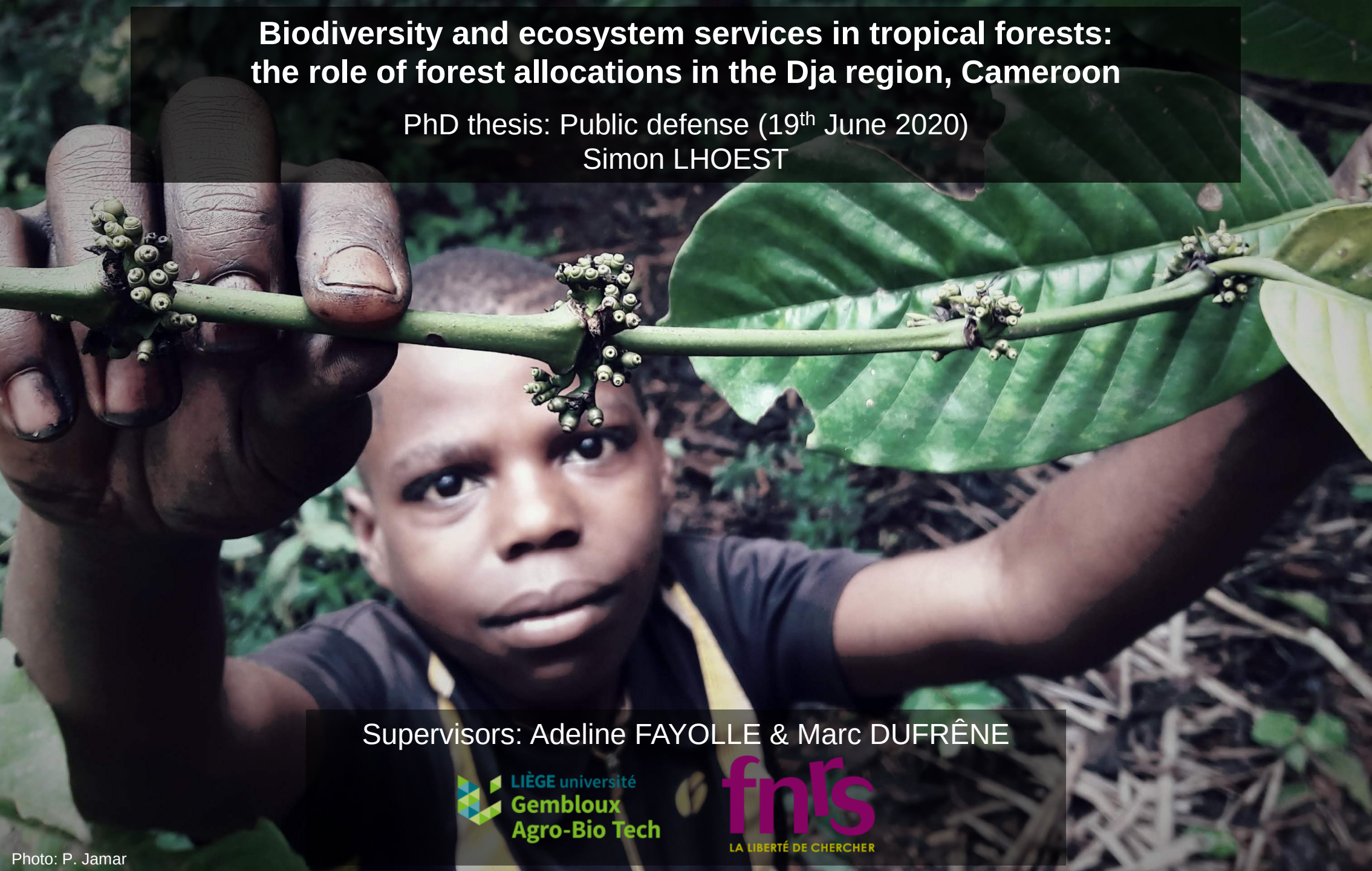
Biodiversity and ecosystem services in tropical forests: the role of forest allocations in the Dja region, Cameroon

PhD thesis: Public defense (19th June 2020)

Simon LHOEST



Supervisors: Adeline FAYOLLE & Marc DUFRÊNE

LIÈGE université Gembloux Agro-Bio Tech

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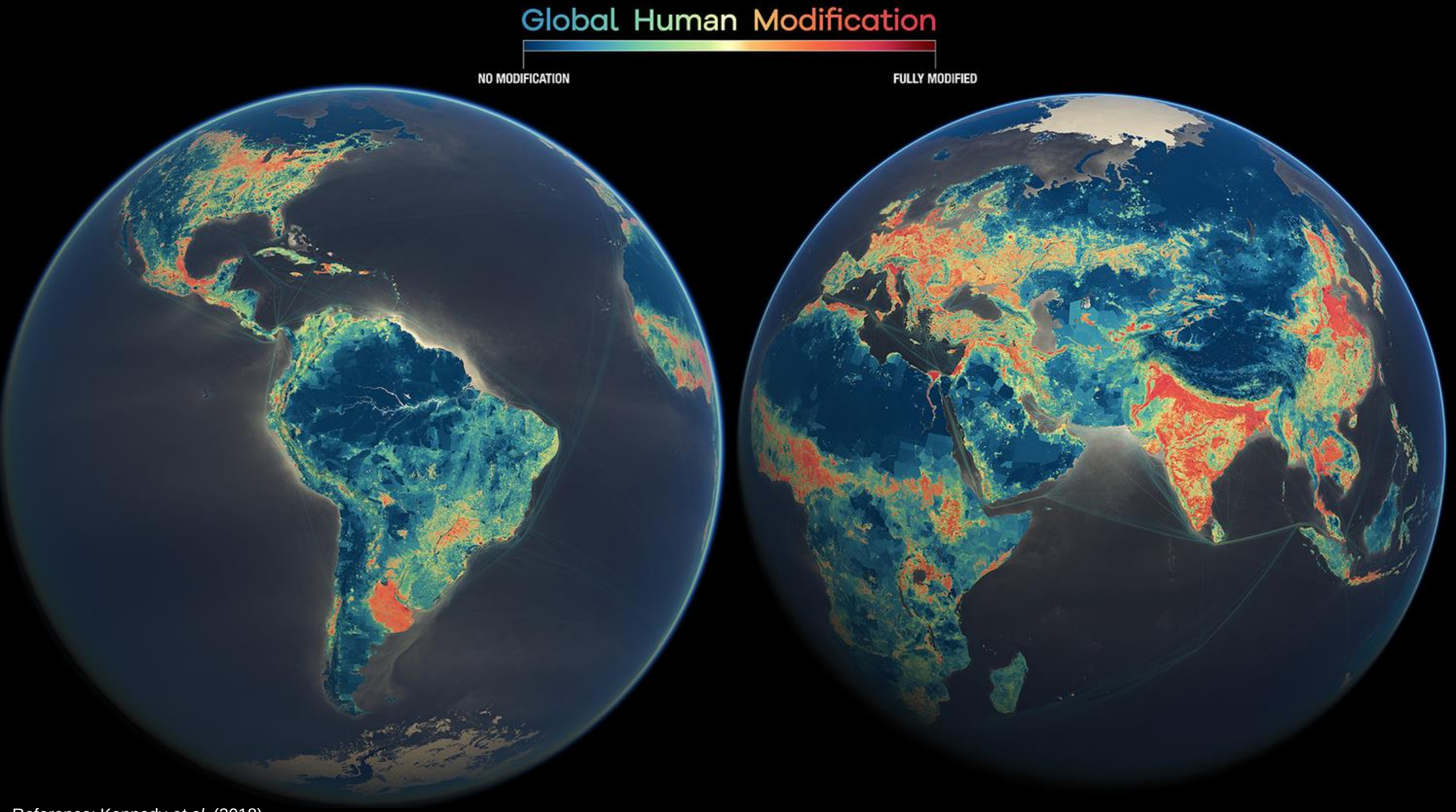
Photo: P. Jamar

1. General introduction

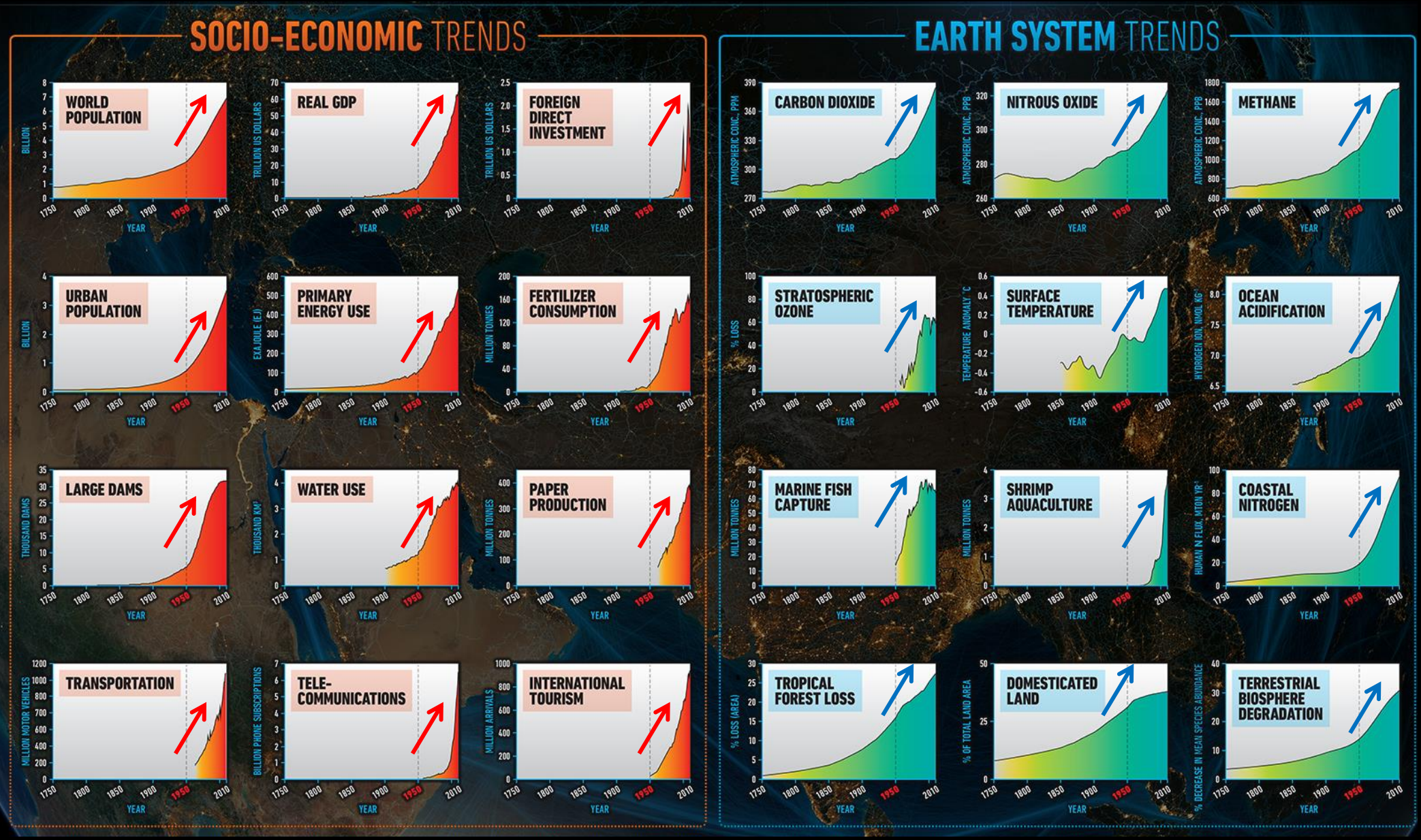
Design: Globaïa

Humanity's influence on Earth



Reference: Kennedy *et al.* (2018)
Design: Globaïa

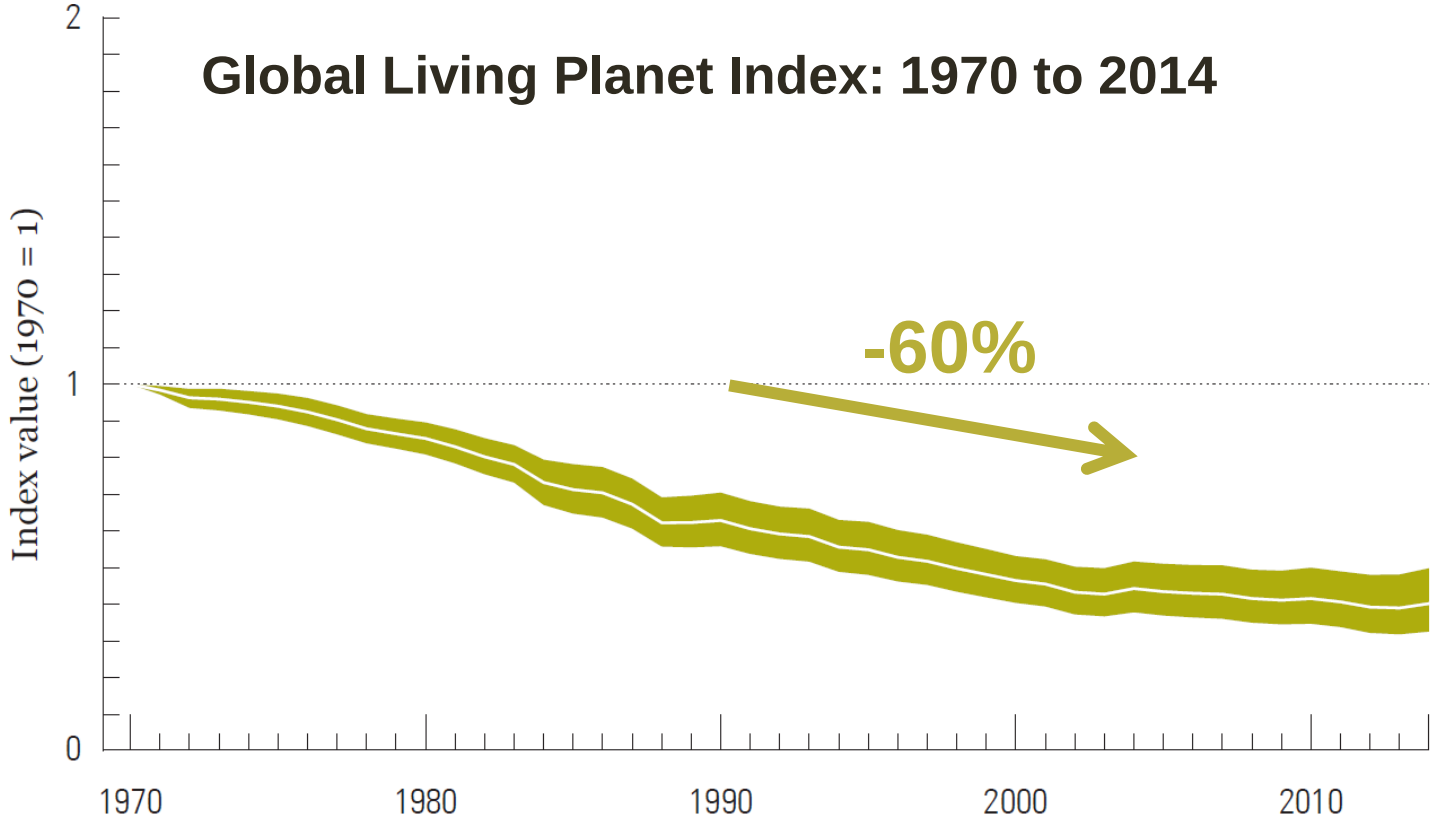
The Anthropocene



Reference: Steffen *et al.* (2015)
Map & design: Félix Pharand-Deschênes / Globaïa

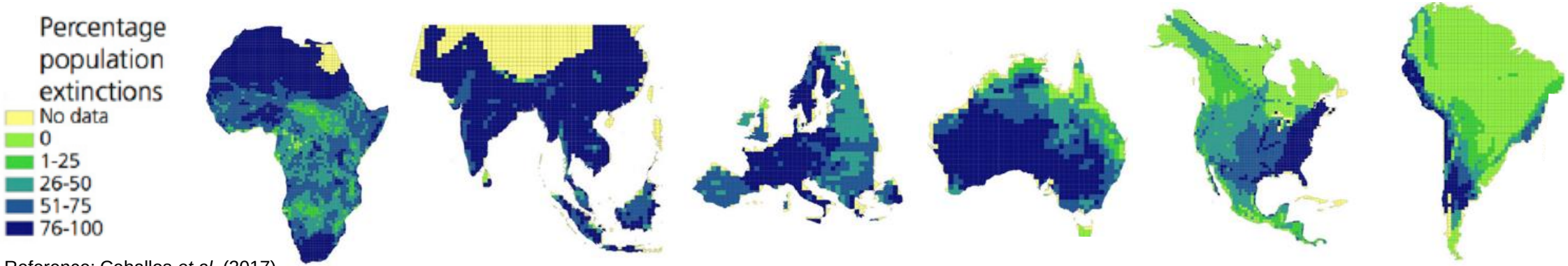
The 6th mass extinction

Global Living Planet Index: 1970 to 2014



Reference:
WWF Living Planet Report (2018)

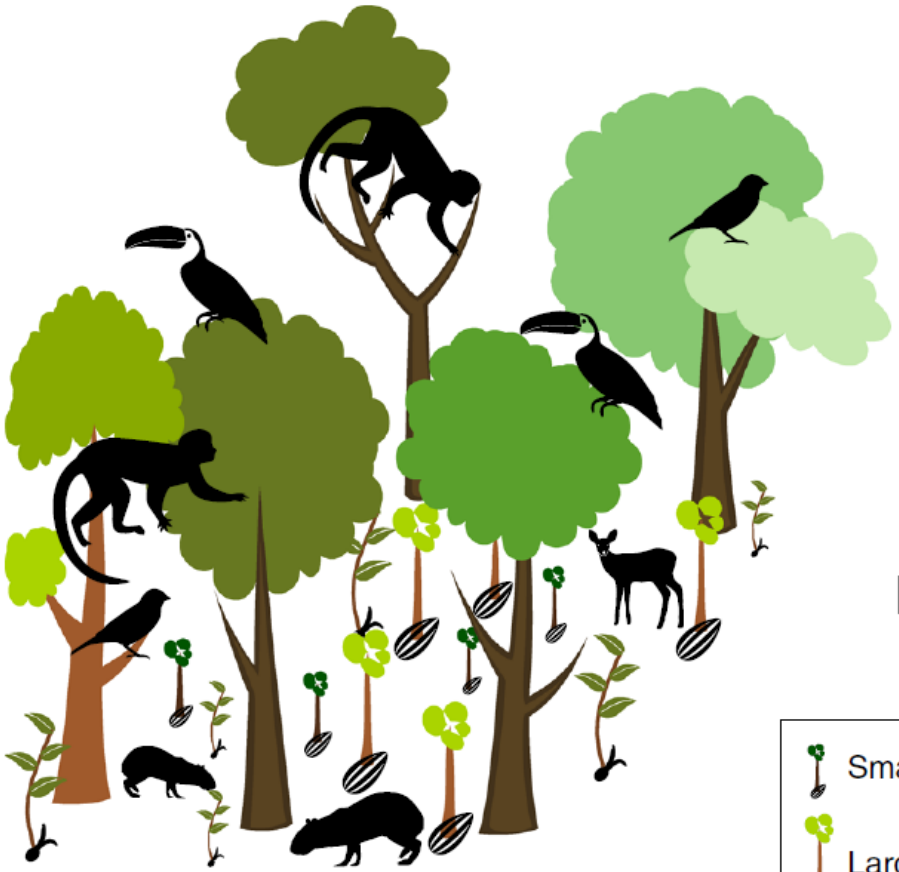
Percentage of local population extinction in 177 species of mammals



Reference: Ceballos *et al.* (2017)

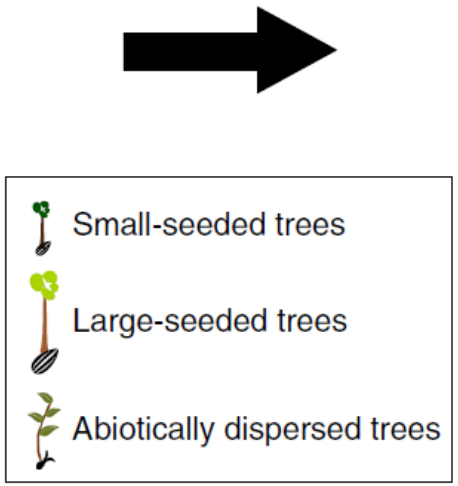
Cascading consequences on ecosystems

Example: forest regeneration



High fauna (natural) vertebrate community

Primates, caviomorph rodents and large-gaped birds disperse large-seeded trees

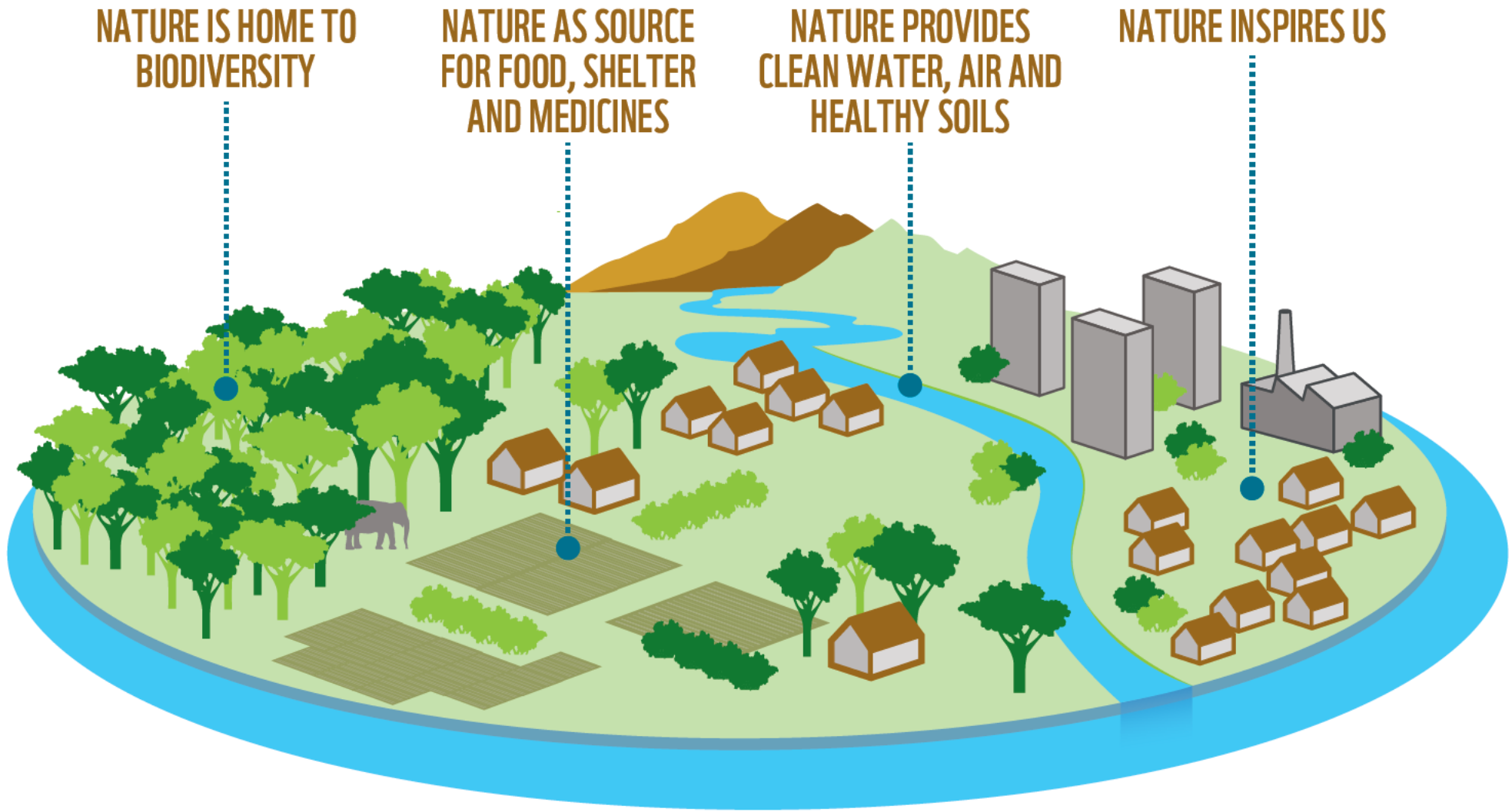


Low fauna (defaunated) vertebrate community

Regeneration of large-seeded tree species is reduced, being replaced by small-seeded or abiotically dispersed tree species

Reference: Gardner *et al.* (2019)

The importance of nature to people



Biodiversity
Ecosystem services

Reference: WWF Living Planet Report (2018)

Biodiversity...

…the variation within the species

Genetic diversity

…all millions of different species

Species diversity

…all the various ecosystems

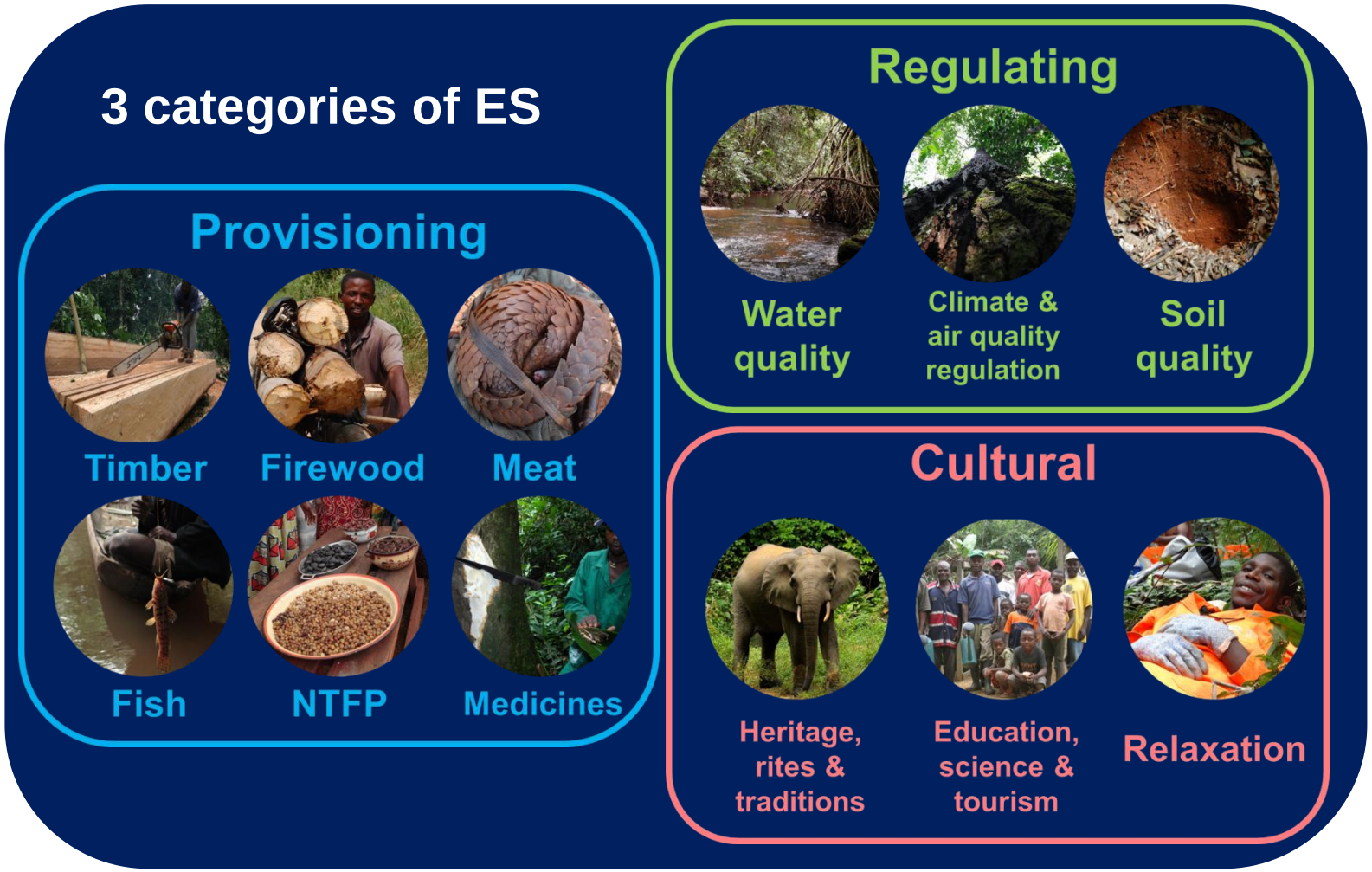
Ecosystem diversity

Conservation value:
role and potential of a delimited area to conserve biodiversity

References: African Man and Biosphere Reserves: guidance to assess ecosystem services (draft manual, 2020), Stork *et al.* (2017)
Photos: S. Dubois, L. Janssens de Bisthoven

Ecosystem services (ES)

The contributions of ecosystems to human well-being



➔ ES **supply** and **use**

References: Burkhard *et al.* (2012), Millennium Ecosystem Assessment (2005)
Photos: J.-Y. De Vleeschouwer, J.-L. Doucet, J. Laporte, S. Lhoest, J. Schure

Tropical forests...

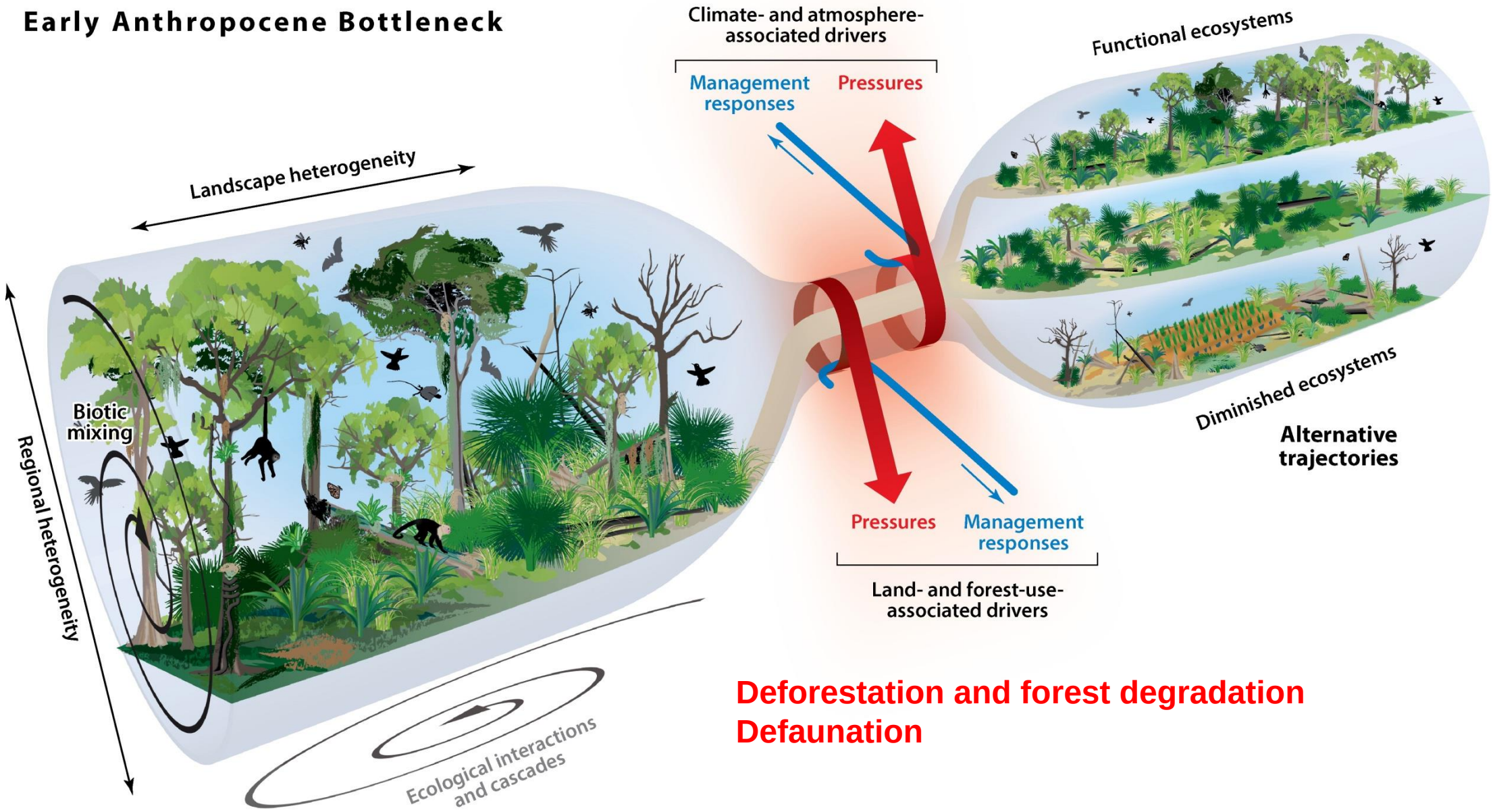
... host >2/3 of global terrestrial biodiversity
... contribute to major ecological processes
... provide ecosystem services to hundreds of millions of people
... are used by humans for tens of thousands of years

Ecosystem services in tropical forests:
6 800 000 000 000 $/year

~ 5% of the global GDP (2019)
~ global cost of the Covid-19 crisis

References: Costanza *et al.* (2014), Edwards *et al.* (2019), Gardner *et al.* (2009), Malhi (2012), Malhi *et al.* (2014)
Photos: Gravity Giant Productions, J. Laporte

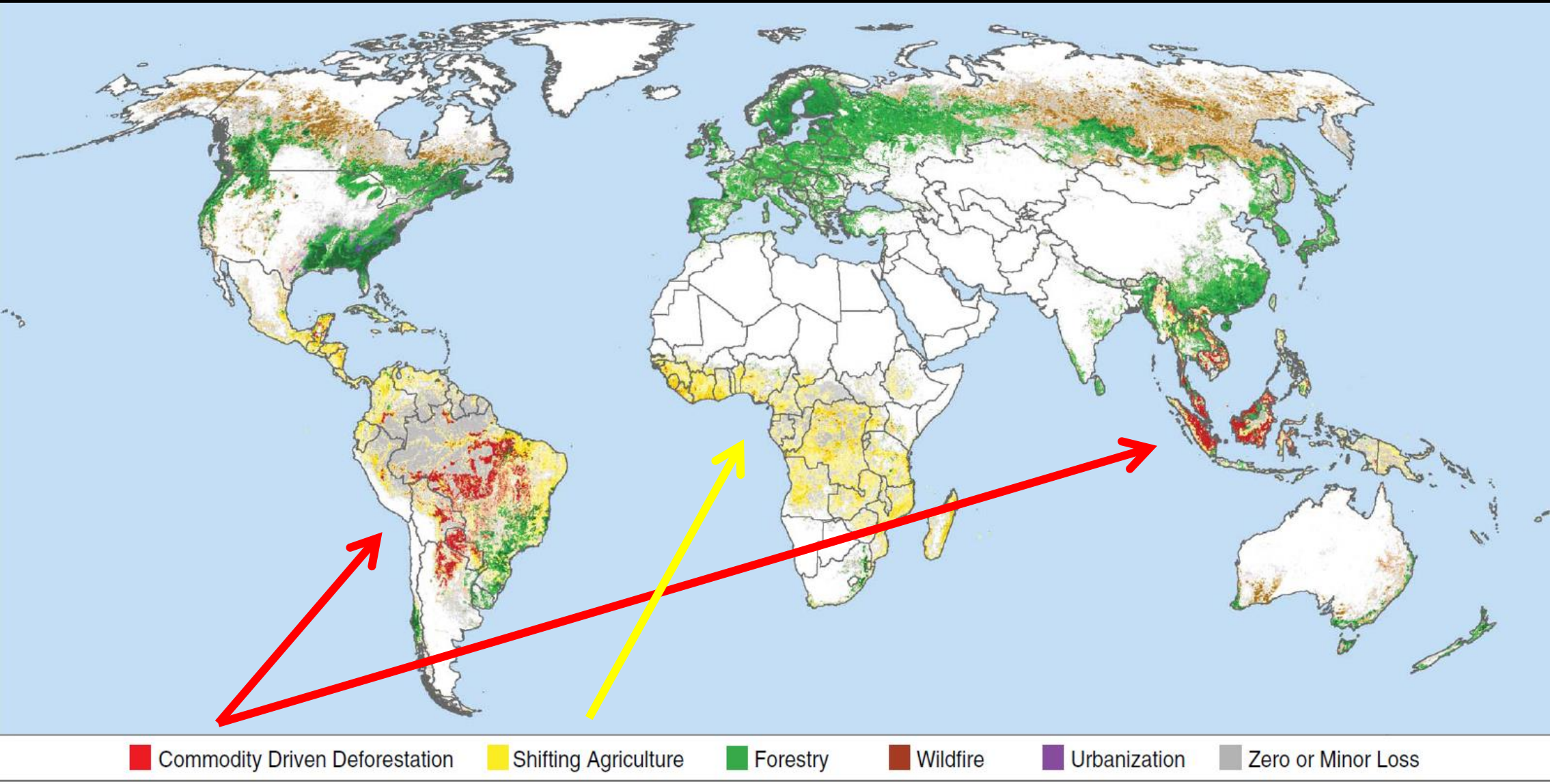
Tropical forests in the Anthropocene



Deforestation and forest degradation
Defaunation

Reference: Malhi *et al.* (2014)

Deforestation and forest degradation

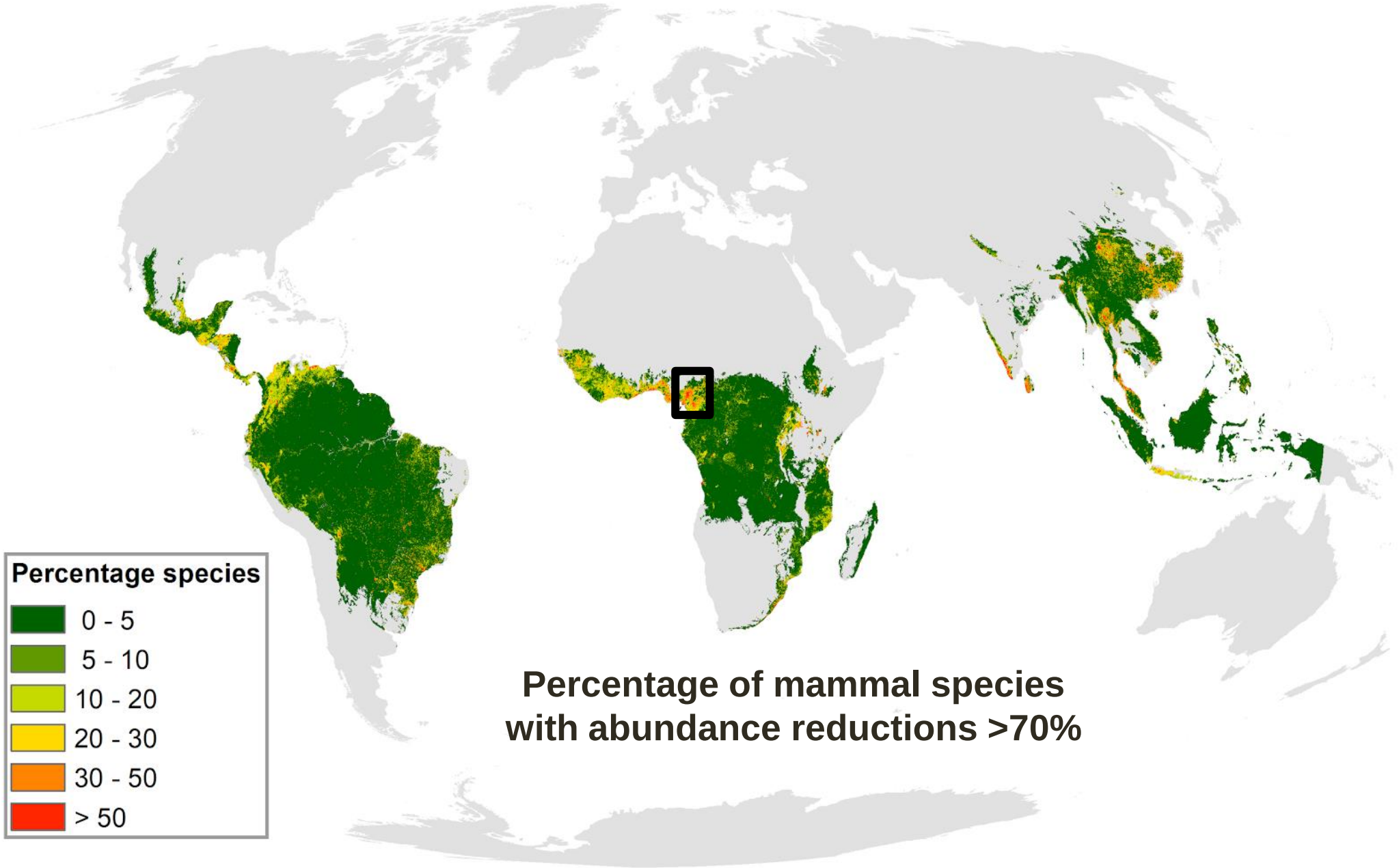


Primary drivers of forest cover loss (2001-2015)

ON A GLOBAL SCALE, THE AREA OF MINIMALLY DISTURBED FORESTS DECLINED BY 92 MILLION HECTARES BETWEEN 2000 AND 2013

References: Curtis *et al.* (2018), WWF Living Planet Report (2018)

Defaunation



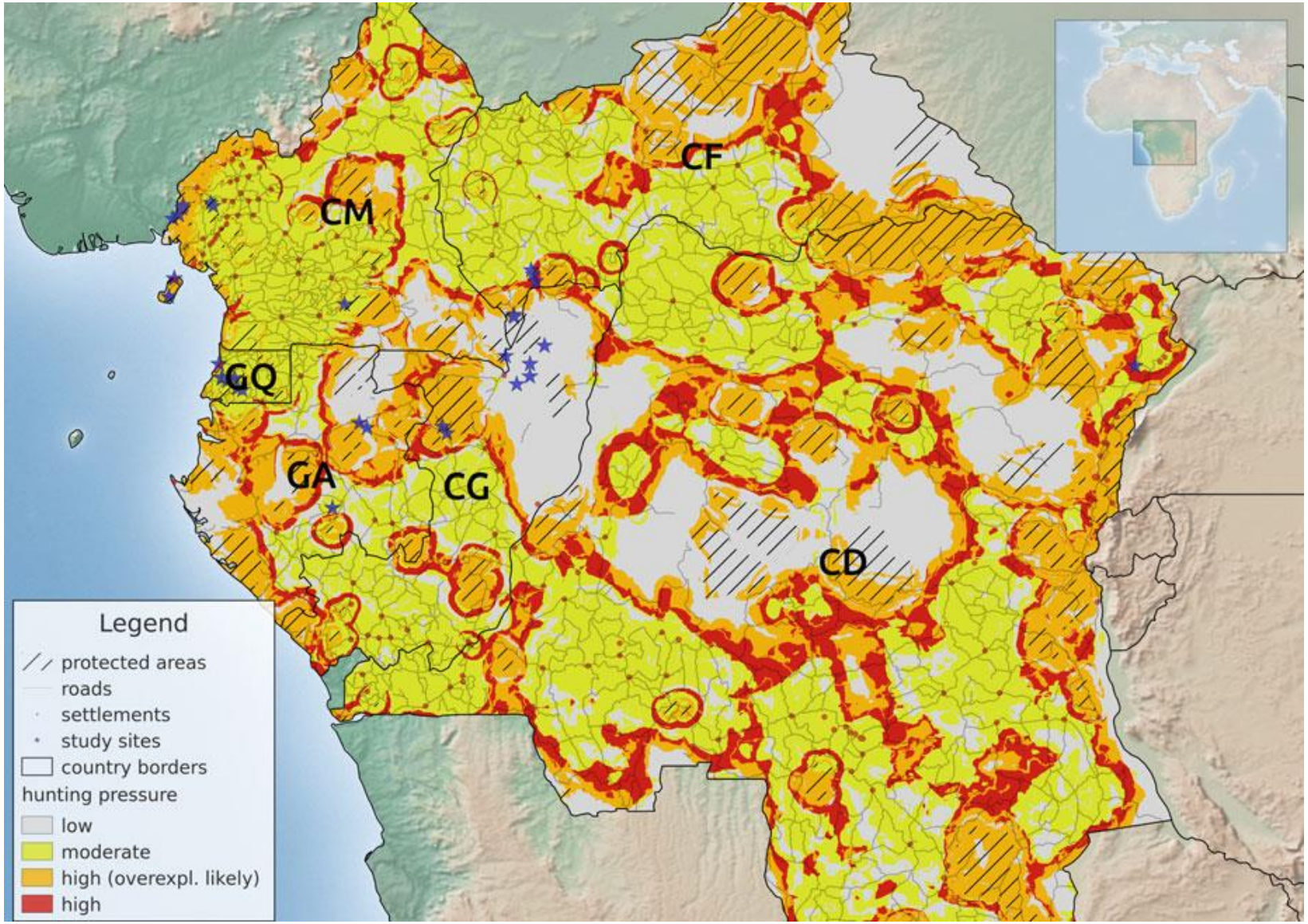
Percentage of mammal species with abundance reductions >70%

Reference: Benítez-López *et al.* (2019)

Defaunation

Spatial prediction of hunting pressure

(using distance to protected areas, roads, and population density)



Reference: Ziegler *et al.* (2016)

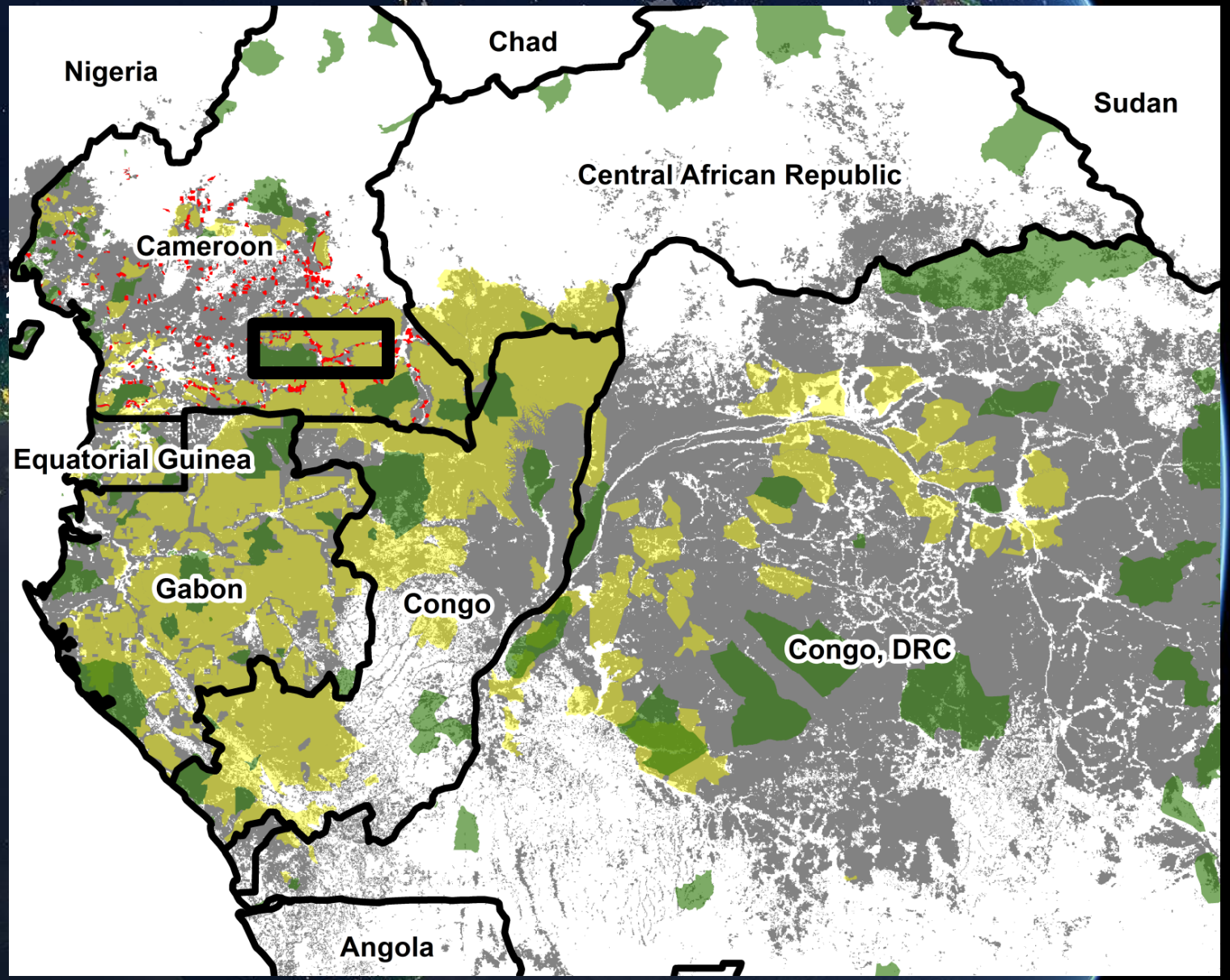
Central Africa

170 million hectares

Contribution to the livelihoods of **>60 million people** in a high-poverty rural context

References: Abernethy *et al*. (2016), Doumenge *et al.* (2015), FRMi (2018), Minang *et al.* (2019), WRI (2012)
Design: Globaïa

Central Africa



Protected areas
45 millions hectares

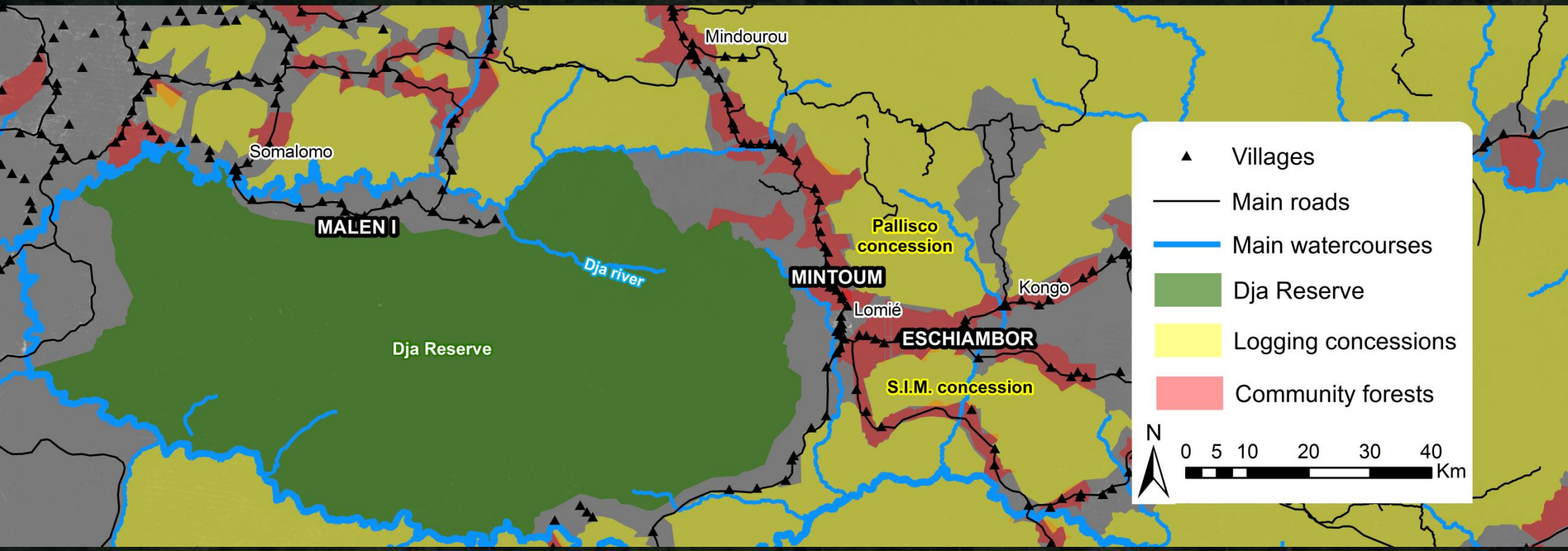
Production forests
51 millions hectares

Community forests
4 millions hectares

Other forests
70 millions hectares

References: Abernethy *et al*. (2016), Doumenge *et al.* (2015), FRMi (2018), Minang *et al.* (2019), WRI (2012)
Design: Globaïa

Social-ecological system (southeastern Cameroon)



- Dense forests of the Guineo-Congolian Region
- Population density: 8 people/km²
- Local populations comprise 2 ethnic groups: Bantu and Baka Pygmy people
- Main activities: shifting agriculture, hunting, fishing, gathering, and artisanal logging
- Frequent conflicts among forest stakeholders

References: Cellule Aménagement Pallisco & Nature+ (2015), Ezzine de Blas *et al.* (2011), Gillet (2016), Samndong and Vatn (2012), Schwartz *et al.* (2012), Vermeulen (2000), www.citypopulation.de
Photo: J. Laporte

Forest land allocations

526 155 ha

340 772 ha

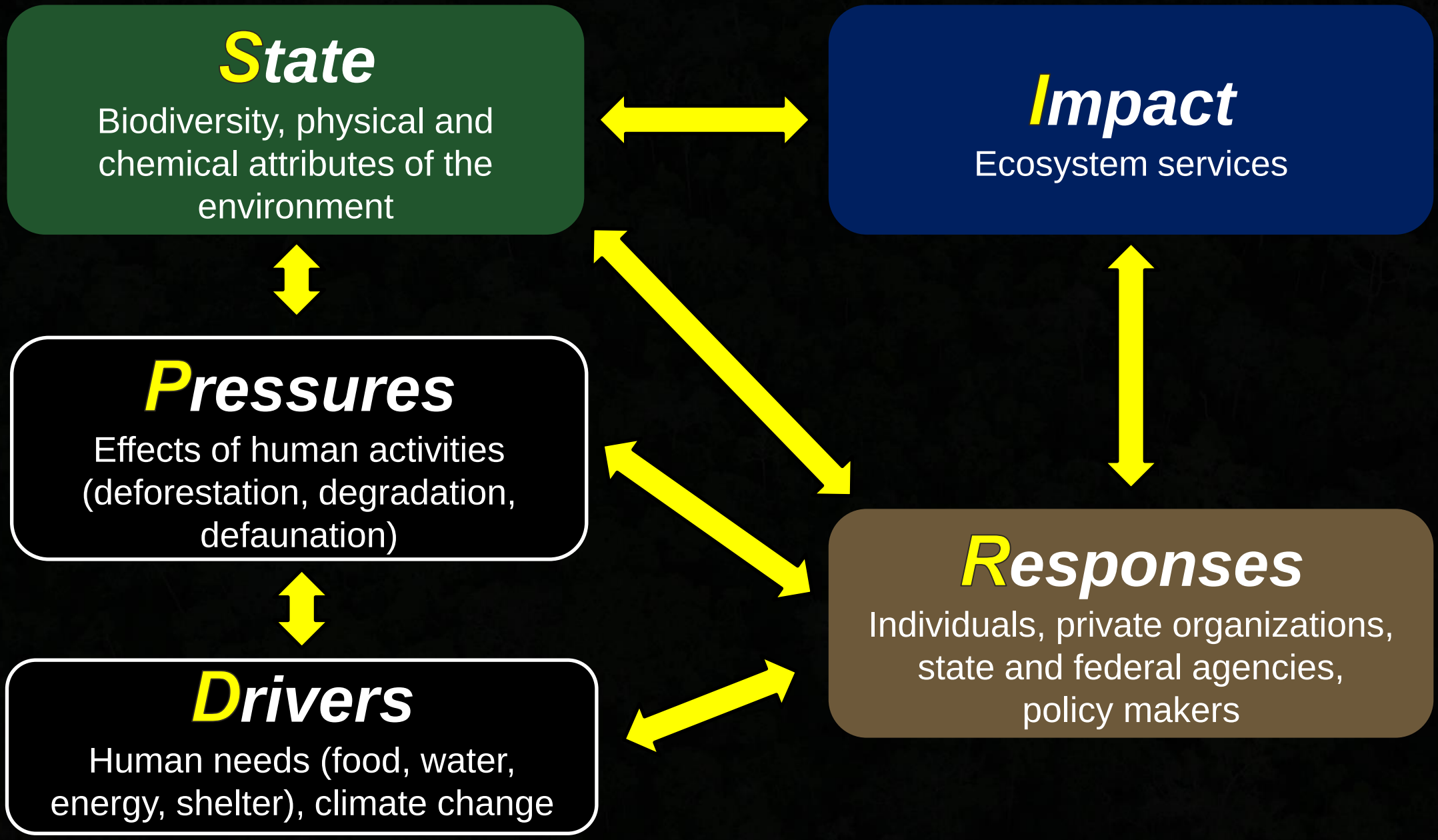
13 466 ha

	Protected area	Logging concession	Community forests
Forest cover	90%	90%	90%
Deforestation rate	0.0%	0.1%	1.5%
Hunting	Prohibited	Regulated*	Regulated*
Gathering	Prohibited	Allowed	Allowed
Agriculture	Prohibited	Prohibited	Allowed
Artisanal logging	Prohibited	Prohibited	Allowed

* Allowed for self-consumption only, with traditional selective techniques, only for non-protected species

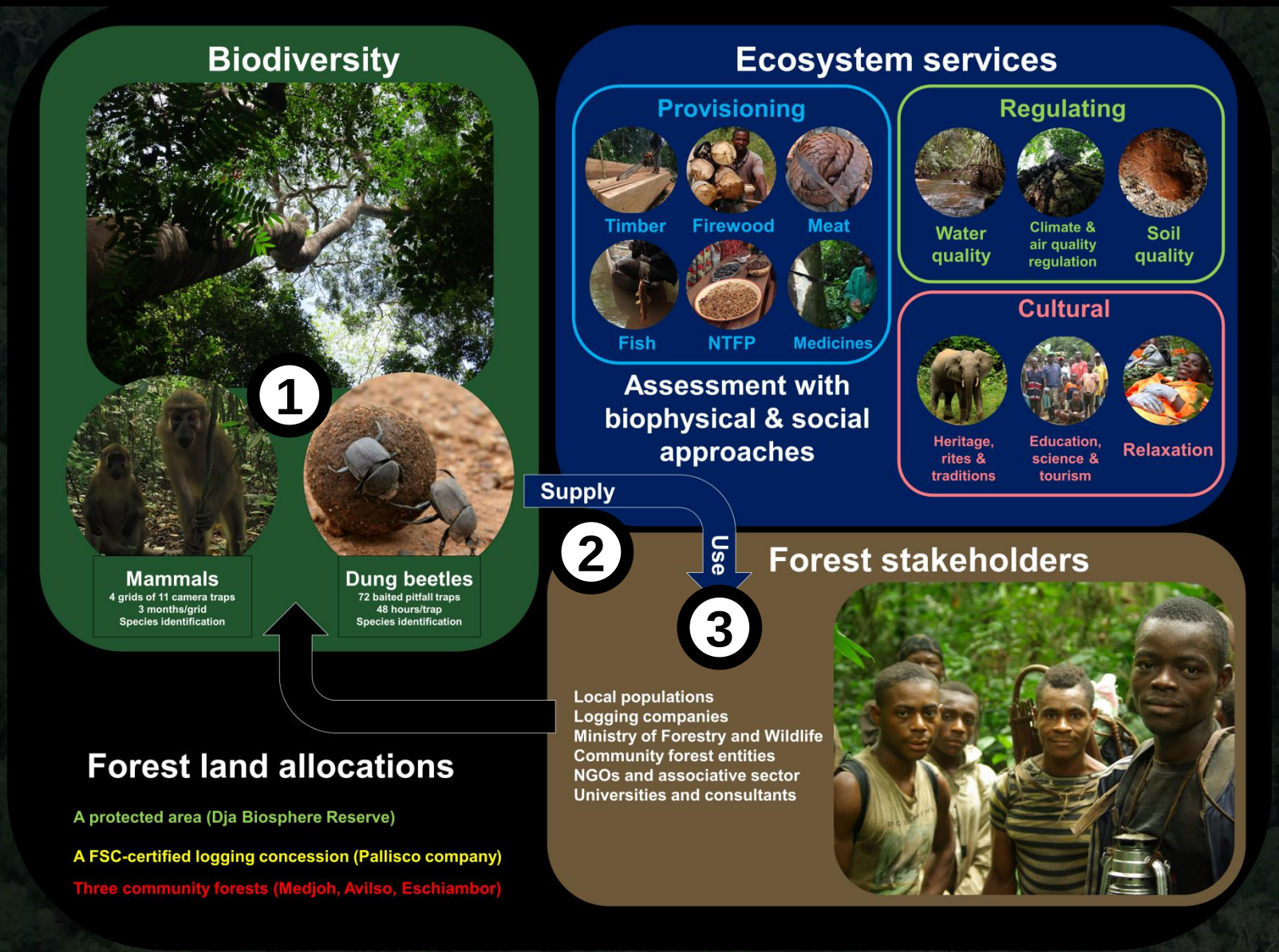
References: Cameroonian Forestry Law (1994), Hansen *et al.* (2014), Management plans of the three forest allocations, WRI (2012)
Photos: S. Hette, J. Laporte, S. Lhoest, C. Vermeulen

DPSIR approach for the analysis of social-ecological systems



Reference: Kelble *et al.* (2013)

Conceptual framework and objectives



General objective: Assess the conservation value of tropical forests in southeastern Cameroon, as well as the supply of ecosystem services and use by local populations, in three contrasted forest land allocations

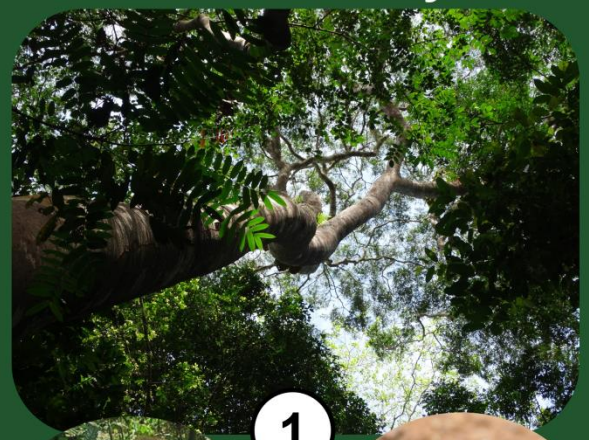
Photos: J. Atkinson, J.-Y. De Vleeschouwer, J.-L. Doucet, D. Fonteyn, J. Laporte, S. Lhoest, J. Schure

2. Conservation value of forest allocations

Lhoest S., Fonteyn D., Daïnou K., Delbeke L., Doucet J.-L., Dufrêne M., Josso J.-F., Ligot G., Oszwald J., Rivault E., Verheggen F., Vermeulen C., Biwolé A. & Fayolle A. (2020). Conservation value of tropical forests: Distance to human settlements matters more than management in Central Africa. *Biological Conservation*, 108351.

Photo: D. Fonteyn, S. Lhoest

Biodiversity



1

Mammals
4 grids of 11 camera traps
3 months/grid
Species identification

Dung beetles
72 baited pitfall traps
48 hours/trap
Species identification

Ecosystem services

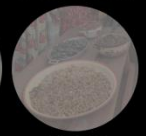
Provisioning


Timber


Firewood


Meat


Fish

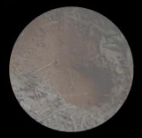

NTFP


Medicines

Regulating


Water quality


Climate & air quality regulation


Soil quality

Cultural


Heritage, rites & traditions


Education, science & tourism


Relaxation

Assessment with biophysical & social approaches

Supply

2

Use

3

Forest stakeholders

Local populations
Logging companies
Ministry of Forestry and Wildlife
Community forest entities
NGOs and associative sector
Universities and consultants

Forest land allocations

A protected area (Dja Biosphere Reserve)

A FSC-certified logging concession (Pallisco company)

Three community forests (Medjoh, Avilso, Eschiambor)

Conservation challenges in forest allocations

Protected areas

- Increasing areas since the middle of the 20th century
- Erosion of biodiversity in protected areas throughout the tropics
- Rapid human population growth at the edge of protected areas

Production forests

- High proportion of tropical areas ➔ potential buffering role?
- If managed responsibly, similar species richness than in protected areas
- Certification for responsible management is scarce

Community forests

- The participation of local populations in forest management can contribute to conservation if they are aware of the risks of unsustainable use
- Community forests are part of the Non Permanent Forest Estate

References: Berkes *et al.* (1994), Blomley (2013), Clark *et al.* (2009), Duguma *et al.* (2018), Edwards *et al.* (2014), Gibson *et al.* (2011), Kellert *et al.* (2000), Laurance *et al.* (2012), Maryudi *et al.* (2012), Minang *et al.* (2019), Nasi *et al.* (2012), Panlasigui *et al.* (2018), Poulsen *et al.* (2011), Putz *et al.* (2012), Ribot (2003), Tranquilli *et al.* (2014), Watson *et al.* (2014), Wittemyer *et al.* (2008)

Photo: J. Laporte

Objectives

Identify the determinants of the conservation value of tropical forests in southeastern Cameroon, disentangling the effects of:

i. Forest allocation
ii. Proximity to human settlements (roads and villages)
iii. Local habitat (forest degradation, canopy openness, proximity to rivers)

Two indicator taxonomic groups:

i. Mammals
ii. Dung beetles

Two components of diversity:

i. Species richness (α- and γ-diversities)
ii. Species composition (β-diversity)

Photo: J. Laporte

Indicator groups of biodiversity

Mammals

First target of **hunting**
Growing hunting pressure ➔ Local extinctions ➔ Empty forests

Strong detrimental effects on forest ecosystems:

- Trophic webs disruption
- Limitation of seed dispersal and forest regeneration
- Other cascading effects

Dung beetles

Sensitive to small habitat disturbances,
such as **reduced-impact selective logging**

Various ecological processes:

- Nutrient cycling and fertilization
- Seed dispersal
- Etc.

References: Abernethy *et al.* (2013), Abernethy *et al.* (2016), Bicknell *et al.* (2014), Cajaiba *et al.* (2017), Gardner *et al.* (2008), Klein (1989), Nervo *et al.* (2017), Nichols *et al.* (2007), Nichols *et al.* (2008), Nichols *et al.* (2009), Nummelin and Hanski (1989), Poulsen *et al.* (2018), Redford (1992), Terborgh *et al.* (2008), Ziegler *et al.* (2016)
Photo: J. Laporte

Biodiversity inventory

44 camera traps
3 months
Density of 1 camera / 2 km²
30-50 cm above ground level
Oriented to animal trails
Herbaceous vegetation cleared

TEAM NETWORK
TROPICAL ECOLOGY ASSESSMENT AND MONITORING

72 baited pitfall traps
18 groups of 4 traps
250 m between traps in each group
48 hours

Photos: L. Delbeke, J. Laporte, S. Lhoest

Mammals

3464 independent detection events

Chimpanzee
(*Pan troglodytes*)

Red River Hog
(*Potamochoerus porcus*)

African Palm Civet
(*Nandinia binotata*)

Giant Pangolin
(*Manis gigantea*)

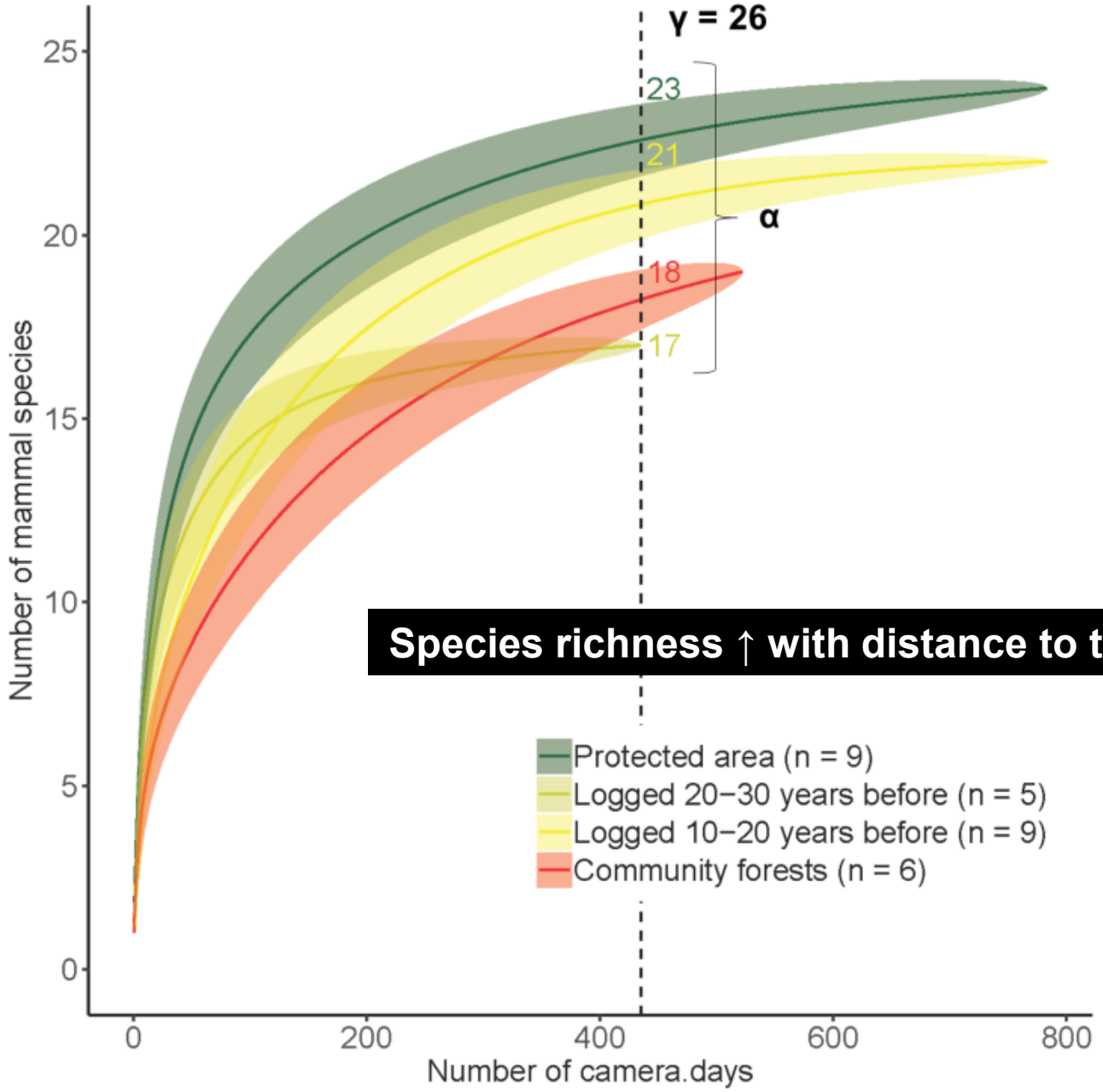
Photos: D. Fonteyn, S. Lhoest

Dung beetles

4475 individuals

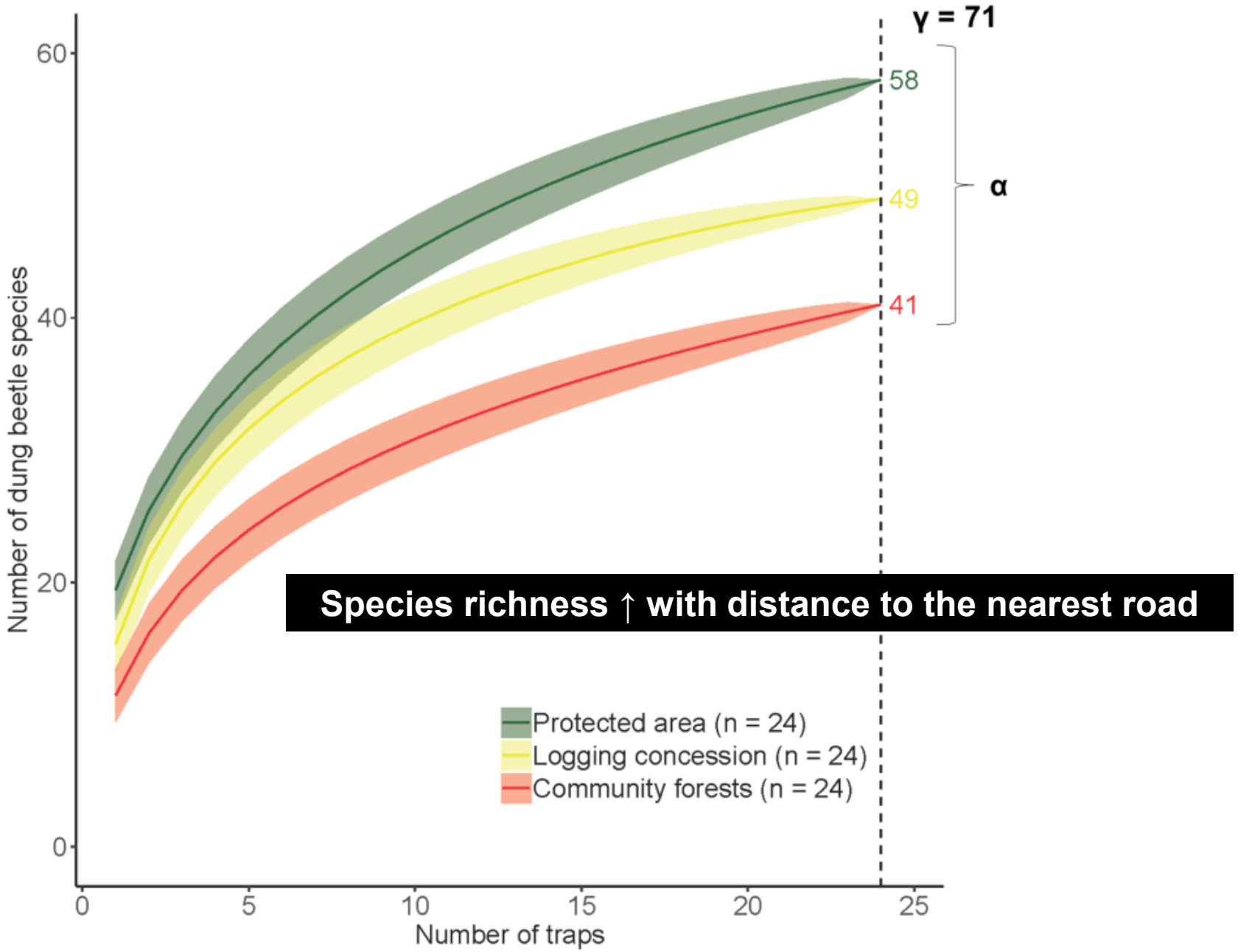
Photos: L. Delbeke

Species richness



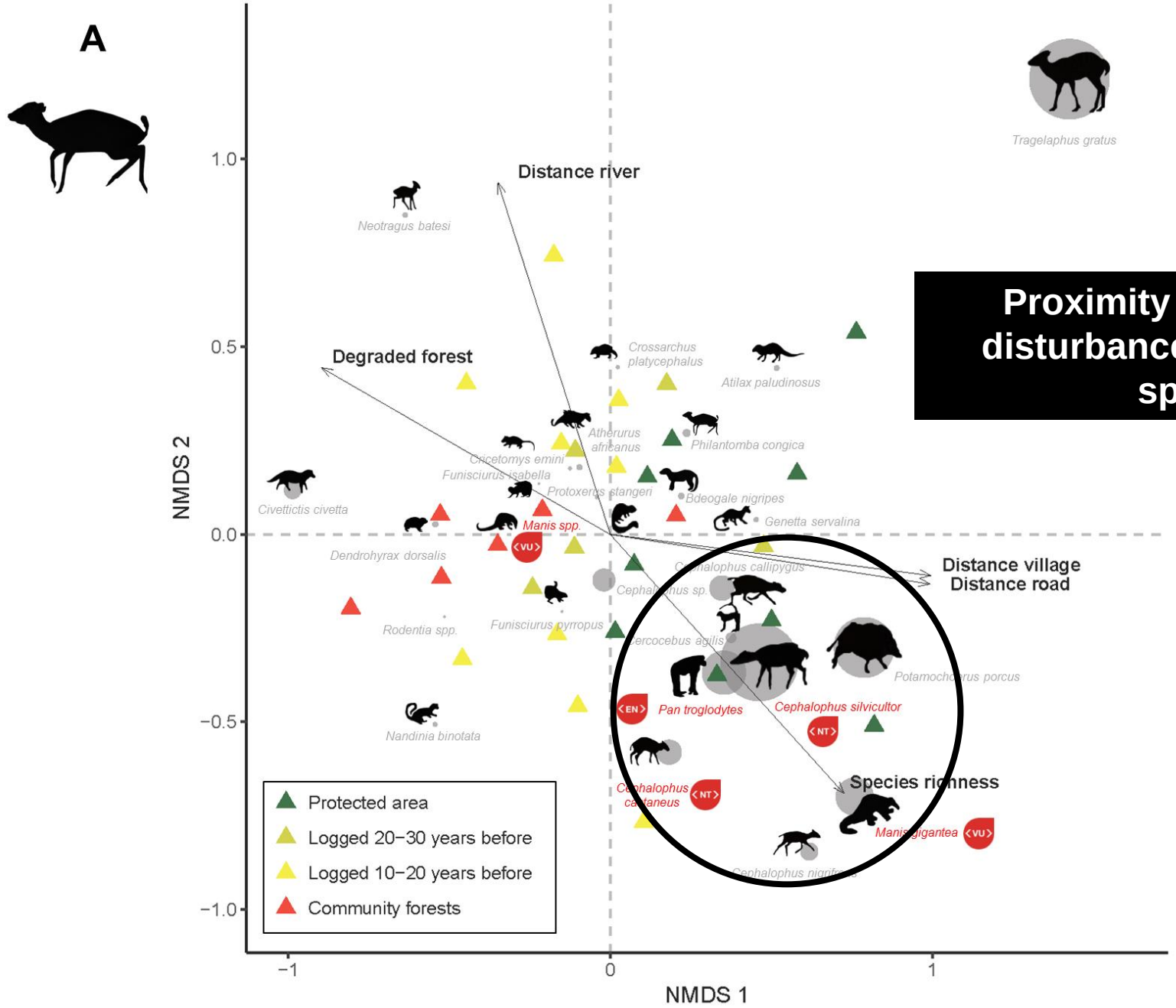
Species richness ↑ with distance to the nearest village

Species richness



Species richness ↑ with distance to the nearest road

Species composition



Proximity to human settlements and disturbance is the main determinant of species composition

Conclusion

Gradient of human pressure on forest biodiversity

Protected area

High conservation value
Not a paper park

Logging concession

High potential for conservation, but high variability in biodiversity patterns

Community forests

Degraded forests, but not empty forests yet

Our results cannot be generalized at the scale
of all Cameroonian / Central African protected and logged forests

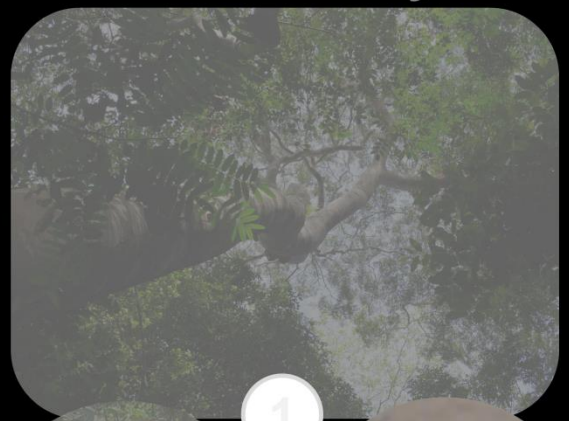
Photos: S. Hette, J. Laporte, S. Lhoest, C. Vermeulen

3. Perceptions of ecosystem services supplied by tropical forests to local populations

Lhoest S., Dufrêne M., Vermeulen C., Oszwald J., Doucet J.-L. & Fayolle A. (2019). Perceptions of ecosystem services provided by tropical forests to local populations in Cameroon. *Ecosystem Services*, 38, 100956.

Photo: S. Hette

Biodiversity



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Firewood

Meat

Fish

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Water quality

Climate & air quality regulation

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Research needs in ES assessment

Integrated approach:
Ecological + Economic + Social

Not enough | Most studies | Urgent need!

Some faults & limitations:

- Commodification of nature
- No ethical dimension of nature & biodiversity
- No consideration of the human dimension

Some advantages:

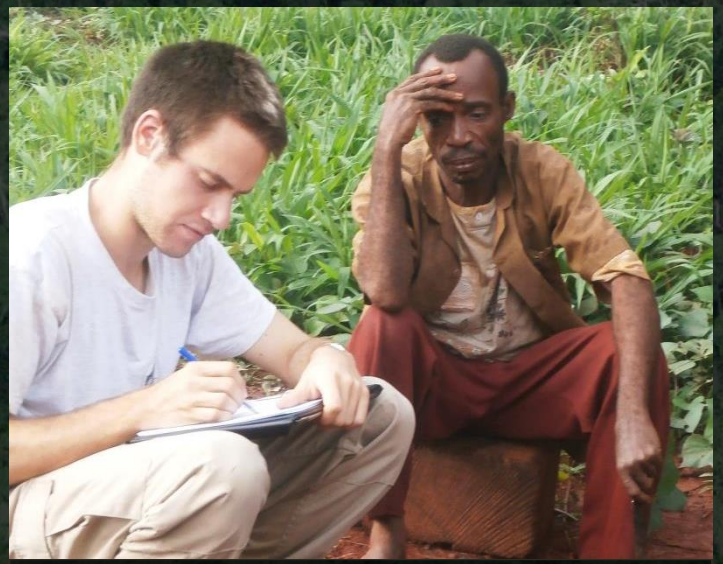
+ Valuation of cultural services
+ Understanding complex socio-ecological systems
+ Assuring social relevance of the ES assessment
+ Strenghtening the policy relevance of ES assessments

References: Burkhard *et al.* (2010), Knights *et al.* (2013), Kosoy & Corbera (2010), Luck *et al.* (2012), Orenstein and Groner (2014), Turnhout *et al.* (2013)
Photo: J. Laporte

Objectives

Assess the perceptions of ecosystem services provided by tropical forests to local populations in southeastern Cameroon, and specifically:

1. Assess the significance and abundance of ecosystem services
2. Identify the determinants of the perceptions of ES abundance among:
   - i. Forest allocations
   - ii. Deforestation
   - iii. Socio-demographic characteristics (gender, age, ethnicity, main occupation)



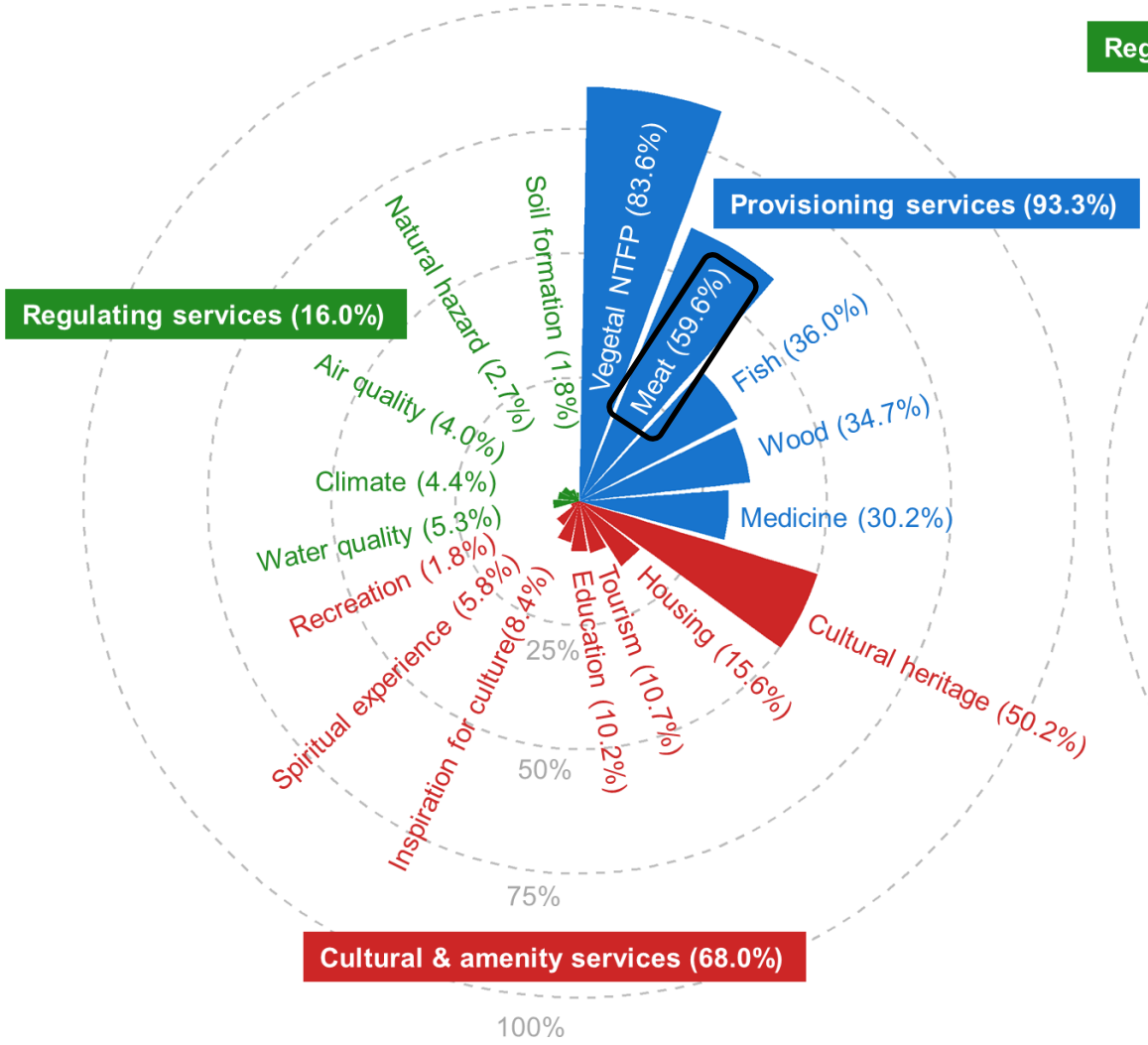
Individual interviews with 225 forest stakeholders in 23 locations

→ 1 open-ended question
➔ **Perceptions of ES significance**
16 directed questions
➔ **Perceptions of ES abundance**

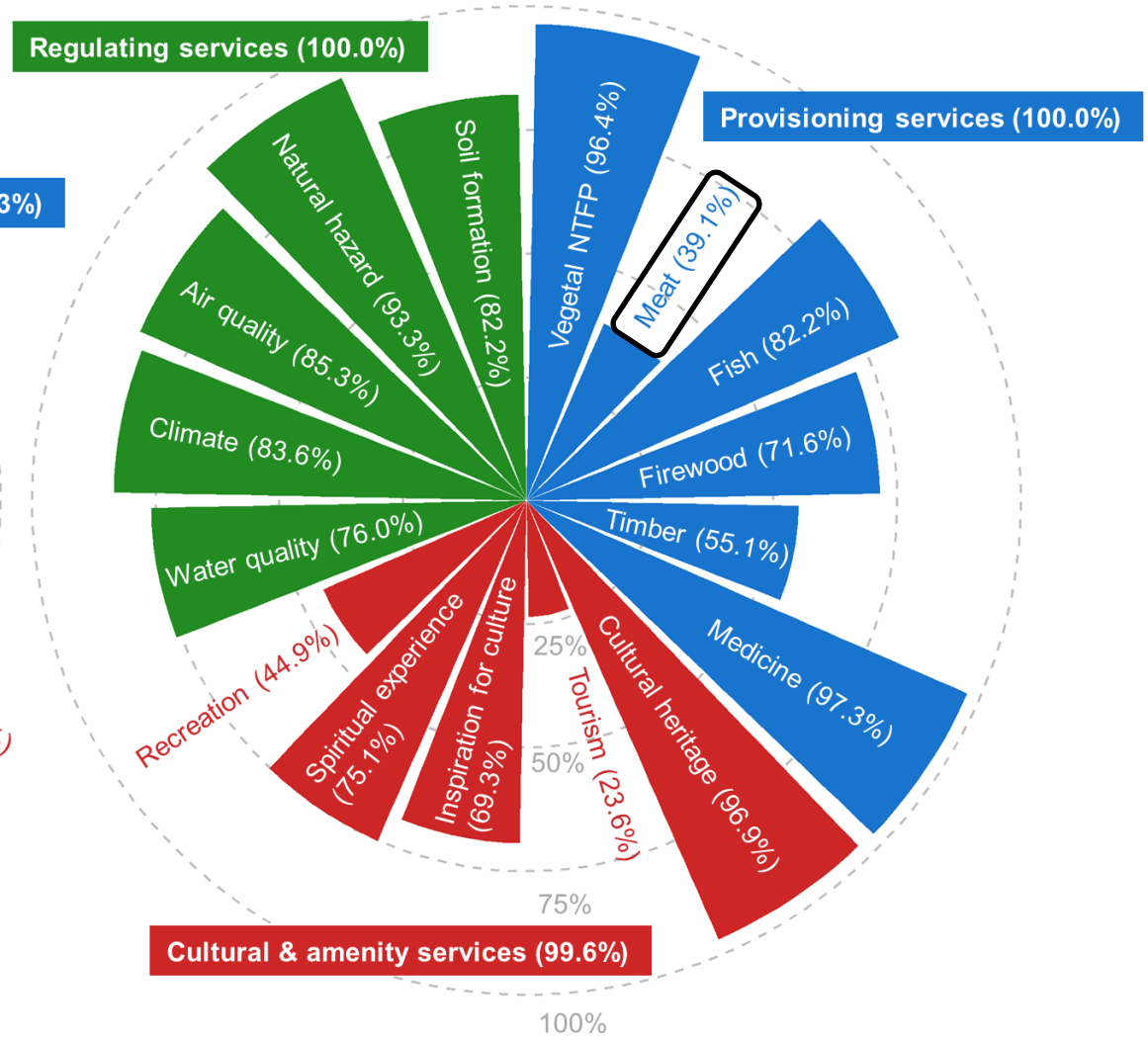
Photos: L. Alombi Moussa, J. Laporte

Perceptions of ecosystem services

Perceptions of ecosystem services significance (percentages of spontaneous mentions)



Perceptions of ecosystem services abundance (percentages of directed mentions)



The ES most frequently perceived as important are provisioning and cultural services. Bushmeat is the only ES perceived as highly important but not very abundant.

Determinants of ES perceptions

Ecosystem services	Forest allocation	Deforestation	Gender	Age	Ethnicity	Occupation
Vegetal NTFP						
Meat (hunting)						***
Fish (fishing)						
Firewood	***	***				
Timber	***	***	***			
Traditional medicine						
Cultural heritage and identity						
Tourism	***					
Inspiration for culture	***			***		
Spiritual experience	***					
Recreation						
Water quality regulation					***	
Climate regulation						
Air quality regulation						
Natural hazard mitigation						
Soil formation and regeneration						

Perceptions of ES abundance are relatively homogeneous.
ES perceptions are mainly explained by spatial parameters >< social parameters.

Conclusion

Most frequently reported ES among local stakeholders:

Provisioning > Cultural > Regulating

Deep disconnection between perceptions of the importance of regulating services of local stakeholders and international priorities (REDD+, PES, ...)

➔ Need to integrate local actors in policy decisions for legitimacy

Qualitative ES assessments are required to implement sustainable management strategies and decisions, with social legitimacy

The most 'controversial' ES should be assessed with complementary methods:

Bushmeat, firewood, timber, cultural services

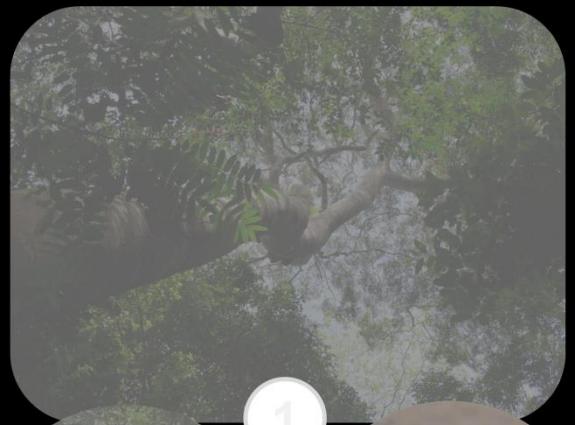
Photo: J. Laporte

4. Use of forest ecosystem services by local populations

Lhoest S., Vermeulen C., Fayolle A., Jamar P., Hette S., Nkodo A., Dufrêne M. & Meyfroidt P. (2020). Use of forest ecosystem services by local populations in southeastern Cameroon. *Sustainability*, 12(6), 2505.

Photo: P. Jamar

Biodiversity



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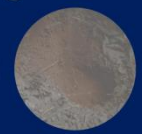

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Three community forests (Medjoh, Avilso, Eschiambor)

Objectives

Quantify the use of important ES provided by tropical forests to local populations in southeastern Cameroon, and specifically:

1. Quantification and mapping of ES use
2. Determinants of ES use at the village scale:
   population size, forest allocations, deforestation rate?
3. Sustainability of the use of provisioning ES?

Data collection in 3 villages:
Field surveys (biophysical approaches) and interviews (social approaches)

3 provisioning services:
Bushmeat, firewood, timber

5 cultural services:
Cultural heritage, inspiration, spiritual experience, recreation, education

Photo: J. Laporte

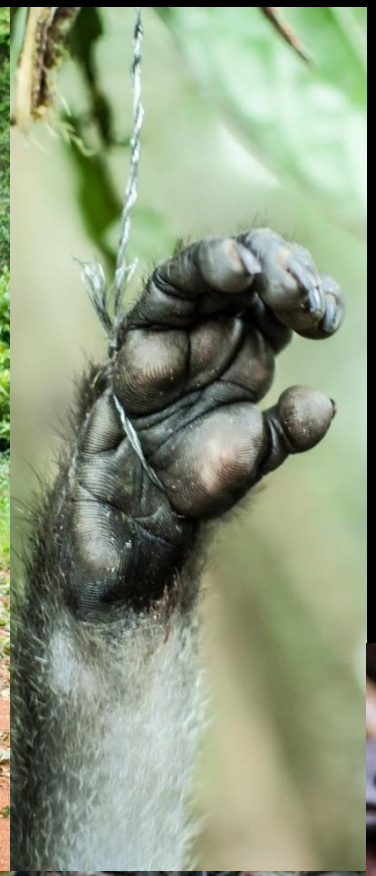
Data collection in 3 villages

- Exhaustive household census (structured interviews, n = 133)
- Sampling of 55 volunteer households stratified by: main source of income & ethnic group

Photos: S. Hette, S. Lhoest

Participatory mapping

Data collection in 3 villages



Photos: S. Hette

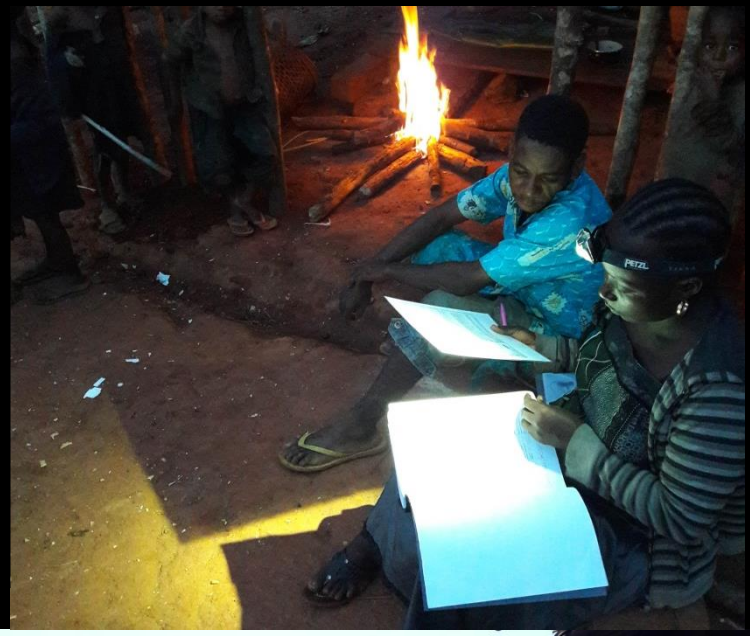
Bushmeat use:

- GPS tracking of volunteer hunters
  (n = 651 km)
- Daily survey of dietary intake: Structured interviews + Weighing
  (n = 3291 meals)

Data collection in 3 villages

Firewood use:

- GPS tracking of volunteer villagers
  (n = 50 km)
- Daily survey of firewood use: Structured interviews + Weighing
  (n = 3367 days)

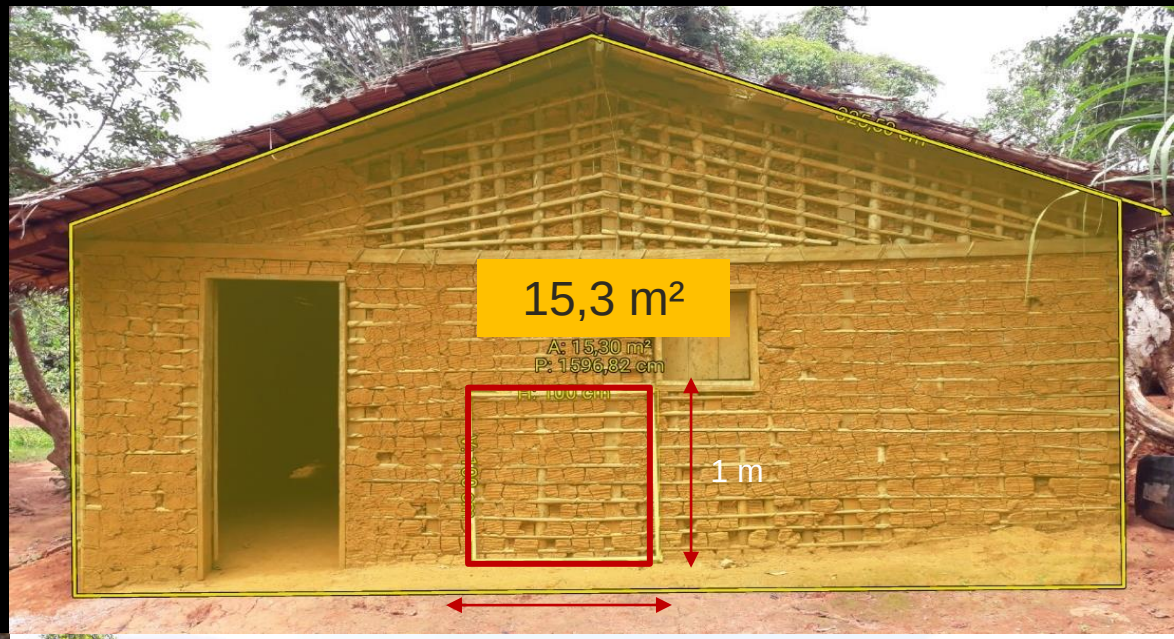


Photos: P. Jamar

Data collection in 3 villages

Timber use:

- Quantification with structured interviews + Measurements
  (n = 69 households)



Photos: P. Jamar

Data collection in 3 villages

Cultural services use:

- Participatory mapping + Georeferencing
  (n = 26 sites)
- Evaluation of the use of cultural services: Structured interviews
  (n = 145 respondents)

Photos: S. Hette, P. Jamar, S. Lhoest

Bushmeat

56 kg / person / year

57 % is purchased

(n = 3291 meals)

Photo: S. Hette

Firewood

1.17 m³ / person / year

1% is purchased

(n = 3367 days)

Photo: P. Jamar

Timber

0.03 m^3 / person / year

21% is purchased

(n = 69 households)

Photo: P. Jamar

Cultural heritage

73% of positive mentions

(n = 145 respondents)

Photo: S. Hette

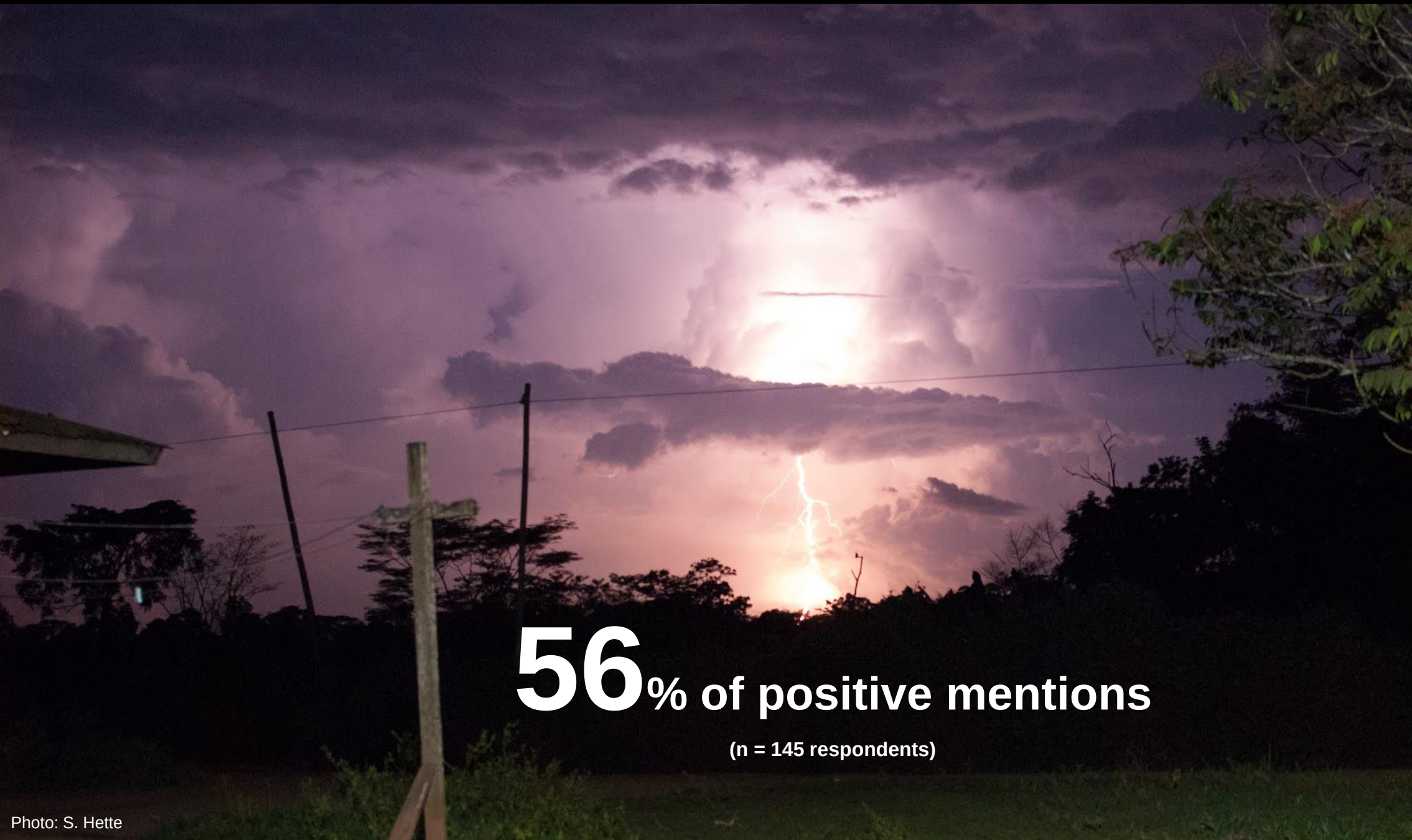
Inspiration

25% of positive mentions

(n = 145 respondents)

Photo: S. Hette

Spiritual experience



56% of positive mentions

(n = 145 respondents)

Photo: S. Hette

Recreation

55% of positive mentions

(n = 145 respondents)

Photo: P. Jamar

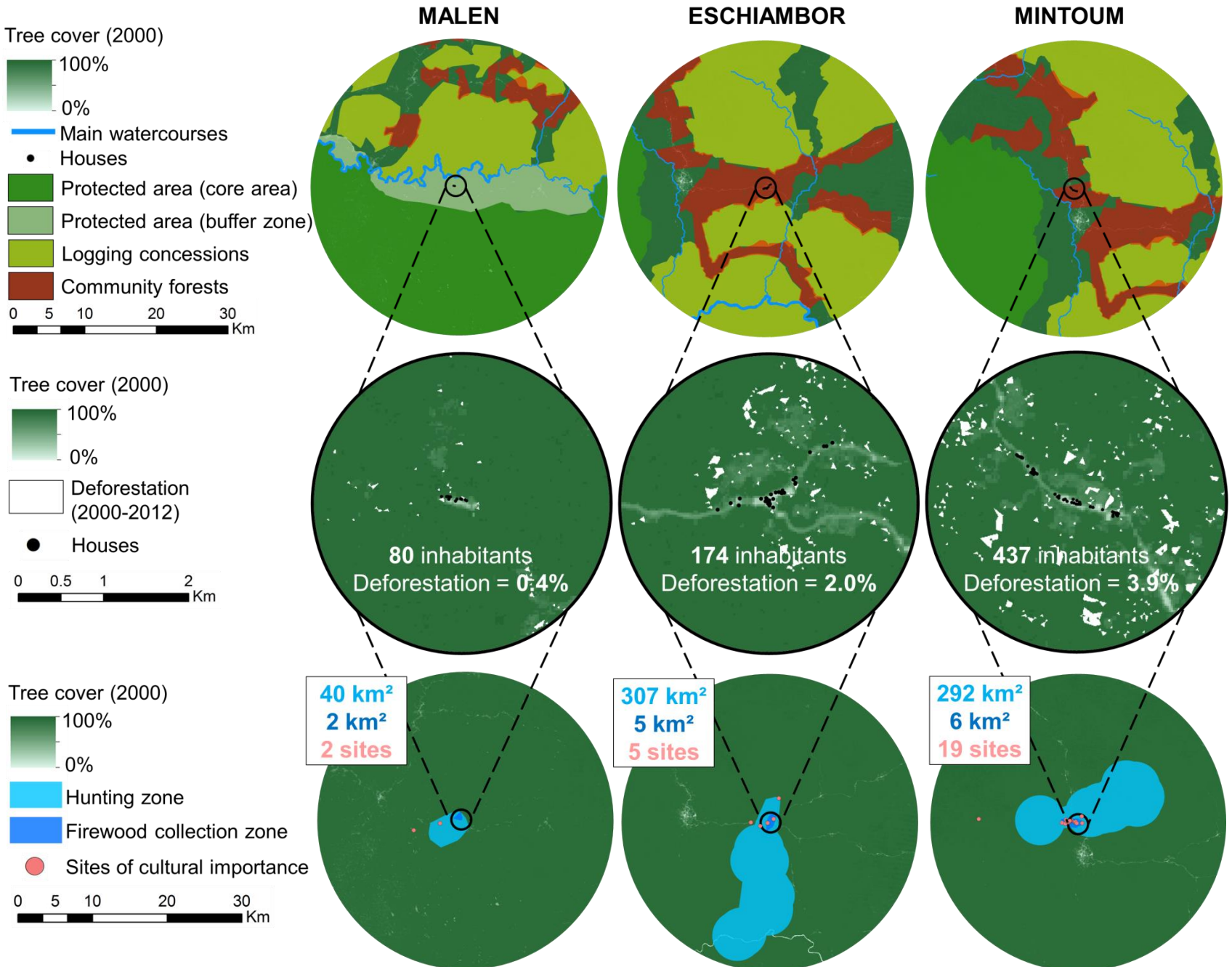
Education

86% of positive mentions

(n = 145 respondents)

Photo: S. Lhoest

Mapping and determinants of ES use at the village scale



Population size, deforestation rate and forest allocations may be important determinants of ES use at the village scale

Sustainability of bushmeat consumption

Dja area (2018)

4.7 km²/household

32 kg/km²/year

8 people/km²

References

- In 2001: 2.0 km²/household
- In 2001: 93 to 173 kg/km²/year
- Maximum production of wild meat in tropical forests: 150-200 kg/km²/year
- Maximum density for sustainable bushmeat consumption: 1 person/km²

Decrease of animal populations since decades (100% of 24 interviewed hunters)
Defaunation, extension of hunting areas, **non-sustainable hunting practices**

References: Delvingt *et al.* (2001), Robinson and Bennett (2000), Vermeulen and Karsenty (2001)
Photo: S. Hette

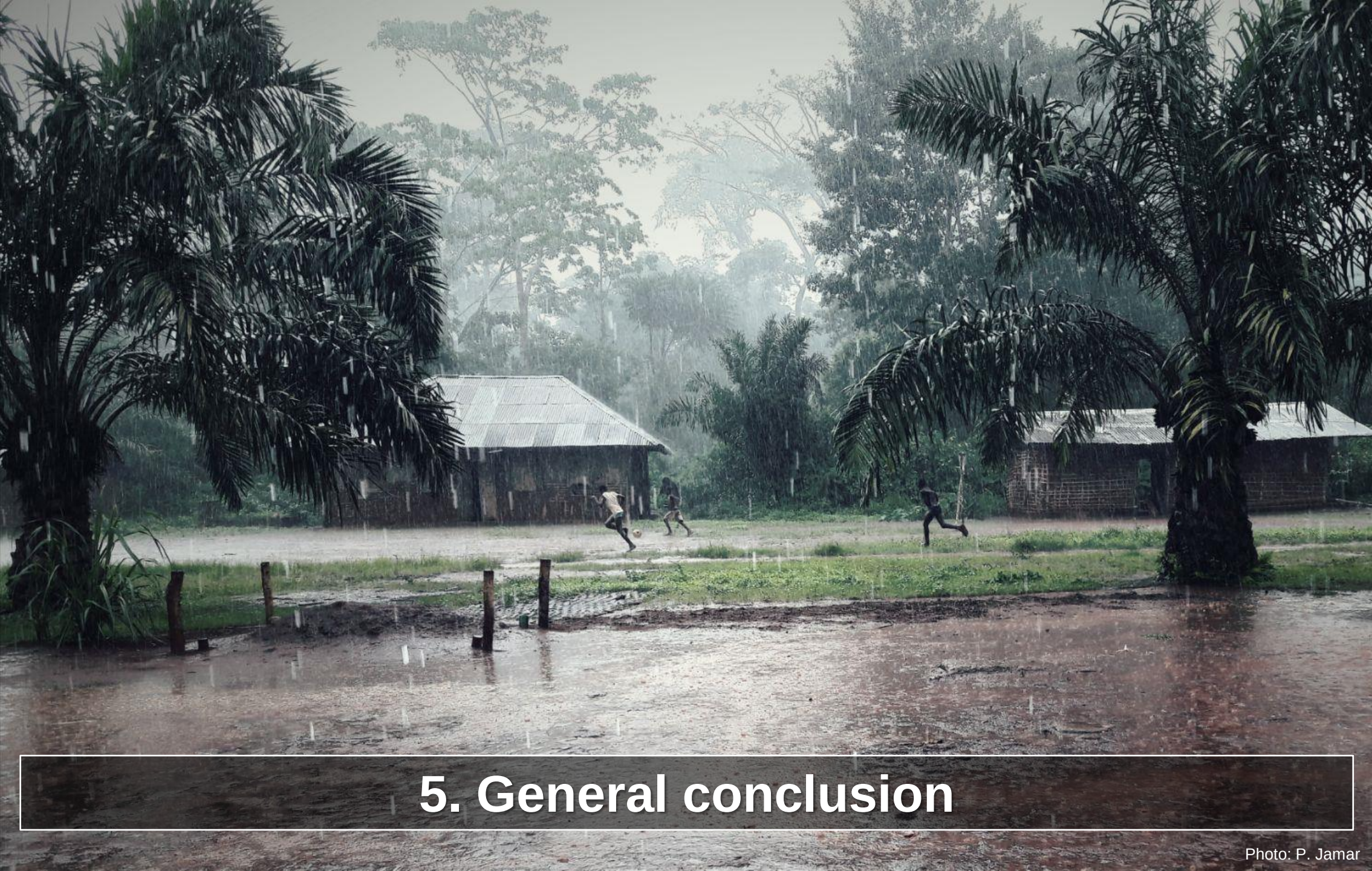
Sustainability of firewood and timber use

Mean use of firewood: 1.8 kg/person/day
Mean use of timber: 3.75 m^3/household
Firewood use = 39 x timber use

Total firewood mass used annually in each village = 0.20 to 0.69 Mg/ha/year
= 4 to 13% of the natural growth of the wood resource based on a biomass increment of 5.46 Mg/ha/year estimated in Cameroon agro-forest areas

Sustainable use of wood by rural populations, minor impact on forest ecosystems

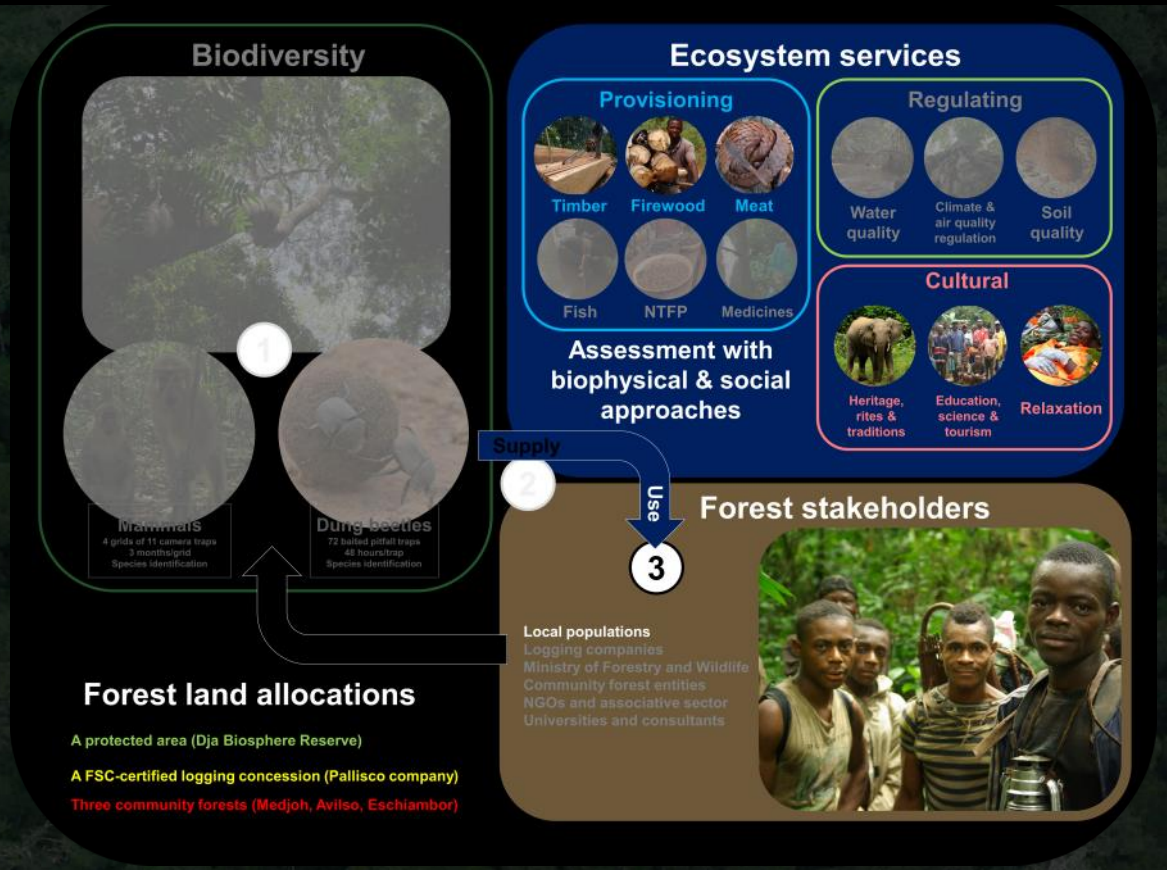
Reference: Djomo *et al.* (2011)
Photo: P. Jamar



5. General conclusion

Photo: P. Jamar

Major findings



1. Contrasted forest allocations with contrasted conservation values
   But distance to human disturbance is the most important determinant of biodiversity

2. All important ES are perceived to be supplied abundantly by forest ecosystems to local populations, except bushmeat

3. Influence of forest allocations, population size and deforestation rate on the use of ES
   Sustainable use of firewood and timber use by local populations >< bushmeat

Photos: J. Atkinson, J.-Y. De Vleeschouwer, J.-L. Doucet, D. Fonteyn, J. Laporte, S. Lhoest, J. Schure

Forest land allocations

Indicators	Protected area	Logging concession	Community forests
Biodiversity	+++	++	+
Provisioning services	+	++	+++
Regulating services	+++	+++	++
Cultural services	+	+++	+++

Photo: J. Laporte

Reconciling conservation and sustainable use of tropical forests?

- A major challenge in the Dja social-ecological system: reconciling wildlife conservation, sustainable hunting practices, food security and human well-being
- Up to 77% of hunting catches are sold: the need for income reinforces the overharvesting
- Social levers identified by local stakeholders:
  - Generalized unemployment in the region
    ➔ Need of new job opportunities (private sector, NGOs, ...)
  - Fishing and NTFP gathering as alternative sources of income and food

Mammal diversity ⟺ *Hunting offtake* ⟺ *Bushmeat consumption*

Photos: S. Hette, Kingdon *et al.* (2013), J. Laporte

Integration of ecosystem services in tropical forest management

- **Integrated ES assessment:**
  - ✓ Holistic way to consider all stakeholders and challenges in a specific social-ecological system
  - ✓ Awareness raising and education
  - ✓ Identification and resolution of conflicts
  - ✓ Support decision making with social inclusiveness and political legitimacy
  - ✓ Numerous methods and tools to be adapted to available time and means

- **Concrete applications:**
  - ✓ FSC-certification of ES
  - ✓ ‘Man and Biosphere’ Reserves
  - ✓ Development projects
  - ✓ ‘Concession 2.0’

References: Arrias-Arévalo *et al.* (2017), Bele *et al.* (2015), Brown & Weber (2011), Brondizio & Tourneau (2016), Carson *et al*. (2018), Chan *et al.* (2016), Chan *et al*. (2018), Díaz *et al.* (2018), Donn *et al.* (2016), Fa *et al*. (2003), Fauvelle & Garcia (2018), Gbetnkom (2008), Hugé *et al.* (2020), Jaligot *et al.* (2018), Karsenty & Vermeulen (2016), Kenter *et al.* (2011), Persha *et al*. (2011), Ponta *et al*. (2019), Robinson (2016), Samndong & Vatn (2012), Sanchez (2000), Waeber *et al*. (2019)
Photos: S. Hette, P. Jamar, J. Laporte

Thanks for your attention!

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