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The land use-climate change-biodiversity nexus in European island stakeholders

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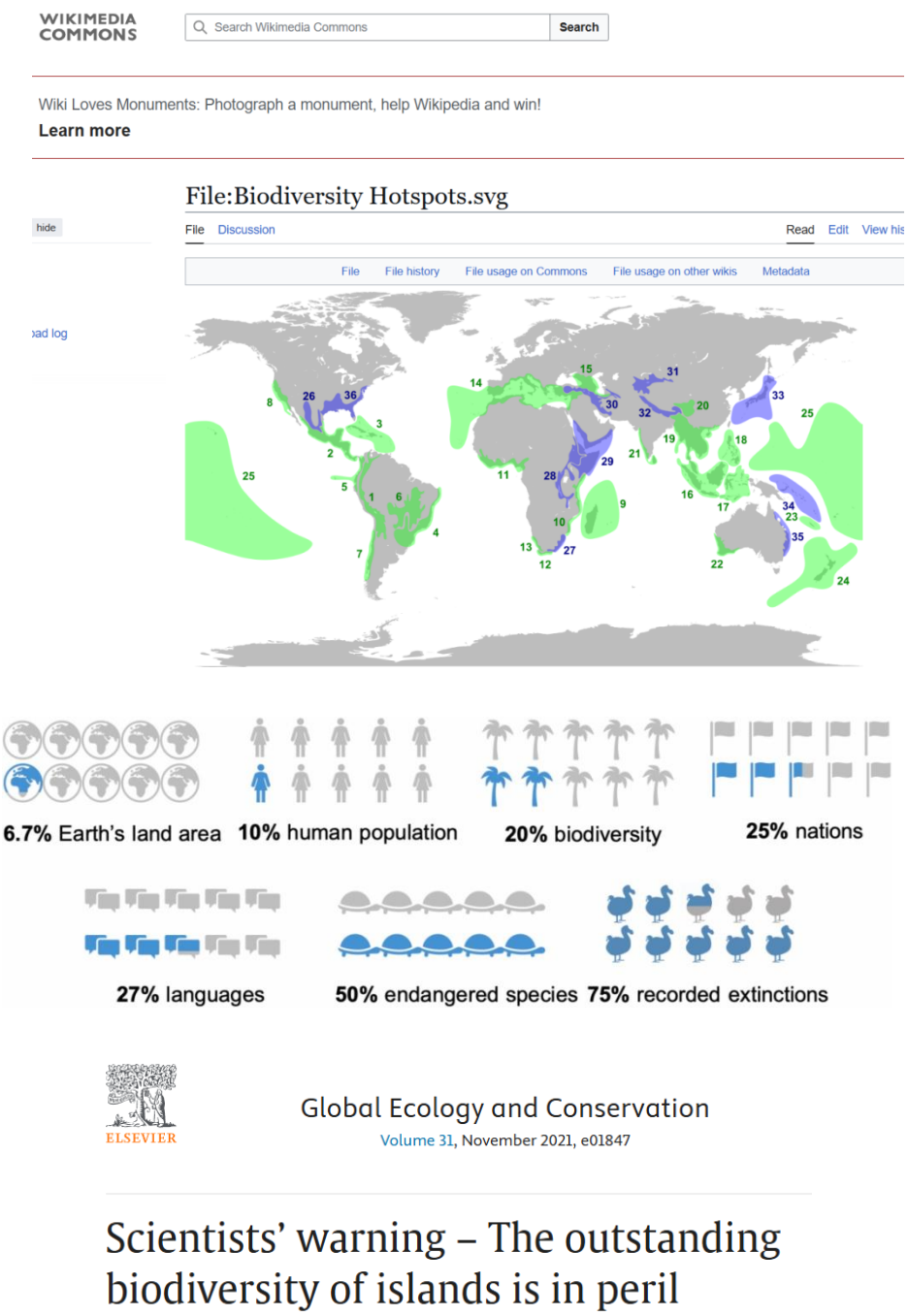
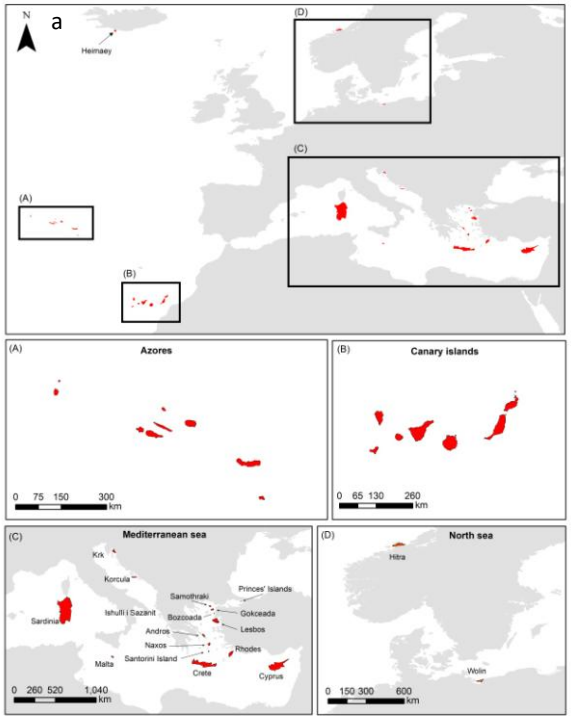
Overview

- **Global change challenges:** Climate change + land-use change → biodiversity loss & reduced ecosystem services.
- **Islands' importance:**
- Cover a small % of Earth's surface.
- Host >⅓ of global biodiversity.
- Provide critical ecosystem services (water, food, regulation, culture).
- **High vulnerability:**
- Climate impacts (temperature, precipitation, extremes).
- Land-use pressures (tourism, urbanization, renewable energy development).



The Land Use – Climate – Biodiversity Nexus

- **Knowledge gap:** Limited understanding of how climate & land-use changes interact on islands.
- **Our study:**
- 21+ European islands/archipelagos.
- Stakeholder-based questionnaire.
- Machine learning to analyze drivers of perception.
- **Research questions:**
- Key climatic & land-use change indicators?
- Impacts on ecosystem services & biodiversity?
- **Combined** relative importance of environmental, social & economic stressors?



b Island	Country	Size (km²)	Stake holders
Sazan	Albania	5.70	30
Krk	Croatia	405.80	30
Korcula	Croatia	279.00	30
Cyprus	Cyprus	9,250.00	60
Crete	Greece	8,336.00	30
Andros	Greece	379.20	30
Santorini	Greece	76.19	30
Rhodes	Greece	1,400.68	30
Naxos	Greece	429.79	69
Samothraki	Greece	180.36	10
Lesvos	Greece	1,633.00	30
Heimaey	Iceland	13.40	10
Sardinia	Italy	24,090.00	91
Malta	Malta	316.00	34
Hitra	Norway	571.50	30
Wolin	Poland	265.00	31
Azores	Portugal	759.00	31
Canary Islands	Spain	7,493.00	41
Princes' Island	Turkey	10.60	30
Gokceada	Turkey	286.00	30
Bozcaada	Turkey	37.60	30

Study Design & Stakeholders

- **737 stakeholders** from **21 islands/archipelagos** across **12 European countries** (Feb–Apr 2024).
- **Stakeholders:**
- Permanent island inhabitants OR
- Individuals with main financial activity on island.
- Sampling approach: opportunistic: academic researcher on-site or online (Google forms) acted as mediator.
- **Diverse professions covered**:
- Public authority & policymakers
- Primary sector (agriculture, fisheries, forestry)
- Technicians & associated professionals
- Food industry
- Financial sector
- Academics/researchers
- Tourism professionals
- Other (students, unemployed, housework, etc.)

- **Questionnaire format:** close-ended, binary (YES/NO) + Likert-type (0–4).
- **Languages:** 12 (including English, Spanish, Italian, Greek, etc.).
- **Distribution methods:**
- Online forms (42%)
- Face-to-face interviews (58%)
- Ecosystem services defined for clarity (with examples: food, water, climate regulation, recreation).

Survey Methodology

- **Question types:**
- Climate change perceptions (temperature, precipitation, storms, sea level rise, etc.)
- Land-use change perceptions (deforestation, coastal degradation, urban expansion, renewables, etc.)
- Problems (tourism, water issues, invasive species, ecosystem destruction, etc.)
- Holistic societal & economic problems (pollution, financial, policy, population growth, etc.)
- Overall climate change impact on ecosystem services
- Overall climate change impact on ecosystem services

Table 1. Variables recorded and their feasible answers or scores

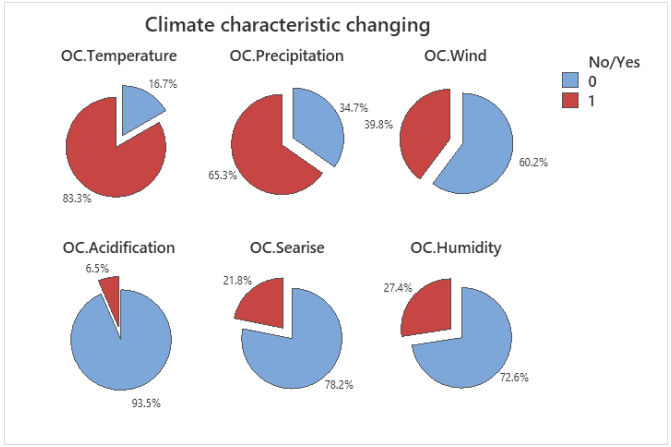
Category	Var Nr	Var Name	Value				
(i) Climate change variables							
Question (i) What are the climate characteristics changing in your island?	1	Temperature	Yes/No				
	2	Precipitation	Yes/No				
	3	Wind increase/storms	Yes/No				
	4	Ocean acidification	Yes/No				
	5	Sea level rise	Yes/No				
	6	Humidity increase	Yes/No				
(ii) Land use / land cover change variables							
Question (ii) What are the observable land use / land cover changes in your island?	7	Deforestation	Yes/No				
	8	Reforestation	Yes/No				
	9	Rewilding	Yes/No				
	10	Wetland modification	Yes/No				
	11	Coastal degradation	Yes/No				
	12	Habitat protection	Yes/No				
	13	Renewable energy facility issues	Yes/No				
	14	Mining related issues	Yes/No				
	15	Urban expansion related issues	Yes/No				
(iii)Ranking overall problems	Values ranking the observed effects of problems on the island context, from 0 for Don't Know, 1 for having a small effect, 2 having a moderate effect, 3 having an important, to 4 having a very big/significant effect						
(iii) Rank the effects of these problems on your island	16	Climate change	0	1	2	3	4
	17	Land use change	0	1	2	3	4
	18	Population growth	0	1	2	3	4
	19	Economic growth	0	1	2	3	4
	20	Pollution	0	1	2	3	4
	21	Resource extraction	0	1	2	3	4
	22	Policy changes	0	1	2	3	4
	23	Nature overexploitation	0	1	2	3	4
	24	Austerity	0	1	2	3	4
(iv) Climate change & land use change problems.	Values ranking the perceived presence of each problem induced by climate change, from 0 for Don't Know, 1: Not so much, 2: Relative change yes 3: Yes, observable change to 4: Yes, very much climate -induced change.						
Question (iv) How would you assess the main climate and land use change induced problems in your island? (0-4)	25	Tourism	0	1	2	3	4
	26	Damages in habitats, protected areas or monuments etc	0	1	2	3	4
	27	Primary sector (Agriculture, fisheries etc)	0	1	2	3	4
	28	Ecosystem Destruction/Biodiversity loss	0	1	2	3	4
	29	Changes in urban environment	0	1	2	3	4
	30	New diseases	0	1	2	3	4
	31	Invasive species	0	1	2	3	4
	32	Carbon sequestration	0	1	2	3	4
	33	Pollination	0	1	2	3	4
	34	Energy related issues	0	1	2	3	4
	35	Soil erosion	0	1	2	3	4
	36	Water related issues	0	1	2	3	4
	37	Ecosystem recreation	0	1	2	3	4
	38	Infrastructure damages	0	1	2	3	4
Climate change impact on the benefits of biodiversity.	39	Climate change impact on ecosystem services	Negative	Unclear	Neutral	Positive	
Land use change impact on the benefits of biodiversity	40	Land use change impact on ecosystem services	Negative	Unclear	Neutral	Positive	

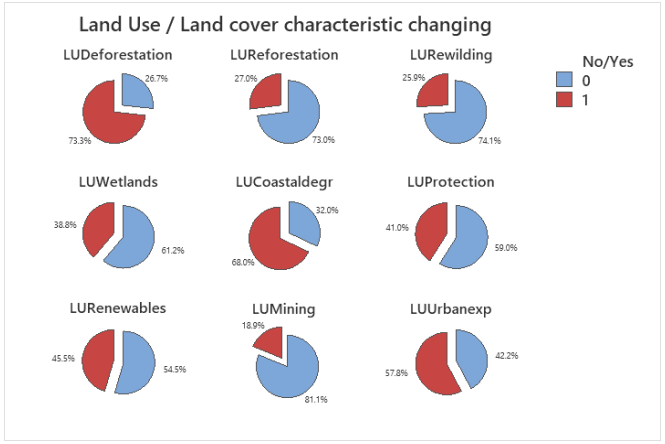
Analysis Approach

- **Goal:** Identify drivers of perception regarding biodiversity & ecosystem service impacts.
- **Dependent variables:**
- Perceived *climate change* impacts on ecosystem services (scores: negative, unclear, neutral, or positive).
- Perceived *land-use change* impacts on ecosystem services.
- **Explanatory variables (38):**
- Climate change characteristics (binary)
- Land-use characteristics (binary)
- Climate/land-use related problems (ranked)
- Overall problems (ranked)
- **Method:** Random Forest classifiers (Machine learning).
- Handles complex, high-dimensional, noisy data.
- 70/30 train-test split (validated with sensitivity analysis).
- Variable importance chart → identifies most influential predictors.

Climate & Land Use Change Characteristics: perceptions of change

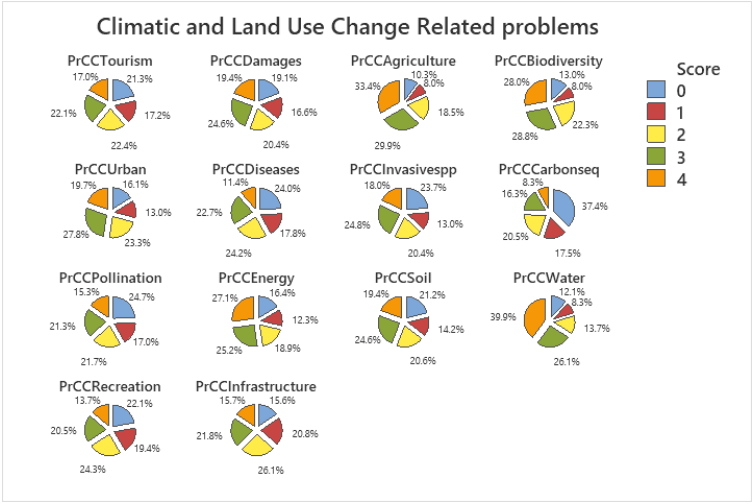
- **Climate change:**
- Most reported: **Temperature**, then precipitation, wind, humidity.
- Least reported: **Sea level rise** & **acidification**.
- **Land use change:**
- Most reported: **Deforestation**, coastal degradation, urban expansion.
- Renewable energy facilities = 4th.
- Habitat protection = insufficient.
- Rewilding/reforestation also raised concerns.

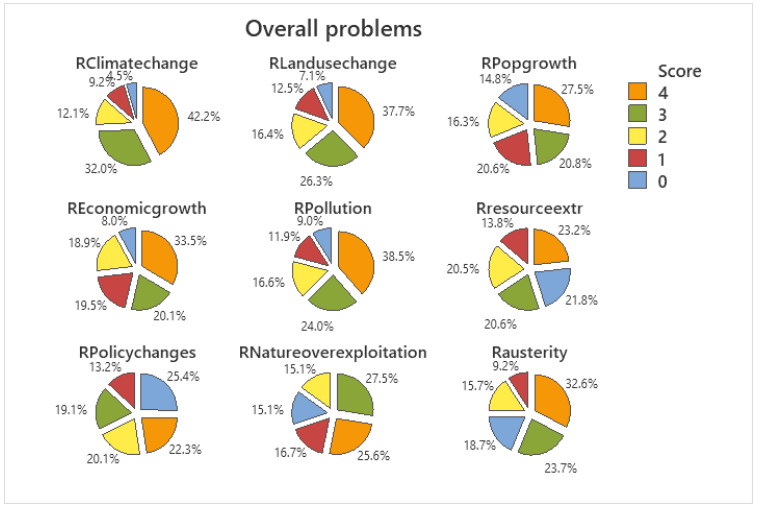




Problem Severity Rankings: Perceived Problems on Islands

- **Most severe problems:**
- Water-related issues
- Primary production sector (agriculture, food)
- Biodiversity loss
- Renewable energy facilities
- **Moderate:** Urban expansion, habitat destruction, soil erosion.
- **Lower:** Carbon sequestration, diseases, pollination, recreation.
- **Overall problems:**
- Highest = Climate change
- Then = Land-use change + Pollution.
- Economic growth & austerity = moderate.
- Lowest = Policy changes.





Climate Change Impacts on Ecosystem Services (ML Results)

What Drives Perceptions of Climate Change Impacts?

- **(a) Negative impacts (62.8% of stakeholders):**

-Driven by **habitat destruction, biodiversity loss, invasive species, water issues, overexploitation**.

-Accuracy: ~67%.

- **(b) Unclear impacts (19.4%):**

-Linked to **biodiversity loss, water issues, carbon sequestration, recreation, invasive species**.

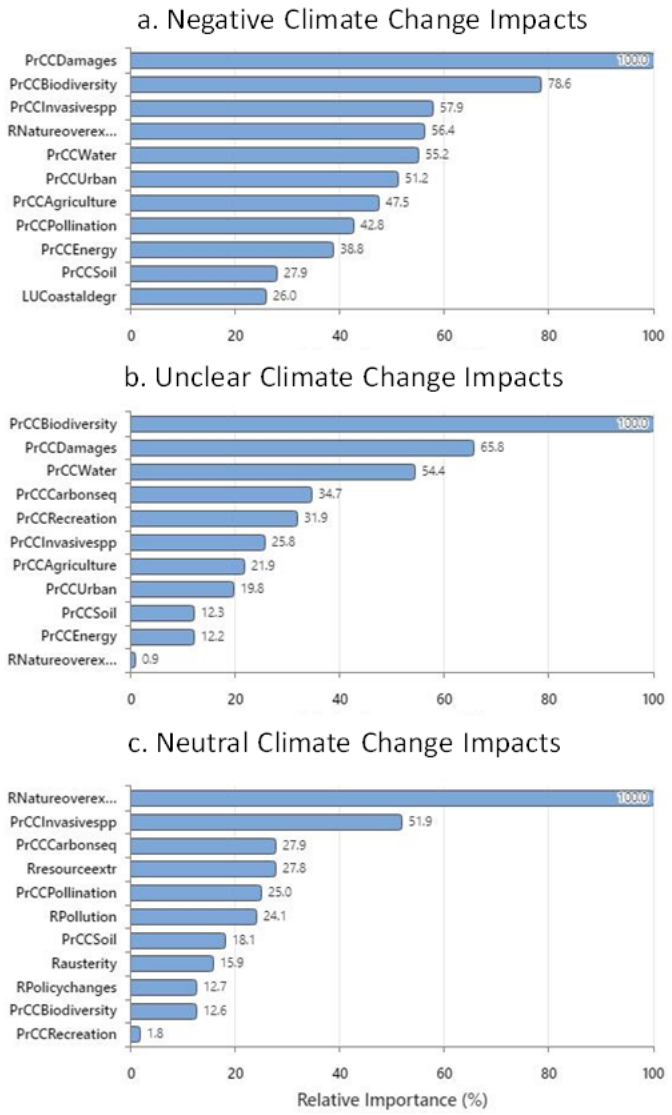
-Accuracy: ~62%.

- **(c) Neutral impacts (14.4%):**

-Connected to **overexploitation, invasive species, carbon sequestration, pollution, policy changes**.

-Accuracy: ~59%.

- **Positive impacts (3.4%):** Insufficient data.



Land Use Change Impacts on Ecosystem Services (ML Results)

Title: *What Drives Perceptions of Land Use Change Impacts?*

- **(a) Negative impacts (54.4% of stakeholders):**

-Driven by **coastal degradation, biodiversity loss, pollution, infrastructure damage, invasive species**.

-Accuracy: ~63%.

- **(b) Unclear impacts (21.4%):**

-Linked to **rewilding, urban expansion, austerity, recreation, policy changes, wetlands**.

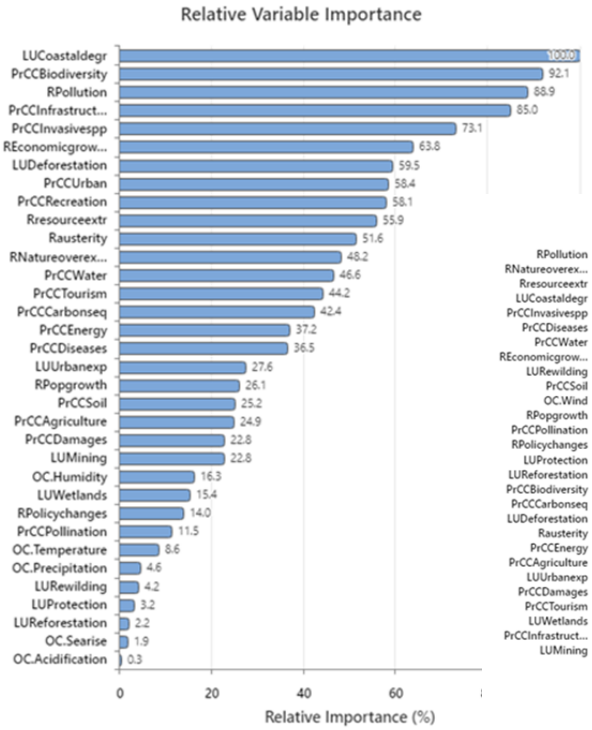
-Accuracy: ~69%.

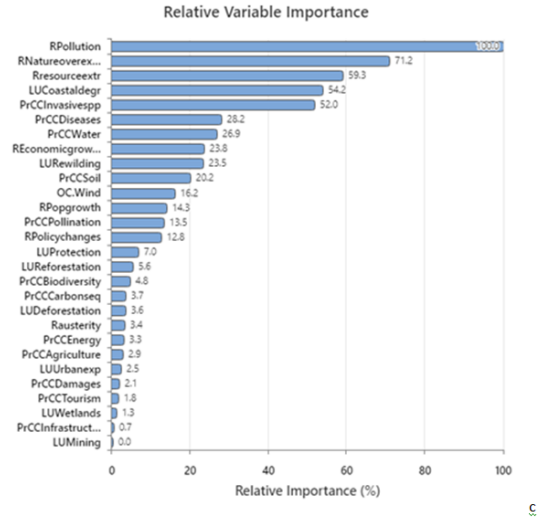
- **(c) Neutral impacts (21.4%):**

-Associated with **pollution, overexploitation, resource extraction, coastal degradation, invasive species, disease**.

-Accuracy: ~72%.

- **Positive impacts (2.7%):** Too few responses to model.





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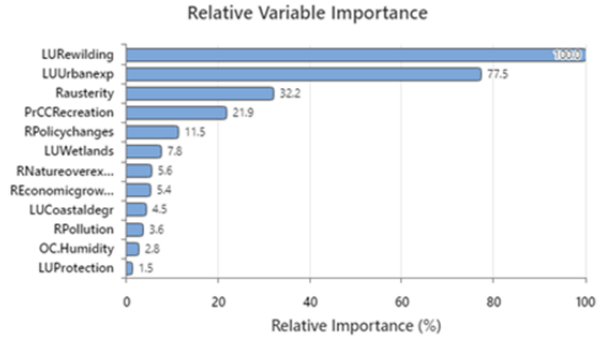

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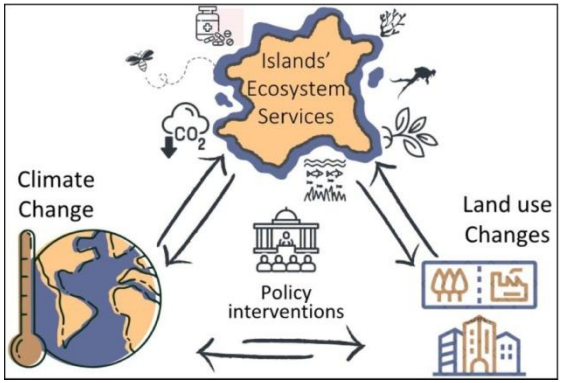
Key Findings & Stakeholder Perceptions: *Take-Home Messages from Stakeholders*

- **Climate change concerns:** Temperature > Precipitation > Sea level rise/acidification.
- **Land use concerns:** Deforestation > Coastal degradation > Urban expansion.
- **Top priority problems:** Water scarcity/management, energy concerns (supply & renewables), biodiversity loss.
- **Perceived impacts:**
- Climate change → mostly negative impacts on ecosystem services (biodiversity loss & habitat destruction).
- Land use change → also negative but influenced by more diverse factors.
- **Consistency across islands:** *Stakeholders can differentiate climate vs land-use impacts*, suggesting targeted & integrated management is needed.



Climate & Land Use Drivers: *Drivers of Negative Impacts*

- **Climate:** Temperature changes, habitat destruction, biodiversity loss, water issues.
- **Land use:** Coastal degradation, biodiversity loss, pollution, infrastructure damage, renewable energy facilities.
- **Water issues:** Highly perceived by stakeholders but not top predictor in ML analysis → may reflect management issues more than climate-driven changes.
- **Temperature:** Strongly perceived as the main climate driver, aligning with other European and global studies.

Reuters

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By Angeliki Koutantou and Stelios Misinas

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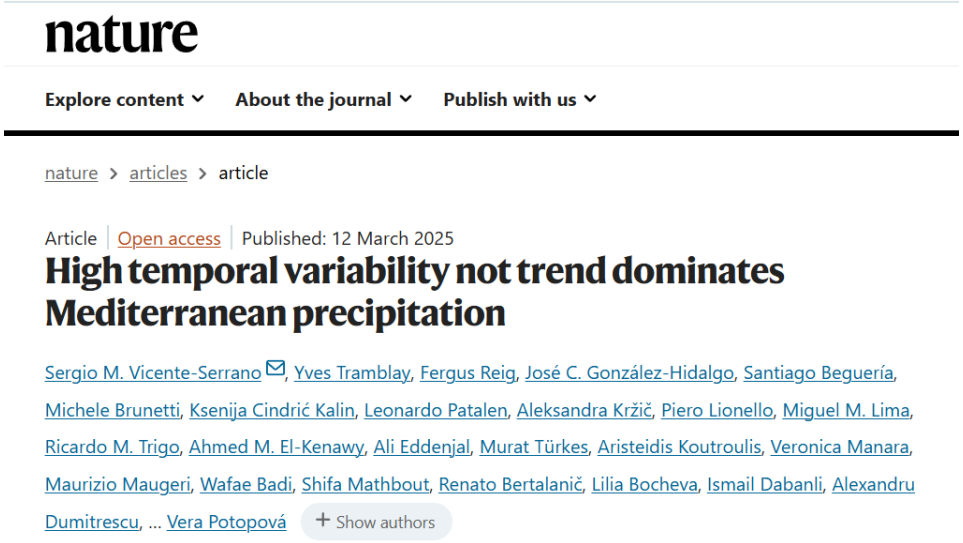

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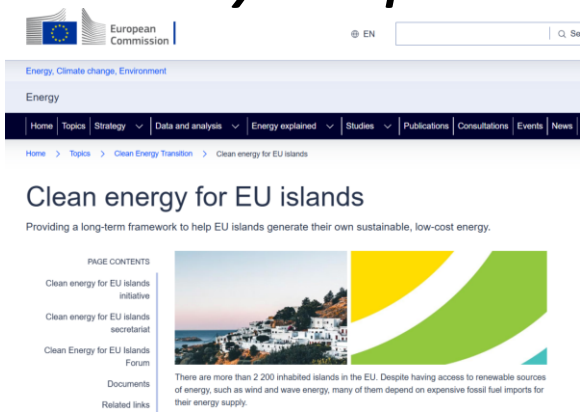
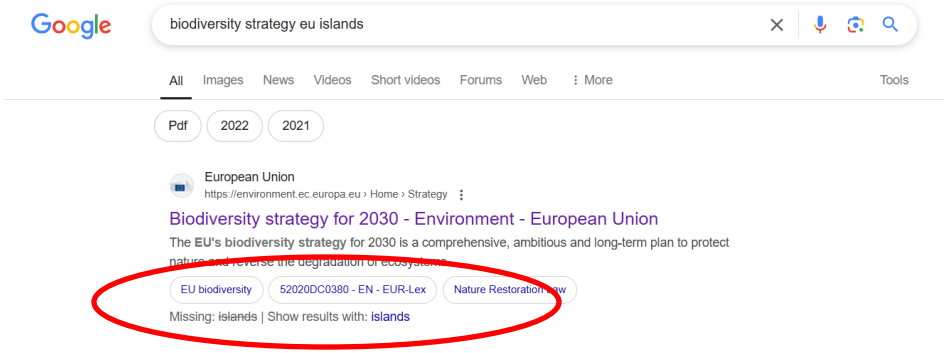
Energy & Policy Implications: *Energy, Renewable Infrastructure & Policy Gaps*

- **Energy concerns:**
- Wind & solar facilities → land take, habitat fragmentation, biodiversity loss.
- Renewable initiatives (e.g., EU "Renewable Islands 2030") often lack local consultation.
- **Policy perception:**
- Not ranked highly by stakeholders → may reflect low awareness or perceived ineffectiveness.
- **Management need:** Integrated solutions combining **biodiversity conservation, energy planning, and stakeholder engagement**.

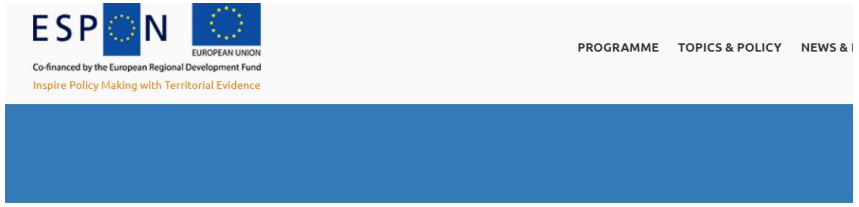


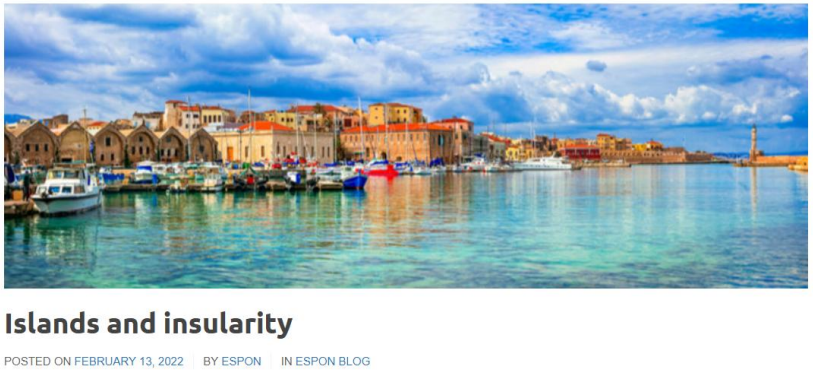


Limitations & Future Directions: *Looking Ahead*

- **Factors affecting perceptions:**
- Island size, location, ecosystem type (marine vs terrestrial), stakeholder profession & socioeconomic status.
- **Future research:**
- Map perceptions geographically to understand variation.
- Explore policy efficacy & communication gaps.
- **Are climate change perceptions predictable?**

- **Conclusion:**
- Climate and land use change negatively affect ecosystem services; water, energy, and biodiversity are key concerns.
- Stakeholder perceptions should guide **island-specific European policies** for effective management.





WG3: Climatic changes, land use changes, and ecosystem services

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Climate land use and other drivers' impacts on island ecosystem services: A global review

Aristides Moustakas [a], Shiri Zemah-Shamir [b], Mirela Tase [c], Savvas Zotos [d], Nazli Demirel [e], Christos Zoumides [f], Irene Christoforidi [g], Turgay Dindaroglu [h], Tamer Albayrak [i j], Cigdem Kaptan Ayhan [k], Mauro Fois [l], Paraskevi Manolaki [d], Attila D. Sandor [m n], Ina Sieber [o], Valentini Stamatiadou [p], Elli Tzirkalli [d], Ioannis N. Vogiatzakis [d q], Ziv Zemah-Shamir [r], George Zittis [s]

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