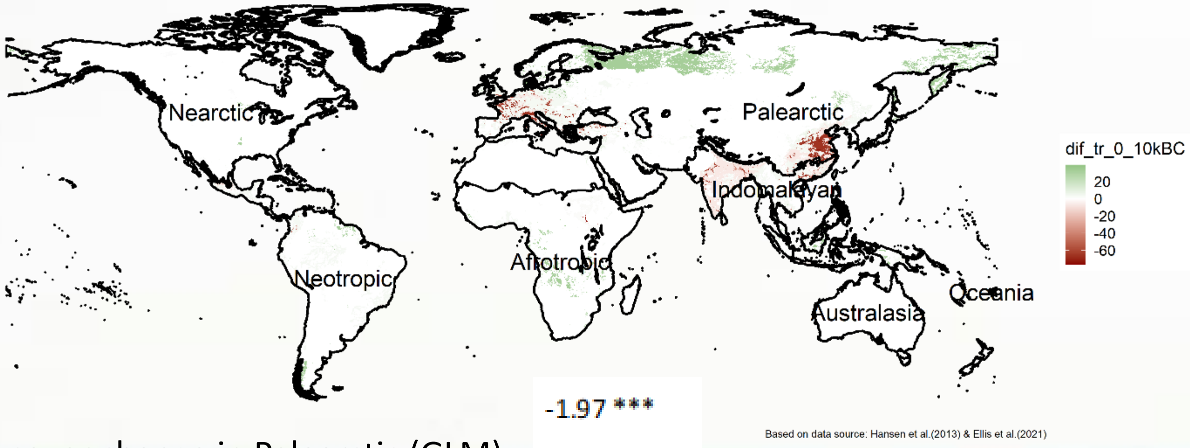
TC-EAE	0.00 (-0.00 – 0.00)	0.083
HM-EAE	-1.06 (-1.06 – -1.06)	**<0.001**

Ellis *et al.*, 2021

Effect of human pressure change



Effect of tree cover change



Effect of tree cover change in Palearctic (GLM)

-1.97 ***

[-2.71, -1.23]

European tree

Mean range filling: 38.3%

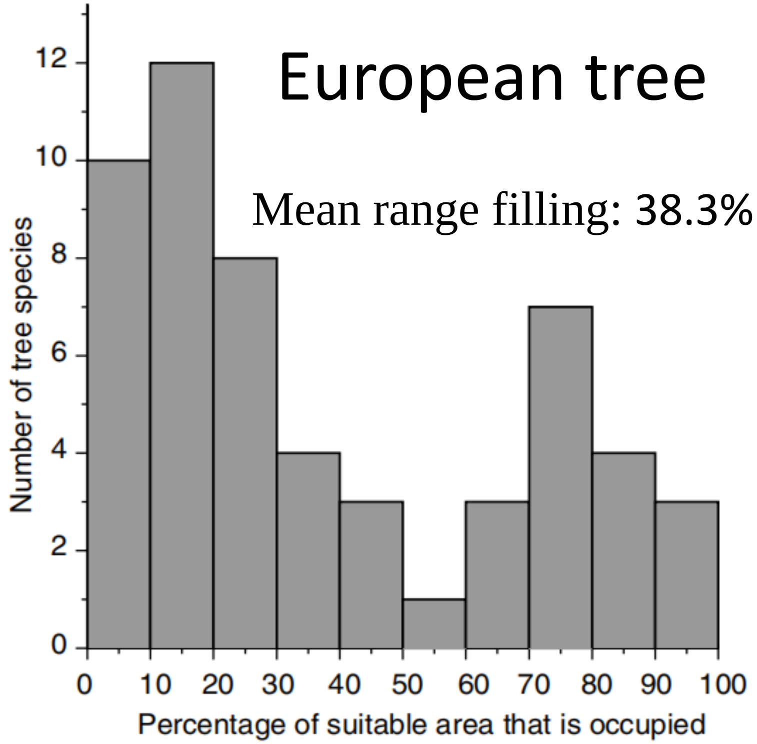
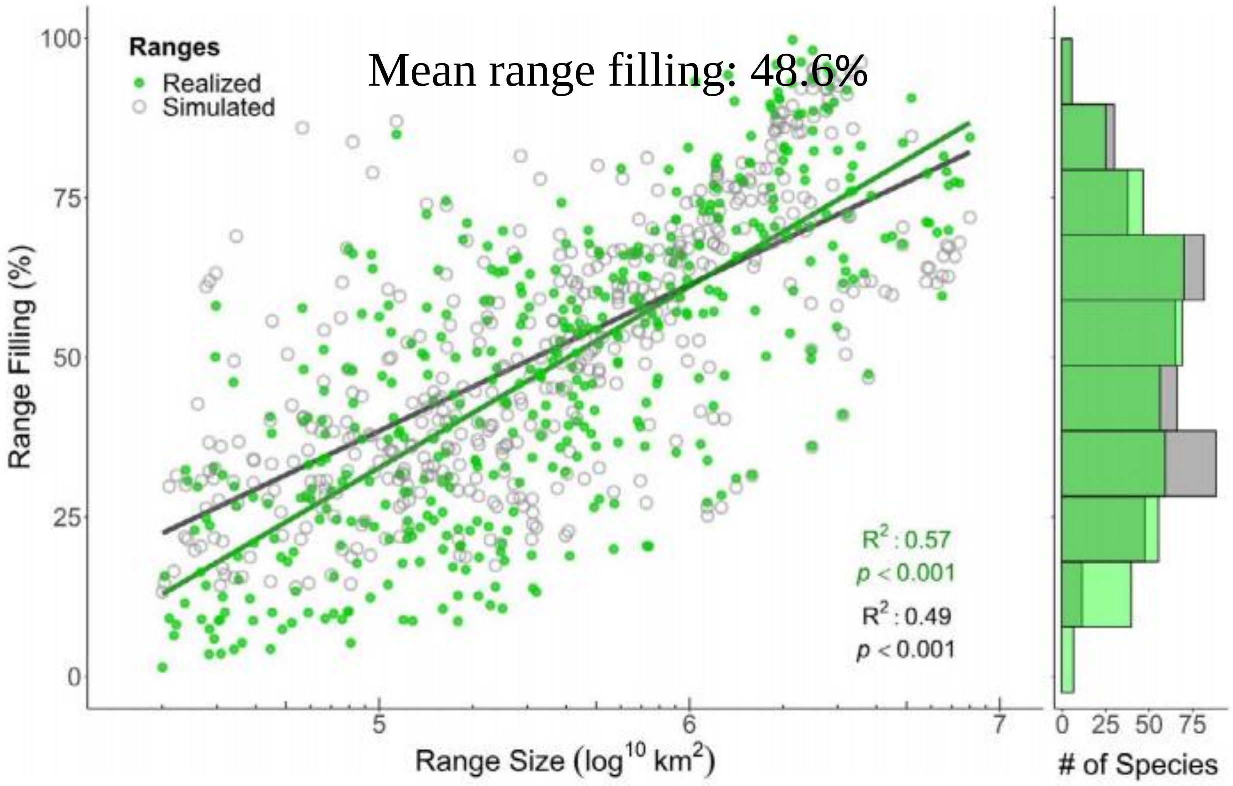


Figure 3 Histogram of range filling (*R/P*; the proportion of its potential climatic range that a species actually occupies, estimated for the 55 AFE species with more than one occurrence using bioclimatic envelope modelling; see Methods).

Svenning *et al*., 2004

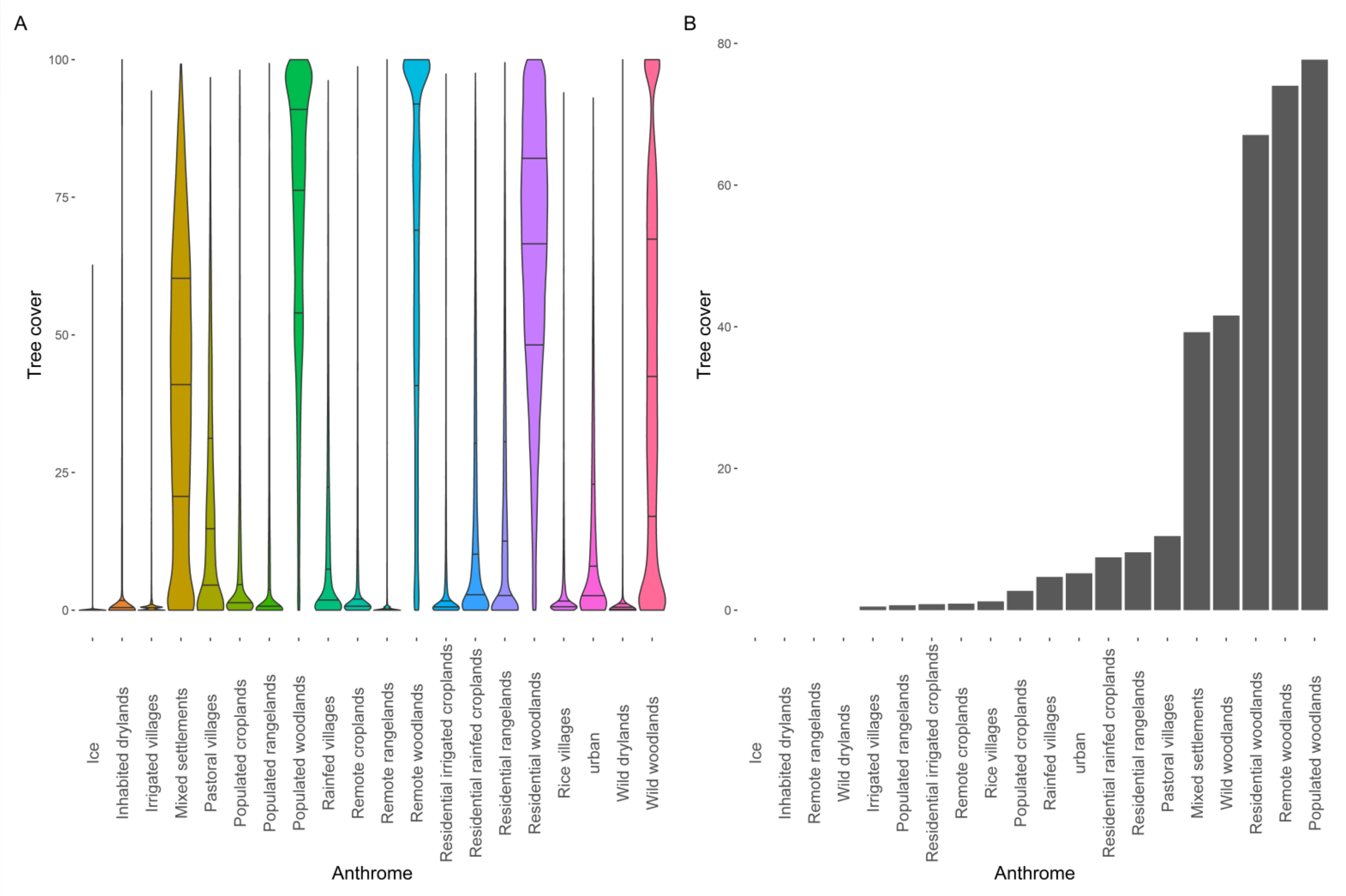
North American tree

Mean range filling: 48.6%



Seliger *et al*. 2021

Tree species are poorly filled their potential range!



A
100
75
50
25
0
Tree cover
Ice
Inhabited drylands
Irrigated villages
Mixed settlements
Pastoral villages
Populated croplands
Populated rangelands
Populated woodlands
Rainfed villages
Remote croplands
Remote rangelands
Remote woodlands
Residential irrigated croplands
Residential rainfed croplands
Residential rangelands
Residential woodlands
Rice villages
urban
Wild drylands
Wild woodlands
Anthrome
B
80
60
40
20
0
Tree cover
Ice
Inhabited drylands
Remote rangelands
Wild drylands
Irrigated villages
Populated rangelands
Residential irrigated croplands
Remote croplands
Rice villages
Populated croplands
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Populated woodlands
Anthrome