

Plant ecophysiology in tropical freshwater wetlands on three continents



Suriname, Coppename River

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Floodplains in tropical freshwater wetlands

Idea of the present talk:

What do we know?

Characteristics of
floodplains across biomes
(forests)?

Tree responses to flooding
(variability of responses)?

Lacks?



Amazon floodplain, *Tabernaemontana juruana*

Wide Wetlands of the World

Criteria for choice:

- Vast continuous freshwater floodplains with forest patches (i.e. trees occur naturally) in **tropical** climate
- Flooding at large scale, with a significant regular flood pulse (not merely flash floods after heavy rain events) associated to major river systems



Botswana, Okavango Delta (Moremi Reserve)

Similarities: Flood pulse as major driving force

TERRESTRIAL SYSTEMS

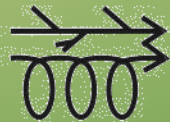
Wetlands with **stable** water level
(Bogs, marshes, fens, etc.)

AQUATIC SYSTEMS



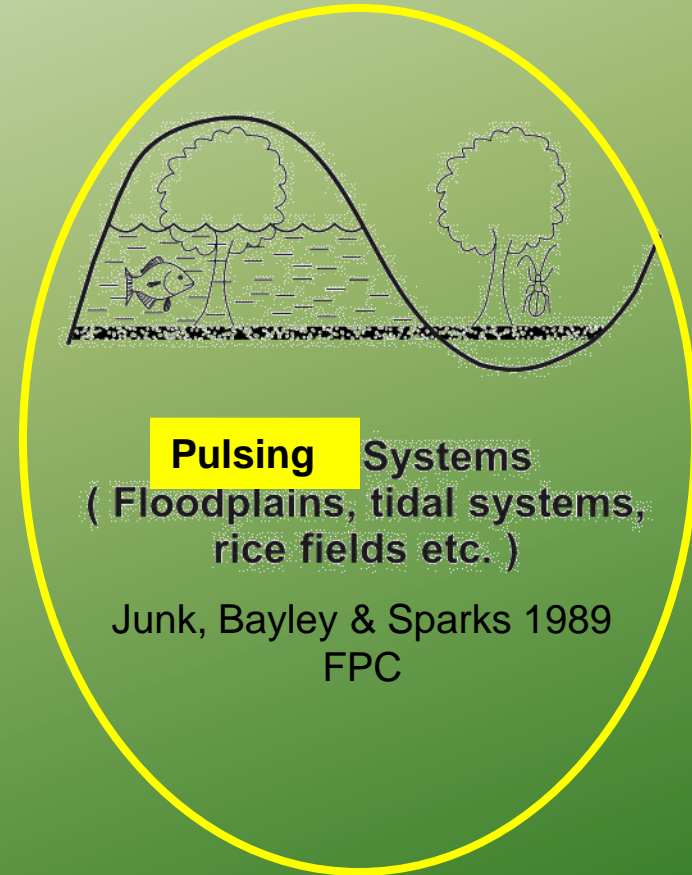
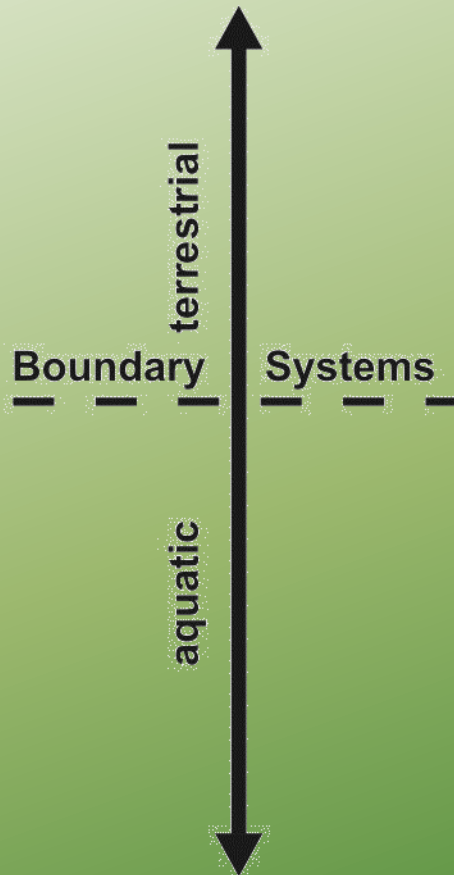
Lakes

Thienemann,
Ruttner
and others
between
1915-1935
Seetypenlehre

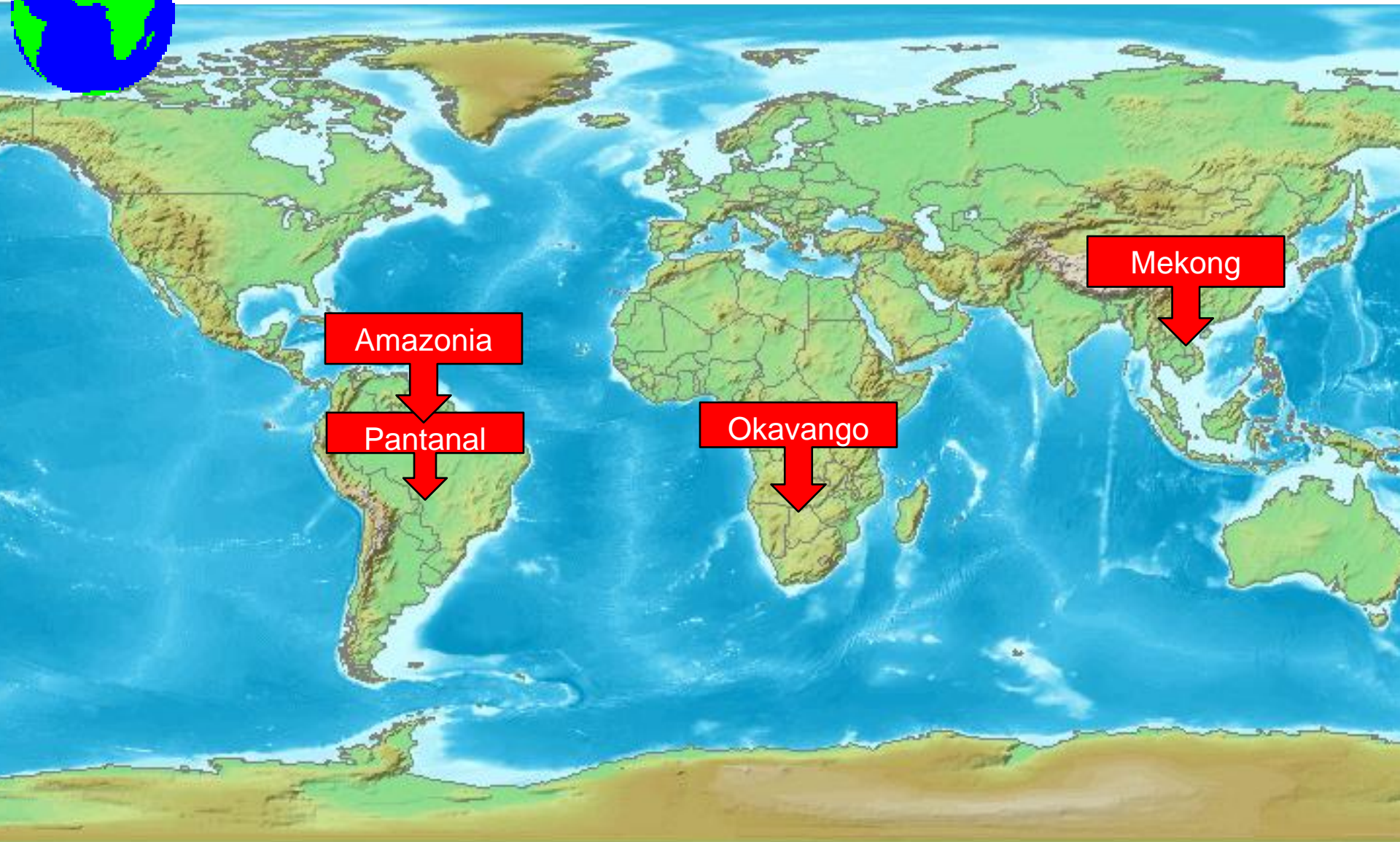


Running waters

Illies et al. 1950-1960
Vannote et al.
RCC 1979



Chosen flood-pulsed tropical freshwater wetlands



Amazonia

Pantanal

Okavango

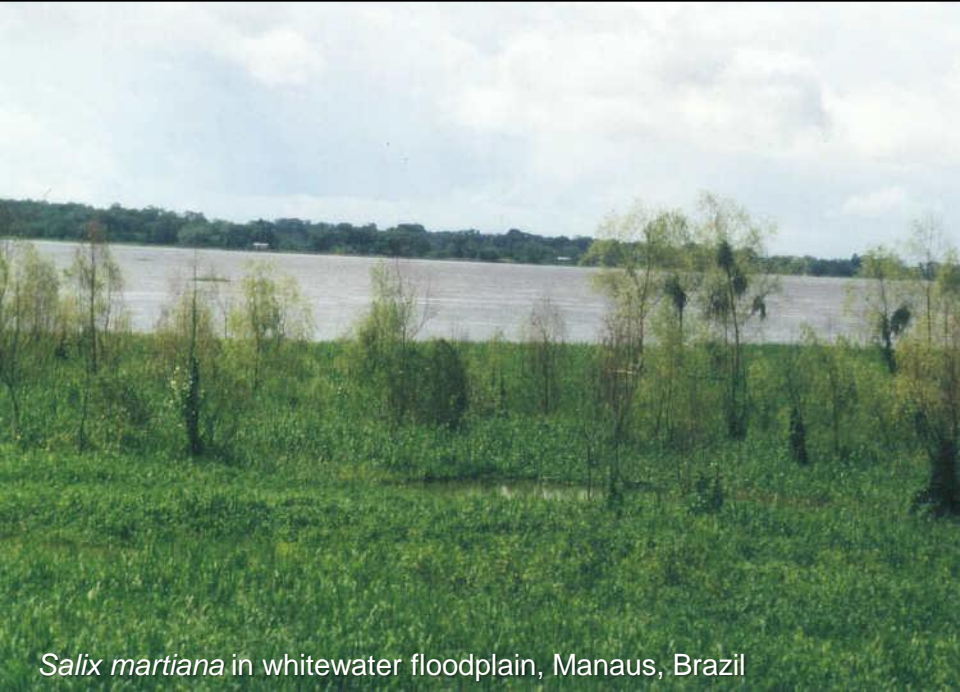
Mekong

	Amazonia	Pantanal	Okavango Delta	Mekong
Flood duration where trees grow	7 months	5 months	<8 months?	6-8 months
Max flood height on tree stems	<u>8m</u>	2,5m	root level	<2m
Influence of fire and salt	no	Fire! (no salt)	Fire and salt!	no
Number of flood-tolerant tree species	> 1000	400	10	15
Age of ecosystem (Irion <i>et al.</i> 1997; Junk <i>et al.</i> 2006)	2.4 Mio y	2.5 Mio y	80.000 y	7,500 y
Density of human population (inhabitants per km ²)	3,3-20	1-2	< 6	50-450

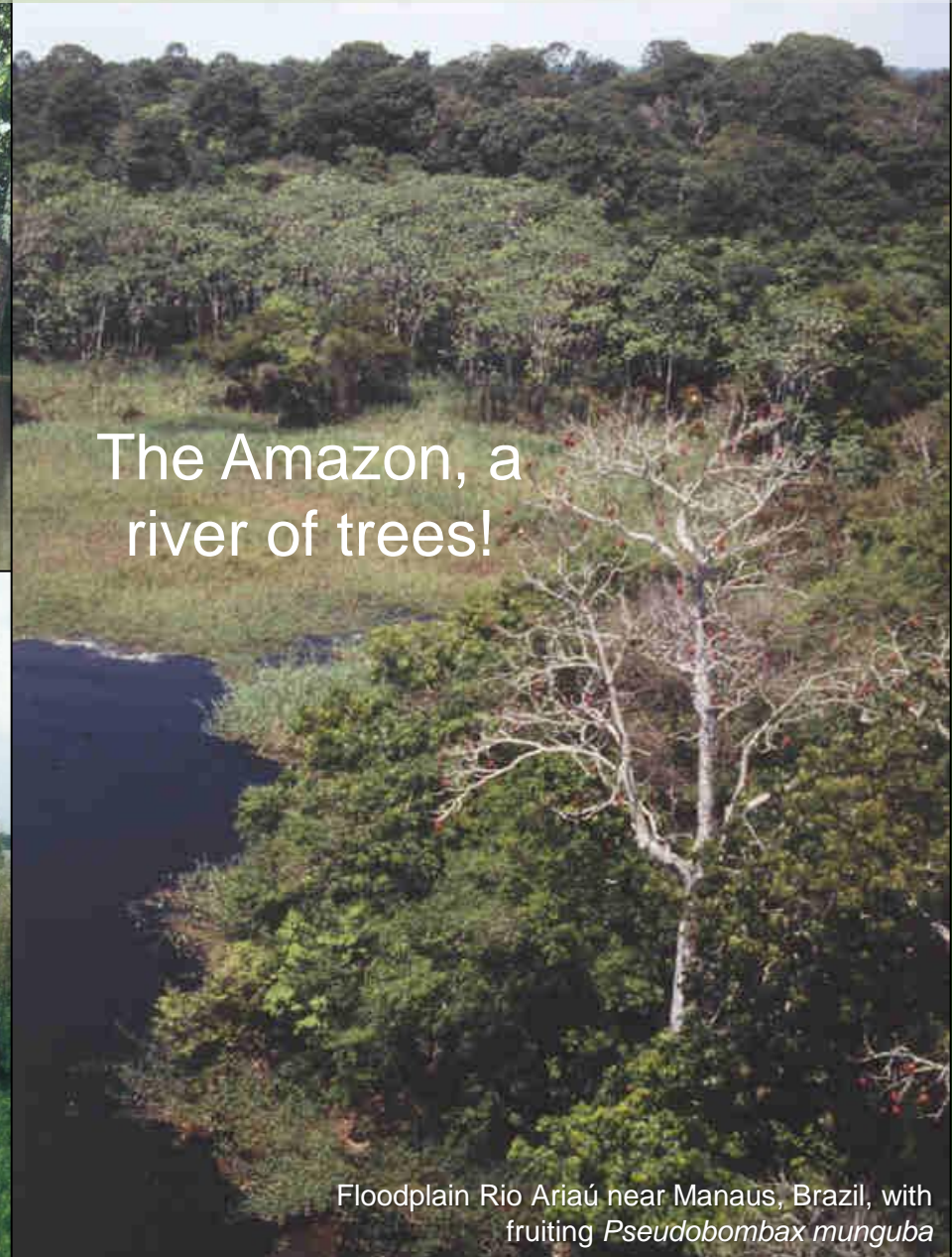
Main vast floodplain ecosystems:
South America: Amazonian floodplains



Whitewater floodplain, Manaus, Brazil



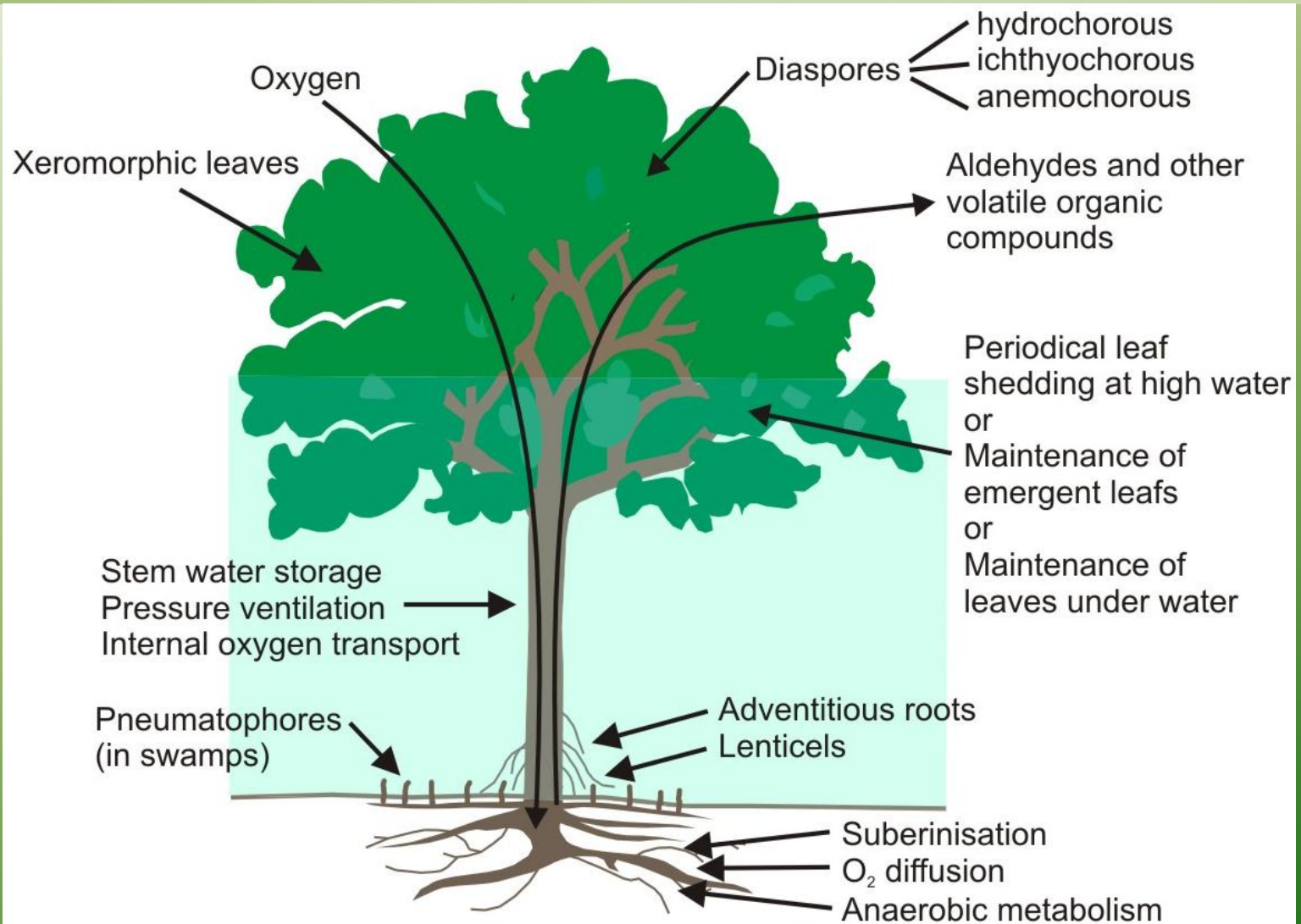
Salix martiana in whitewater floodplain, Manaus, Brazil



The Amazon, a
river of trees!

Floodplain Rio Ariáú near Manaus, Brazil, with
fruiting *Pseudobombax munguba*

South America: Central Amazonian floodplains: Tree responses to flooding: diverse sets of adaptations



Phenology

Worbes 1989

Parolin 2000; et al. 2010

Schöngart et al. 2002

Piedade et al. 2006

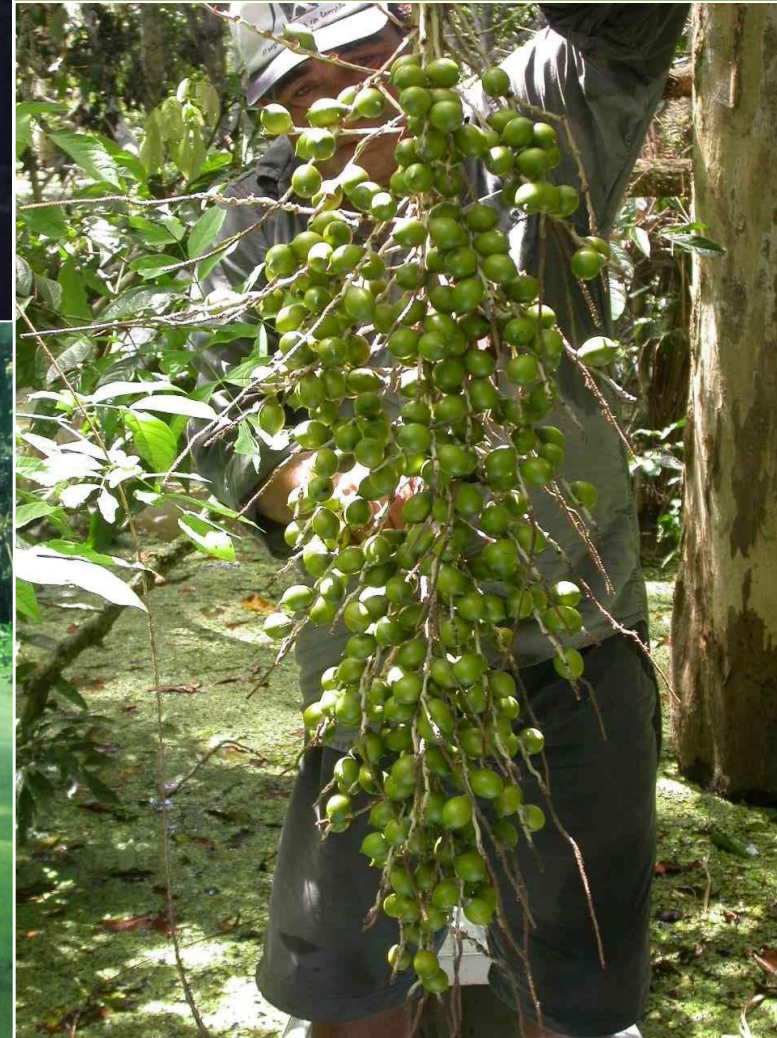
*Palm *Astrocaryum jauari**



Crudia amazonica flushing new leaves
in whitewater floodplain, Manaus, Brazil



Tabebuia barbata



Leaf maintenance under water

Parolin et al. 2009 Annals of Botany

Parolin et al. 2010 Aquatic Botany

mature, previously submerged leaves



Symmeria paniculata

new mature leaves

Leaf anatomy and morphology

Traits of leaves of 34 tree species

- large epidermal cells
- thick outer epidermis walls
- thick cuticula
- compact spongy parenchyma
- few and small intercellular spaces
- sunken stomata
- transcurrent vascular bundles with a strong sclerenchymatous bundle sheath

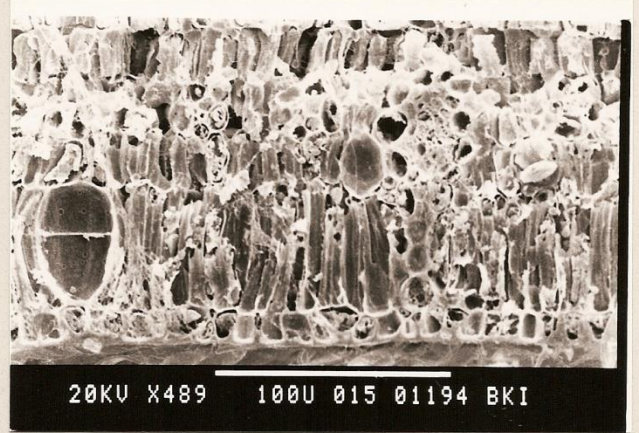
= Traits generally related to leathery leaves and/or xeromorphism (but: typical pattern in tropical trees!)

72



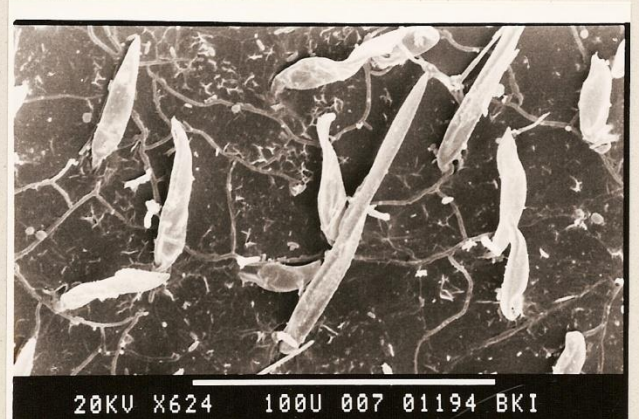
05

70



05

84



05

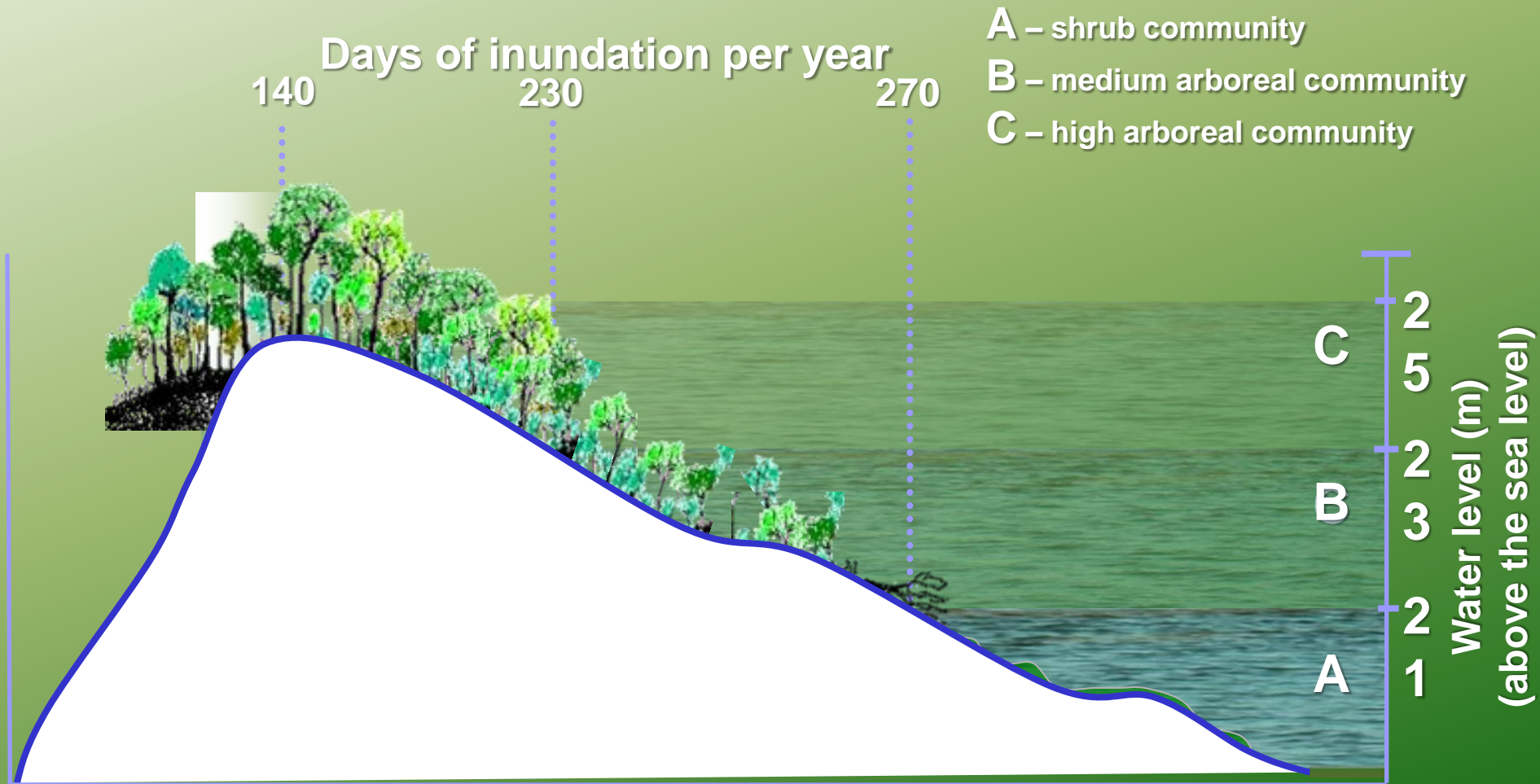


Ecophysiological
measurements

to assess
responses to
flooding stress

Submergence
experiments without
/ with light

South America: Central Amazonian floodplains: Significance of flooding for tree distribution Clear zonation!

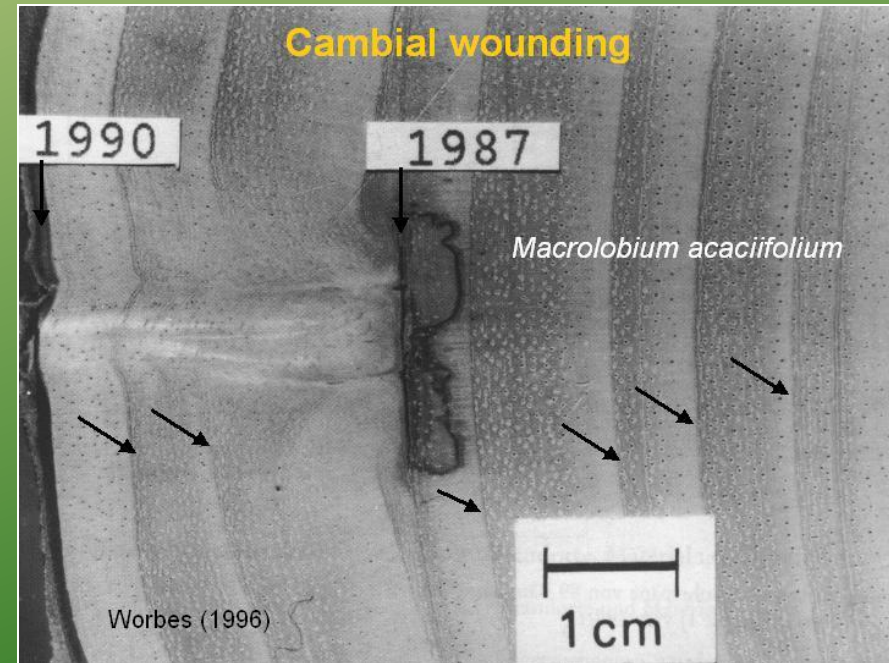


Growth and productivity

Annual increments

Tree ring analyses

Etc.



Worbes 1989 Ecology
Schöngart et al. 2002, 2005 Oecologia

South America: Pantanal

Flooded grasslands!!



Northern Pantanal near Cuiabá, Brazil

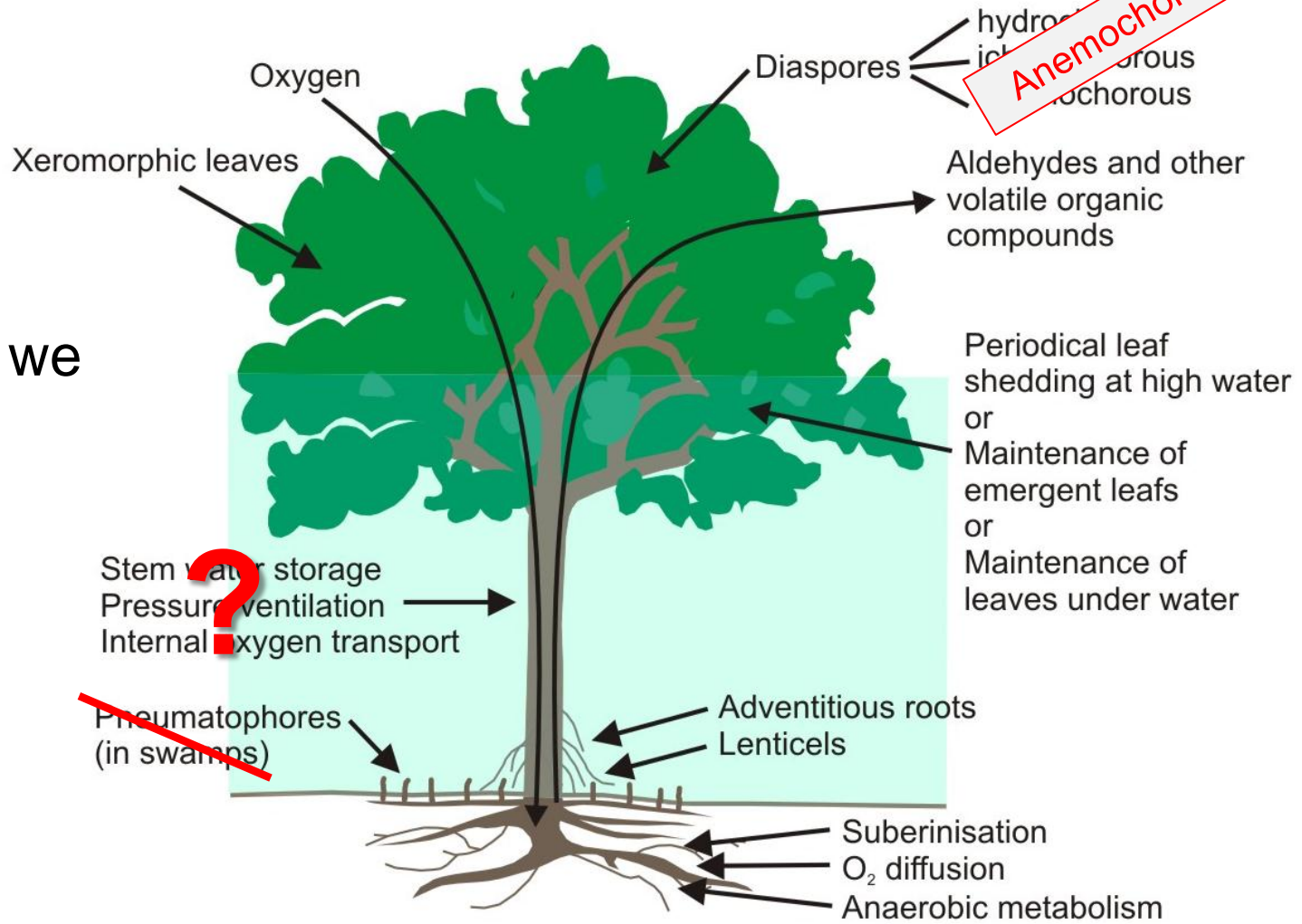


Vochysia divergens



South America: Pantanal

Tree responses to flooding: similar to Amazonian floodplains?!



What do we know?

Phenology



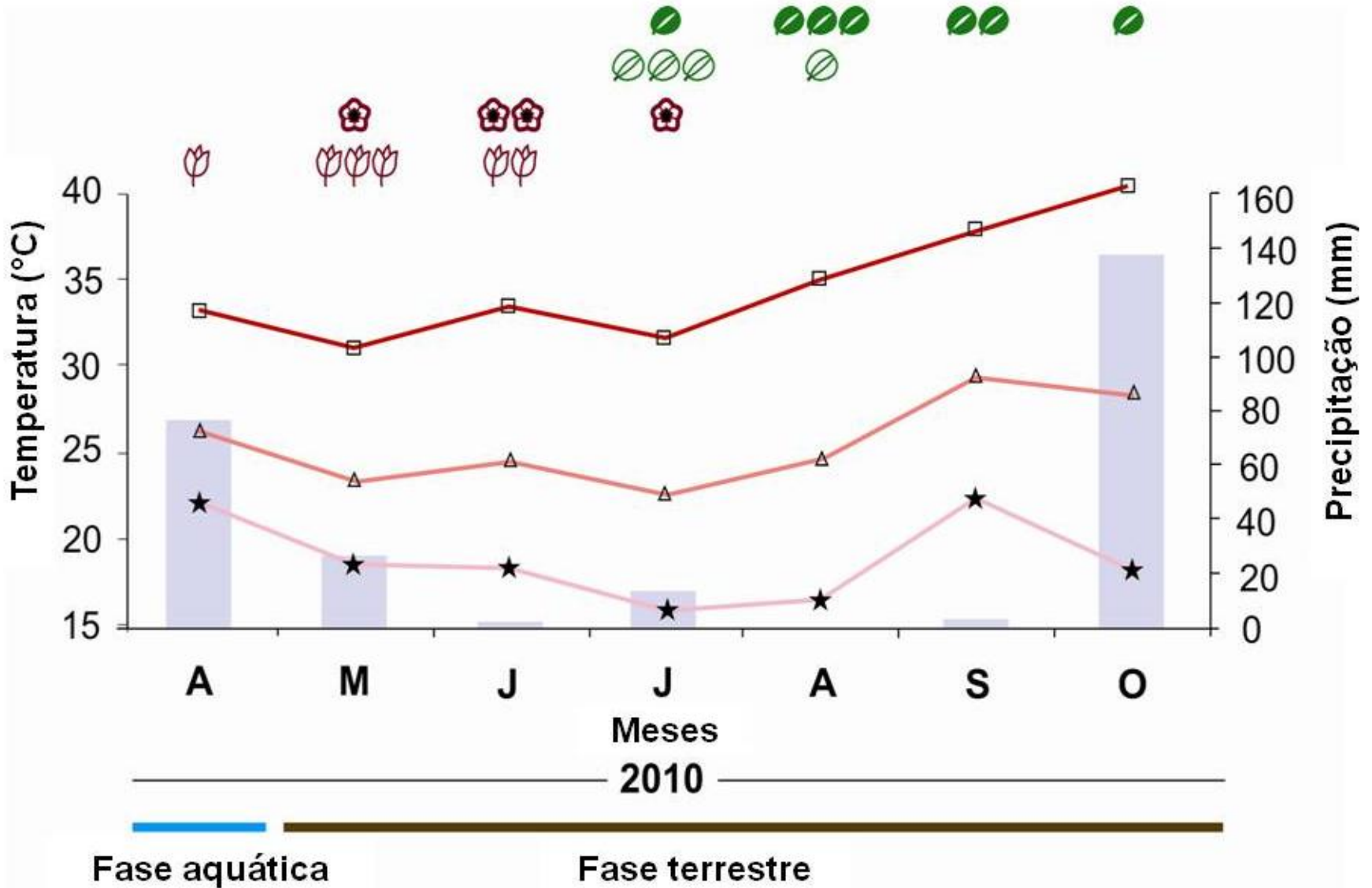
Deciduous to semi-deciduous
to (semi-) evergreen

Leaves shed in dry period
(some in high water period,
e.g. Bombacaceae)

During flooding: growth
reductions

Fruit peak at high and at low
water, depending on position
in flooding gradient

Phenology: example *Combretum lanceolatum*





Seedling establishment



Dispersal syndromes: mostly anemochoric

Seed germination: only in dry period with onset of rains

Seedling growth and physiology ...

Seedling survival vs mortality (long-term plots) ...

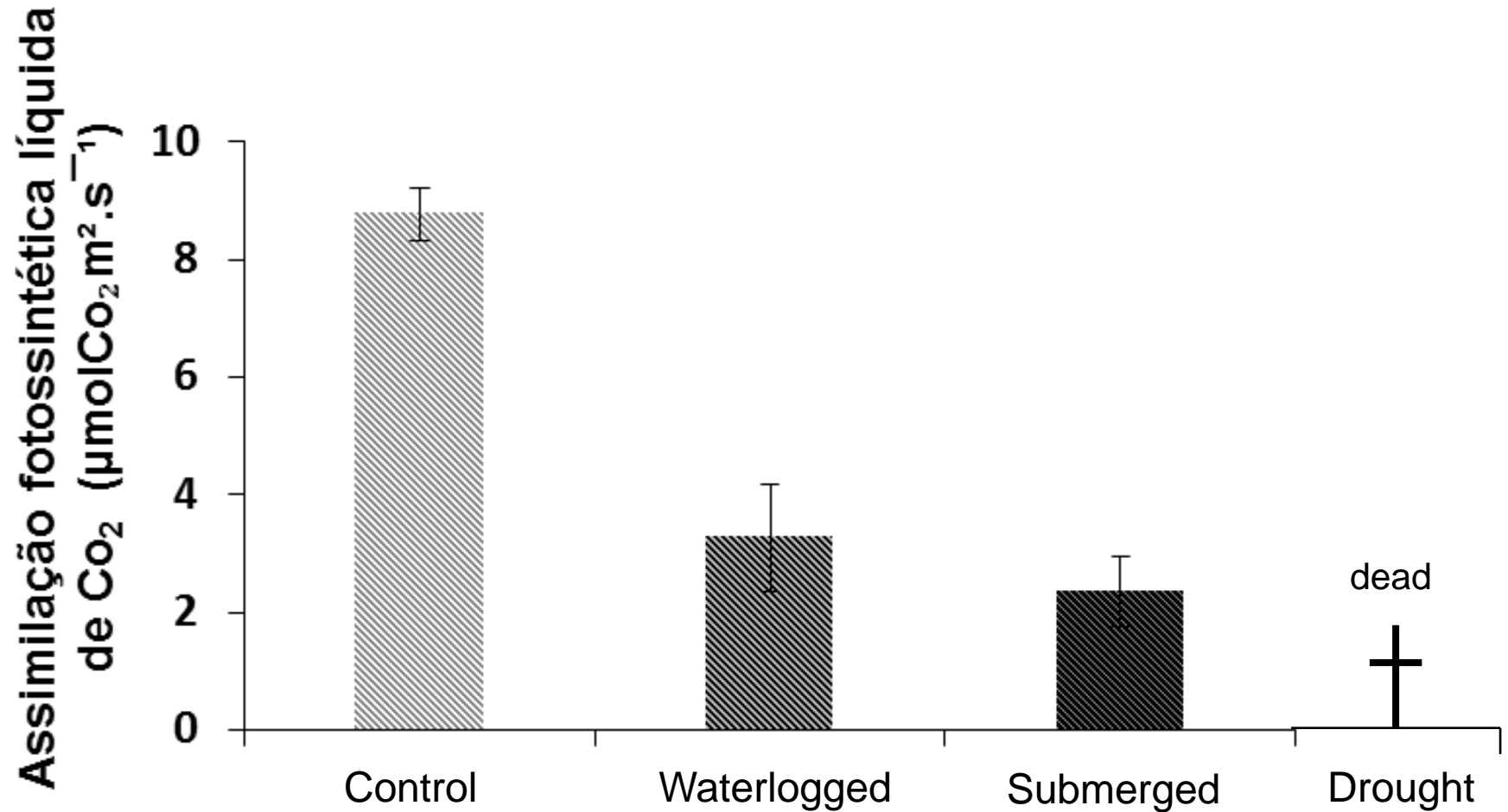
Leaf physiology and anatomy



Not much known...

Responses to flooding and drought

Photosynthetic assimilation of *Combretum laxum* after 120 days of flooding and drought



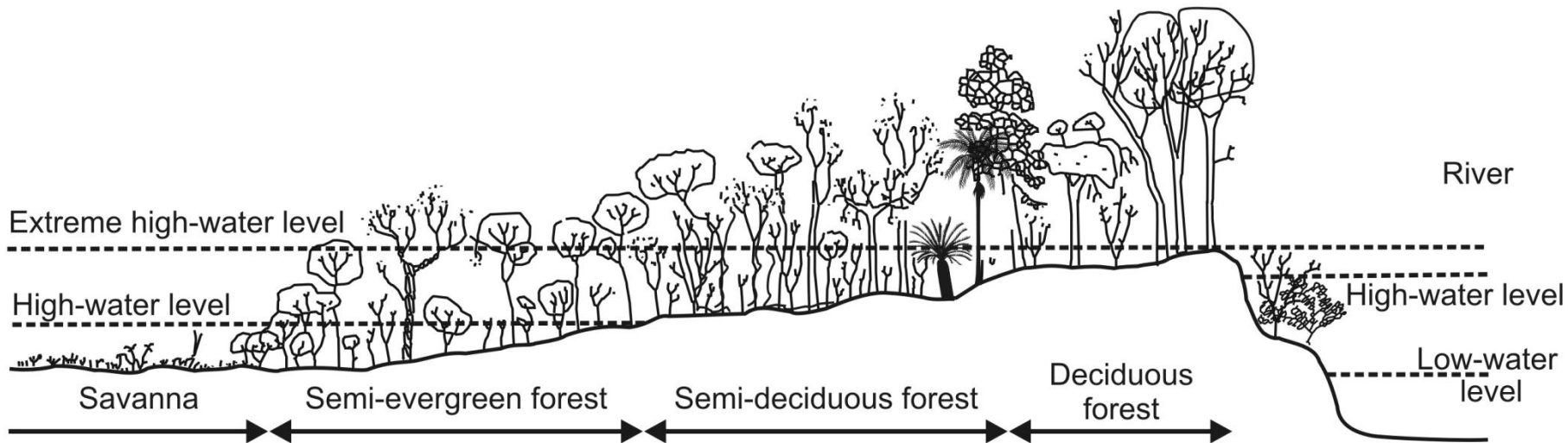
South America: Pantanal

Significance of flooding for tree distribution: zonation!



Significance of flooding for tree distribution

Zonation is related to flooding (and drought) tolerance of the plants



Da Cunha et al. 2007 Amazoniana

Growth and productivity

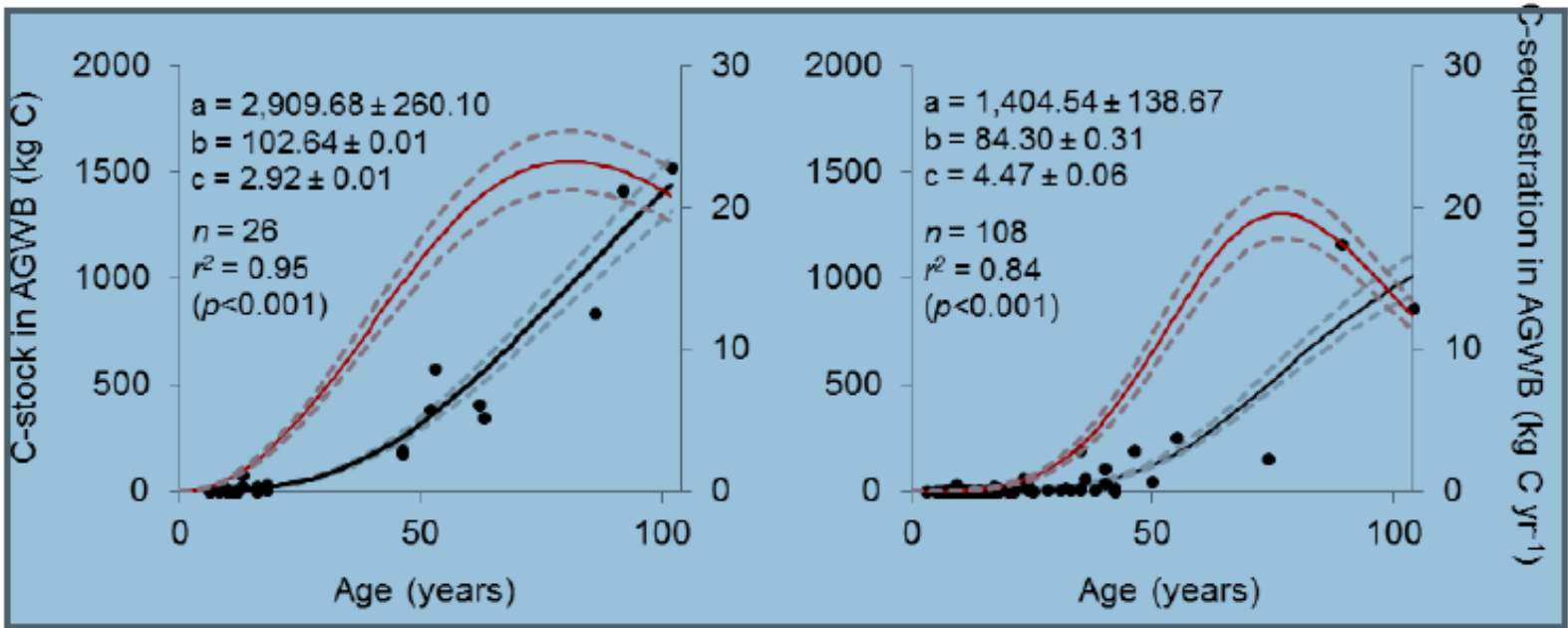


Fig. 4. C-stocks (black curve) and C-sequestration (red curve) of AGWB from *Vochysia divergens* and other tree species from Pantanal wetland forests related to tree ages. Indicated parameters are for Eq. (11). The dotted lines indicate the standard deviation.



Tree ring chronologies, C-cycles, annual increments

Africa: Okavango Delta





Phoenix reclinata in Moremi reserve (Pompom)

Africa: Okavango Delta



Max. flood height: mostly at root level

- salt, key role of riparian trees in perpetuating water quality (salt)

Moremi reserve (Pompom)



Chobe River National Park

Mopane tree

Significance of flooding for tree distribution

Africa:
Okavango
Delta

Distribution related to hydrological regime (depth, duration, timing of inundation) + soil chemistry

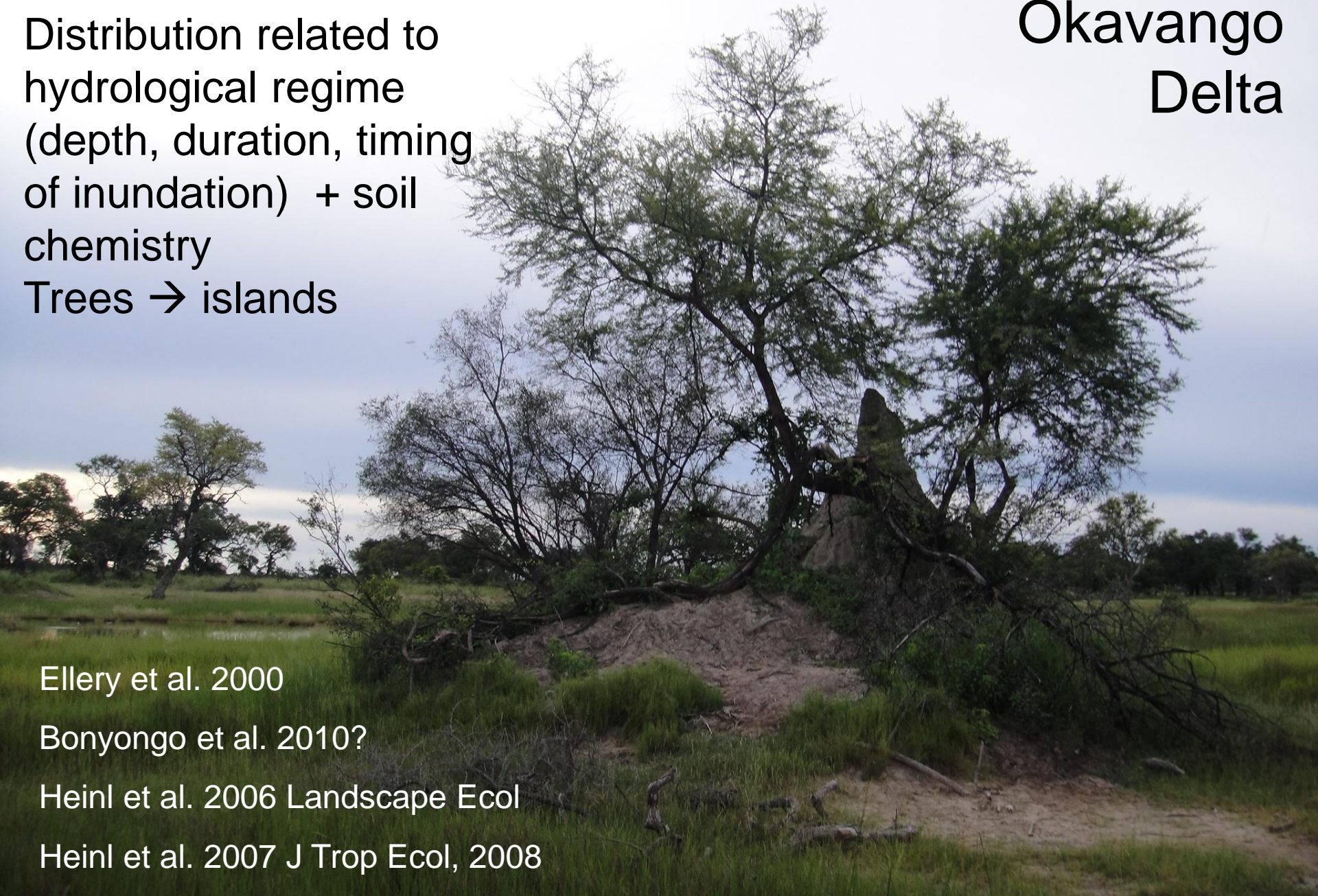
Trees → islands

Ellery et al. 2000

Bonyongo et al. 2010?

Heinl et al. 2006 Landscape Ecol

Heinl et al. 2007 J Trop Ecol, 2008



Africa: Okavango Delta

Tree responses to flooding ?

Moremi reserve (Pompom)

All I could find:
Acacias and Mopane are less flood tolerant, Pechuel is rather tolerant of flooding, and also of fire

Ringrose et al. 2003

Mantlana 2008 PhD thesis

Ellery et al. (2000), In: Biodiversity in wetlands: assessment, function and conservation. Backhuis, Leiden



Phenology

Waterberry *Syzygium* (?) on Chobe River



Seedling establishment



Dispersal syndromes

Seed germination

Seedling growth and
physiology

Seedling survival vs
mortality (long-term plots)

Tree growth and productivity



Annual increments

Tree ring analyses

...

Asia: Mekong Floodplains

Tonle Sap Freshwater Swamp Forests, Cambodia



Mekong Floodplains



Barringtonia acutangula (Lecythidaceae)



Invasive *Eichhornia crassipes* (Pontederiaceae)



Asia: Mekong Floodplains

Tree responses to flooding

Many deciduous at high water

Some maintain leaves below water (up to 8 mo) → physiological adaptations postulated

Fruit maturation at high water → dispersal linked to water

Huete 2007

Maltby et al. 2009

Sarkkula et al. 2009?



Asia: Mekong Floodplains

Significance of flooding for tree distribution:

Structure + composition of woody vegetation largely a function of microheterogeneity

soil moisture conditions, seasonal flood dynamics



Huete 2007

Maltby et al. 2009

Sarkkula et al. 2009?

Seedling establishment



Dispersal syndromes

Seed germination

Seedling growth and
physiology

Seedling survival vs
mortality (long-term plots)

Tree growth and productivity



Annual increments

Tree ring analyses

...

Overview shows that ...

Data availability (very) scarce!

(tree growth, ecophysiology, adaptations, seedlings establishment, growth, productivity ... ???)

→ Motivation to study these important ecosystems!

→ here today: only overview of 4 selected very large floodplains

Threats for worldwide wetlands

Increasing degree of human pressure:

Water abstraction

Changes in natural flood regime

Land reclamation

Pollution

Exploitation of natural resources

Increasing drought, climatic changes?



Lacks

World Wetland Day 2010: Max Finlayson:

“We still do not know HOW MUCH WETLAND we have in the world!”

Pia: so how can we possibly know how tree / forest ecology works, reforestation etc.??

Lack of basic knowledge

Vegetation (tree) distribution is described but

→ not really understood why

→ basic data for management plans, restoration and replanting, sustainable use – missing!

Conclusions: scientific point of view

Publish knowledge and data
(not only grey literature or lists
in the drawer)



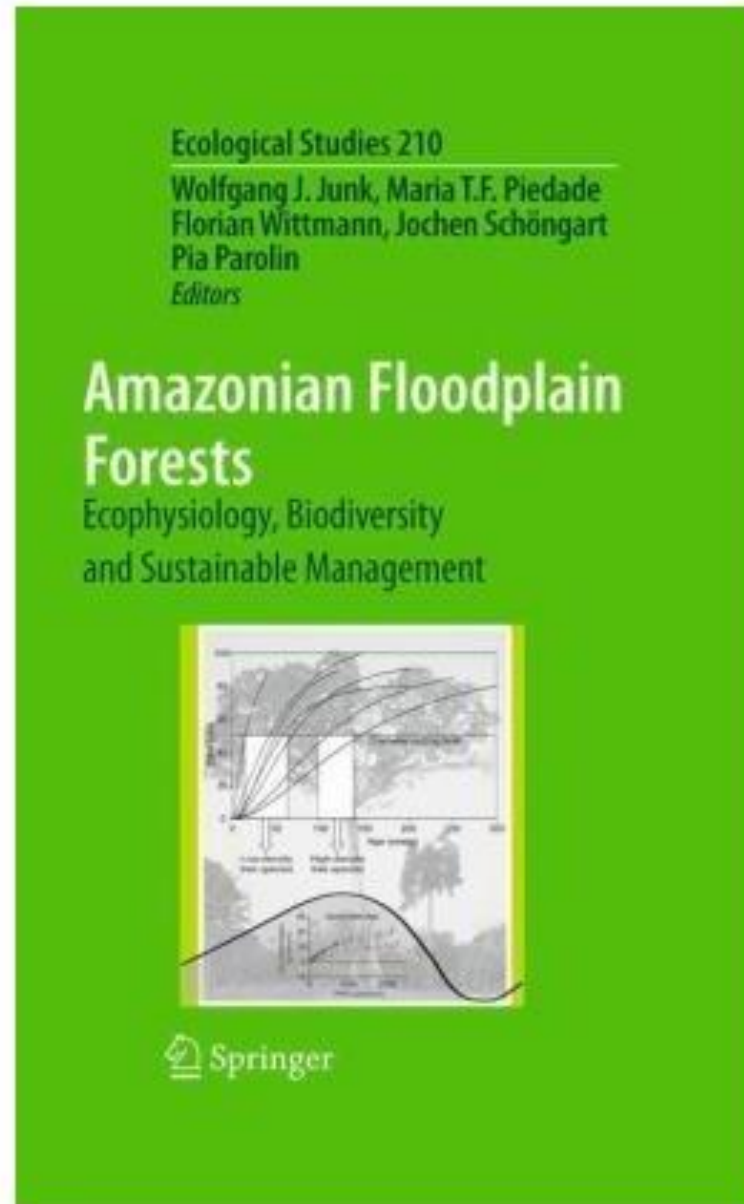
**Information exchange, discuss sampling
methods, compare results, classifications, joint
research projects – across continents**

**Ensure that the outcomes of research reach
those who need the information!**

SPRINGER BOOK 2010

In: Ecological Studies,
Springer Verlag,
Heidelberg

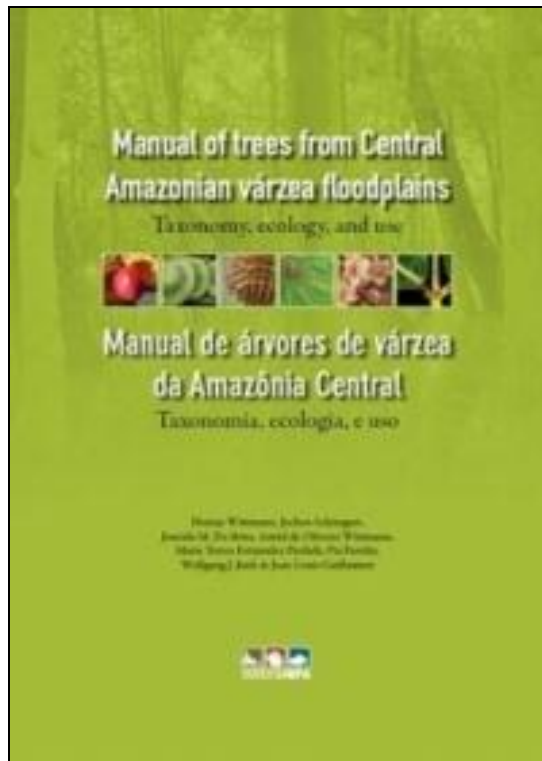
Wolfgang J. Junk, Maria T.
F. Piedade, Pia Parolin,
Florian Wittmann and
Jochen Schöngart (eds.)



Wittmann F., Schöngart J., Brito J.M., Wittmann A.O., Piedade M.T.F., Parolin P., Junk W.J. & Guillaumet J.-L., 2010.

Manual of trees from Central Amazonian várzea floodplains: taxonomy, ecology and use.

Instituto Nacional de Pesquisas da Amazonia - INPA, Manaus. 310 pp.



Lecythidaceae

Couropita guianensis Aubl.

Local name: *Macacareoula*, *Castanha de macaco*, *Abrió de macaco* (BR), *Ayahuma* (PE), *Cannonball tree* (Engl.)

Synonyms: *C. acreensis* R. Knuth, *C. antillana* Miels, *C. froesii* R. Knuth, *C. idiolica* Dwyer, *Courarati pedicellaris* Rizzini

GD: CA, WA, CA, WA
Habitat HV, TF
Sc: late
St: HC
H: 30-35 m
Ph: deciduous
Wd: 0.40-0.65 g cm⁻³
MDI: 5.92 ± 3.38 mm yr⁻¹



Descrição: árvore decídua do estrato superior, frequente nas margens dos paranás, mas rara em florestas com dossel fechado. Tronco monopodial, ramos com crescimento rítmico. Ritidoma liso. Folhas simples, sem glândulas, espiralmente agregadas. Flores amarelas ou avermelhadas em racemas, cauliflorais, terminais. Ornitófila ou cheiropterofila. Frutos grandes, pesados (às vezes acima de 5 kg), diretamente no tronco ou nos ramos principais, **circumscissile** (panela de macaco), com muitas sementes pequenas e polpa branca, mas verde quando oxida.

Uso: Extrato de flores, frutos, folhas e casca da raiz com propriedades antelmínticas e antimicóticas. Usado em perfumes e cosméticos. Frutos comestíveis, mas com odor desagradável. Árvore ornamental, cultivada na América Central e SE-USA. Madeira para móveis, brinquedos, embalagens e laminados.

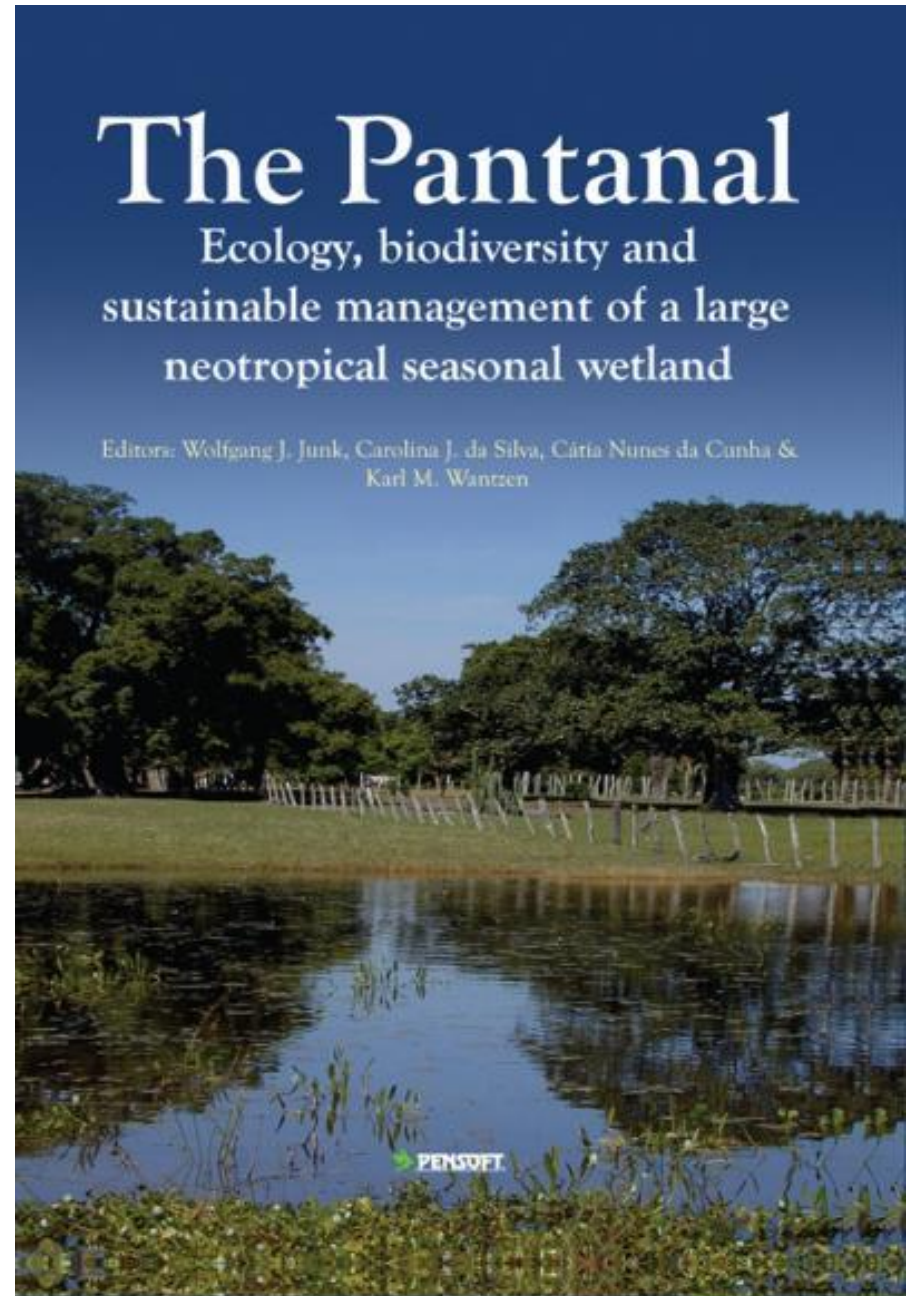
Description: deciduous tree of the upper canopy, frequent on river banks, but rare within close canopy forests. Monopodial trunk, rhythmic branching. Bark smooth. Leaves simple, not gland-dotted, spiral aggregated. Flowers yellow or red in racemes, cauliflorous, terminal. Ornithophilous, or cheiropterophilous. Fruits large, heavy (sometimes up to 5 kg), directly on the trunk and main branches, circumscissile ('monkey pots'), many small seeds, white flesh, but green when oxidating.

Use: Antimicrobial and antifungal extract from flowers, fruits, leaves and root bark. The flowers are used to scent perfumes and cosmetics. Fruits are edible but with unpleasant odor. Ornament tree in Central America and SE-USA. Timber for furniture, toys, packing material, and laminated fiber sheets.



**The Pantanal: Ecology,
biodiversity and
sustainable management
of a large neotropical
seasonal wetland.**

W. J. Junk, C. J. da Silva, C.
Nunes da Cunha, and K. M.
Wantzen (eds. 2010): Pensoft
Publishers, Sofia, 857pp.



Thanks to...

Max-Planck Limnology / Tropical Ecology group in Plön,
Germany (WJ Junk)

INPA / Max-Planck-group Manaus, Brazil

All colleagues and students and fishermen

