

Mangroves and their services are at risk from climate-modified tropical cyclones and sea level rise

Sarah Hülsen^{1,2}, Laura Dee³, Simona Meiler^{1,4}, Chahan M. Kropf^{1,2}, David N. Bresch^{1,2} ¹Institute for Environmental Decisions, ETH Zürich; ²Federal Office of Meteorology and Evolutionary Biology, University of Colorado Boulder, ⁴Department of Civil and Environmental Engineering, Stanford University

. Introduction

Mangrove ecosystems provide vital contributions to human wellbeing, which are increasingly threatened by climate change. However, these ecosystems are subject to both **slow-onset climate-related** changes, such as sea-level rise, and changes in the intensity and frequency of extreme events, such as tropical cyclones.

Changes in the disturbance regimes ecosystems are adapted to can have far reaching implications for ecological functions and services.

Thus, a **risk assessment** that accounts for changes in ecosystem disturbance through tropical cyclones and simultaneous sea-level rise for both mangroves and their services is urgently needed.

2. Methods



References

- 1. K. Emanuel. (2021). "Response of Tropical Cyclone Activity to Increasing CO₂: Results from Downscaling CMIP6 Models". Journal of Climate 34(1): 57-70.
- 2. G. Aznar-Siguan, D.N. Bresch. (2019). "CLIMADA v1: a global weather and climate risk assessment platform". Geosci Model Dev 12: 3085-3097.
- 3. Garner, G. G., Hermans, T., Kopp, R. E., Slangen, A. B. A., Edwards, T. L., Levermann, A., Nowicki, S., Palmer, M. D., Smith, C., Fox-Kemper, B., Hewitt, H. T., Xiao, C., Aðalgeirsdóttir, G., Drijfhout, S. S., Golledge, N. R., Hemer, M., Krinner, G., Mix, A., Notz, D., ... Pearson, B. (2021). IPCC AR6 Sea Level Projections (Version 20210809)







Fig 3. Risk hotspots and affected ecosystem services under SSP370 by 2100.

 Table 1. Percentages of current global mangrove extents at risk for SSP245, 370, 585 by 2100

Mangrove area [%] at risk of tropical cyclone disturbance regime shift globally

			L (4)	Madium (0)		Maraakirah (4)	0
		None (0)	Low (1)	Medium (2)	High (3)	Very high (4)	Severe (5)
SSP245	Total	50.51	<0.01	9.24	24.35	14.62	1.27
	Top 25%	31.93	0.02	25.35	26.96	15.53	0.22
	Top 10%	29.07	0.02	11.40	34.69	24.00	0.82
SSP370	Total	52.70	0	1.30	9.60	23.51	12.88
	Top 25%	37.83		0.93	17.09	29.03	15.12
	Top 10%	30.20		0.02	11.36	33.44	24.98
SSP585	Total	44.44	0	<0.01	9.58	26.48	19.50
	Top 25%	28.57		0.02	20.25	28.45	22.72
	Top 10%	26.27		0.02	3.17	36.19	34.35

In each cell the top number refers to the percentage of global mangrove extents, while the middle and bottom numbers refer to the proportion for the subsets of the top 25% and 10% ranked mangrove conservation priority areas, which are optimized based on mangrove species biodiversity, coastal protection for properties and people, carbon sequestration, and fishery benefits.

- coastal habitat is likely at warming levels above 1.5 °C. Nature, 621(7977).
- areas to protect mangroves and maximise ecosystem services. Nature Communications 14(1).



4. Discussion

Global mangrove area at risk

- be at high to severe risk by 2100
- in Southeast Asia, it will be **52-78%**

affected

benefits

Non-analog tropical cyclone disturbance regimes are projected to emerge even for the lowest emission pathways

across the globe

Changes in disturbance to affect ecosystem function and services

- on these services

Management implications

5. Outlook

We are currently using remote sensing data of cyclone induced degradation of mangroves to establish linkages between hazard intensity and frequency, and ecosystem recovery and resistance.

Moving forward, we aim to model **mangrove ecological responses to** potential future tropical cyclone disturbance regimes.

4. Saintilan, N., Horton, B., Törnqvist, T. E., Ashe, E. L., Khan, N. S., Schuerch, M., Perry, C., Kopp, R. E., Garner, G. G., Murray, N., Rogers, K., Albert, S., Kelleway, J., Shaw, T. A., Woodroffe, C. D., Lovelock, C. E., Goddard, M. M., Hutley, L. B., Kovalenko, K., ... Guntenspergen, G. (2023). Widespread retreat of

5. P. Bunting, A. Rosenqvist, R.M. Lucas, L.-M. Rebelo, Lammert Hilarides, N. Thomas, A.Hardy, T. Itoh, M.Shimada, C.M. Finlayson. (2018). "The Global Mangrove Watch – A new 2010 Global Baseline of Mangrove Extent". *Remote Sens* 10(1669): 1-19.

6. Dabalà, A., Dahdouh-Guebas, F., Dunn, D. C., Everett, J. D., Lovelock, C. E., Hanson, J. O., Buenafe, K. C. V., Neubert, S., & Richardson, A. J. (2023). Priority



Read the publication here





depending on the SSP, **40-56%** of the total global mangrove area will

Areas with high ecosystem service provision are disproportionally

under SSP585 almost **20%** of all mangroves will be at severe risk, but it is **34%** for the highest-rankingg mangroves in terms of biodiversity, coastal protection, carbon sequestration, and fishing

 by 2100 mangrove areas in the Philippines will experiences tropical cyclone winds at frequencies which are currently unprecedented

the widespread changes in disturbance regimes may substantially affect ecosystem structure, function, and recovery pathways

potential ecological shifts may further impact the provision of the vital regulating and provisioning ecosystem services provided by mangroves, with negative implications for the populations depending

risk index helps identify priority areas for monitoring of recovery pathways and can support restoration planning