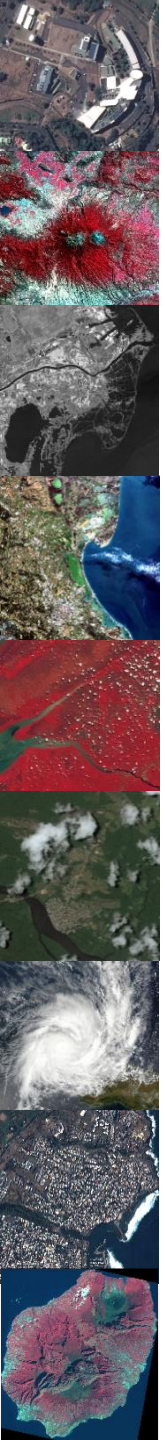

Mangrove ecological services at the forefront of coastal change in the French overseas territories

Thibault Catry, Trégarot Ewan, Caillaud Anne, C. Cornet Cindy, Taureau Florent, M. Cragg Simon, Failler Pierre

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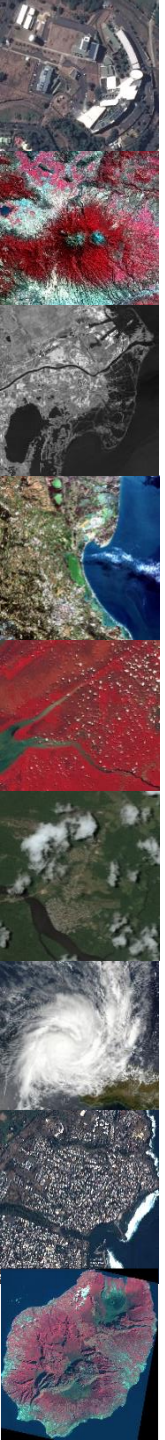
Oceania Geospatial Symposium, November 2022



Context of the study

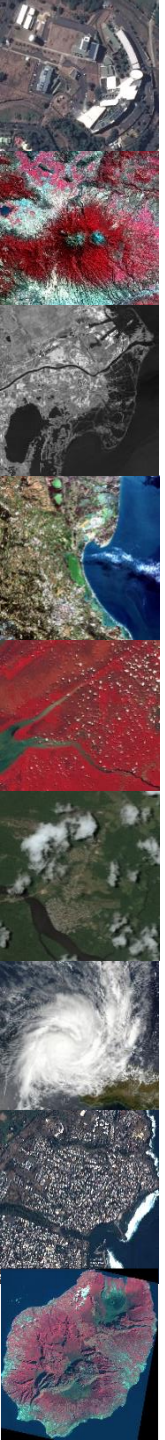
Mangrove ecosystems globally are expected to be substantially influenced by climate change-related physical processes in the future.

Mangroves are one of the most effective ecosystems on Earth to mitigate and to adapt to the effects of climate change.

Complexity of mangrove ecosystems.

Located in a wide range of geographical contexts, not all mangroves are thus equal in the face of rising sea levels and storm surges.

⇨ Advanced modellings are, therefore, needed to understand the cumulative effects of multiple risks on mangroves, and to predict their context-dependent response to climate change and other anthropogenic pressures



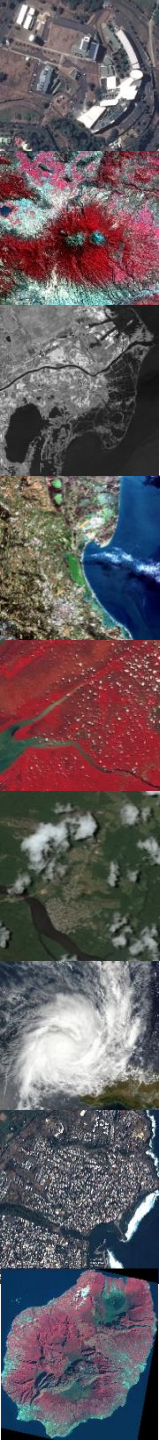
Objective of the study

Examine the vulnerability of mangroves to anthropogenic drivers and global changes to adjust their provision of services to humans, based on the assumption that an increase in habitat vulnerability is likely to decrease the supply of ecosystem services.

Provide the first ecosystem services valuation of all mangrove forests present in the French Overseas territories.

⇨ Present the distribution of mangrove forests in French Overseas territories.

⇨ Provide a tailored assessment of mangroves production functions using the vulnerability index that we developed specifically for this exercise and present the monetary value per territories of each ecosystem services.



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Mangrove ecological services at the forefront of coastal change in the French overseas territories

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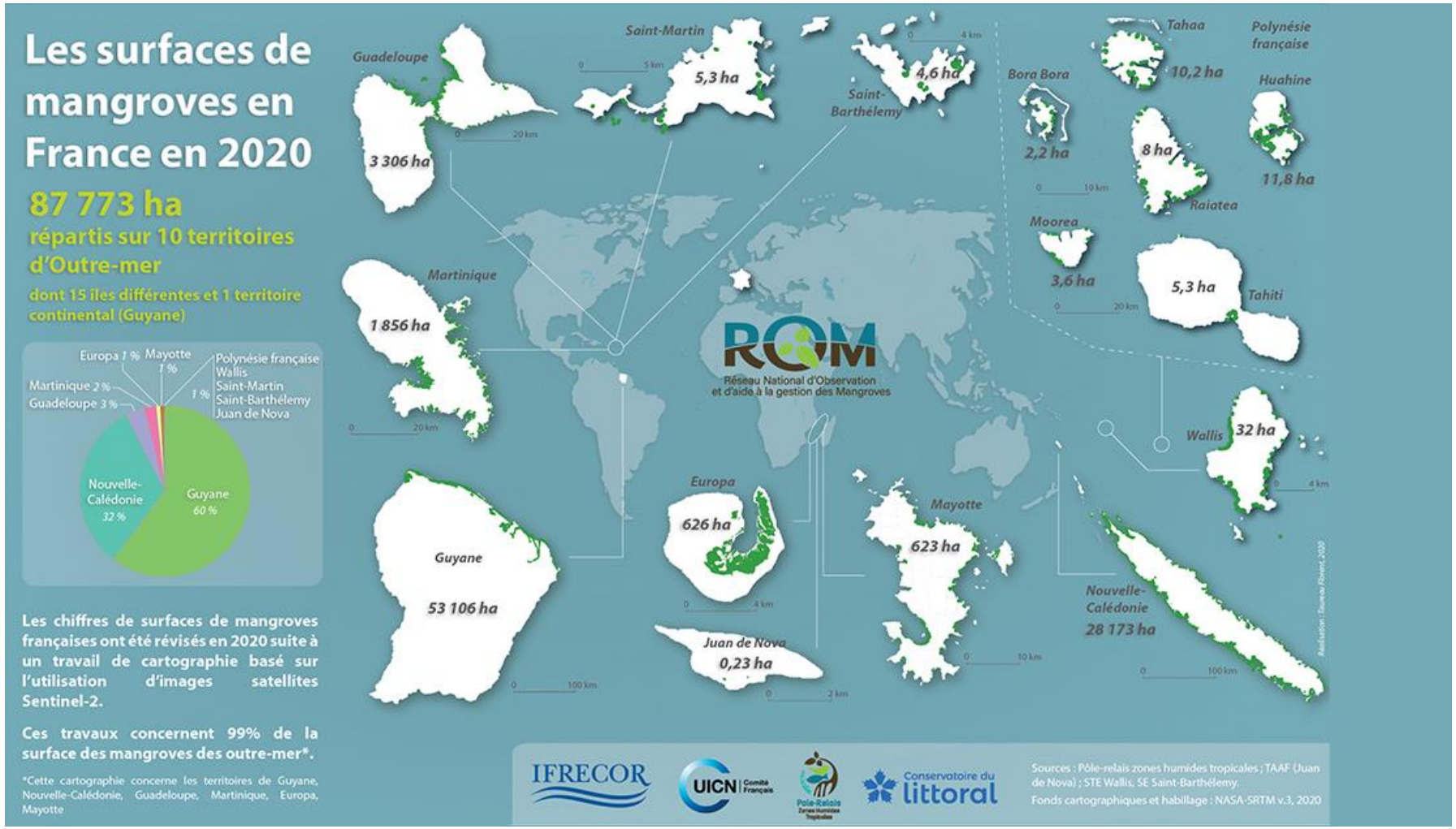
Area of interest

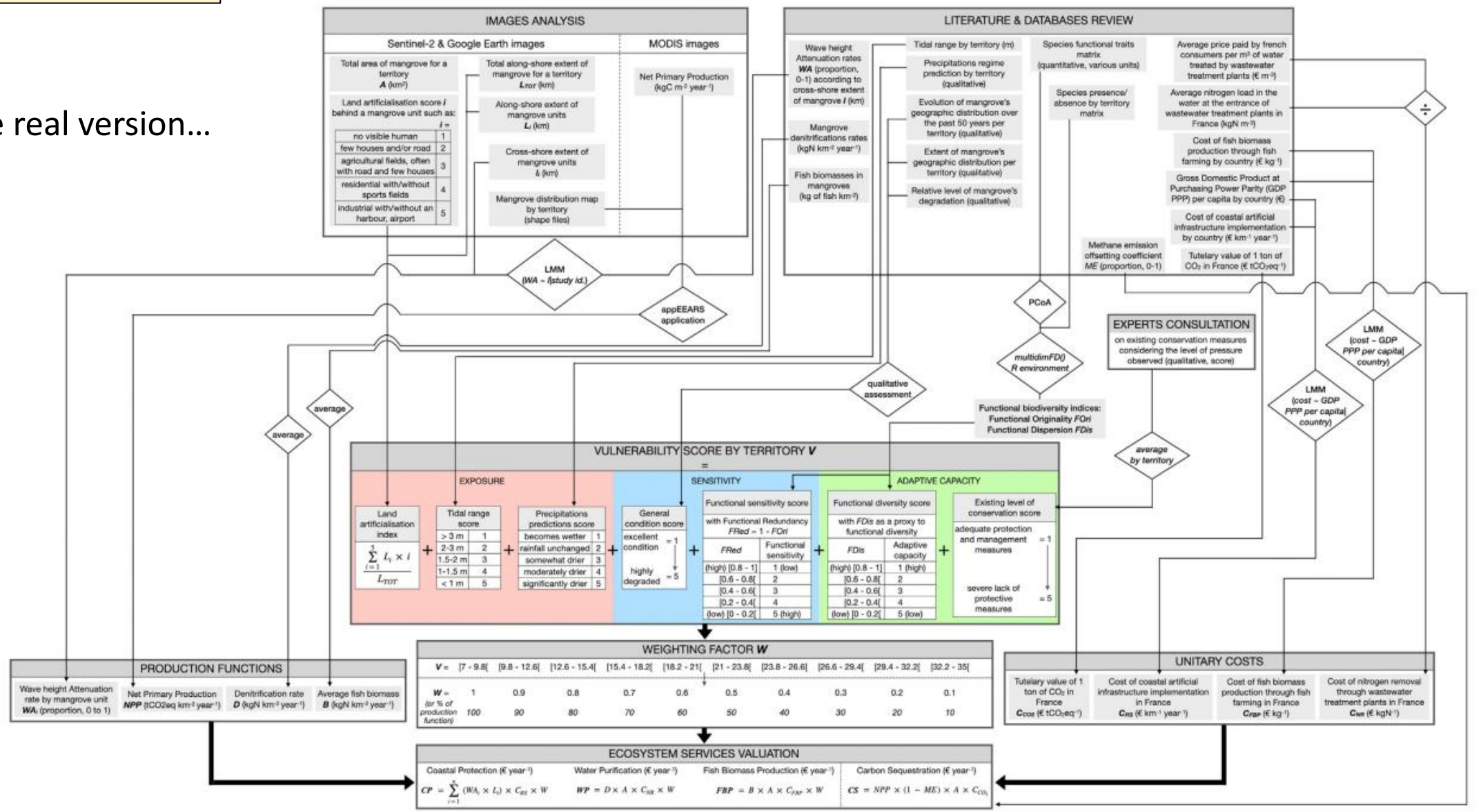
Mangroves in French Overseas territories are widely distributed across the Earth and therefore, grow under many different geomorphic settings, environmental conditions and anthropogenic pressures.



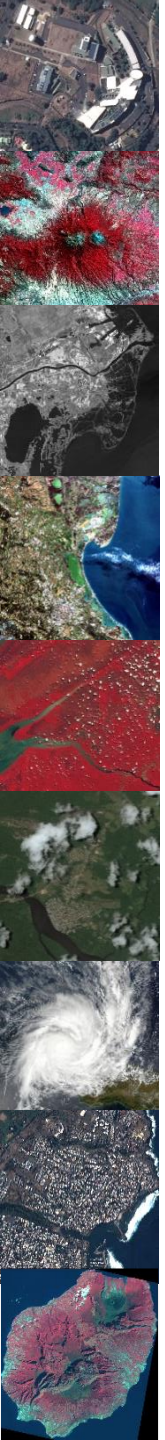
Distribution of mangroves in French overseas territories

Methodology

The real version…



Operational flow chart for the assessment of ecosystem services provided by mangroves in French overseas territories



Methodology

The simplified, friendly version…

IMAGE ANALYSIS
Mangrove distribution and morphology
Urbanization
Net Primary Production

LITERATURE AND DATABASE REVIEWS
Exposure to environmental and anthropogenic stressors
Associated sensitivity
Related adaptive capacity

VULNERABILITY SCORE BY TERRITORY
=
EXPOSURE + SENSITIVITY + ADAPTIVE CAPACITY

PRODUCTION FUNCTIONS
Wave height attenuation
Net primary production
Denitrification rate
Average fish biomass

WEIGHTING FACTOR

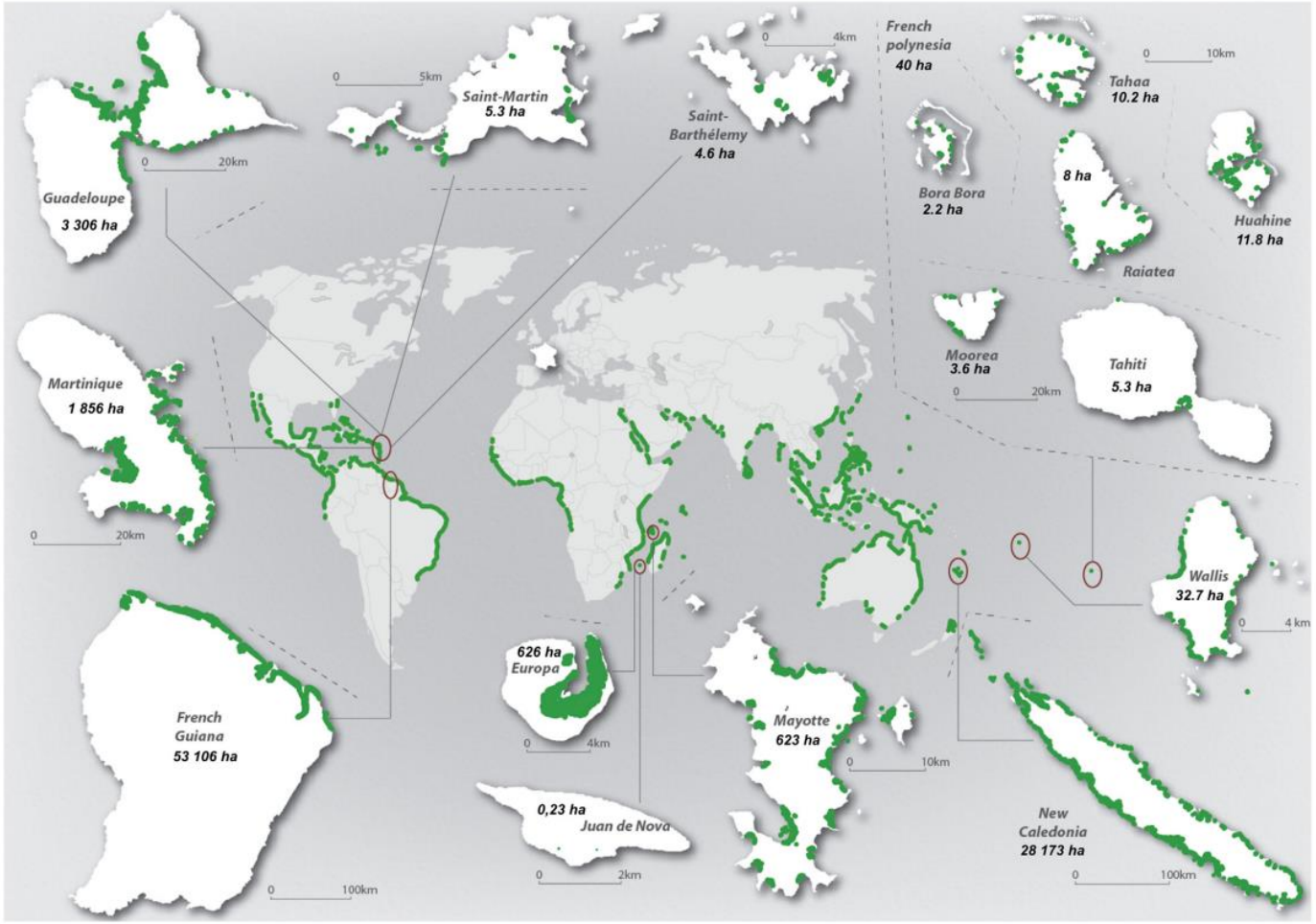
UNITARY COSTS
Ton of CO2
Coastal artificial infrastructure
Fish biomass production
Nitrogen removal

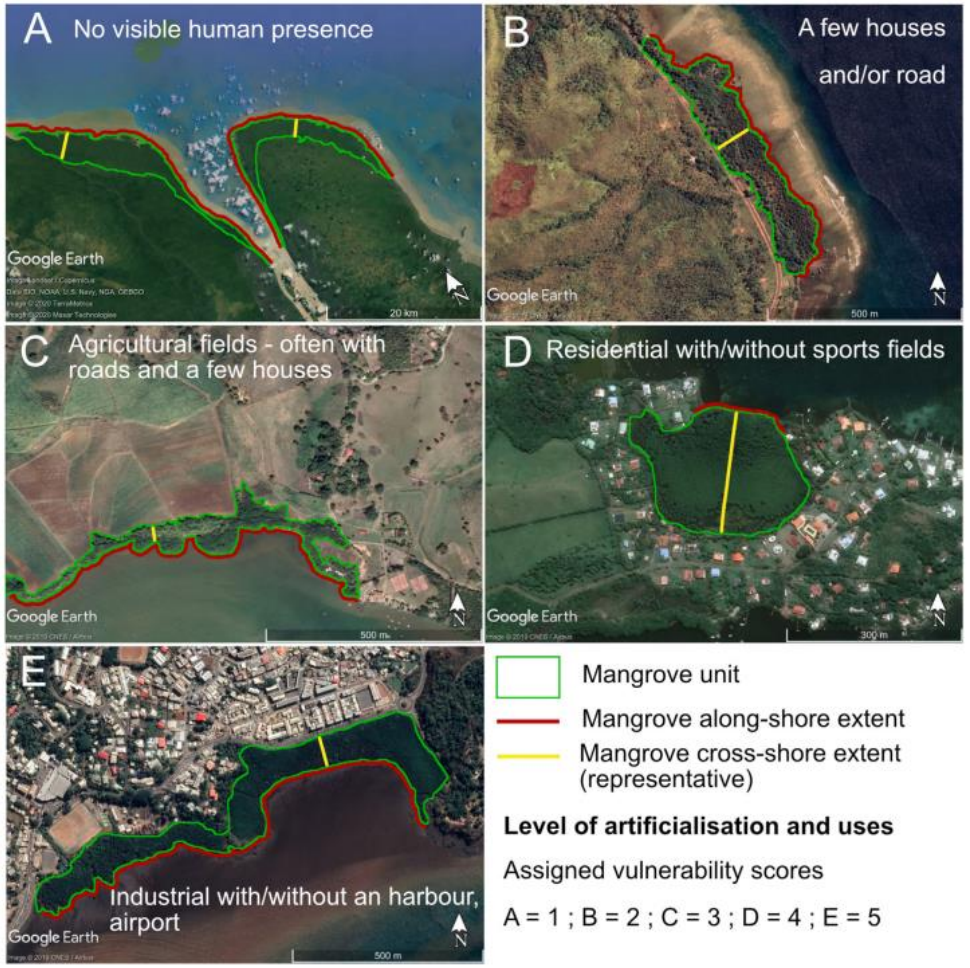
ECOSYSTEM SERVICES
Coastal protection Water purification Fish biomass Carbon sequestration

Operational flow chart for the assessment of ecosystem services provided by mangroves in French overseas territories

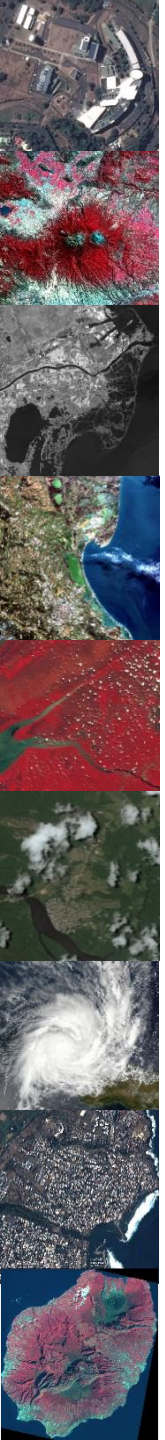
Mapping of mangrove and level of arificialisation/urbanization

Mangrove mapping in French overseas territories (2016) was updated using a mixt approach combining Sentinel-2 images from 2020 and manual photo interpretation to adjust the contours.





Net Primary Production values based on MODIS images were provided by NASA (AppEEARS application)



Ecosystem vulnerability and production function weighting

Vulnerability assessment

Criteria for ranking mangrove vulnerability in French overseas territories.

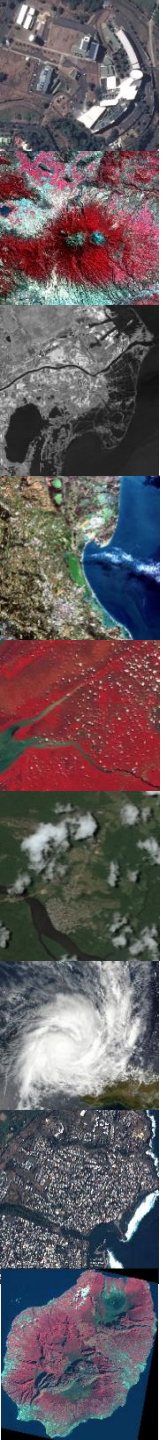
Scores range from 1 to 5.
5 = most vulnerable category

Vulnerability criteria	FG	G	MQ	SM	SB	MY	SI	NC	WF
Exposure components									
Tidal range	2	4	5	5	5	1	1	3	3
Precipitation regime	2	3	3	3	3	2	2	1	2
Land artificialisation	2	3	3	3	3	4	1	1	2
Sensitivity components									
Mangrove condition	1	3	3	5	3	3	2	2	2
Functional sensitivity	3	3	2	3	3	2	3	3	2
Adaptive capacity components									
Functional dispersion	1	1	1	2	2	1	3	2	2
Mangrove protection	2	3	3	4	2	3	1	3	2
Ranking									
Vulnerability Rank	13	20	20	25	21	16	13	15	15
Weighting factor *W*	0.8	0.6	0.6	0.4	0.5	0.7	0.8	0.8	0.8

FG: French Guiana, G: Guadeloupe, M: Martinique, SM: Saint-Martin, SB: Saint-Barthelemy, MY: Mayotte, SI: Scattered Islands, NC: New-Caledonia, WF: Wallis and Futuna.

Low vulnerability of mangroves in French Guiana, the Scattered Islands, New-Caledonia, and Wallis

Mangroves presenting the highest vulnerability are in the Lesser Antilles



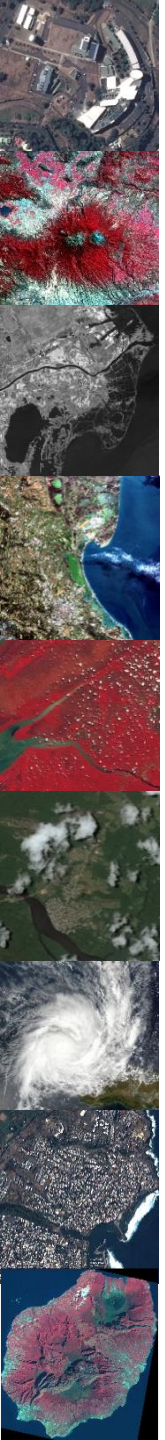
Ecosystem vulnerability and production function weighting

Coastal protection

Economic value of the service of coastal protection provided by mangroves annually in the French overseas territories expressed as mean [min-max] according to the cost of each artificial structure.

French overseas territory	Along-shore extent L (km)	CP (€ year^{-1}) Breakwaters	CP (€ year^{-1}) Seawalls	CP (€ year^{-1}) Rock Fills	CP (€ year^{-1}) Artificial Reefs	Mean Value (€ year^{-1})
French Guiana	344.60	143,399,009 [135,291,070–148,306,220]	245,683,325 [231,792,117–254,090,774]	213,010,226 [200,966,391–220,299,580]	92,937,185 [87,682,413–96,117,558]	173,757,436 [87,682,413–254,090,774]
Martinique	71.22	15,211,631 [11,944,326–17,975,083]	26,061,854 [20,464,031–30,796,434]	22,595,923 [17,742,546–26,700,857]	9,858,688 [7,741,142–11,649,687]	18,432,024 [7,741,142–30,796,434]
Guadeloupe	65.42	17,617,252 [15,211,292–19,012,297]	30,183,367 [26,061,273–32,573,478]	26,169,321 [22,595,419–28,241,574]	11,417,776 [9,858,469–12,321,908]	21,346,929 [9,858,469–32,573,478]
Saint-Martin	4.57	340,510 [223,486–469,697]	583,391 [382,896–804,724]	505,807 [331,975–697,705]	220,685 [144,842–304,411]	412,598 [144,842–804,724]
Saint-Barthelemy	3.80	72,829 [32,260–119,045]	124,776 [55,270–203,957]	108,182 [47,920–176,833]	47,200 [20,908–77,153]	88,247 [39,089–144,247]
Mayotte	34.04	7,993,462 [6,101,974–9,766,876]	13,695,076 [10,454,419–16,733,438]	11,873,786 [9,064,100–14,508,081]	5,180,579 [3,954,702–6,329,932]	9,685,726 [7,393,799–11,834,582]
Scattered Islands	8.16	3,584,646 [2,985,372–3,604,935]	6,141,519 [5,114,793–6,176,279]	5,324,767 [4,434,583–5,354,904]	2,323,216 [1,934,826–2,336,365]	4,343,537 [1,934,826–6,176,279]
New Caledonia	555.83	172,430,679 [138,952,505–198,811,697]	295,422,840 [238,065,198–340,621,034]	256,134,949 [206,405,224–295,322,296]	111,752,668 [90,055,397–128,850,259]	208,935,284 [168,369,581–240,901,321]
Wallis and Futuna	6.65	901,123 [540,839–1,270,383]	1,543,879 [926,611–2,176,528]	1,338,561 [803,382–1,887,074]	584,019 [350,019–823,338]	1,091,896 [655,337–1,539,331]
French Polynesia	13.79	1,533,065 [775,122–2,412,127]	2,626,577 [1,328,004–4,132,661]	2,277,272 [1,151,394–3,583,064]	993,583 [502,358–1,563,305]	1,857,624 [502,358–4,132,661]
All territories	1108.05	363,084,206 [312,058,246–401,748,359]	622,066,605 [534,644,610–688,309,307]	539,338,795 [463,542,935–596,771,968]	235,315,600 [202,245,574–260,373,916]	439,951,302 [378,122,841–486,800,888]
All territories max	1108.05	469,058,355 [402,587,059–519,414,315]	803,630,491 [689,746,238–889,904,586]	696,756,741 [598,017,804–771,557,359]	303,997,659 [260,917,479–336,633,457]	568,360,811 [260,917,479–889,904,586]

Mean annual value reaches 440 million euros per year for all French overseas territories.
The value would be 568 million euros per year if we did not consider the vulnerability of mangroves.



Ecosystem vulnerability and production function weighting

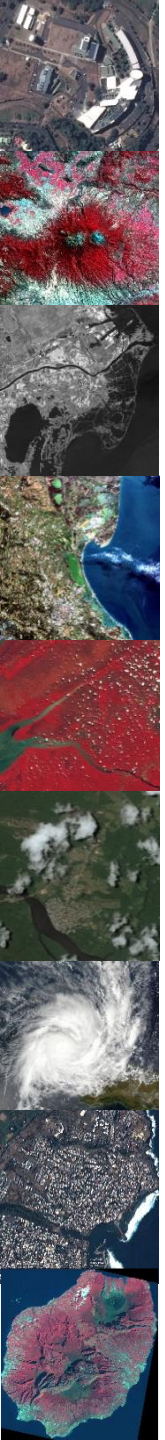
Carbon sequestration

Annual monetary value of the service of carbon sequestration by the mangroves of the French overseas territories (€ year^{-1}).

French overseas territory	Net primary production ($tCO_2eq\ ha^{-1}\ year^{-1}$)	Carbon sequestration $tCO_2\ year^{-1}$	Emission in 2017 - $tCO_2\ year^{-1}$ (trend since 2015)	Offset (2017)	Annual monetary value (€ $year^{-1}$)
French Guiana	56.89 [42.57–64.59]	3,020,935 [2,260,829-3,430,223]	3,910,000 (−4.24%)	77.26%	604,186,962 [452,165,726-686,044,550]
Martinique	37.80 [24.96–50.65]	70,159 [46,318-93,999]	2,465,000 (−0.51%)	2.85%	14,031,731 [9,263,667-18,799,795]
Guadeloupe	39.64 [26.79–52.11]	131,037 [88,571-172,289]			26,207,323 [17,714,209-34,457,777]
Saint-Martin	20.19 [19.45–20.92]	107 [103—111]	2,874,000 (+0.65%)	4.57%	21,396 [20,618-22,174]
Saint-Barthelemy	29.36 [27.53–34.50]	135 [127–159]			27,011 [25,323-31,738]
Mayotte	45.14 [11.01–65.69]	28,123 [6859-40,927]	479,000 (+8.15%)	5.87%	5,624,569 [1,371,846-8,185,348]
Scattered Islands	31.56 [10.64–53.95]	19,765 [6665-33,784]	NA	NA	3,953,014 [1,332,993-6,756,896]
New Caledonia	50.28 [5.14–85.14]	1,416,510 [144,753-2,398,762]	5,024,000 (−1.56%)	28.19%	283,302,053 [28,950,575-479,752,382]
Wallis and Futuna	46.24 [42.57–47.71]	1512 [1392-1560]	27,000 (+2.32%)	5.60%	302,423 [278,421-312,023]
French Polynesia	54.32 [52.85–56.52]	2173 [2114-2261]	900,000 (+1.24%)	0.24%	422,528 [422,784-452,144]
All terr.		4,690,455 [2,557,731-6,174,074]	15,680,000 (−1.25%)	29.91%	938,091,011 [511,546,163-1,234,814,829]
All terr. max		428,013 ± 57,648	15,680,000 (−1.25%)	2.73%	1190,322,795 [650,857,527-1,567,109,345]

Mangroves sequestration rate in French overseas territories reaches on average 41.14 tCO2 eq ha−1 yr−1 from the NPP MODIS product.

The service of carbon sequestration reaches an annual estimated value of 938 ± 427 million euros.
The value would be around 1190 ± 539 million euros if we considered the mangroves were not vulnerable to anthropogenic pressure and climate change



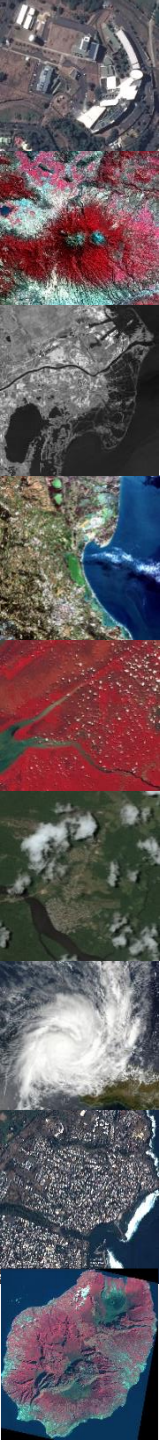
Ecosystem vulnerability and production function weighting

Water purification

Water purification annual monetary value in the mangroves of the French overseas territories (€/year).

French overseas territory	Denitrification (kgN year^{-1})	Denitrification carrying capacity/population	Cost of removing 1 kgN (€)	Annual monetary value (€ year^{-1})
French Guiana	4,928,237 [1,401,998–7,307,386]	335%	13.0	64,067,078 [18,225,979–94,996,013]
Martinique	129,178 [36,749–191,539]	6.3%	25.7	3,319,864 [944,444–4,922,557]
Guadeloupe	230,098 [65,459–341,179]	10.8%	20.0	4,601,952 [1,309,176–6,823,584]
Saint-Martin	4943 [1406–7329]	0.1%	20.1	4943 [1406–7329]
Saint-Barthelemy	5363 [1526–7952]	0.5%	20.1	5363 [1526–7952]
Mayotte	50,588 [14,391–75,009]	3.7%	24.0	1,214,102 [345,391–1,800,221]
Scattered Islands	58,114 [16,532–86,169]	22,113.4%	20.1	1,168,094 [332,303–1,732,002]
New Caledonia	2,614,454 [743,767–3,876,605]	175.9%	13.1	34,249,353 [9,743,350–50,783,523]
Wallis and Futuna	3035 [863–4500]	4.8%	19.9	60,388 [17,179–89,540]
French Polynesia	4640 [1320–6880]	0.3%	13.2	61,248 [17,424–90,816]
All territories	8,018,855 [2,281,226–11,890,027]	77,7%		108,752,385 [30,938,179–161,253,537]
All territories max	10,181,648 [2,896,503–15,096,927]	98.6%		139,452,931 [39,671,955–206,775,036]

Annual value of the service of water purification to be on average 109 million euros, which is 31 million less than if mangroves were not considered vulnerable.



Ecosystem vulnerability and production function weighting

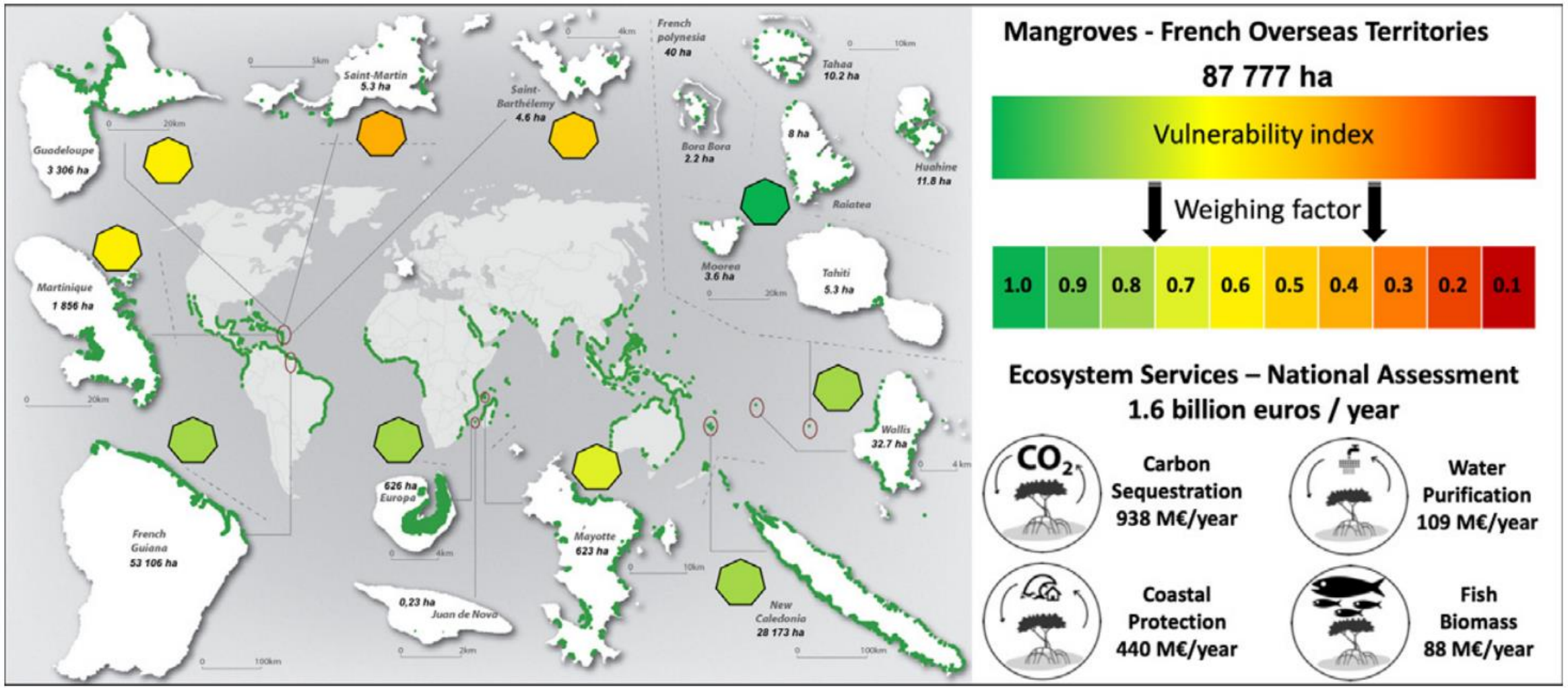
Fish biomass production

Fish biomass production annual monetary value of mangroves in the French overseas territories (€ year^{-1}).

French overseas territory	Fish biomass production kg yr^{-1} (mean ± s.e)	Annual monetary value (€ year^{-1}) expressed as mean [min–max]
French Guiana	6,344,270 ± 895,967	54,009,908 [29,416,585-84,183,240]
Martinique	166,294 ± 23,485	1,415,693 [771,060-2,206,588]
Guadeloupe	296,212 ± 41,832	2,521,703 [1,373,450-3,930,485]
Saint-Martin	317 ± 45	2695 [1468-4201]
Saint-Barthelemy	343 ± 49	2924 [1593–4557]
Mayotte	65,123 ± 9197	554,403 [301,957-864,128]
Scattered Islands	74,812 ± 10,565	636,889 [346,883-992,695]
New Caledonia	3,365,667 ± 475,315	28,652,528 [15,605,646-44,659,632]
Wallis and Futuna	3906 ± 552	33,257 [18,113-51,836]
French Polynesia	5973 ± 844	50,851 [27,696-79,260]
All territories	10,322,917 ± 1457,850	87,880,851 [47,864,450-136,976,623]
All terr. max	13,107,146 ± 1,851,051	111,583,496 [60,774,134-173,921,055]

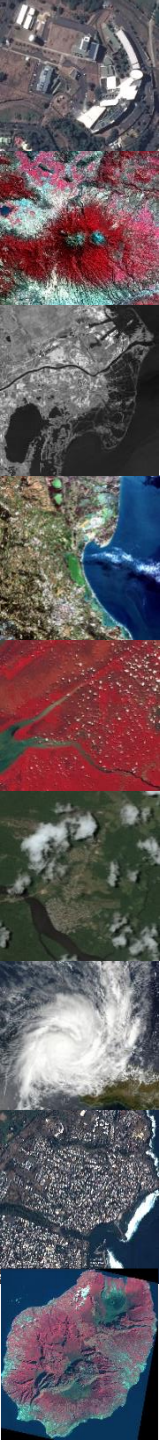
French mangroves produce annually 10,323 ± 1457 tons of fish, that correspond to a monetary value of 89 million euros on average, that is 79% of the maximal monetary value if mangroves were considered in excellent condition.

Overall mangroves services to mitigate coastal change



We estimated mangroves' services to mitigate coastal change at € 1.6 billion per year.

Ecosystem services provisioning is the lowest in the French West Indies due to higher vulnerability.



Conclusions

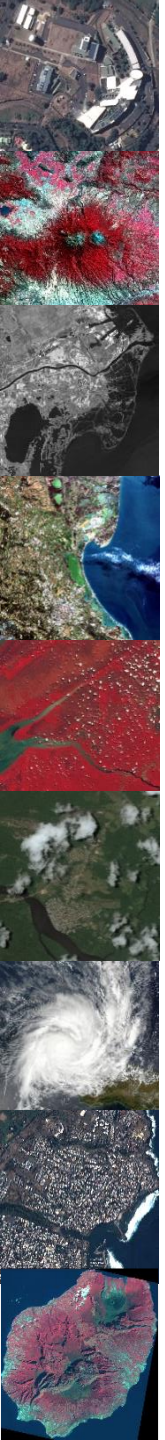
Mangroves provide essential ecosystem services in French overseas territories, and contribute to the good functioning of coral reefs and seagrass beds.

Money-wise, the service of carbon sequestration has the highest value and directly mitigates climate change through its feedbacks on atmospheric carbon concentration.

The vulnerability index used here is a first step in adjusting mangroves production functions in French overseas territories, and lots of other parameters could be included

Assessment of mangroves' ecosystem services at the French national scale, with conclusions that can be directly useful to managers and decision-makers.

This study isn't a global framework for monetary valuation of mangroves in France but is rather a starting point for more detailed, territory-specific valuation.



Thank you for your attention

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