Ecological restoration planning of fragmented tropical vegetation

*An example from New Caledonia's mining areas - Introducing the **restoptr** R package*

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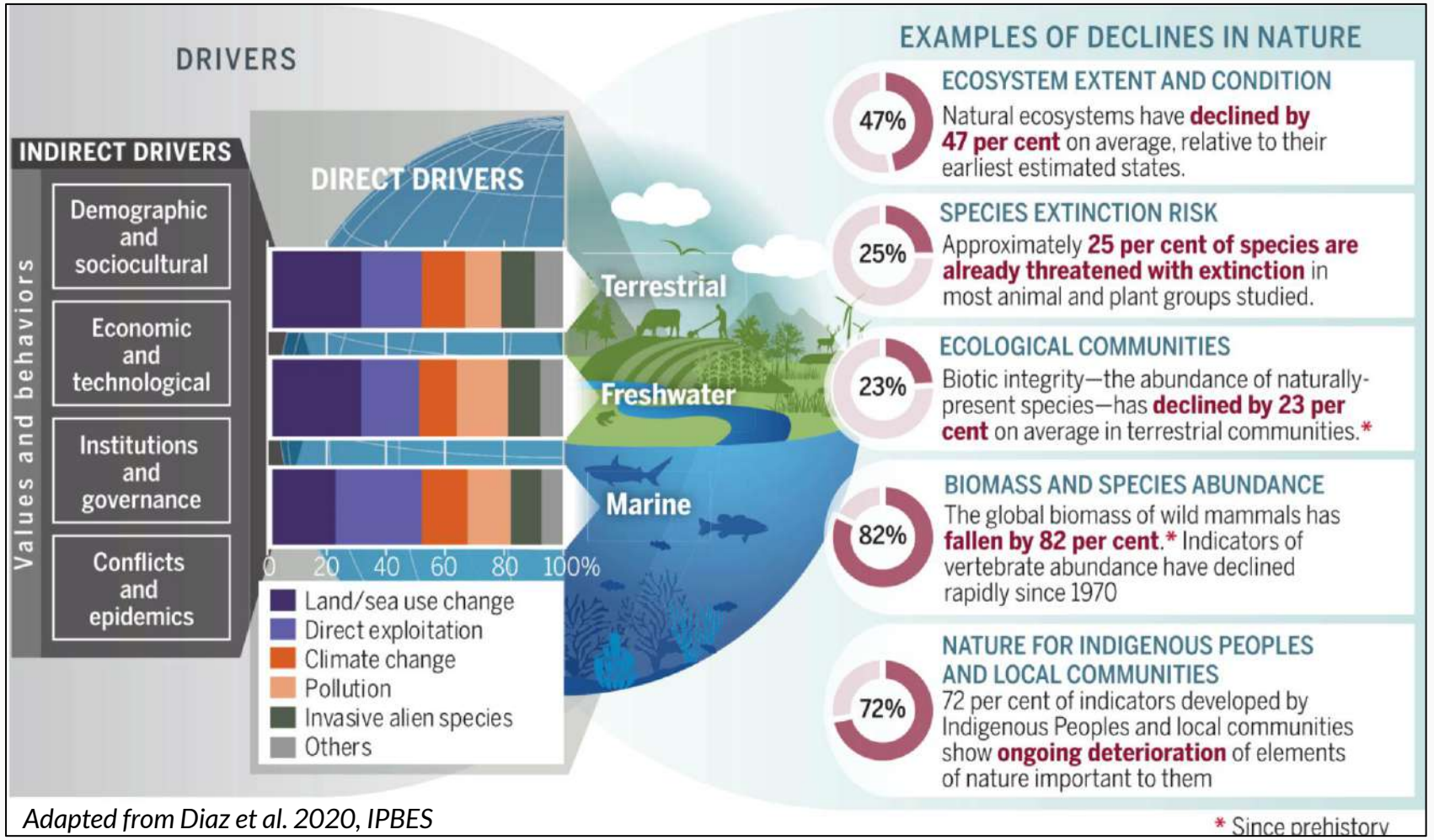
endemia.nc
Carleton University

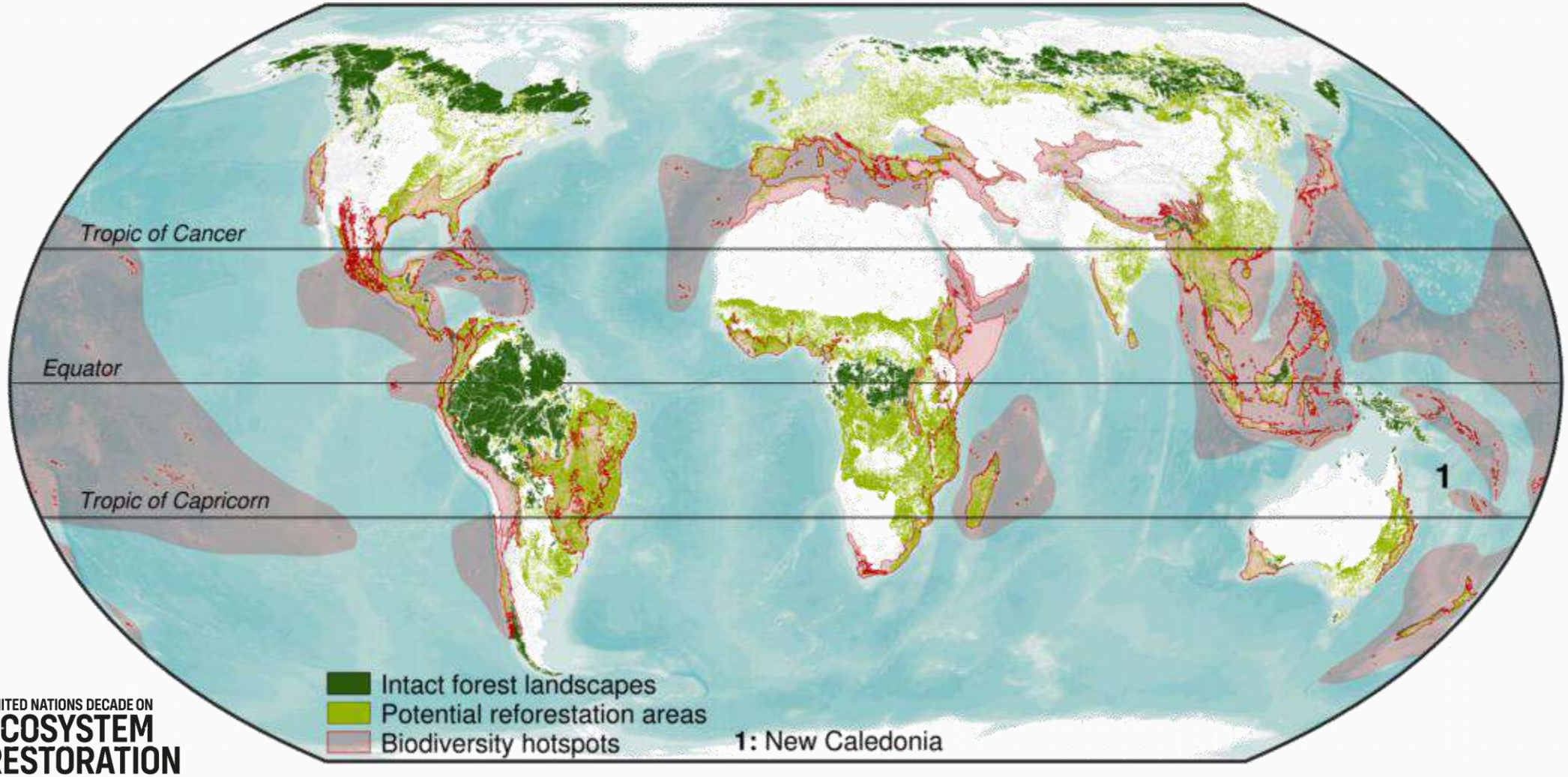
Land-use change is the primary cause of biodiversity loss in tropical terrestrial regions



Adapted from Diaz et al. 2020, IPBES

Ecological restoration as a key strategy to counter habitat loss

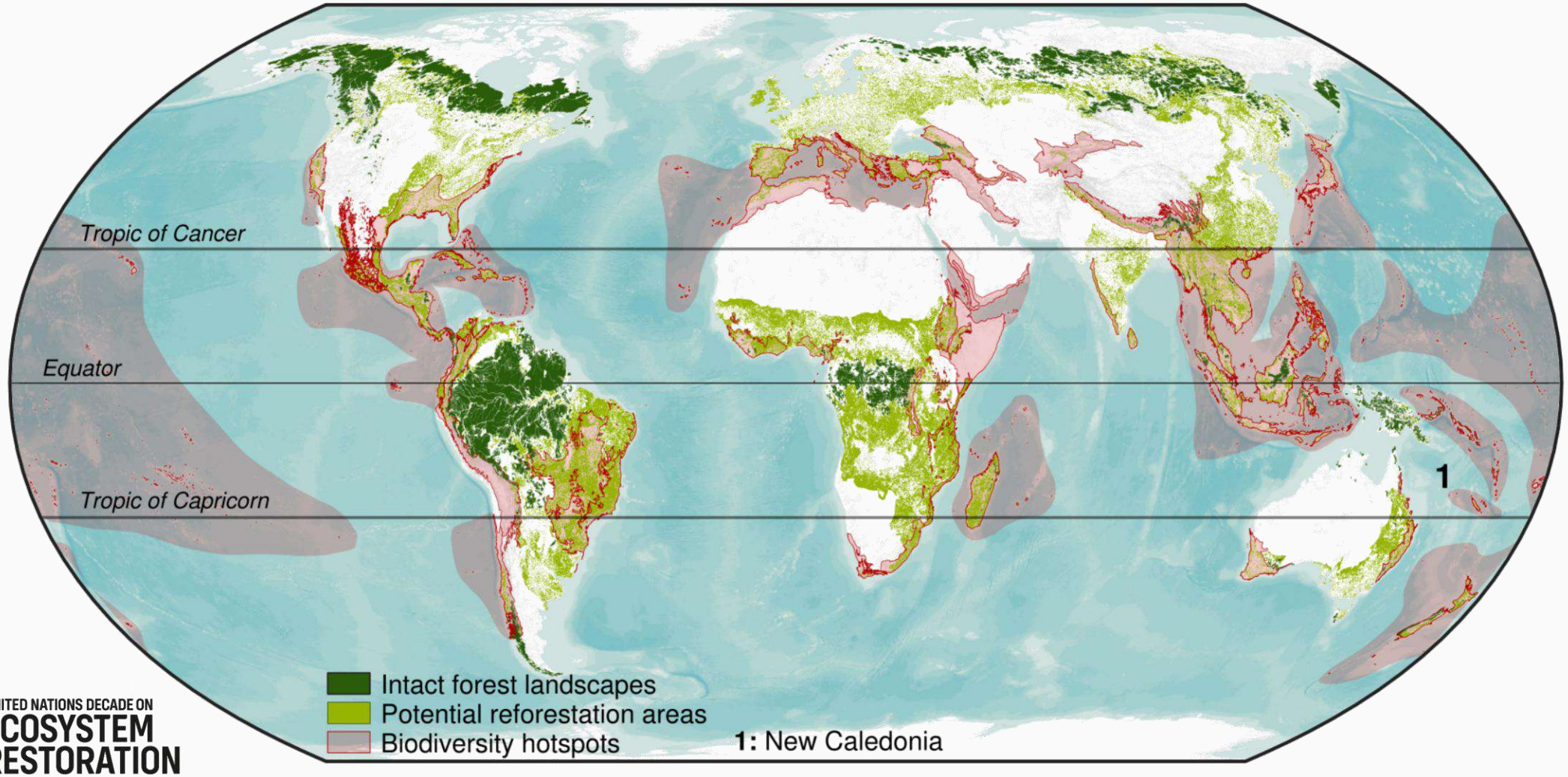
Example: reforestation opportunities



UNITED NATIONS DECADE ON ECOSYSTEM RESTORATION 2021-2030

Data from Mittermeier et al. (2005), Potapov et al. (2017), and Griscom et al. (2017)

How to **support stakeholders** in the **planning** of ecological **restoration actions**?



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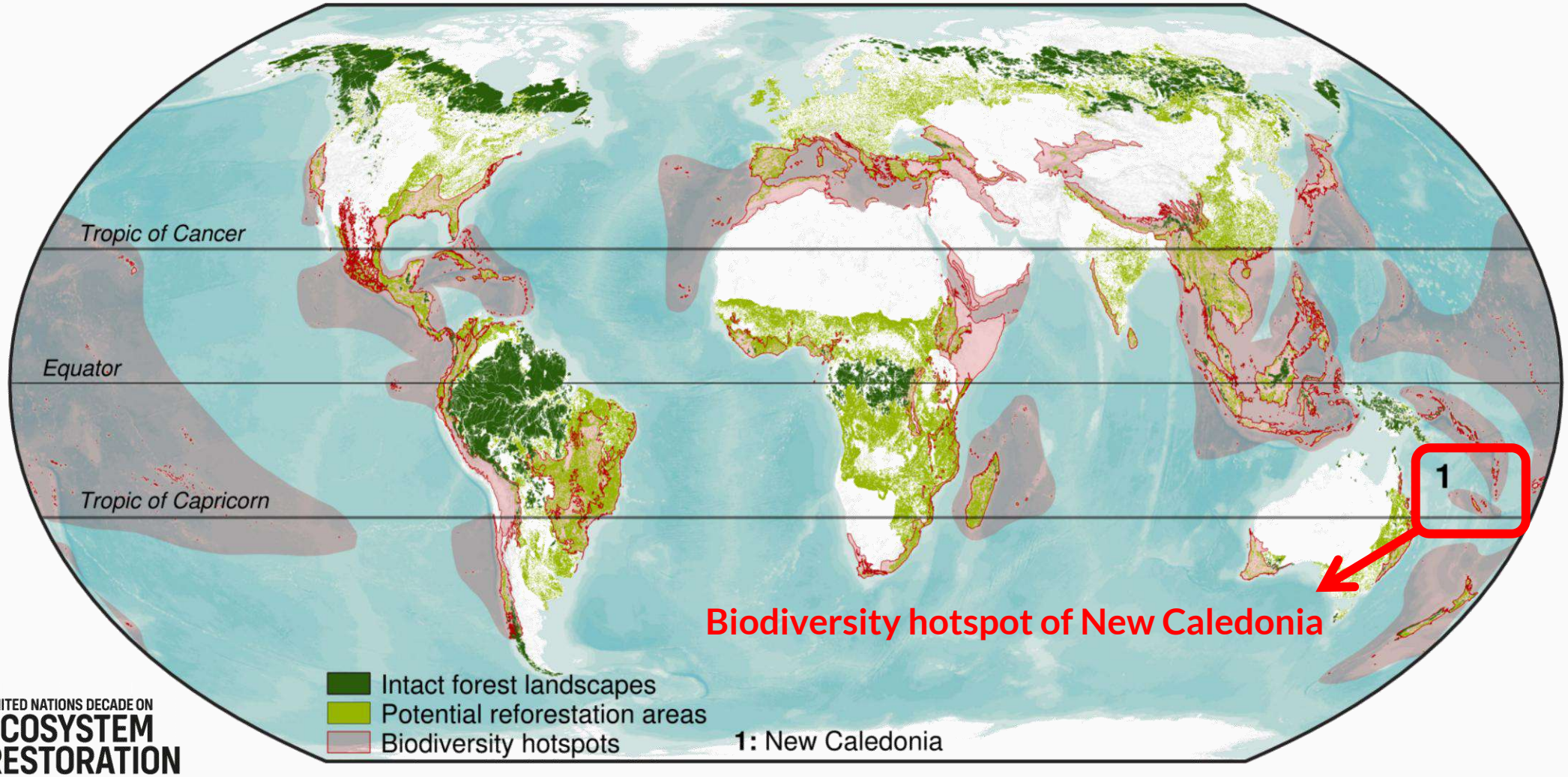

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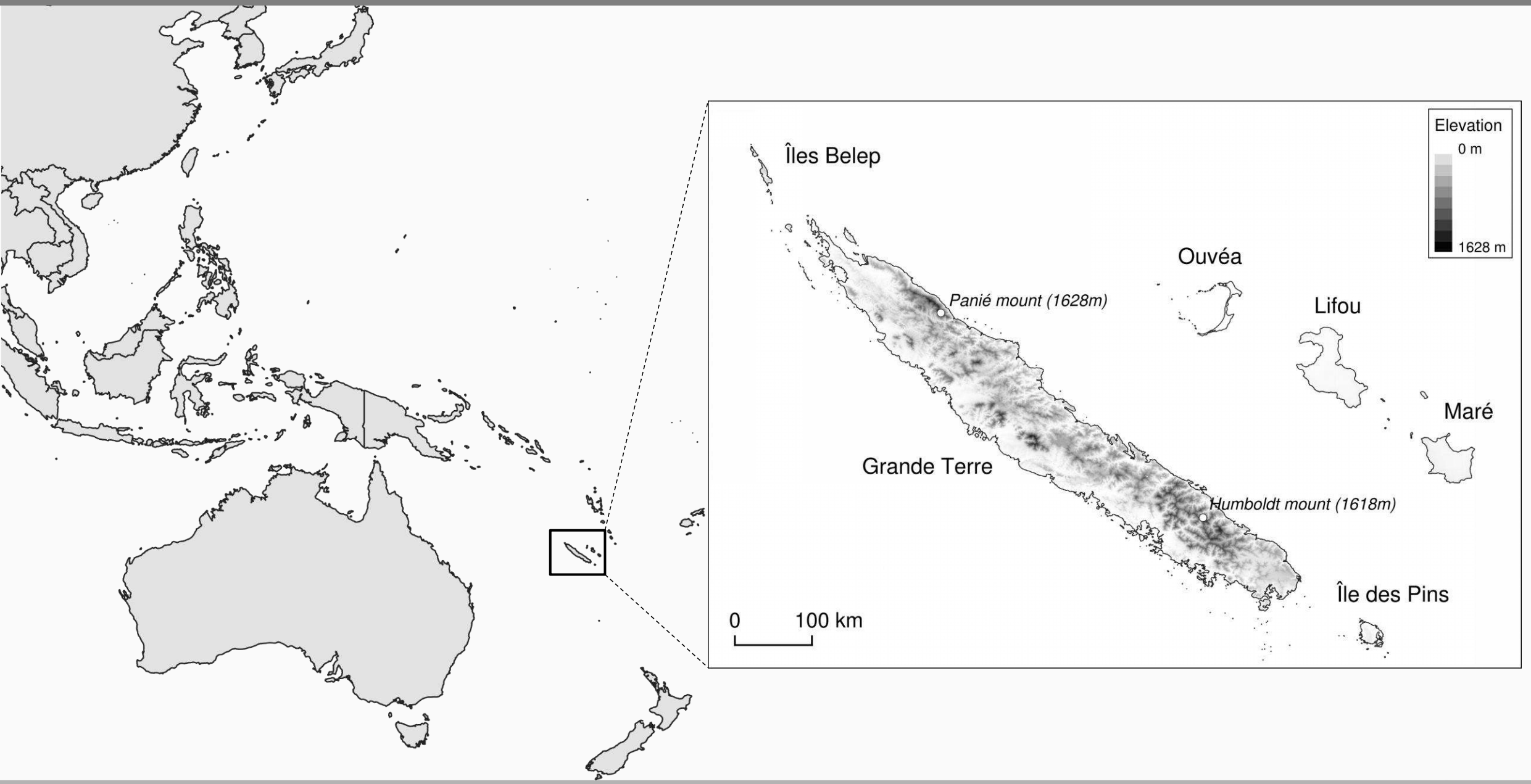
New Caledonia, a tropical archipelago in the South Pacific



New Caledonia, the smallest biodiversity hotspot in the world - terrestrial flora

An exceptional flora

- High endemism: ~76% for +3400 vascular plant species
- High beta-diversity: heterogeneous vegetation mosaic
- A unique flora: e.g. nickel hyperaccumulators

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- A unique flora: e.g. nickel hyperaccumulators

Many threats

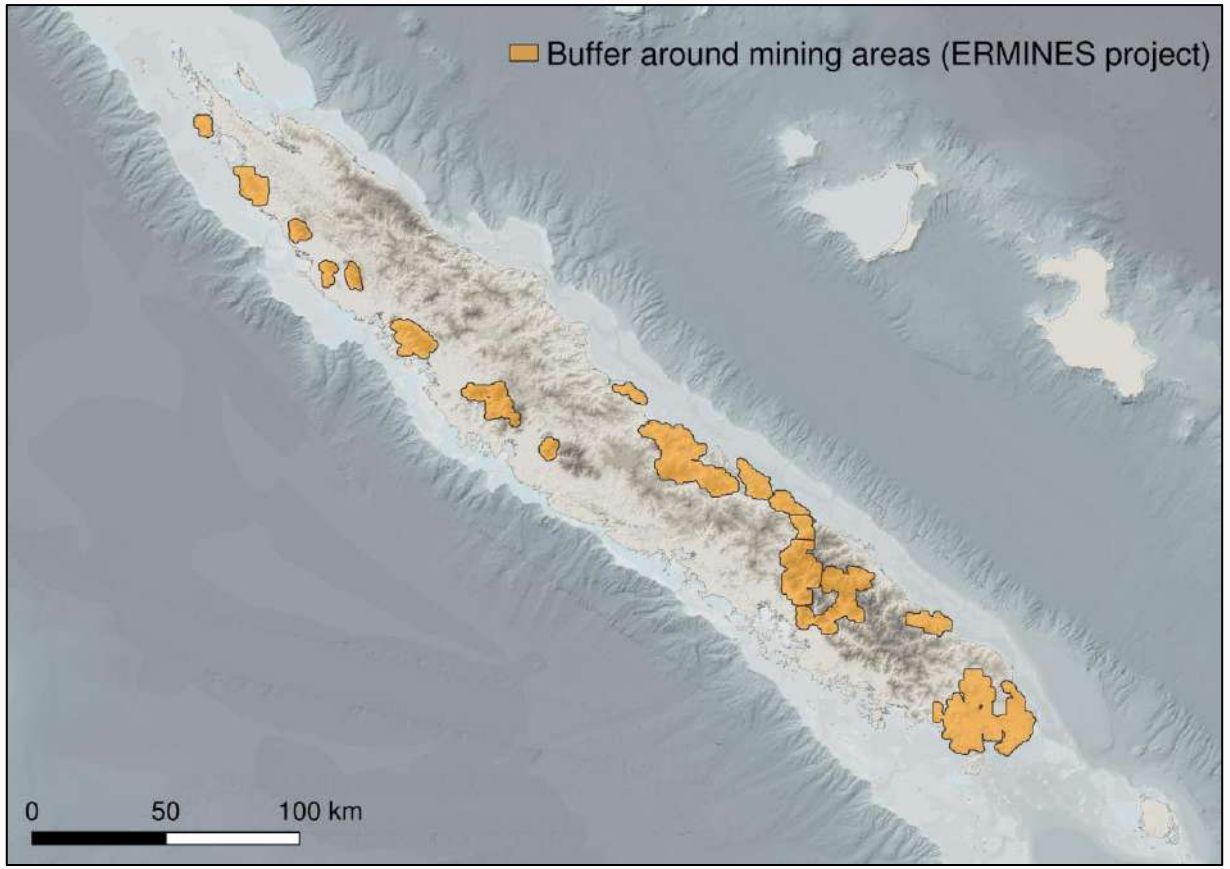
- Bushfires: 24 145 ha burnt in 2017
- Mining: ~20 000ha degraded, 300 000 ha in concession
- Invasive alien species: e.g. deer, rat, cat

Objective: planning ecological restoration in New Caledonian mining areas

ERMINES' project areas (Endemia, IAC, IRD, CNRT)

- Buffer around mining areas
- Mining companies must invest in restoration
- Can we propose **reforestation plans** that are:
    - Efficient to **reduce forest fragmentation**?
    - **Socio-economically feasible**?

→ *Such plans can help mining companies, and serve as a reference for New Caledonian authorities.*



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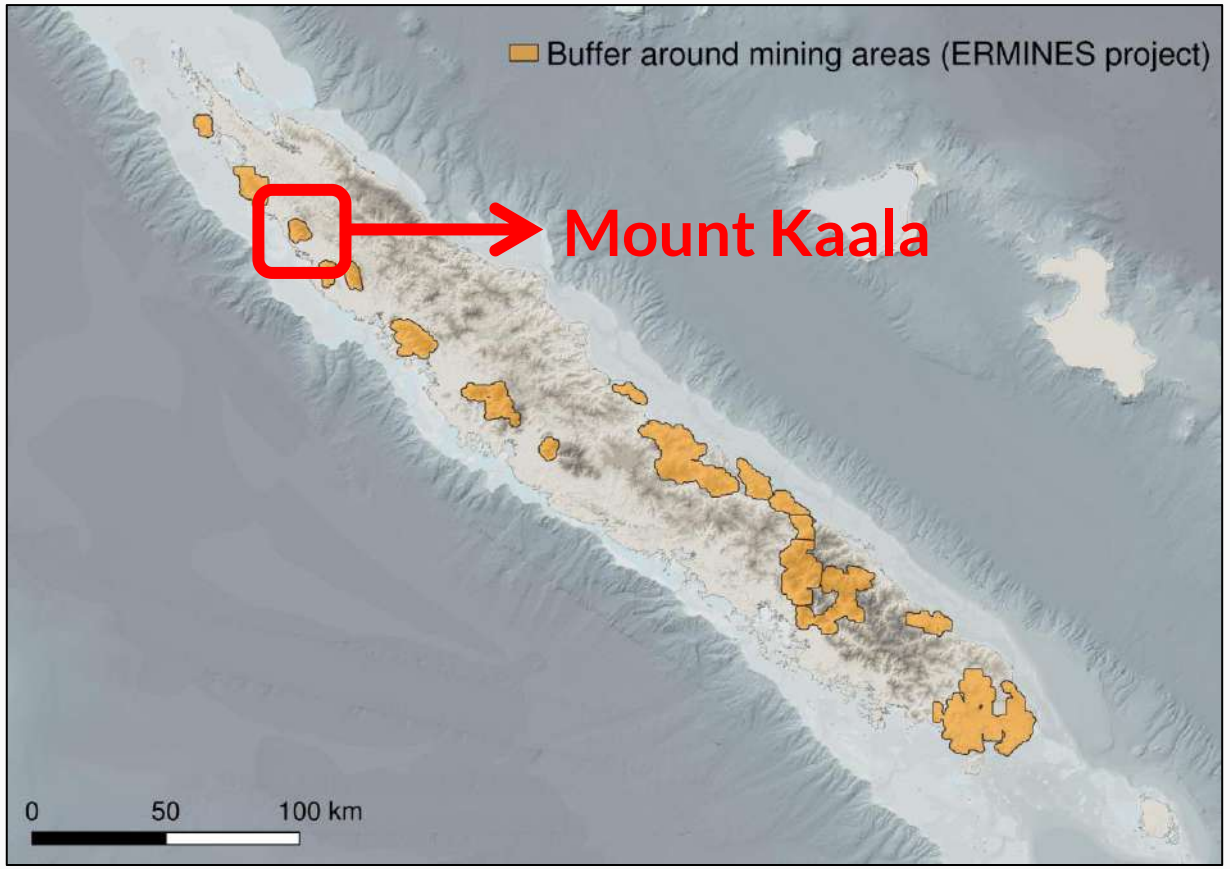
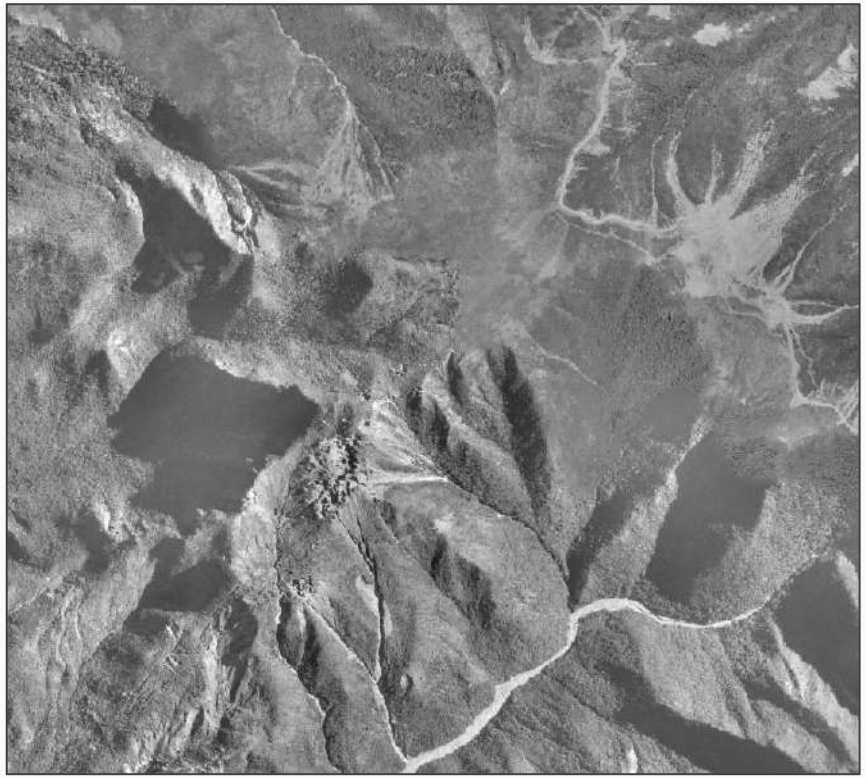


Material and methods

- ***Forest cover data*** *- 1976 and now*

- ***restoptr:*** *a new R package for ecological restoration planning*

Forest cover data: forest cover in 1976 and now

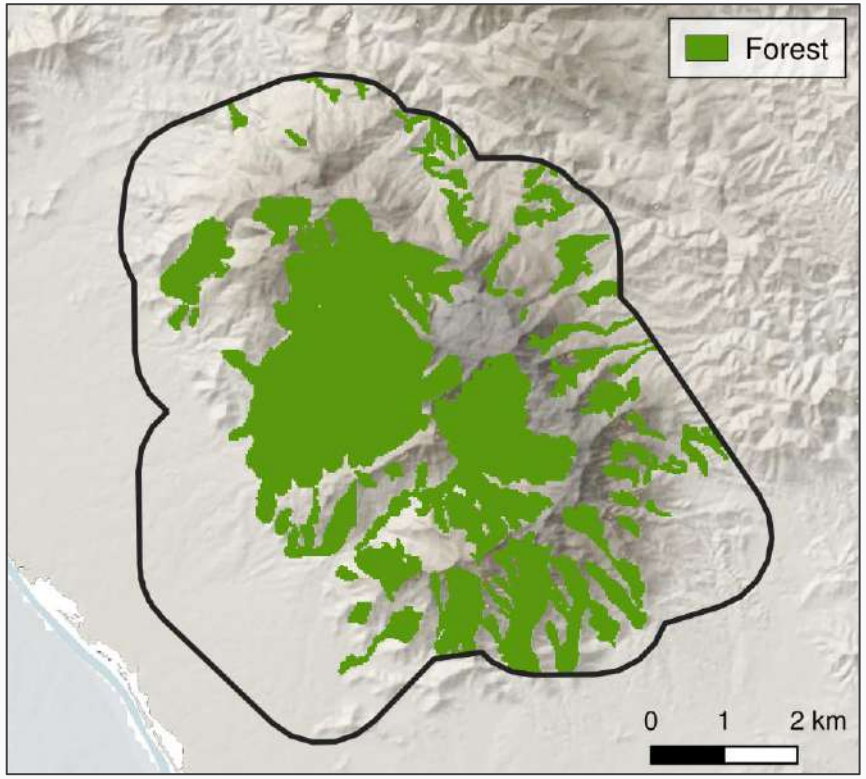


1976

now

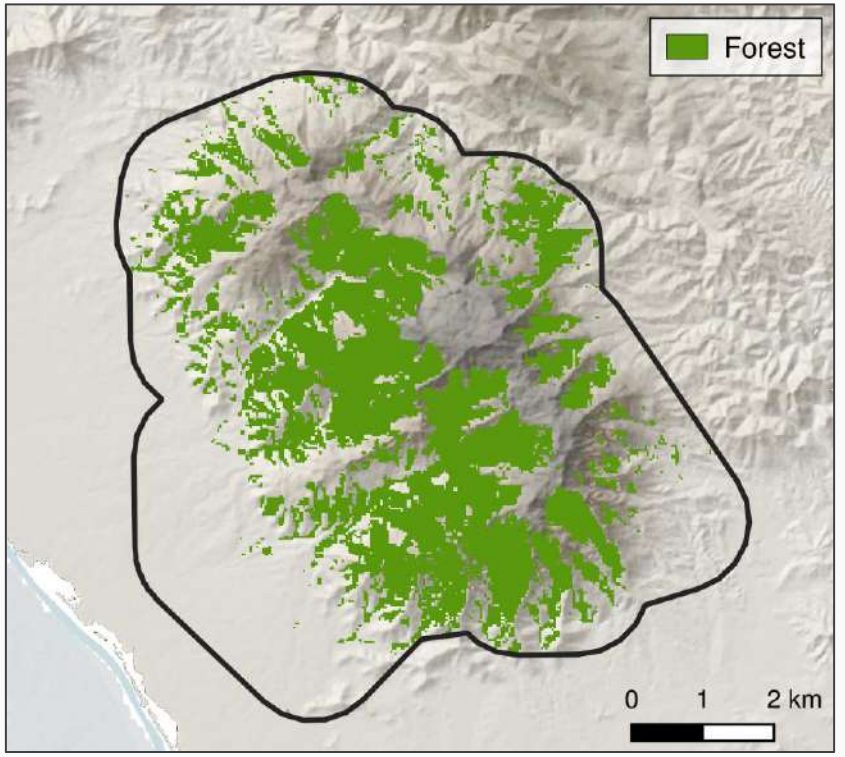
data from georep.nc (DITTT, New Caledonia)

Forest cover data: binary forest presence at 30x30m resolution



Expert digitization

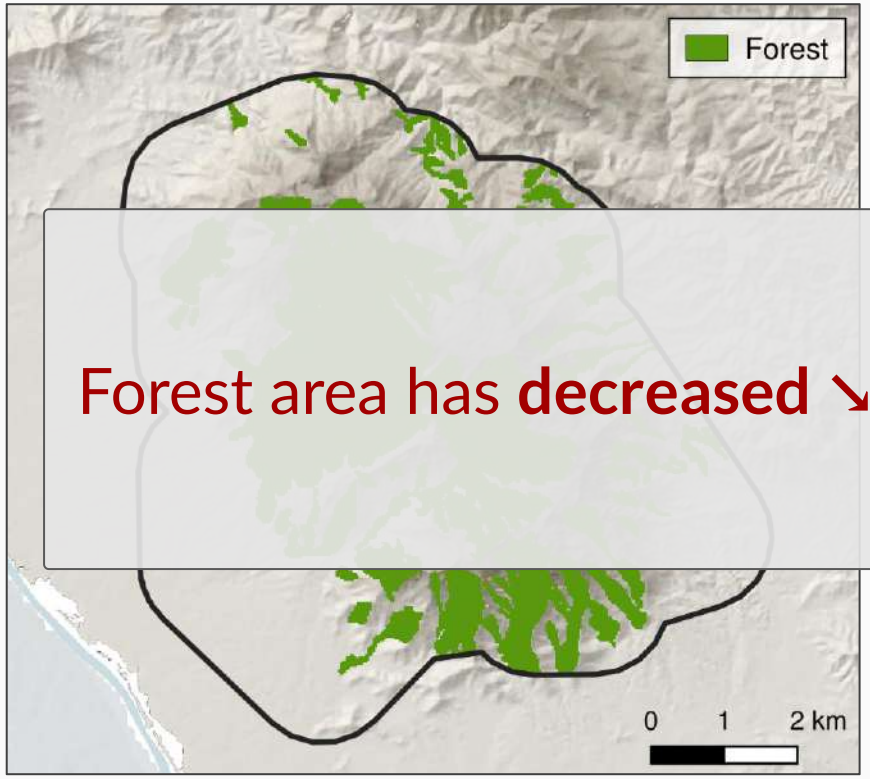
From 1976 black and white orthophotos

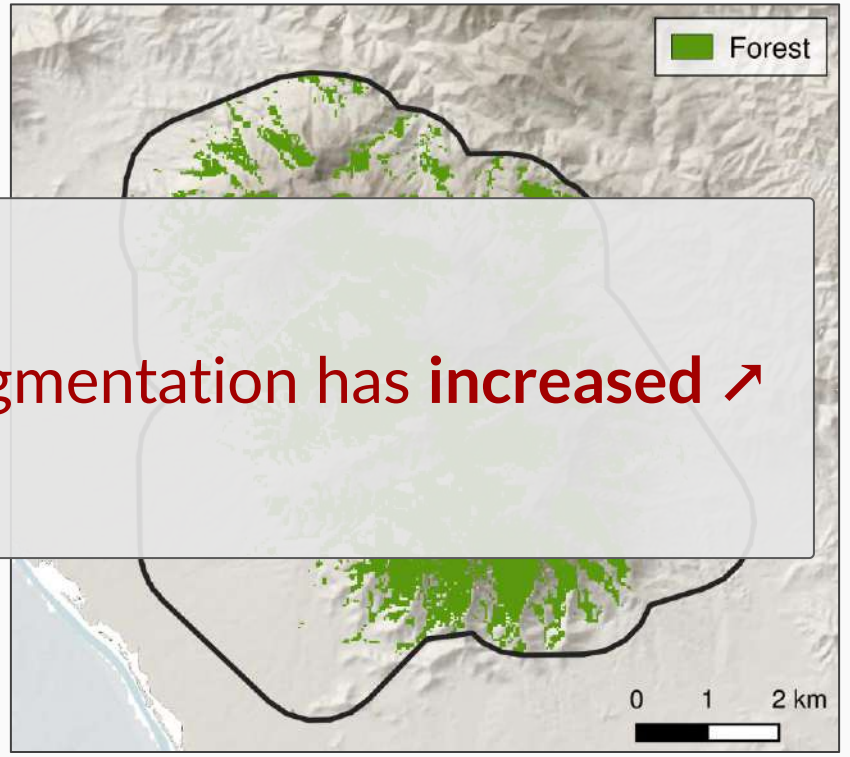


Automatic

Landsat time series analysis, Vantcutsem et al. (2021)

Forest cover data: binary forest presence at 30x30m resolution





Forest area has **decreased** ↘ , fragmentation has **increased** ↗

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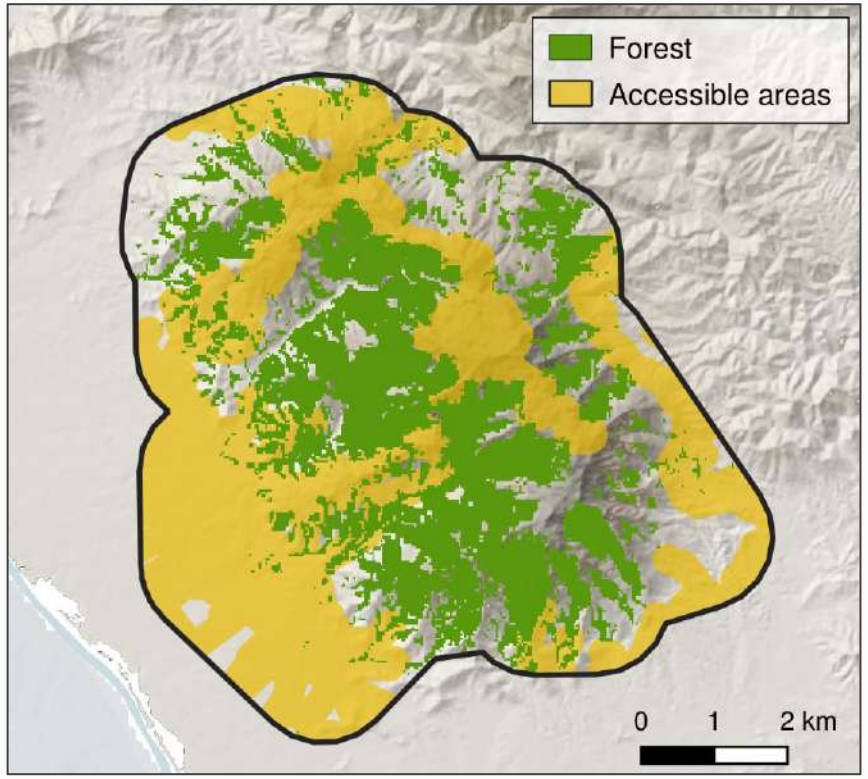
Problem formulation

Can we identify a restoration area that:

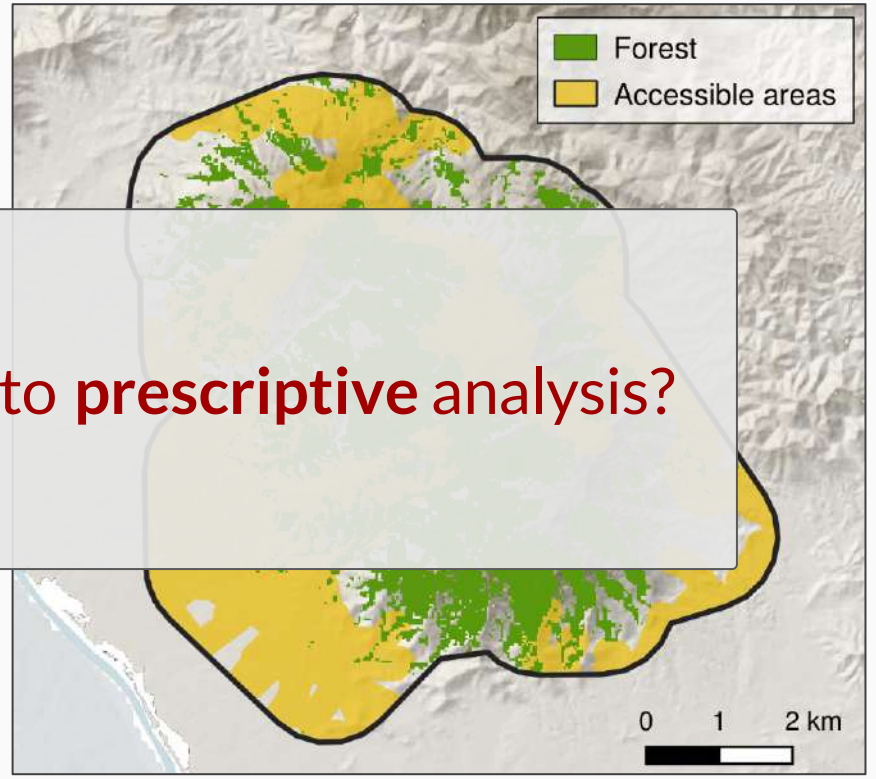
- Restores the fragmentation level of 1976?
  (effective mesh size - MESH, jaeger; 2000)
- Is located in accessible areas?
  (*150m buffer around tracks)*
- Is *connected* and *compact*?
  (*does not exceed a diameter of 900m)*
- At minimal cost?
  (*minimizes the restoration area)*



Can we identify a restoration area that:

- Restores the fragmentation level of 1976?
  (*effective mesh size - MESH, jaeger; 2000)*
- Is located in accessible areas?
  (*200m of roads and rivers*)
- Is *connected* and *compact*?
  (*does not exceed a diameter of 200m)*
- At minimal cost?
  (*minimizes the restoration area)*

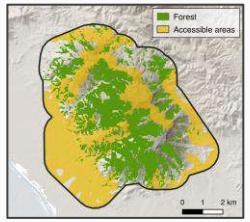
How do we move from **descriptive** to **prescriptive** analysis?

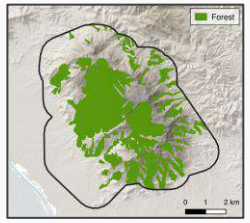


Overview of the **restoptr** R package for ecological restoration planning

restopt problem

- Descriptive habitat data
- Ecological constraints
- Socio-economic constraints
- Optimization objective





restoptr

Describe the problem

original methodology from Justeau-Allaire et al. (2021)

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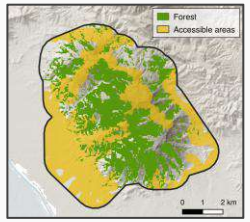
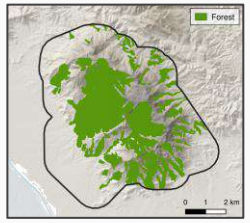


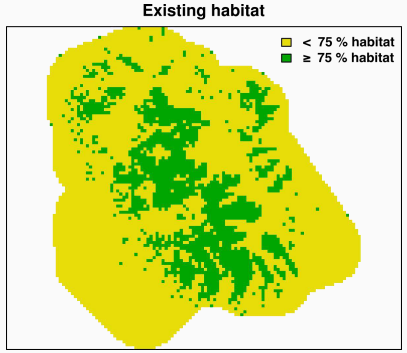


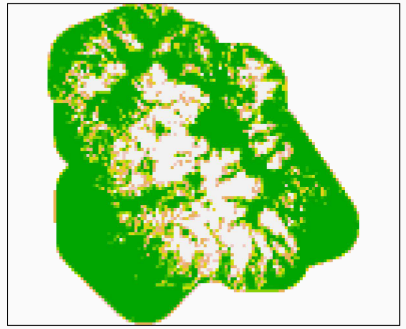
Describe the problem

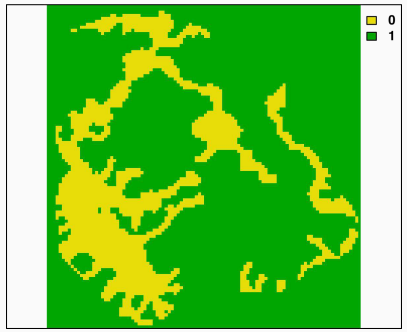
restoptr

Ensure tractability

Preprocessed data







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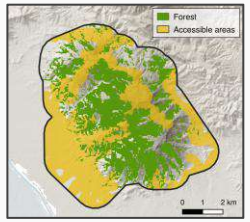
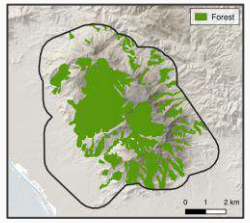




Describe the problem

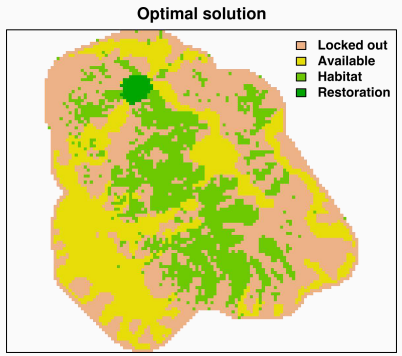
restoptr

Java

CHOCO

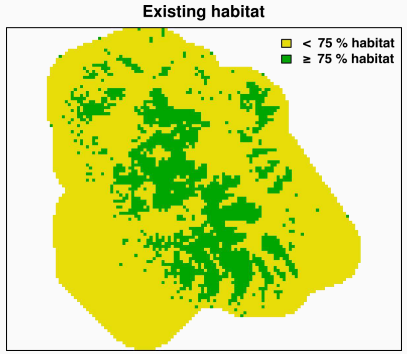
Ensure tractability

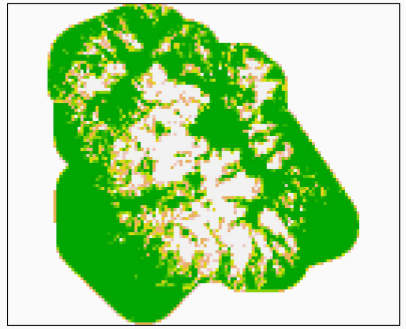
*Relies on **Constraint Programming**, an Artificial Intelligence technique (automated reasoning)*

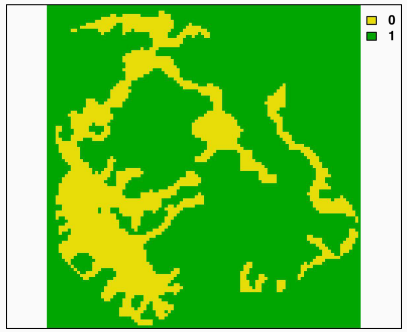


Optimal solution

Preprocessed data







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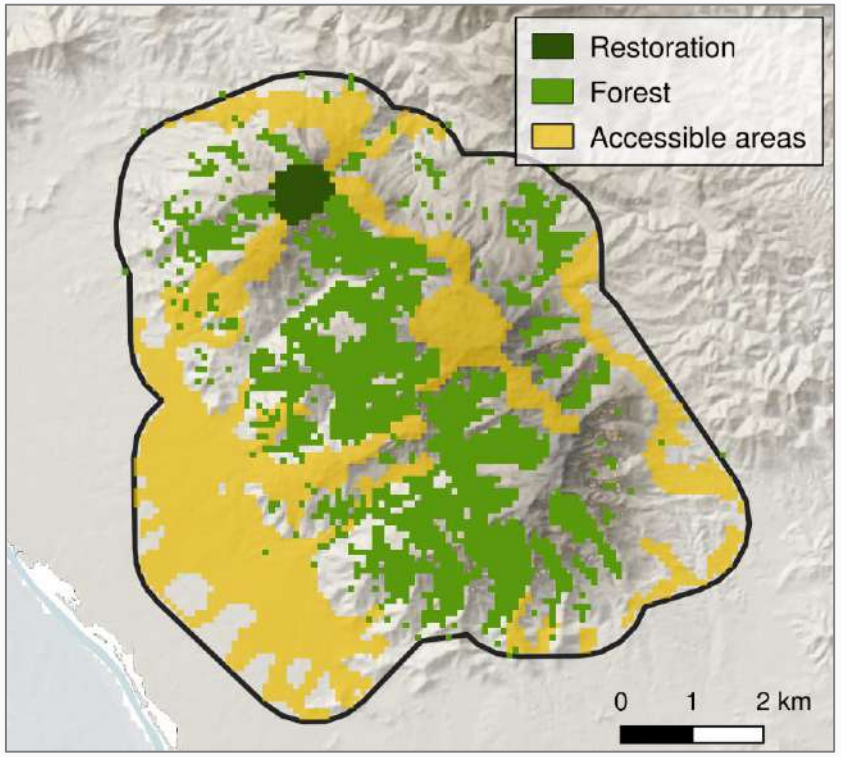
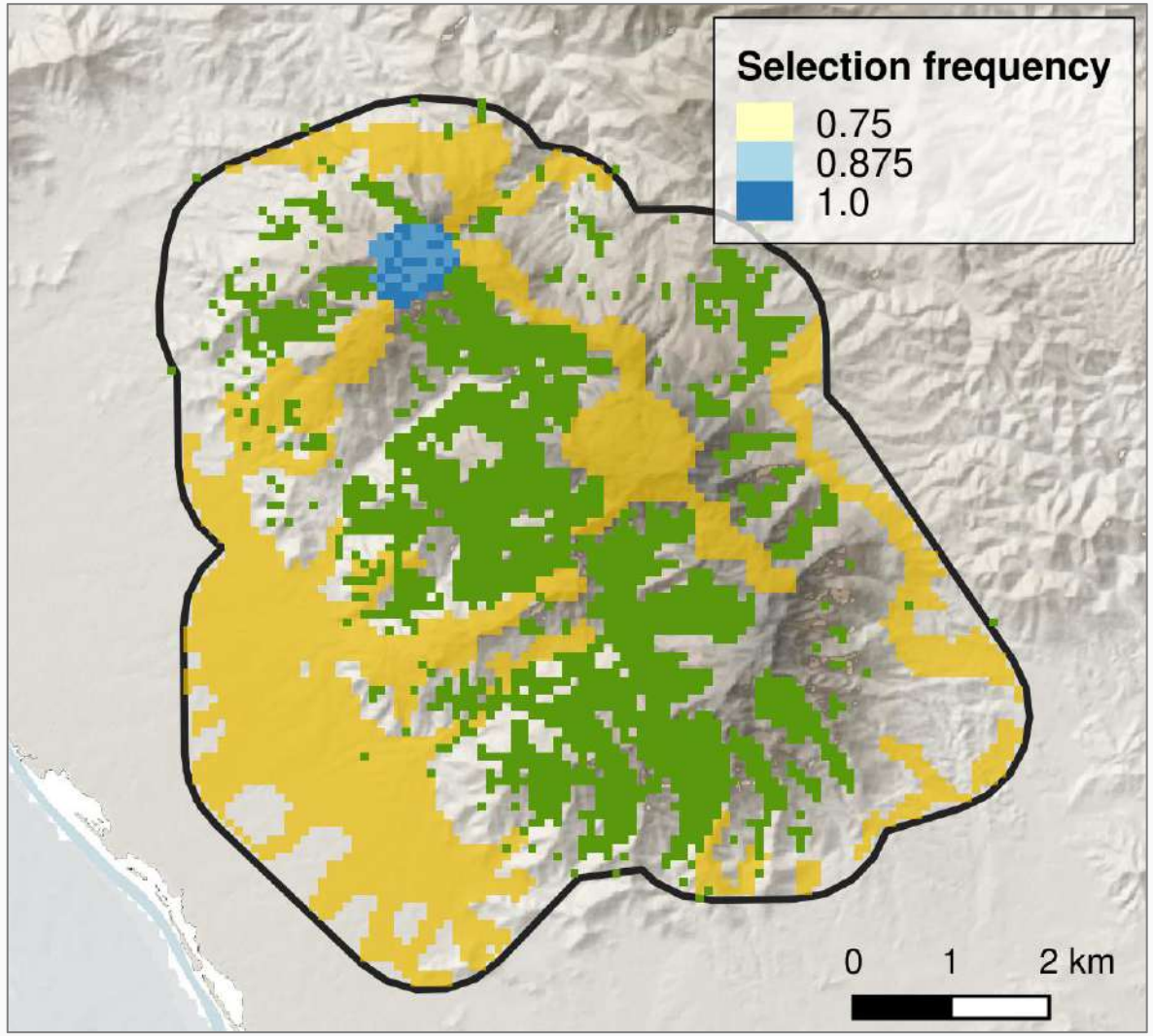
Results in detail



Forest cover	Forest area	*Δ area*	MESH	*Δ MESH*
1976	1984 ha		202.4 ha	
Now	1819 ha	***-165 ha***	171.4 ha	***-31 ha***
Restored	1855 ha	***+36 ha***	202.6 ha	***+31.2 ha***

Results in detail - set an optimality gap of 0.1 and compute selection frequency (over 1000 solutions)



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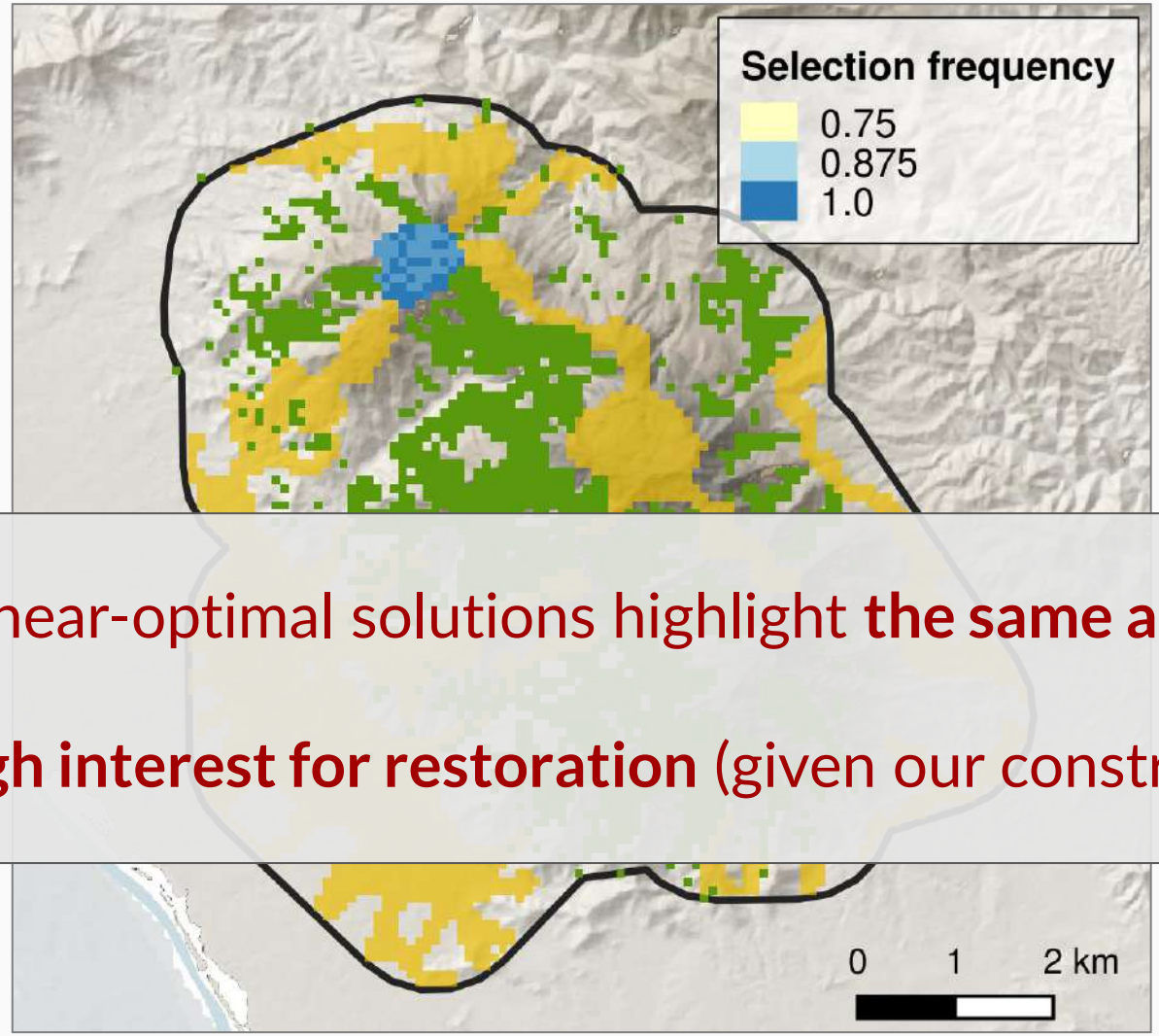
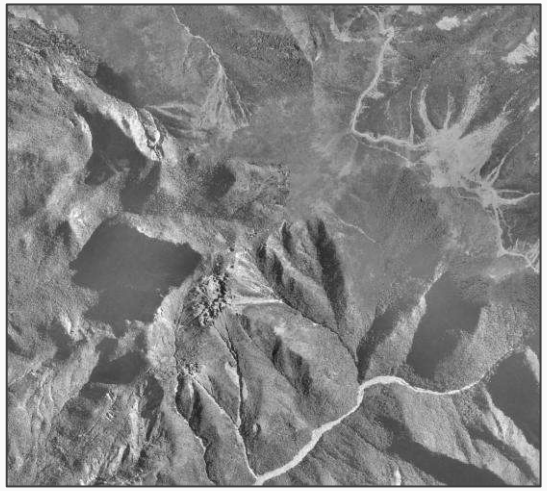


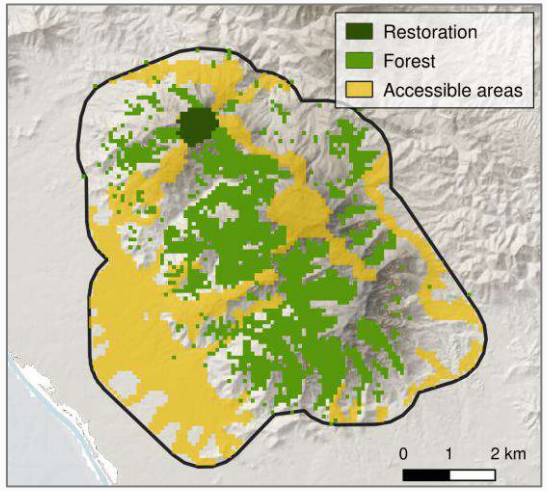
All near-optimal solutions highlight **the same area**

→ **High interest for restoration** (given our constraints)

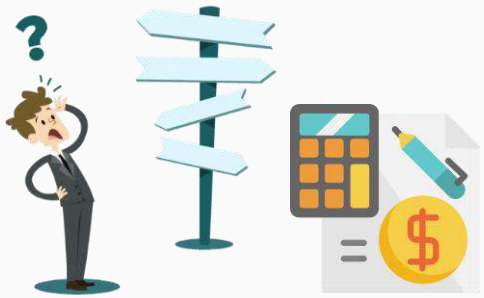
Discussion and take home messages - Decision support

- **Spatial planning** through **constrained optimization** enables **prescriptive analytics** and **decision support**
- We showcased a practical example useful to support the **restoration of mining areas in New Caledonia**
- Our analysis used **historical data** to set **restoration targets**
- Our results on the Kaala mount highlighted a promising area for ecological restoration
- **Future directions**: for more relevance we will include **maquis vegetation** and **species distribution models**





- We relied on **restoptr**, an **R package** that we specifically developped for **ecological restoration planning**
- **restoptr** provides several **constraints** and **optimization objectives (ecological** and **socio-economical)**
- **restoptr** is **flexible**, **extensible**, **free**, and **open-source**



https://cran.r-project.org/package=restoptr

https://github.com/dimitri-justeau/restoptr

Discussion and take home messages - Pitfalls to avoid

- **Spatial planning** is a decision **support** tool, not a decision making tool !
- **Data** and **problem formulation** must always be subject to hindsight before taking any decision.
- The «truth» is always **on the field**...

Thank you for listening !

Questions ?

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Check out the restoptr R package at:

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