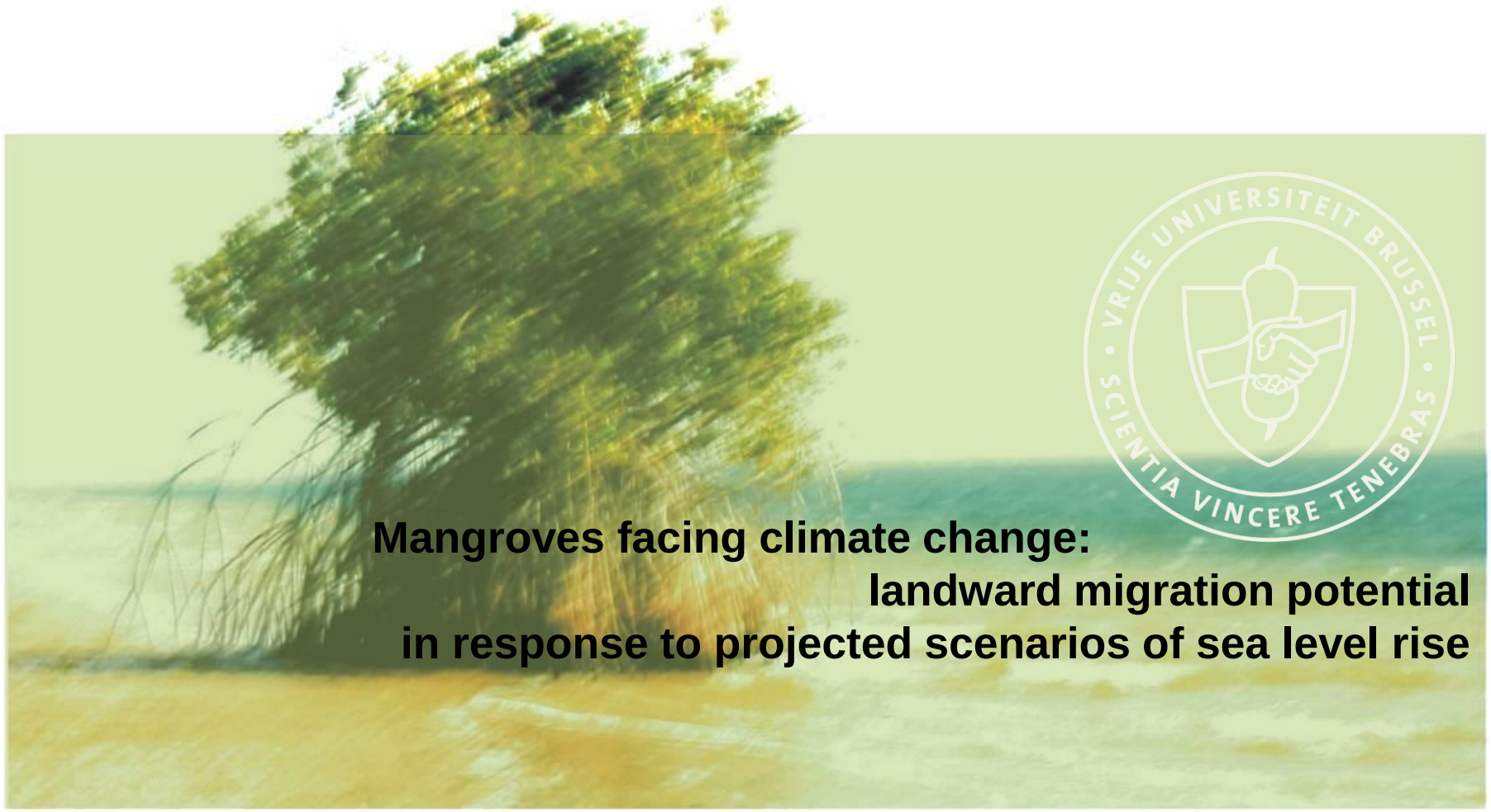


Mangroves facing climate change: landward migration potential in response to projected scenarios of sea level rise

Diana Di Nitto, Elisabeth M.R. Robert, Silvia Lechthaler, Griet Neukermans, Nico Koedam, Helen Defever, Frank Pattyn, James G. Kairo & Farid Dahdouh-Guebas

Research funded by VLIR, FWO, Fonds David & Alice Van Buuren
In collaboration with Deltares, Delft

Vrije Universiteit Brussel

ULB UNIVERSITÉ LIBRE DE BRUXELLES, UNIVERSITÉ D'EUROPE

FWO VLAANDEREN

vliruos SHARING MINDS, CHANGING LIVES

Introduction

What when the ‘weather’ changes ?

Move to better places

Greece, 37°N

Adapt

France, 51°N

Introduction

What when the ‘weather’ changes ?

Move to better places

Mauritania, 19°N

Adapt

France, 51°N

Introduction

What when the ‘weather’ changes ?

Introduction

What when the ‘climate’ changes ?

Move to better places ?

Adapt ?

Introduction

What when the ‘climate’ changes ?

Move to better places ?

A case study on forecasted local mangrove **biotope shift** (SLR)

A case study on forecasted mangrove **range shift** (climate)

Adapt ?

A case study on mangrove **hydraulic plasticity**

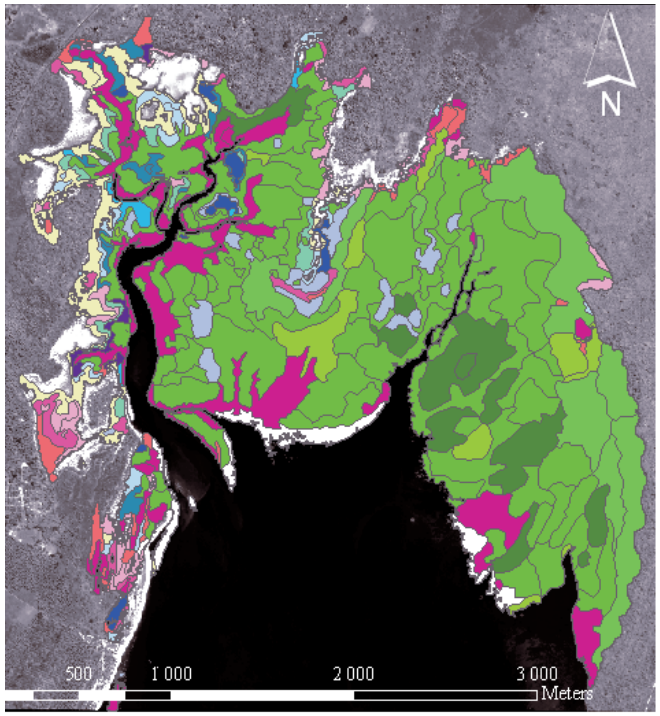
A case study on mangrove **stress responses**

Move to better places ?

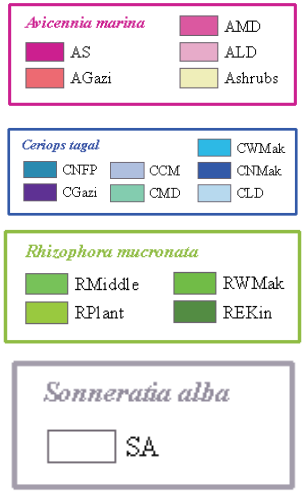
A case study on forecasted local mangrove **biotope shift** (SLR)

Gazi Bay, Kenya

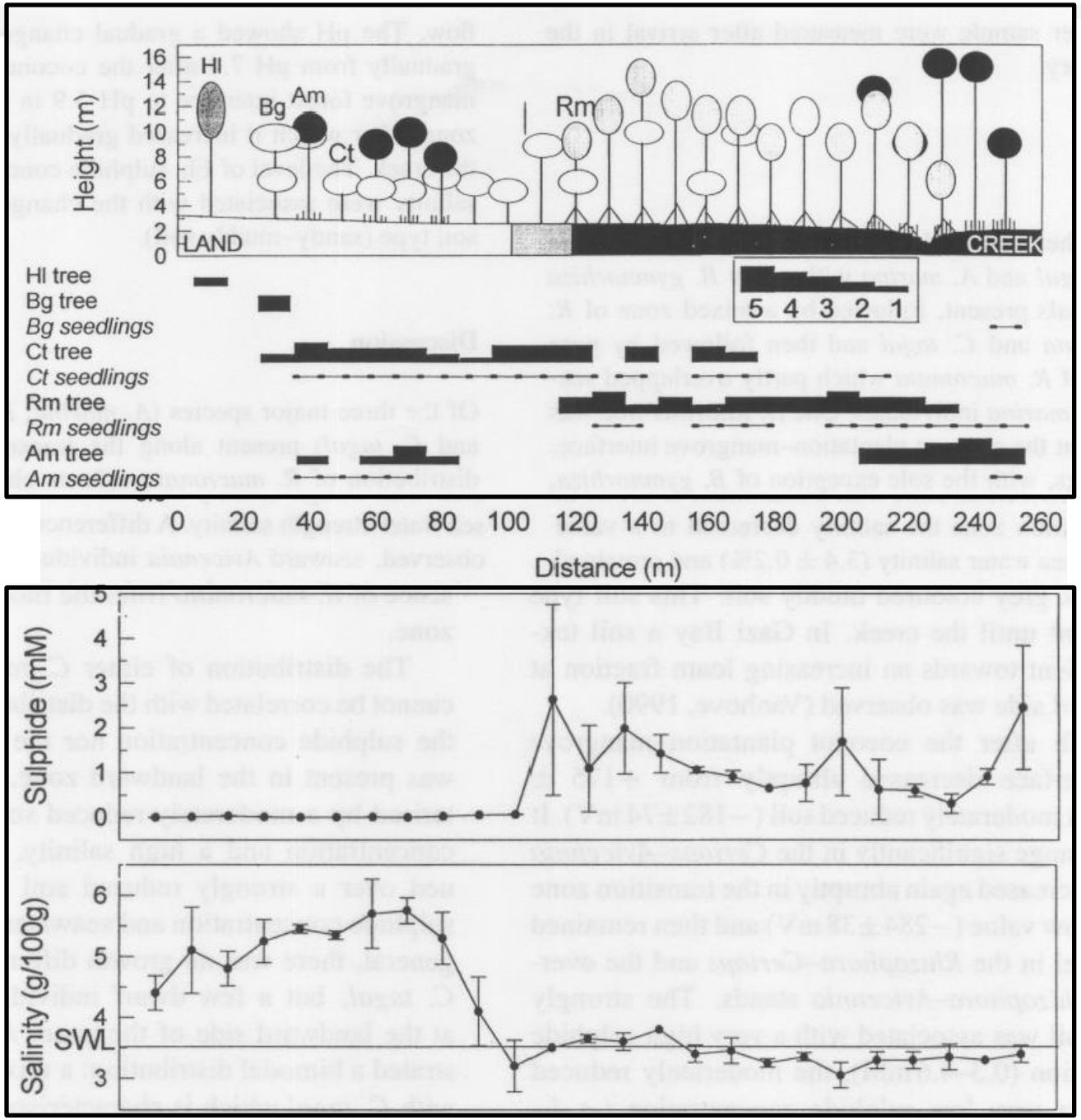
Visually delineated and labeled mangrove stands



Various species dominances



Neukermans *et al.*, 2008



Various species dominances and environmental conditions as related to **tidal position**

Gazi Bay

Matthijs *et al.*, 1999

Move to better places ?

A case study on forecasted local mangrove **biotope shift** (SLR)

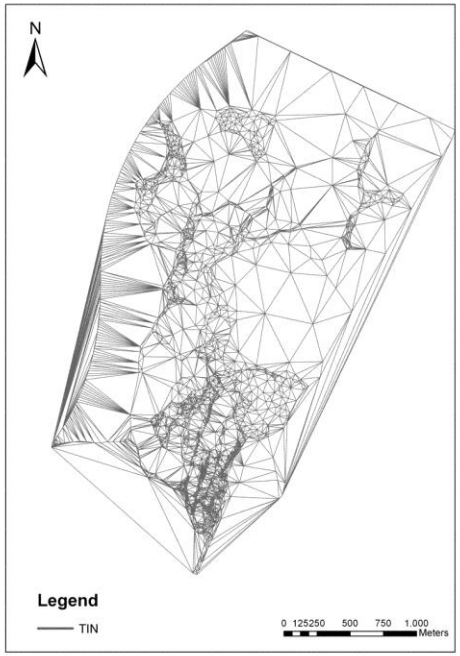
parsimonious expectation:
with Sea Level Rise a landward biotope shift will take place

Methodology

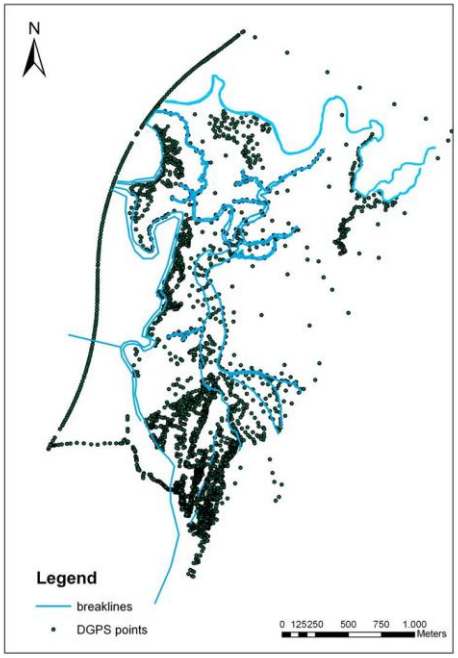
A very high resolution assessment of a section of Gazi Bay mangrove forest

DGPS

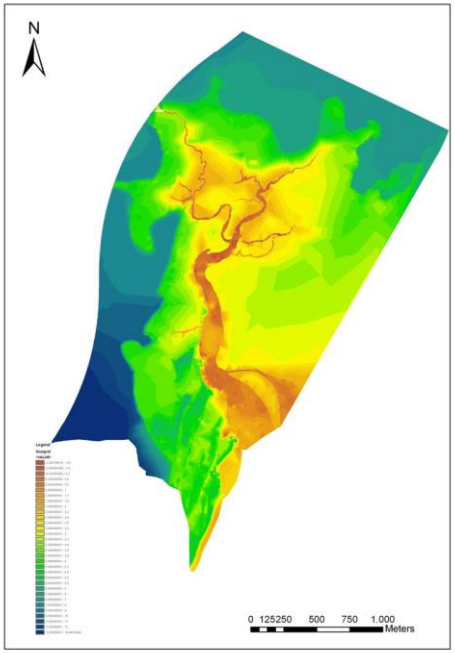
TIN



Breaklines



Final DTM

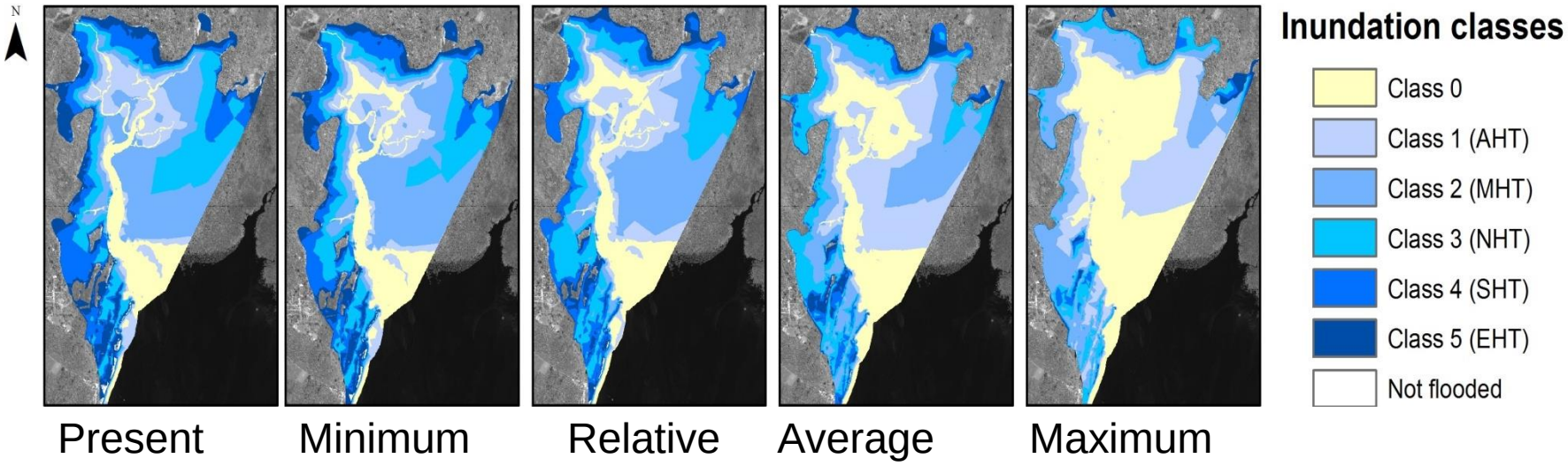


Differential GPS

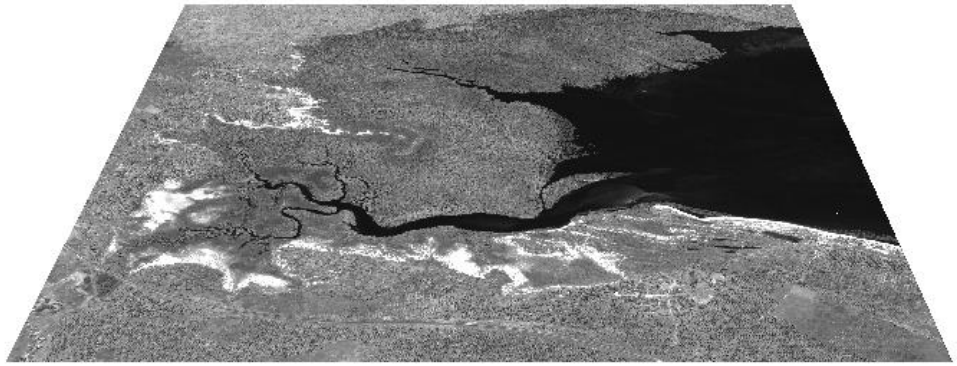
Digital terrain model

A very high resolution assessment of a section of Gazi Bay mangrove forest

Inundation classes under different scenarios of SLR ‘raising the tides’



A very high resolution assessment of a section of Gazi Bay mangrove forest



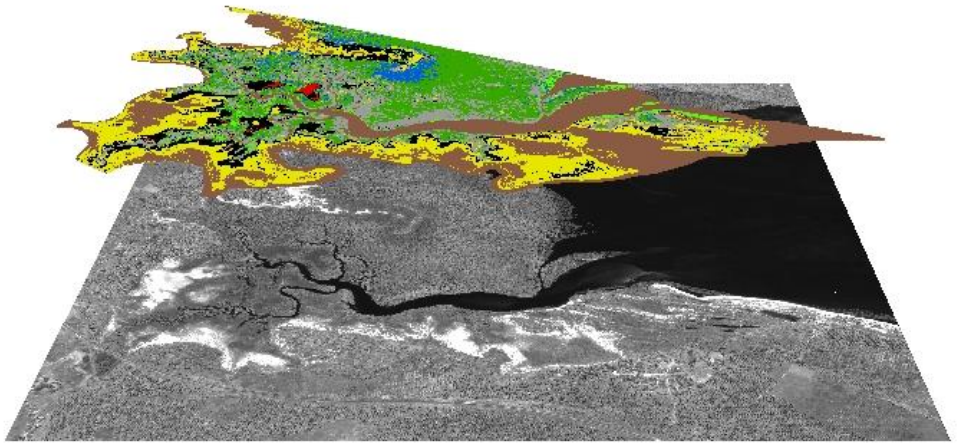
Inundation classes

Vegetation map

(*Griet Neukermans, 2004)*

Quickbird

A very high resolution assessment of a section of Gazi Bay mangrove forest



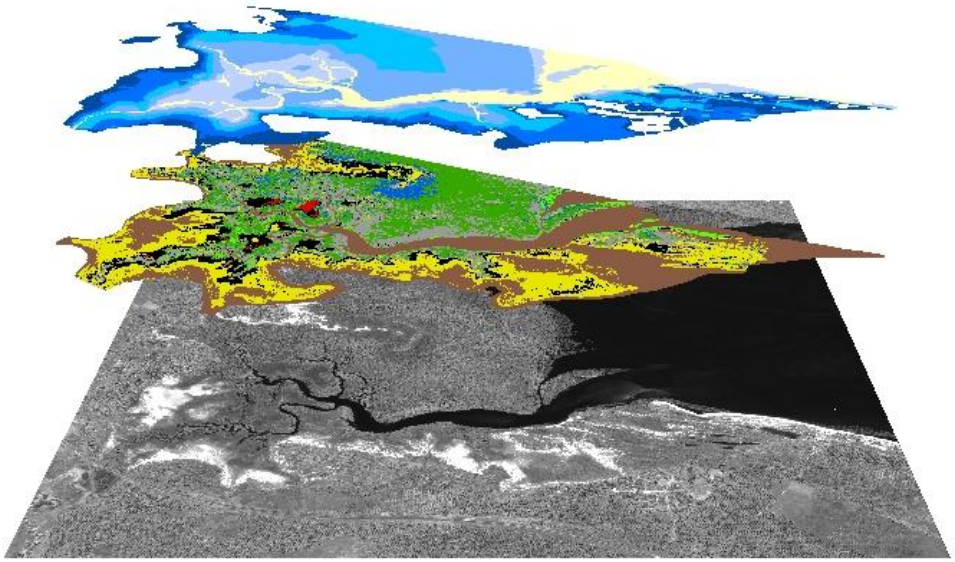
Inundation classes

Vegetation map

(*Griet Neukermans, 2004)*

Quickbird

A very high resolution assessment of a section of Gazi Bay mangrove forest



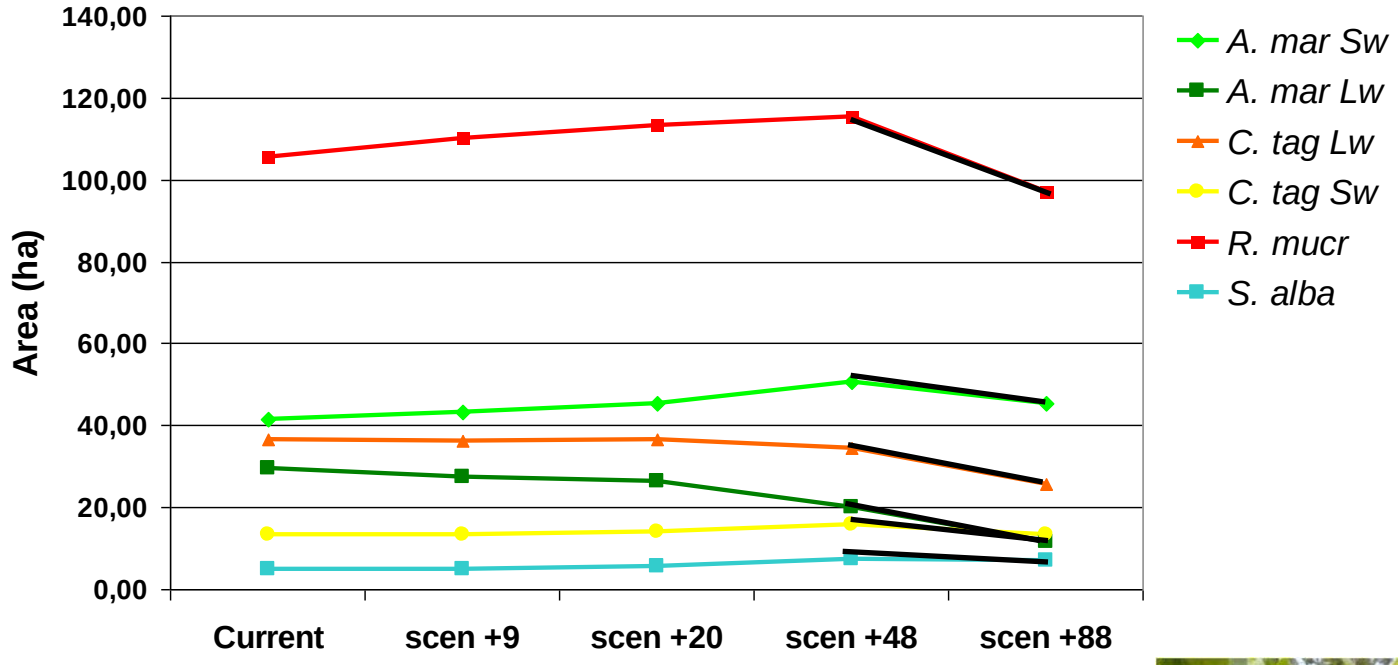
Inundation classes

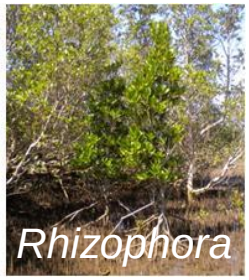
Vegetation map

(*Griet Neukermans, 2008)*

Quickbird

Total increase/decrease per species within the 4 SLR scenarios





Move to better places ?

A case study on forecasted local mangrove **biotope shift** (SLR)

parsimonious expectation:
with Sea Level Rise a landward biotope shift will take place

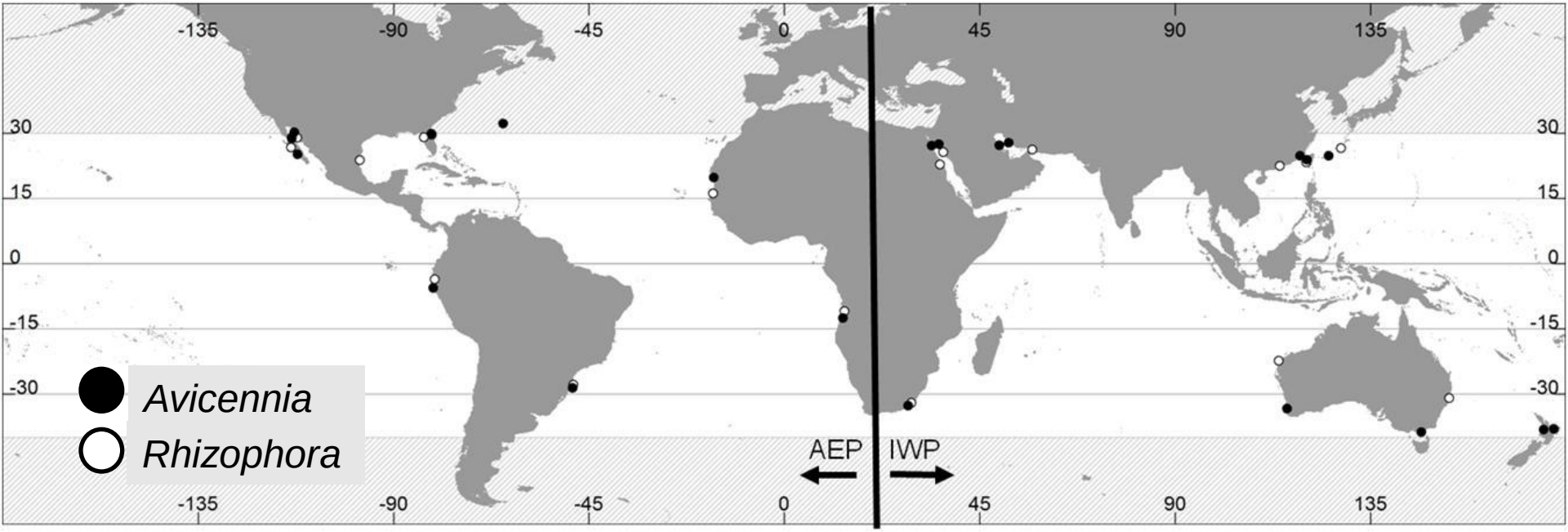
mangroves of Gazi Bay (Kenya):
potential for landward migration with moderate SLR scenarios, however:
floristic balance shifts at high SLR scenarios

X

Move to better places ?

A case study on forecasted mangrove **range shift** (climate)

Global distribution of mangroves



Quisthoudt *et al.*, 2012

Move to better places ?

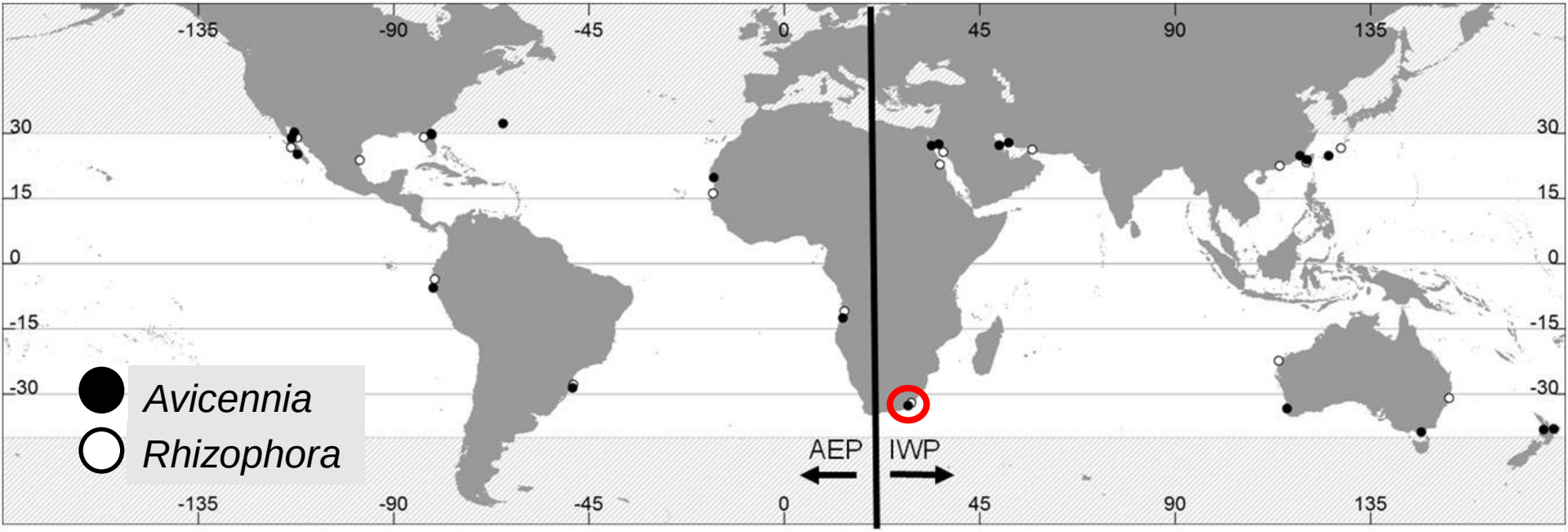
A case study on forecasted mangrove **range shift** (climate)

parsimonious expectation:
with global warming mangrove ranges will shift poleward

Move to better places ?

A case study on forecasted mangrove **range shift** (climate)

Global range limits of mangroves



Quisthoudt *et al.*, 2012

Species distribution modelling (*A. marina*, *B. gymnorrhiza*, *R. mucronata,* 'all mangroves') in South Africa

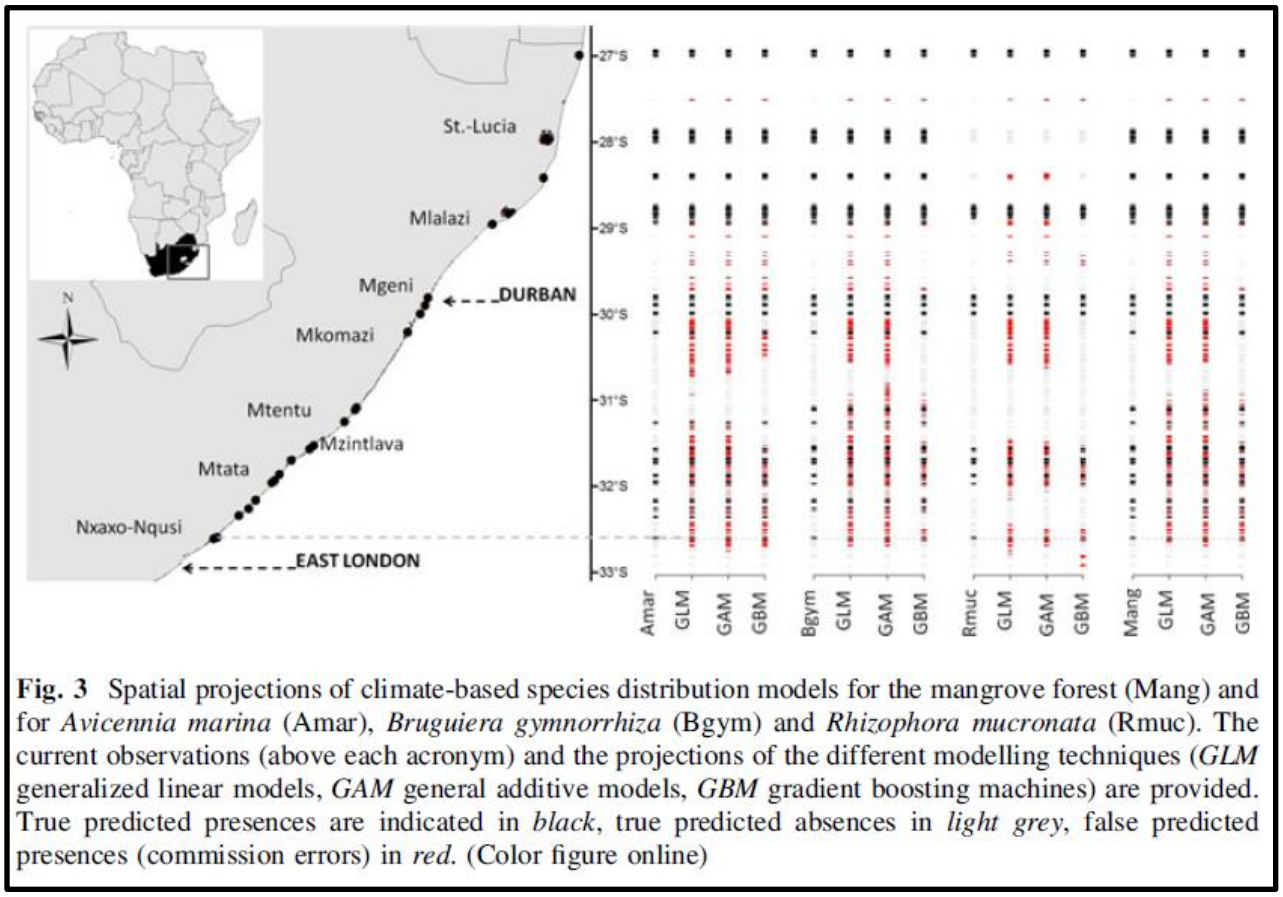


Fig. 3 Spatial projections of climate-based species distribution models for the mangrove forest (Mang) and for *Avicennia marina* (Amar), *Bruguiera gymnorrhiza* (Bgym) and *Rhizophora mucronata* (Rmuc). The current observations (above each acronym) and the projections of the different modelling techniques (*GLM* generalized linear models, *GAM* general additive models, *GBM* gradient boosting machines) are provided. True predicted presences are indicated in *black*, true predicted absences in *light grey*, false predicted presences (commission errors) in *red*. (Color figure online)

Quisthoudt *et al.,* 2013

Prediction:

True presence

True absence

False presence

Collaboration with Janine Adams (South Africa), Anusha Rajkaran (South Africa), Christophe F. Randin (Switzerland)

Predicted latitudinal position change of *A. marina*, *B. gymnorrhiza*, *R. mucronata* and 'all mangroves' in South Africa

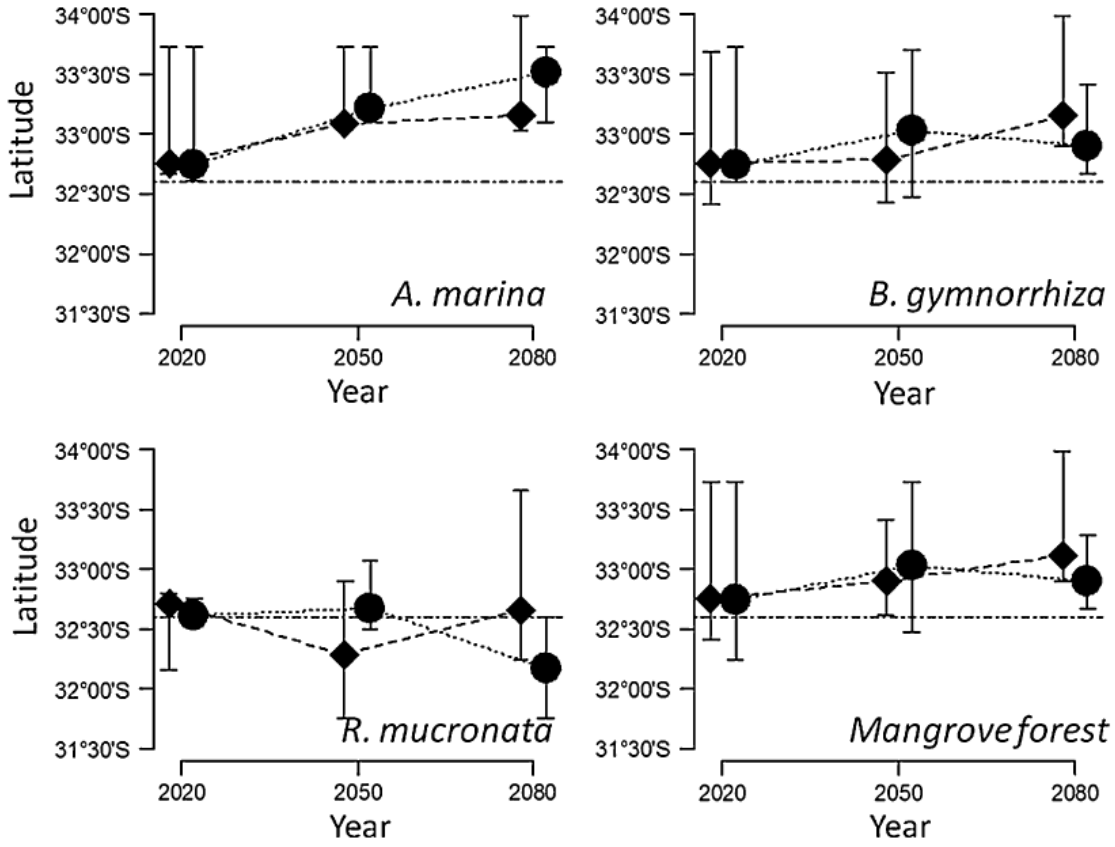


Fig. 4 Predictions of the future position of the latitudinal limits of the mangrove forest and its species in South-Africa. The positions of the limits given by the majority of the model predictions (majority is four out of six outcomes given by two GCMs × three modelling techniques) for each of the two climate scenarios is represented by *diamonds* for A2a and *circles* for B2a. The upper latitudinal limits of the most progressive and most conservative model predictions are indicated with the *error bars*. The current latitudinal limit is shown with a *horizontal dot-dash line*

Quisthoudt *et al.,* 2013

Move to better places ?

A case study on forecasted local mangrove **biotope shift** (SLR)

parsimonious expectation:
with global warming mangrove ranges will shift poleward

mangroves of South African range limit:
both poleward shifts and reduction scenarios under global warming

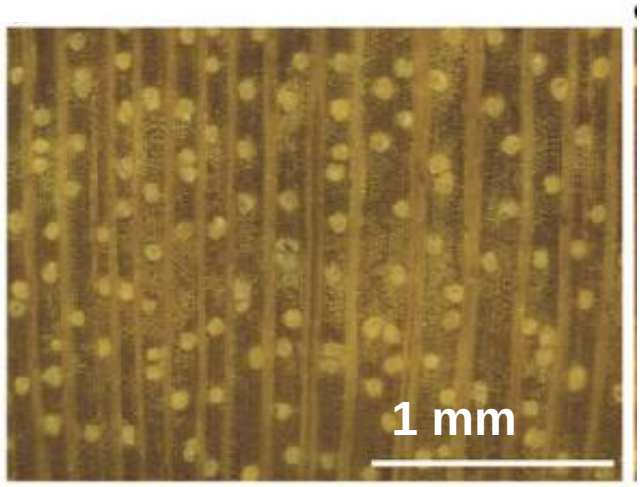
X

Adapt ?

A case study on mangrove **hydraulic plasticity**

stem section

vessels



Robert *et al.,* 2010

$$\dot{V} = \frac{-\pi r^4 \delta P}{8 \eta \ \delta x} \qquad [m^3 s^{-1}] \qquad \textbf{(law of Hagen-Poiseuille)}$$

$\dot{V}$ = volume flux density

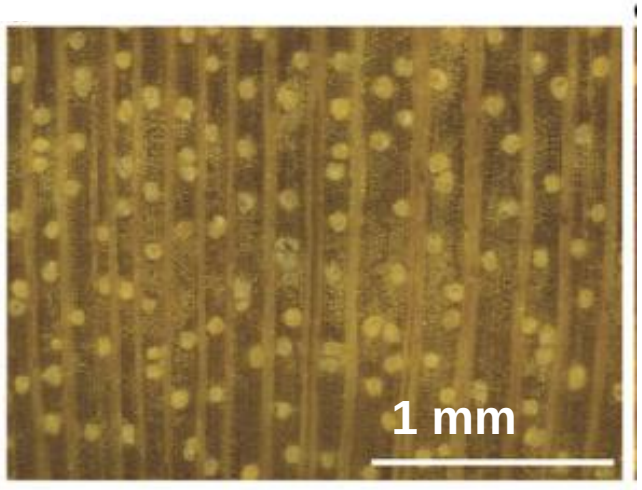
r = radius vessel

Adapt ?

A case study on mangrove **hydraulic plasticity**

stem section

vessels



Robert *et al.,* 2010

…but trade-off: embolism risk (gas bubble blocking water transport under water stress)

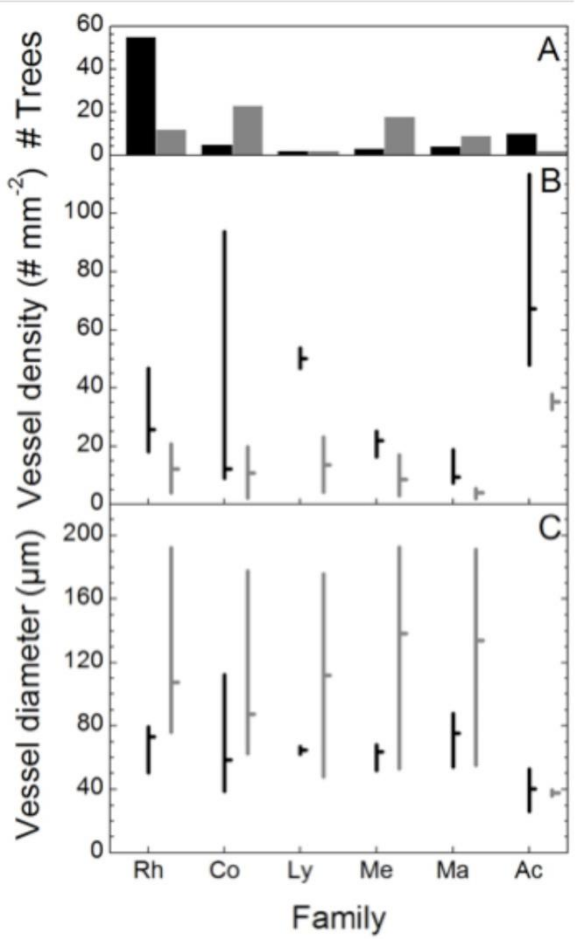
$$\dot{V} = \frac{-\pi r^4 \delta P}{8 \eta \ \delta x}$$

[$m^3 s^{-1}$] (law of Hagen-Poiseuille)

$\dot{V}$ = volume flux density

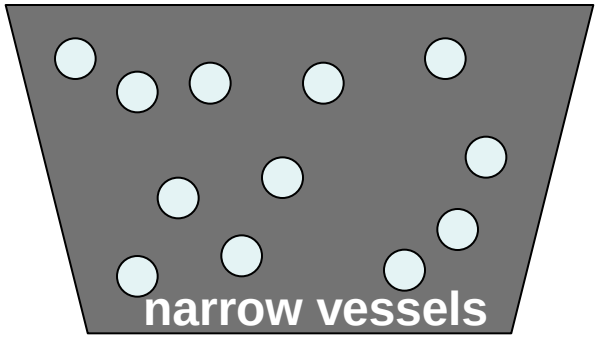
r = radius vessel

Mangrove wood anatomy convergent

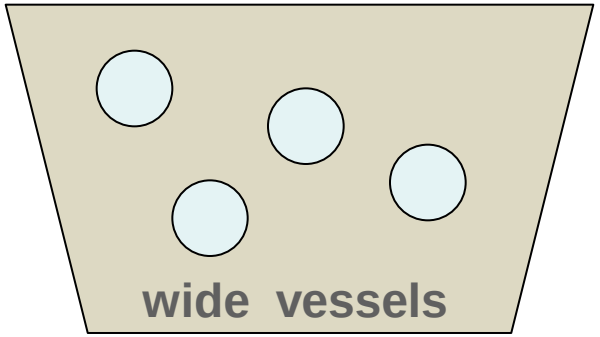


Black: mangroves
Grey: non-mangrove relatives

MANGROVES



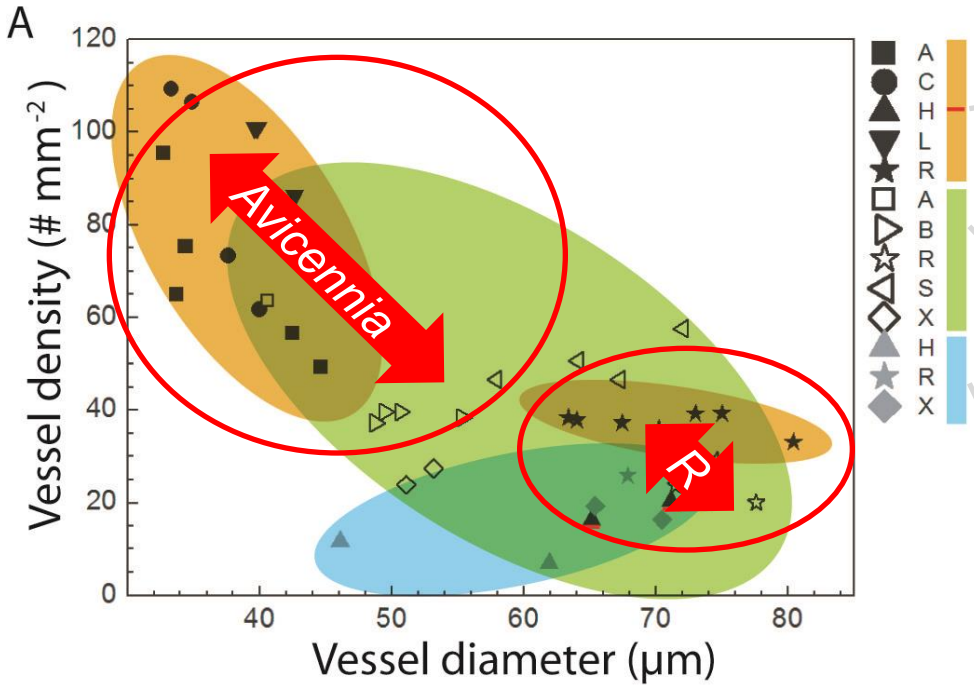
NON-MANGROVE RELATIVES



Survival in the mangrove forest requires numerous narrow vessels : **‘a mangrove hydraulic signature’**

wood anatomy ~ mangrove distribution: adaptation

A



B

Site	Species	Range of soil water salinity (‰)		Inund. Freq.
		Dry season	Rainy season	(days/month)
Landward	A, C, H, L	40 - 90	10 - 57	5
Landward	R	58 - 70	40 - 61	23
Seaward	A, B, R, S, X	34 - 46	21 - 35	27
Upstream	H	42 - 61	5 - 68	5
Upstream	R, X	7 - 31	0 - 11	11

landward

= high risk for embolism

seaward

= lower risk for embolism

upstream

= lowest risk for embolism

Adapt ?

A case study on mangrove **hydraulic plasticity**

Move to better places ?

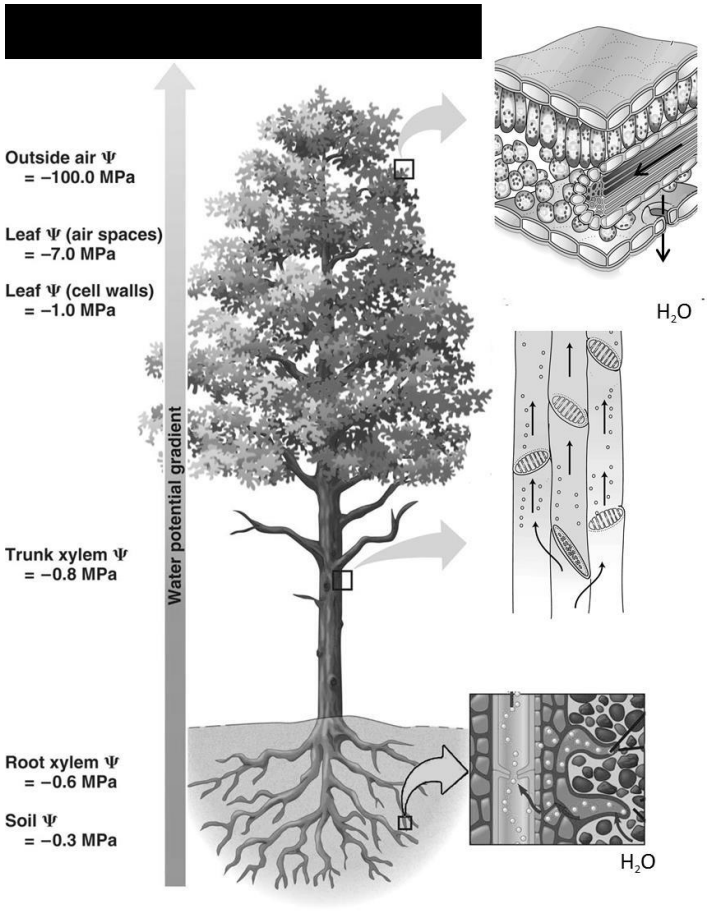
A case study on mangrove **hydraulic plasticity**

parsimonious expectation:
mangroves have a specific hydraulic architecture and flexibility therein as a function of environmental conditions

expectations corroborated. √

Adapt ?

A case study on mangrove **stress responses**



IN MANGROVE ENVIRONMENT

Sea water salt concentration: ~ 35 ‰

Soil water salinity (daily inundation): ~ 35 ‰

Soil water salinity (rare inundation): ~ 110 ‰

Rapid changes can also be induced by rainfall

Soil water potential ~ - 2.5 MPa

Figure adapted from Reece 2011 and Taiz and Zeiger 2010

Adapt ?

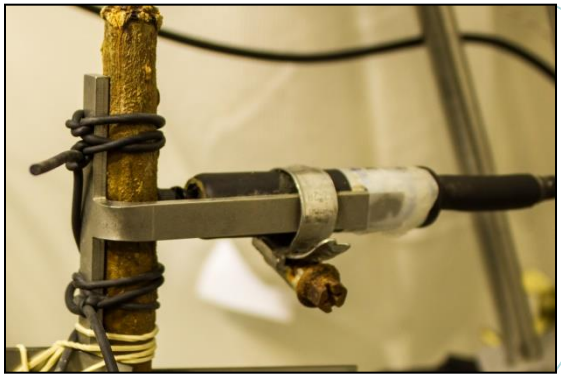
A case study on mangrove **stress responses**

parsimonious expectation:
fast and large salinity changes affect young mangrove plants negatively

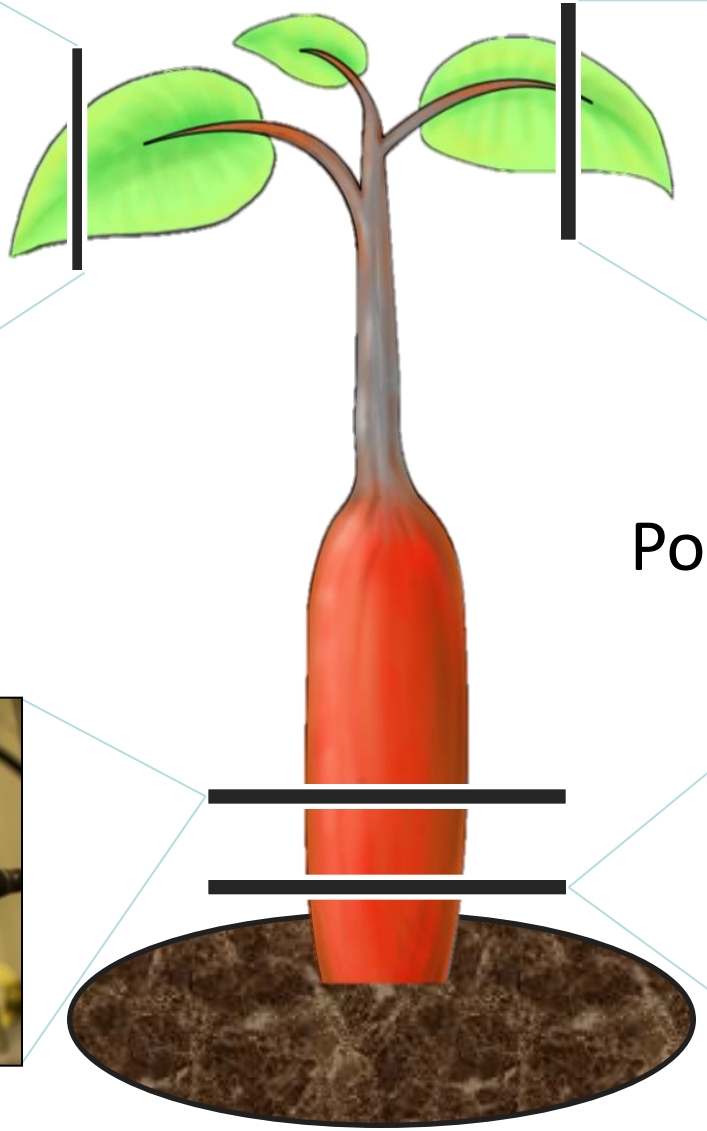
Rm (N=2), Bg (N=2)

Dendrometers

swelling | shrinking



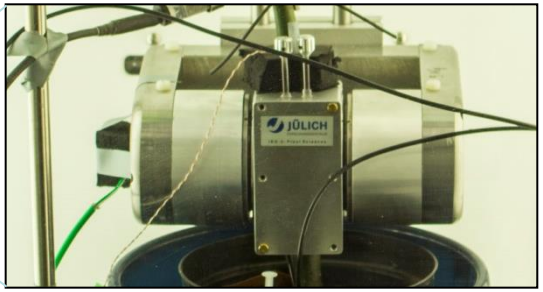
Rm (N=2), Bg (N=2)



Rm (N=1), Bg (N=1)

Portable NMR devices

water | content



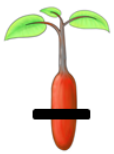
Rm (N=1), Bg (N=1)

* To avoid interferences between the two NMR devices, hypocotyl and leaf measurements were done on two different plants of the same species.

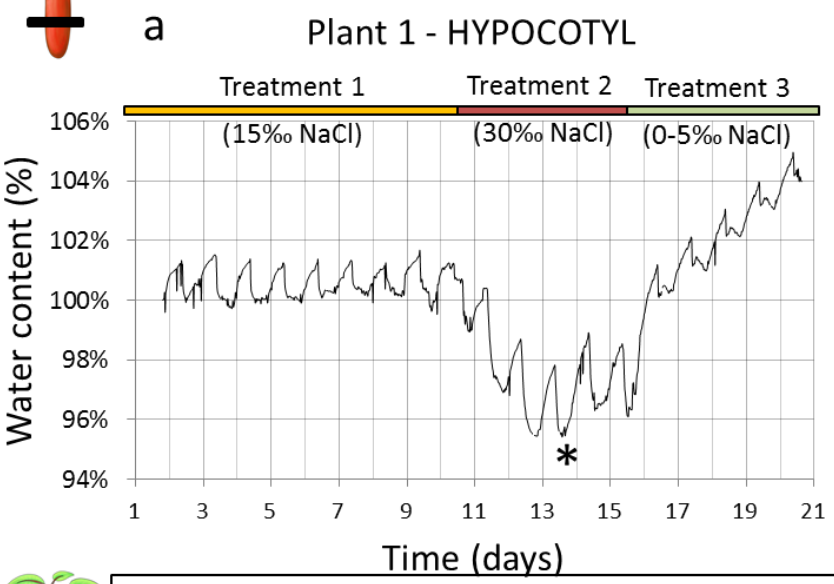
Guidance by Dr Carel Windt (Forschungszentrum Jülich)

Water content variations

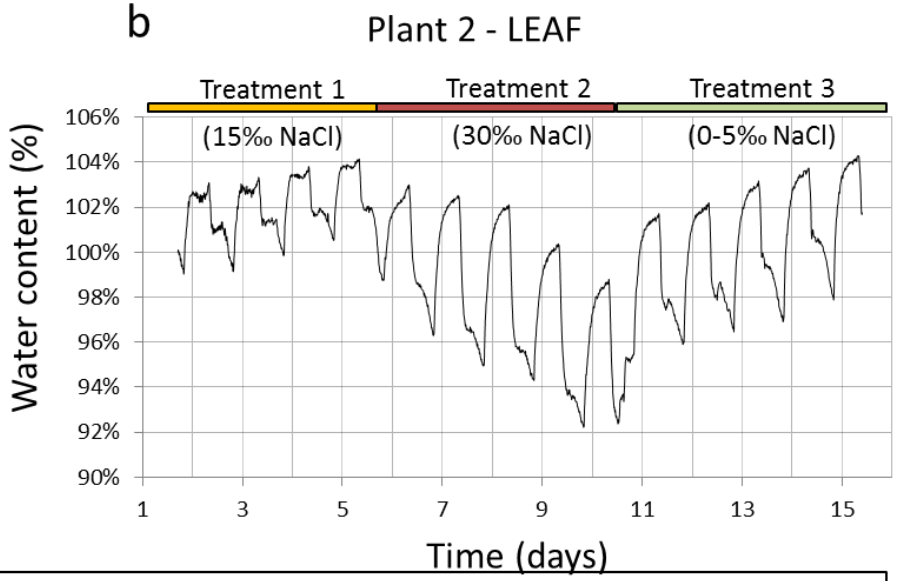
Rhizophora mucronata



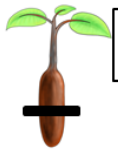
a



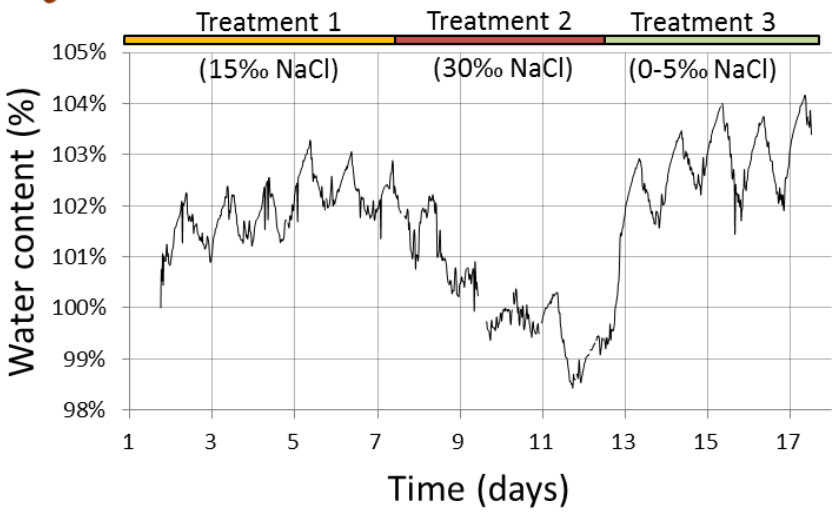
b



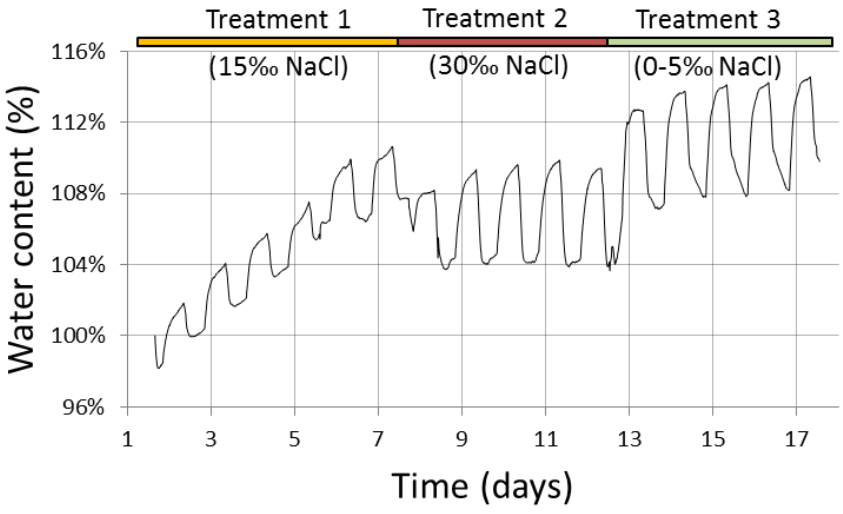
Bruguiera gymnorrhiza



c



d



Adapt ?

A case study on mangrove **stress responses**

parsimonious expectation:
fast and large salinity changes affect young mangrove plants negatively

mangroves studied (limited number !) show important resilience to major and sudden salinity changes at a time scale of several weeks.

X

Composite conclusion*

What when the ‘climate’ changes ?

Move to better places ?

Mangrove assemblages are expected to change floristically upon SLR and do not respond simply to climate change by range expansion.

Adapt ?

Mangrove hydraulic architecture is characteristic but flexibly adapted (within limits) and responds in a resilient way to abrupt salinity changes

* The conclusion is composite (based on a diverse set of data) and extrapolating on basis of some **simple assumptions**. Hence, its universal nature is not proven and a coherent **understanding is preliminary**. Integrated and coherent answers to CC responses can as yet not be given.