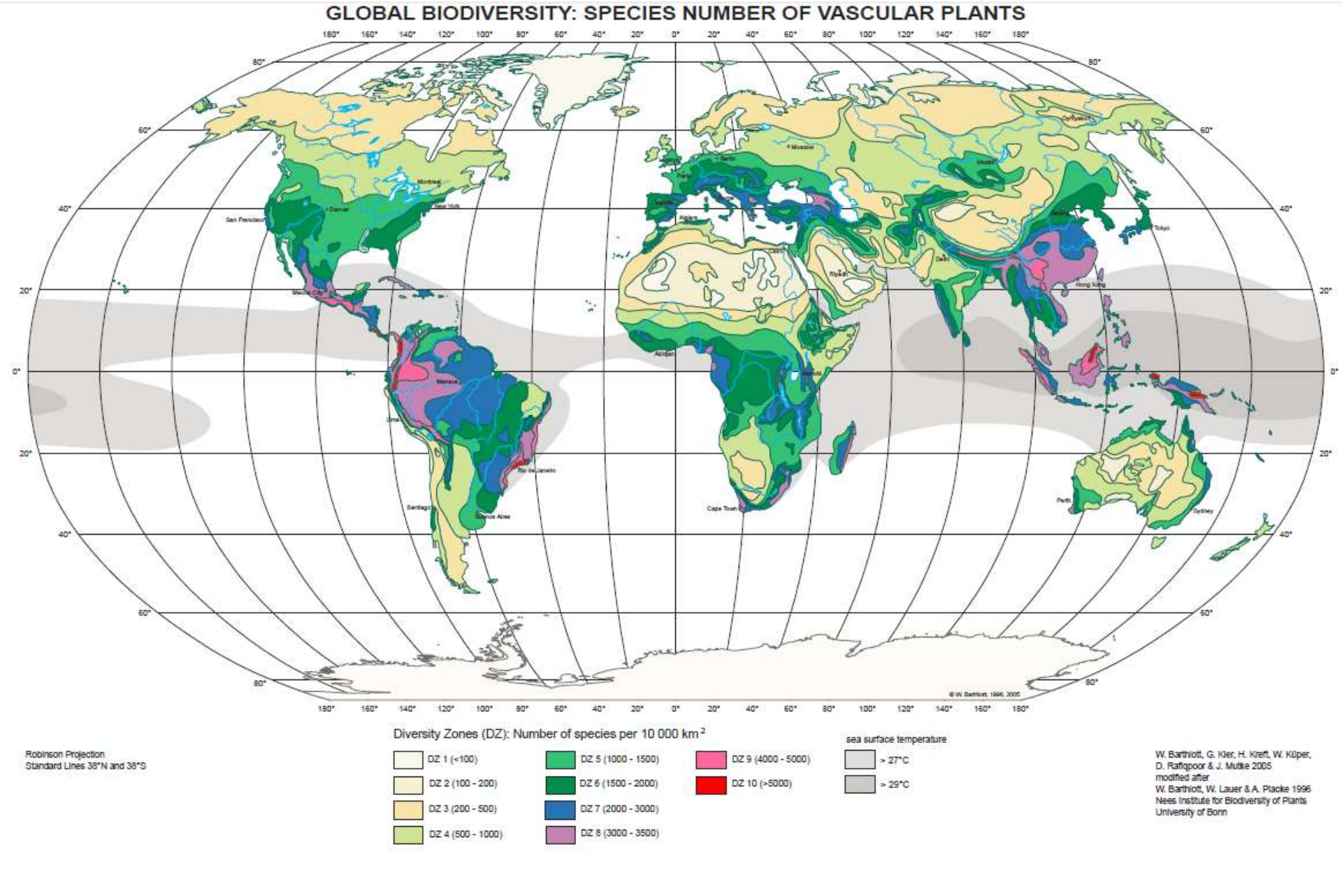
Forest floristics

Calamus exilis Blume – 1, part of a young stem with leaf-sheath and proximal part of the blade; 2, distal part of the leaf with cirrus; 3, proximal portion of the inflorescence; 4, fruit.

Species richness of vascular plants per 100 x 100 km quadrats



Five centers of plant megadiversity: all long altitudinal gradients in wet tropics

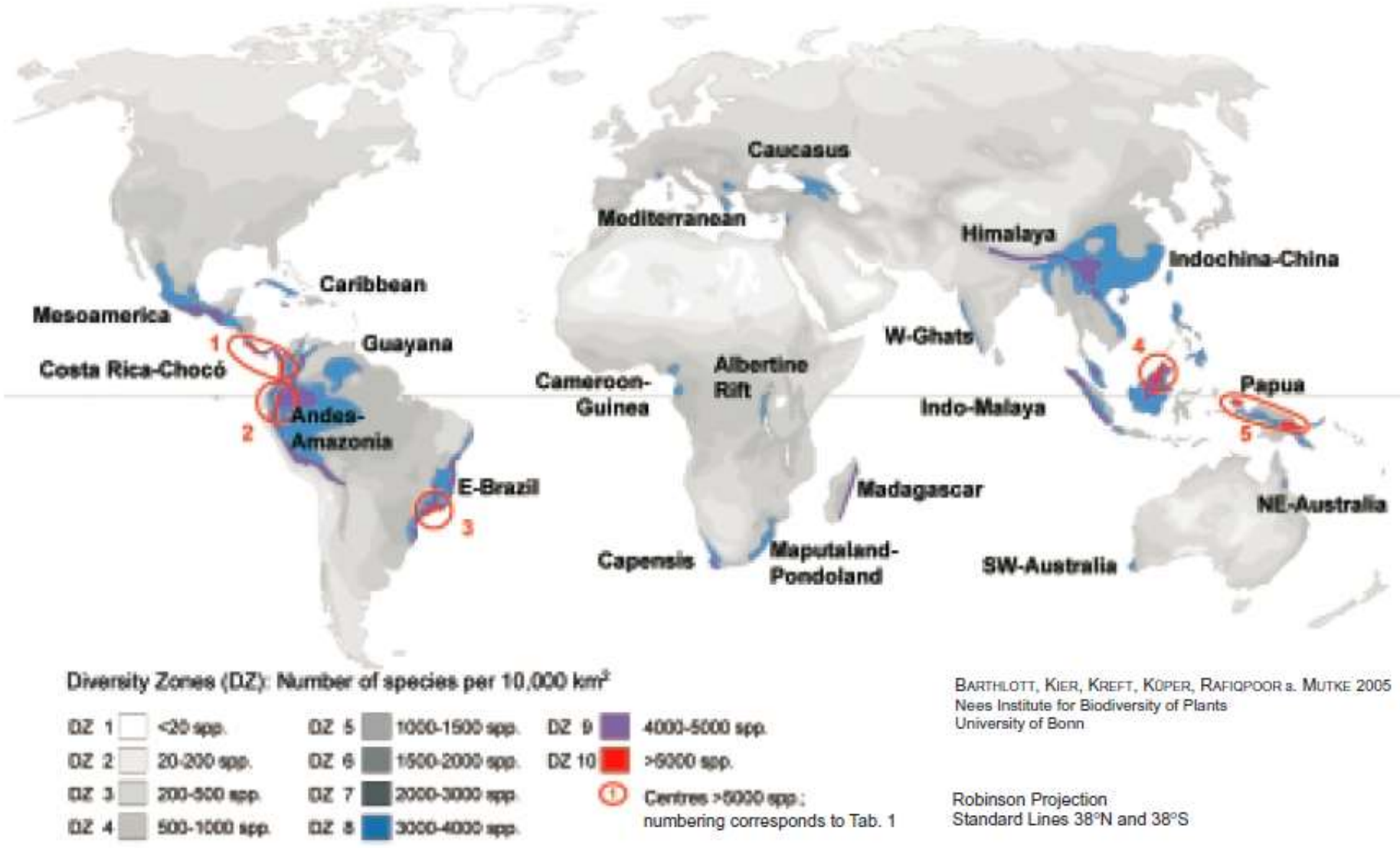


Fig. 2: Global centres of vascular plant diversity. The five centres of megadiversity are highlighted

Barthlott et al. 2007

Angiosperm families per 3,500 km^2 quadrats

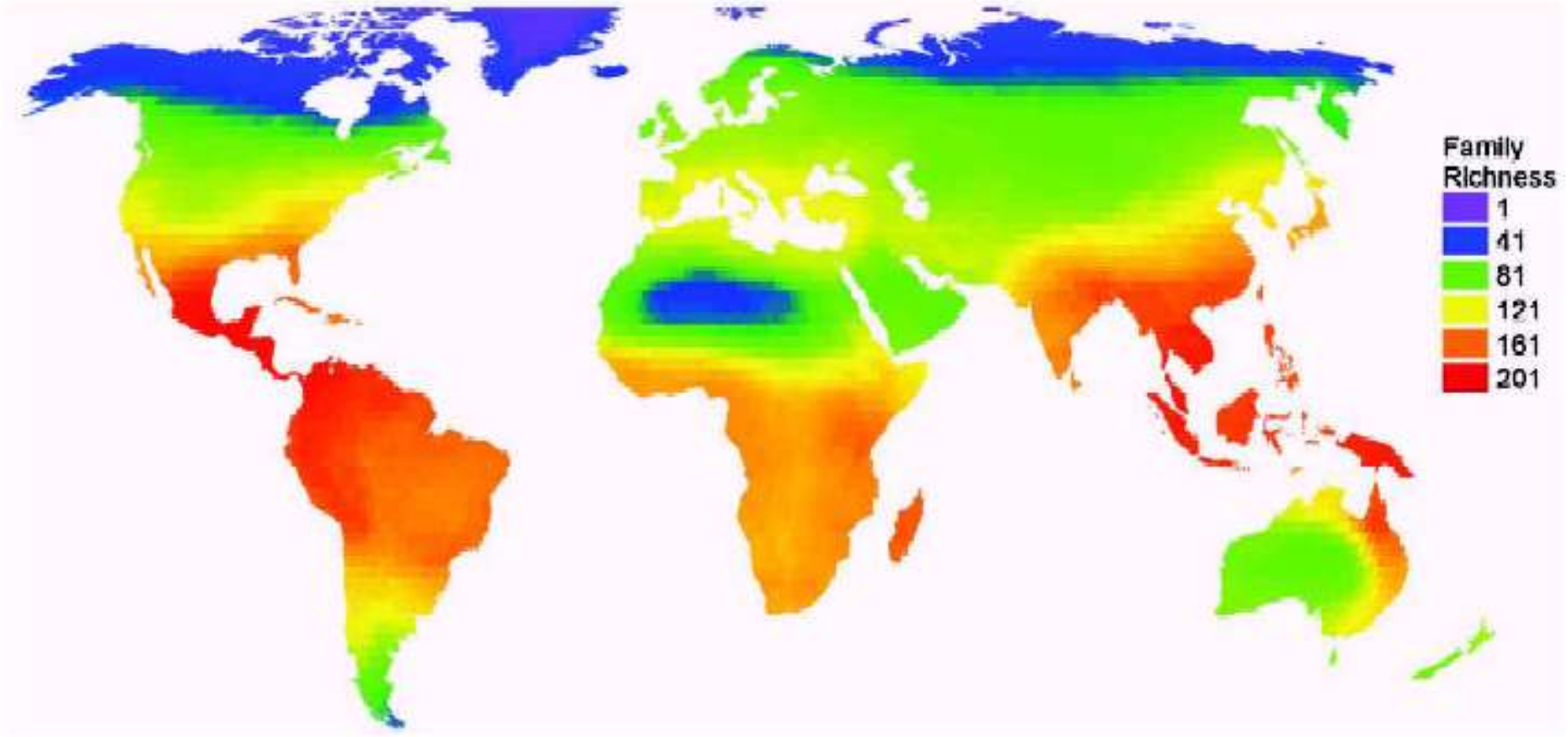
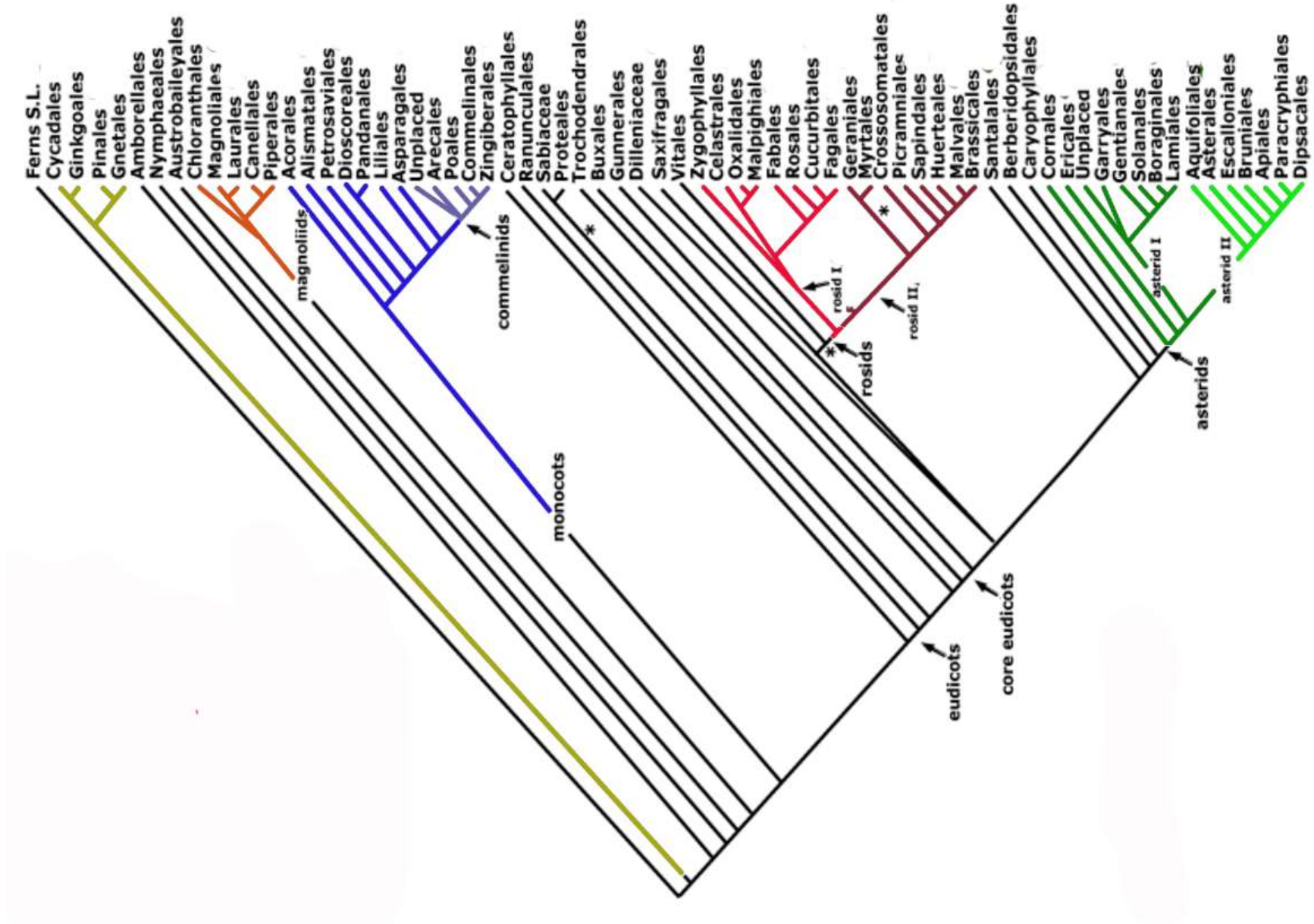


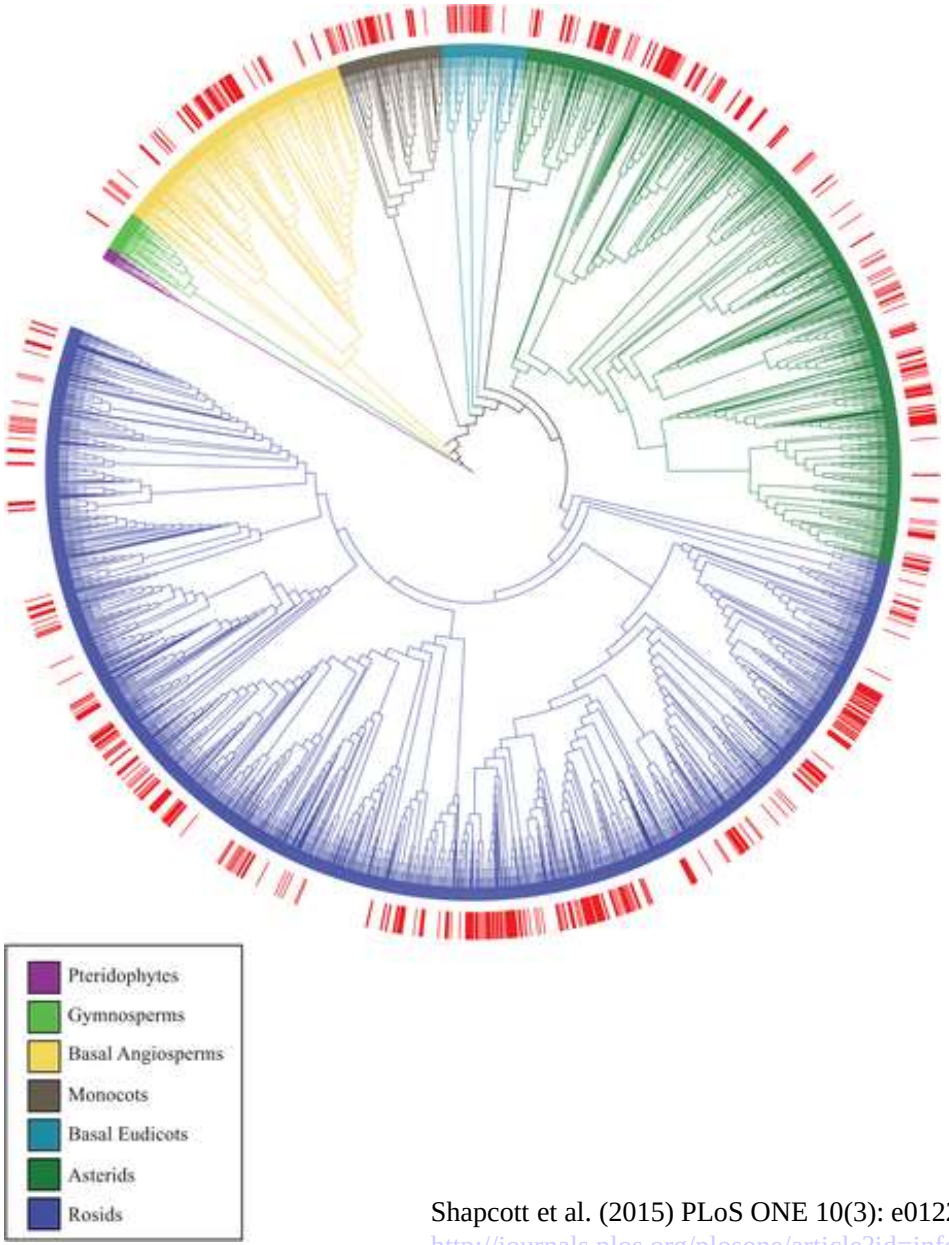
Figure 1: A map of the global variation in the number of angiosperm families per 3.5×10^4 km^2 quadrat, on the basis of Heywood's (1993) distribution maps.

Current plant phylogeny [Angiosperm Phylogeny Group]

www.mobot.org/mobot/research/APweb/

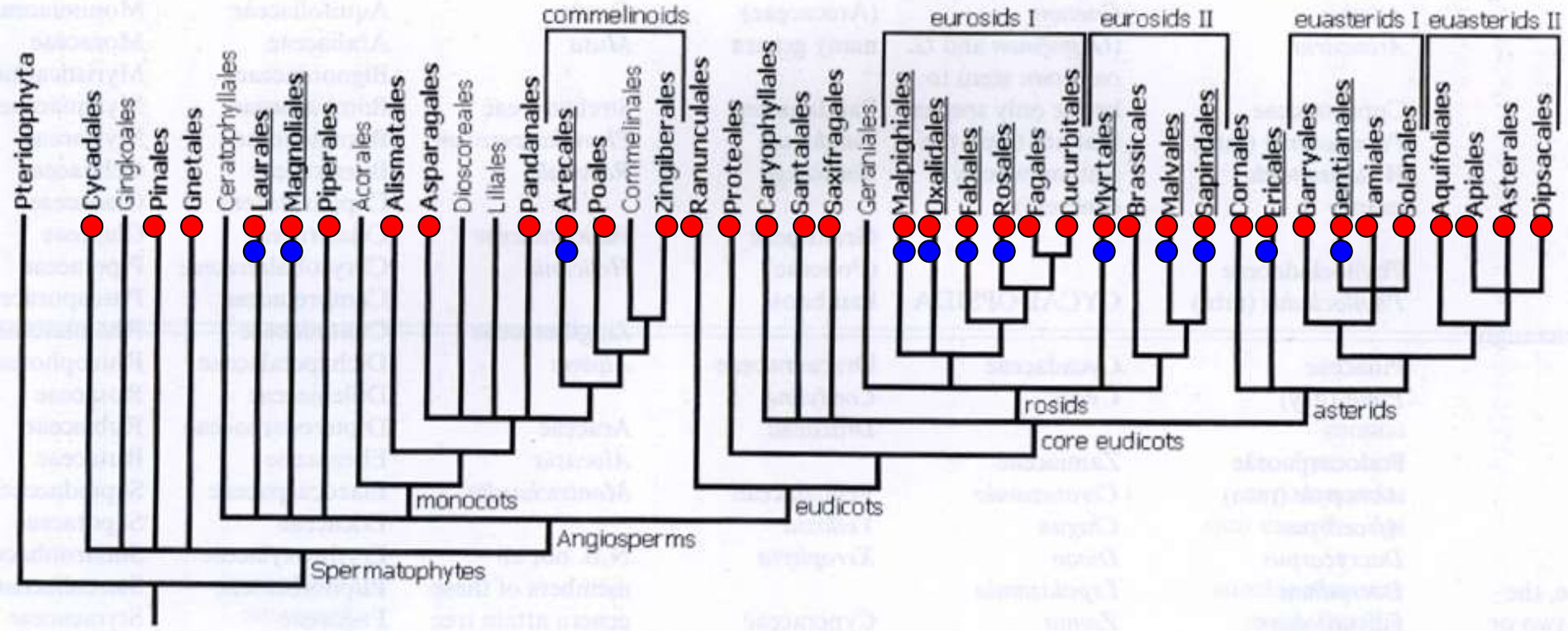


Phylogeny of the tropical rainforest flora in SE Queensland



Shapcott et al. (2015) PLoS ONE 10(3): e0122164. doi:10.1371/journal.pone.0122164
http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0122164

It is normal to be a tree



- taxa with tropical tree species
- taxa dominated by tropical tree species

There is ~40,000 - 53,000 tropical tree species

(trees defined as DBH>10cm)

Using a forest tree database of 657,630 trees from 11,371 species, Fisher's log-series alpha and total number of trees were estimated and used to extrapolate total species richness

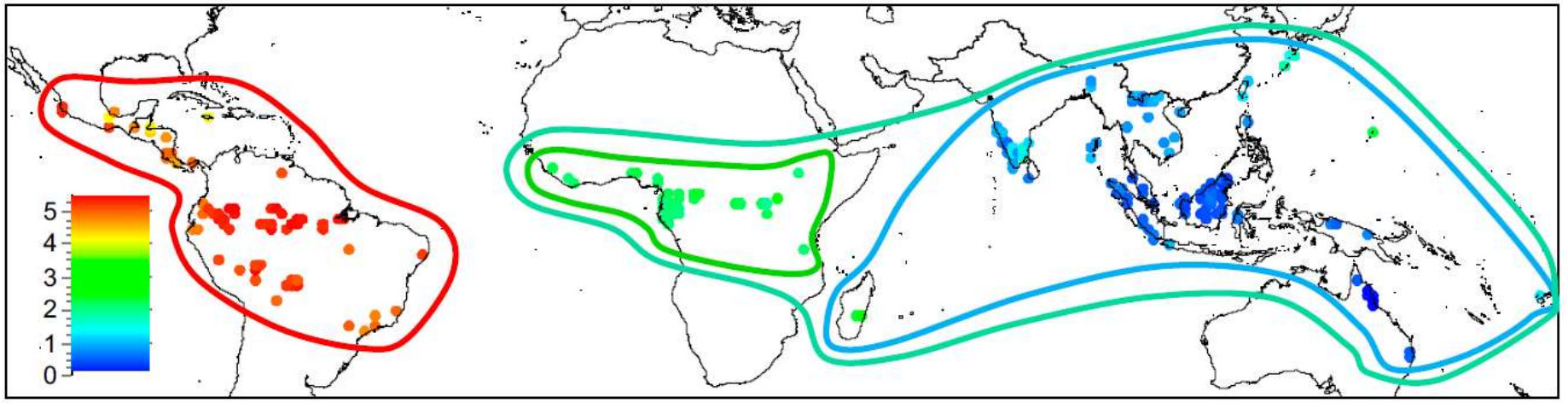
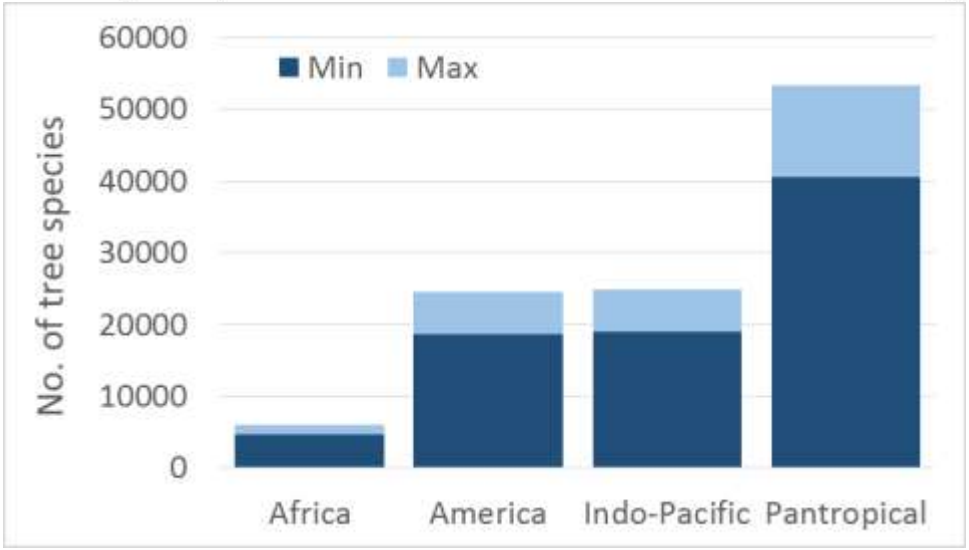


Fig. 1. Overview of sample locations and their floristic affinities (point colors correspond to scores on the first DCA axis with similar colors indicating similar generic composition, and the lines indicate the floristic affinities as determined by cluster analysis).

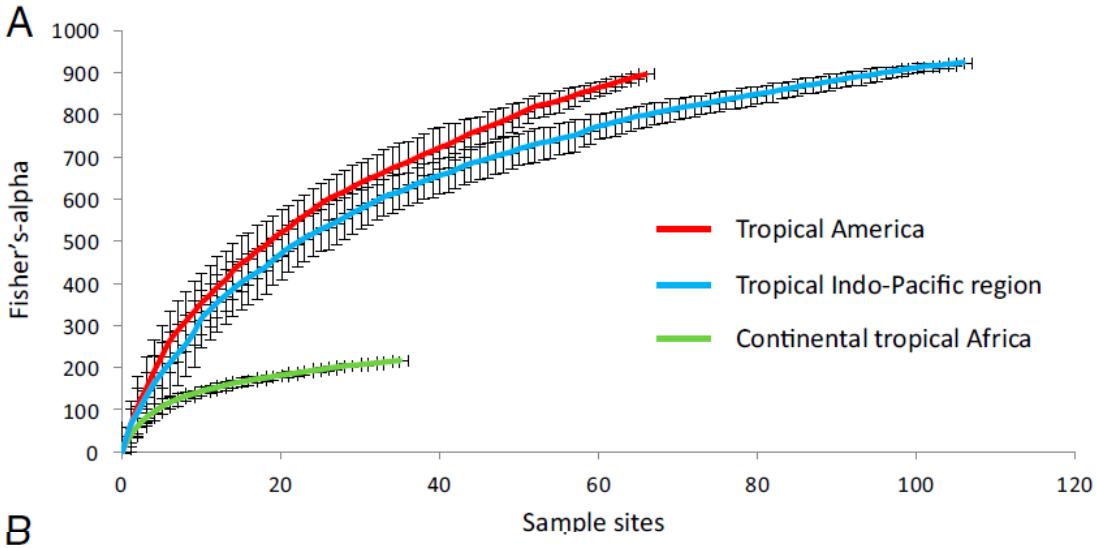


How many tropical forest tree species are there?

J. W. Ferry Slik[1], Victor Arroyo-Rodriguez[2], Shin-Ichiro Aiba[3], Patricia Alvarez-Loayza[4], Luciana F. Alves[5], Peter Ashton[6], Patricia Balvanera[7], Meredith Bastian[1], Peter J. Bellingham[8], Eduardo van den Berg[9], Luis Bernacci[5], Polyanna da Conceição Bispo[10], Lilian Blanc[11], Katrin Böhning-Gaese[12], Pascal Boeckx[13], Frans Bongers[14], Brad Boyle[15], Matt Bradford[16], Francis Q. Brearley[17], Mireille Breuer Ndoundou Hockemba[18], Sarayudh Bunyavejchewin[19], Darley Calderado Leal Matos[20], Miguel Castillo-Santiago[21], Eduardo L. M. Catharino[22], Shauna-Lee Chai[23], Yukai Chen[24], Robert K. Colwell[25,26], Robin L. Chazdon[25], Connie Clark[4], David B. Clark[27], Deborah A. Clark[27], Heike Culmsee[28], Kipiro Damas[29], Handanakere S. Dattaraja[30], Gilles Dauby[31], Priya Davidar[32], Saara J. DeWalt[33], Jean-Louis Doucet[34], Alvaro Duque[35], Giselda Durigan[36], Karl Eichhorn[37], Pedro V. Eisenlohr[38], Eduardo Eler[39], Corneille Ewango[18], Nina Farwig[40], Kenneth J. Feeley[41], Leandro Ferreira[22], Richard Field[42], Ary T. de Oliveira Filho[43], Christine Fletcher[44], Olle Forshed[45], Geraldo Franco[46], Gabriella Fredriksson[46], Thomas Gillespie[47], Jean-François Gillet[48], Giriraj Amarnath[49], Daniel M. Griffith[50], James Grogan[51], Nimal Gunatilleke[52], David Harris[53], Rhett Harrison[54,55], Andy Hector[56], Jürgen Homeier[28], Nobuo Imai[19], Akira Itoh[57], Patrick A. Jansen[58,59], Carlos A. Joly[60], Bernardus H.J. de Jong[61], Kuswata Kartawinata[62], Elizabeth Kearsley[13], Daniel L. Kelly[63], David Kenfack[64], Michael Kessler[65], Kanehiro Kitayama[66], Robert Kooyman[67], Eileen Larney[68], Yves Laumonier[69], Susan Laurance[70], William Laurance[70], Michael J. Lawes[58], Ieda Leao do Amaral[36], Susan G. Letcher[71], Jeremy Lindsell[72], Xinghui Lu[73], Asyraf Mansor[27], Antti Marjokorpi[74], Emanuel H. Martin[75,76], Henrik Meilby[77], Felipe P. L. Melo[78], Dan Metcalfe[79], Vincent P. Medjibe[4], Jean Paul Metzger[80], Jerome Millet[81], D. Mohandass[82], Juan Carlos Montero[83], Márcio de Morisson Valeriano[84], Badru Mugerwa[85], Hidetoshi Nagamasu[86], Rueben Nilus[87], Susana Ochoa-Gaona[13], Onrizal[88], Navendu Page[89], Pia Parolin[90], Marc Parren[14], Narayanaswamy Parthasarathy[91], Ekananda Paudel[92], Andrea Permana[93], Maria T. F. Piedade[38], Nigel Pitman[94], Lourens Poorter[14], Axel Poulsen[95], John Poulsen[4], Jennifer Powers[96], Rama Chandra Prasad[97], Jean-Philippe Puyravaud[98], Jean-Claude Razafimahaimodison[99], Jan Reitsma[100], João Roberto dos Santos[38], Wilson Roberto Spironello[38], Hugo Romero-Saltos[101], Francesco Rovero[102], Andes Rozak[92], Kalle Ruokolainen[103], Ervan Rutishauser[27], Felipe Saiter[104], Philippe Saner[41], Braulio A. Santos[105], Fernanda Santos[36], Swapan Kumar Sarker[106], Manicharin Satdichanh[32], Christine B. Schmitt[107], Jochen Schöngart[108], Mark Schulze[109], Marcio Seiji Suganuma[38], Douglas Sheil[27,110], Eduardo da Silva Pinheiro[111], Plinio Sist[104], Tariq Stevart[107], Raman Sukumar[30], Fang Sun[106], Terry Sunderland[27], H.S. Suresh[30], Eizi Suzuki[3], Marcelo Tabarelli[78], Jangwei Tang[82], Natália Targhetta[112], Ida Theilade[77], Duncan W. Thomas[109], Peguy Tchouto[113], Johanna Hurtado[111], Renato Valencia[112], Johan van Valkenburg[114], Tran Van Do[114], Rodolfo Vasquez[100], Hans Verbeeck[13], Victor Adekunle[115], Simone A. Vieira[36], Campbell Webb[116], Timothy Whitfeld[117], Serge Wich[118,119], John Williams[120], Florian Wittmann[121], Hannsjoerg Woll[122], Xiaobo Yang[123], C. Yves Adou Yao[124], Sandra Yap[125], Tsuyoshi Yoneda[3], Rakan A. Zahawi[111], Rahmad Zakaria[13], Runguo Zang[17]

Slik et al. PNAS 2015 An estimate of the number of tropical tree species

Diversity increase with the number of sample sites and the geographical extent of sites included



Fisher's-alpha values can be used to extrapolate species richness of a defined region if the number of individuals is known.

Fisher's log-series

$$S = \alpha \ln\left(1 + \frac{N}{\alpha}\right)$$

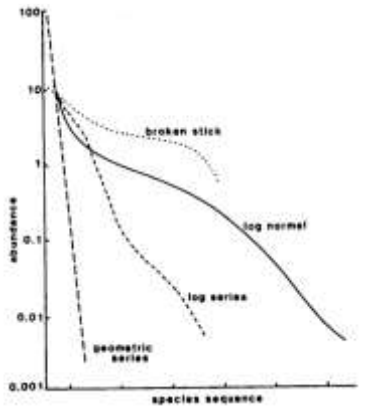
S = the number of species
N = the number of individuals
α = a constant derived from the data

$$S_n = \frac{\alpha x^n}{n}$$

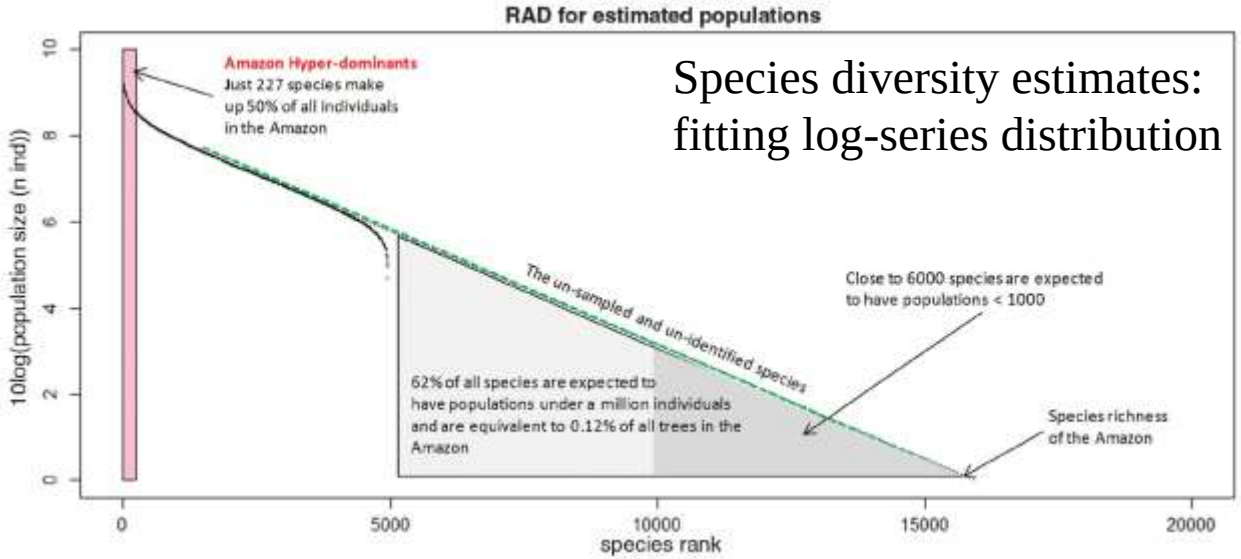
S_n = the number of species with abundance n
x = a constant ($0 < x < 1$) derived from the data

The number of species with 1, 2, 3, … , n individuals:

$$\alpha, \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \ldots, \frac{\alpha x^n}{n}$$

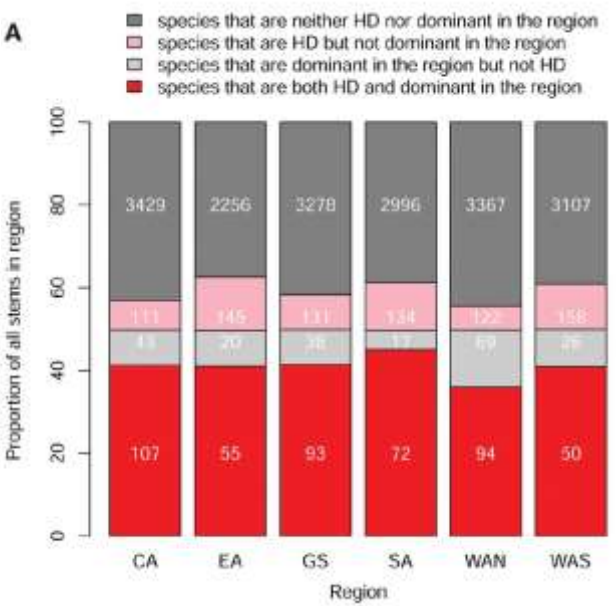


Slik et al. PNAS 2015 An estimate of the number of tropical tree species



Species diversity estimates: fitting log-series distribution

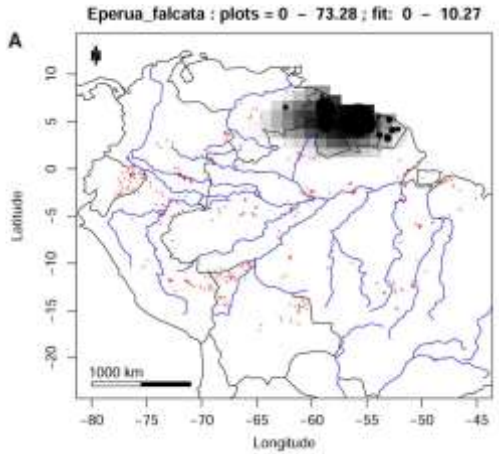
% of stems from species that are/are not hyper-dominant (HD) and/or regionally dominant



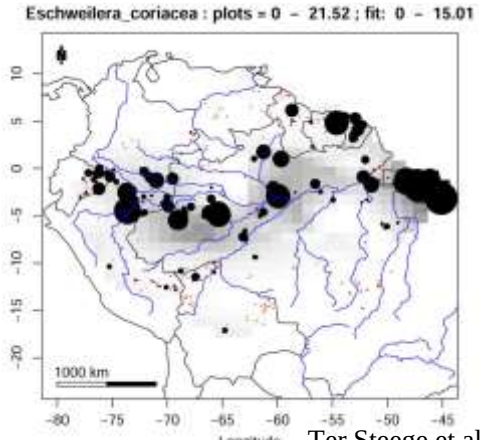
Regions – see the map on the left

Plots on terra firme; seasonally or permanently flooded terrain (várzea, igapó, swamps); white-sand podzols

Examples of species distributions:



E. falcata, 13th in abundance, with an eastern distribution



E. coriacea, 3rd in abundance, with a pan-Amazonian distribution.

Ter Steege et al. 2013, Science 342, 10.1126/science.1243092

Pleutorhallis
Neotropical
4,000 spp.

Bulbophyllum
Palaeotropics
4,000 spp.

Epidendrum
Neotropics
1,000 spp.

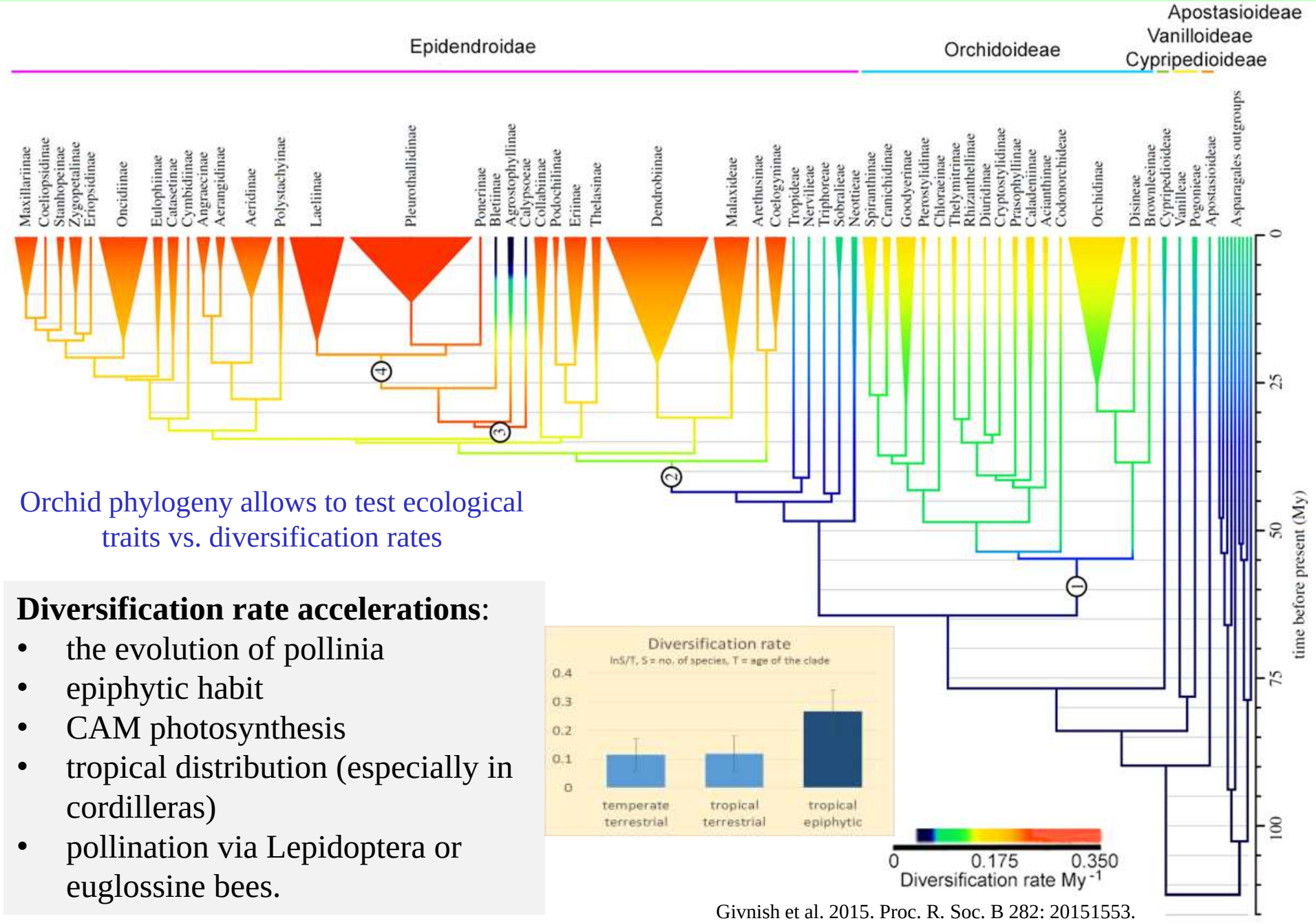
Dendrobium
Palaeotropics
1,000 spp.

The largest plant families:

1. Orchidaceae 18,500 spp.
2. Rubiaceae: 10,200 spp.
3. Melastomataceae 5,000 spp.

Orchids: half of diversity in four large, tropical and epiphytic genera

Why are there so many species of orchids?



Orchid phylogeny allows to test ecological traits vs. diversification rates

Diversification rate accelerations:

- the evolution of pollinia
- epiphytic habit
- CAM photosynthesis
- tropical distribution (especially in cordilleras)
- pollination via Lepidoptera or euglossine bees.

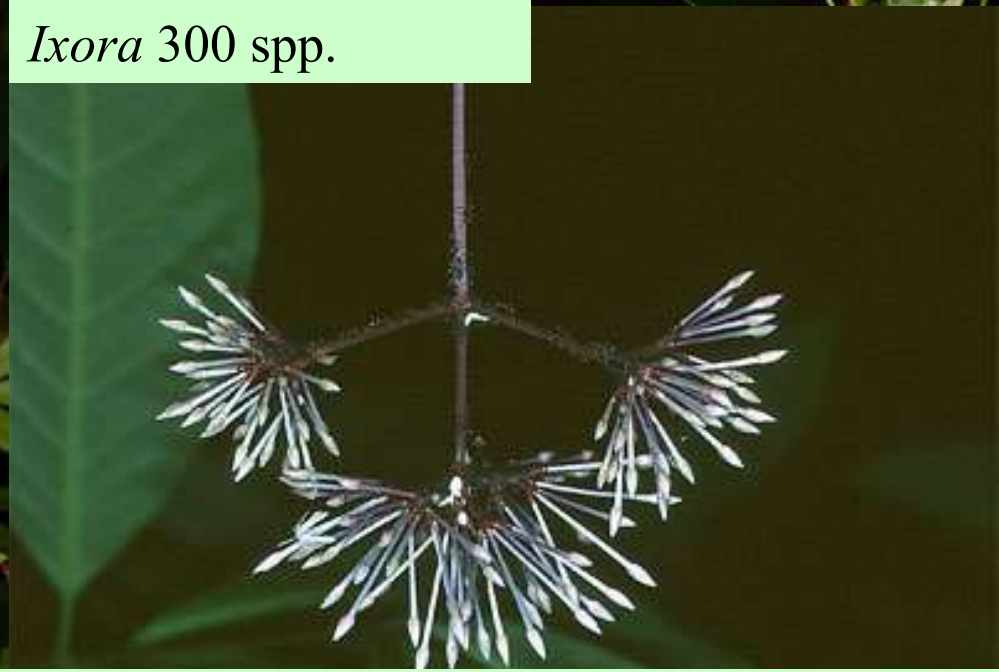
Givnish et al. 2015. Proc. R. Soc. B 282: 20151553.

Psychotria 1500 spp.

Pavetta 400 spp.

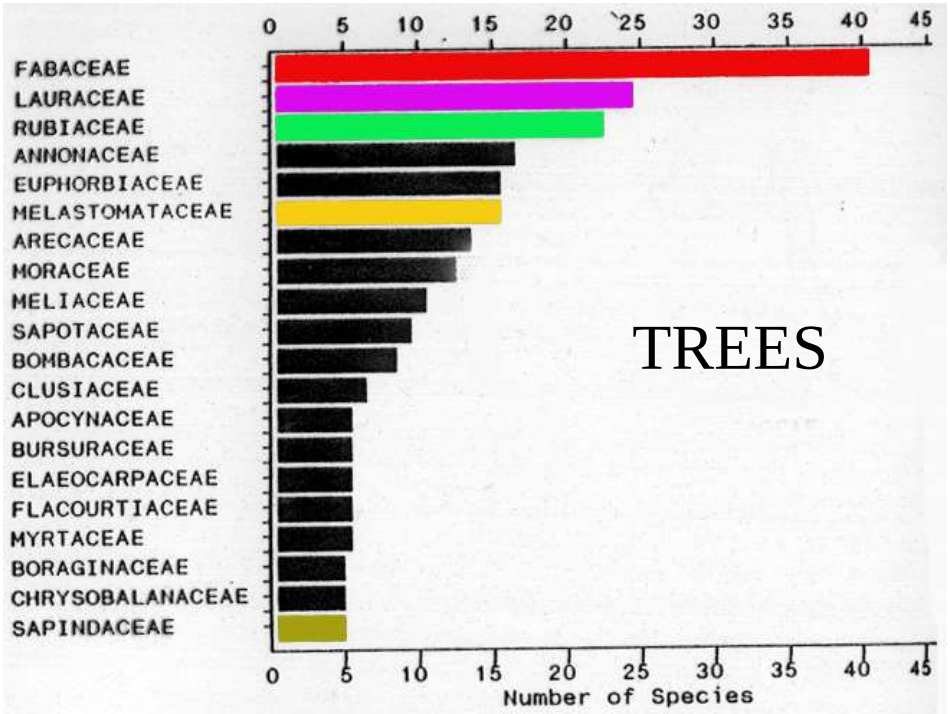
Galium 300 spp.

Ixora 300 spp.

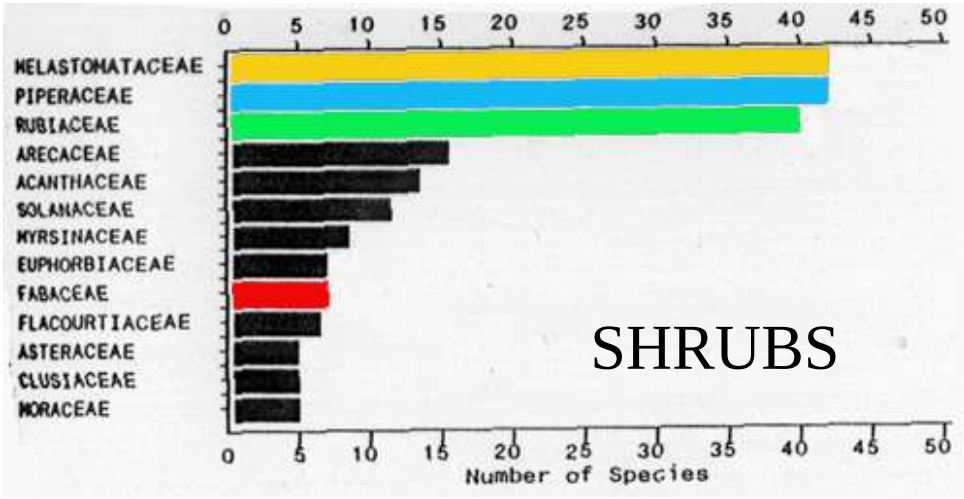


Four largest genera of Rubiaceae, (3 tropical shrubs, 1 temperate herbs)

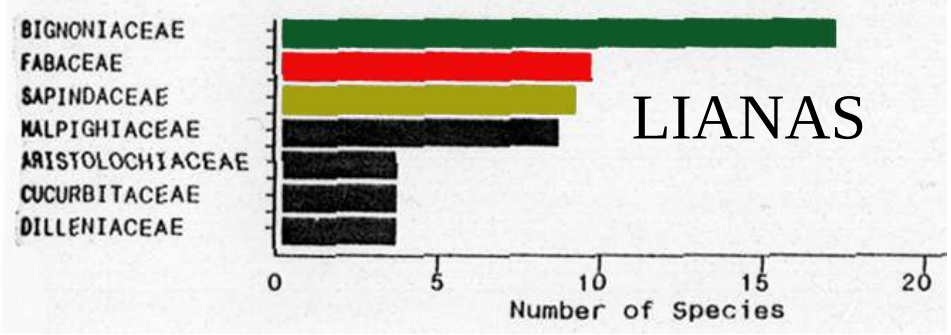
La Selva lowland rainforest (Costa Rica) dominant plant families



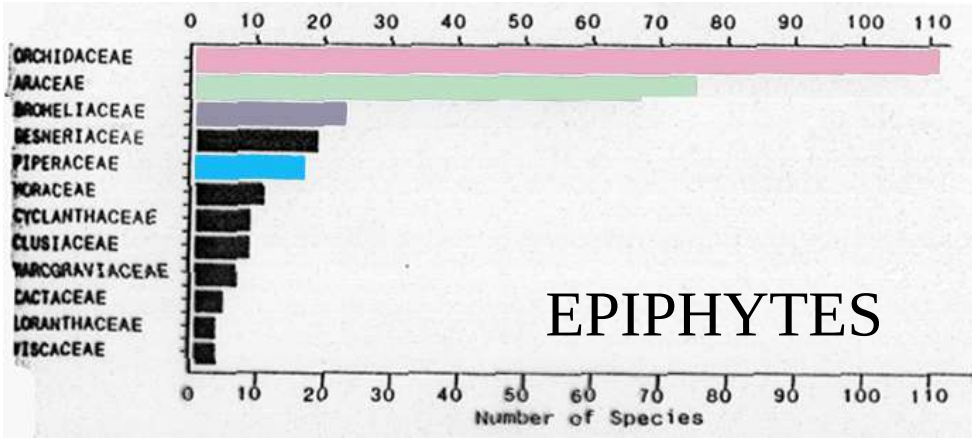
TREES



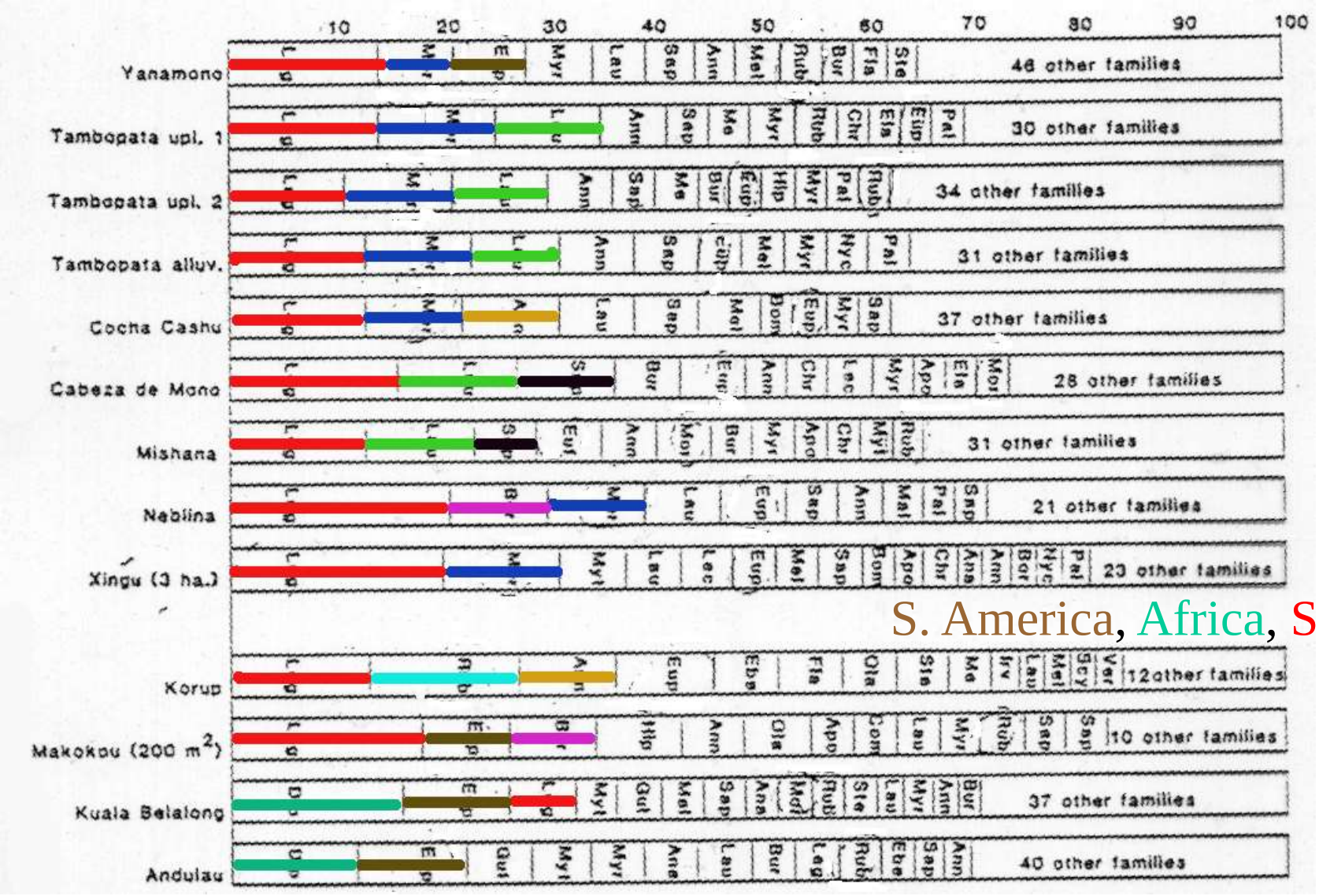
SHRUBS



LIANAS



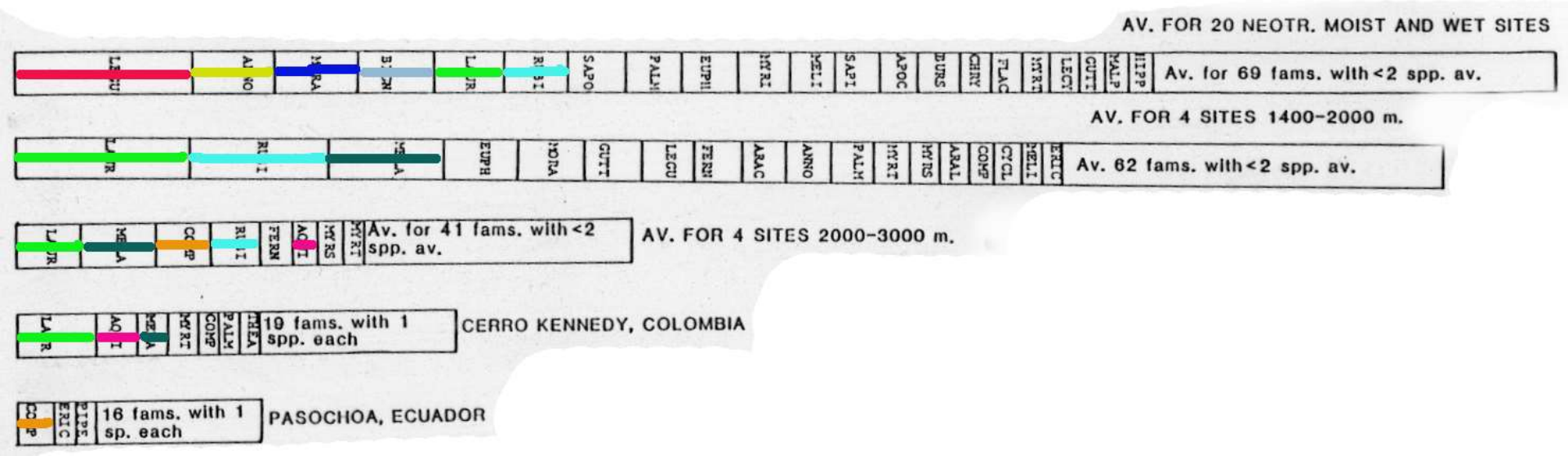
EPIPHYTES



Fabaceae, Moraceae, Lauraceae, Dipterocarpaceae, Euphorbiaceae, Annonaceae, Burseraceae, Sapindaceae, Rubiaceae

Dominant plant families of trees in lowland rainforests (DBH>10cm)

Dominant plant families along a Neotropical altitudinal gradient



Fabaceae, Moraceae, Lauraceae, Compositeae, Aquifoliaceae, Rubiaceae, Annonaceae, Melastomataceae, Bignoniaceae

TABLE 9.2 Largest genera of vascular plants, including weeds, in local florulas

Rio Palenque[1]	N	La Selva[2]	N	BCI[3]	N	Cocha Cashu[4]	N	Manaus (Ducke)[5]	N
Piper	22	Piper	44	Piper	21	Ficus	34	Licania	21
Ficus	18	Psychotria	38	Psychotria	20	Inga	26	Inga	17
Solanum	18	Philodendron	31	Inga	18	Piper	25	Protium	14
Peperomia	15	Anthurium	25	Ficus	16	Pouteria	21	Eschweilera	13
Philodendron	15	Miconia	25	Miconia	14	Paullinia	19	Swartzia	13

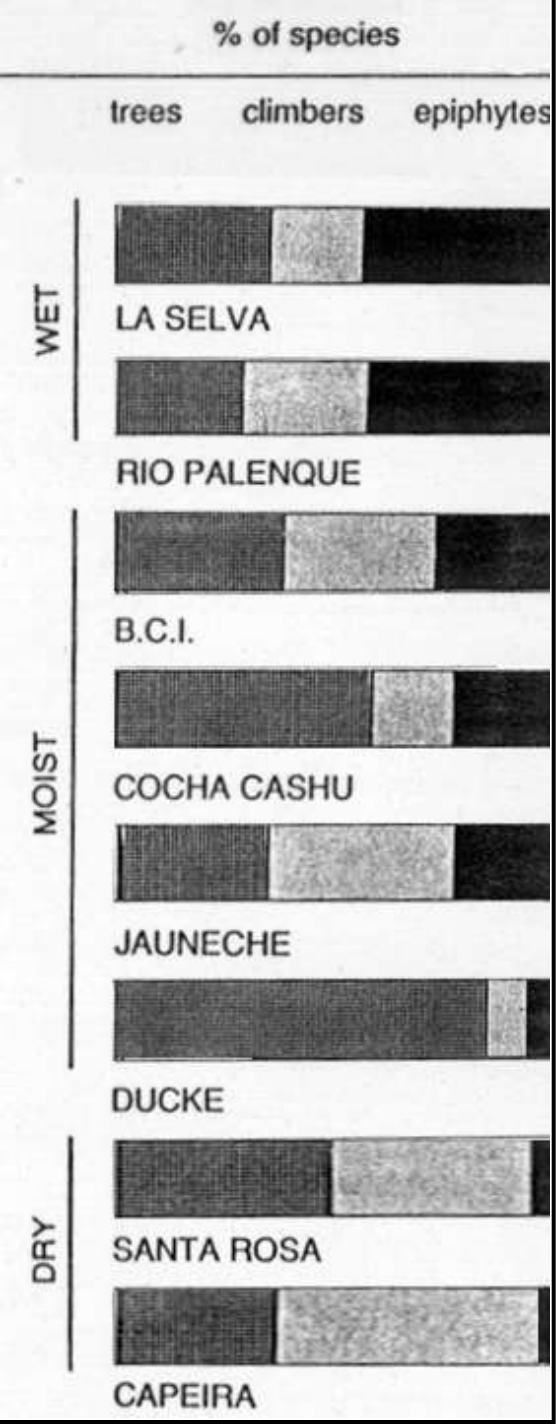

Ficus


Piper


Psychotria

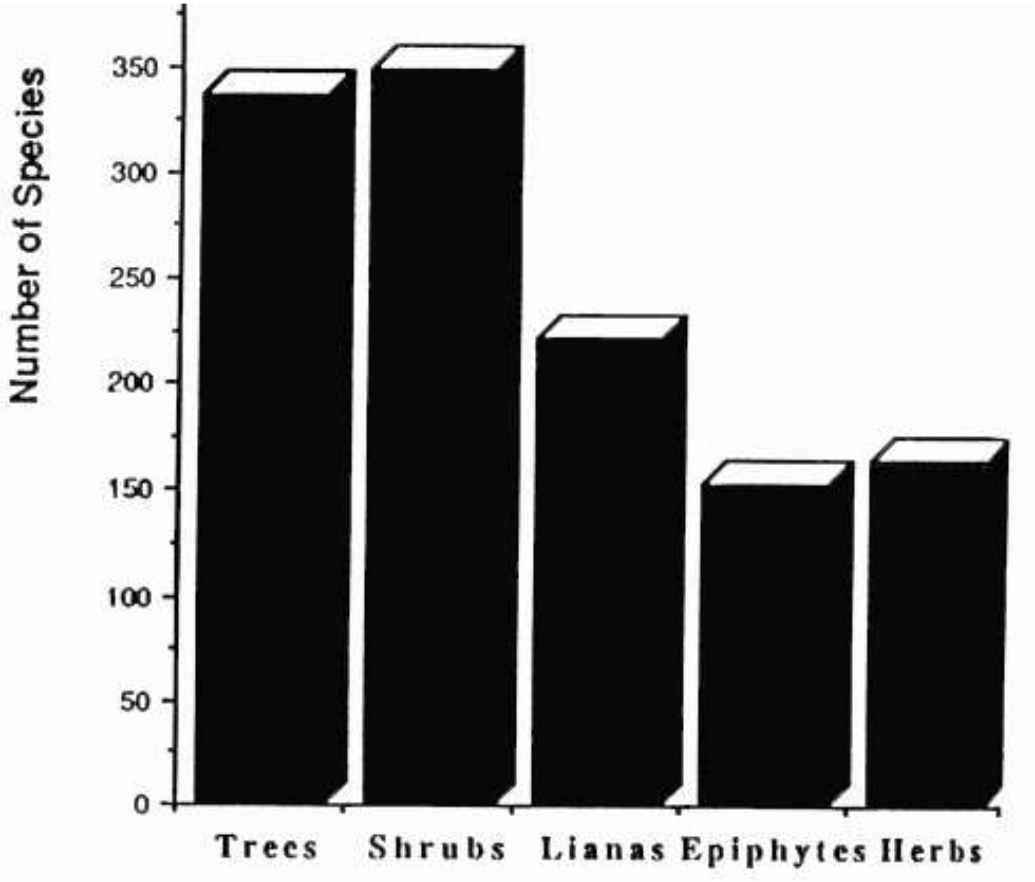
Inga


Licania

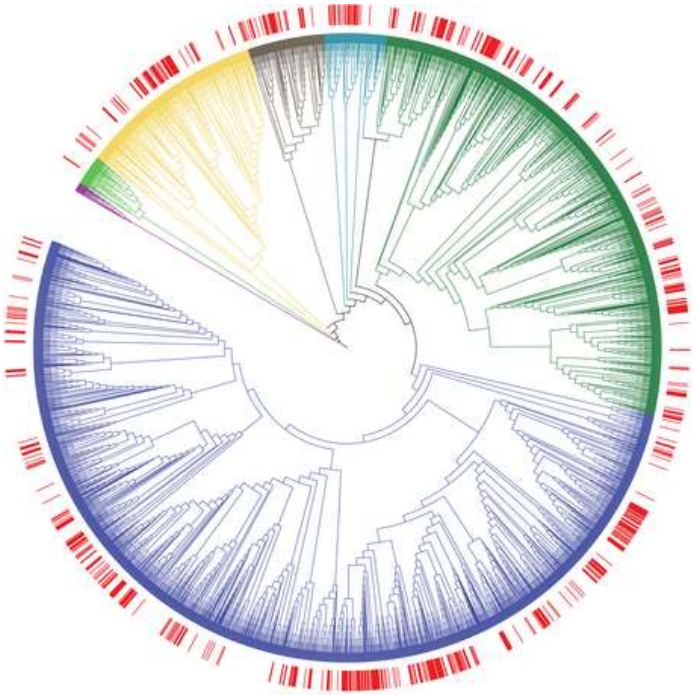


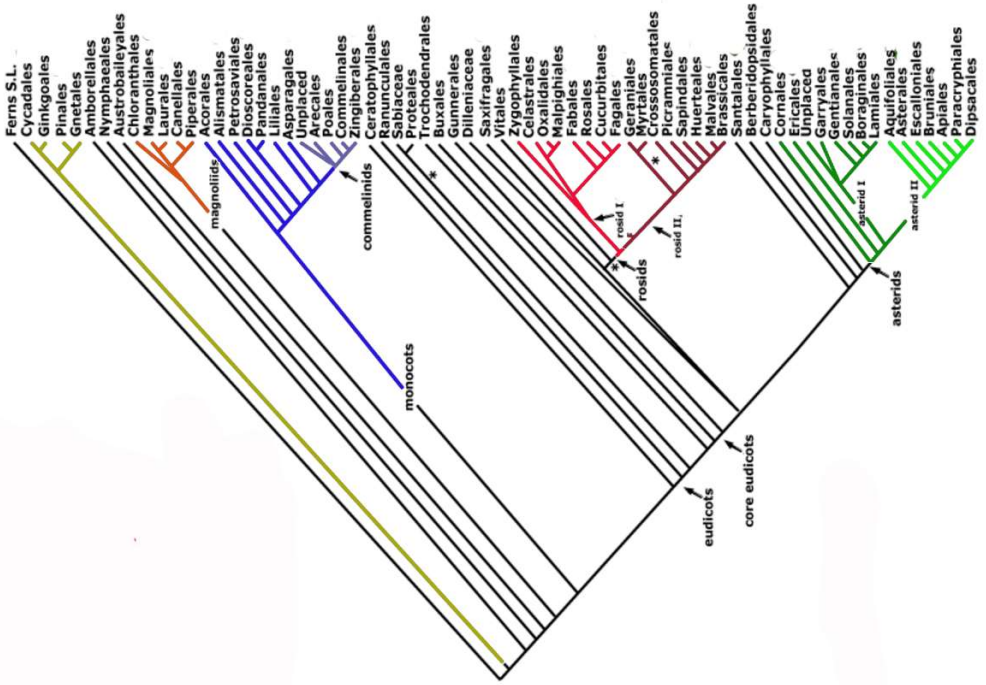
Growth form representation in local florulas along rainfall gradient

Growth form diversities in the Manu lowland rainforest



A quick tour of plant taxonomic diversity in the tropics





Gymnosperms:
Cycadales
Gnetales
Pinales
[Ginkgoales]

Cycas rumphii

Gnetum gnemon

Photo J Leps

Gymnosperms: diversity hotspot at the Himalayan foothills, followed by the US East Coast and New Guinea

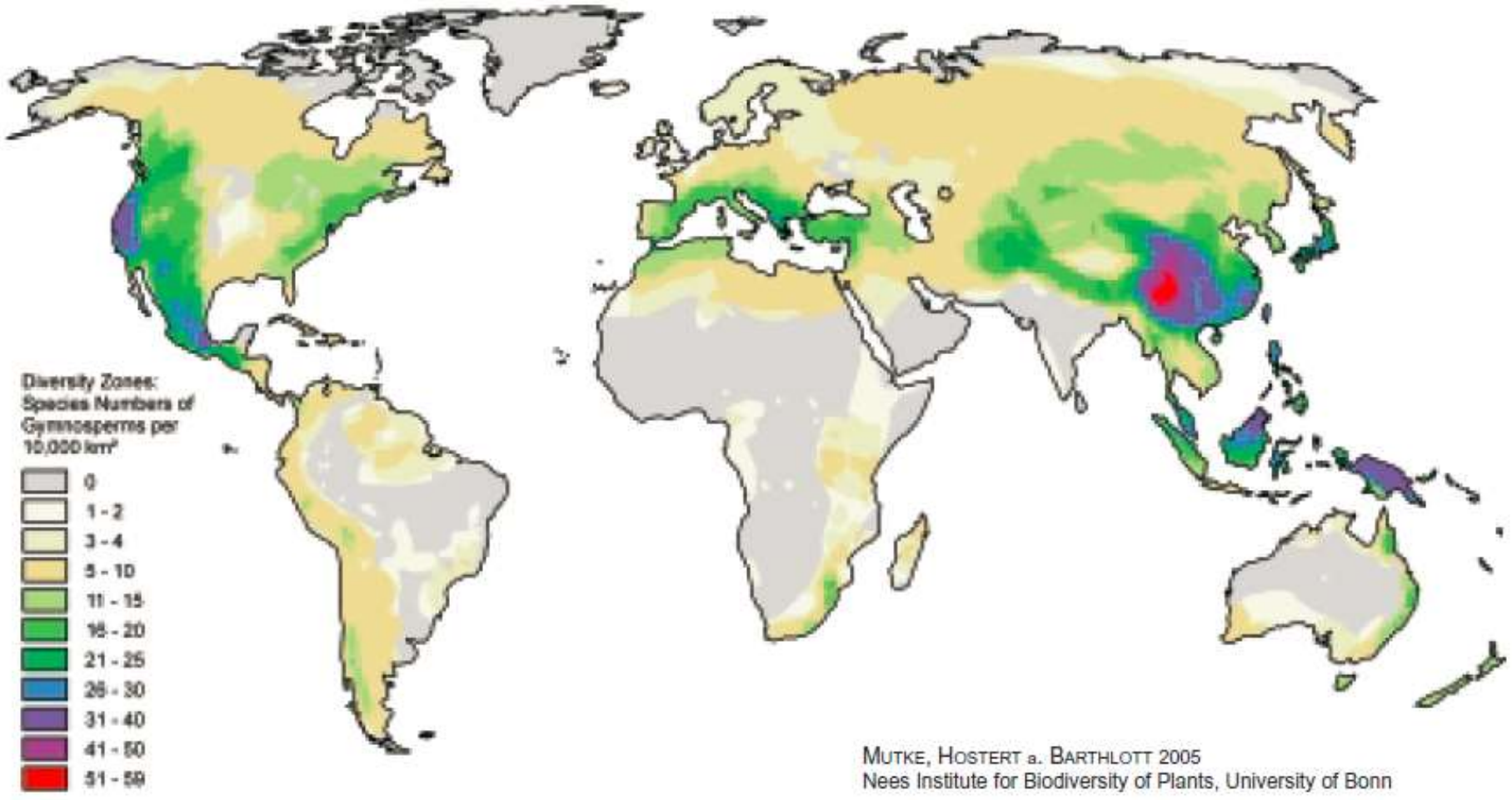


Fig. 3: Global map of gymnosperm diversity based on the distributional ranges of 862 species (number of species per 10,000 km^2)

Pinales: tropical conifers

Pinaceae: Pinus
Araucariaceae: Araucaria, Agathis
Podocarpaceae: Podocarpus

Araucaria

Podocarpus

Agathis (Araucariaceae) New Guinea

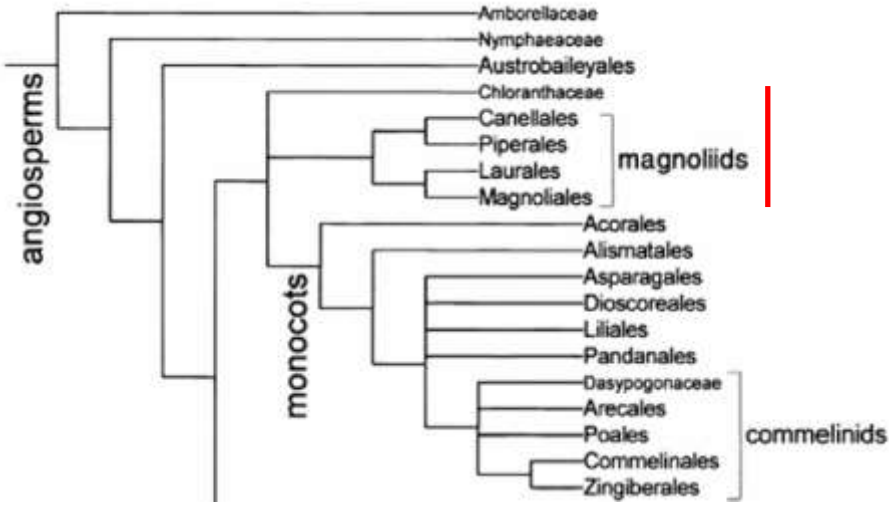
Pinus caribaea, Bahamas

Pinus merkusii

Pinus:
often used for tropical plantations

Photo Tim Block

Agathis (Araucariaceae) New Guinea



Magnoliids: the monocots' sisters

Piperales: Piperaceae

Laurales: Lauraceae, Monimiaceae

Magnoliales: Annonaceae, Eupomatiaceae, Myristicaceae

Piper

APG 2003

Piperales: Piperaceae
Laurales: Lauraceae, Monimiaceae
Magnoliales: Magnolicaeae, Eupomatiaceae, Myristicaceae

Kibara, Monimiaceae

Litsea, Lauraceae

Photo M. Janda

Annonaceae: a pantropical family

Polyalthia

Photo M. Janda

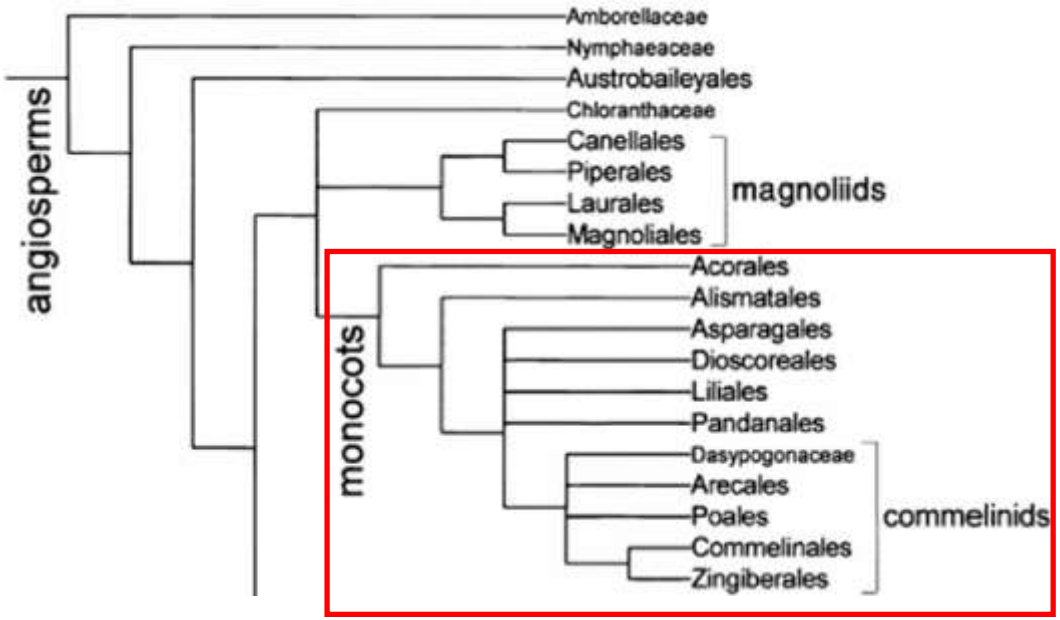
Popowia

Annona squamosa


Annonaceae
Annona


Desmopsis


COPYRIGHT 2000
MONIQUE REED
Annona



An epiphyte of the orchid family

Monocots:

Alismatales: Araceae

Asparagales: Orchidaceae, Agavaceae

Pandanales: Pandanaceae

Arecales: Arecaceae

Poales: Poaceae, Bromeliaceae

Commelinales: Commelinaceae

Zingiberales: Zingiberaceae Maranthaceae, Heliconiaceae, Musaceae

Pleutorhallis
Neotropical
4,000 spp.

Bulbophyllum
Palaeotropics
4,000 spp.

Epidendrum
Neotropics
1,000 spp.

Dendrobium
Palaeotropics
1,000 spp.

Orchidaceae: largest plant family, 20,000 species

Agavaceae, Yucca

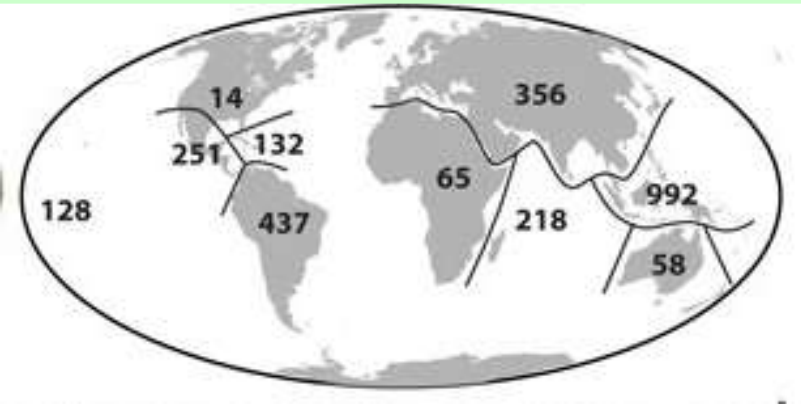
Araceae, Amorphophallus

Pothos

Photo M. Janda

Pandanaceae (Palaeotropics) & Cyclanthaceae (Neotropics) sister families

Arecaceae: palms [diversity max SE Asian islands & New Guinea, min in Africa]



Elaeis

Areca

Caryota

Climbing palms – rattans, Calamus
Mostly SE Asia

Poaceae, Imperata

Bromelias: a distinct feature of Neotropical forests

Bromeliaceae, Ananas

Bromeliaceae, Tillandsia

Photo M. Janda

Commelinaceae, Commelina

Photo M. Janda

Zingiber officinale ROSC.
©Thomas Schoepke

Zingiberaceae, Alpinia

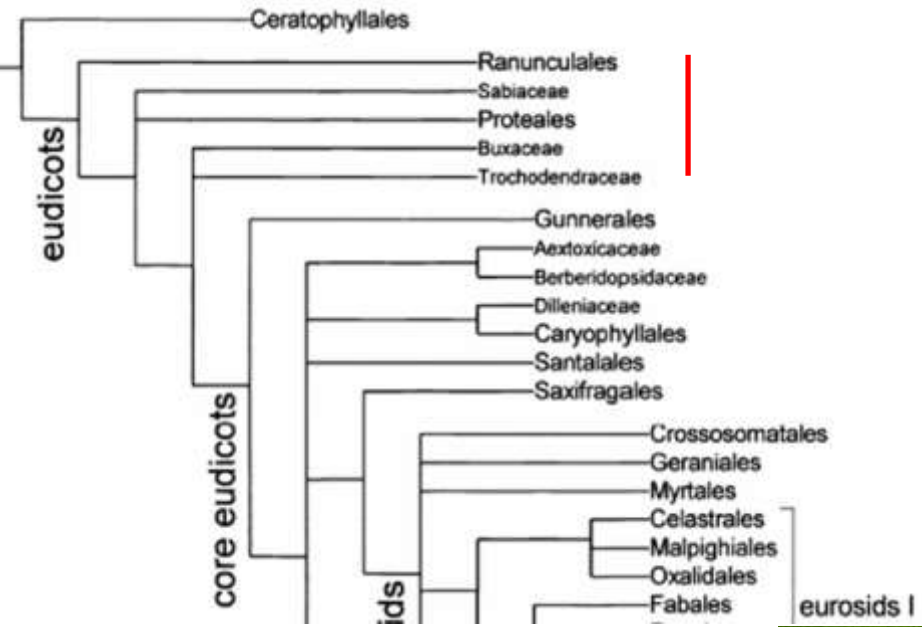
Maranthaceae, Calathea

Heliconiaceae, Heliconia

[mostly Neotropical, pollinated by hummingbirds, in SE Asia pollinated by bats]

Musa, Musaceae

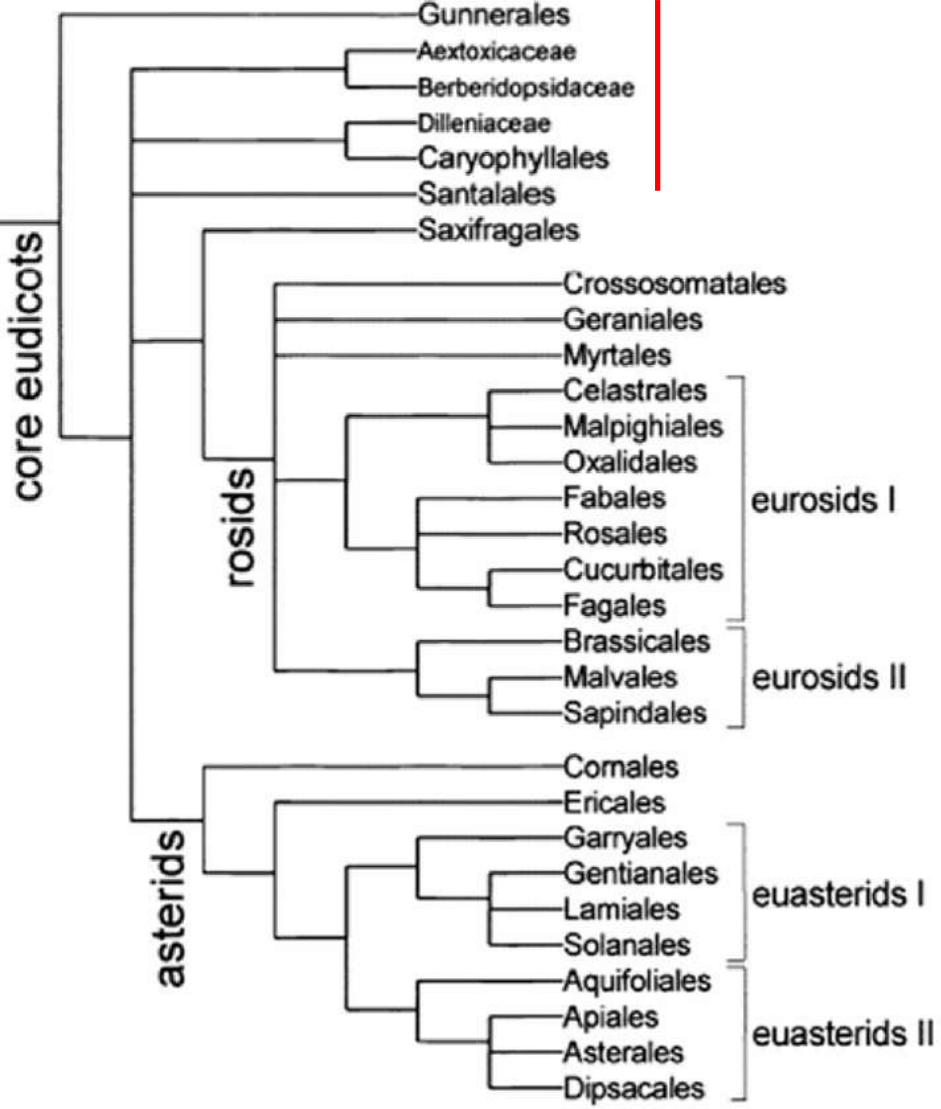
Photo M. Janda



Basal eudicots

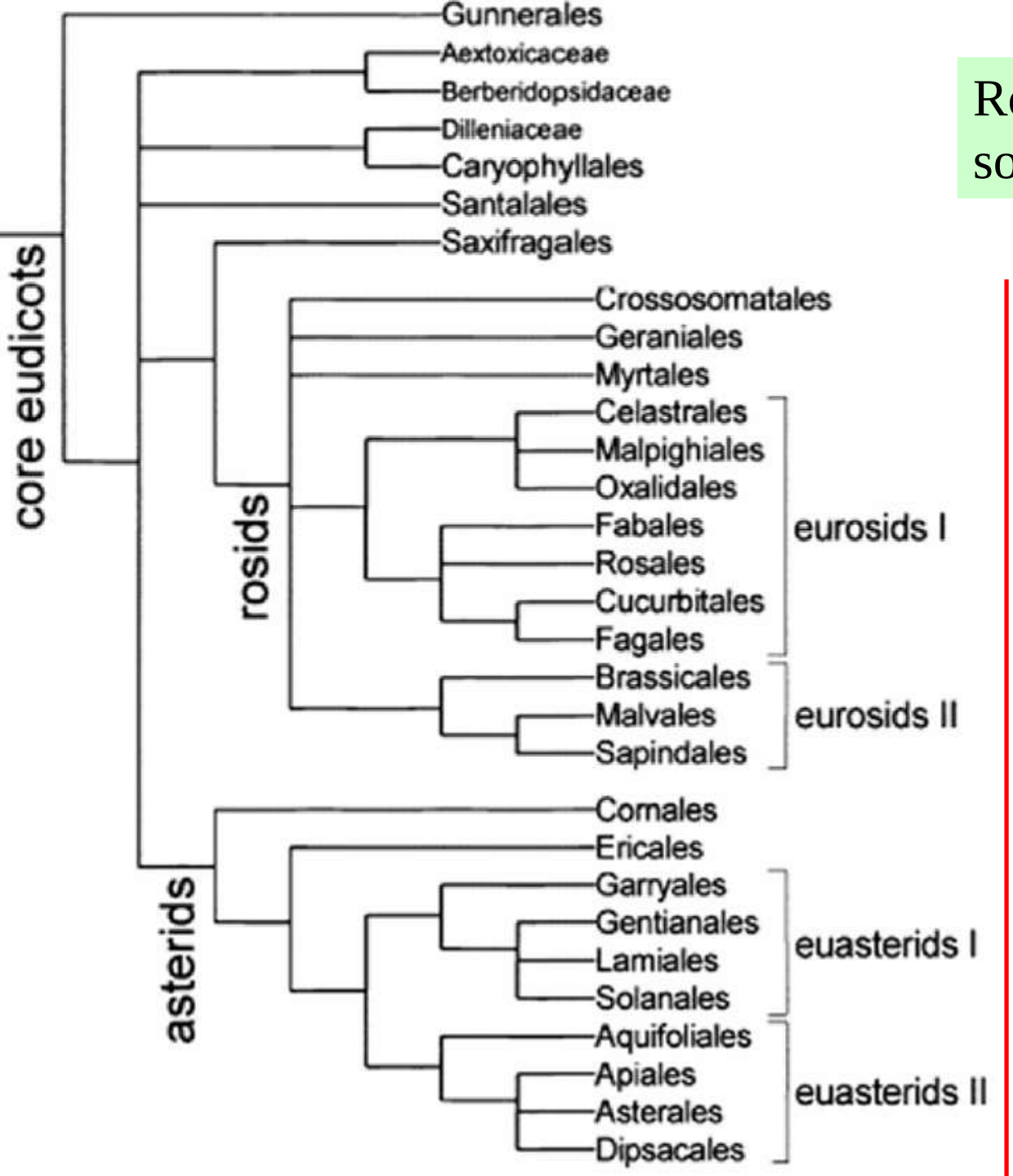
Proteales: Nelumbonaceae

Nelumbo nucifera, lotos



Basal core eudicots

Caryophyllales: Cactaceae, Nepenthaceae



Rosids and asterids: some of the families

Fagales:

Fagaceae: Castanopsis, Lithocarpus

Nothofagaceae: Nothofagus

Casuarinaceae: Casuarina

Myricaceae: Myrica

Notophagus

Castanopsis

Lithocarpus

to by Billy Hau

Photo M. Janda

Fagales:

Fagaceae: Castanopsis, Lithocarpus

Nothofagaceae: Nothofagus

Casuarinaceae: Casuarina

Myricaceae: Myrica

Casuarina

Myrica

Apocynaceae, Cerbera

Photo M. Janda

Bignoniaceae, Bignonia

Spathodea campanulata

Photo M. Janda

Bixaceae, Bixa

Photo M. Janda

Clusiaceae, Garcinia

Photo M. Janda

Combretaceae, Terminalia

Combretaceae, Terminalia impidens

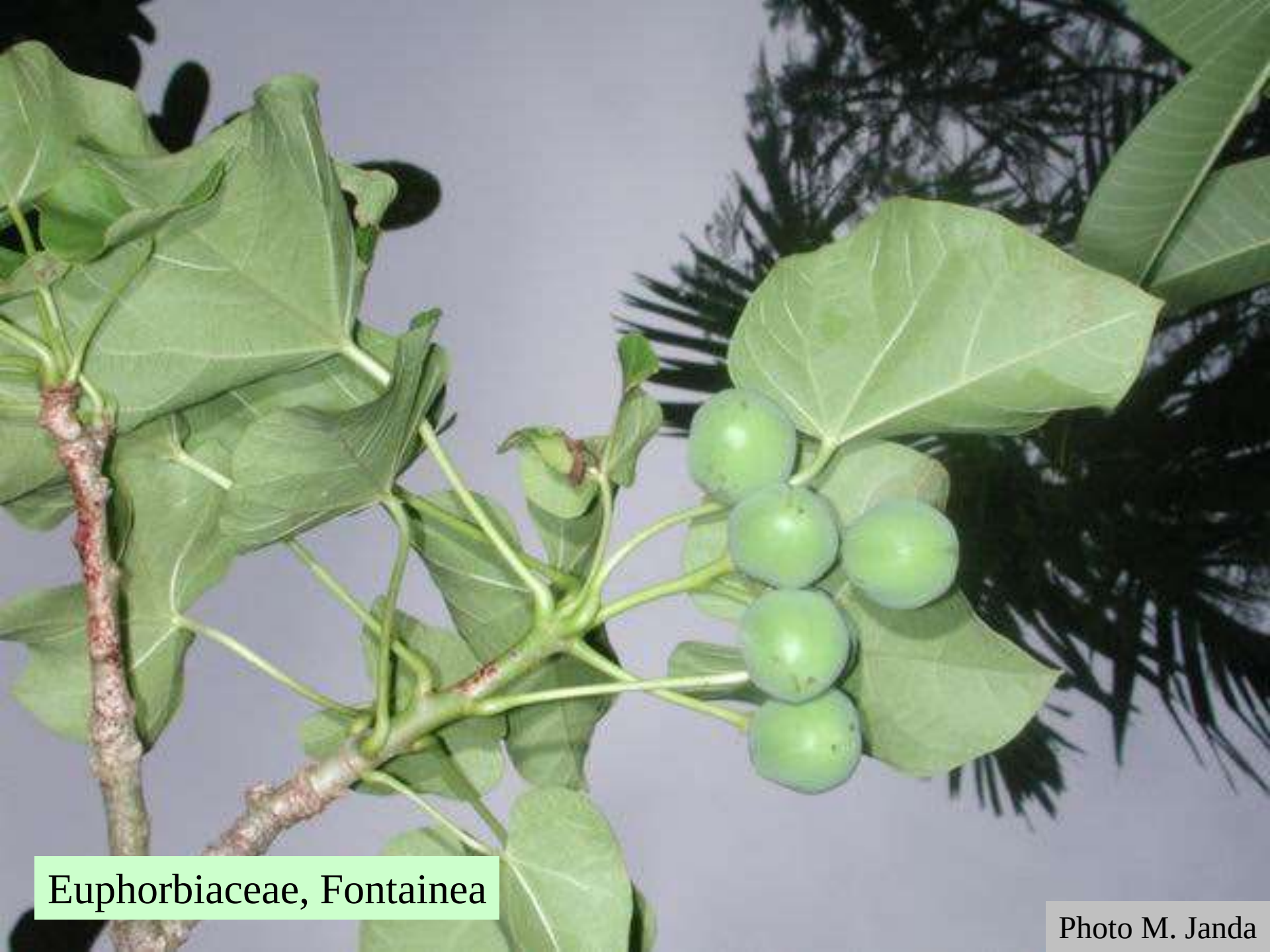
Photo M. Janda

Dipterocarpaceae, Anisoptera

Photo M. Janda

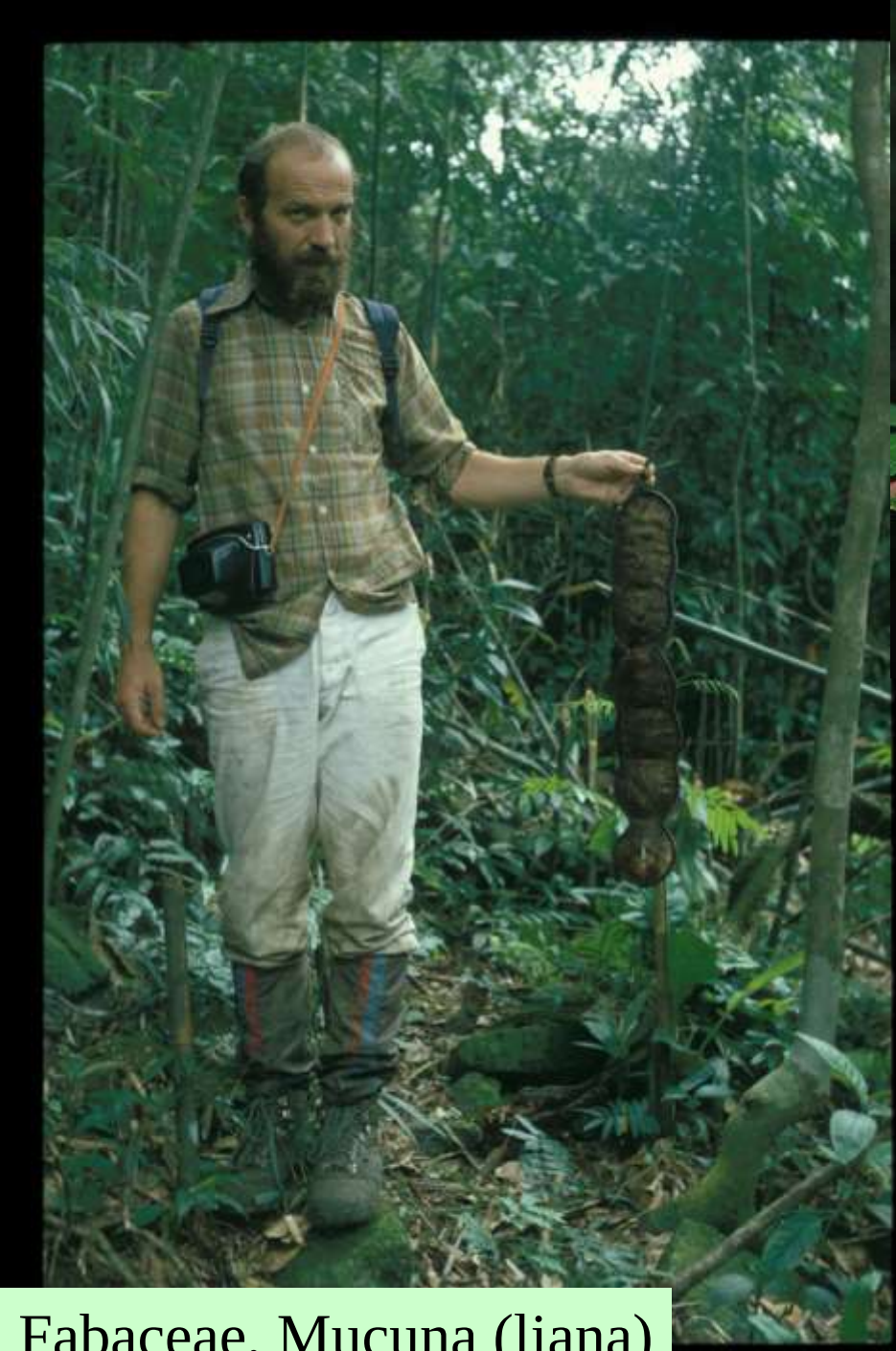
Photo M. Janda

Ebenaceae, Diospyros



Euphorbiaceae, Fontainea

Photo M. Janda



Fabaceae, Mucuna (liana)

Abrus

Maniltoa

Photo M. Janda

Photo M. Janda

Flacourtiaceae: Caesaria

Flacourtia

Gentianaceae: Fagraea

Photo M. Janda

Lecythidaceae, Barringtonia

Photo M. Janda

Lecythidaceae
Lecythis

Leeaceae, Leea indica

Photo M. Janda

Malvaceae: Sterculia schumanniana

Photo M. Janda

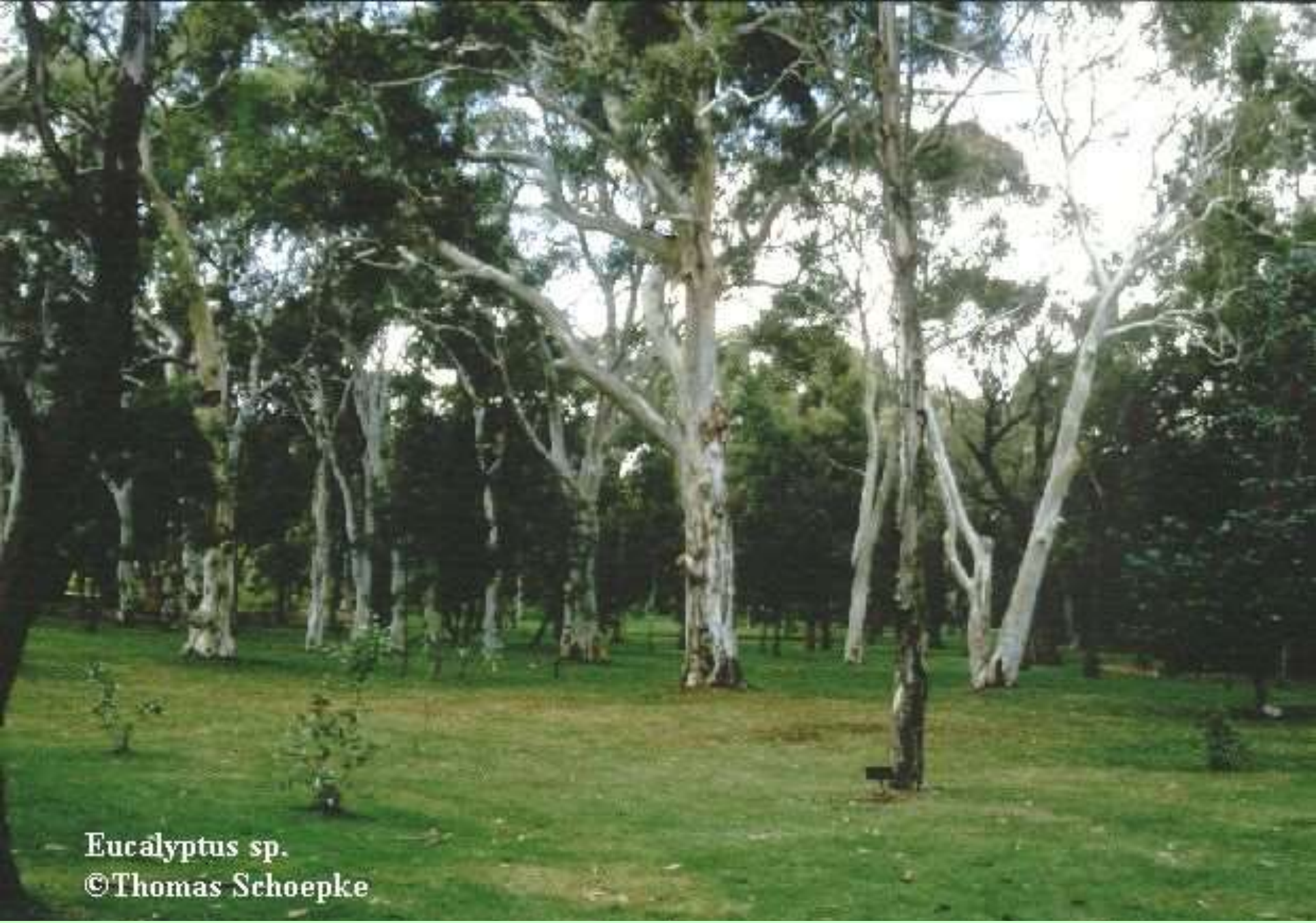
Meliaceae, Swietenia

Aglaia

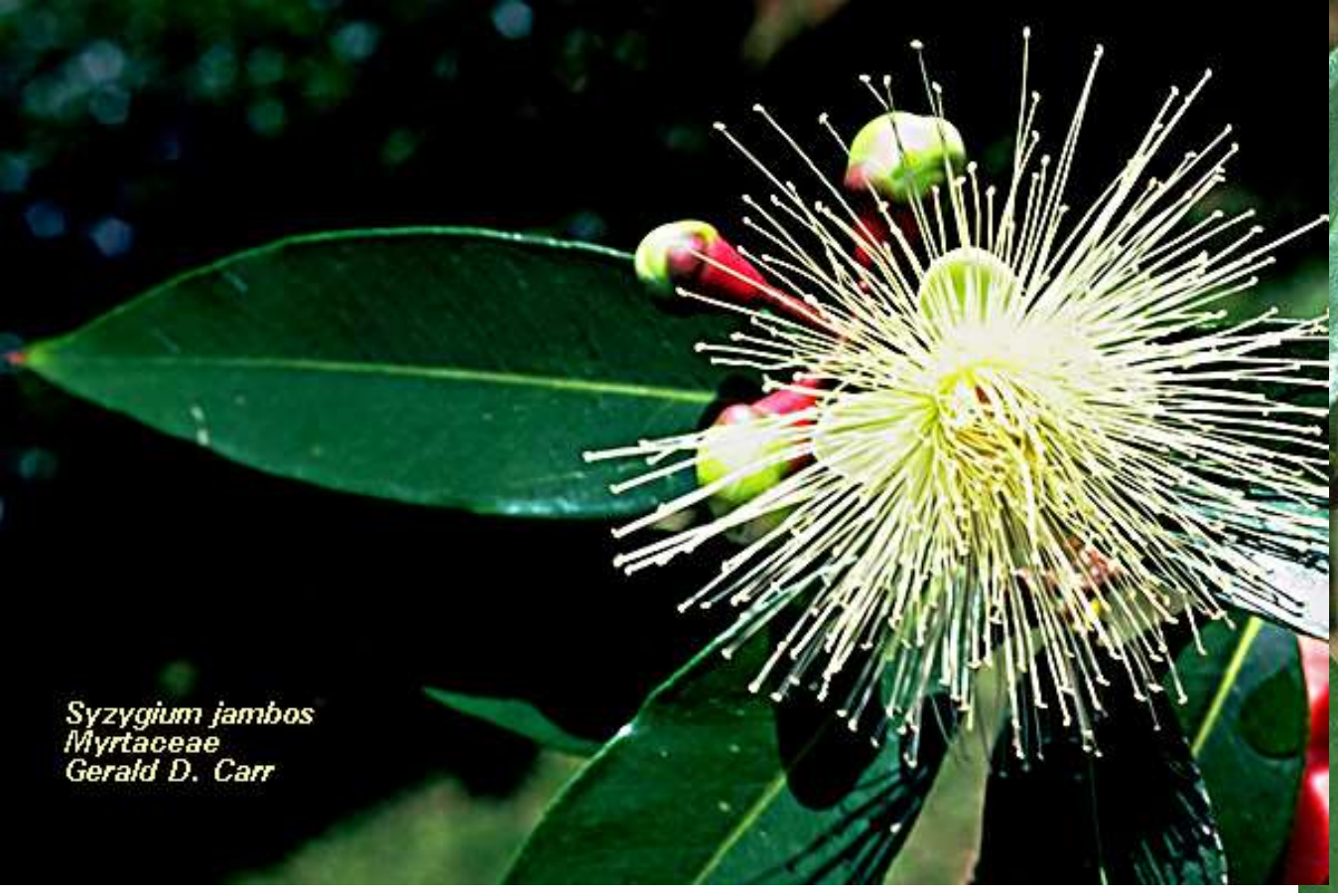
Photo M. Janda

Moraceae: Antiaropsis

Ficus



Myrtaceae, Eucalyptus



Myrtaceae, Syzygium

Pittosporaceae,
Pittosporum

Photo M. Janda

Gardenia

Hydnophytum

Rubiaceae, Mussaenda

Morinda

Photo M. Janda

Sapotaceae, Pouteria

Photo M. Janda

Ulmaceae, Trema orientalis

Photo M. Janda

Urticaceae, Elatostema

Leucosyke capitellata

Photo M. Janda

Verbenaceae, Teijsmaniodendron

Photo M. Janda

Some important tropical crops

Anacardiaceae, *Anacardium occidentale*, cashew ‘nuts’ (flower receptacle)

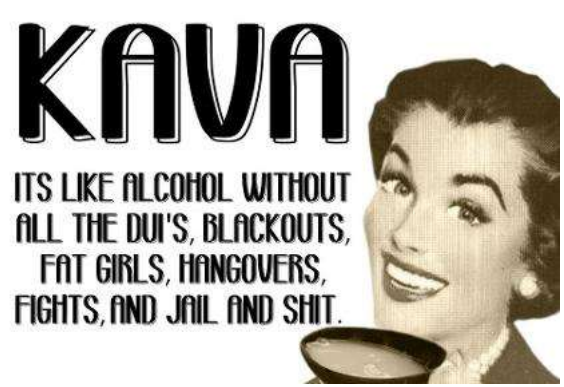
Piper betel: chewed with lime and betel nut






Piper methysticum: kava

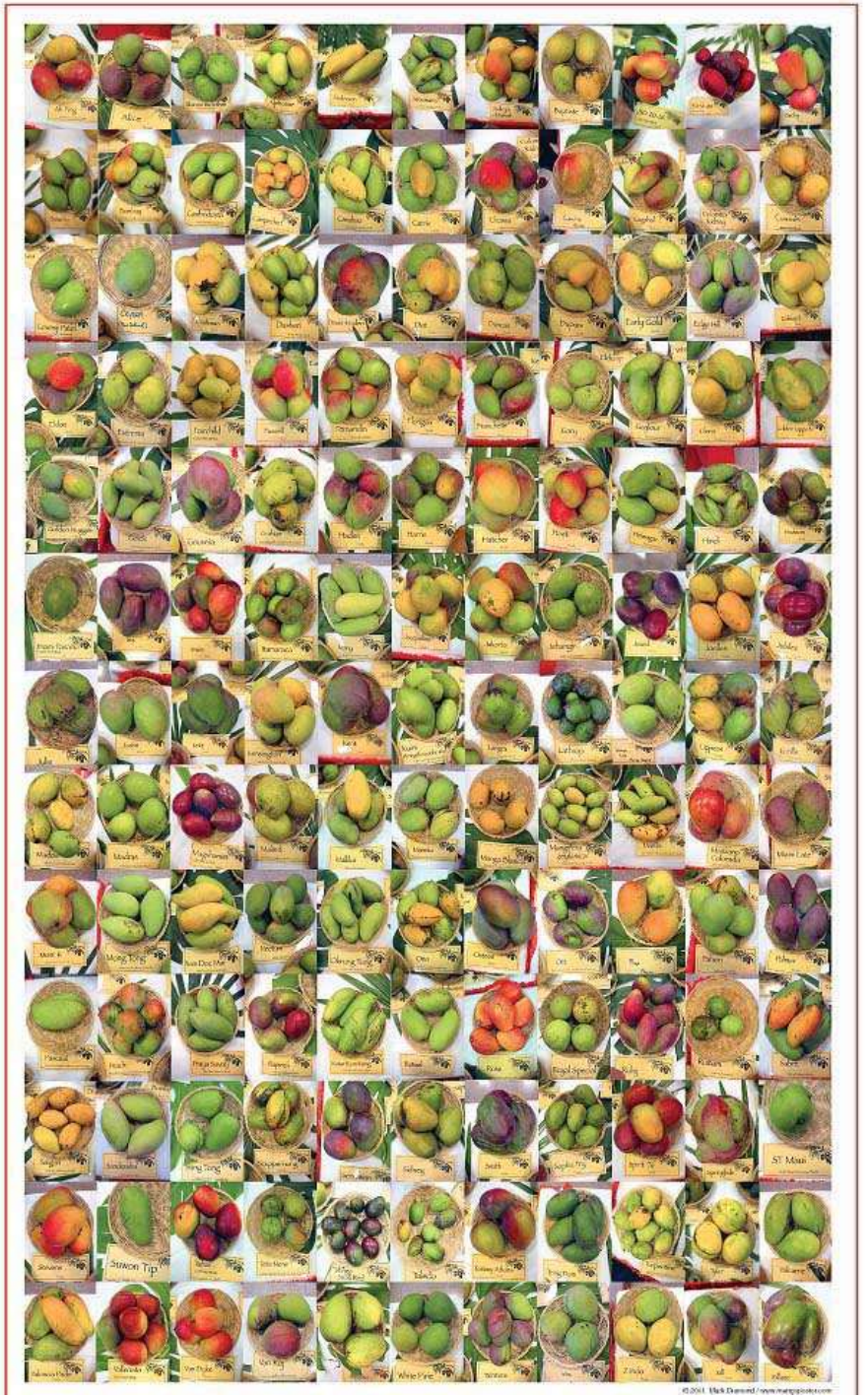


Piper nigrum: pepper

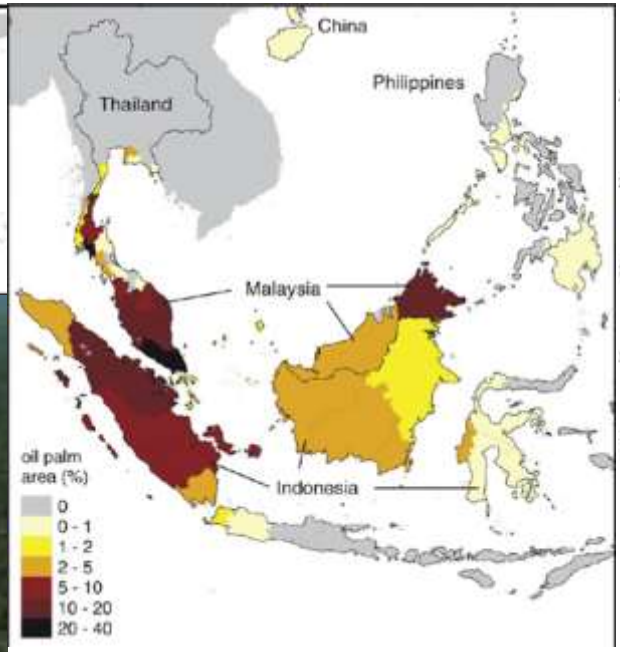


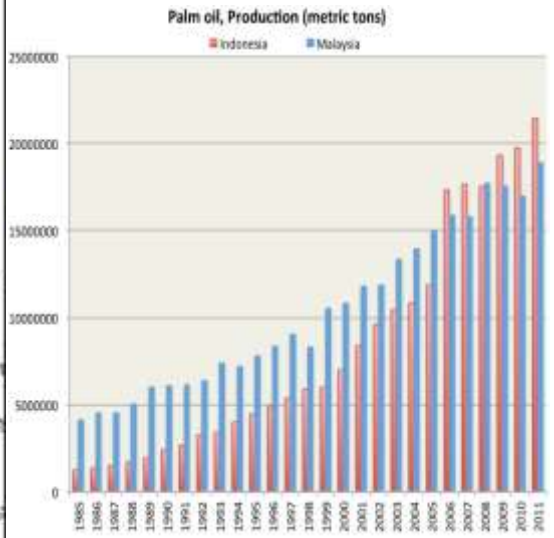

Mangifera indica,
Anacardiaceae, mango

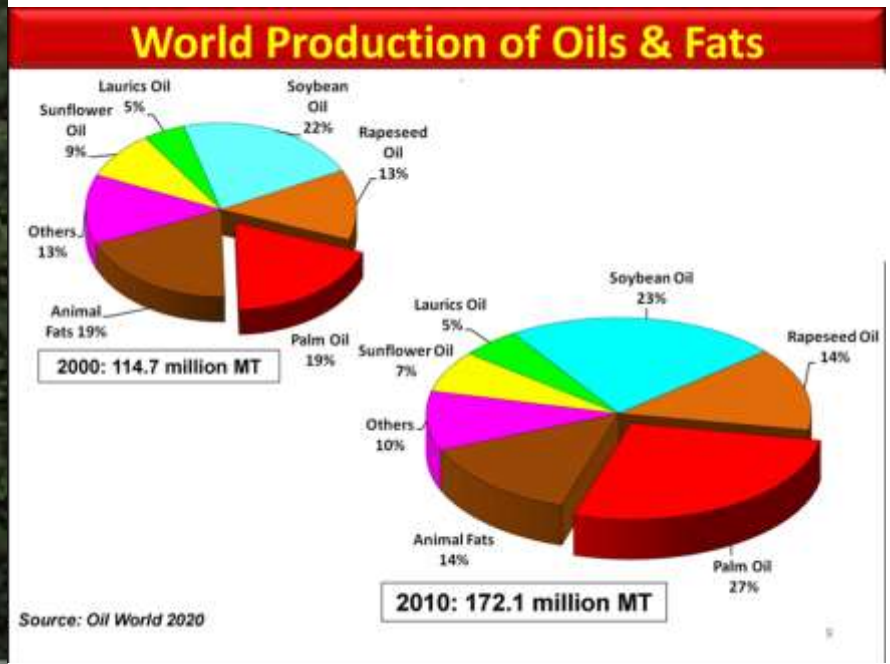


Elaeis guineensis, Arecaceae, oil palm

Oil palm: the fastest expanding plantations in the tropics



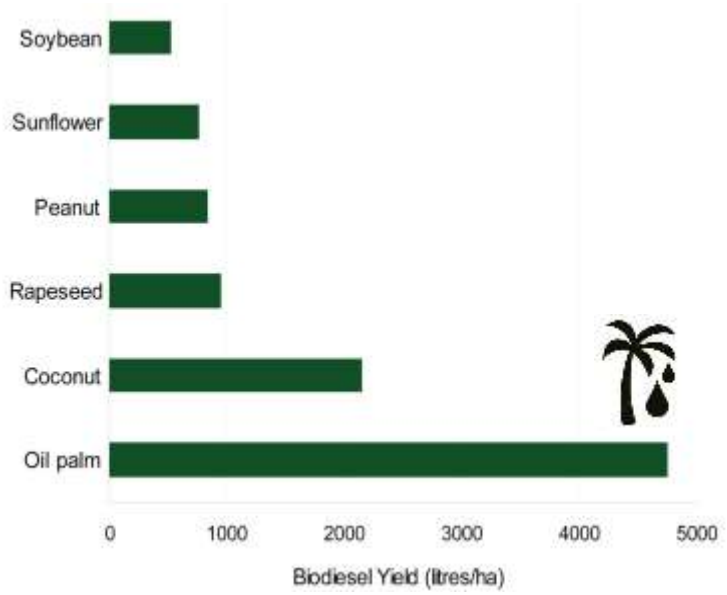


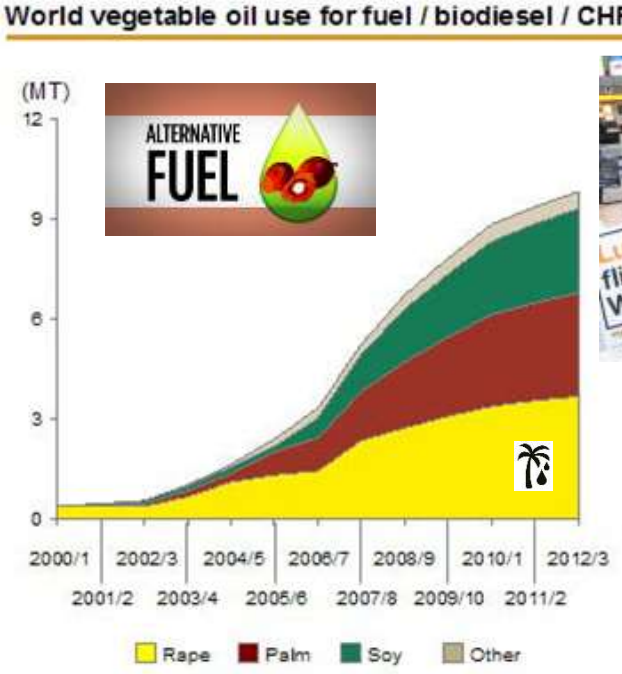


Fitzherbert et al. 2008, TREE 23:538

Biofuels from palm oil: terrible idea creating unlimited demand for rainforest destruction

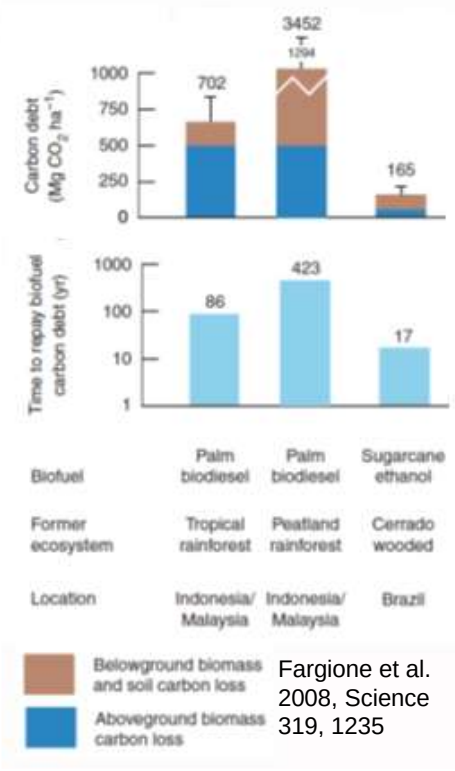
Energetically, palm oil makes sense as a source of biofuels





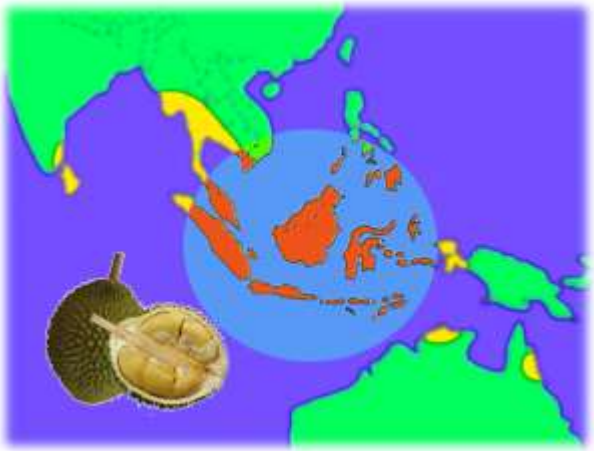
Oil palm is in a suprising variety of foods

Palm oil biofuels from cleared rainforests are carbon neutral after 86 – 423 years



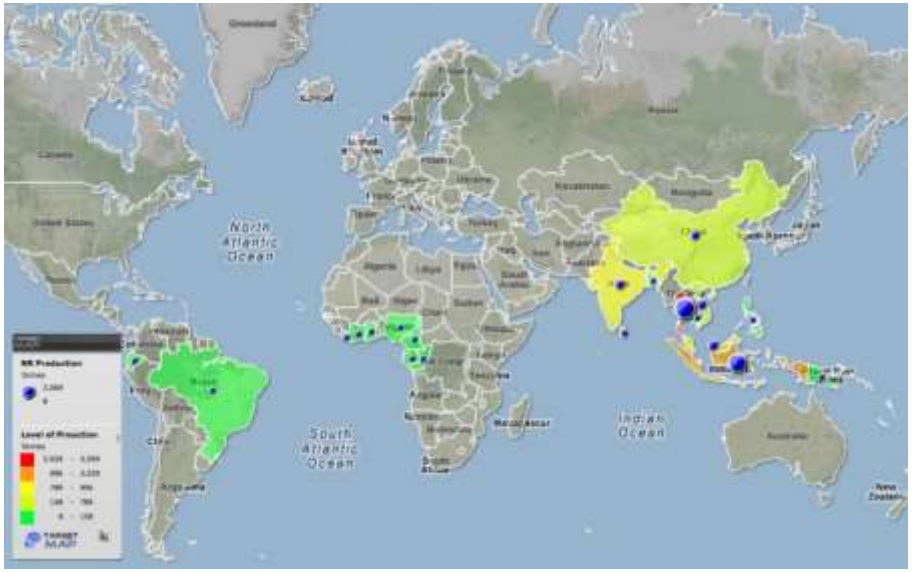
Fargione et al. 2008, Science 319, 1235

Durian: *Durio* spp., Bombacaceae



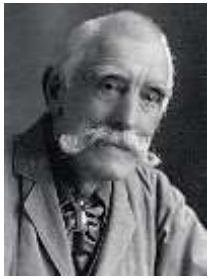
Caricaceae, Carica papaya

Rubber tree: *Hevea braziliensis*, Euphorbiaceae



Rubber boom in the Amazon 1880-1912
(Rubber tree native to the Amazon, Brazil enjoying monopoly)

Henry Wickham stole 70,000 *Hevea* seeds in Brazil in 1876, brought them to Kew Gardens and allowed the British to finish Brazil's monopoly by establishing plantations in Asia



To this day, Brazil remains paranoid about theft of its biodiversity

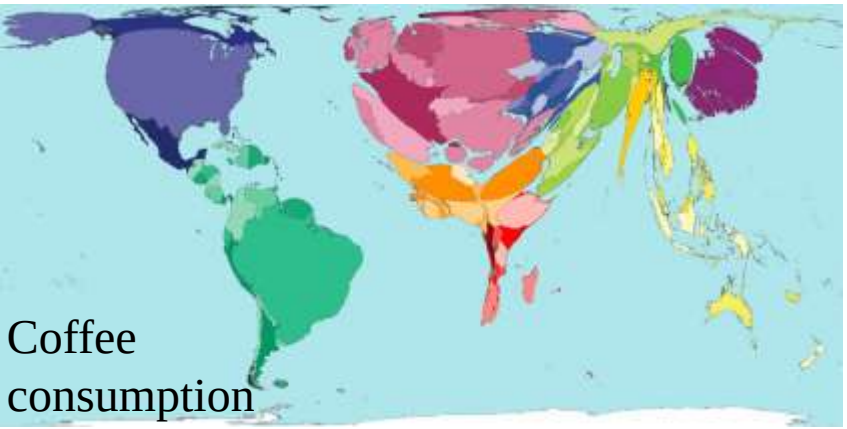
Musa, Musaceae, plantains

Photo Matt Welsh

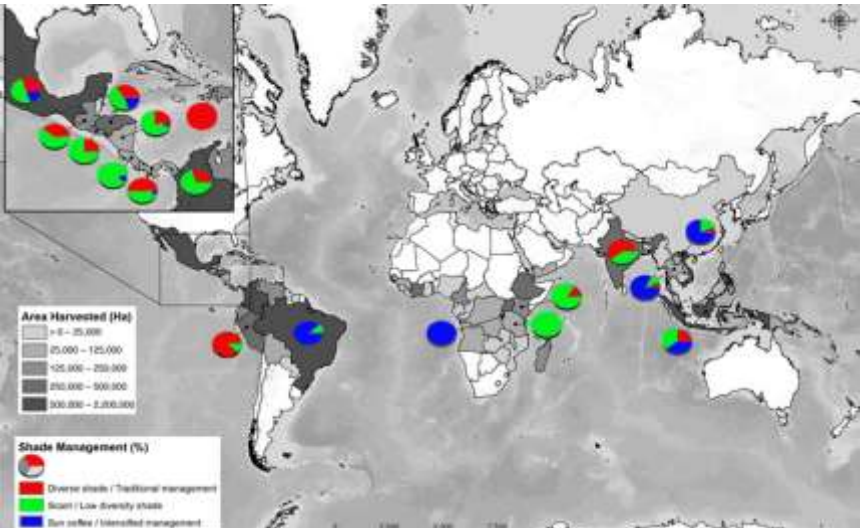
Rubiaceae, *Coffee arabica*

Coffee: production & consumption

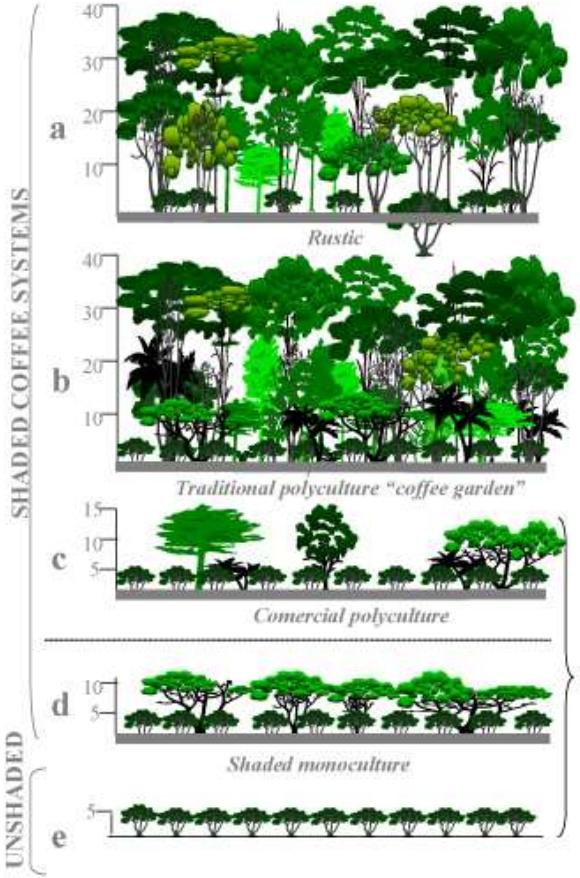
Coffee production



Coffee consumption



Coffee: shade vs. sun agrosystems



Diverse shade trees

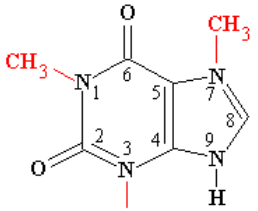
Low diversity shade trees

Sun coffee

http://www.coffeehabitat.com/2006/02/what_is_shade_g/

Shalene et al. BioScience 2014. 64:416-428

Caffeine: one of the ecologically most successful alkaloids enabling *Coffee arabica*, via a mutualistic relationship with a vertebrate species, to outcompete hundreds of plant species



Theaceae, *Camelia sinensis*, tea

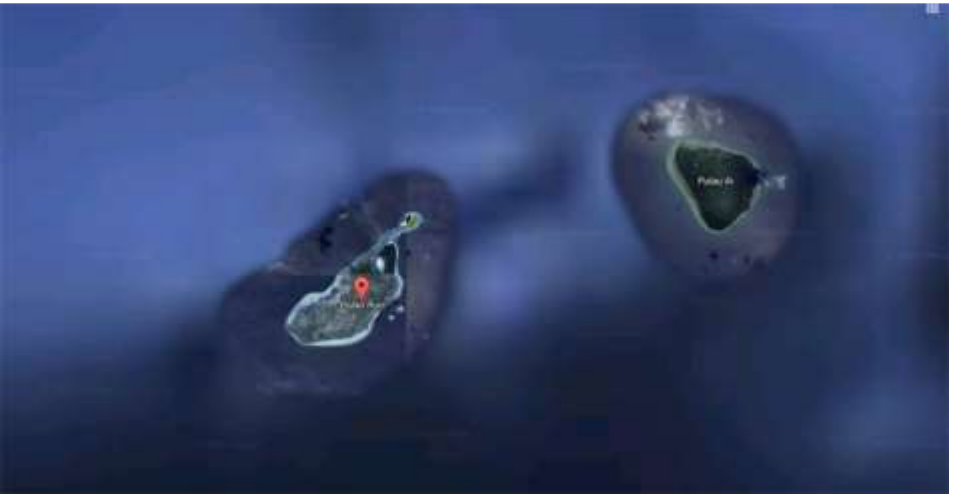
Syzygium (Eugenia) aromaticum, Myrtaceae

Cloves (hřebíček) - dried flower buds

Myristica fragrans – nutmeg (muškátový oříšek) and mace (m. květ)
Myristicaceae

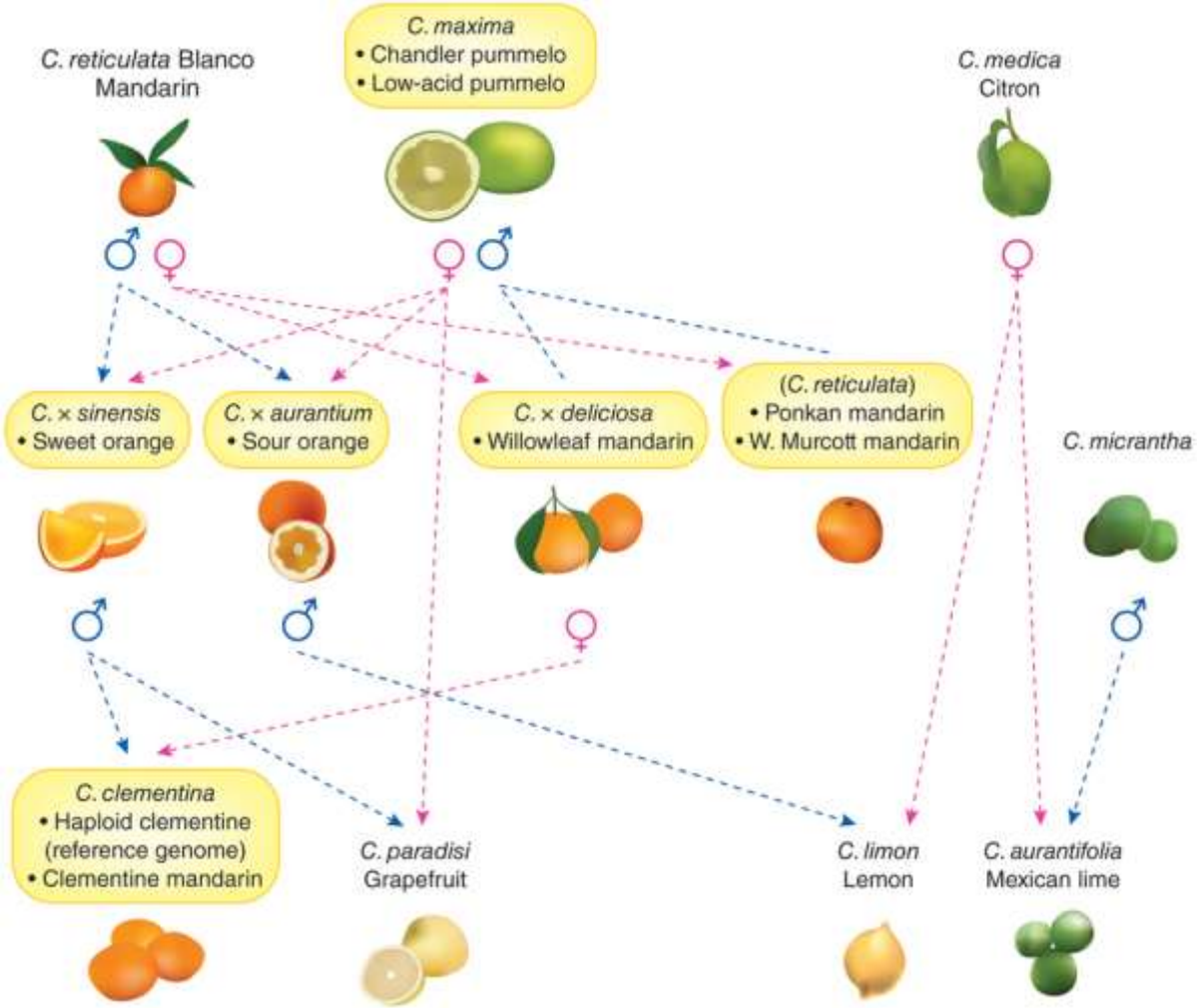
The Moluccas – Maluku Islands – Spice Islands

Some of the most valuable (and profitable) land for several centuries, as the sole source of nutmeg and cloves, traded first by Arabs to Europe, until in 1511 the Portuguese discovered the source of these spices in the Moluccas. Then came the Spanish, and finally by the Dutch with some action from the British – they took over in 1796 and ended the spice monopoly by planting the trees elsewhere in the tropics.



Run island (one of the smallest spice islands in the Moluccas) – became British colony in 1616, after 4-years siege took by the Dutch, and after numerous conflict traded to the Dutch by the British in exchange for the Manhattan island (where New Amsterdam was promptly renamed New York) in 1664.

Rutaceae, *Citrus*



The three major ancestors of citrus species — *Citrus reticulata*, *C. maxima* and *C. medica* — contributed to the origins of all currently cultivated citrus species. Species not highlighted in yellow were not included in the current analysis. Lines with arrowheads indicate contributions to hybrids; lines without arrowheads represent simple introgression.

Velasco & Licciardello 2014. Nature Biotechnology 32, 640–642

Sapindaceae, Nephelium (rambutan)

Sterculiaceae, Theobroma cacao

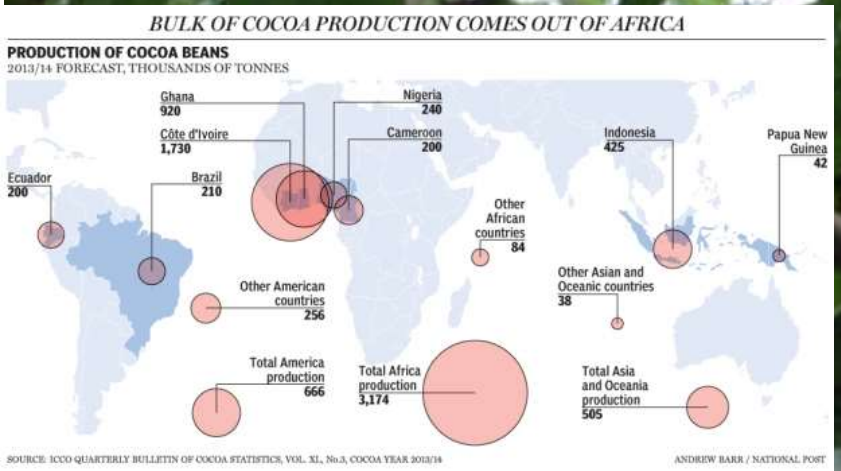
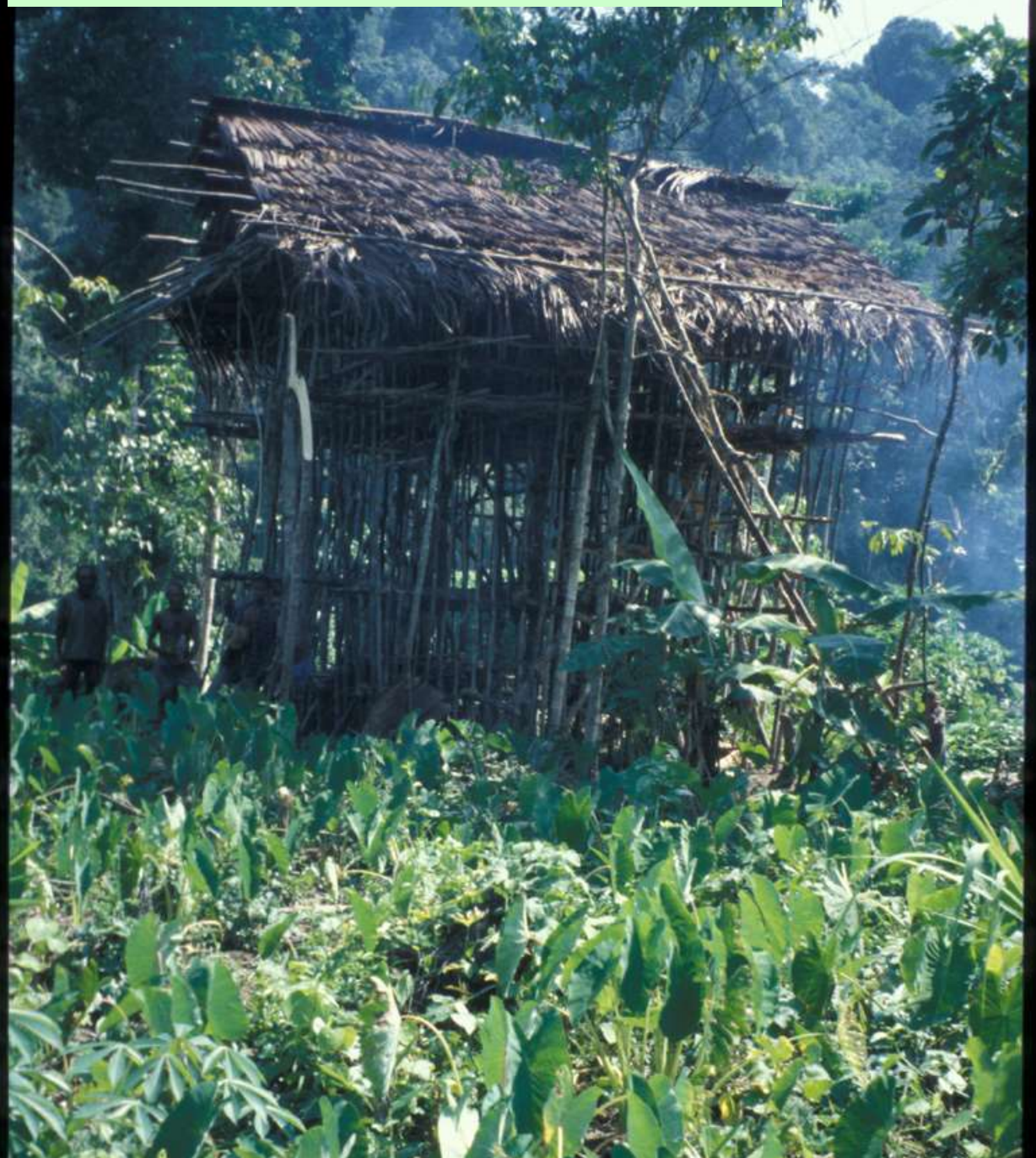


Photo M. Janda

Passifloraceae, Passiflora

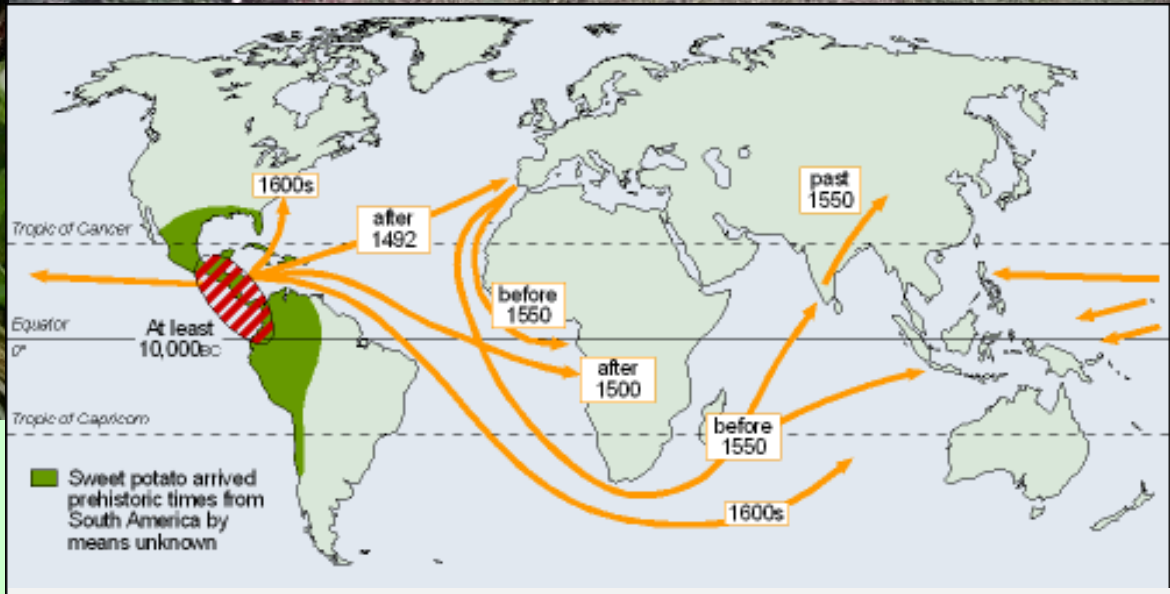
Burseraceae,
Canarium
indicum,
galip nut

Colocasia esculenta, Araceae, taro



Dioscorea alata, Dioscoreaceae, yam

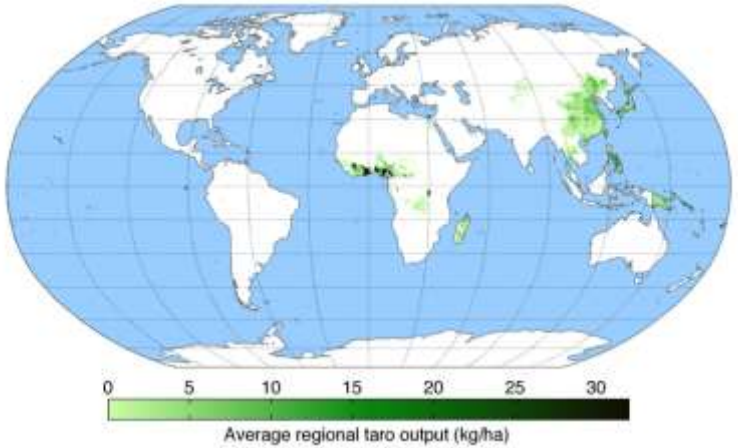
Ipomoea batatas,
Convolvulaceae,
sweet potato



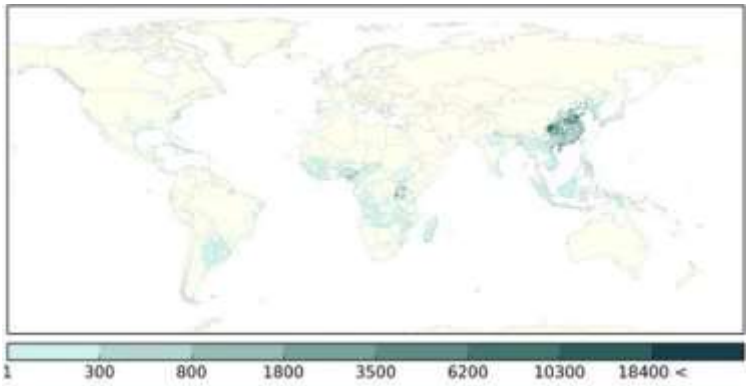
Early spread of sweet potato

Manihot utilissima, Euphorbiaceae, cassava, manihot, manioc

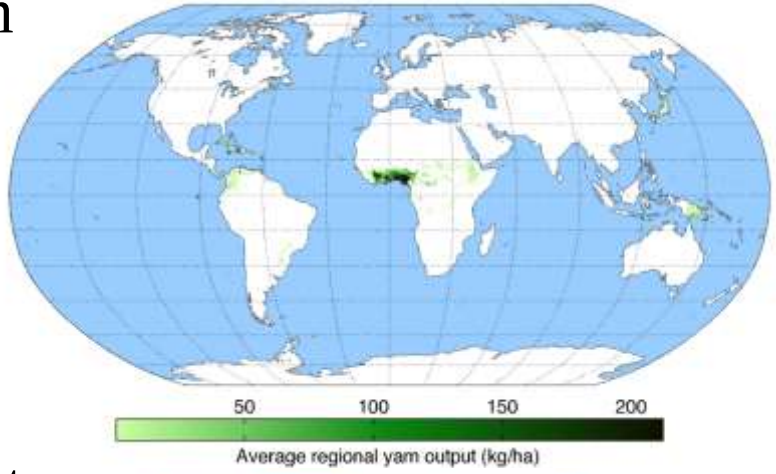
taro



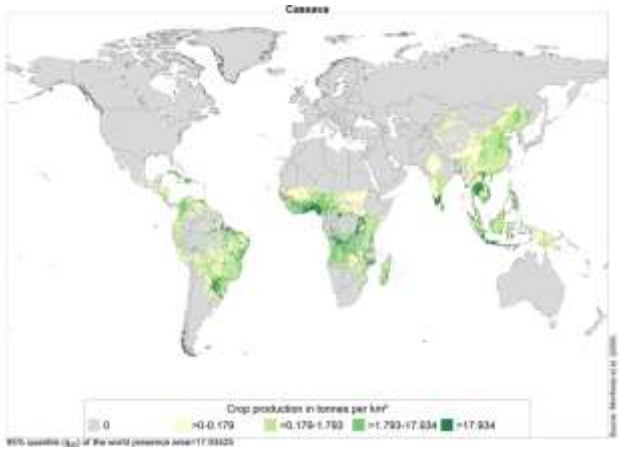
sweet potato



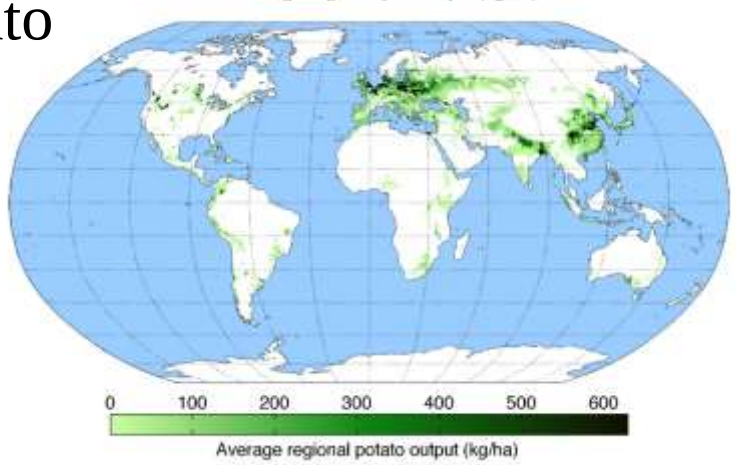
yam



cassava



potato



plantain & banana