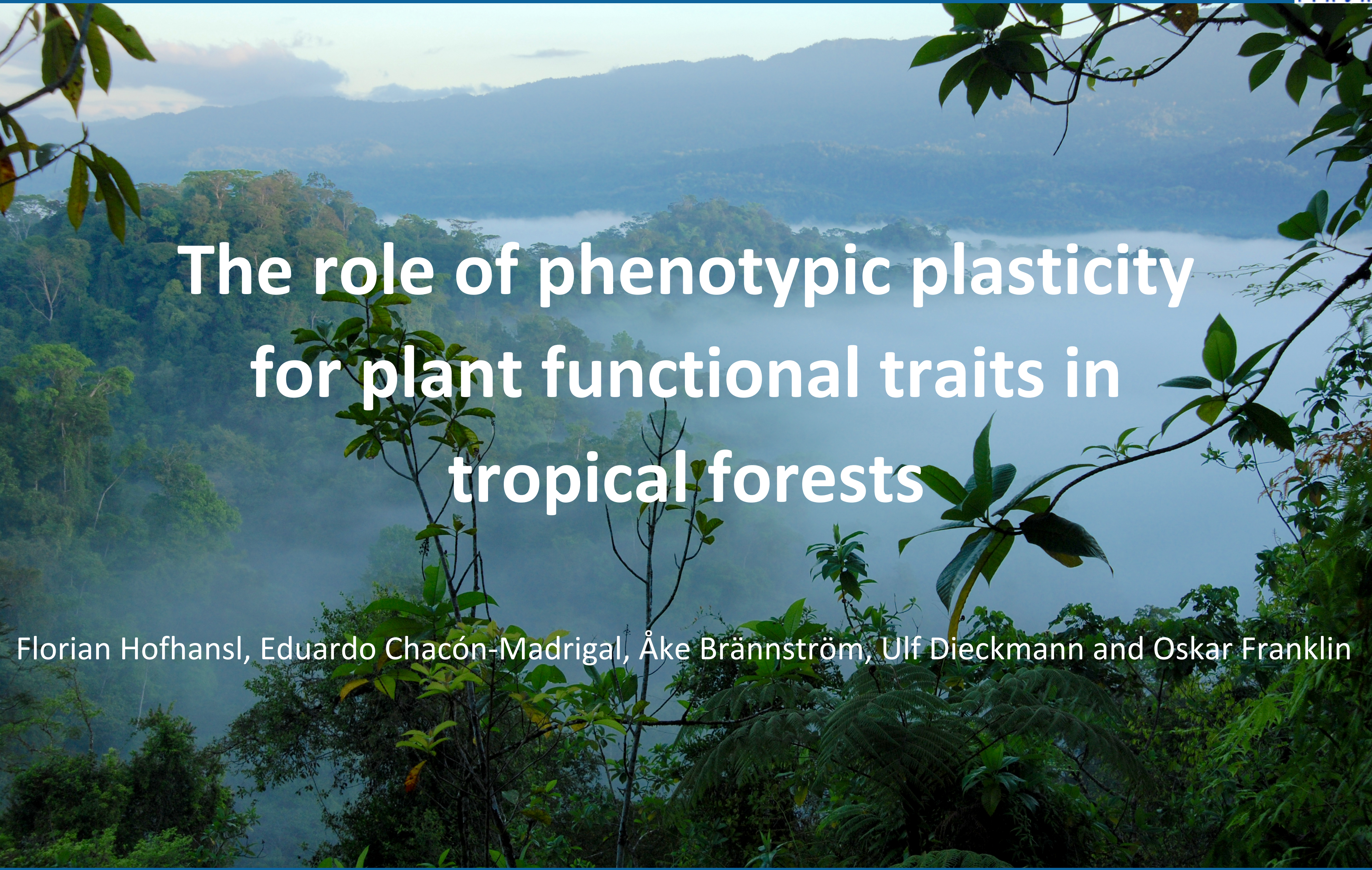


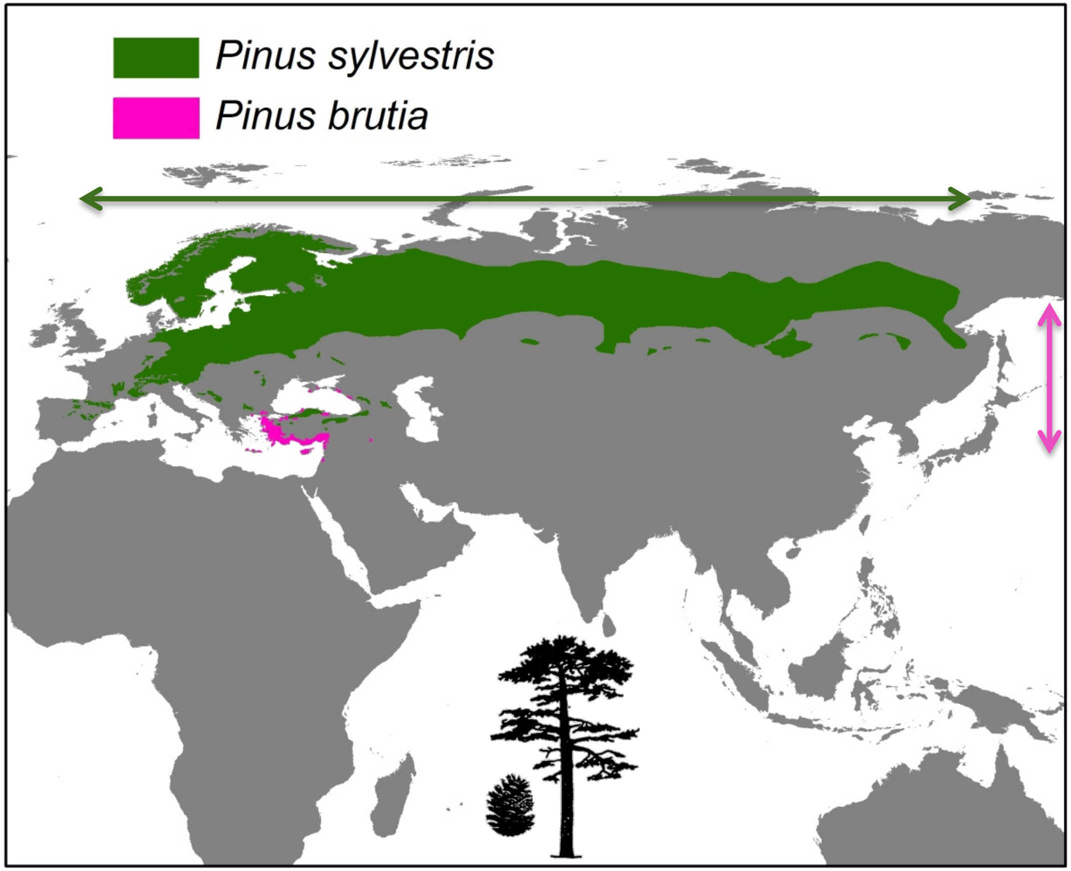
The role of phenotypic plasticity for plant functional traits in tropical forests

Florian Hofhansl, Eduardo Chacón-Madrigal, Åke Brännström, Ulf Dieckmann and Oskar Franklin

Geographical range size varies greatly between species

Range of sizes of species' geographical distribution

100 m^2 ↔ 300 000 000 Km^2



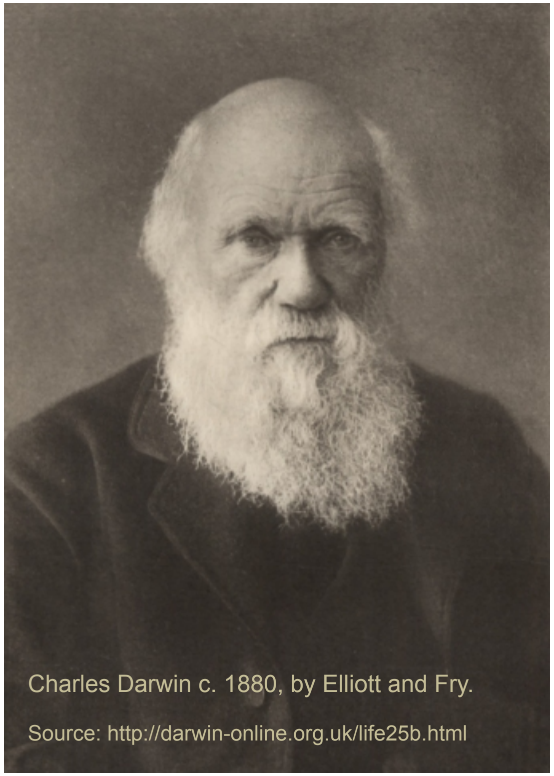
Source: EUFORGEN:http://www.euforgen.org/distribution_maps.html

Genetic heritability ?

Phenotypic plasticity ?

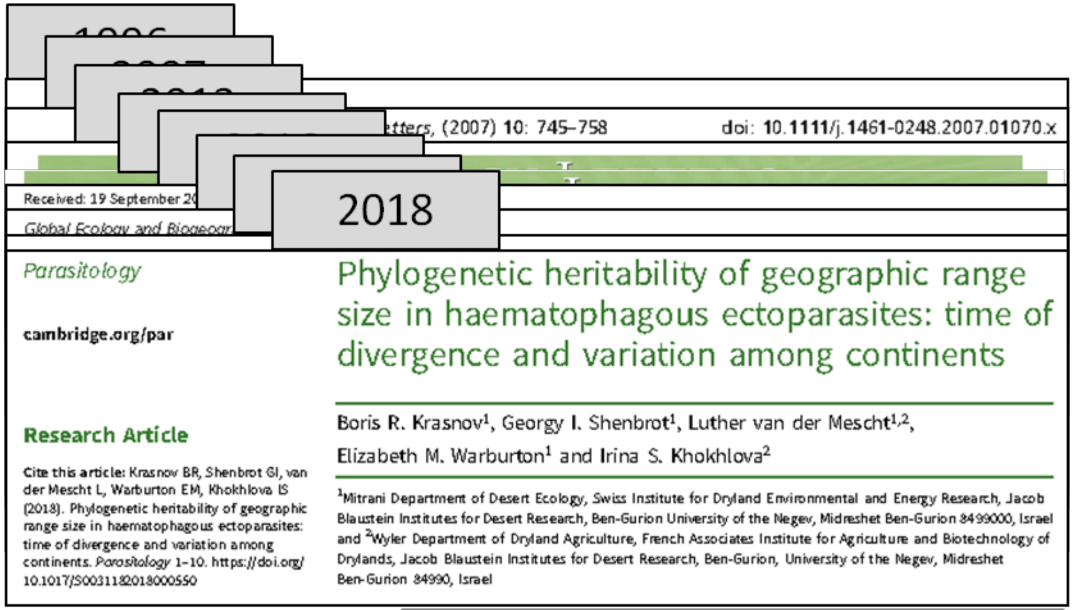
Source: EUFORGEN:http://www.euforgen.org/distribution_maps.html

Introduction – Species range size



Charles Darwin c. 1880, by Elliott and Fry.

Source: http://darwin-online.org.uk/life25b.html



2018

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Global Ecology and Biogeogr...

Parasitology

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Research Article

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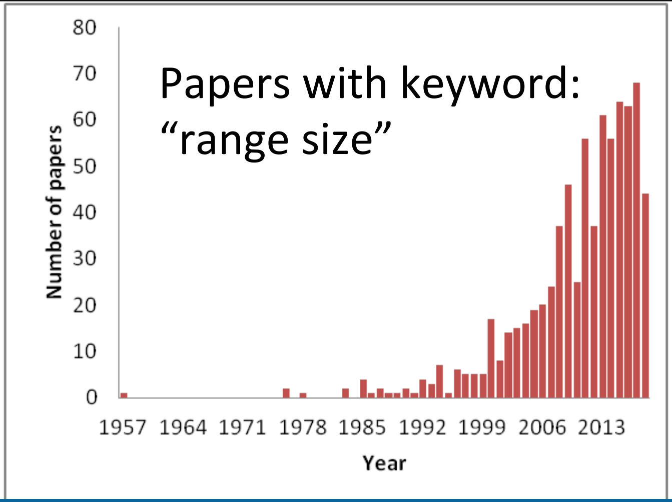
Phylogenetic heritability of geographic range size in haematophagous ectoparasites: time of divergence and variation among continents

Boris R. Krasnov[1], Georgy I. Shenbrot[1], Luther van der Mescht[1,2], Elizabeth M. Warburton[1] and Irina S. Khokhlova[2]

[1]Mitrani Department of Desert Ecology, Swiss Institute for Dryland Environmental and Energy Research, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Midreshet Ben-Gurion 8499000, Israel and [2]Wyler Department of Dryland Agriculture, French Associates Institute for Agriculture and Biotechnology of Drylands, Jacob Blaustein Institutes for Desert Research, Ben-Gurion, University of the Negev, Midreshet Ben-Gurion 84990, Israel



"*Who can explain why one **species ranges widely** and is very numerous, and why another allied species has a **narrow range and is rare**?*"

Charles Darwin, The Origin of Species (1856)

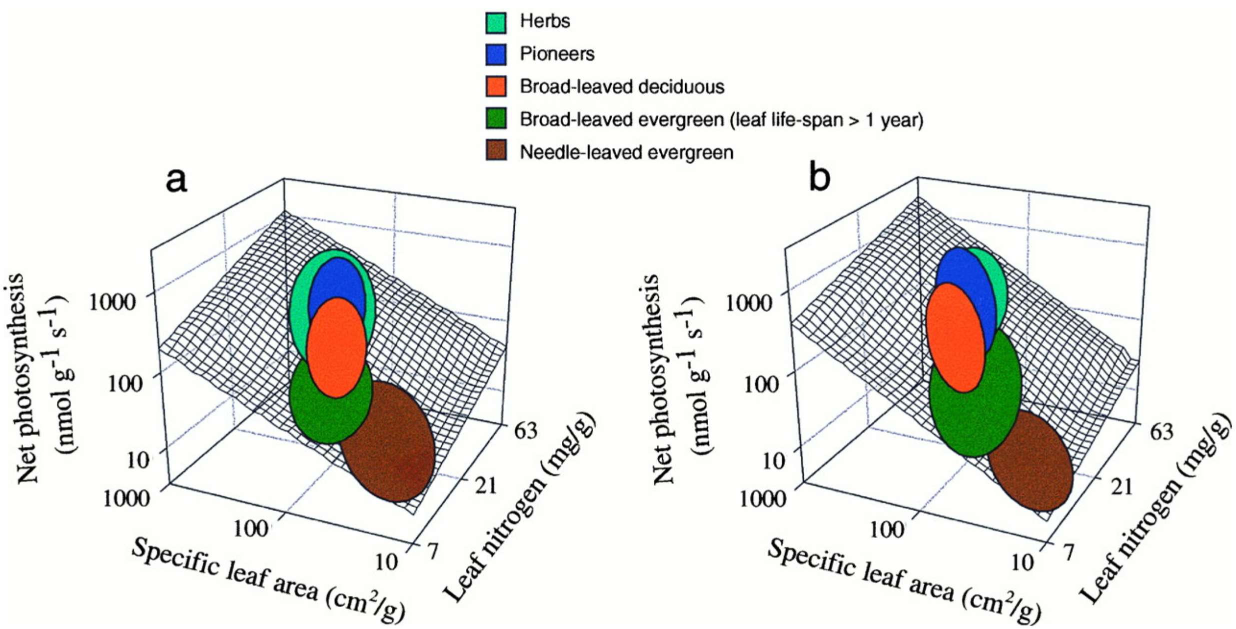
Source: Charles Darwin, The Origin of Species (1856)

Introduction – Tropical plant species

Why there are striking differences in the geographical range size of close related tropical plant species?

Introduction – Plant economics spectrum

Fast strategy **Slow strategy**



Plants with different forms and from different biomes present a **coordination in their traits:**

e.g. plants achieving high photosynthetic rates:

→ high leaf N content

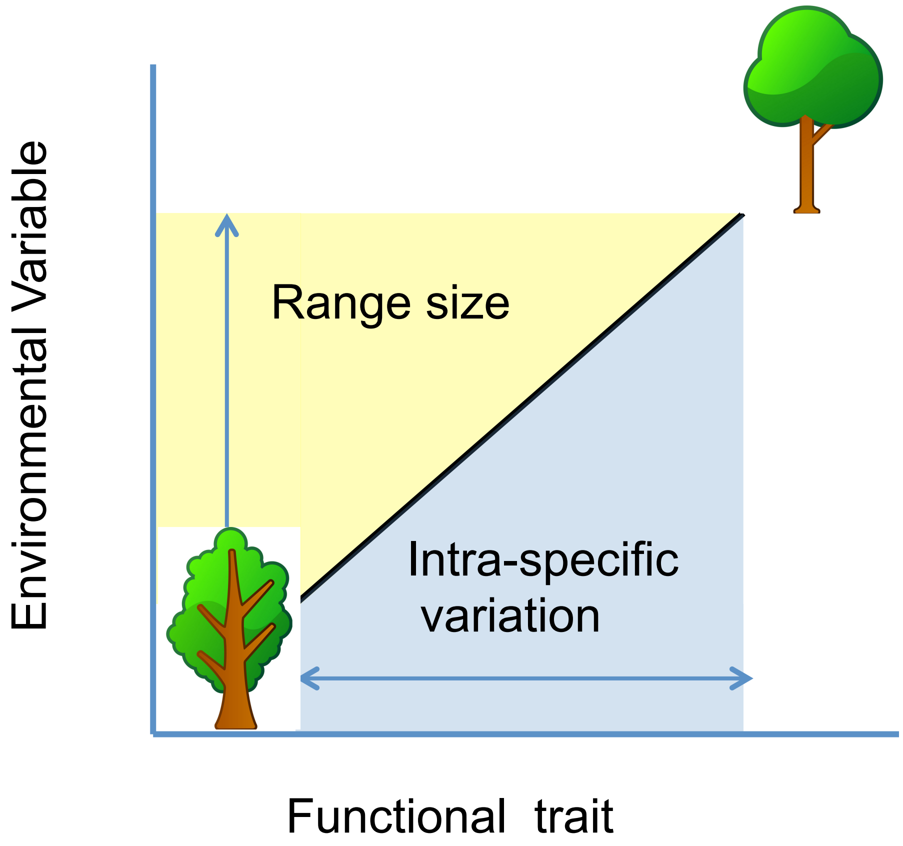
→ high specific leaf area (relation leaf area /mass)

→ low leaf lifespan.

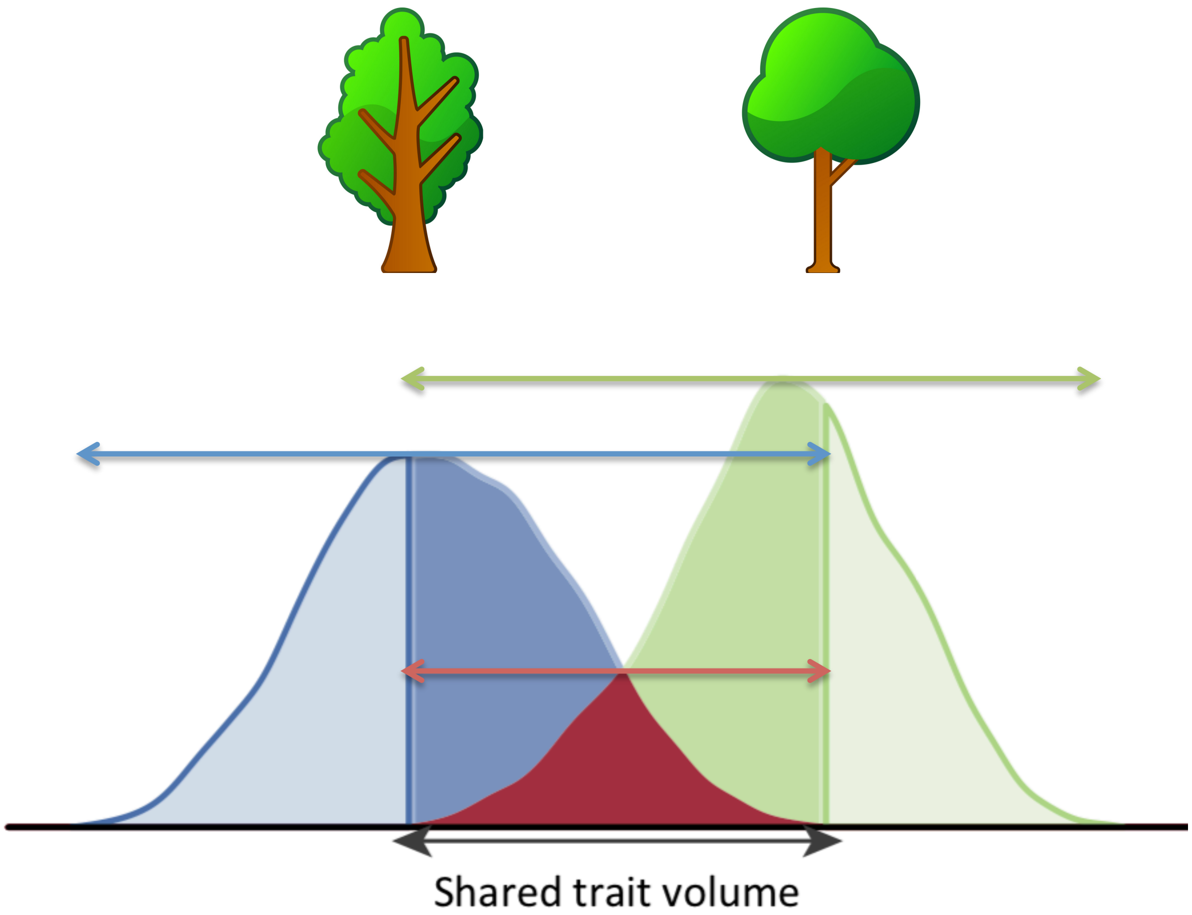
Species with <u>slow life history traits and conservative resource use should have smaller ranges</u> than ‘fast living’ pioneers.

Introduction – Intraspecific variability

Intraspecific trait variation is related to niche breadth



Introduction – Interspecific variability



At the **species level**, trait combinations exhibit **trade-offs** representing different ecological strategies

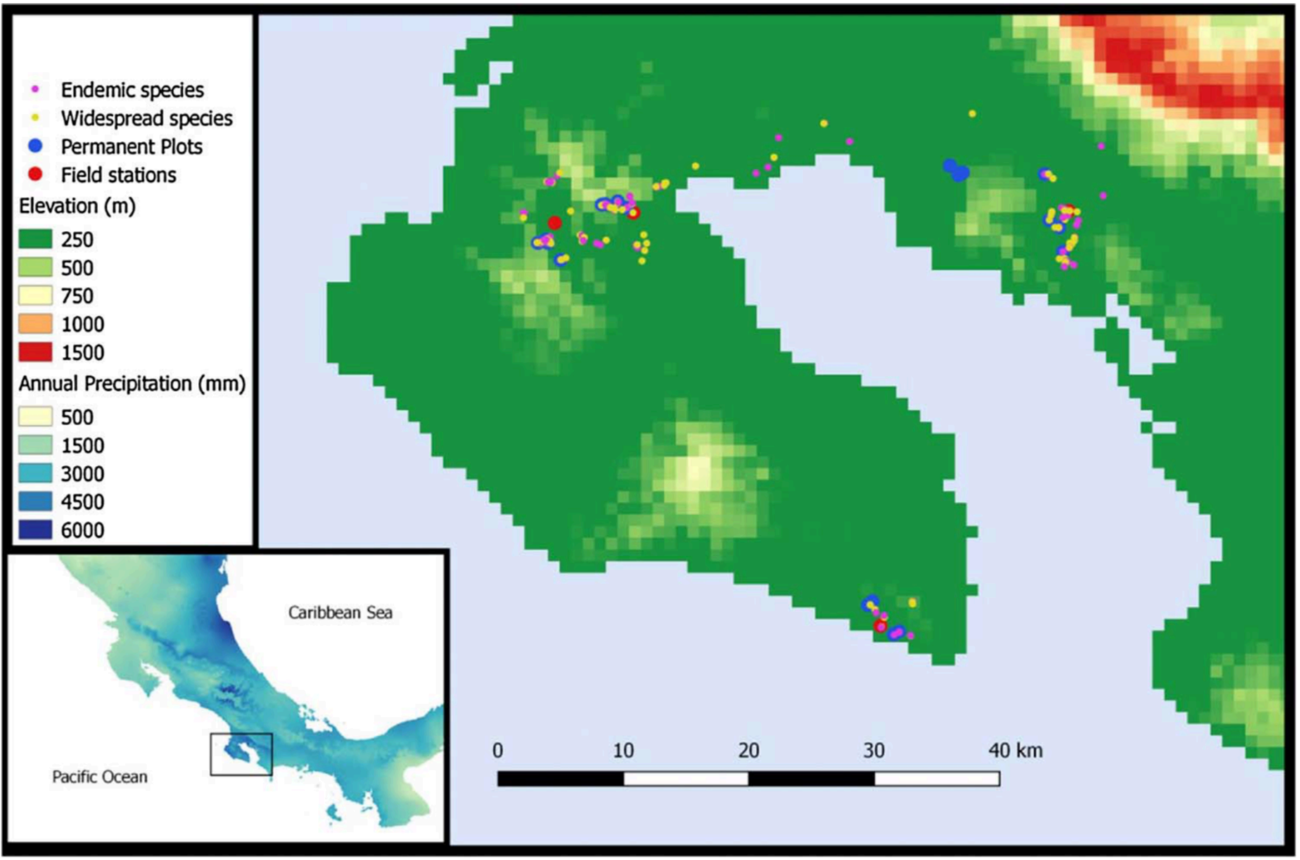
At the **community level** trait combinations are expected to be **decoupled from trade-offs**

because different strategies can facilitate co-existence within communities.

under similar macro-environmental conditions, **communities can vary greatly in trait means and variances**, consistent with high local variation in species' trait values.

→ trait combinations seem to be predominantly
→ filtered by local-scale factors such as disturbance,
→ fine-scale soil conditions, niche partitioning and biotic interactions.

Local study – Plant functional trait data



Range size/functional traits:

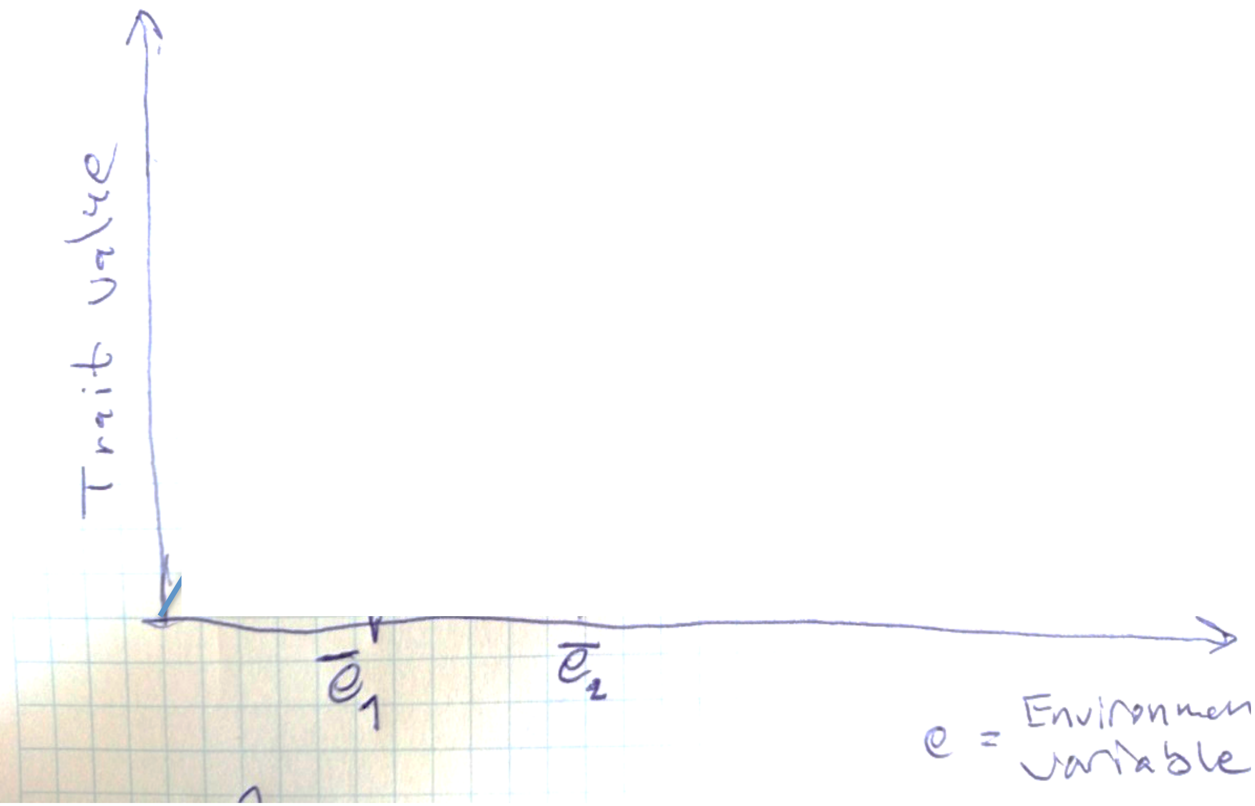
Study sampled 345 trees from 35 species in 14 genera and analysed functional traits

specific leaf area (SLA), **leaf thickness (LT)**, **leaf dry matter (LDMC)**, **leaf nitrogen (N), leaf phosphorus (P), leaf potassium (K), leaf N:P ratio (NP), wood specific gravity (WSG)**

Compare functional traits among narrow range **endemic species** and **widespread congeners**

Source: Chacón-Madrigal, et al., 2018. Journal of PPEES Sources 32:30–37.

Hypothesis – Individual variation



Tropical tree communities & associated trait components

(1) individual trait variation allows a species to adjust to spatial gradients in local environmental conditions.

(2) non-plastic component increases with geographic distance due to local adaption to different environments.

(3) plastic component increases with environmental distance among sites and thus with the range size of species.

Functional traits – components

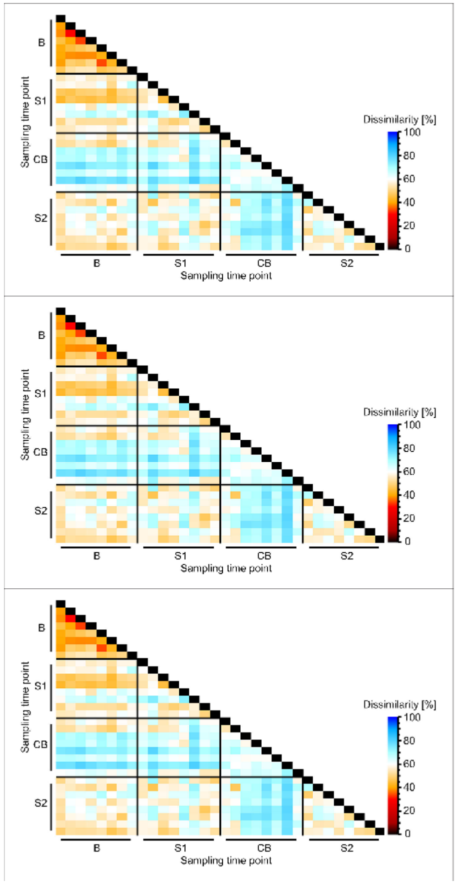
<u>Distance Matrices:</u>

1) Geographic distance
2) Environmental distance
3) Trait distance (i.e. variation)

Fixed component =(**T*****D**)-**E**

Plastic component =(**T*****E**)-**D**

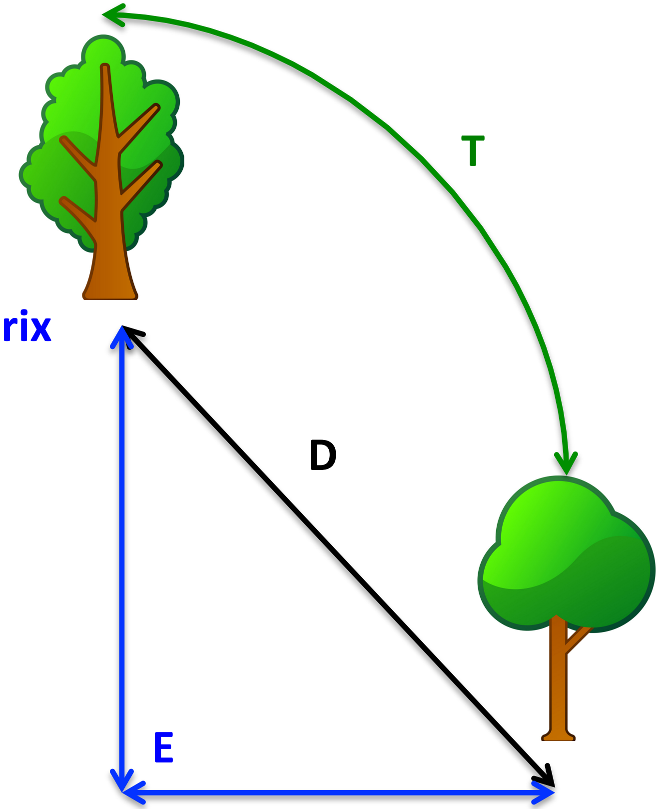
Spatial component =(**D*****E**)-**T**



D .. Distance matrix

E .. Environment matrix

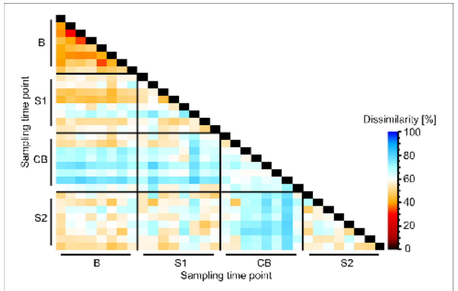
T .. Trait matrix



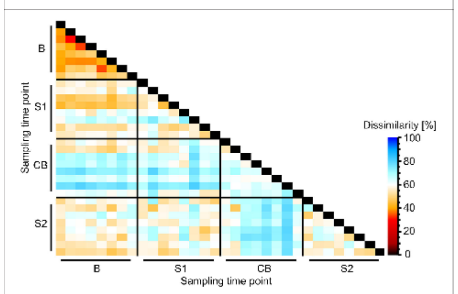
Functional traits – community

Analysis	Matrix 1	Matrix 2	Matrix 3	SCALED data	
Mantel test	x	y	Z	r	p
	trait	**distance**		0.06	**0.006**
	trait	**environment**		-0.03	0.966
	distance	**environment**		0.44	**0.001**
Partial Mantel	x	y	Z	r	p
HERITABLE	**trait**	**distance**	**environment**	0.08	**0.001**
PLASTIC	**trait**	**environment**	**distance**	-0.06	0.998
SPATIAL	**distance**	**environment**	**trait**	0.44	**0.001**

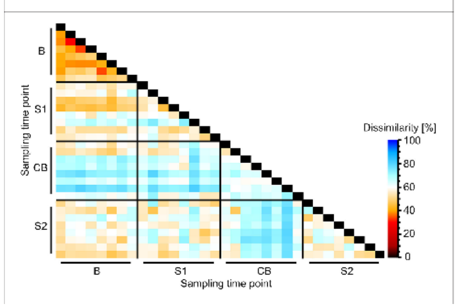
Trait / COMPONENT	**HERITABLE**		**PLASTIC**		**SPATIAL**	
ENVI PC1	r	p	r	p	r	p
WSG	-0.01	0.707	0.01	0.33	0.45	**0.001**
Height	0.04	0.073	-0.03	0.866	0.45	**0.001**
SLA	0.08	**0.012**	-0.02	0.693	0.45	**0.001**
LA	0.02	0.32	-0.03	0.793	0.45	**0.001**
LT	0.03	0.138	-0.01	0.618	0.45	**0.001**
LDMC	0.08	**0.002**	-0.07	1	0.45	**0.001**
N	0.08	**0.011**	-0.02	0.795	0.45	**0.001**
P	0.06	**0.05**	-0.02	0.687	0.45	**0.001**



(D*E)-T ☑



(T*E)-D ☒

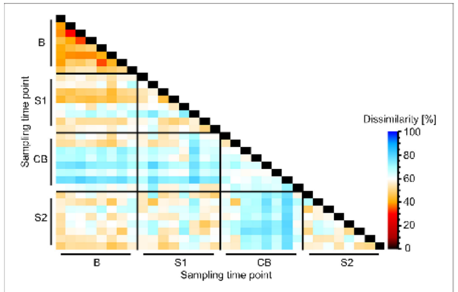


(T*D)-E ☑

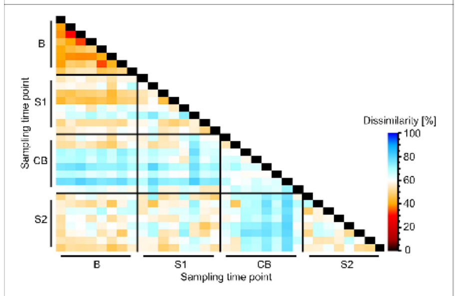
Source: Hofhansl et al., 2019 in prep.

Functional traits – species

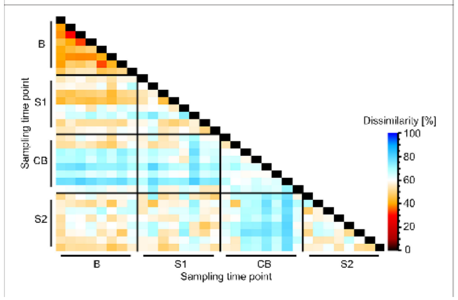
Analysis	Matrix 1	Matrix 2	Matrix 3	SCALED data	
Mantel test	x	y	Z	r	p
	trait	distance		0.06	**0.006**
	trait	environment		-0.03	0.966
	distance	environment		0.44	**0.001**
Partial Mantel	x	y	Z	r	p
HERITABLE	trait	distance	environment	0.08	**0.001**
PLASTIC	trait	environment	distance	-0.06	0.998
SPATIAL	distance	environment	trait	0.44	**0.001**



(D*E)-T



(T*E)-D



(T*D)-E

Fixed component

ARCOM	-0.13	0.11	0.21	0.18	0.2	0.19	-0.44	0.09
ARDUN	-0.01	-0.03	0.24	-0.05	0.12	0.08	-0.09	-0.03
CHGLA	0.29	-0.22	-0.06	-0.08	0.51	-0.15	0.27	0.28
CHSKU	0.1	-0.03	0.37	0.39	0.52	-0.12	0.03	0.02
COCYM	0.14	0.6	-0.19	0.17	0.06	-0.17	-0.15	-0.07
COLIE	-0.01	-0.08	0.05	-0.13	0.22	-0.06	0.41	0.27
DEARB	-0.02	0.42	0.12	-0.32	-0.03	0.05	0.02	-0.11
DERAV	0.47	-0.18	0.04	-0.14	-0.04	0.21	-0.16	-0.14
FAOCC	0.3	0.2	0.03	-0.03	0.48	-0.07	0.07	-0.18
FAPER	0.05	-0.07	-0.02	0.01	0.03	0.36	-0.08	0.21
GAAGU	0.21	-0.2	-0.2	-0.2	-0.23	-0.22	0.23	-0.12
GAMAG	-0.17	0.15	0.25	0.21	0.75	-0.12	0	-0.13
GUAMP	0.01	-0.01	-0.11	-0.01	-0.19	0.07	-0.21	0.3
GUCHI	0.31	-0.19	0.04	0.14	-0.06	0.13	0.05	0.08
GUPUD	0.14	0.03	0.21	0.28	0.1	-0.16	-0.26	-0.02
GUROS	0.08	0.18	0.08	0.07	0.05	0.08	0.16	-0.07
INSKU	0.21	-0.19	0.48	0.16	0.03	0.04	0.26	0.74
INSPE	-0.18	0.08	-0.01	-0.06	-0.09	0	-0.31	-0.35
MIDIS	-0.15	-0.1	-0.12	-0.2	-0.03	-0.03	-0.01	-0.32
MIDON	0.19	0.12	-0.04	-0.12	0.3	0.29	-0.16	0.08
MIOSA	0.51	0.07	-0.04	0.11	0.11	0.21	-0.16	-0.02
MITRI	0.07	-0.18	-0.09	-0.16	-0.02	-0.07	0.01	-0.05
OCMOL	-0.02	0.12	0.07	-0.08	0.07	-0.16	-0.08	-0.09
OCRIV	-0.21	0.25	-0.29	-0.08	-0.22	-0.1	0.54	0.48
POLEC	-0.01	-0.07	0.05	0.07	-0.06	0.14	0.37	0.38
POSUB	0.09	0.28	0.15	-0.03	0.36	-0.18	0.31	-0.13
POTOR	-0.15	0.01	0.45	0.24	0.1	-0.02	0.61	0.78
POTRI	-0.2	-0.28	-0.19	-0.37	0.56	-0.13	0.01	-0.29
PRPAN	0.65	-0.08	-0.04	0.18	-0.12	0.05	-0.23	0.06
PRPEC	0.18	-0.06	0.15	-0.05	0.37	0.06	0.5	-0.06
SAALL	0	0.17	0.02	-0.12	0.23	-0.01	-0.17	-0.18
SAGLA	0.1	0.12	0.47	-0.26	0.41	0.14	-0.19	0.22
UNOSA	-0.09	0.13	-0.13	0.55	0.16	-0.03	-0.01	-0.13
UNTHE	-0.02	-0.09	0	-0.24	0.13	0	0.18	0.32

Plastic component

ARCOM	0.2	-0.11	-0.26	-0.22	-0.26	-0.21	0.49	0.03
ARDUN	-0.16	-0.24	-0.21	0.22	0.06	0.09	-0.17	0.14
CHGLA	0.11	-0.28	0.1	-0.11	0.23	-0.19	0.29	0.23
CHSKU	-0.21	0.23	-0.18	0.4	0.11	-0.1	-0.04	-0.1
COCYM	-0.2	-0.01	0.53	-0.28	0.08	0.44	0.37	0.51
COLIE	0.25	0.26	0.08	-0.01	-0.19	0.02	0.23	-0.29
DEARB	-0.01	-0.12	-0.1	0.4	-0.01	-0.12	-0.06	0.19
DERAV	-0.39	0.12	0	0.05	0.33	-0.1	0.33	0
FAOCC	0.14	-0.2	-0.16	0.09	-0.27	0.7	0.38	0.15
FAPER	0.16	0.23	0.24	0.02	0.17	0	-0.03	-0.08
GAAGU	0.28	0.46	-0.07	-0.17	-0.1	-0.2	0.01	-0.08
GAMAG	0	0.14	0.14	-0.02	0.32	-0.07	-0.02	-0.1
GUAMP	-0.07	-0.12	0.13	-0.18	0.26	-0.3	0.08	-0.24
GUCHI	-0.25	0.03	-0.09	0.12	0.04	-0.12	0.05	-0.03
GUPUD	-0.06	0	0.08	0.15	-0.04	0.09	0.01	0
GUROS	0	0.13	-0.27	-0.08	-0.16	0.01	-0.35	-0.09
INSKU	0.28	0.15	-0.18	-0.22	-0.2	0.16	-0.23	-0.28
INSPE	0.04	0.07	0.54	-0.07	0.52	0.13	0.68	0.4
MIDIS	-0.01	0.06	-0.01	0.17	0.05	0.07	0.15	0.31
MIDON	-0.23	-0.01	0.15	0.41	-0.16	-0.11	0.58	-0.11
MIOSA	-0.39	0.41	-0.04	-0.1	0.13	-0.12	0.05	0.1
MITRI	-0.23	0.15	0.01	0.49	-0.07	0.07	-0.03	0.06
OCMOL	-0.03	-0.12	0	-0.04	0.03	0.1	0.03	0.01
OCRIV	0.25	-0.13	0.29	0.24	0.3	0.41	0.21	0.04
POLEC	0.01	0.17	-0.07	-0.15	0.1	-0.18	-0.3	-0.31
POSUB	-0.2	-0.01	-0.1	0.19	-0.02	0.04	-0.19	0
POTOR	0.42	0.4	-0.08	-0.07	-0.07	-0.16	-0.57	-0.71
POTRI	-0.01	0.14	0.28	0.07	0.19	0.09	0.39	0.59
PRPAN	0.55	-0.2	0.54	-0.28	0.32	0.07	0.16	0.51
PRPEC	-0.15	0.31	-0.07	0	-0.3	0.16	-0.13	0.03
SAALL	0.02	-0.21	-0.06	0.29	-0.1	0.08	0.21	0.24
SAGLA	-0.06	-0.13	0.44	0.14	0.5	0.13	0.05	-0.18
UNOSA	0.23	0.12	0.17	0	-0.13	0.04	-0.05	0.01
UNTHE	-0.06	0.21	-0.18	0.52	0.09	-0.2	-0.25	-0.26

Spatial component

ARCOM	0.87	0.87	0.87	0.87	0.87	0.87	0.89	0.86
ARDUN	0.14	0.14	0.19	0.16	0.14	0.14	0.13	0.15
CHGLA	-0.28	-0.31	-0.25	-0.27	-0.34	-0.28	-0.32	-0.31
CHSKU	0.43	0.42	0.45	0.2	0.3	0.4	0.29	0.29
COCYM	0.57	0.45	0.57	0.57	0.55	0.57	0.57	0.52
COLIE	0.5	0.6	0.6	0.6	0.62	0.61	0.45	0.64
DEARB	0.79	0.77	0.8	0.82	0.79	0.79	0.79	0.8
DERAV	0.79	0.75	0.74	0.74	0.71	0.74	0.74	0.73
FAOCC	0.04	0.12	0.09	0.09	0.2	0.11	0.2	0.26
FAPER	0.8	0.81	0.8	0.82	0.8	0.76	0.86	0.86
GAAGU	-0.01	0.14	0.04	0.01	0.03	0	0.05	0.04
GAMAG	0.45	0.43	0.4	0.45	0.05	0.45	0.46	0.44
GUAMP	0.8	0.8	0.81	0.79	0.81	0.79	0.8	0.82
GUCHI	0.67	0.63	0.64	0.61	0.64	0.65	0.64	0.64
GUPUD	0.47	0.46	0.44	0.39	0.46	0.47	0.29	0.3
GUROS	0.44	0.41	0.45	0.45	0.45	0.44	0.44	0.4
INSKU	0.27	0.37	0.39	0.38	0.35	0.34	0.39	0.44
INSPE	0.44	0.43	0.37	0.43	0.42	0.44	0.47	0.46
MIDIS	0.61	0.62	0.61	0.63	0.62	0.62	0.58	0.62
MIDON	0.6	0.57	0.58	0.57	0.59	0.58	0.56	0.58
MIOSA	0.66	0.44	0.52	0.52	0.5	0.53	0.52	0.52
MITRI	0.71	0.72	0.71	0.7	0.71	0.72	0.72	0.72
OCMOL	0.66	0.66	0.66	0.65	0.65	0.66	0.66	0.66
OCRIV	0.85	0.84	0.85	0.83	0.85	0.81	0.58	0.72
POLEC	0.83	0.83	0.83	0.83	0.83	0.83	0.85	0.85
POSUB	0.75	0.72	0.75	0.74	0.71	0.74	0.76	0.74
POTOR	0.55	0.49	0.52	0.54	0.55	0.53	0.7	0.79
POTRI	0.79	0.81	0.82	0.78	0.55	0.81	0.75	0.8
PRPAN	-0.25	0.15	0.16	0.21	0.2	0.17	0.2	0.12
PRPEC	0.85	0.82	0.84	0.84	0.86	0.82	0.79	0.84
SAALL	0.58	0.6	0.58	0.59	0.59	0.58	0.63	0.64
SAGLA	0.62	0.62	0.28	0.63	0.29	0.59	0.62	0.63
UNOSA	0.48	0.45	0.48	0.39	0.48	0.47	0.47	0.47
UNTHE	0.69	0.7	0.68	0.7	0.68	0.68	0.71	0.72

Source: Hofhansl et al., 2019 in prep.

Functional traits – fixed component

Widespread <<< Endemic

Widespread

ARCOM	0.18	0.2	0.19	0.21	−0.44	0.09	0.34	−0.13
CHGLA	−0.08	0.51	−0.15	−0.06	0.27	0.28	−0.07	0.29
COCYM	0.17	0.06	−0.17	−0.19	−0.15	−0.07	0.02	0.14
DEARB	−0.32	−0.03	0.05	0.12	0.02	−0.11	0.26	−0.02
FAOCC	−0.03	0.48	−0.07	0.03	0.07	−0.18	0.32	0.3
GAMAG	0.21	0.75	−0.12	0.25	0	−0.13	0.09	−0.17
GUAMP	−0.01	−0.19	0.07	−0.11	−0.21	0.3	0.13	0.01
GUROS	0.07	0.05	0.08	0.08	0.16	−0.07	−0.25	0.08
INSPE	−0.06	−0.09	0	−0.01	−0.31	−0.35	−0.12	−0.18
MIDON	−0.12	0.3	0.29	−0.04	−0.16	0.08	0	0.19
MITRI	−0.16	−0.02	−0.07	−0.09	0.01	−0.05	0	0.07
OCMOL	−0.08	0.07	−0.16	0.07	−0.08	−0.09	−0.2	−0.02
POSUB	−0.03	0.36	−0.18	0.15	0.31	−0.13	0.06	0.09
POTOR	0.24	0.1	−0.02	0.45	0.61	0.78	0.45	−0.15
PRPAN	0.18	−0.12	0.05	−0.04	−0.23	0.06	−0.09	0.65
SAGLA	−0.26	0.41	0.14	0.47	−0.19	0.22	0.02	0.1
UNTHE	−0.24	0.13	0	0	0.18	0.32	0.4	−0.02

Endemic

ARDUN	−0.05	0.12	0.08	0.24	−0.09	−0.03	0.06	−0.01
CHSKU	0.39	0.52	−0.12	0.37	0.03	0.02	0.19	0.1
COLIE	−0.13	0.22	−0.06	0.05	0.41	0.27	0.02	−0.01
DERAV	−0.14	−0.04	0.21	0.04	−0.16	−0.14	0.12	0.47
FAPER	0.01	0.03	0.36	−0.02	−0.08	0.21	0.24	0.05
GAAGU	−0.2	−0.23	−0.22	−0.2	0.23	−0.12	−0.1	0.21
GUCHI	0.14	−0.06	0.13	0.04	0.05	0.08	0.01	0.31
GUPUD	0.28	0.1	−0.16	0.21	−0.26	−0.02	0.11	0.14
INSKU	0.16	0.03	0.04	0.48	0.26	0.74	0.58	0.21
MIDIS	−0.2	−0.03	−0.03	−0.12	−0.01	−0.32	−0.14	−0.15
MIOSA	0.11	0.11	0.21	−0.04	−0.16	−0.02	−0.17	0.51
OCRIV	−0.08	−0.22	−0.1	−0.29	0.54	0.48	−0.05	−0.21
POLEC	0.07	−0.06	0.14	0.05	0.37	0.38	0.37	−0.01
POTRI	−0.37	0.56	−0.13	−0.19	0.01	−0.29	−0.42	−0.2
PRPEC	−0.05	0.37	0.06	0.15	0.5	−0.06	−0.06	0.18
SAALL	−0.12	0.23	−0.01	0.02	−0.17	−0.18	−0.09	0
UNOSA	0.55	0.16	−0.03	−0.13	−0.01	−0.13	−0.06	−0.09

Source: Hofhansl et al., 2019 in prep.

Functional traits – plastic component

Widespread >>> Endemic

Widespread

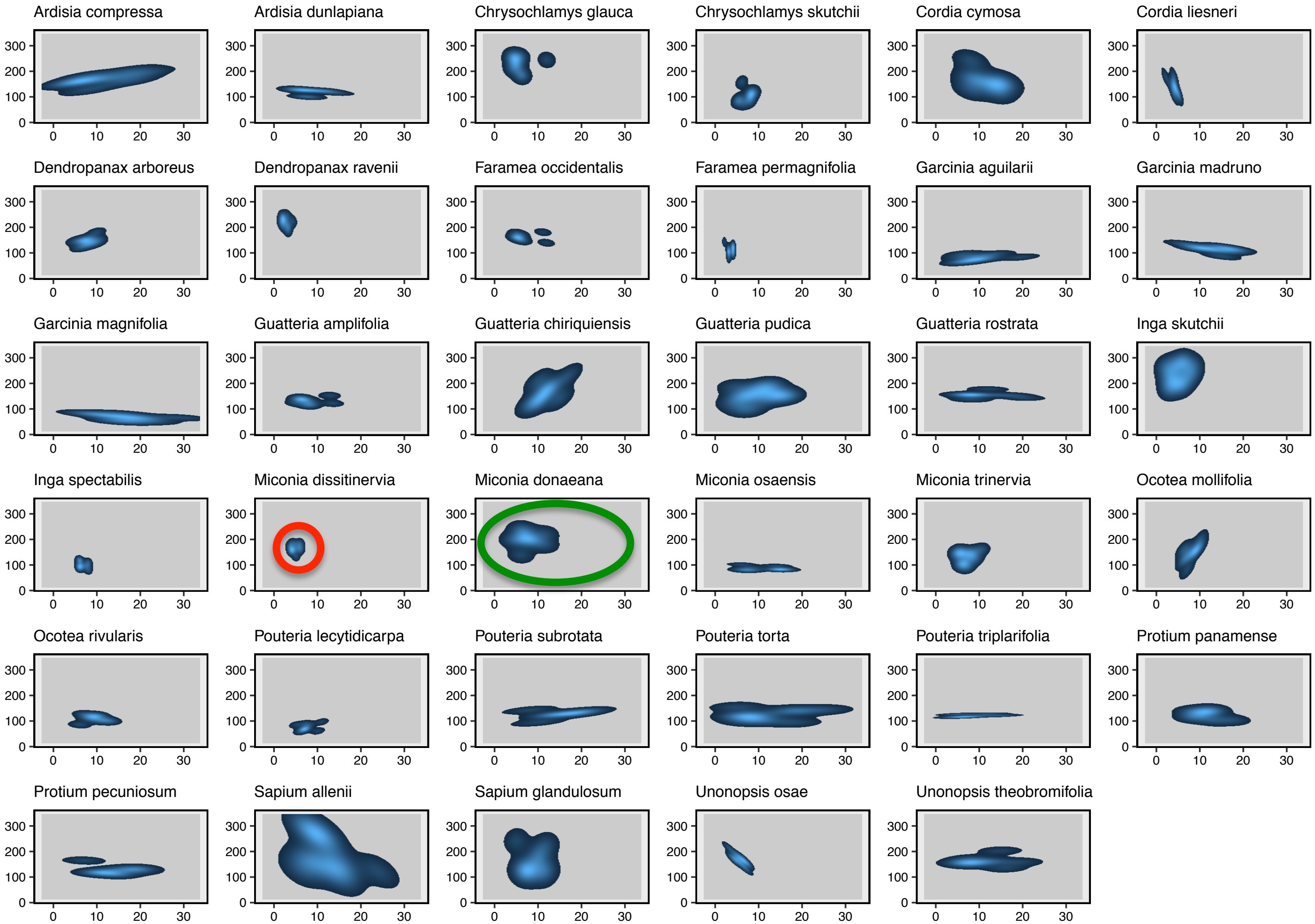
ARCOM	−0.22	−0.26	−0.21	−0.26	0.49	0.03	−0.19	0.2
CHGLA	−0.11	0.23	−0.19	0.1	0.29	0.23	0.24	0.11
COCYM	−0.28	0.08	0.44	0.53	0.37	0.51	0.29	−0.2
DEARB	0.4	−0.01	−0.12	−0.1	−0.06	0.19	0.04	−0.01
FAOCC	0.09	−0.27	0.7	−0.16	0.38	0.15	0.02	0.14
GAMAG	−0.02	0.32	−0.07	0.14	−0.02	−0.1	−0.14	0
GUAMP	−0.18	0.26	−0.3	0.13	0.08	−0.24	−0.1	−0.07
GUROS	−0.08	−0.16	0.01	−0.27	−0.35	−0.09	0.37	0
INSPE	−0.07	0.52	0.13	0.54	0.68	0.4	0	0.04
MIDON	0.41	−0.16	−0.11	0.15	0.58	−0.11	−0.22	−0.23
MITRI	0.49	−0.07	0.07	0.01	−0.03	0.06	0.11	−0.23
OCMOL	−0.04	0.03	0.1	0	0.03	0.01	0.1	−0.03
POSUB	0.19	−0.02	0.04	−0.1	−0.19	0	−0.14	−0.2
POTOR	−0.07	−0.07	−0.16	−0.08	−0.57	−0.71	−0.46	0.42
PRPAN	−0.28	0.32	0.07	0.54	0.16	0.51	0.3	0.55
SAGLA	0.14	0.5	0.13	0.44	0.05	−0.18	−0.08	−0.06
UNTHE	0.52	0.09	−0.2	−0.18	−0.25	−0.26	−0.28	−0.06

Endemic

ARDUN	0.22	0.06	0.09	−0.21	−0.17	0.14	−0.05	−0.16
CHSKU	0.4	0.11	−0.1	−0.18	−0.04	−0.1	−0.08	−0.21
COLIE	−0.01	−0.19	0.02	0.08	0.23	−0.29	−0.18	0.25
DERAV	0.05	0.33	−0.1	0	0.33	0	−0.18	−0.39
FAPER	0.02	0.17	0	0.24	−0.03	−0.08	−0.16	0.16
GAAGU	−0.17	−0.1	−0.2	−0.07	0.01	−0.08	−0.08	0.28
GUCHI	0.12	0.04	−0.12	−0.09	0.05	−0.03	0.02	−0.25
GUPUD	0.15	−0.04	0.09	0.08	0.01	0	0.1	−0.06
INSKU	−0.22	−0.2	0.16	−0.18	−0.23	−0.28	−0.32	0.28
MIDIS	0.17	0.05	0.07	−0.01	0.15	0.31	0.04	−0.01
MIOSA	−0.1	0.13	−0.12	−0.04	0.05	0.1	0.12	−0.39
OCRIV	0.24	0.3	0.41	0.29	0.21	0.04	−0.03	0.25
POLEC	−0.15	0.1	−0.18	−0.07	−0.3	−0.31	−0.35	0.01
POTRI	0.07	0.19	0.09	0.28	0.39	0.59	0.15	−0.01
PRPEC	0	−0.3	0.16	−0.07	−0.13	0.03	0.01	−0.15
SAALL	0.29	−0.1	0.08	−0.06	0.21	0.24	0.33	0.02
UNOSA	0	−0.13	0.04	0.17	−0.05	0.01	−0.1	0.23

Source: Hofhansl et al., 2019 in prep.

Outlook – multidimensional trait space



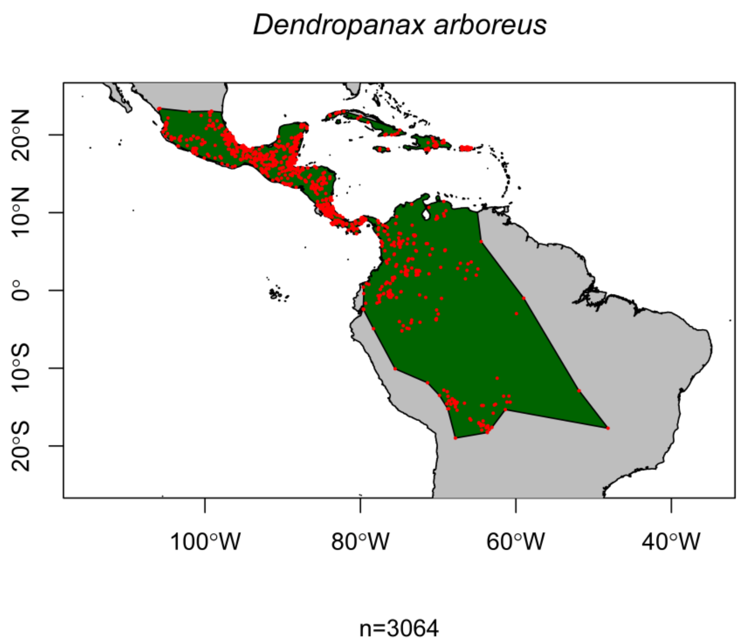
Functional traits and environmental niche space differs among tropical tree species:

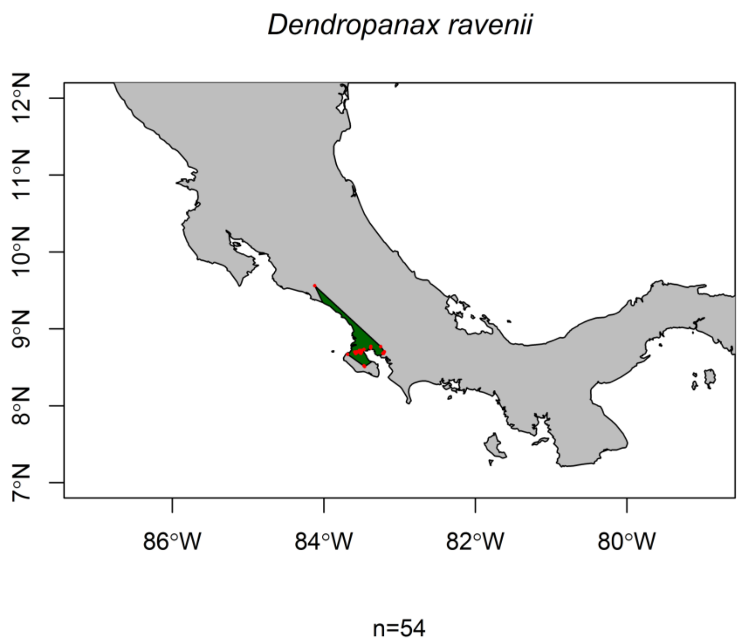
- **Differences in niche space**
- **Distinct plasticity among tree species**
- **Account for multi-dimensional trait-space in models**
- **Project response of ecosystem function**

Source: Carmona et al., 2016 1. Traits Without Borders: Integrating Functional Diversity Across Scales. Trends in Ecol & Evol 31, 382–394 (2016).

Functional traits – niche space

Species range size and trait space





Widespread species **Endemic species**

- **Need to account for trait plasticity and species composition to project ecosystem responses under future scenarios**

Databases – data availability

1) **TRY** – Plant Trait Database https://www.try-db.org/TryWeb/Home.php
2) **BIEN** – Botanical Information and Ecology Network http://bien.nceas.ucsb.edu/bien/
3) **FOS** – Forest Observation System https://forest-observation-system.net/

PLOT INFORMATION

BDEF-LG-RAV (1)

Costa Rica

Network: IIASA

Institutions: Uni Wien

Link: http://www.univie.ac.at/bdef

PIs: Wolfgang Wanek, Florian Hofhansl

Established: 2012

Plot area: 0.25 ha

Altitude: 135 m **Slope:** 11 %

Census: 2012

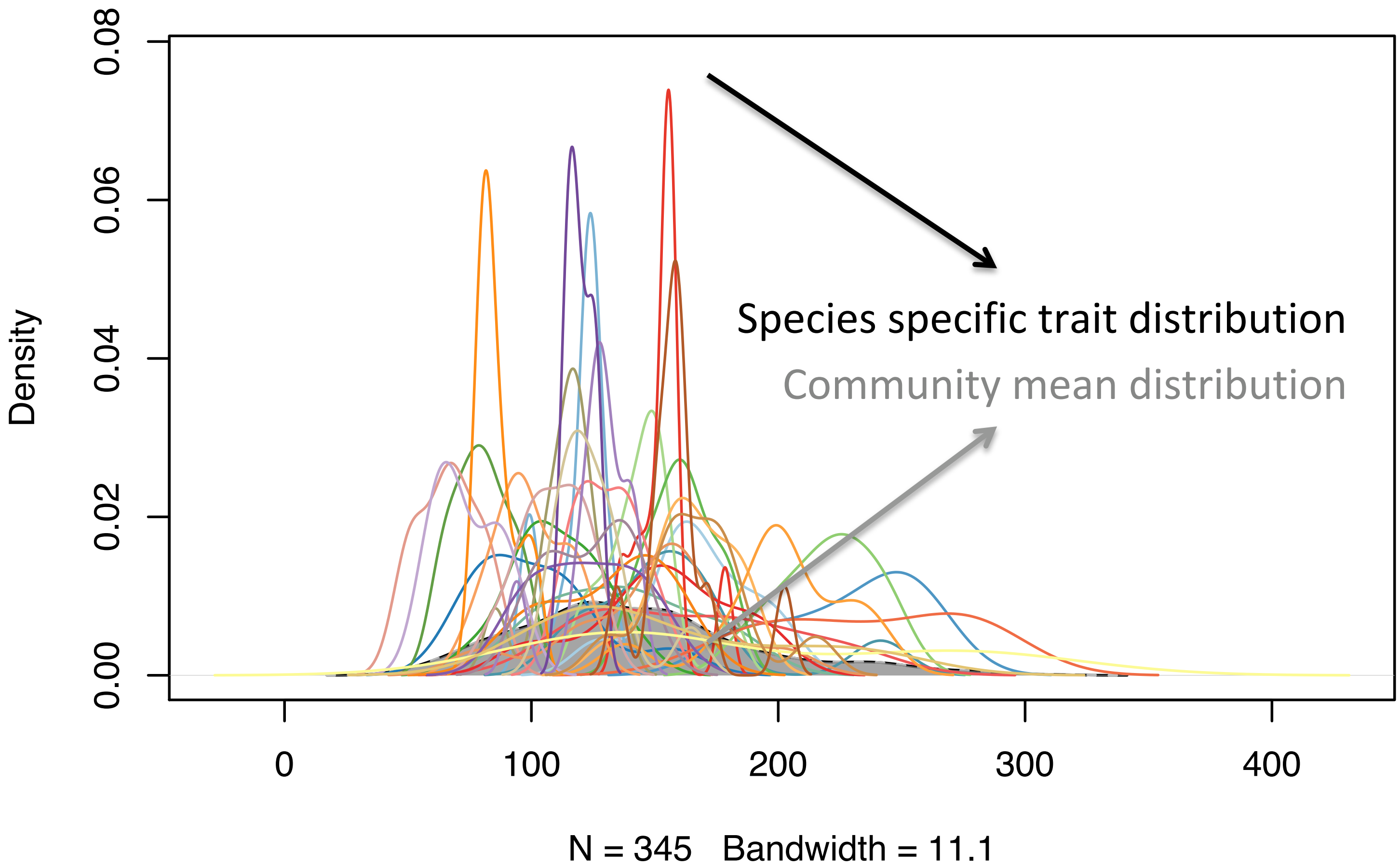
Measurements:
AGB Local HD : 277 t/ha
H Lorey Local: 24.8 m
H Max Local: 47.6 m
Min DBH : 10 cm
Wood Density : 0.535 t/m3

Reference: Taylor, P., Asner, G., Dahlin, K., Anderson, C., Knapp, D., Martin, R., Mascaro, J., Chazdon, R., Cole, R., Wanek, W., Hofhansl, F., Malavassi, E., Vilchez-Alvarado, B. & A. Townsend (2015). Landscape-Scale Controls on Aboveground Forest Carbon Stocks on the Osa Peninsula, Costa Rica. PLoS ONE, 10, e0126748.

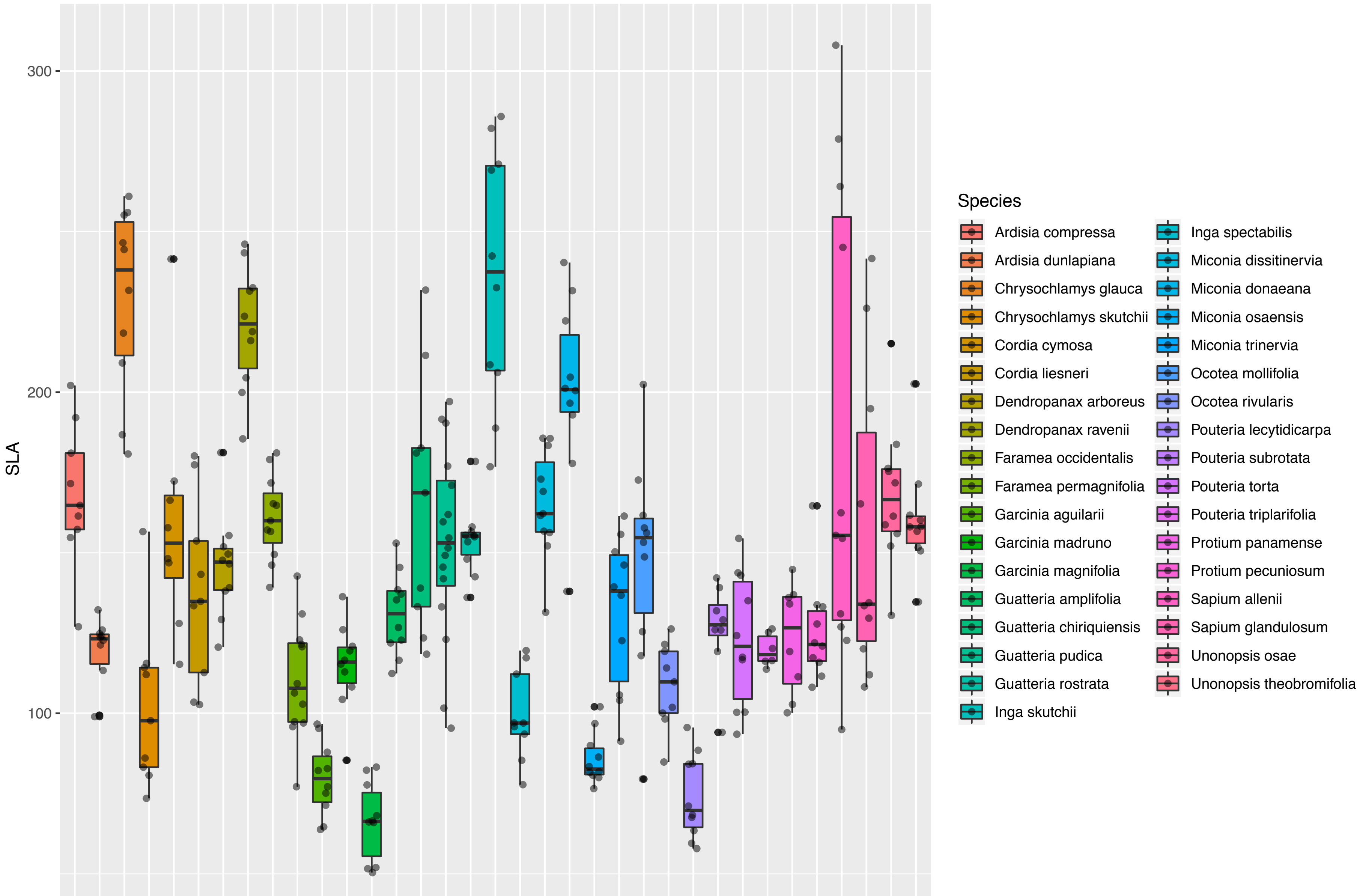
➢ **Data: https://www.forest-observation-system.net**

Results – Trait variation

Trait variation (Specific leaf area)

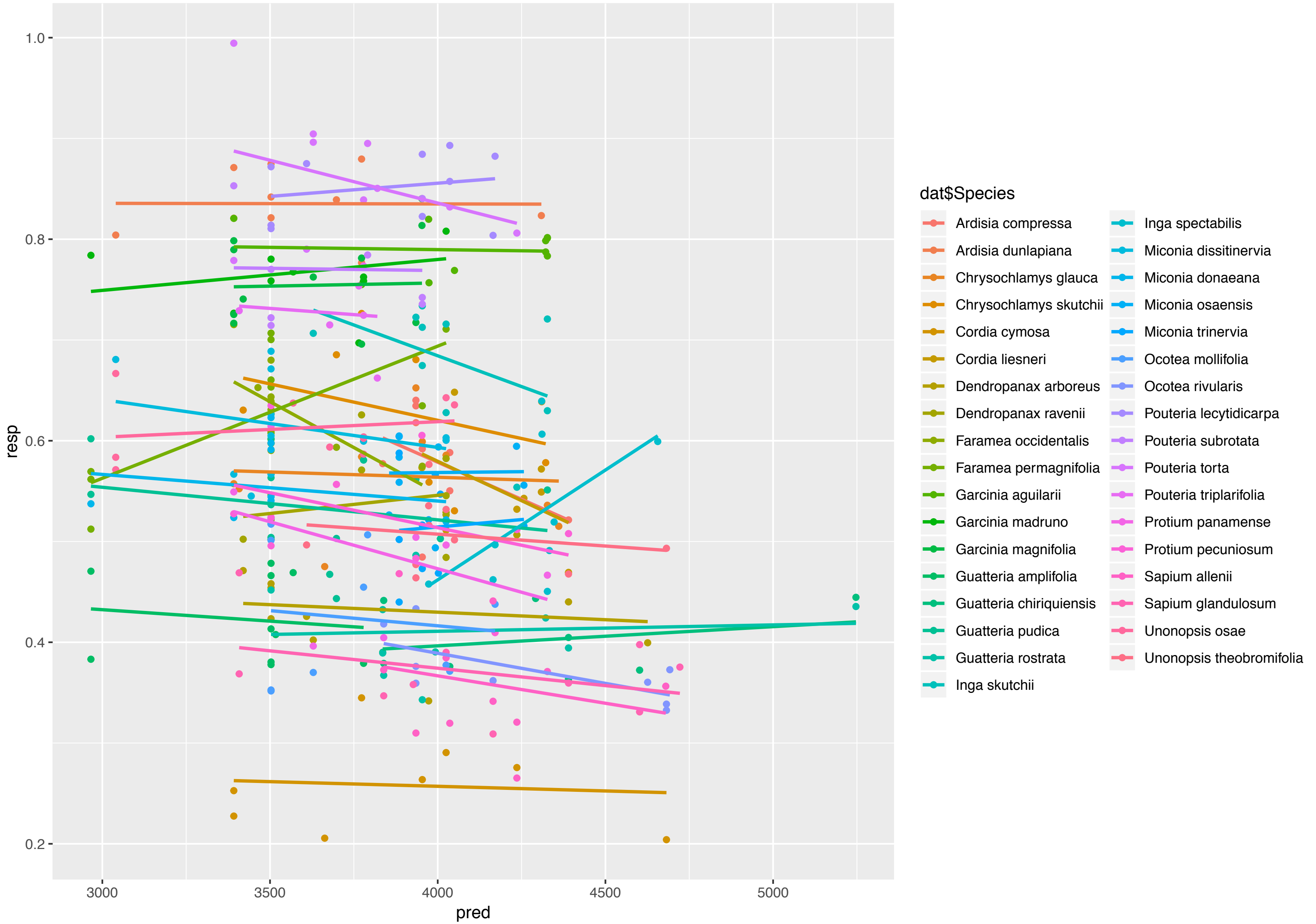


Results – Trait variation among species



Source: Carmona et al. (2016).

Results – Trait reaction norm - species



Source: Hofhansl et al., 2019 in prep.

Results – Trait reaction norm - sites

Source: Hofhansl et al., 2019 in prep.