INFORMING SPATIAL PRIOROTIZATION USING A R2R CONCEPTUAL FRAMEWORK IN TROPICAL ISLANDS SETTINGS

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R2R Technical meeting

February 5-7th 2020

Pacific islands

Volcanic origin

Fletcher et al. 2008

Rainfall gradients carve steep topographic relief

Izuka et al. 2013

Marine ecosystems are sculpted by **waves**

Dollar 1982

Small size & steep gradients

Land & **Sea** are tightly **connected** through **social** and **ecological** processes

Jupiter et al. 2017

Land & **Sea** are **connected** through **multiple pathways**

Streams

Stormwater

Groundwater

Global changes

Climate change is threatening ecosystems through **increased SST, storms…** Mumby et al. 2013, Hughes et al. 2003

Human population & global markets

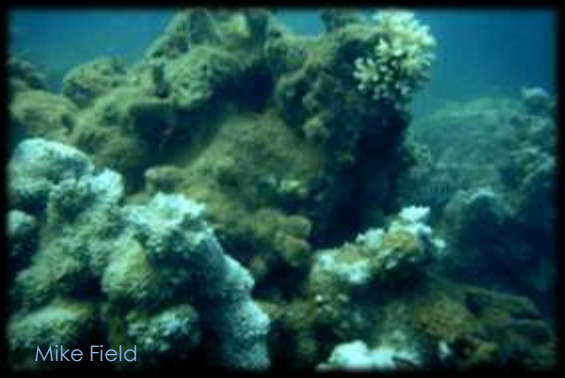
Increase pressure on **natural resources** through exports

Brewer et al. 2012, Halpern et al. 2013

Local changes

Land use change due to agriculture expansion & urbanization threatens **marine ecosystems** through **land-based source pollution**

Klein et al. 2014



Fishing pressure removes **herbivores**

Bellwood 2004

Protected areas

Marine Protected Areas protect coral reefs from **direct threats** (fishing) Halpern 2003

Fail when exposed to high **sedimentation** Halpern et al. 2013

Terrestrial protected areas & **restoration** can benefit marine ecosystems' resilience

Klein et al. 2014

Ridge-to-reef management

Where terrestrial management actions can benefit the **marine environment**

Klein et al. 2014

Hughes et al. 2007, Mumby et al. 2014

Project goals

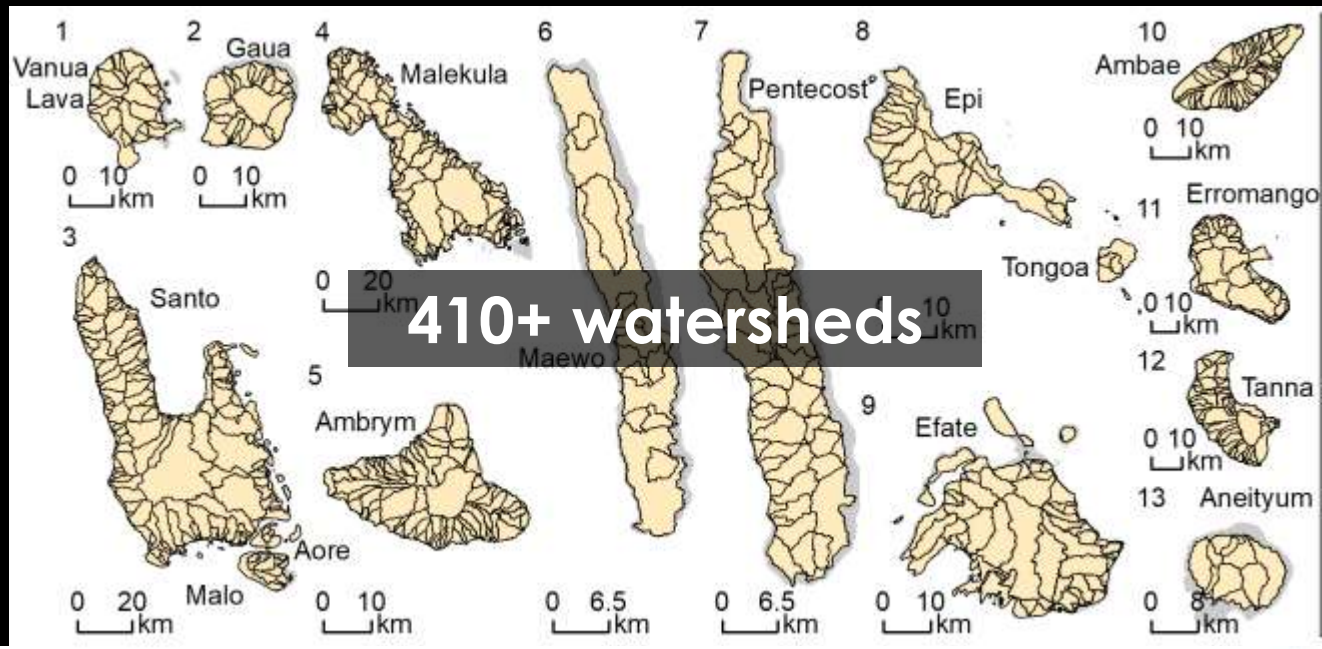
National scale approach: Adapt & apply a **spatially-explicit framework** with **scenario planning** to identify **national priority areas** that benefit land & sea

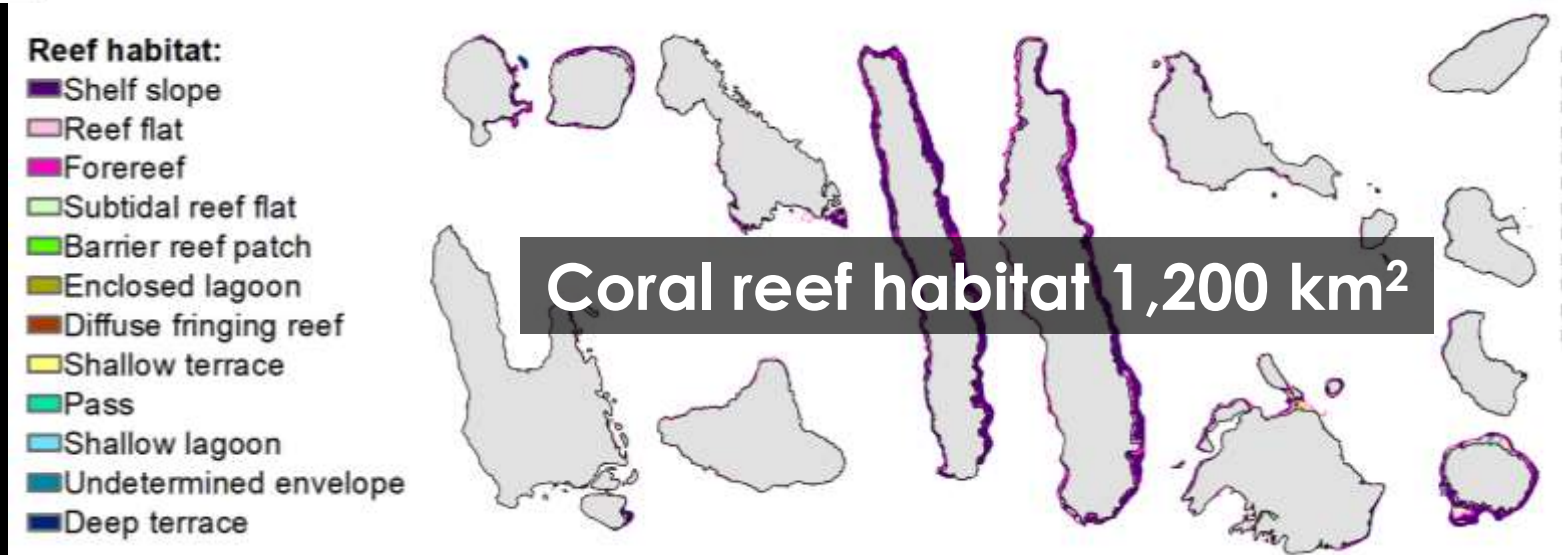
Local scale approach: **Downscale** this framework to **test** the effect of proposed **local R2R management actions** in one priority watershed

NATIONAL-SCALE APPROACH METHODS

Winston Wellborn

17 islands - 11,500 km² Vanuatu





Andrefouet et al. 2006

National-scale R2R framework

Scenarios

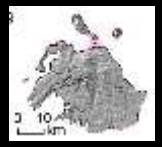
Present LUC

Deforestation

Sediment model

Sediment Delivery Ratio

Topography



Rainfall

Soils

Land drivers

Sediment plume model

GIS-based model

Topography

Currents

Marine drivers

R2R impact assessment

Marine impact assessment

Reef surveys

Link

Source watersheds

Outputs

R2R tool

Vulnerable reefs

Priority watersheds

Land use change scenarios

Low deforestation:

- Elevation < 300 m
- Slope < 10°

High deforestation:

- < 400 m*
- < 20°

- < 3 km of existing human settlements & roads
- Buffers coastal zone (100 m) & streams (20-30 m)*

* Vanuatu logging codes (McIntosh 2013)

(Eckardt et al. 2008)

InVEST SDR

Land cover
Vegetation cover

Topography

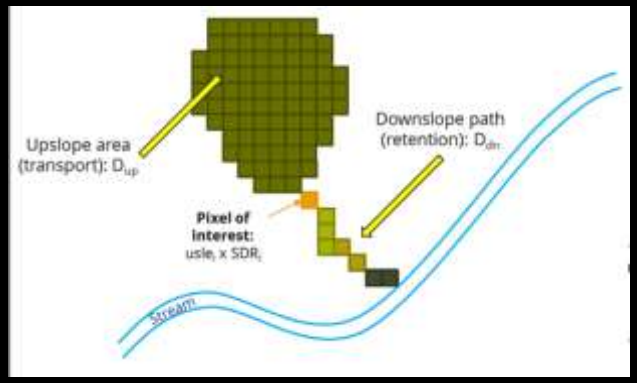
Soil
erodibility

Rainfall
erosivity

Landscape
(hydrological)
connectivity

Sediment Yield

Sediment Export



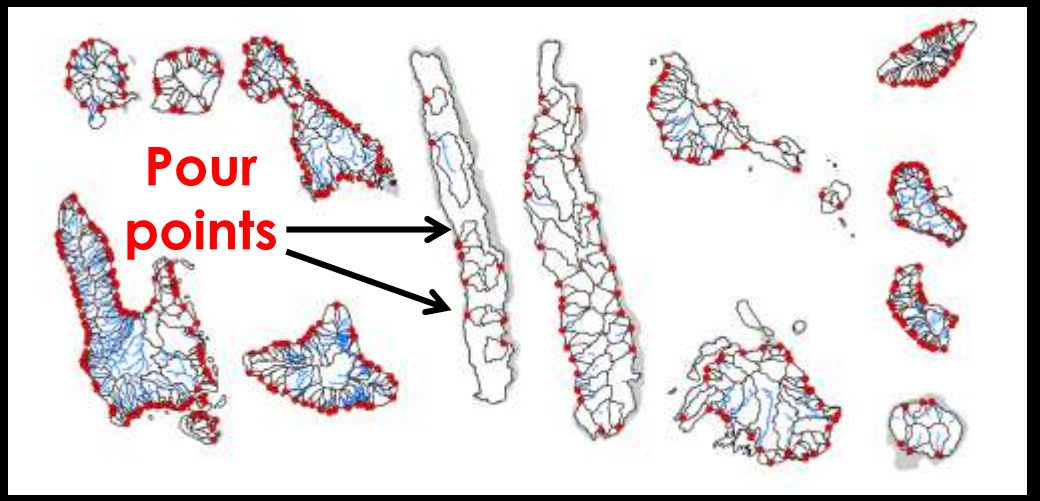
InVEST
integrated valuation of ecosystem services and tradeoffs

natural capital PROJECT

Hammel et al. 2015, Borselli et al. 2008

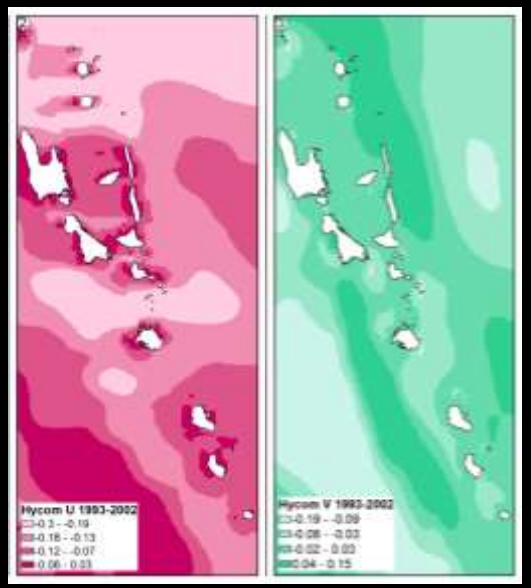
Sediment plume model

410+ streams



Bathymetry

Currents



Sediment plumes:

- < 3km
- Depth
- Currents

adapted Halpern et al. 2008, Delevaux et al. 2018

Tracing land-sea linkages

1. Model the **sediment export** & **plume** under **present** & each **deforestation scenario**

2. Identify **coral reef areas** exposed to **significant** change in **sediment** for **each scenario** compared to **present**

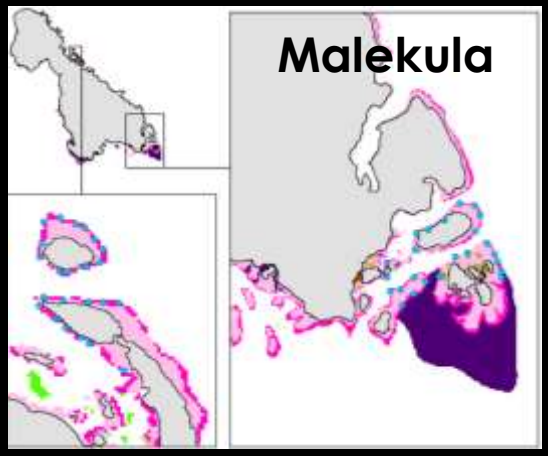
3. Identify the **watersheds** supplying the most **sediment** (>40%) to those **coral reef areas**

Spatial prioritization

1. Characterize the **potential marine impact** using **coral % cover** & **fish biomass** from **empirical data**

2. Prioritize **watersheds** by **potential marine impact**

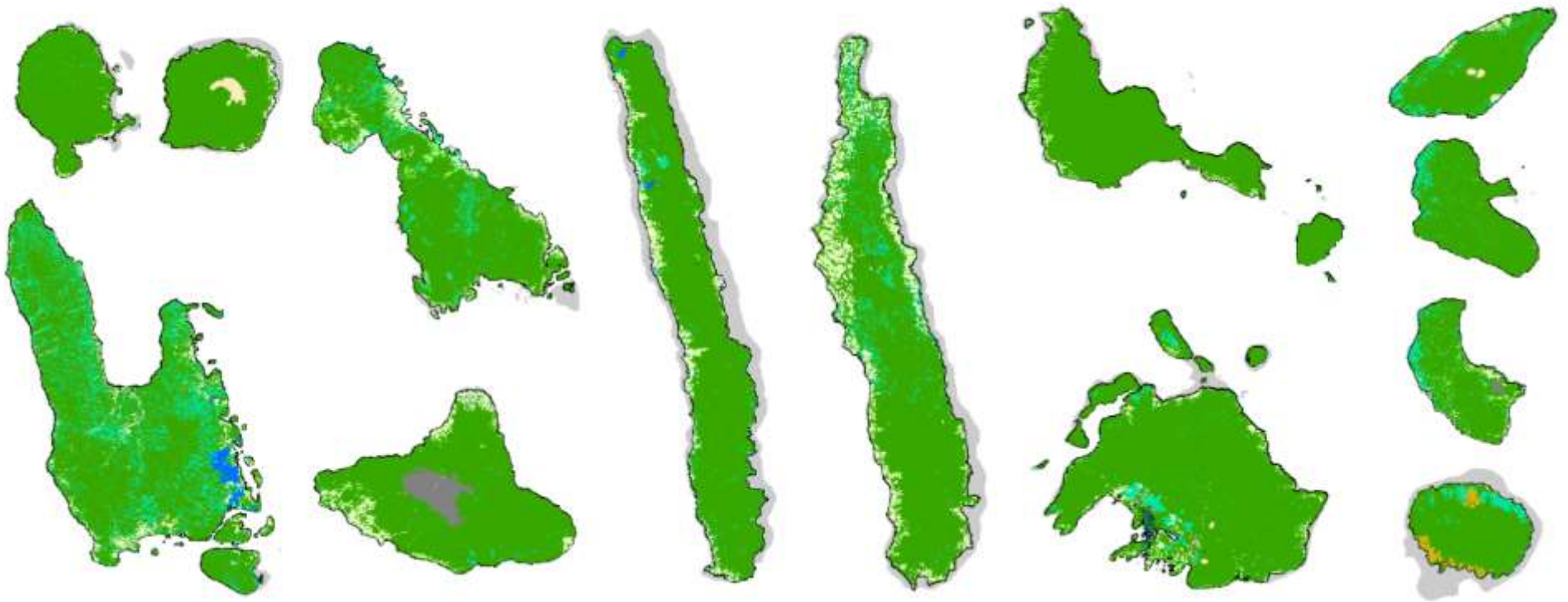
3. Identify **land areas** exposed to **significant** change in **sediment export** under **each scenario** compared to **present**



130 sites

NATIONAL-SCALE APPROACH RESULTS

Present land use/cover



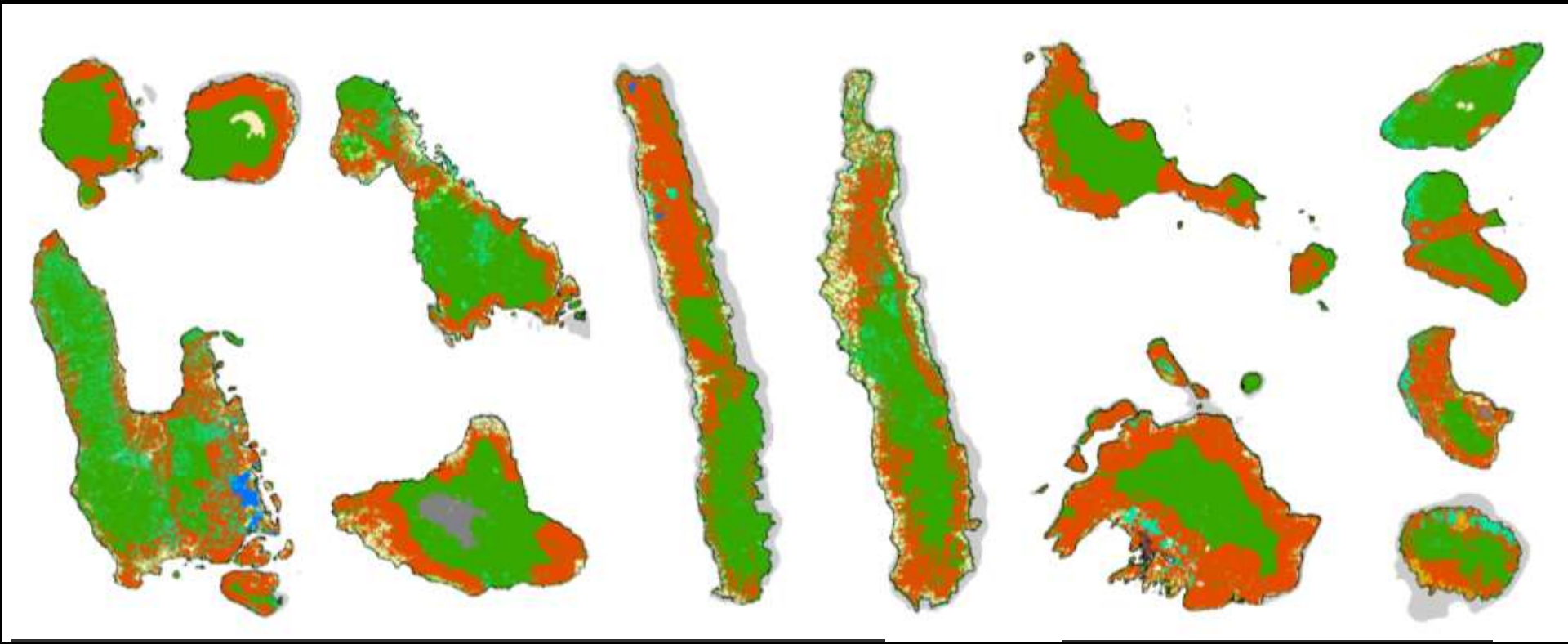
Forest 82%

Grass/shrubland 10%

Human LUC 7%

Caveat: The land use map is a few years old based on satellite imagery

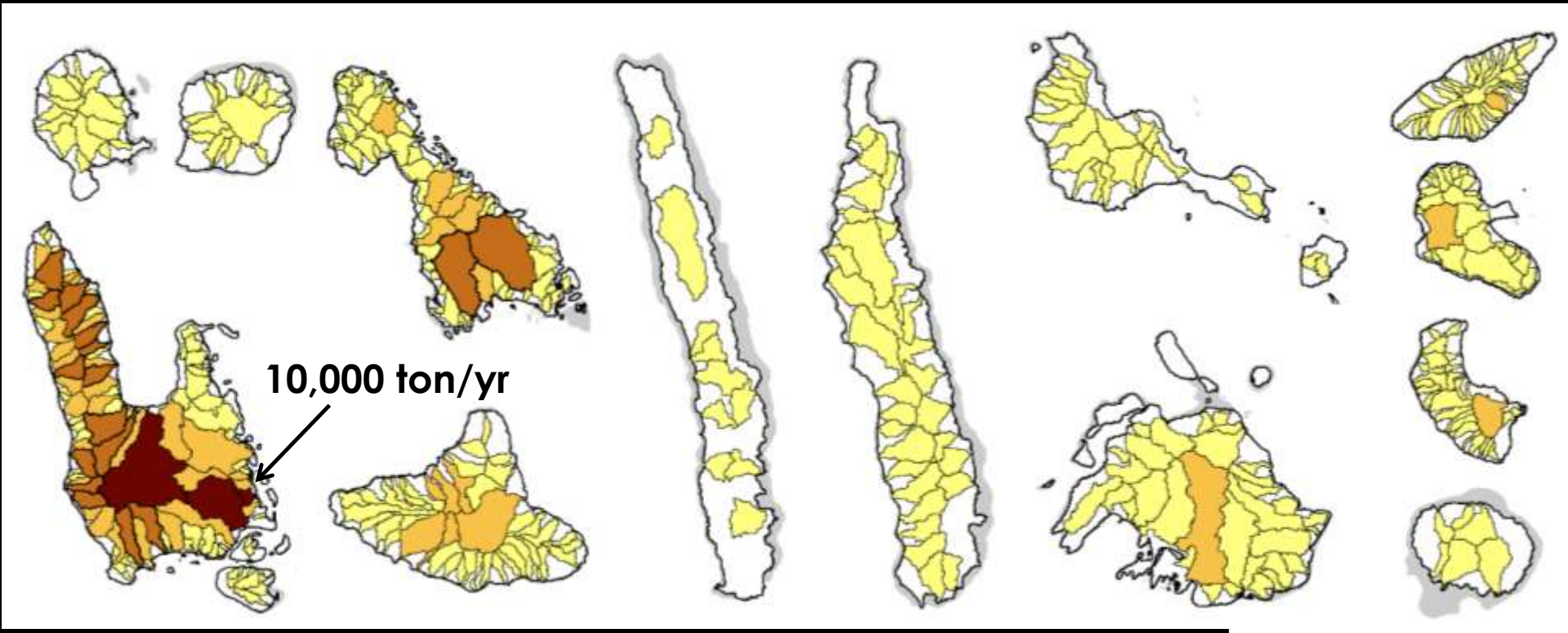
High deforestation scenario



Forest - 4,050 km^2
- 40 %

Human LUC

Present sediment export



Sediment export ~ 140,000 ton/yr

~ 16 ton/km^2/yr

Change in sediment export

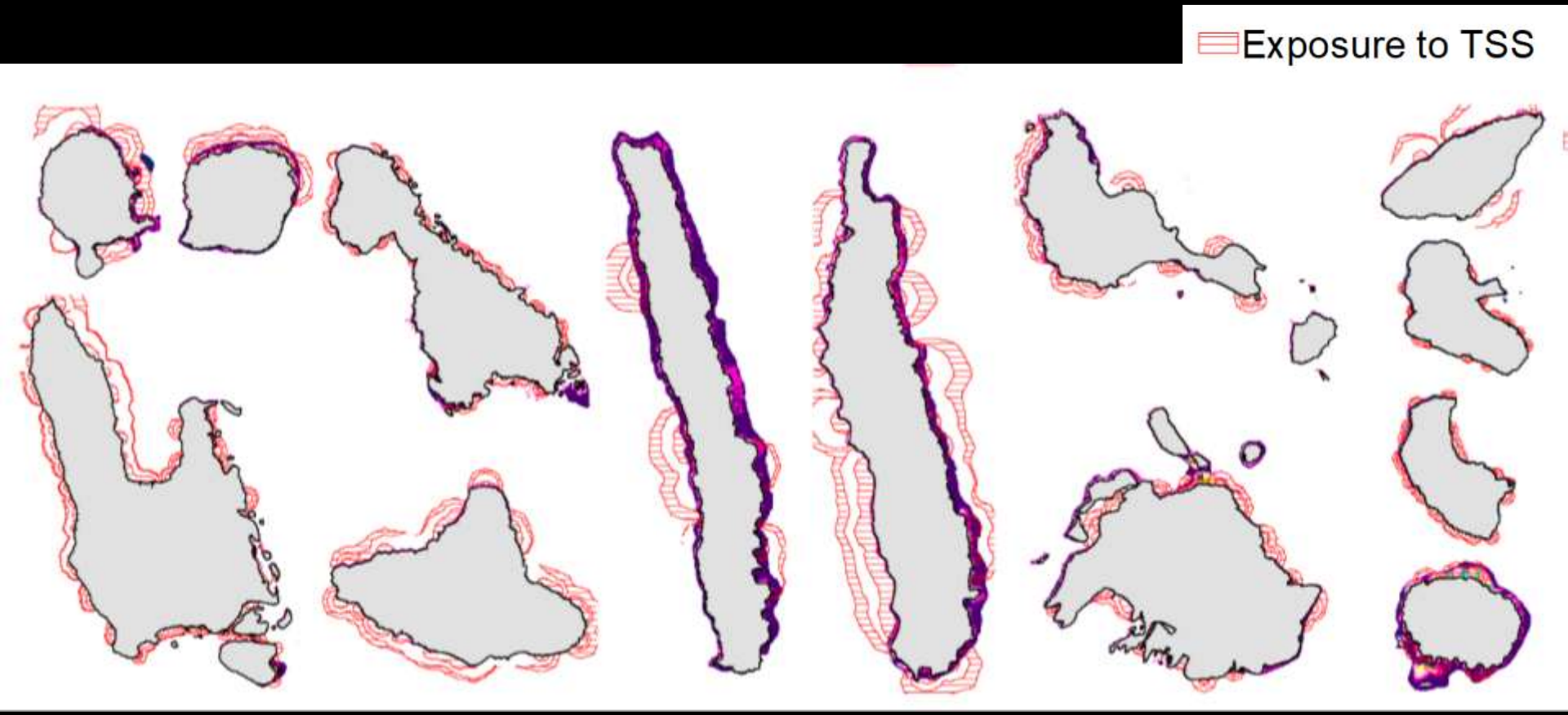
Sediment export (t/yr)
0 - 1976
1977 - 5599
5600 - 13842
13843 - 45117

+ 1,160,000 ton/yr
+ 150 ton/km^2/yr

TSS increase (t/yr)
176 - 1,581
1,582 - 4,393
4,394 - 10,015
10,016 - 44,805

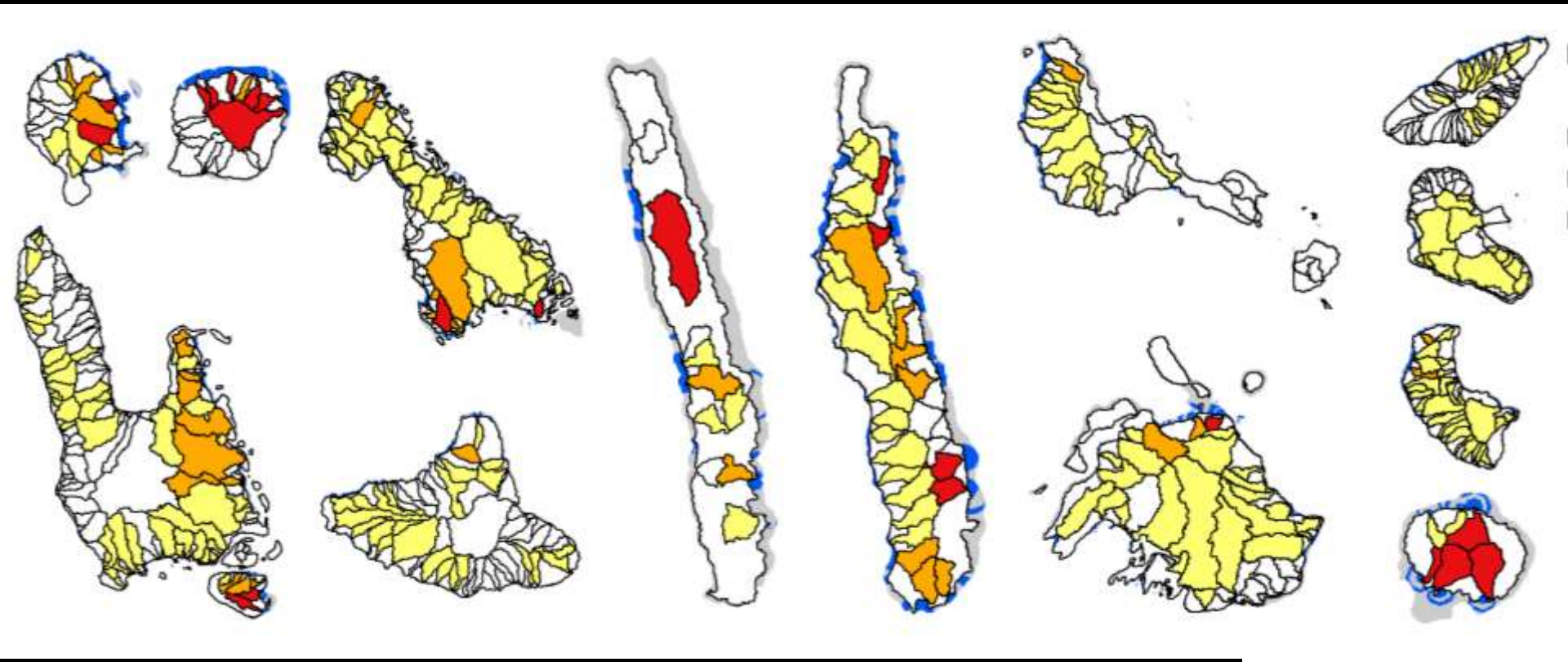
Check highest change in sed export

Marine impact assessment



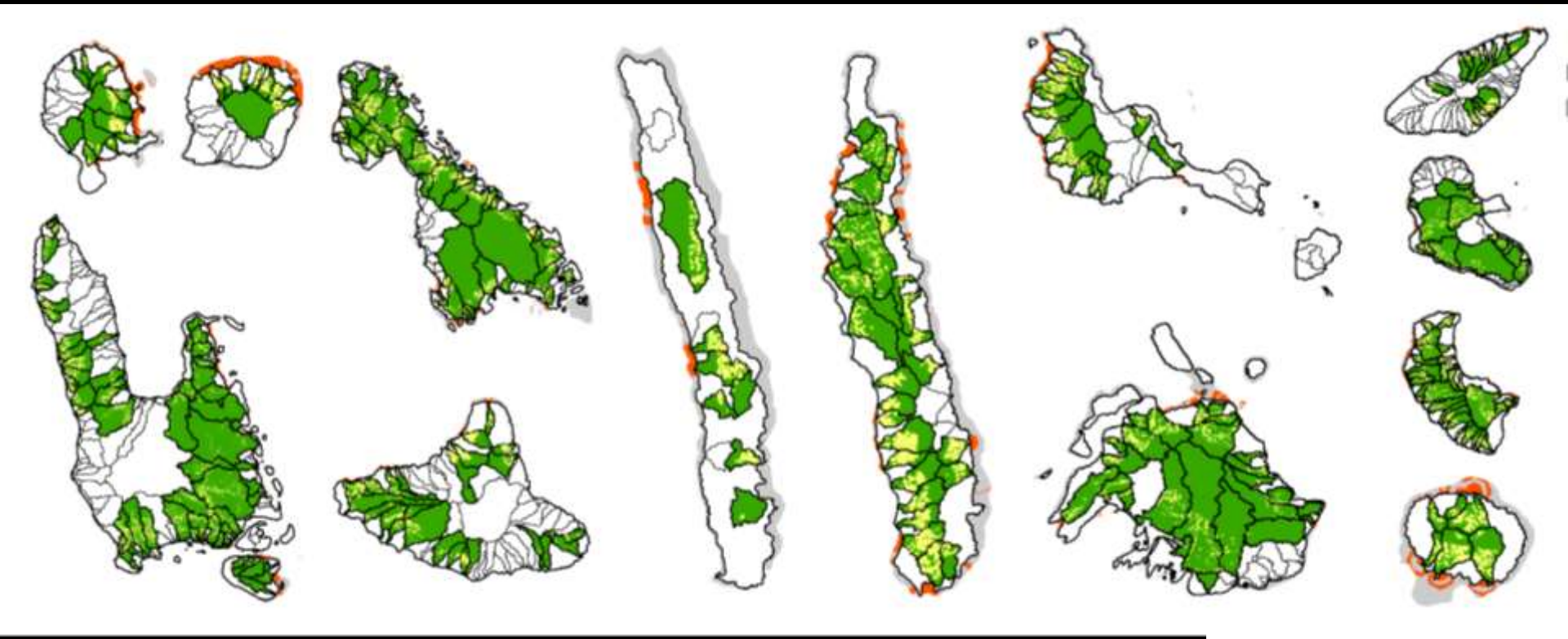
Habitat area	Coral cover	Fish biomass
490 km^2 (39.6 %)	-100 km^2 (40.1 %)	-50 tons (40.5 %)

Prioritize watersheds



275 watersheds linked to **coral reefs** by **sediment runoff**

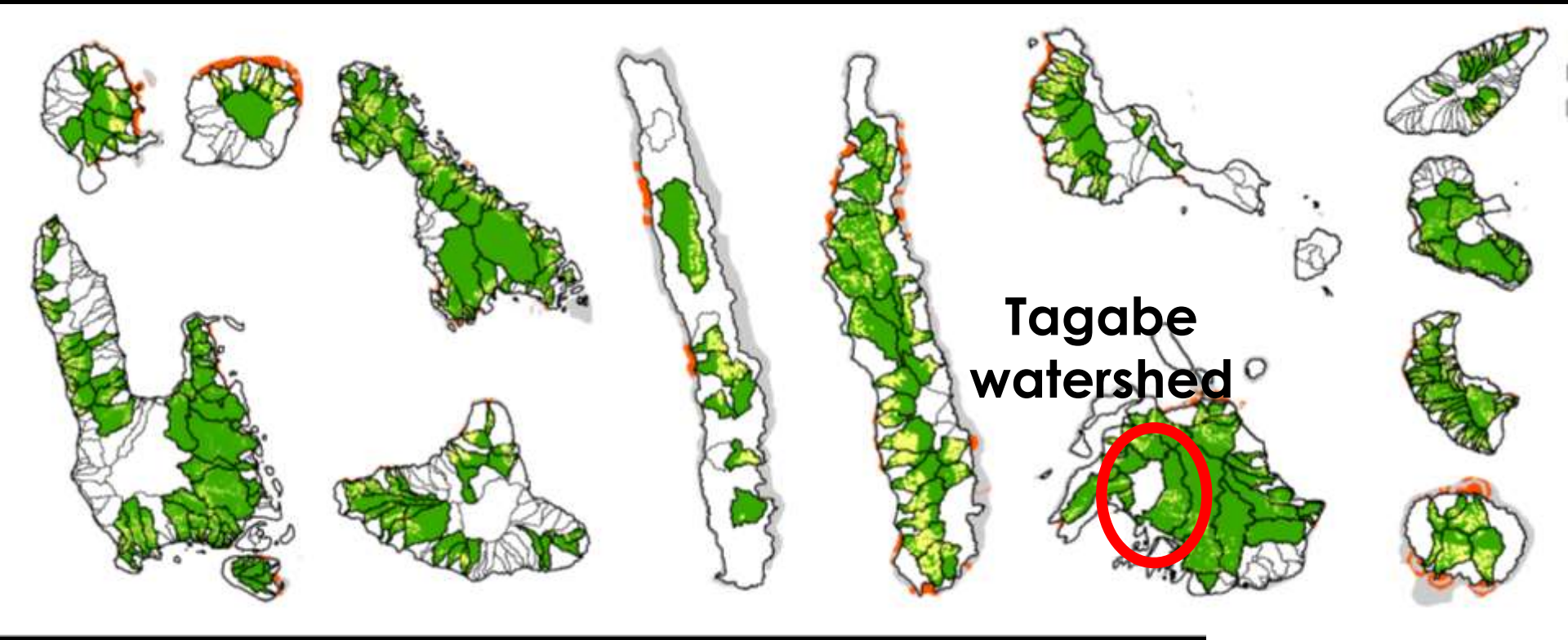
Prioritize forest areas



Erosion prone areas

Priority watersheds
Priority areas
Coral reef at risk

Social & economic drivers



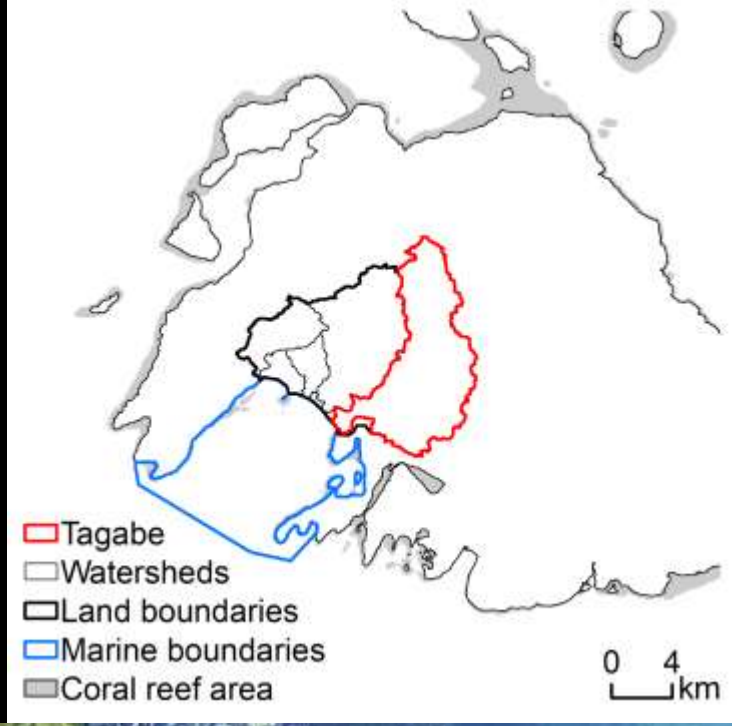
LOCAL-SCALE APPROACH METHODS

Tagabe R2R system

100% **drinking water** of Port Vila

Key **protein** source for local communities

Increased **urbanization** & growing population



Local management actions

Tagabe **watershed** management plan

Ifira **marine** management plan

→ Protect **drinking water**, restore the **forest** & nearshore **fisheries** for **people wellbeing**

Management scenarios

Land management

- **Restoration:**
  3 conservation zones + 30 m river buffer → restored to native forest

- **Urbanization:**
  Slopes < 30° +
  elevation < 400 m +
  protect conservation zones & 30m river buffer

Marine management

- **Fishing pressure:**
  Relative index of fishing pressure derived from participatory mapping

- **Marine closure:** Tagabe reef is closed to fishing

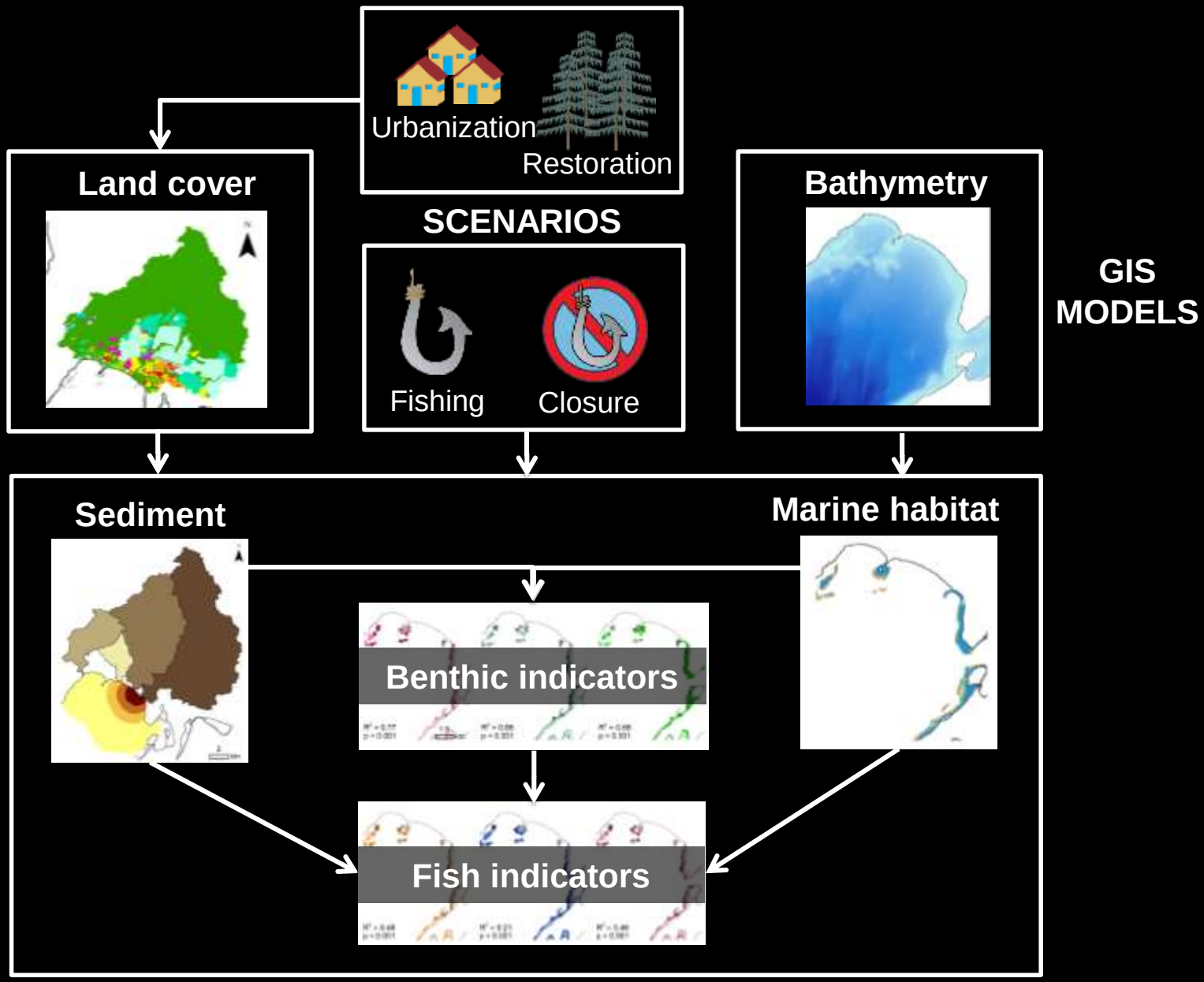
Local-scale R2R framework

natural capital PROJECT

InVEST SEDIMENT MODEL + PLUME MODEL

PREDICTIVE CORAL REEF MODELS

OUTPUTS: DISTRIBUTION MAPS



Calibrate coral reef models

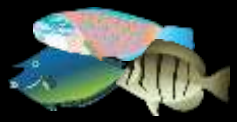

Corals


Macroalgae


Turf algae

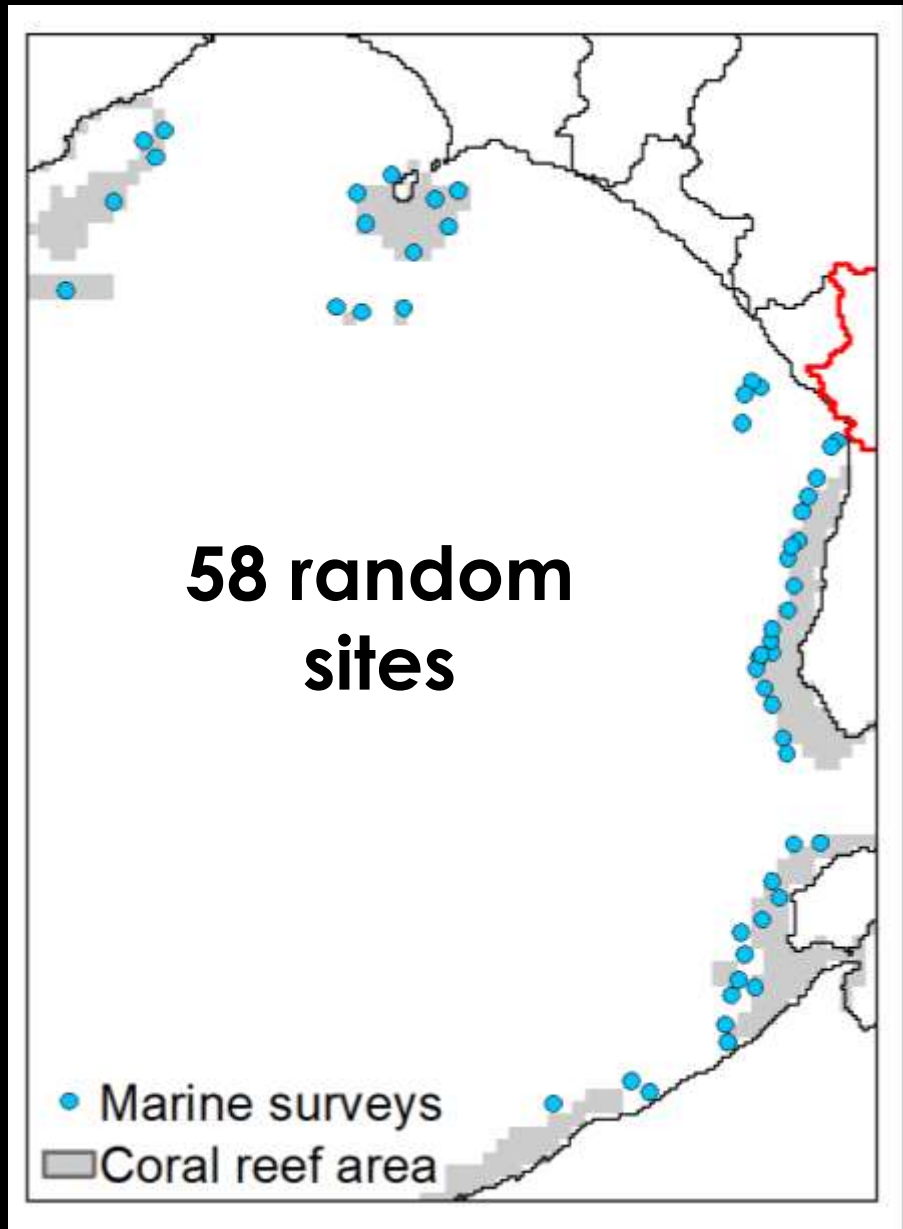
Benthic models =
sediment + habitat


Total biomass


Herbivore biomass


Targeted biomass

Fish models =
sediment + habitat +
benthic indicators



Delevaux et al. 2017, Elith et al. 2008, Smith et al. 2016

Scenario analysis

1. Predict coral reef **benthic** & **fish indicators** under **present** & **each scenario**

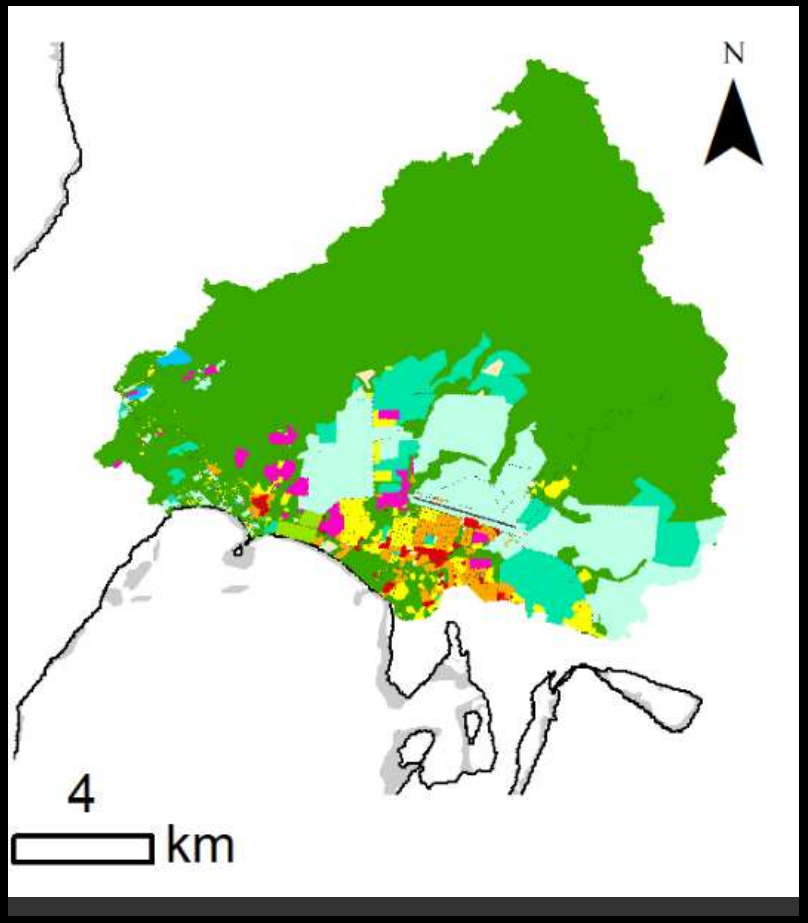
2. Calculate the coral reef **indicators** change for **each scenario** compared to **present**

LOCAL-SCALE APPROACH RESULTS

CORAL REEF ALLIANCE

Present scenario

8% of **Human LUC**

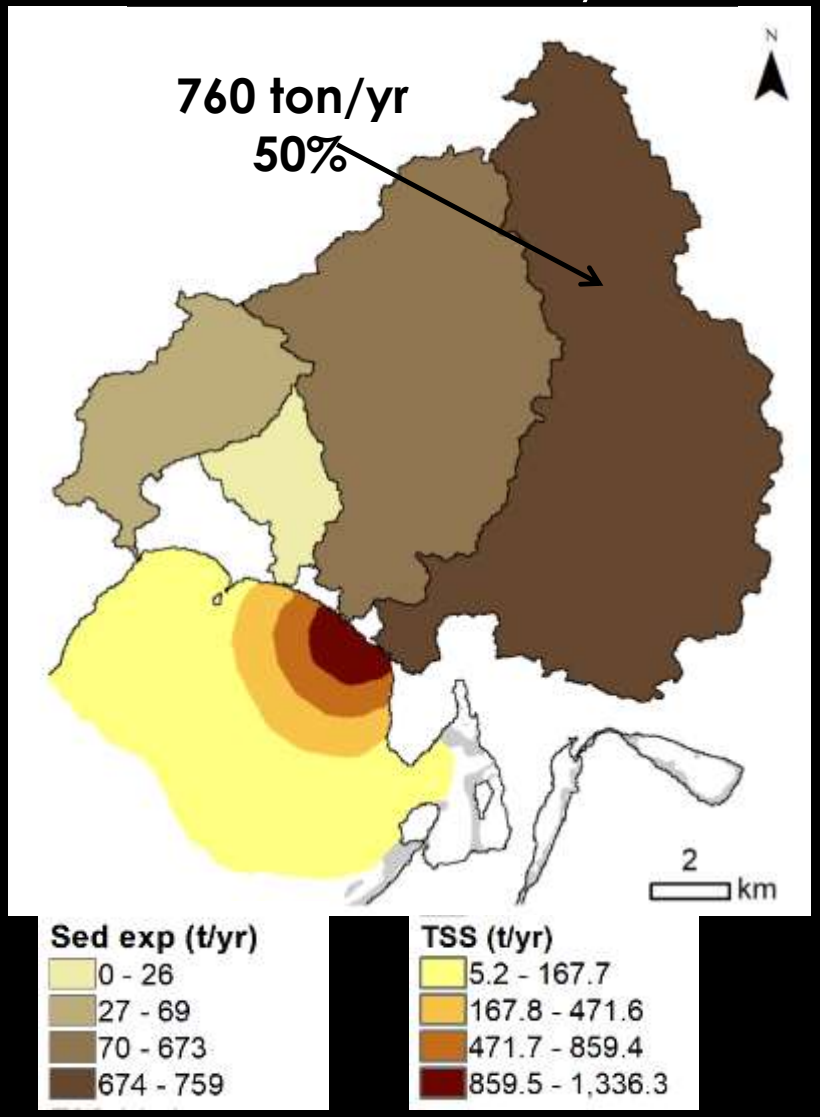


69% of **Native forest**

22% of **Grass/shrubland**

1,260 ton/yr

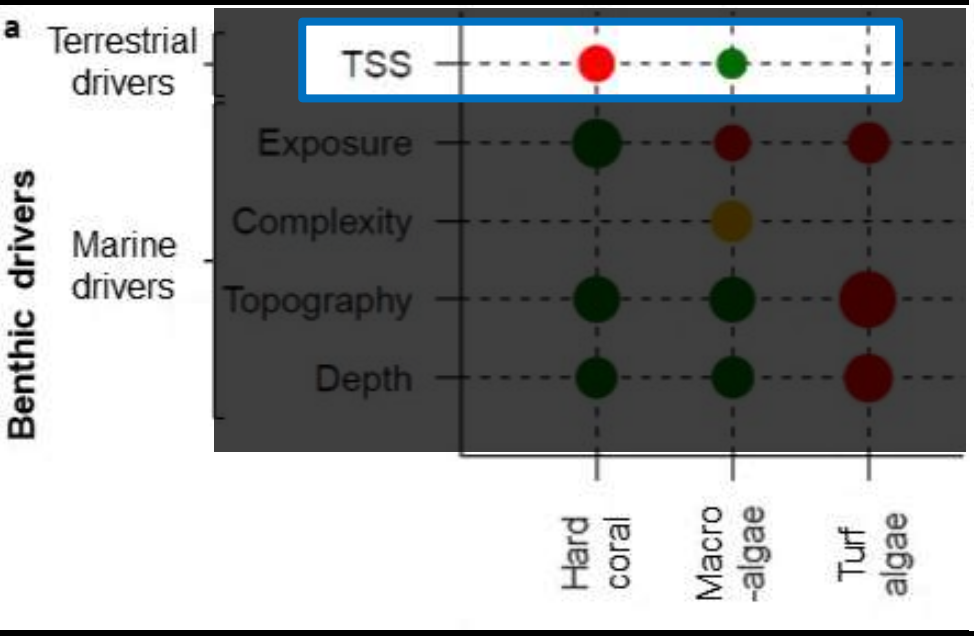
9.7 ton/km^{-2}/yr

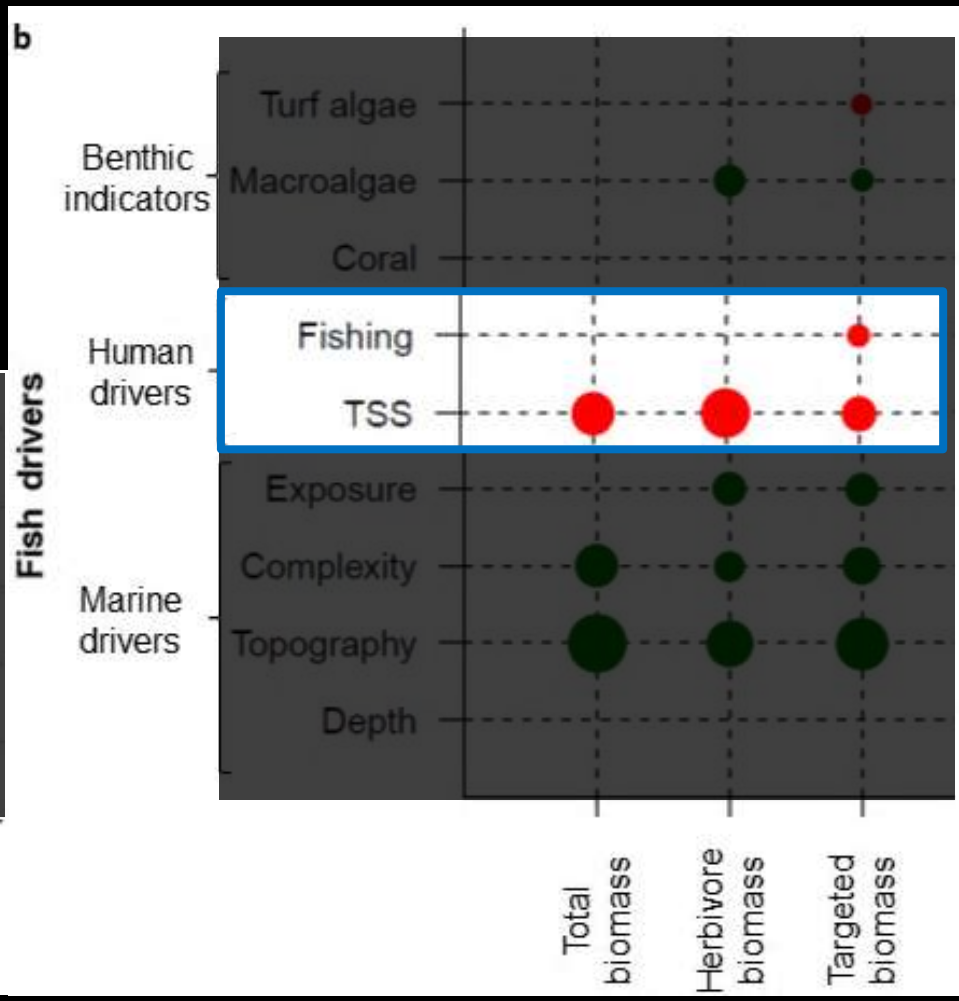


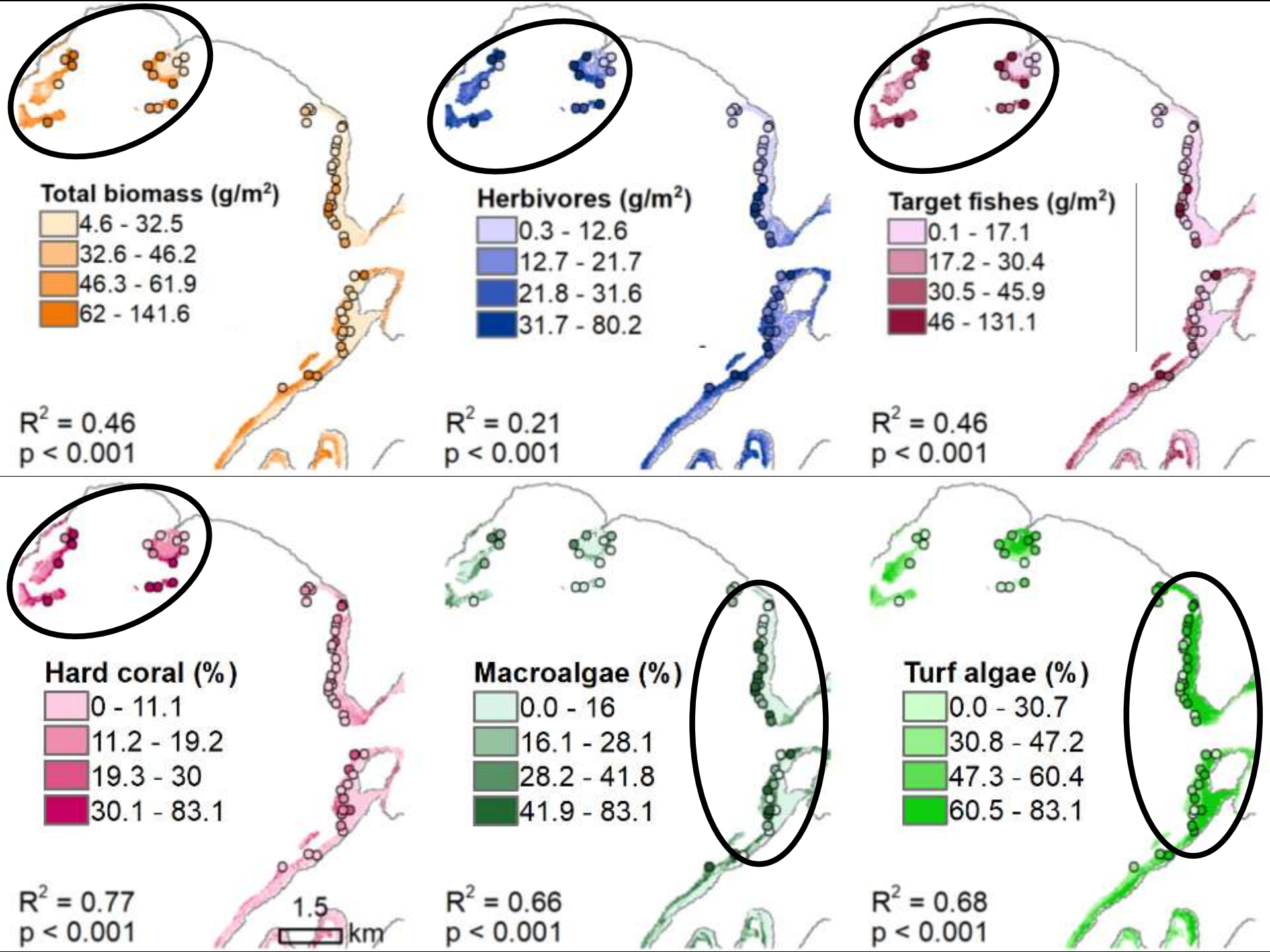
Calibrated coral reef models

Relationships:

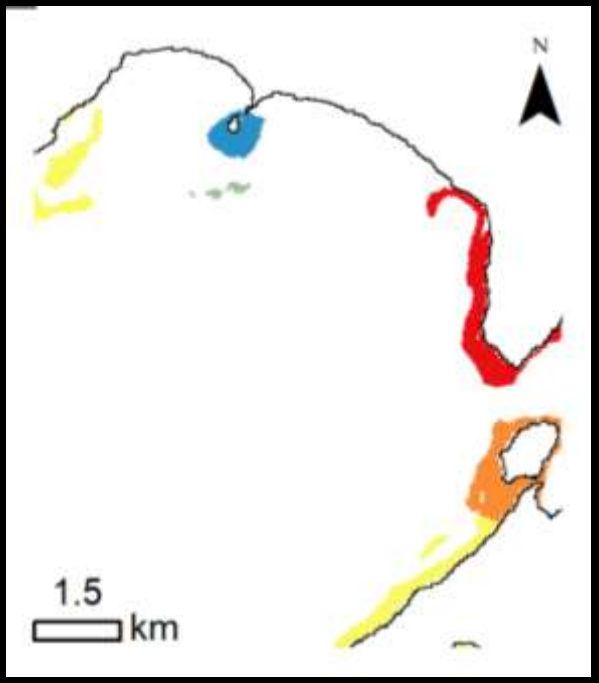
Positive Negative Concave or Convex

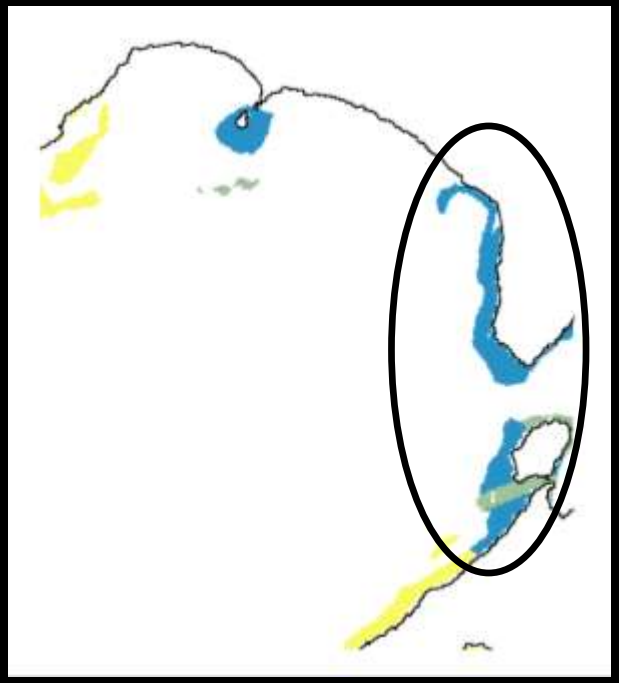


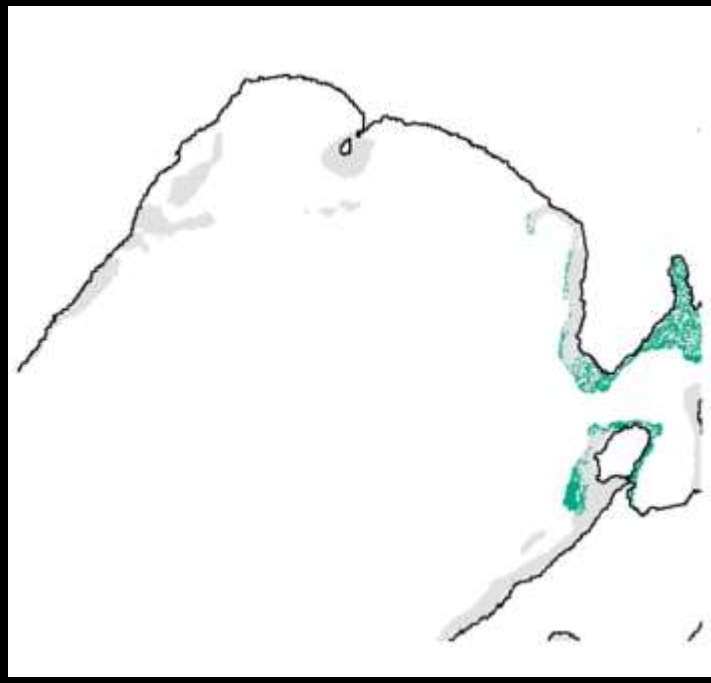



Total biomass (g/m²)
4.6 - 32.5
32.6 - 46.2
46.3 - 61.9
62 - 141.6
R² = 0.46
p < 0.001
Herbivores (g/m²)
0.3 - 12.6
12.7 - 21.7
21.8 - 31.6
31.7 - 80.2
R² = 0.21
p < 0.001
Target fishes (g/m²)
0.1 - 17.1
17.2 - 30.4
30.5 - 45.9
46 - 131.1
R² = 0.46
p < 0.001
Hard coral (%)
0 - 11.1
11.2 - 19.2
19.3 - 30
30.1 - 83.1
R² = 0.77
p < 0.001
1.5
km
Macroalgae (%)
0.0 - 16
16.1 - 28.1
28.2 - 41.8
41.9 - 83.1
R² = 0.66
p < 0.001
Turf algae (%)
0.0 - 30.7
30.8 - 47.2
47.3 - 60.4
60.5 - 83.1
R² = 0.68
p < 0.001

Marine closure scenario







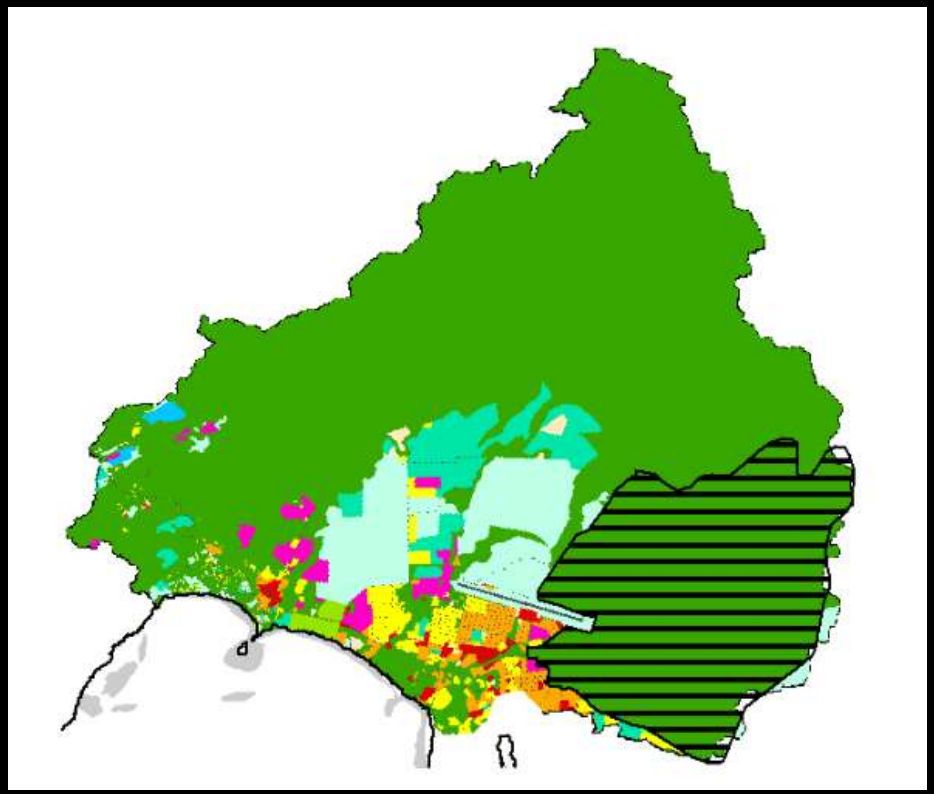
Fishing index
- 0 - Closure
- 1 - Low
- 2 - Moderate
- 3 - High
- 4 - Very high

Closed area

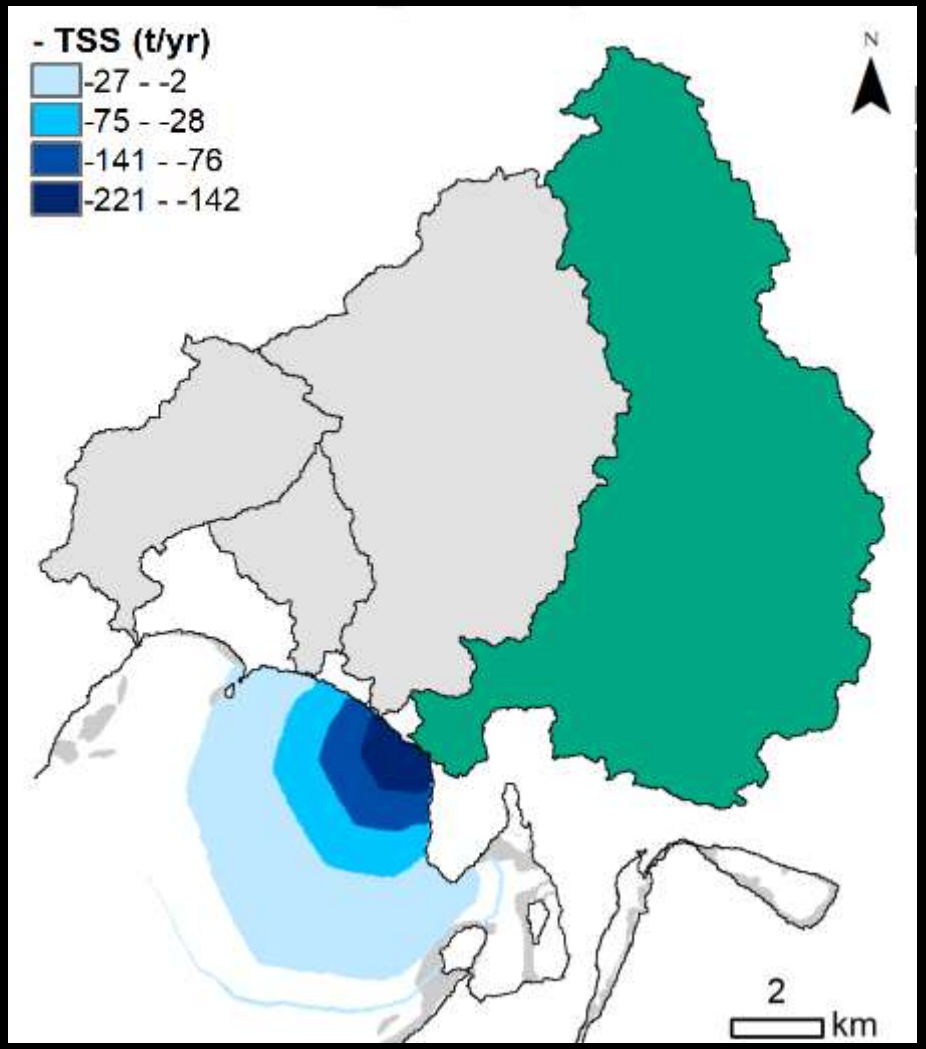
Fish biomass
+2.5 tons

Restoration scenario

+1,330 ha of
Native forest

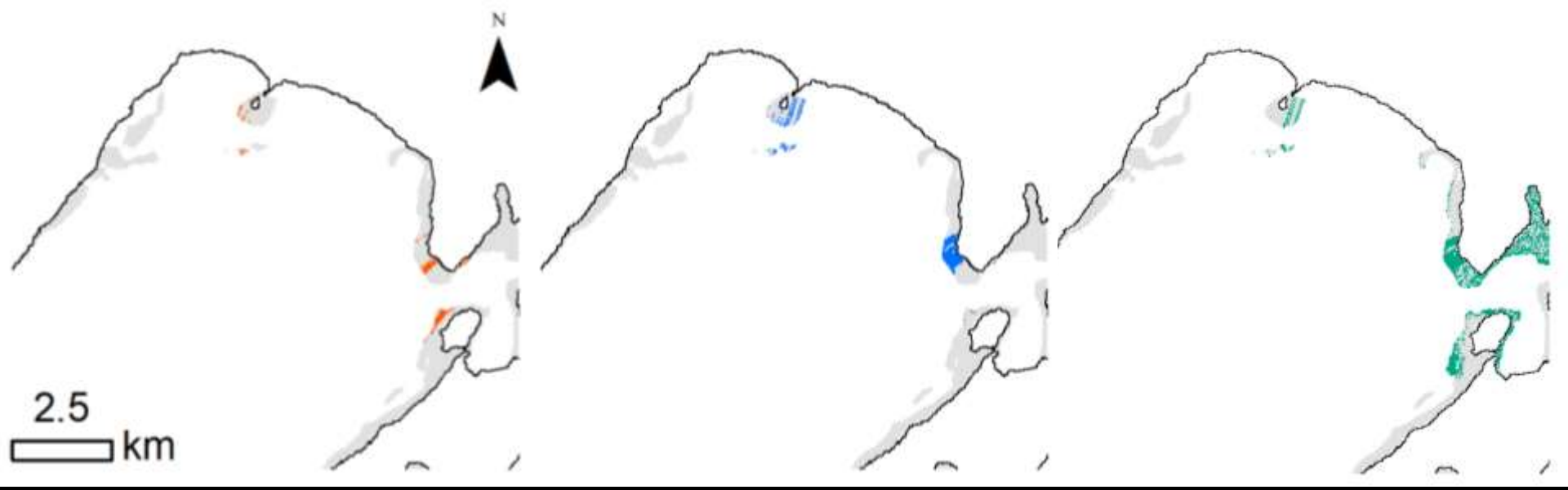


- 210 ton/yr



Restoration scenario

+Marine closure



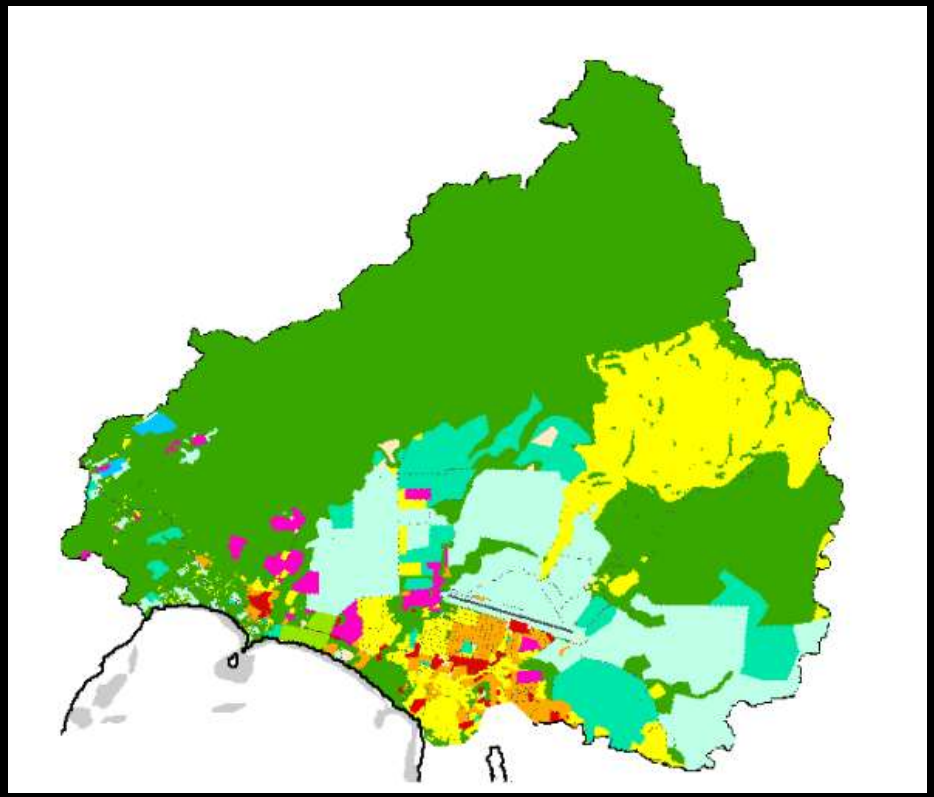
Habitat quality
20 ha
+3% coral
-1.5% macroalgae

Fish biomass
+0.7 tons

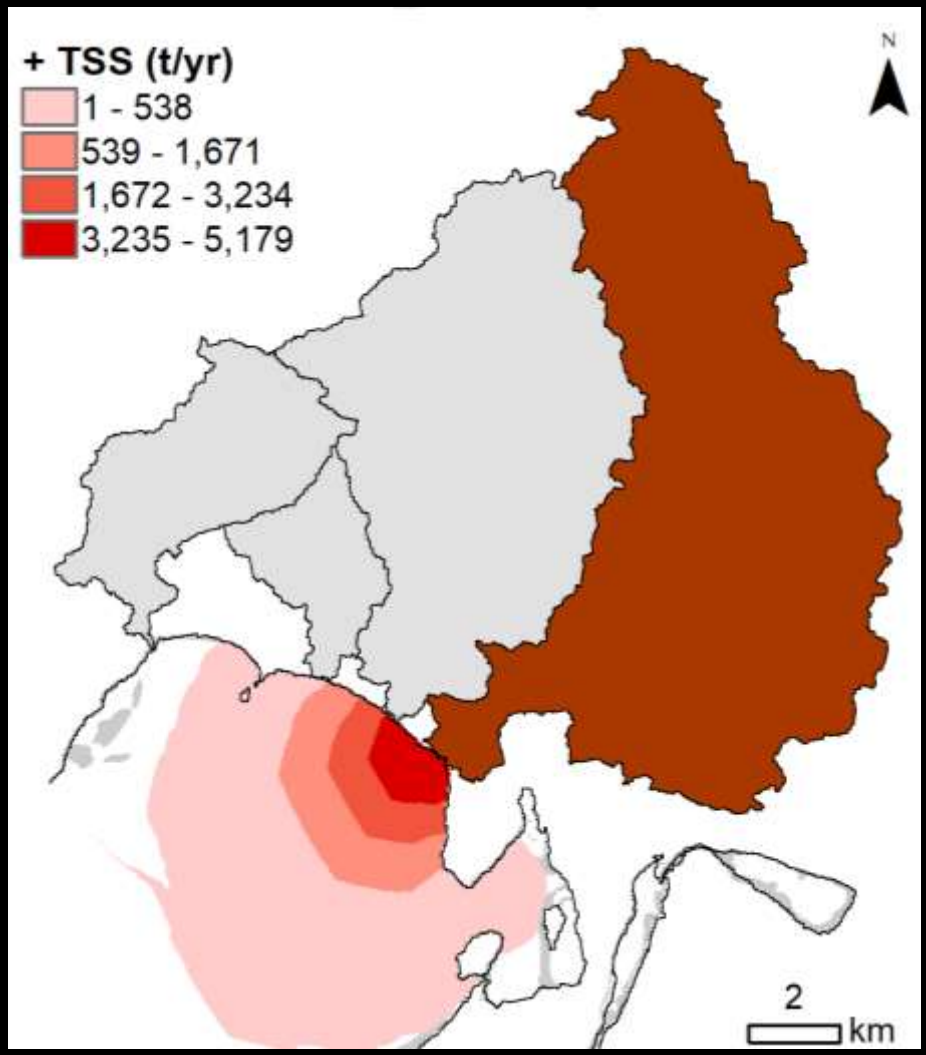
Fish biomass
+3.3 tons

Urbanization scenario

+ 1,340 ha of
Human LUC

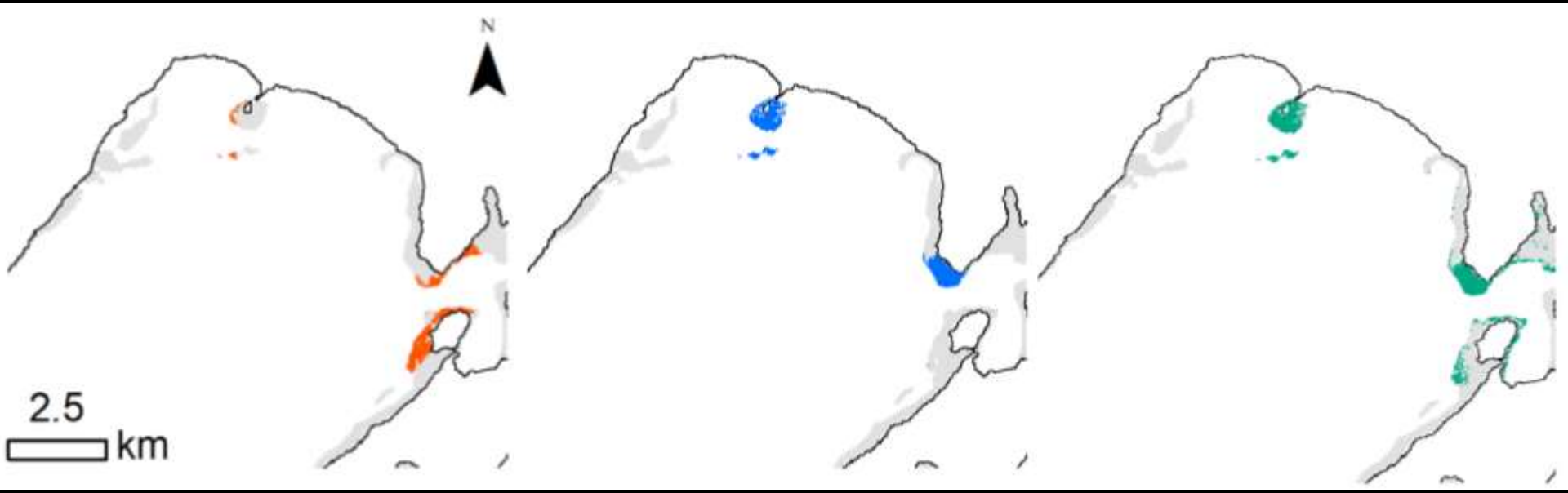


+ 5,180 t/yr



Urbanization scenario

+Marine closure



Habitat quality
75 ha
-7% coral
+2% macroalgae

Fish biomass
-6.7 tons

Fish biomass
-5 tons

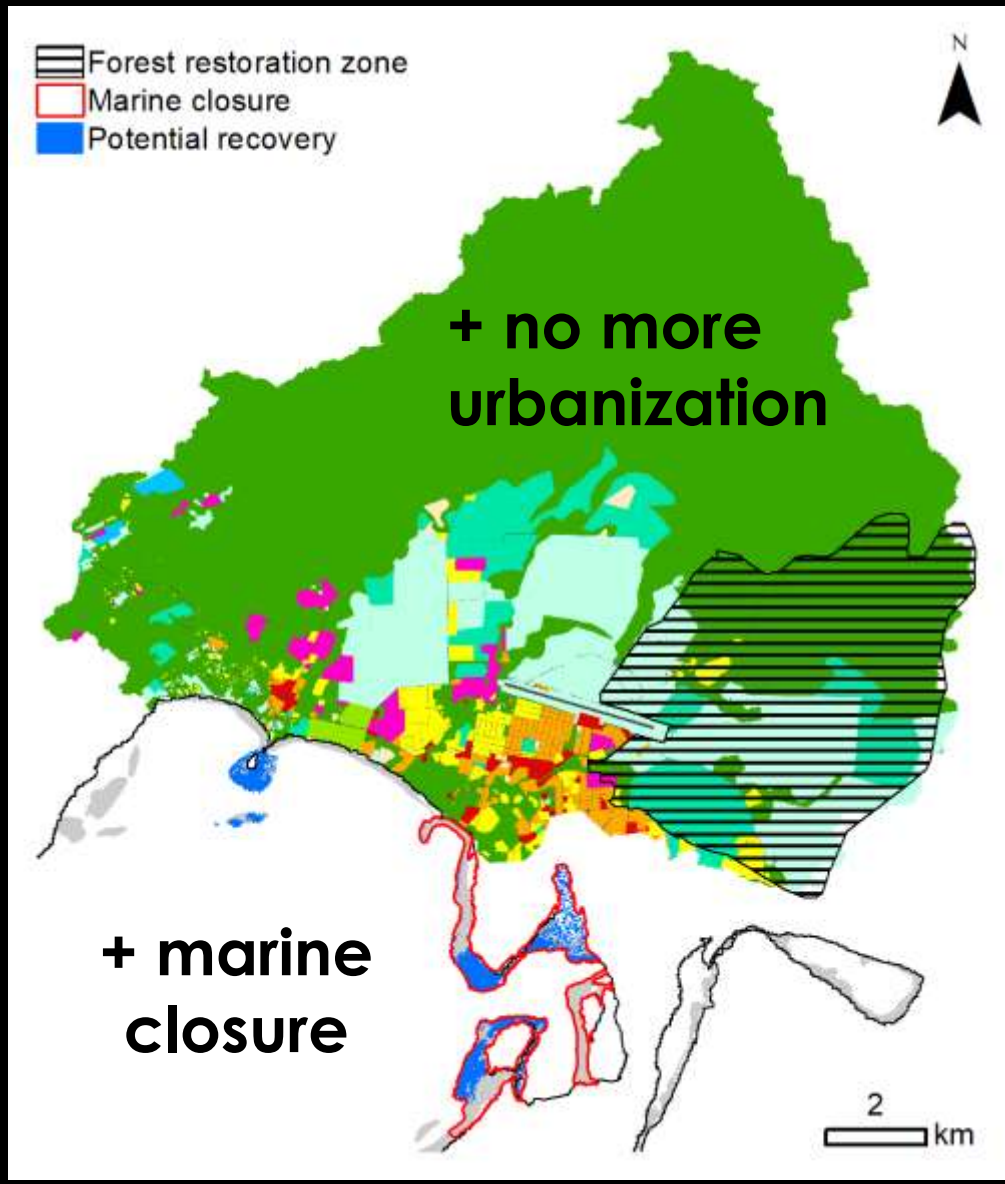
Benefits of R2R approach

Restore **native forest**:
+1,330 ha

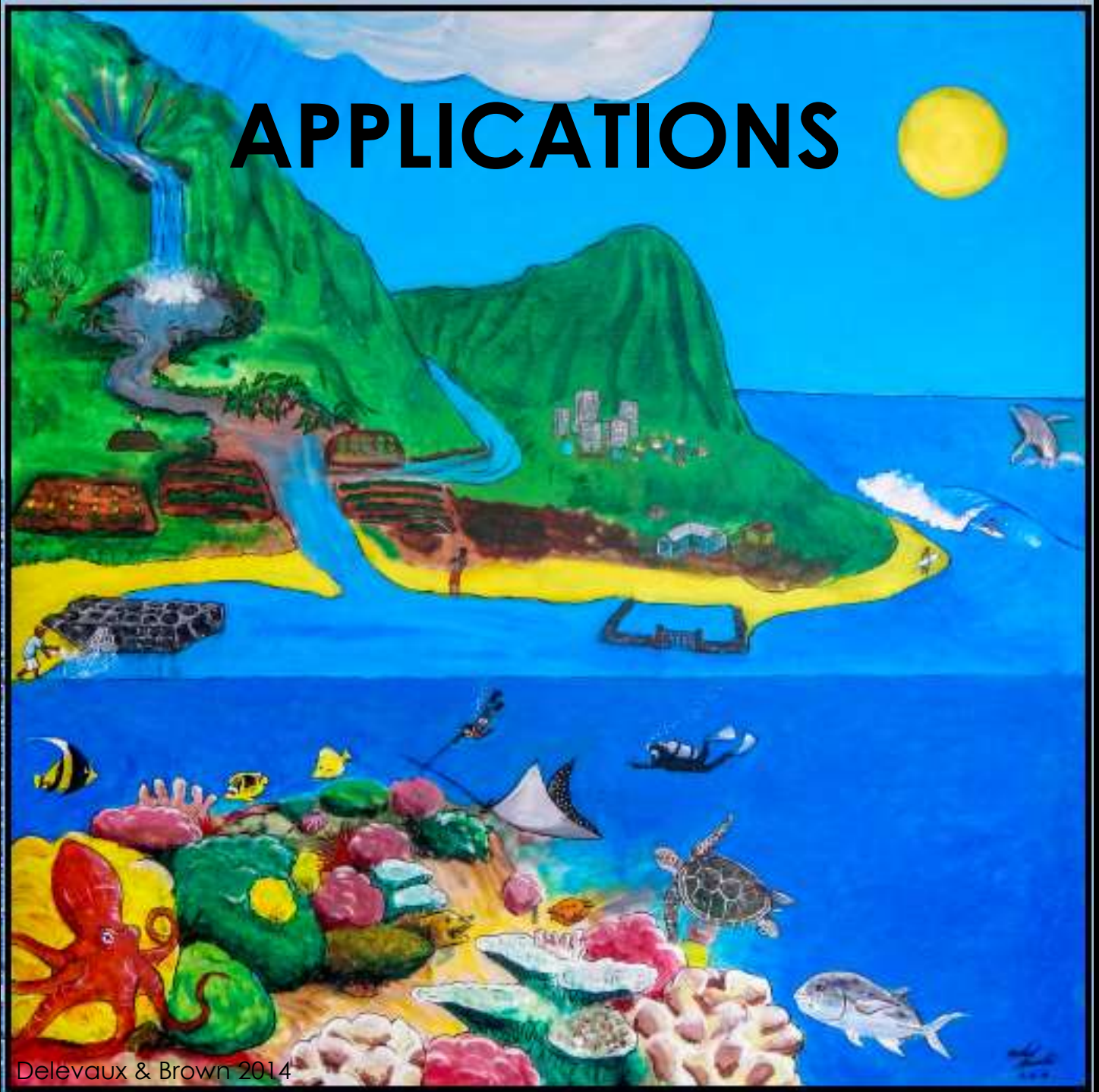
-210 ton/yr of **sediment**

Restore/protect **marine habitat**:
Up to 75 ha

Restore/protect **fish** biomass:
Up to 8.3 ton



APPLICATIONS

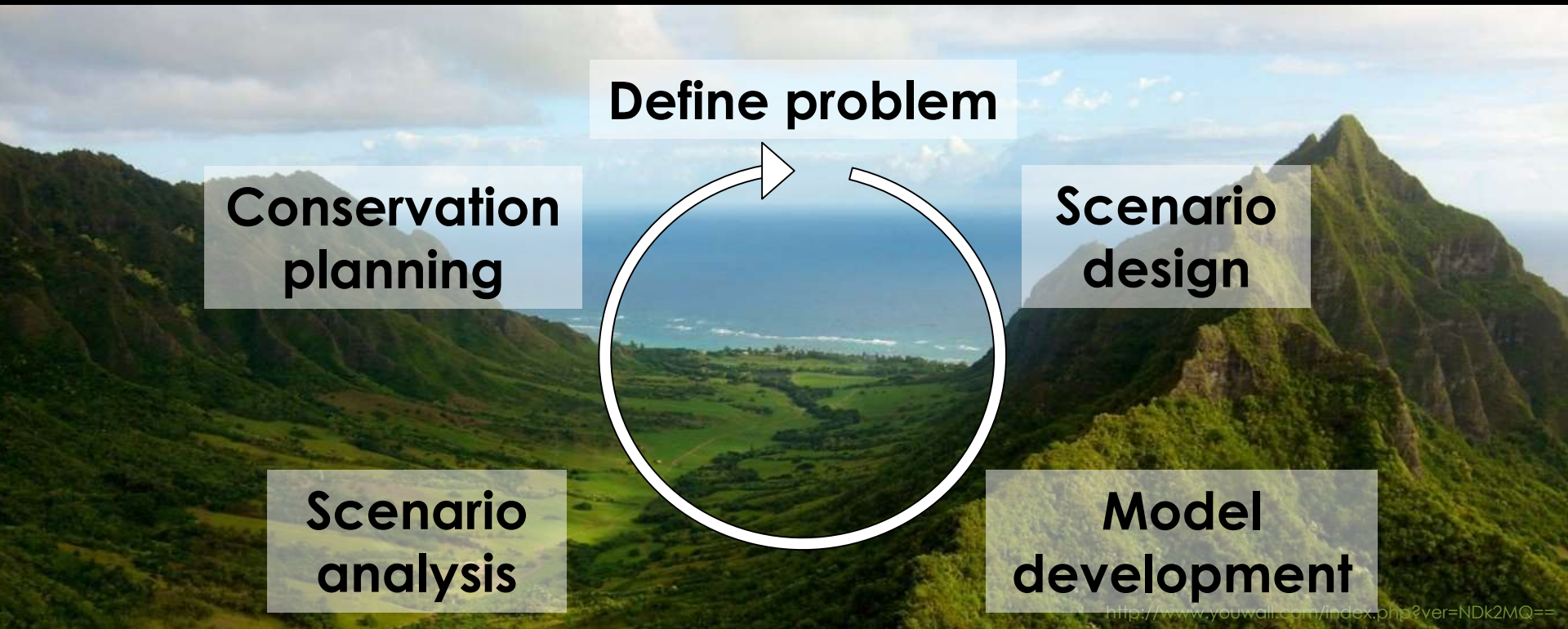


Delevaux & Brown 2014

Collaborative management

1. Provide **information** to foster **dialogue** between **decision-makers**

2. Can be applied as part of an **iterative** decision-making **process**



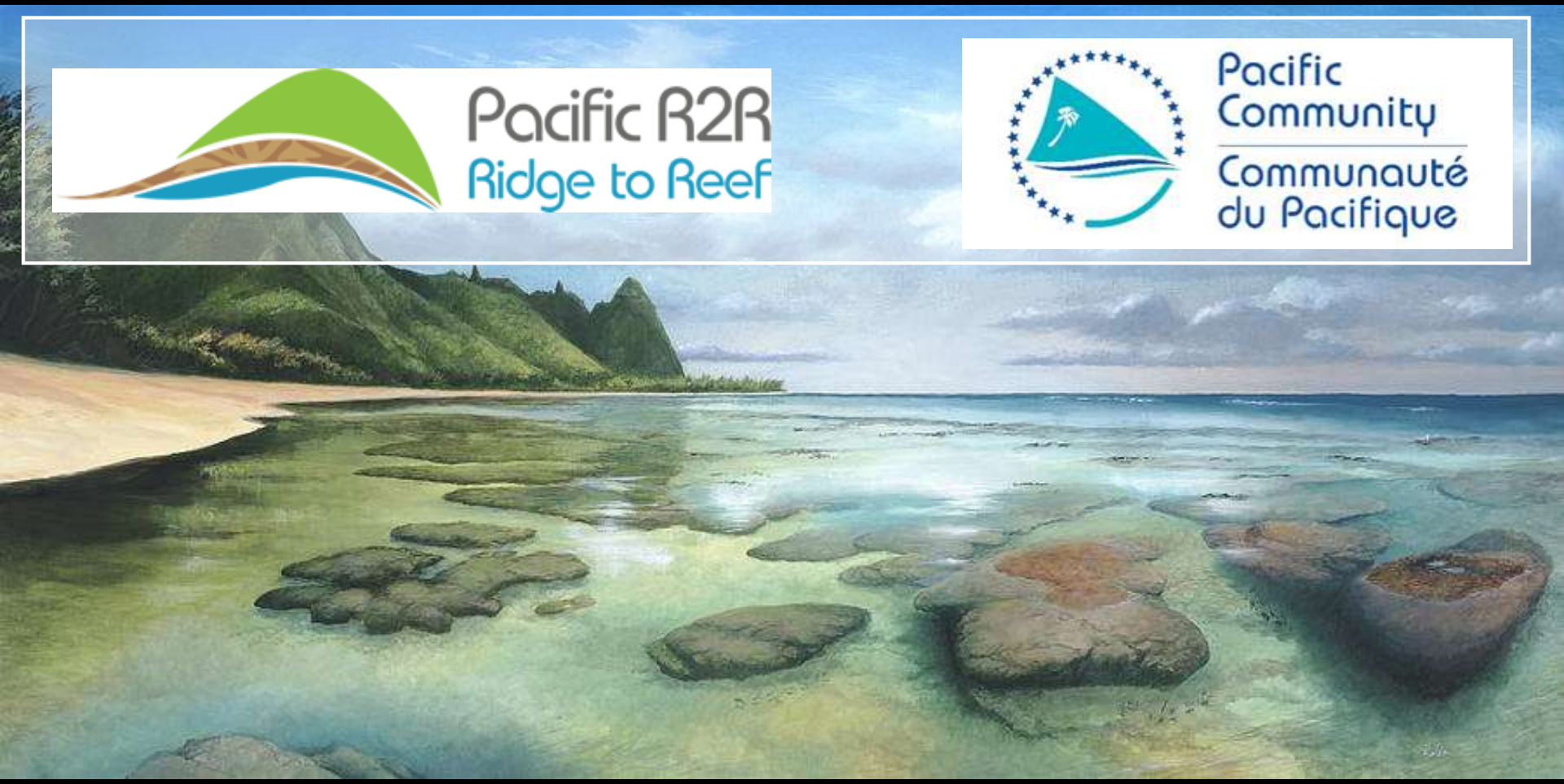
Support decision making

1. Prioritize **conservation areas** at the **national-scale** that can **benefit** both **terrestrial** & **marine** environments

2. Support **local** decision-making by testing **policy actions** & estimating potential **outcomes** prior implementation

Vinaka – Questions?

Contact: jade@seascape.solutions



Wallace Kong 2012

References

To be completed!