Flood-induced Endemism in Amazonian Floodplain Trees

Florian Wittmann
Ethan Householder, Jochen Schöngart, Maria T. F. Piedade, Rafael L. de Assis, Pia Parolin & Wolfgang J. Junk

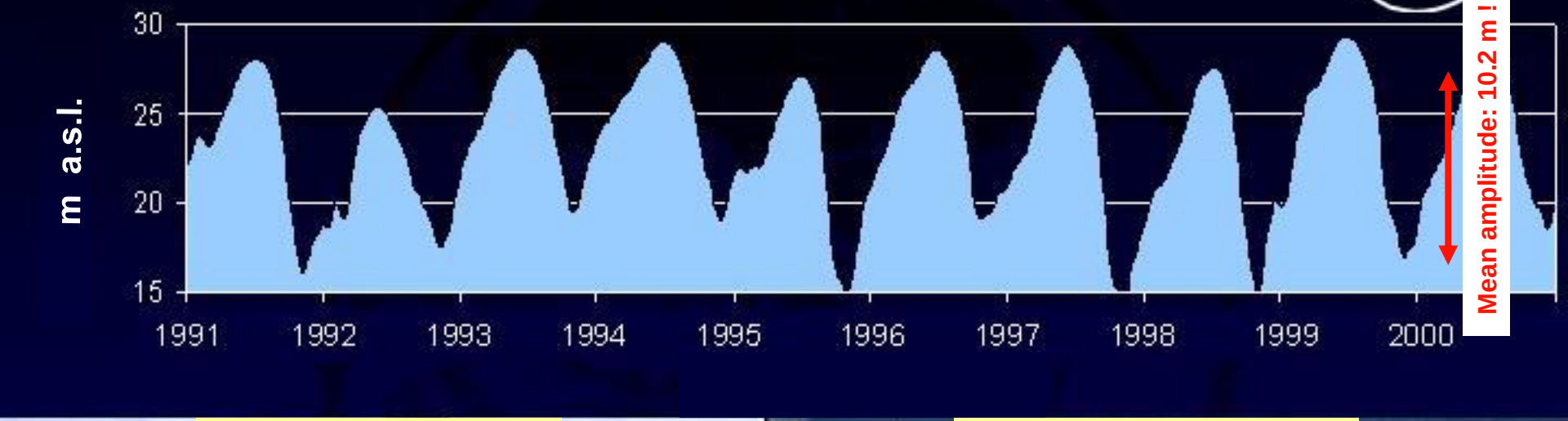
Max-Planck-Institute for Chemistry

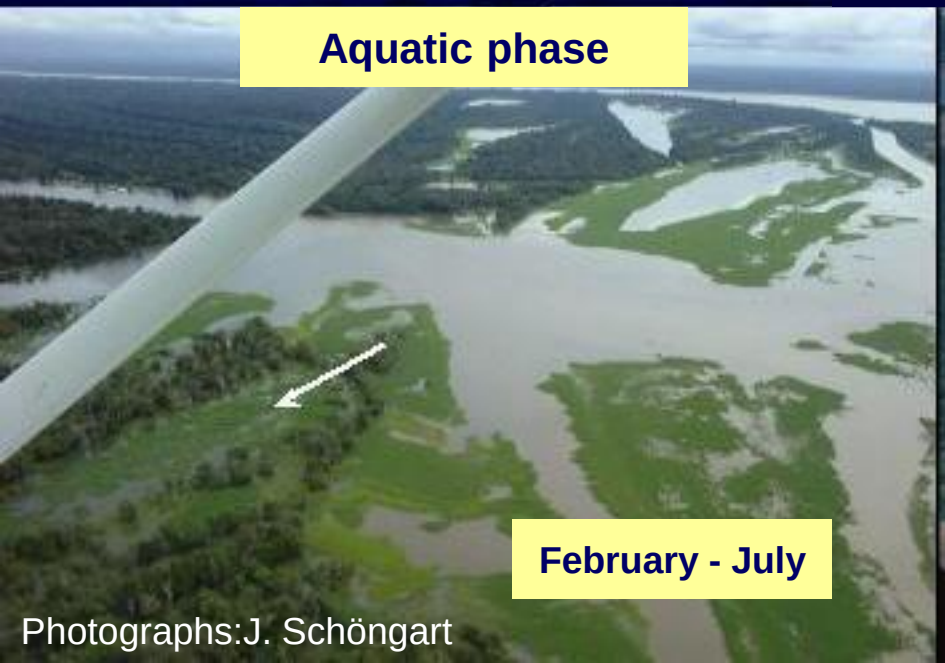
Monitoring of Amazonian Wetlands - MAUA

Instituto Nacional de Pesquisas da Amazônia

Monomodal flood pulse

(Junk *et al.* 1989)





Photographs:J. Schöngart

Trees establish where annual inundations average < 7.5 m (white-water) or < 9.0 m (black water), which correponds to a waterlogged or submersed period of 230 and 270 days year^{-1} (forest border)

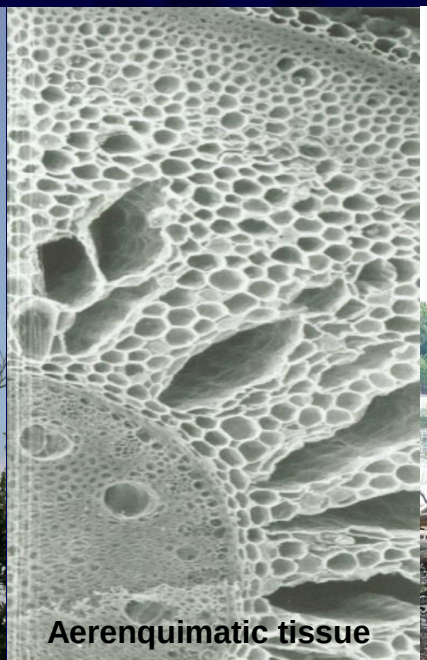
Inundation reduces oxygen availability to trees by the factor 10^4

Jackson & Drew (2002): *Ann Bot*

Amazonian floodplain tree species combine several adaptive strategies to tolerate the anaerobic site conditions:

- Morpho-anatomical adaptations: Increase of root surfaces, hypertrophic lenticels, aerenquimatic tissues;

- Physiological adaptations: leaf shedding during high-water periods, reduction of photosynthesys, switch to anaerobic respiration, elevated production of anti-oxidant compounds = reduction of metabolism = cambial dormancy.



Tree species diversity in white-water floodplains

Floristic inventories in várzea forests totaling >60 ha across the Amazon basin

Total number of trees:	39.497
Total number of morphotypes:	1.900
Total number of identified species:	918
Total number of genera:	320
Total number of families:	73

Várzea forest are the most species-rich floodplain forests worldwide:

-20 x higher than in the European temperate zone (Schnitzler *et al*. 2005)

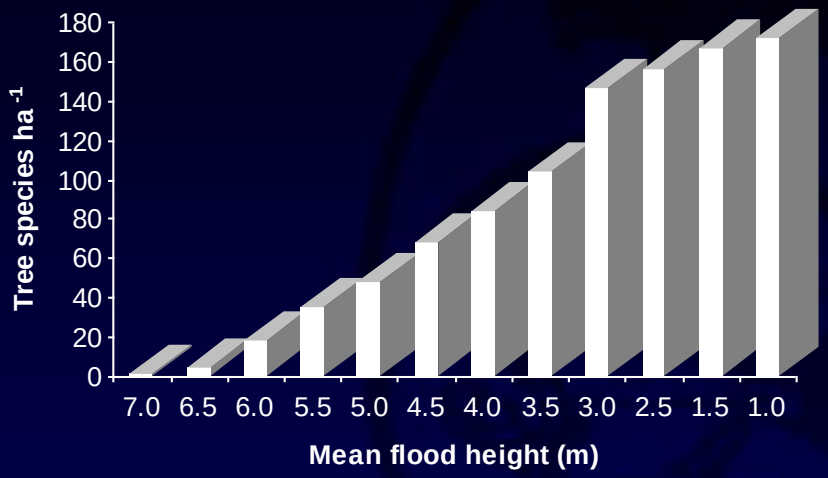
-10 x higher than in subtropical bottomland forests of N-America
(Johnson & Little 1967, Clark & Benforado 1981)

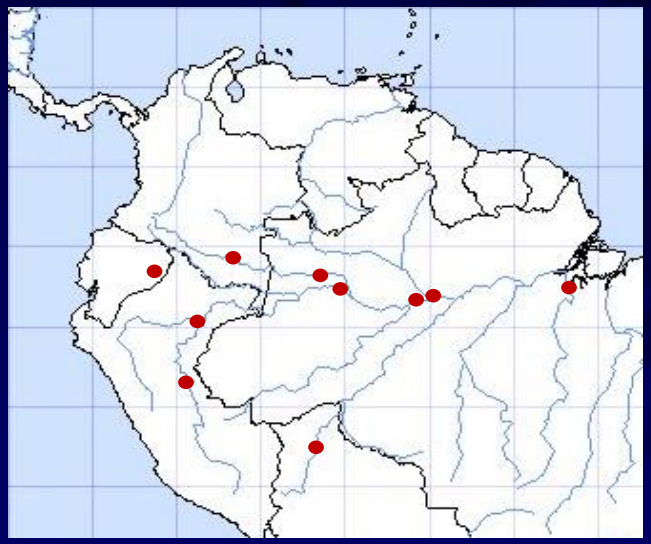
-10 x higher than in neotropical savannas and SE-Asian floodplains
(Junk *et al.* 2006, Campbell *et al*. 2006)

Wittmann *et al*. (2006): *J Biogeography*

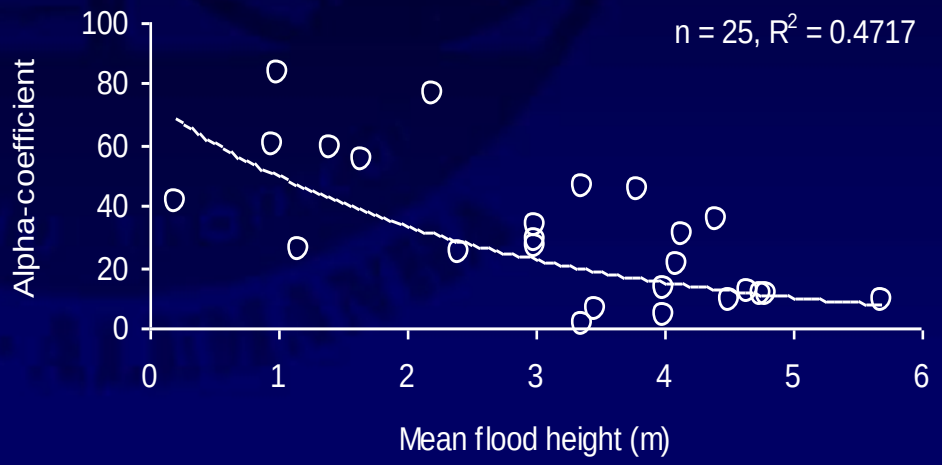
Tree species richness and diversity along the flooding gradient

n=83 plots totaling 5.24 ha; 2.631 individuals, 306 species
(Wittmann *et al*. 2002: *J Trop Ecol*)





n=44 plots totaling 62.3 ha; 39.497 individuals, 918 species
(Wittmann *et al*. 2006: *J Biogeography*)



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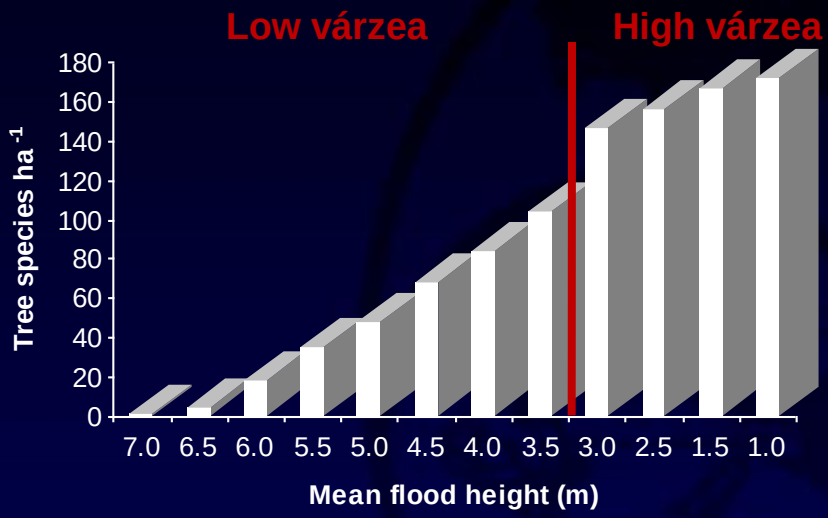

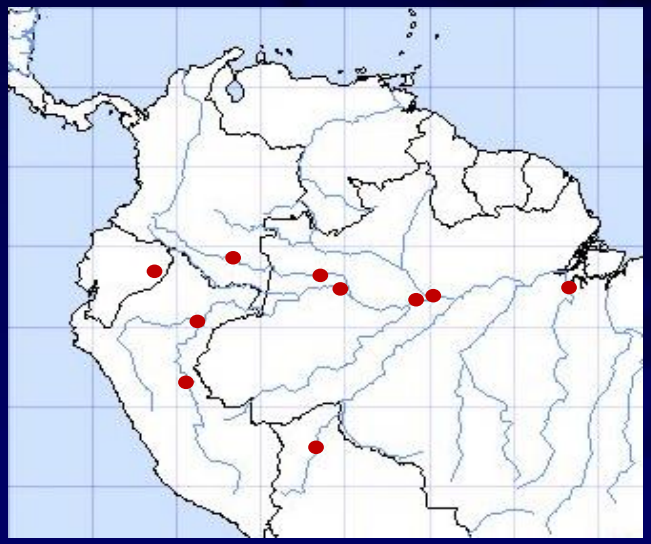

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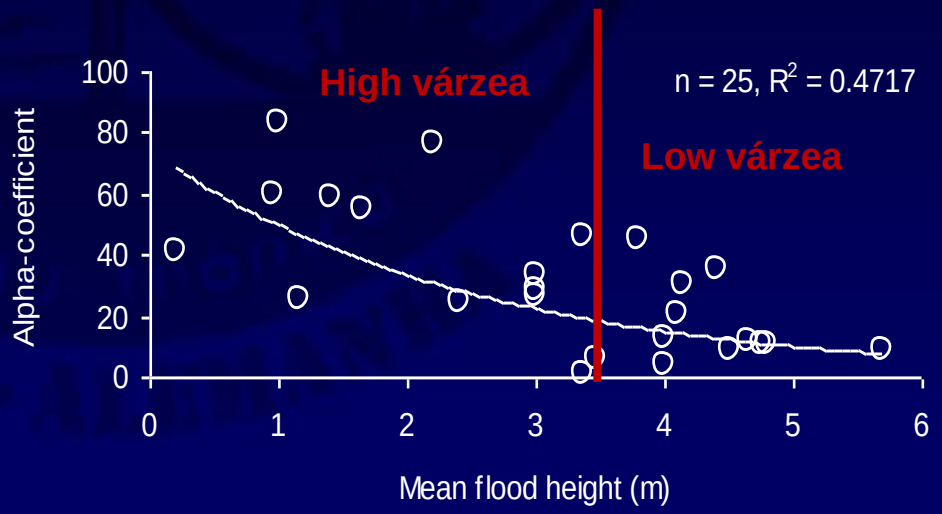
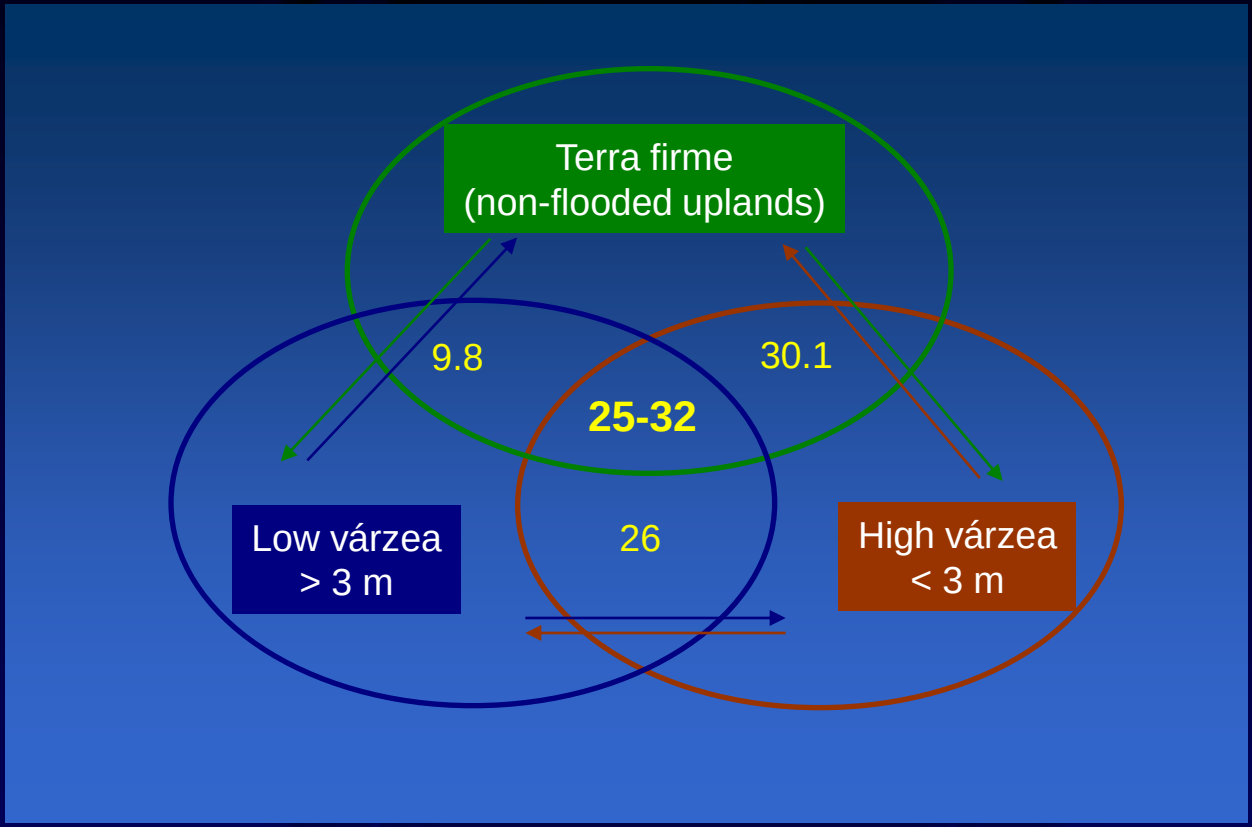


Floristic similarity between Amazonian várzea and upland forests



Floodplain data resumed in:
Wittmann *et al*. (2006): *J Biogeography*

Terra firme data resumed in:
Oliveira & Nelson (2001), Pitman *et al.* (2002), Ter Steege *et al*. (2006)

From where came the várzea tree species? Are there endemic tree species?

1. Taxonomic-evolutionary hypothesys:
Floodplain genotypes originate from adjacent upland forests (Kubitzki 1989)

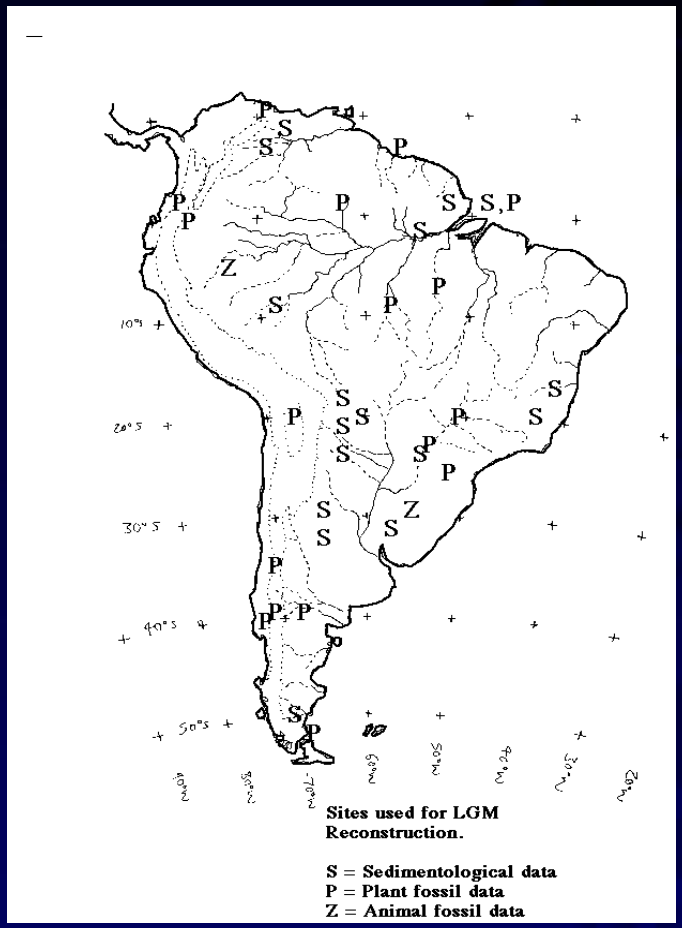
2. Physiological hypothesys:
Several Amazonian floodplain genera and species originate from ecosystems/biomes with climatologically and/or edaphically aridity = neotropical savannas (Prance 1979, Worbes *et al.* 1992).

3. Endemism:
Due to the exceptional high inundations, and the high number of adaptive strategies of trees to flooding, Amazonian floodplains are rich in endemic tree species (Kubitzki 1989, Junk 1989). This is in contrast to other neotropical wetlands, where endemic tree species are rare, or even absent (Junk *et al*. 2006, Veneklaas *et al*. 2005, Wittmann *et al.* 2010)

Prance (1979): *Brittonia;* Junk (1989): Academic Press, London; Kubitzki (1989): *Plant Syst Evol;* Worbes *et al*. (1992): *J Veg Sci;* Veneklaas *et al*. (2005): *Ecography*; Junk et al. (2006): *Aquatic Sci;* Wittmann *et al*. (2010): Springer , New York

Evolution of Amazonian Wetlands

The existence of tropical forests within the Amazon basin is evident since the upper Eocene (approx. 30 Ma B.P.) (Burnham & Johnson 2004: *Phil Trans R Soc Lond*)



Behling *et al*. (2001): *Palaeogeo Plaeoclima Palaeoeco*

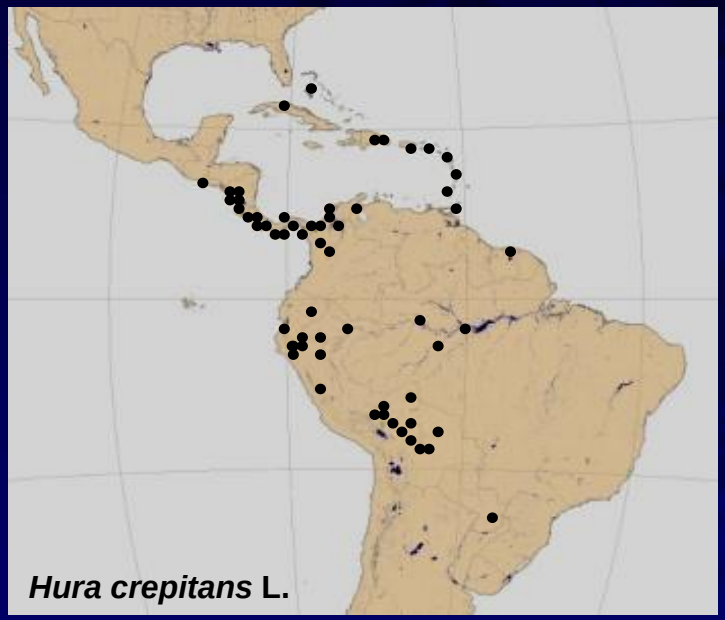
83-67 Ma	
61-60 Ma	Repeated marine ingressions in the pre-Andean depression
12-10 Ma	
43-40 Ma	Formation of Lago Pozo (alluvial, Andean sediment)
20-12 Ma	Formation of Lago Pebas (alluvial, Andean sediment)
13.5 Ma	Fossil of fruit-feeding fish (*Colossoma macropomum*) indicate no changes to recent diet
8 Ma	Amazon starts to drain eastwards
< 1 Ma	Pleistocene and Holocene climate changes strongly influence the Sea level and thus the Amazon River system.

Occurrence and distribution of the 658 most important (abundant and frequent) várzea tree species

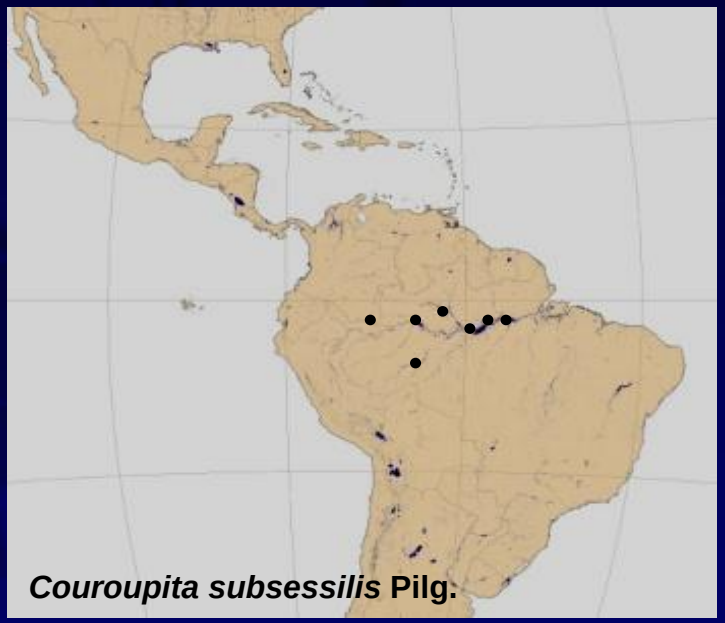
- In Inventories, Checklists and Floras published in literature (up to700 ha and 280.000 individuals across the entire Neotropics)

- In herbaria (e.g., MOBOT, NYBG, RBG Kew, Nationaal Herbarium Utrecht, Jardim Botânico do Rio de Janeiro, herbário do INPA)

- In digital databases (e.g., *Flora Brasiliensis*, International Legume Database, etc.).



***Hura crepitans* L.**



***Couroupita subsessilis* Pilg.**

Data base

- 22 own inventories in the central and western Brazilian Amazon
- Review of 30 inventories available in literature

Authors:
Black *et al*. (1950)
Pires & Koury (1959)
Balslev *et al*. 1987
Revilla (1991)
Campbell *et al*. (1992)
Worbes *et al*. (1992)
Ayres (1993)
Queiroz (1995)
Dallmeier *et al*. (1996)
Klinge *et al*. (1996)
Urrego (1997)
Nebel *et al*. (2001)
Bentes-Gama *et al.* (2002)
Cattanio *et al.* (2002)
Duque *et al.* (2002)
Wittmann *et al*. (2002)
Schöngart (2003)
Ferreira *et al.* (2005)
Carim *et al*. (2008)
Assis & Wittmann (2011)
J.C. Monteiro (unpubl.)

= 80 ha, 92.000 individuals

Species selection and definition of importance

- **In each inventory, the Importance Value (IV) was derived:**

  IV = rAb + rDom + rF (Curtis & McIntosh 1951)

- **For each species, the Overall (continental) Importance Value (OIV) was calculated:**

  $OIV = \Sigma_{1\text{-}80}$ (rIVI) + rF (80 inventories) (Wittmann *et al*. 2006)

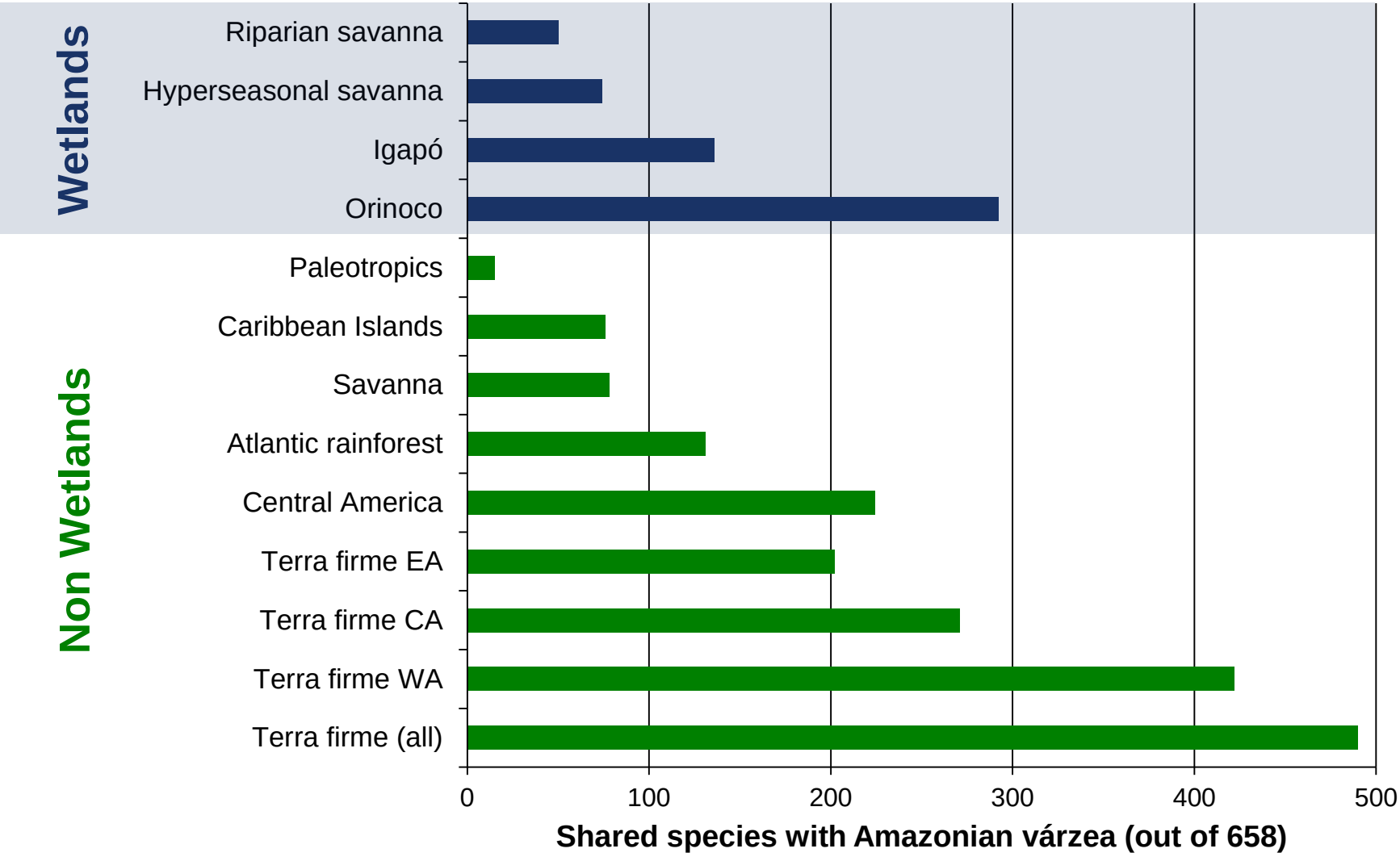
We only selected trees (by excluding vines, lianas, epiphytes), and species that occurred at least in two distinct inventories, performed by distinct authors. Singletons were excluded from the list.

= 658 tree species from the original 918

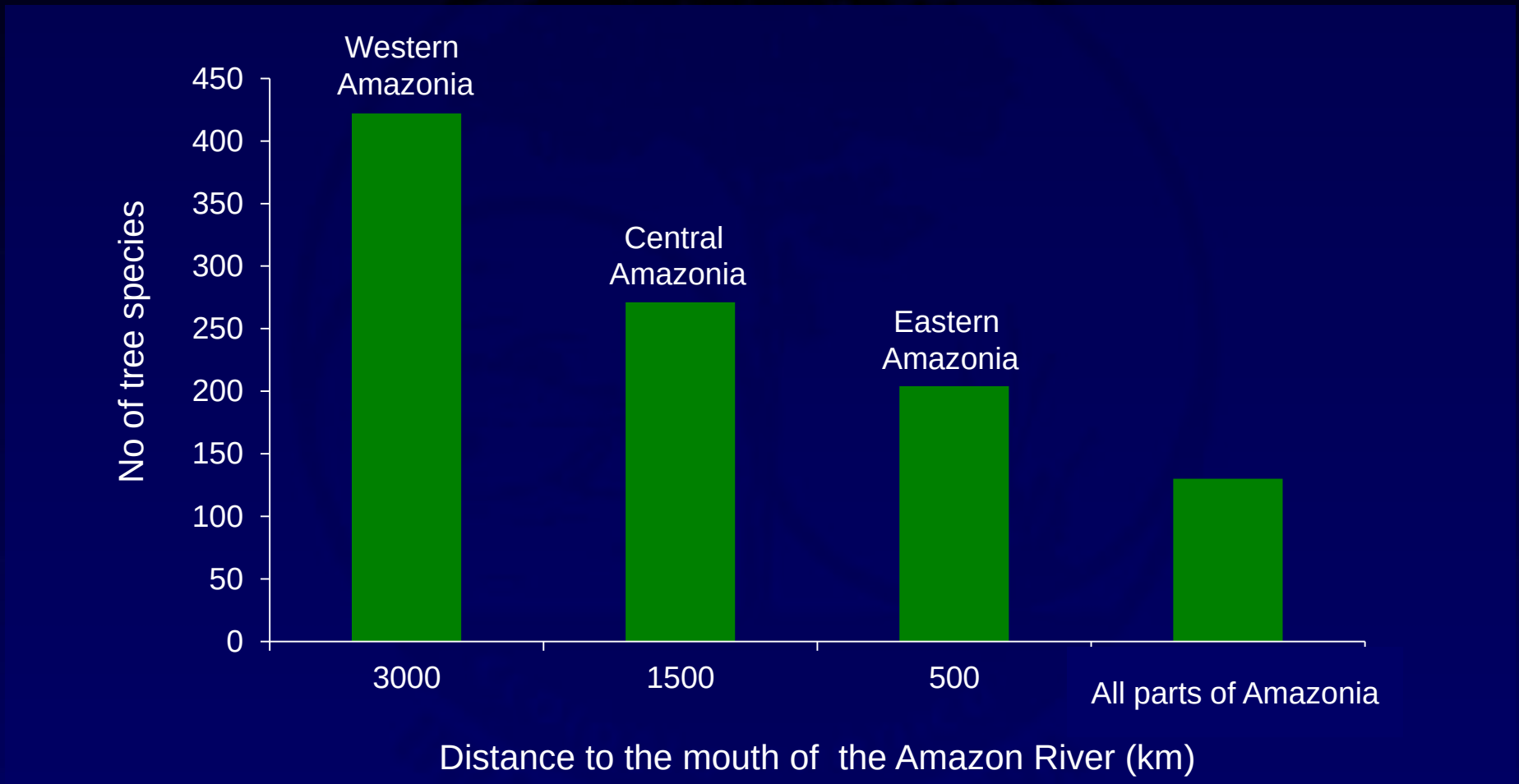
Most important biomes/ecosystems containing várzea tree species

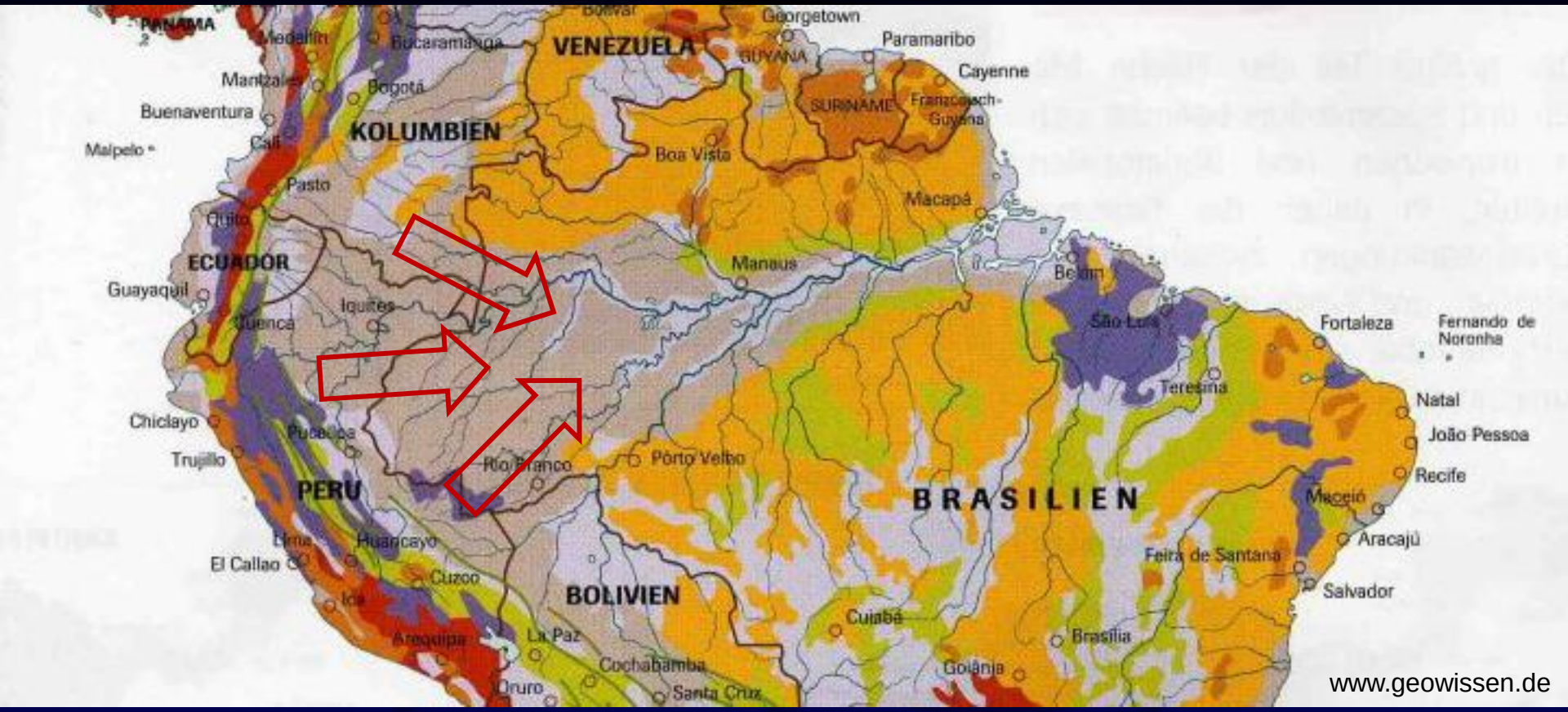
Distribution of várzea tree species

(90% occur in non-várzea environments)



Numbers of várzea tree species in Amazonian uplands





The várzea is a geochemical extension of the Andes

(Irion 1984)

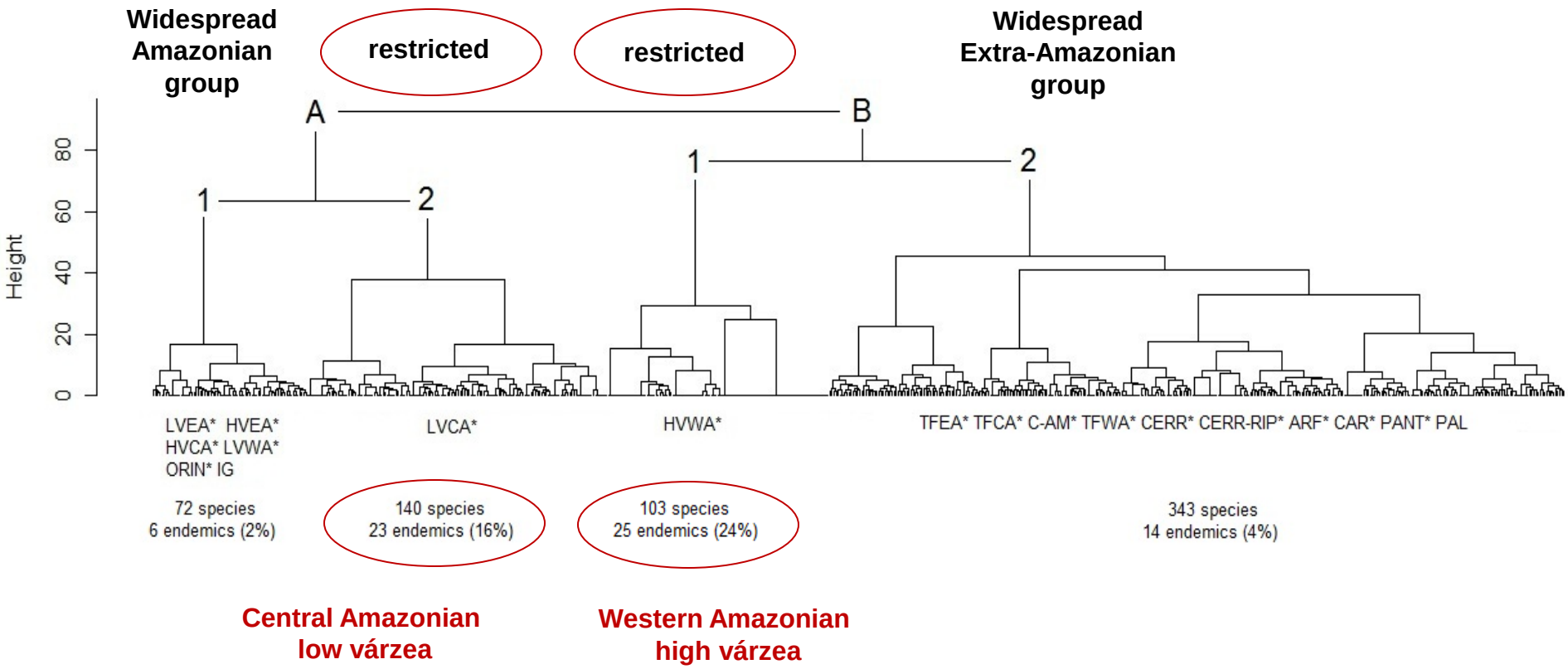
Irion (1984): *Z. Naturwissenschaften*

Indicator Species Analysis investigating the occurrence of the 658 most important várzea tree species

140 várzea tree species (21.3%) with occurrence < 5% in non-várzea environments = Habitat Specialists

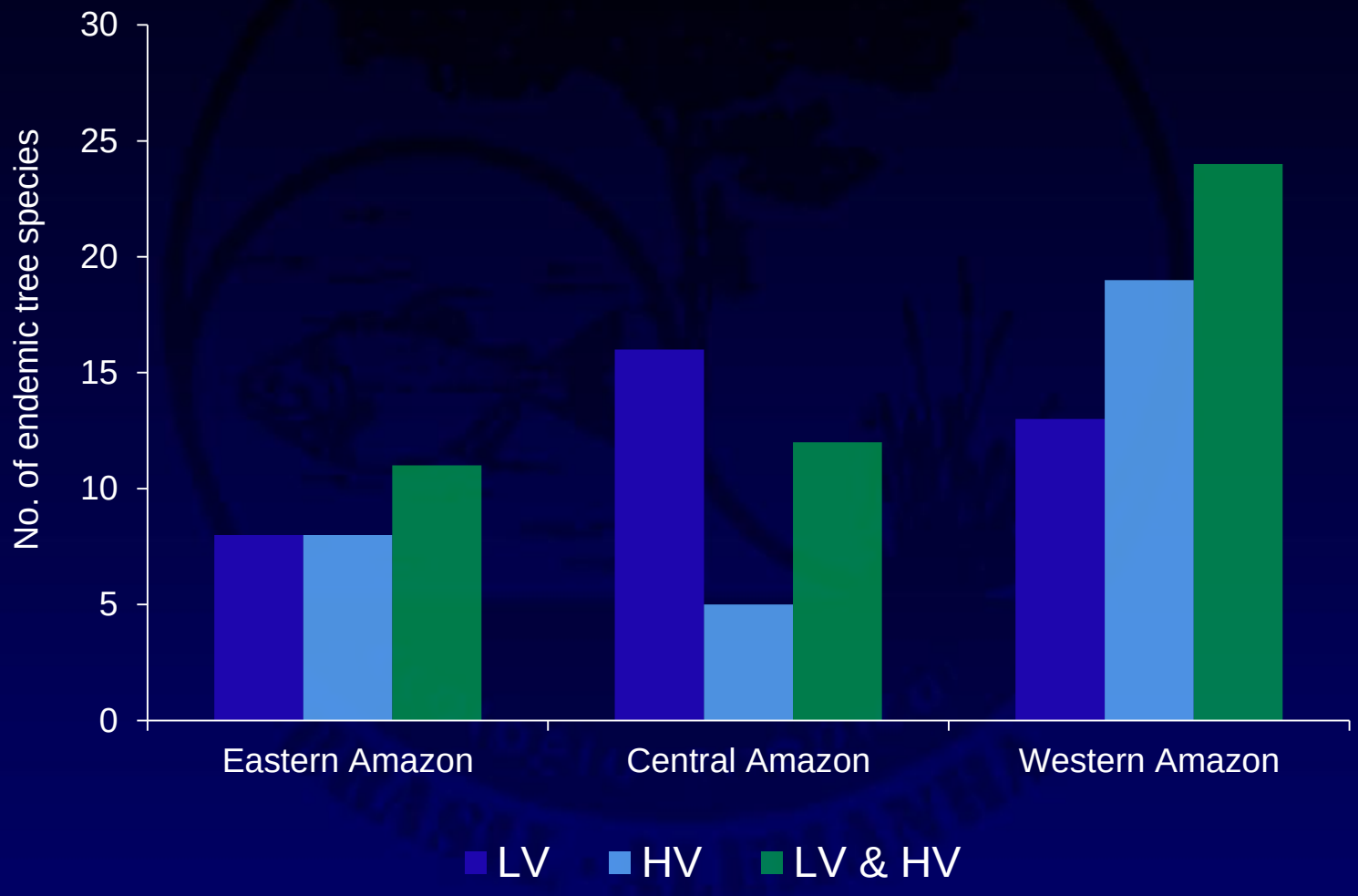
68 várzea tree species (10.3%) restricted to Amazonian várzea = Ecological Endemics

Cluster-Analysis (Ward) combined with association-tests (Šidàk) of várzea tree species occurrence across Neotropical biomes, indicating two centers of endemism



Wittmann *et al*. (subm. to *Ecography*)

Degrees of endemism vs. flooding gradient



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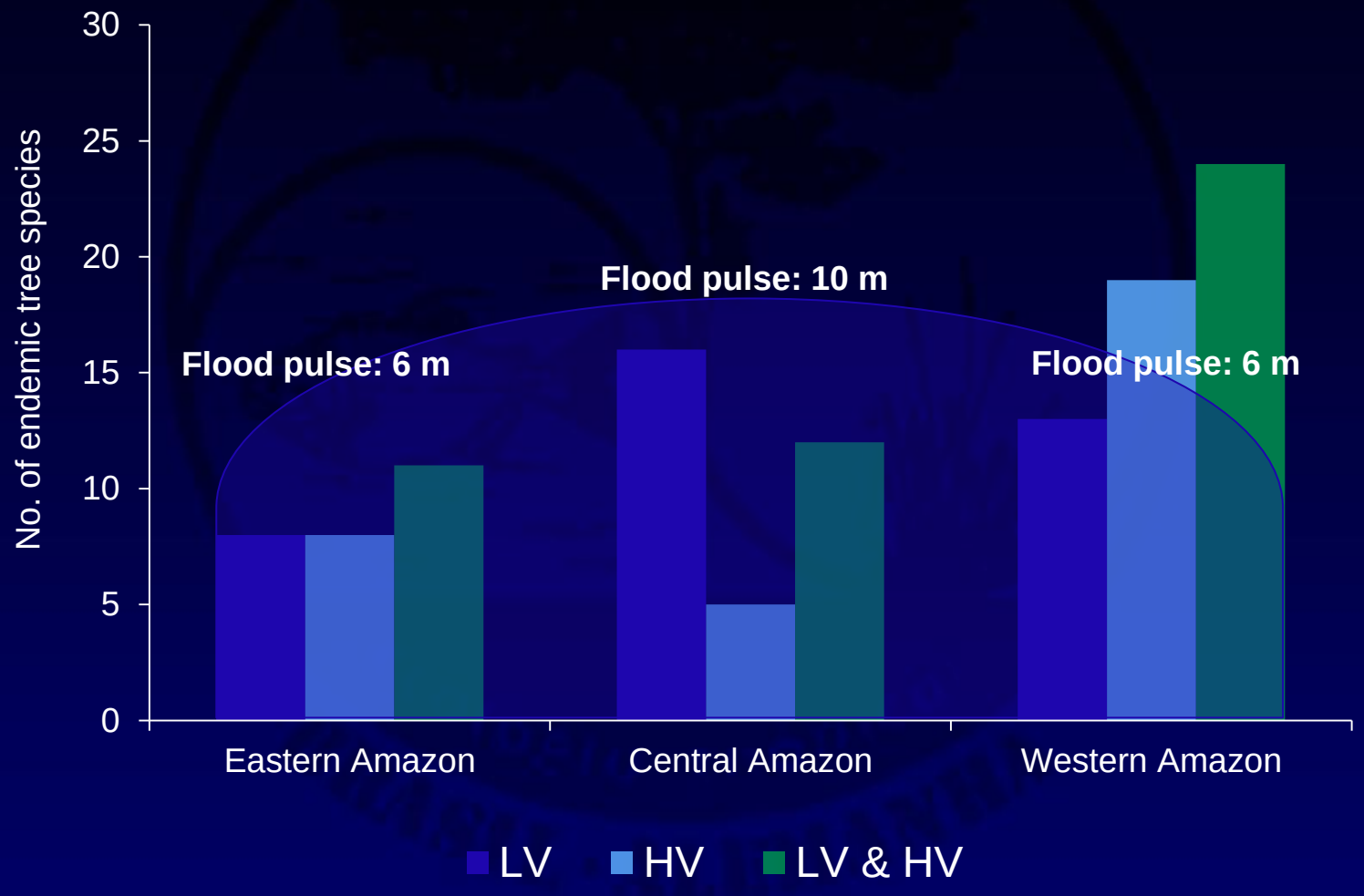
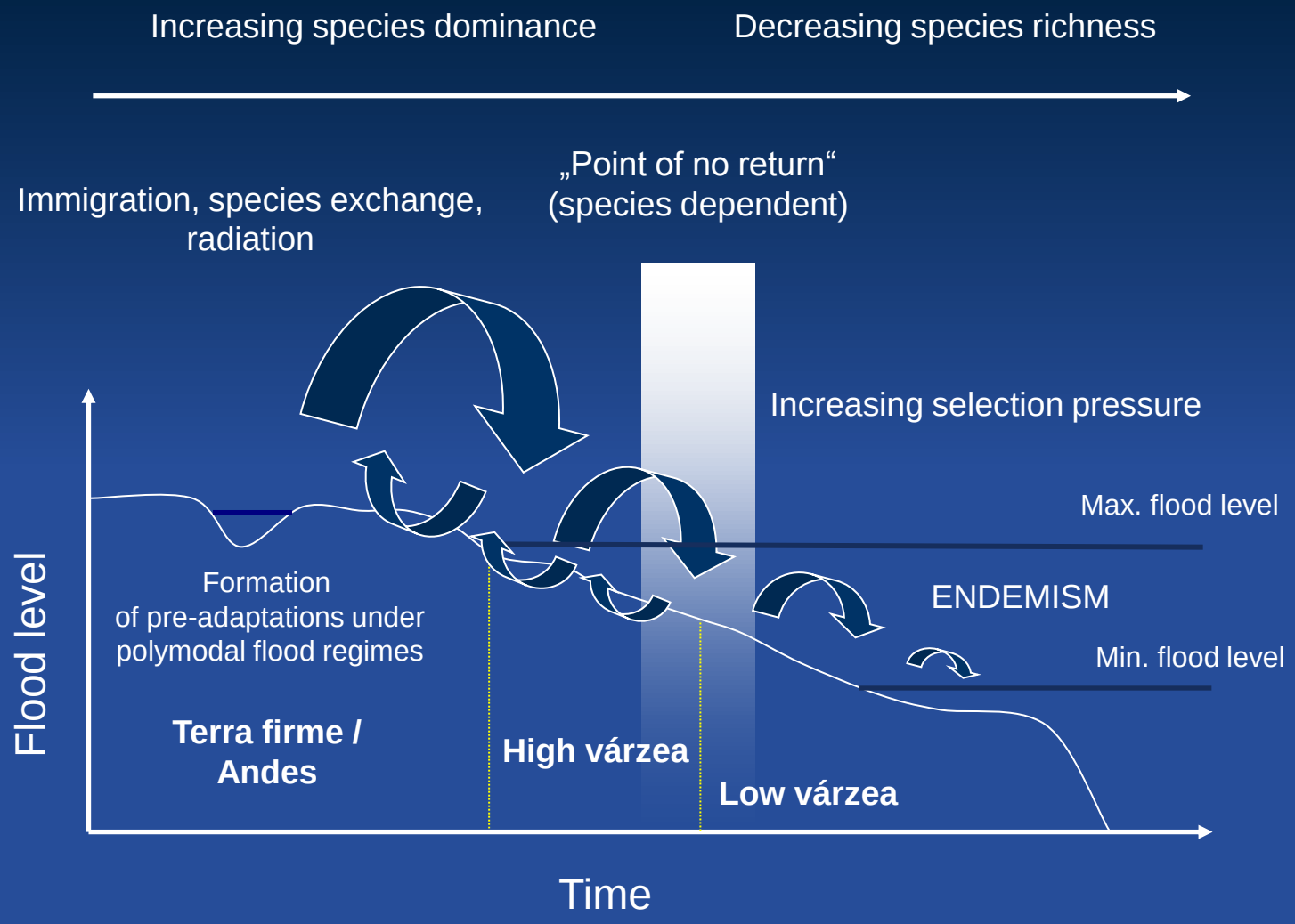


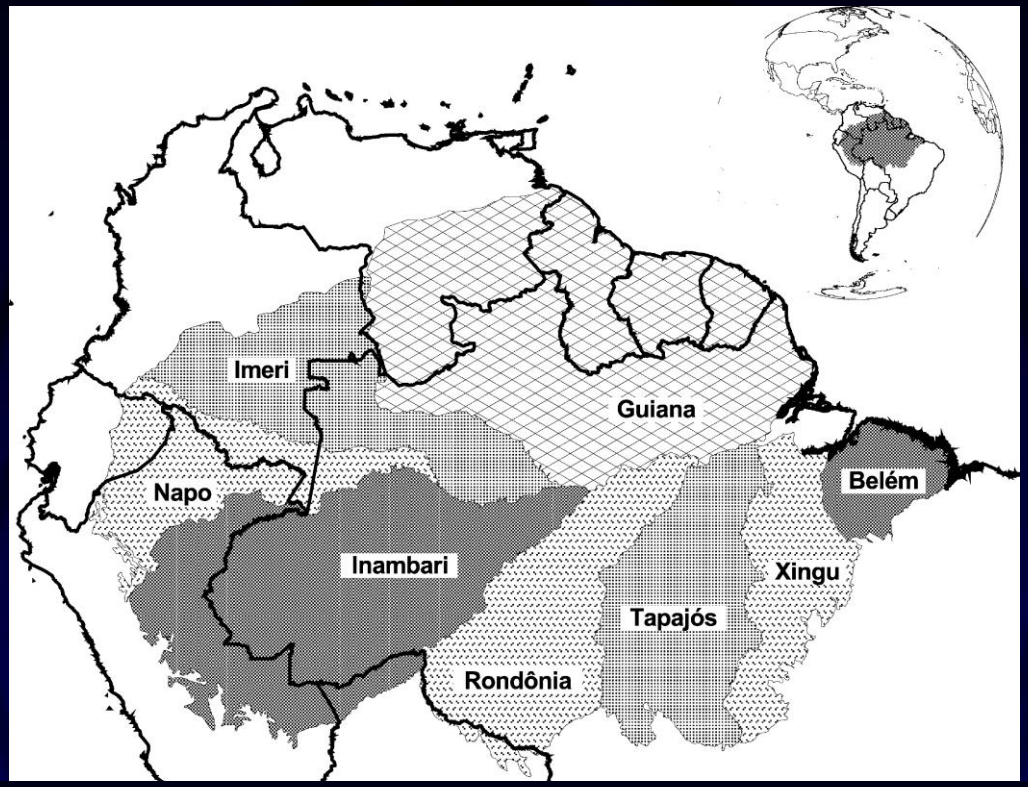
Tree species colonization concept in Amazonian Várzea floodplains



Wittmann *et al*. (2010): Springer , New York

Amazonian lowland areas of endemism

(developed on ranges of terrestrial organisms)



„For (terrestrial) animals, Rivers are important distribution barriers“

(Silva *et al*. 2005: *Conserv Biol* 19:689-964)

„For (terrestrial) tree species, Rivers are important areas of speciation, being one of the most prevalent adaptive gradients in the Amazon basin“

(Wittmann *et al*. In press: *Ecography*)

THANK YOU !