Canopy structure mediates the influence of edge effects on tropical forest diversity, function, biomass and microclimate.

Grégoire Blanchard*, Nicolas Barbier, Ghislain Vieilledent, Thomas Ibanez, Vanessa Hequet, Stéphane McCoy and Philippe Birnbaum

* AMAP, French Research Institut for Development, New Caledonia

EUROPEAN CONFERENCE OF TROPICAL ECOLOGY | Montpellier FRANCE 7- 9 June 2022

AMAPlab

Herbarium NOU

IRD Institut de Recherche pour le Développement FRANCE

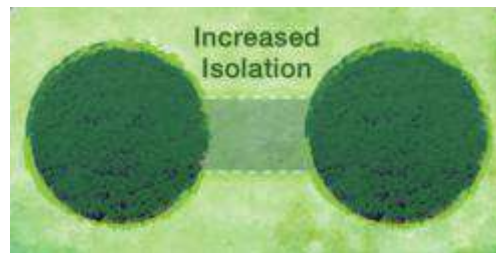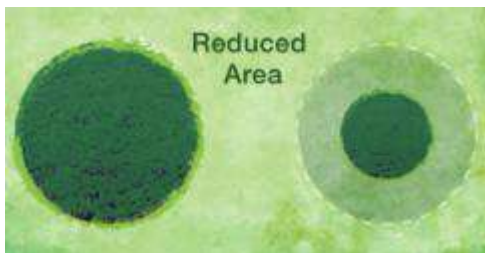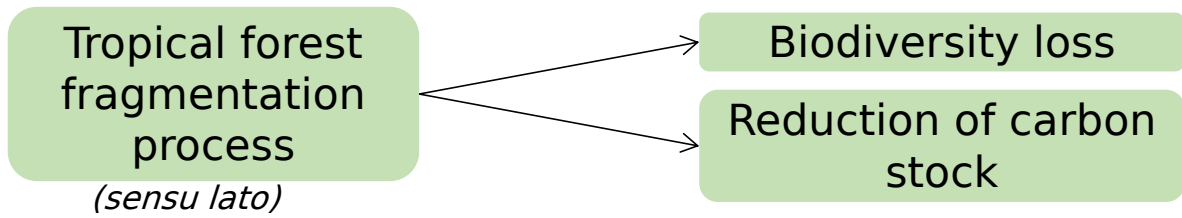cirad

CNRT NICKEL & son environnement

Tropical forest fragmentation: a global concern

~20% of tropical forests have disappeared since 1990 *(Vancutsem et al. 2021, Sci. Adv.)*

- Fragmentation experiments: 13 to 75% of biodiversity loss in 35 years *(Haddad et al. 2015, Sci. Adv.)*
- Reduction of carbon stock of ~ 425 teragrams of carbon per year (2003-2014) *(Baccini et al. 2017, Sci. Adv.)*

From ForestAtRisk website (Vieilledent G., C. Vancutsem, and F. Achard. 2022).

Tropical forest fragmentation process → Biodiversity loss

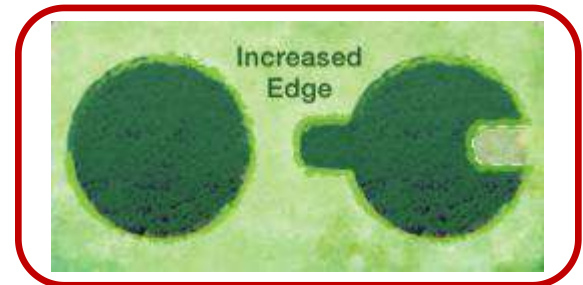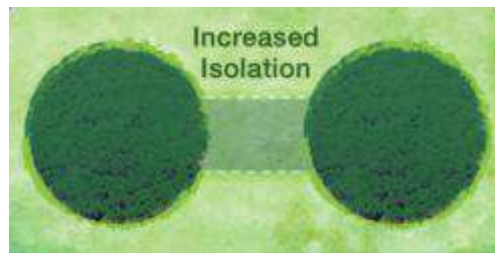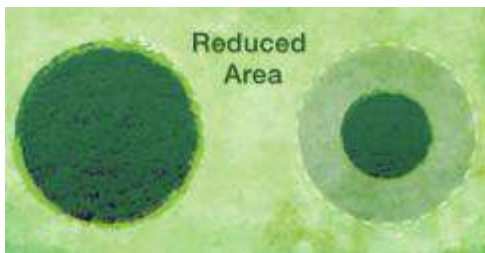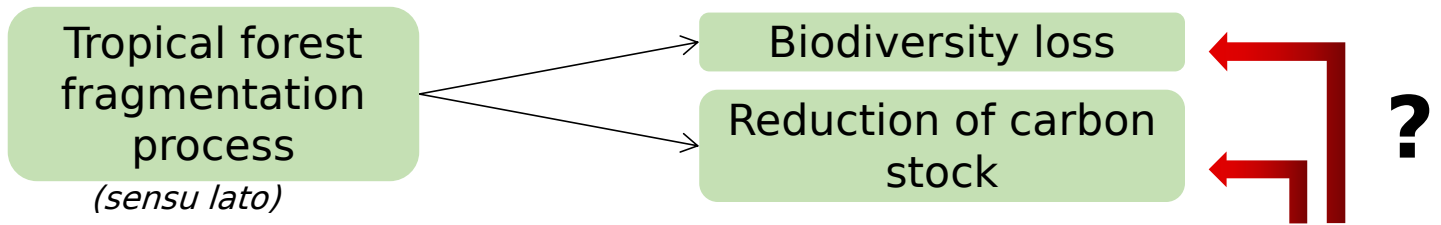Tropical forest fragmentation process → Reduction of carbon stock

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Tropical forest fragmentation process *(sensu lato)*

→ Biodiversity loss

→ Reduction of carbon stock

Reduced Area

Increased Isolation

Increased Edge

(Adapted from Haddad et al. 2015)

Tropical forest fragmentation: a global concern

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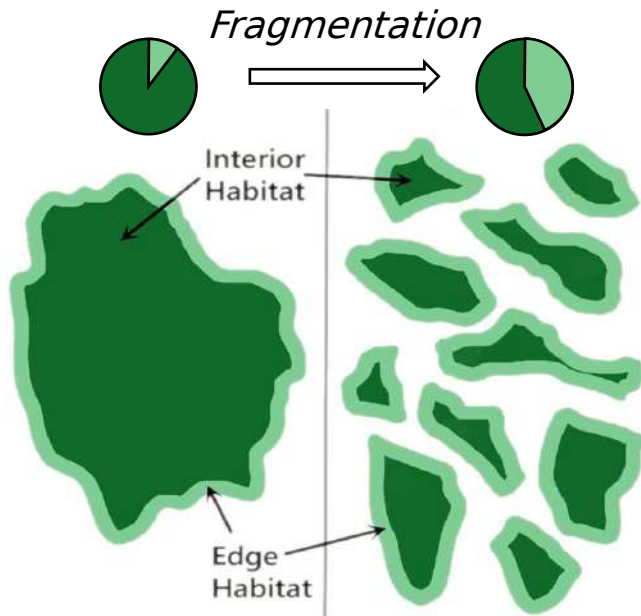- Reduction of carbon stock of ~ 425 teragrams of carbon per year (2003-2014) *(Baccini et al. 2017, Sci. Adv.)*

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Tropical forest fragmentation process *(sensu lato)*

Biodiversity loss

Reduction of carbon stock

?

Reduced Area

Increased Isolation

Increased Edge

(Adapted from Haddad et al. 2015)

Increasing fragmentation means increasing edge influence

Fragmentation

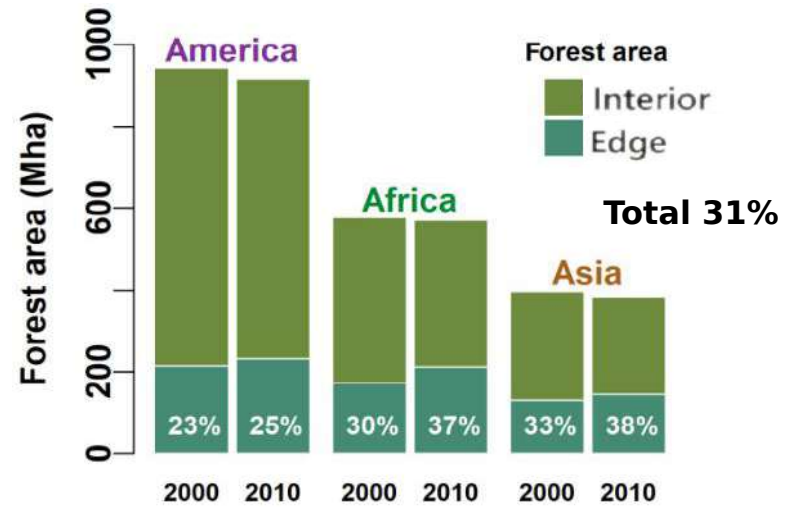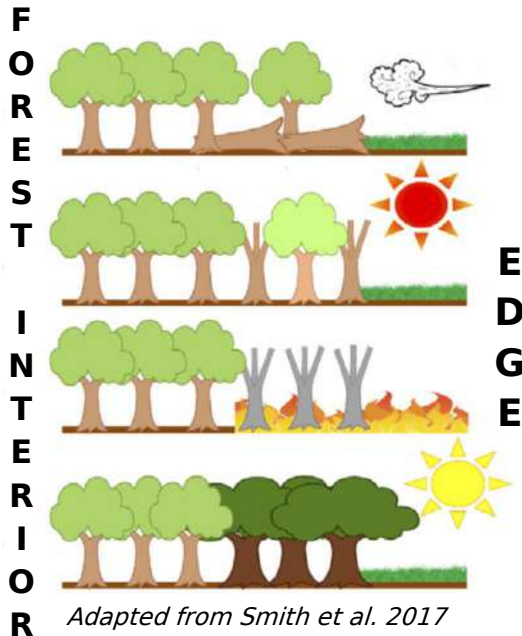Globally increasing edge area in tropical forests (<100 m from edge)

Total 31%
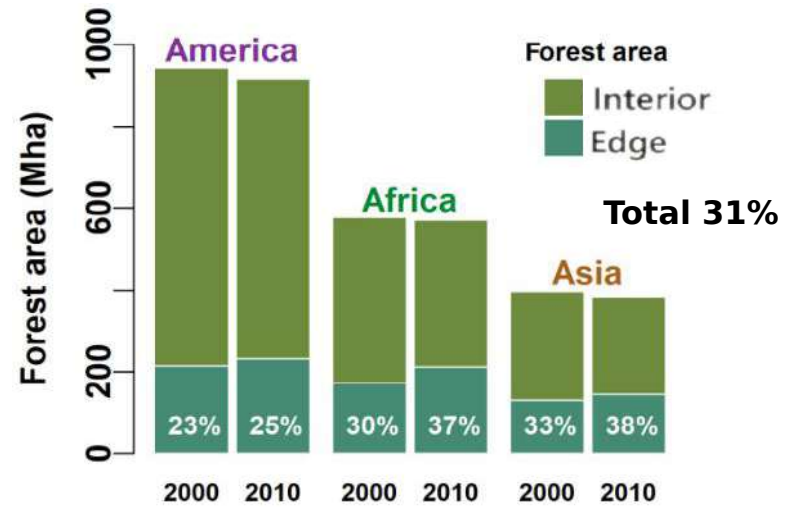
From Fischer et al. 2021, Sci. Adv.

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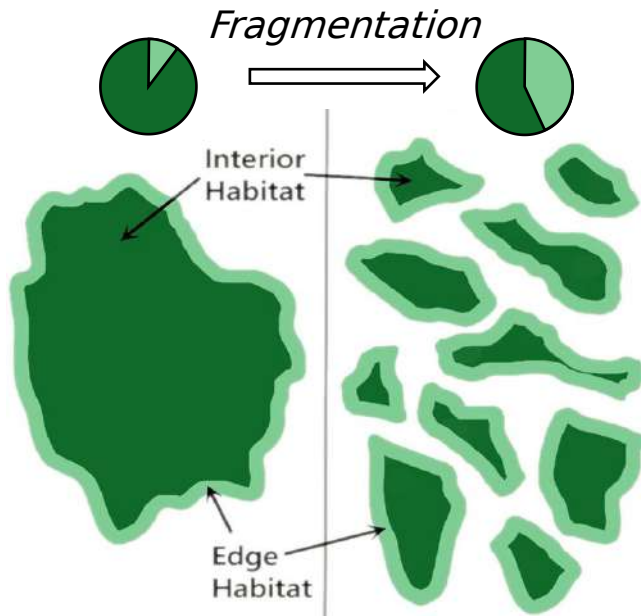
Fragmentation

Interior Habitat

Edge Habitat

Globally increasing edge area in tropical forests (<100 m from edge)

Forest area (Mha)

America

Africa

Total 31%

Asia

Forest area
Interior
Edge

	2000	2010	2000	2010	2000	2010
	23%	25%	30%	37%	33%	38%

From Fischer et al. 2021, Sci. Adv.

F O R E S T

I N T E R I O R

Adapted from Smith et al. 2017

E D G E

Altered environmental conditions

Altered structure, diversity and composition

Edge effects on tropical forest :

• Increasing exposure to wind and fire

• Hotter and drier microclimate

• Biomass reduction (large trees decline)

• Diversity loss

• Change in species composition

*=> **Different forest characteristics!***
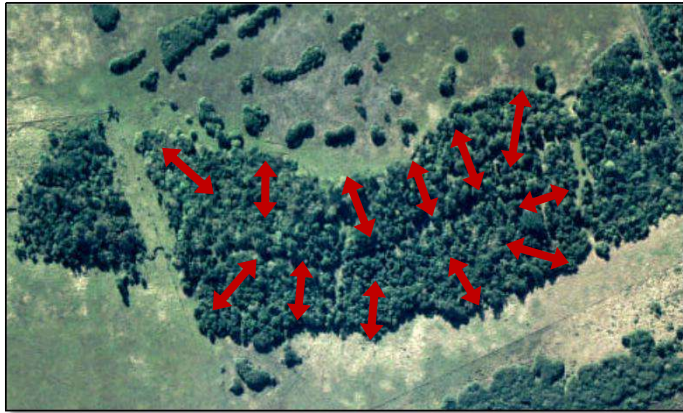
Assessing the influence of edge: new perspectives

Traditional use of landscape metrics such as distance to the nearest forest edge

distance to forest edge

From Laurance et al. 2002

Edge influence → Biomass, Microclimate, Diversity, Functions
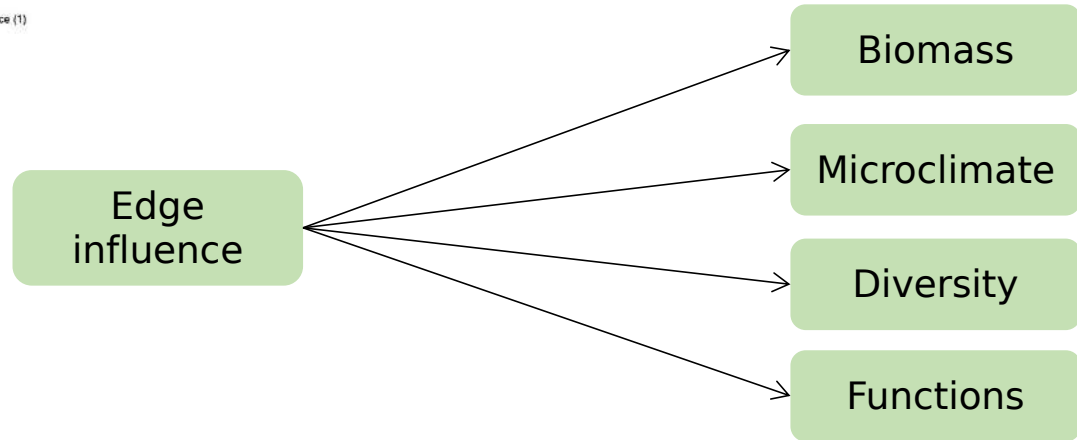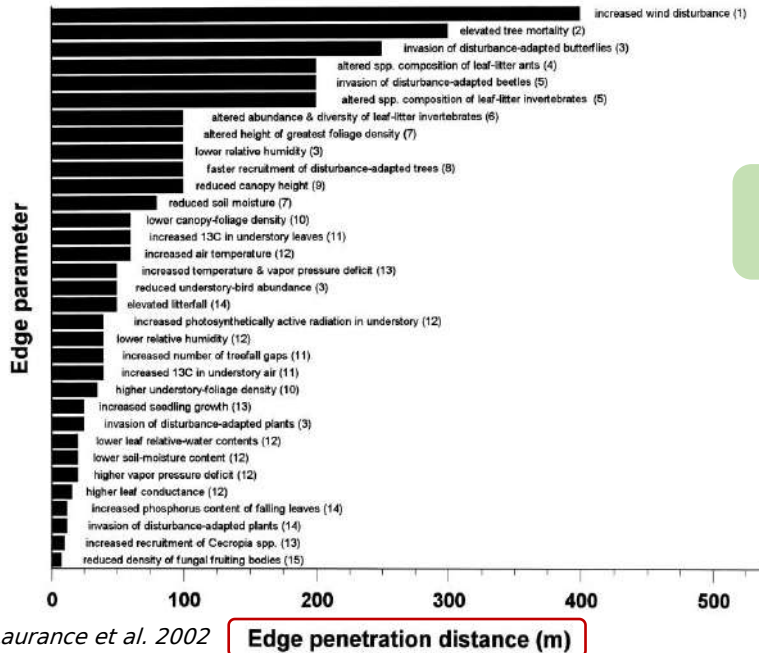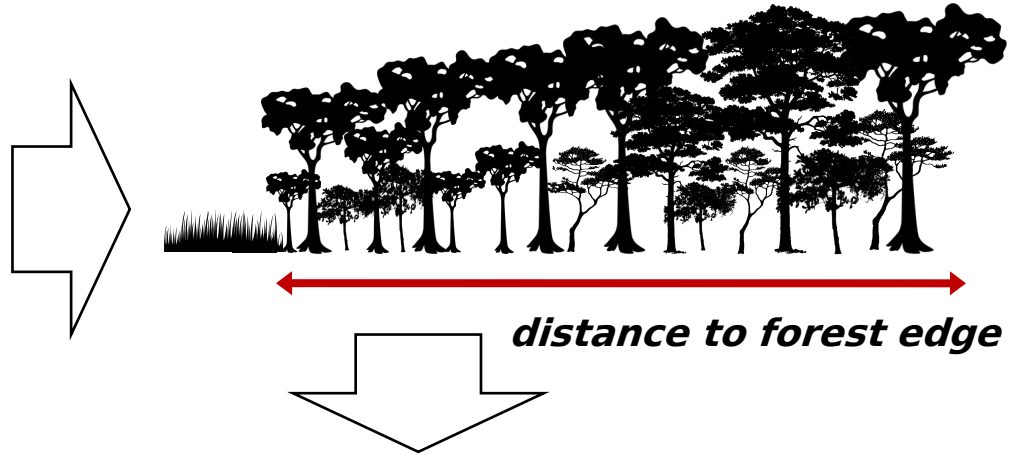
Assessing the influence of edge:
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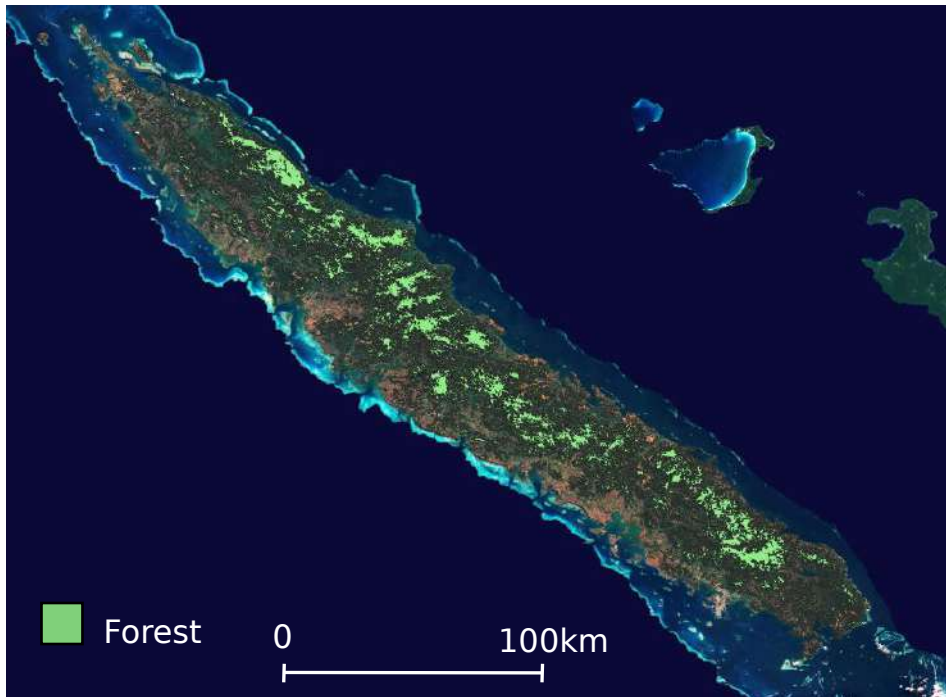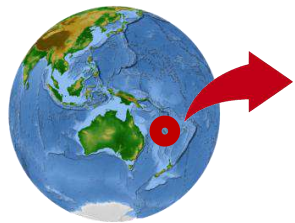New perspectives from remote-sensing tools such as Lidar

Edge influence → **Canopy structure**

Biomass

Microclimate

Diversity

Functions
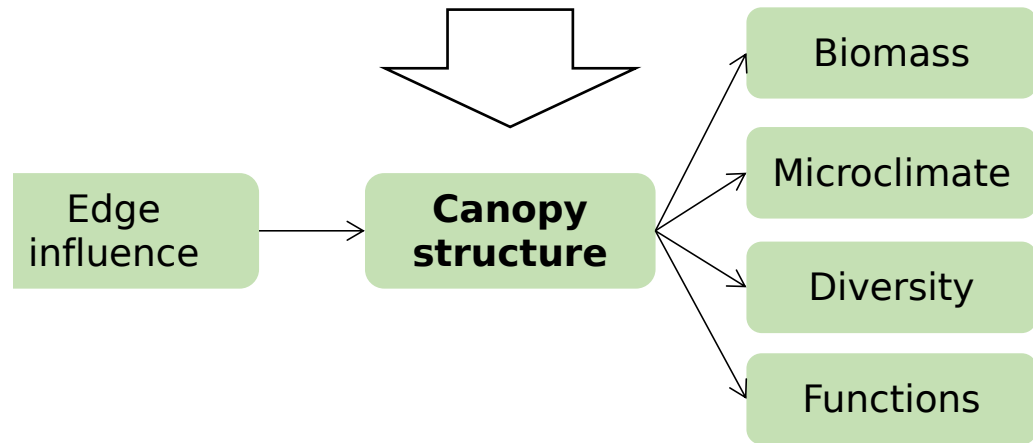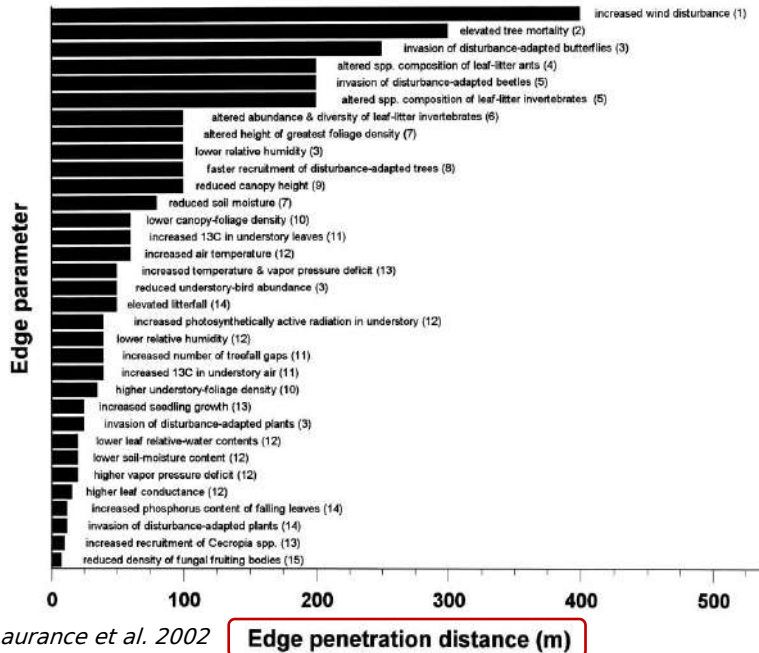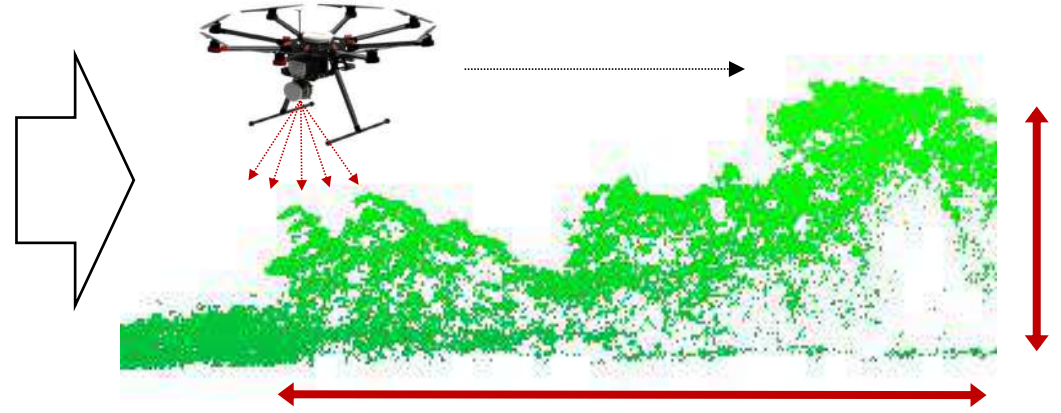
=> *Assessing fine-scale variation in canopy structure should improve our understanding of edge influence on different forest characteristics*

From Laurance et al. 2002

Studying edge effects
in New-Caledonia's moist forest: Context

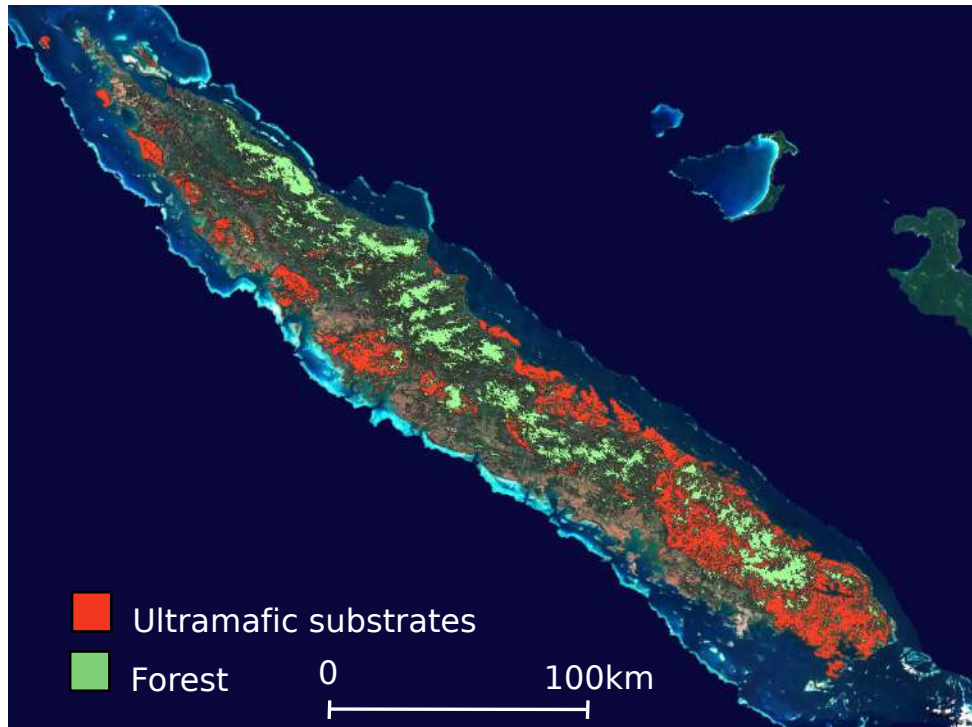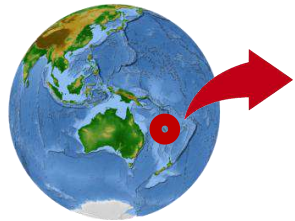**New Caledonia's biodiversity hotspot** (~18 000 km²), South West Pacific:

- \> 3000 plant species (75% endemism)
- < 20% of natural vegetation remaining

Forest   0   100km

Studying edge effects
in New-Caledonia's moist forest: Context

New Caledonia's biodiversity hotspot (~18 000 km²), South West Pacific:

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- Ultramafic substrates 1/3 the main island (~30% of the worldwide stocks of nickel)
 => *low nutrient availability, low water retention, high levels of toxic metals*

Ultramafic substrates

Forest

0   100km

Studying edge effects
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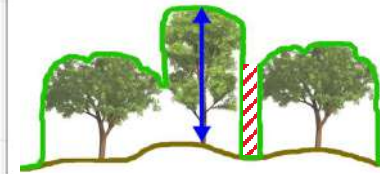***Mining activities + Bushfires***
= Increasing forest fragmentation

From Ibanez et al. 2018, Biodivers. Conserv.
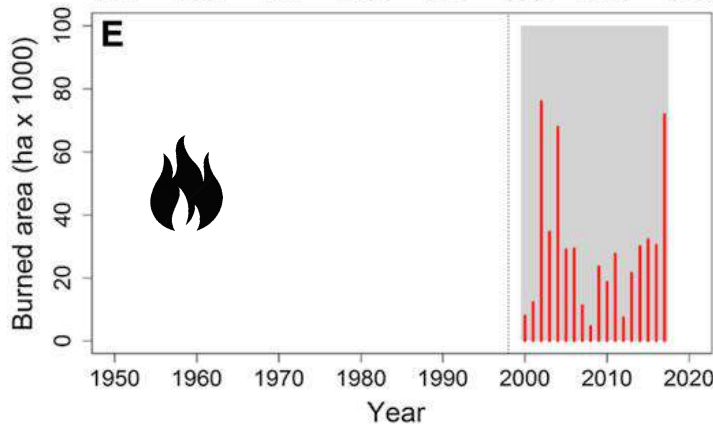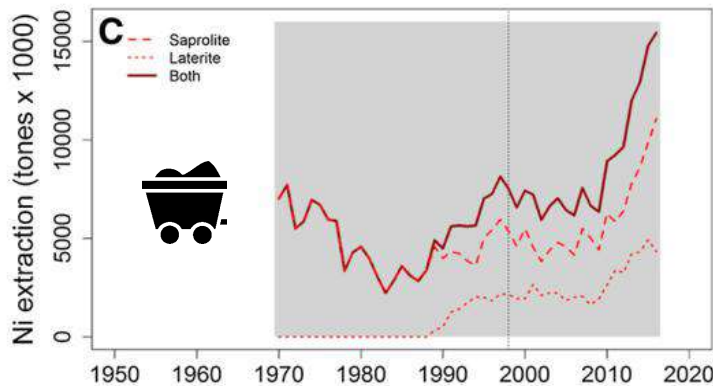
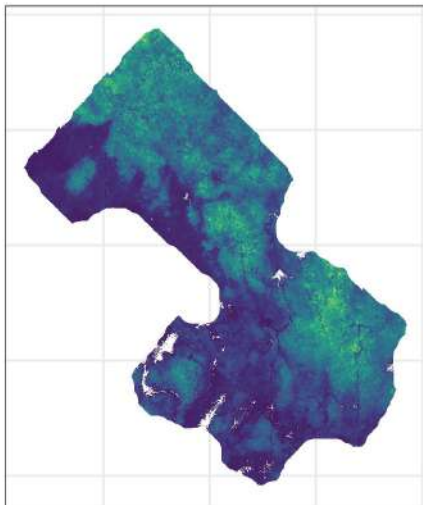# Studying edge effects
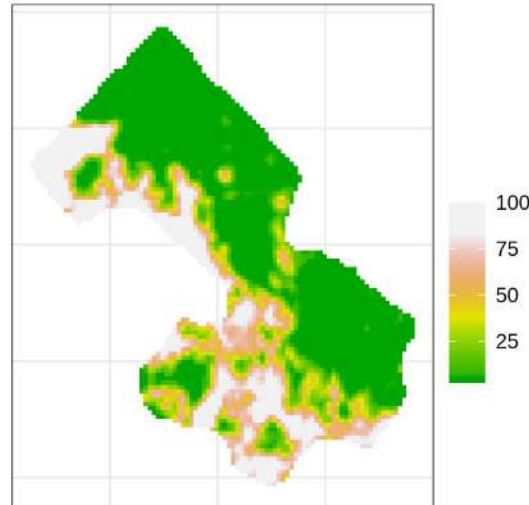## in New-Caledonia's moist forest: Methods
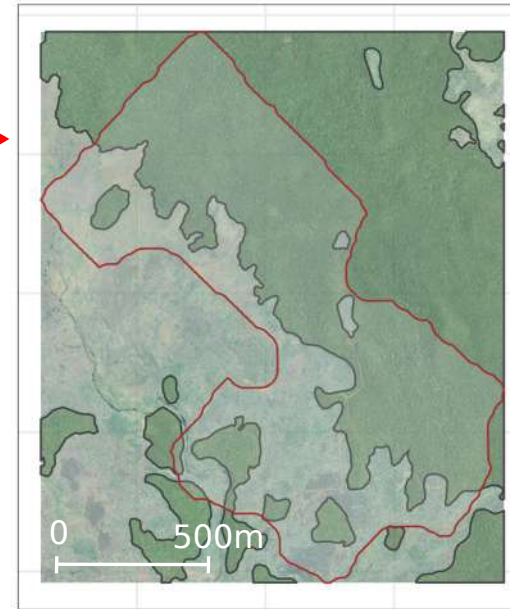
~ **200ha**

Forest

Lidar area
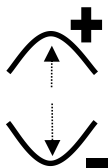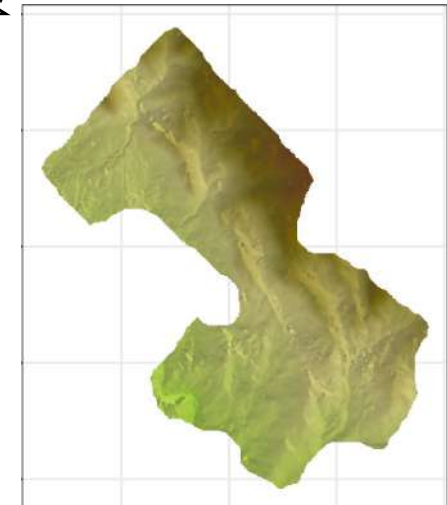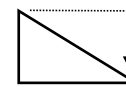
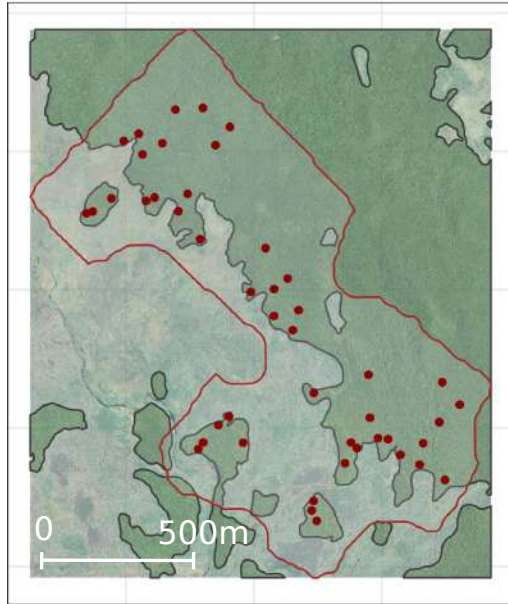*3-D structure*

=> Lidar metrics

Canopy height (m)

Canopy gap fraction (%)

Fine-scale topography (slope, curvature)

Studying edge effects
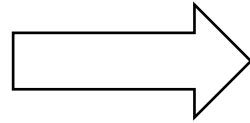## in New-Caledonia's moist forest: Methods

~ 200ha

Forest

Lidar area

• Plots

0   500m

• **46 plots** (400m²) located at different distance from the forest edge (10-300m)
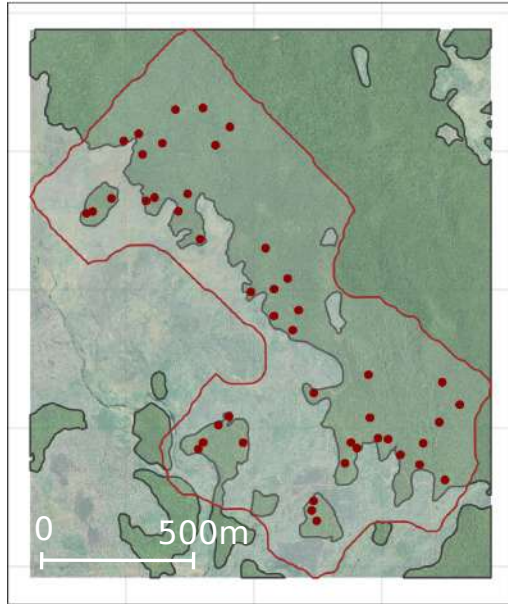
• All trees DBH>10cm, (2093 trees, 115 sp.)

Studying edge effects
in New-Caledonia's moist forest: Methods

~ **200ha**

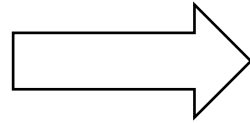Forest

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Abovegroud biomass (AGB)

$$\mathrm{AGB}_{est} = 0.0673 \times (\rho D^2 H)^{0.976}$$

From Chave et al. 2014, Glob. Change Biol.

Studying edge effects
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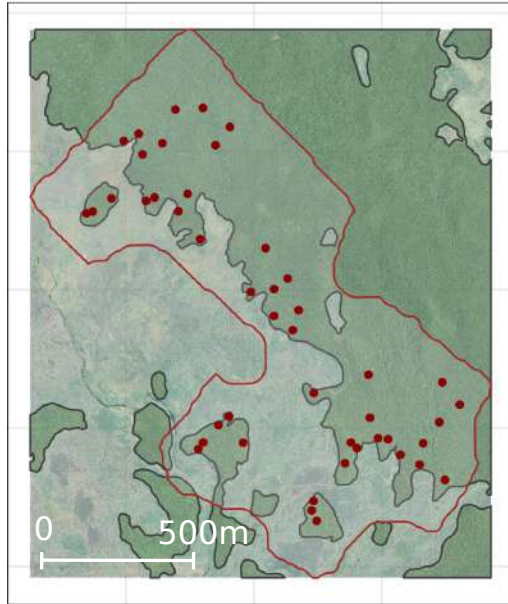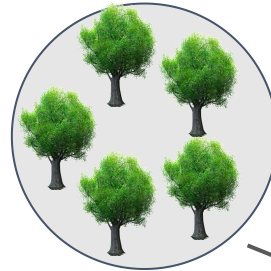
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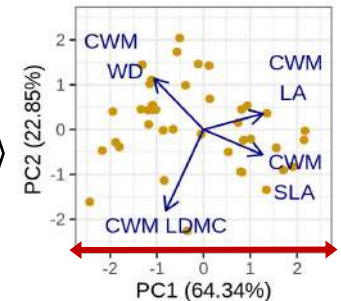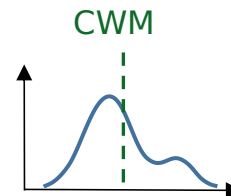
Functional traits
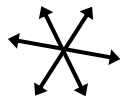
Wood density

Leaf area
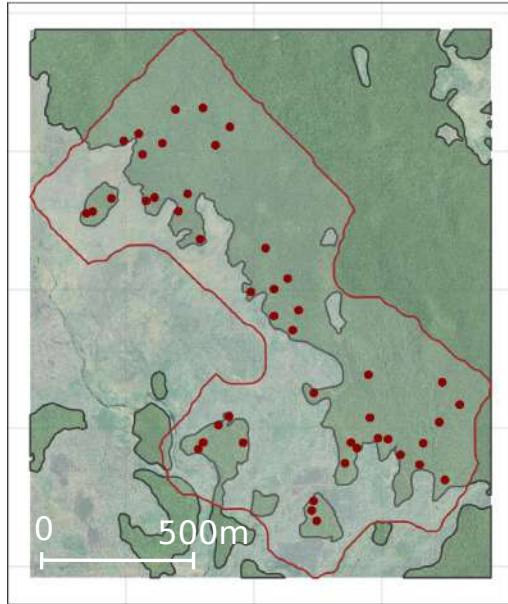*Specific leaf area*
Leaf dry matter content

• *Functional composition axis*
(community weighted mean traits, PCA axis)

CWM

• *Functional diversity*
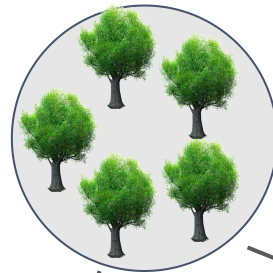*(functional divergence)*

Studying edge effects
in New-Caledonia's moist forest: Methods

~ **200ha**

Forest

Lidar area

• Plots

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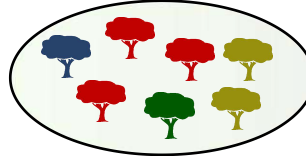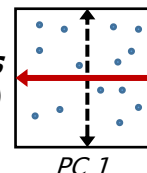*Functional traits*

Wood density

Leaf area
Specific leaf area
Leaf dry matter content

Taxonomic composition

• *Functional composition axis*
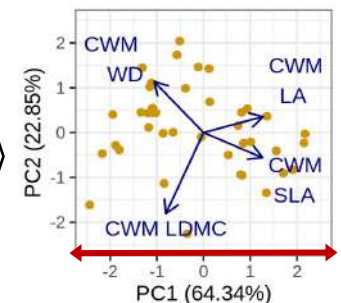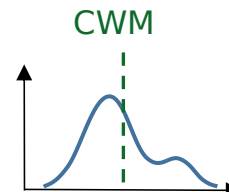(community weighted mean traits, PCA axis)

CWM

• *Species richness*
(rarefied)

• *Beta diversity axis*
(rarefied, PCoA axis)

PC 1

• *Functional diversity*
(functional divergence)

Studying edge effects
in New-Caledonia's moist forest: Methods

~ **200ha**

Forest

Lidar area

• Plots

• Microclimate loggers

• **46 plots** (400m²) located at different distance from the forest edge (10-300m)

• All trees DBH>10cm, (2093 trees, 115 sp.)

• **Microclimate** sensors located at the center of plots
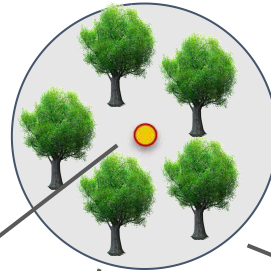
Aboveground biomass (AGB)

$$\text{AGB}_{est} = 0.0673 \times (\rho D^2 H)^{0.976}$$

From Chave et al. 2014, Glob. Change Biol.

Functional traits

Wood density

Leaf area
Specific leaf area
Leaf dry matter content

• ***Functional composition axis*** *(community weighted mean traits, PCA axis)*

CWM

Microclimate

T°   HR %

• ***Vapor Pressure Deficit (VPD)***

$$VP_{saturated} = 0.6108 \times \exp\left(\frac{17.27 \times T°}{T° + 237.3}\right)$$

$$VP_{air} = \frac{HR}{100 \times VP_{saturated}}$$

$$VPD = VP_{saturated} - VP_{air}$$

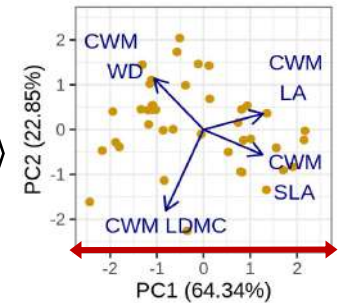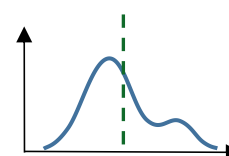### *Taxonomic composition*
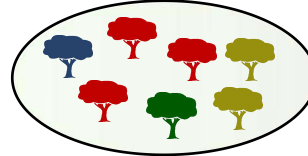
• ***Species richness*** *(rarefied)*

• ***Beta diversity axis*** *(rarefied, PCoA axis)*

PC 1

• ***Functional diversity*** *(functional divergence)*
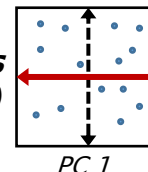
Does canopy structure mediates the influence of edge on forest biomass, microclimate, diversity and functions?

tance from

er of plots

o 115 sp.

ss (AGB)

$D^2 H)^{0.976}$

Change Biol.

?

Biomass

Microclimate

Diversity

Functions

Edge distance → **Canopy structure**

0   500m

Micr...

T°

its

f area
leaf area
atter content

CWM
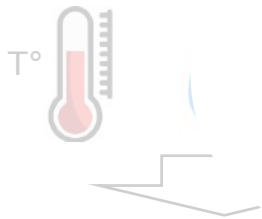
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- **Species richness**
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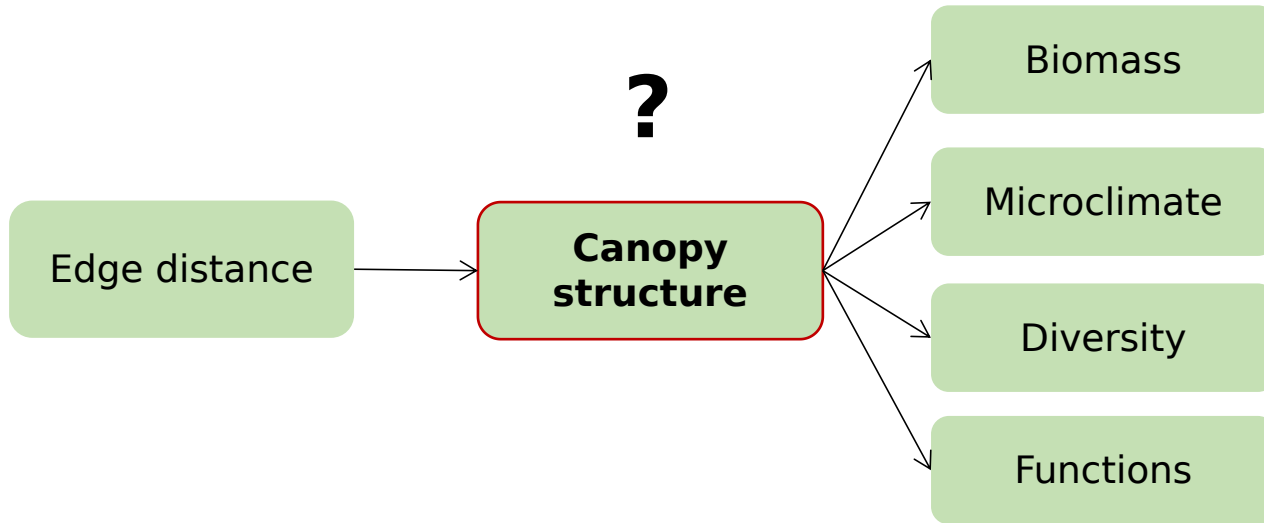
- **Functional composition**
  (community weighted mean traits)

- **Functional diversity**
  (functional divergence)
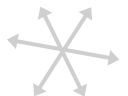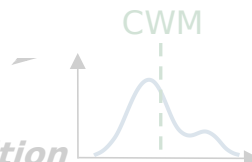
Studying edge effects
in New-Caledonia's moist forest: Results

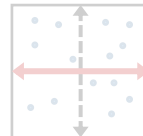- Influence of edge on canopy structure

  Forest plots and *whole landscape (20*20m cells)*
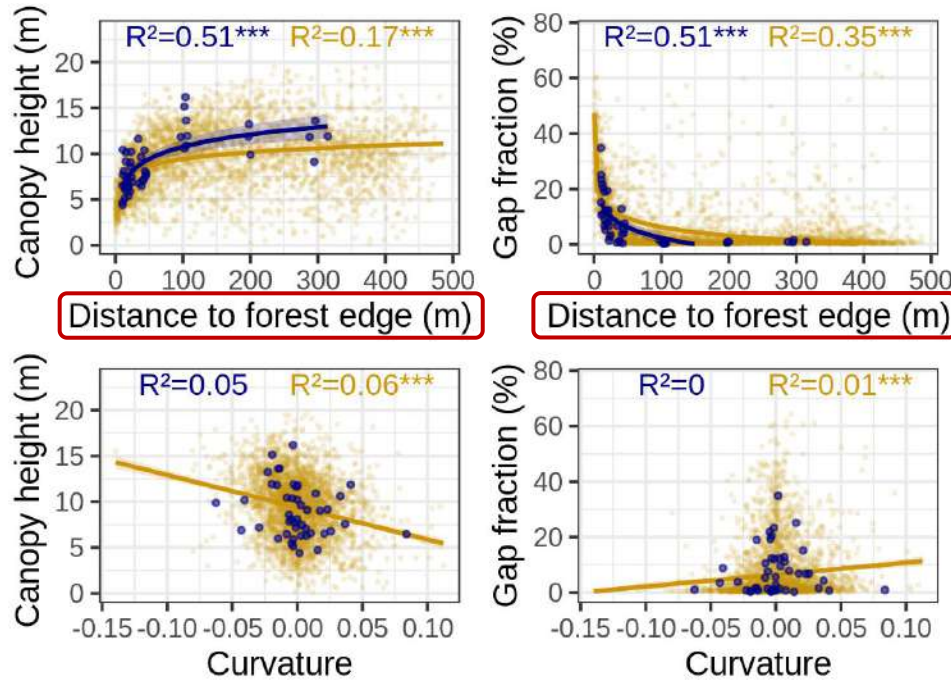
1) Strong influence of distance to edge on canopy structure

=> Weak influence of topography

Forest edge
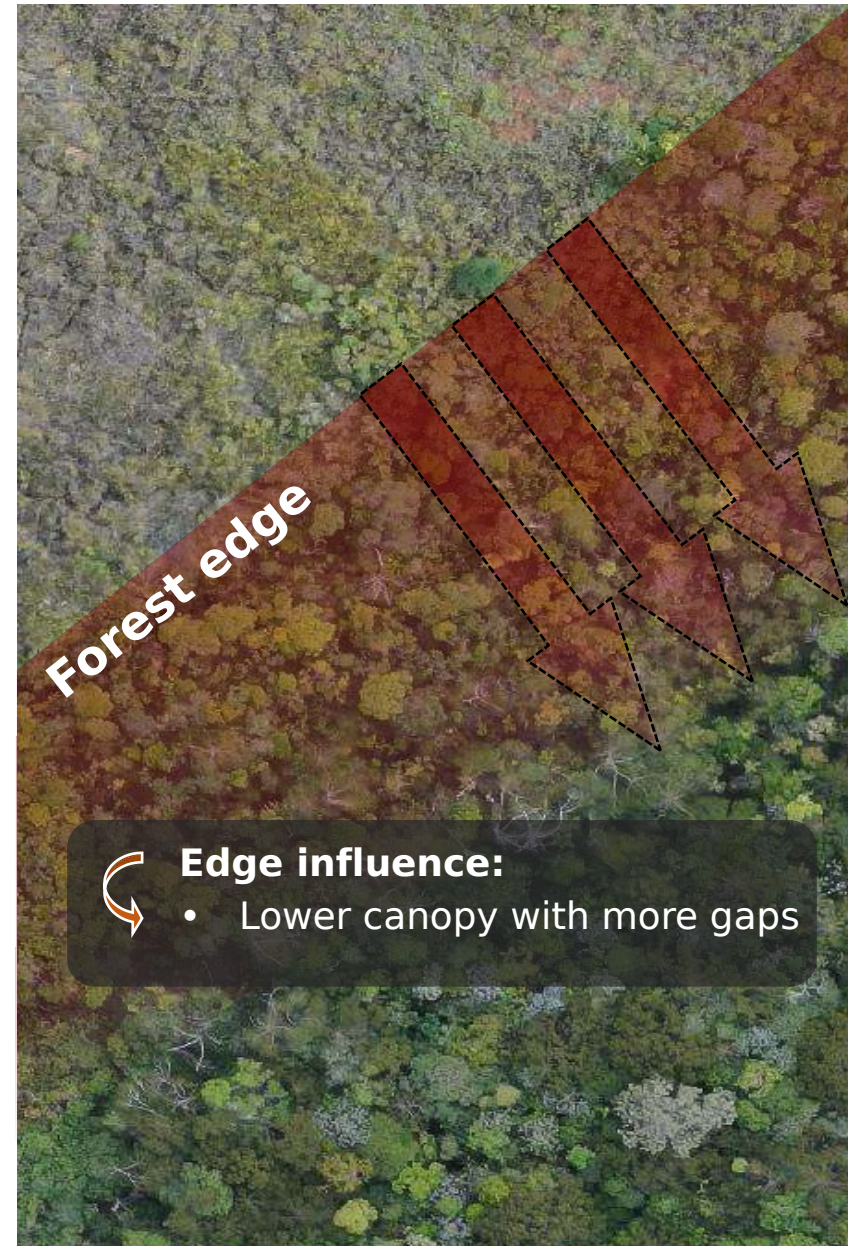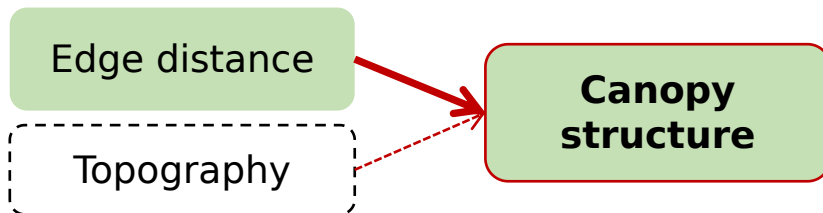
Edge influence:
- Lower canopy with more gaps

Studying edge effects
in New-Caledonia's moist forest: Results

- Influence of edge on forest characteristics

Edge influence:
- Dryer microclimate
- Lower biomass
- Stress-resistant traits
  - ↑Wood density, ↓SLA
- Lower taxonomic diversity

Studying edge effects
in New-Caledonia's moist forest: Results

- Influence of edge on forest characteristics

=> **Environmental filtering**
Dry conditions
Low nutrient availability

Edge influence:
- Dryer microclimate
- Lower biomass
- Stress-resistant traits
  ↑Wood density, ↓SLA
- Lower taxonomic diversity

Forest edge

Studying edge effects
in New-Caledonia's moist forest: Results

- Influence of edge on forest characteristics

$R^2=0.62^{***}$

$R^2=0.48^{***}$

$R^2=0.22^{**}$

$R^2=0.07$

$R^2=0.23^{***}$

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Distance to forest edge (m)   Distance to forest edge (m)
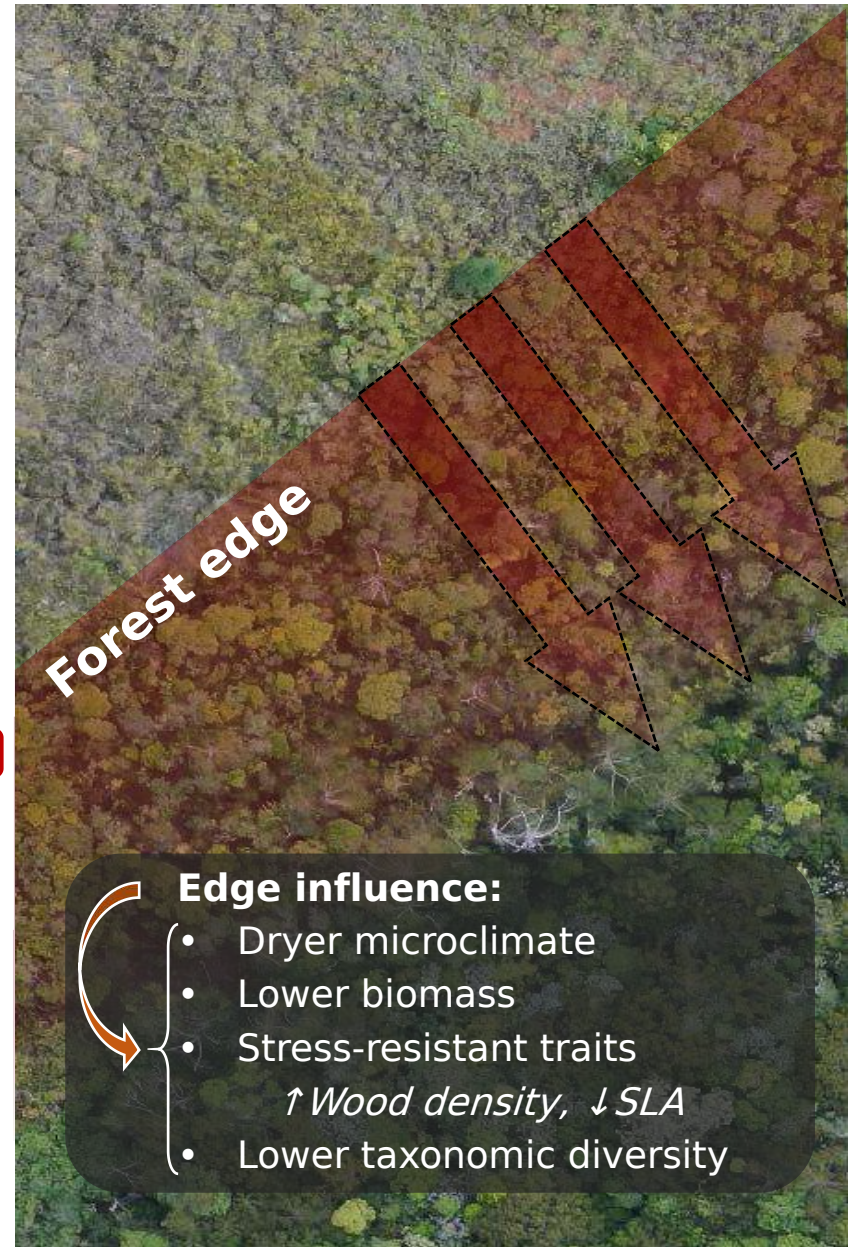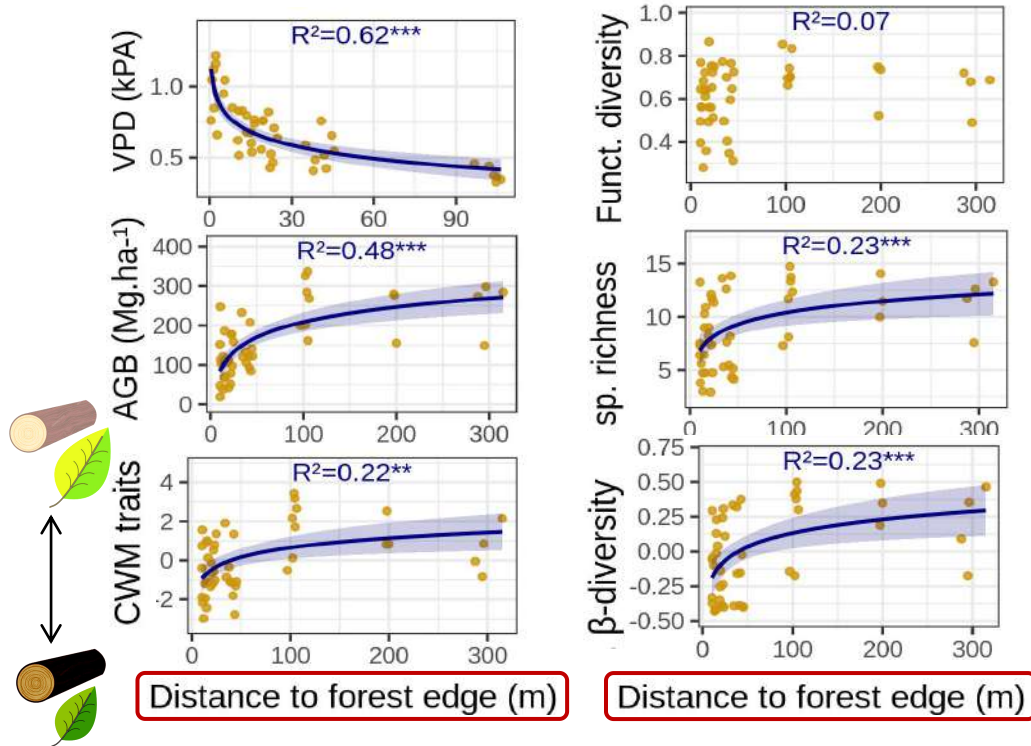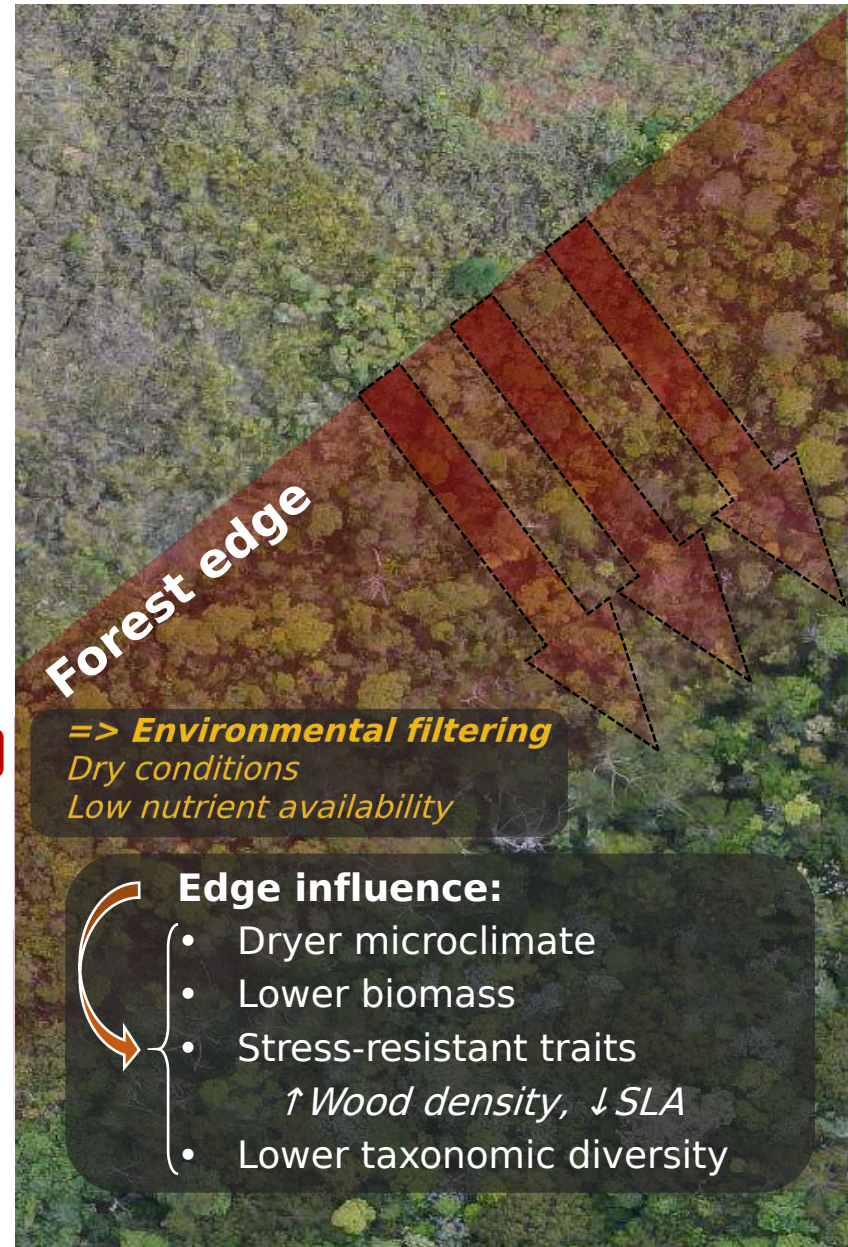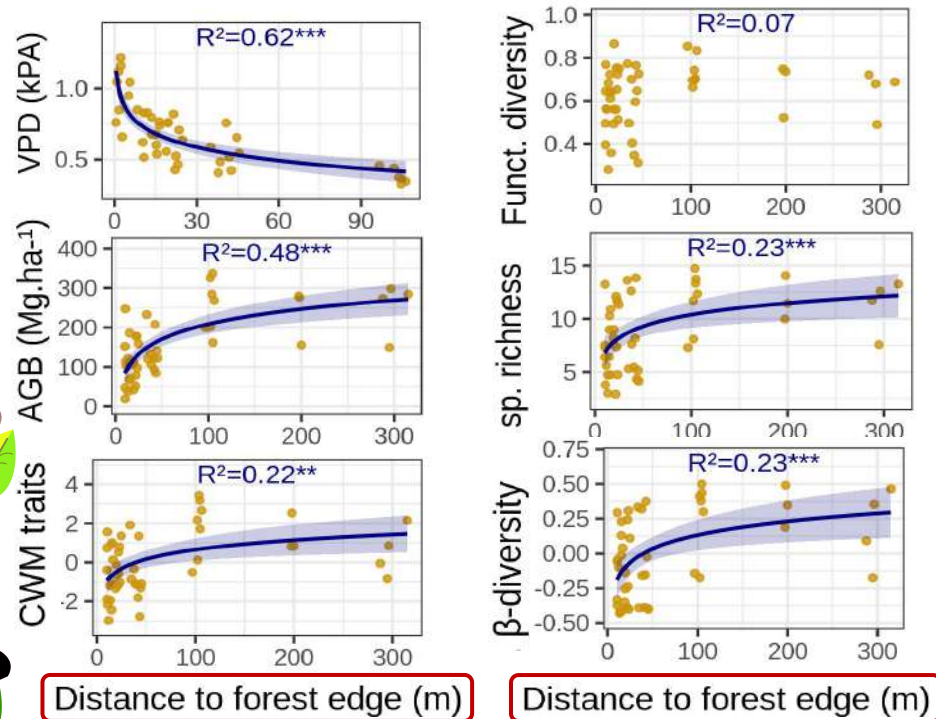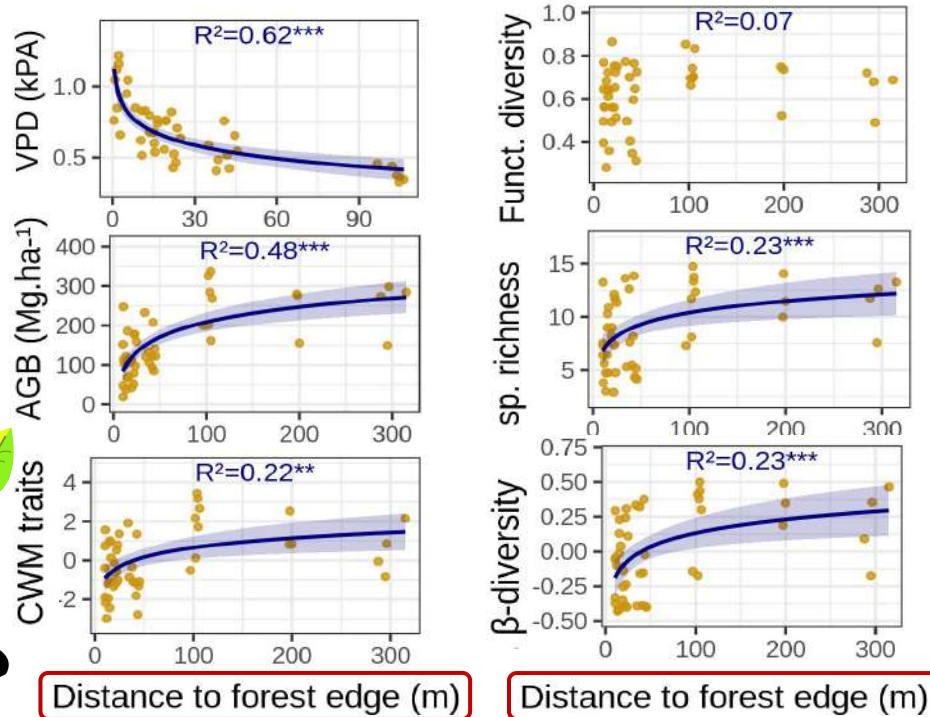
2) Pervasive influence of edge effects
on forest characteristics

Edge influence → Biomass

Edge influence → Microclimate

Edge influence → Diversity

Edge influence → Functions

Forest edge

=> Environmental filtering
Dry conditions
Low nutrient availability

Edge influence:
- Dryer microclimate
- Lower biomass
- Stress-resistant traits
  ↑Wood density, ↓SLA
- Lower taxonomic diversity
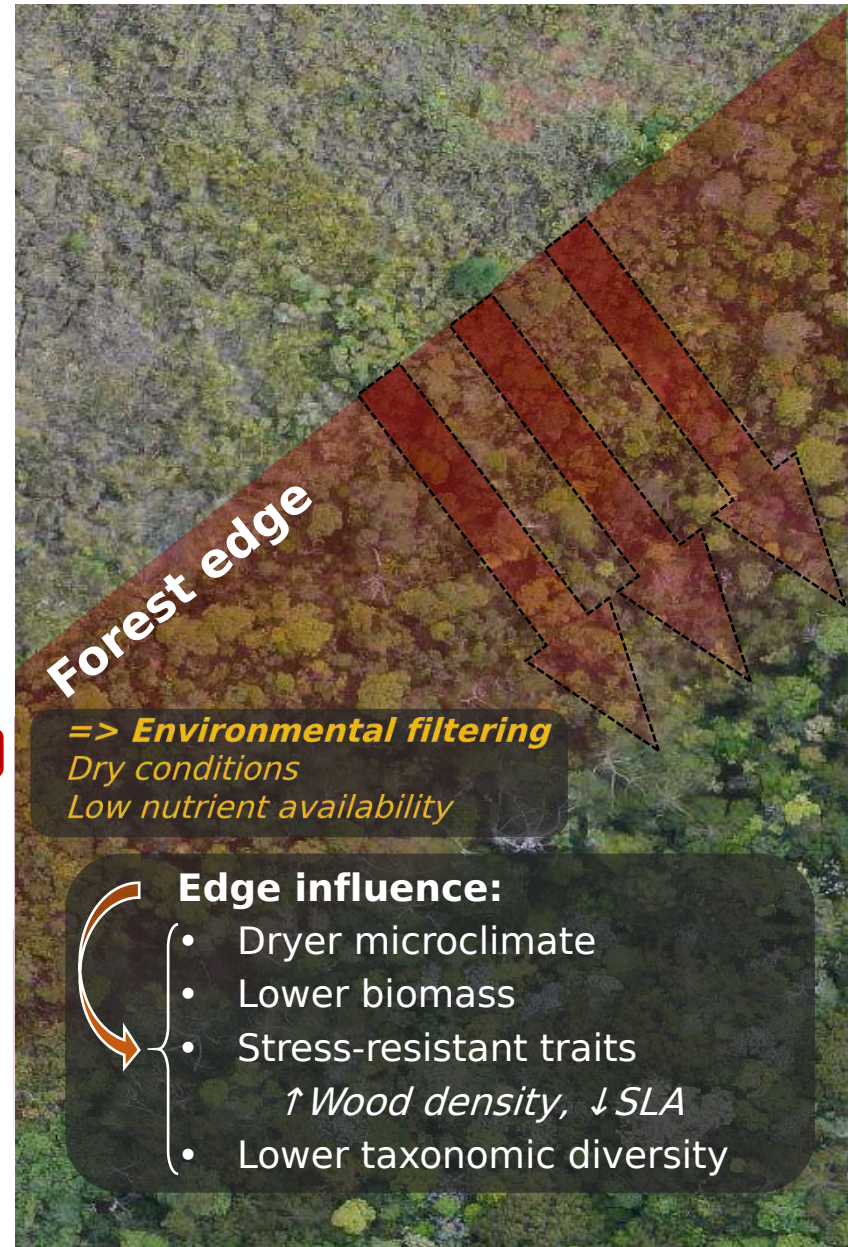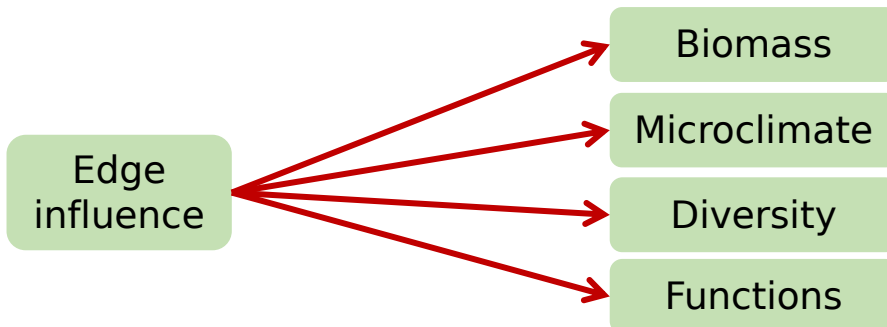
Studying edge effects
in New-Caledonia's moist forest: Results

- **Canopy structure -> forest characteristics**
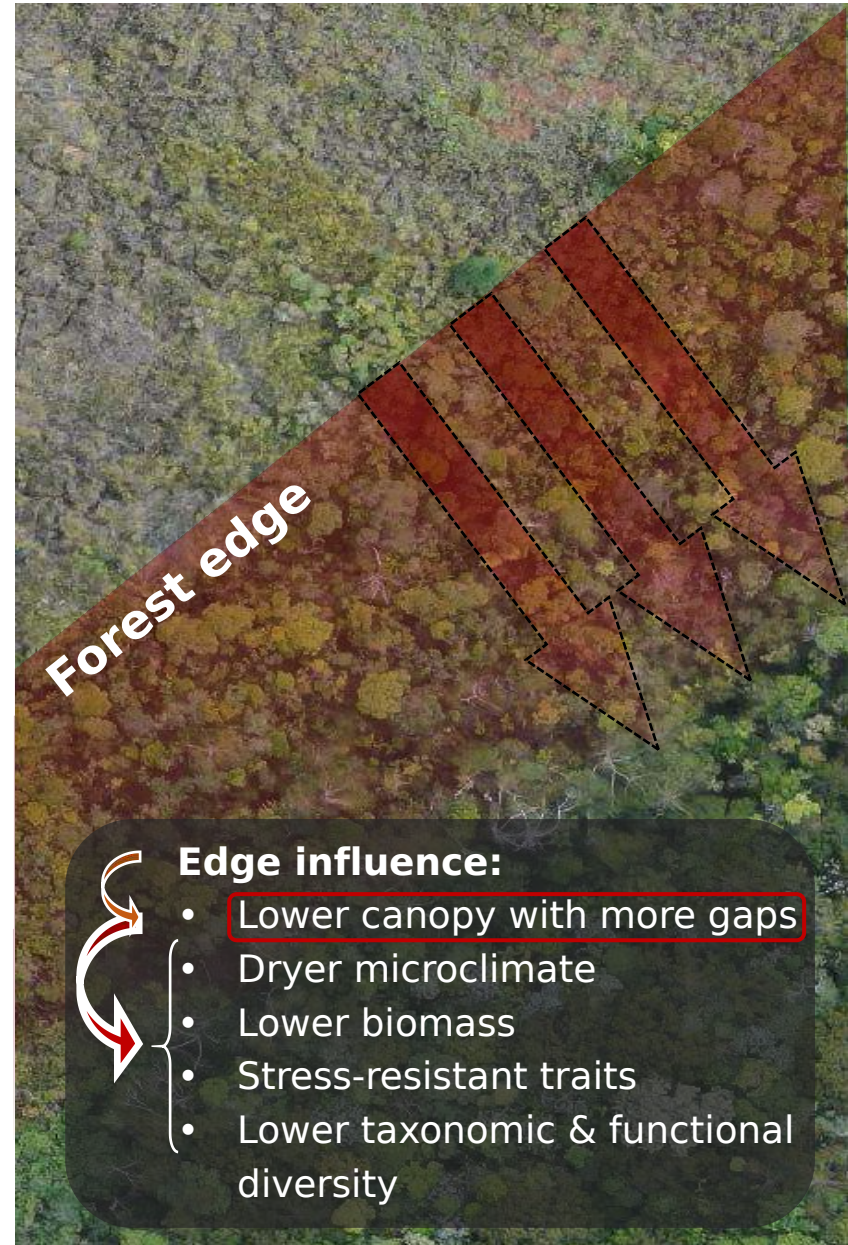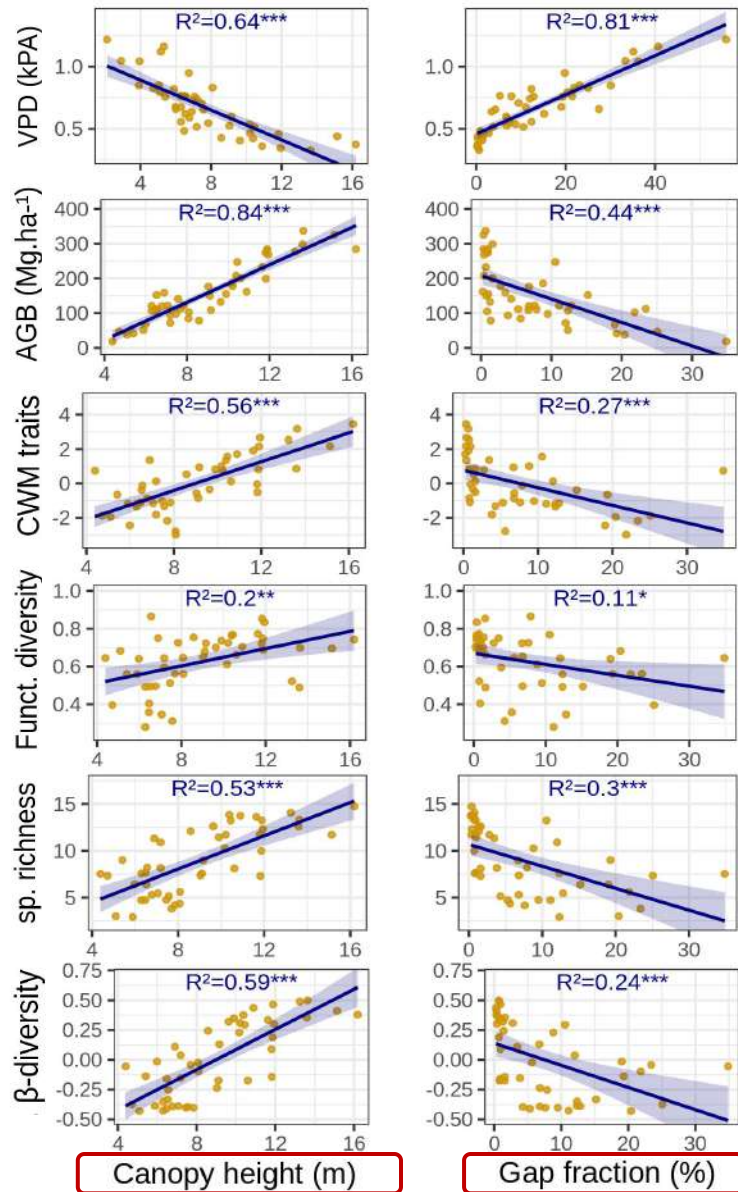
Edge influence:
- Lower canopy with more gaps
- Dryer microclimate
- Lower biomass
- Stress-resistant traits
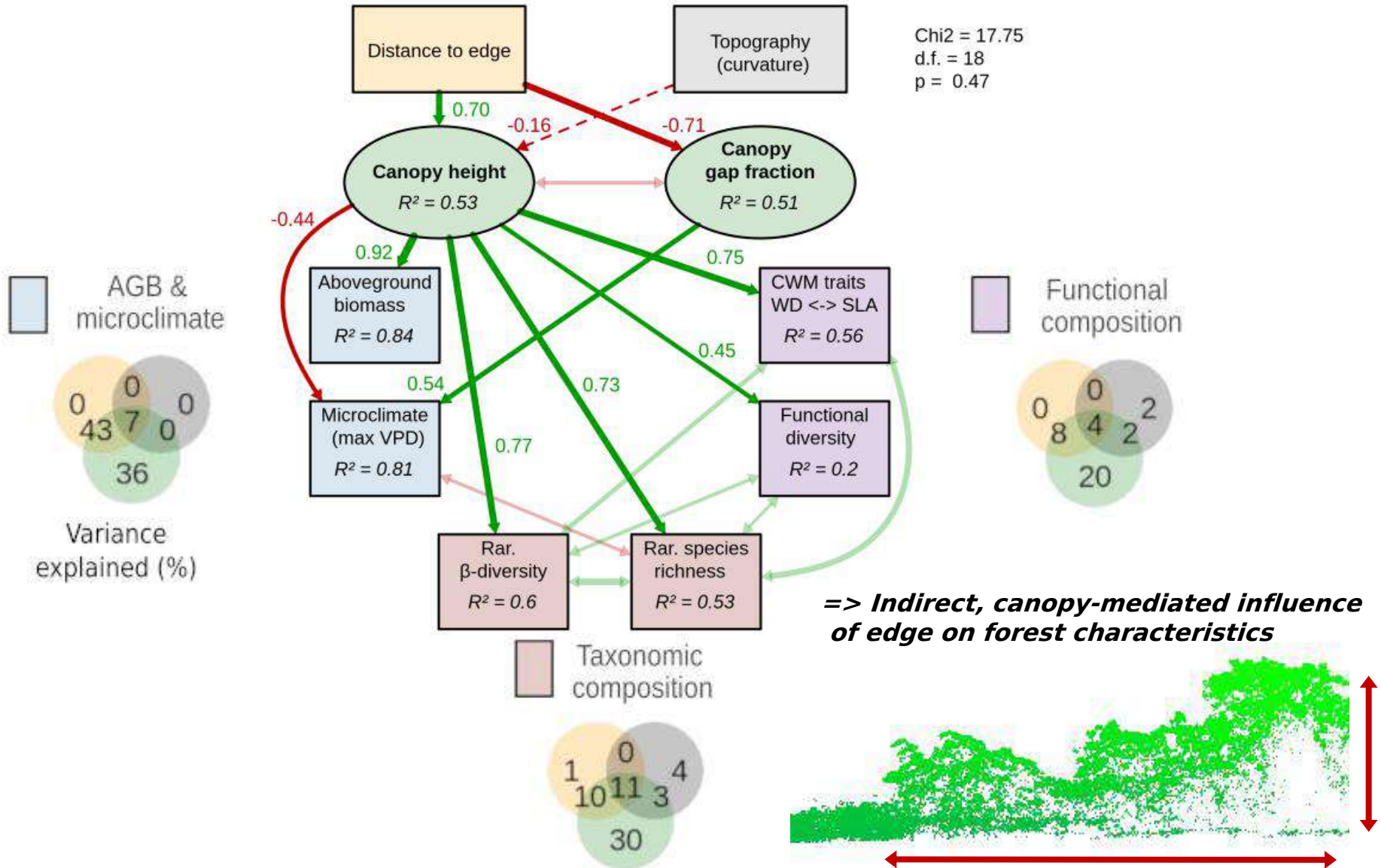- Lower taxonomic & functional diversity

Studying edge effects
in New-Caledonia's moist forest: Results

Structural equation modeling & **Variance partitioning**

Studying edge effects
in New-Caledonia's moist forest: Results

Structural equation modeling & **Variance partitioning**

=> *Indirect, canopy-mediated influence of edge on forest characteristics*
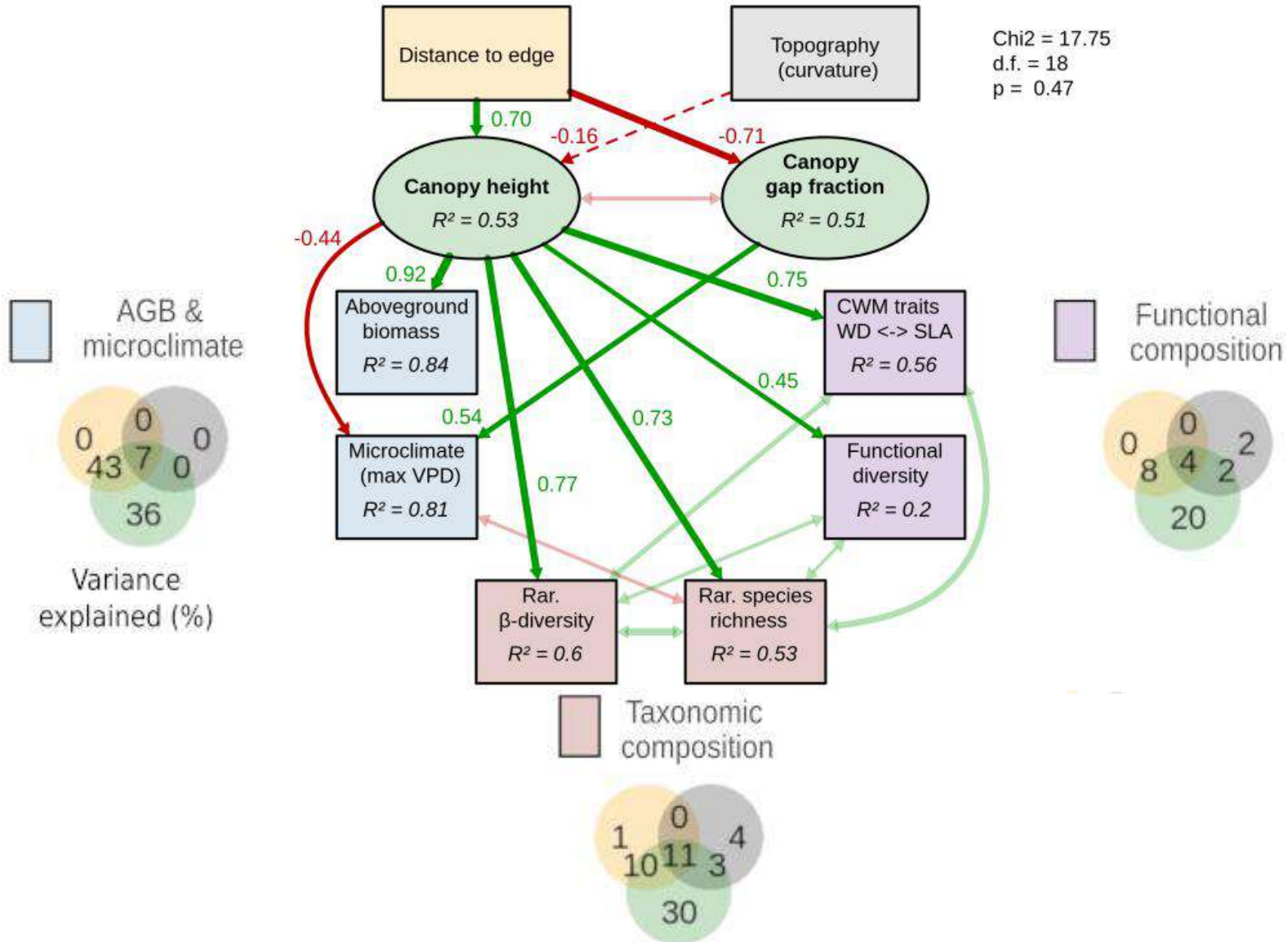
Conclusions

Edge effects:

- Impact different characteristics of tropical forests, related to structure, diversity, function, biomass and microenvironmental conditions.

- Have both direct influence and indirect influence mediated by canopy structure
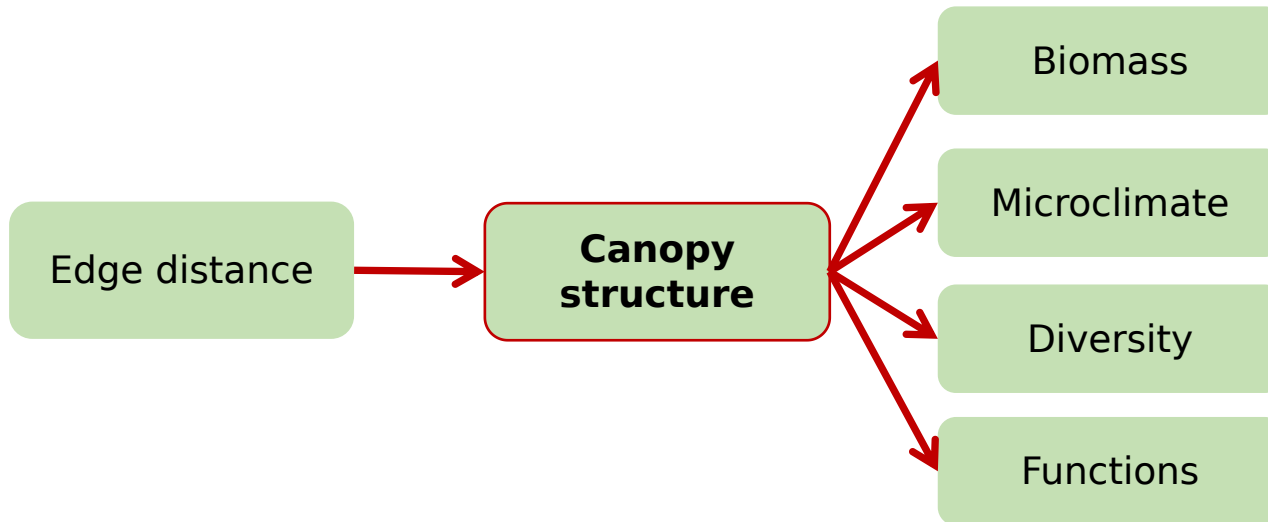
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Lidar :

- The use of Lidar allows to evaluate fine-scale variation in canopy structure

  => Insights on the multiple impacts of edge effects

- Lidar metrics are better predictors of tropical forest composition
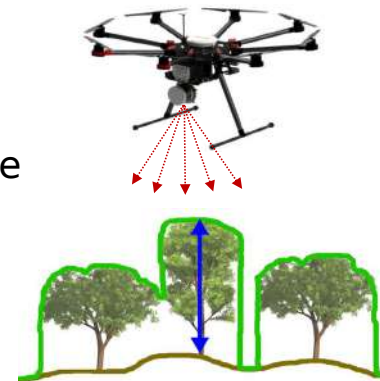 and microclimate than distance to forest edge alone

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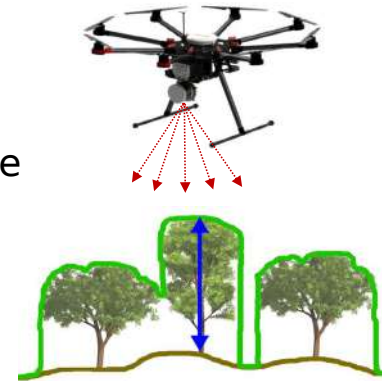
Perspectives:

- Evaluating the consequences of forest fragmentation
    => More precisely
    => At larger scales

- Predicting future responses of forest dynamics and functioning to climate and land-use changes.

Thank you!

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