

Assessing Climate Change in Protected Areas Through Multi-, Inter-, and Transdisciplinary Approaches

Abstract

Protected areas (PAs) are crucial for climate change mitigation and adaptation, but face increasing climate-induced ecological and socio-economic pressures. Tourism, particularly nature-based tourism, plays a central role in shaping pressures, revenues, and local livelihoods in PAs, yet remains only marginally integrated into transdisciplinary climate research. Addressing these challenges requires integrating natural and social sciences through multi-, inter-, and transdisciplinary frameworks. This study, developed within the PACT-VIRA project, systematically reviews 136 peer-reviewed studies (2010–2025) to identify patterns, synergies, and gaps in the application of integrative approaches to PA climate change research. Findings reveal a shift from multi- to inter- and transdisciplinary research; however, tourism remains underrepresented, especially in co-produced, stakeholder-driven frameworks. The proposed framework emphasises methodological integration, stakeholder and tourism engagement, and advancing transdisciplinary collaboration to develop actionable, context-sensitive adaptation strategies that strengthen ecosystem resilience and sustainable PA management under changing climates.

Keywords: protected areas, climate change, transdisciplinary research, interdisciplinary research, tourism integration

1. Introduction

Protected areas (PAs) support climate mitigation and ecosystem resilience (Melillo et al., 2016; Xu et al., 2017; Duncanson et al., 2023) but face growing risks from climate pressures, including temperature increases, altered precipitation, and extreme events (Bruno et al., 2018; Marcos et al., 2021; Agulles et al., 2022). These challenges complicate the balance between conservation, tourism, and community benefits (Belsoy et al., 2012), highlighting the need for integrative approaches. Despite its significance, tourism, including nature-based tourism (NBT), remains insufficiently incorporated into interdisciplinary and transdisciplinary climate assessments, even though it constitutes a key socio-economic driver, a source of ecological pressure, and an important contributor to community resilience (Lindberg et al., 2021).

A transdisciplinary framework, integrating climate science, ecology, hydrology, conservation biology, tourism studies, and socio-economic analysis, among others, is necessary to capture the full spectrum of climate impacts and identify actionable adaptation strategies (Michailidou et al., 2016; Arabadzhyan et al., 2021). Interdisciplinary integration translates climate projections into operational management tools that inform decision-making in real-world contexts (Rannow et al., 2014; Njoroge, 2015). The limited integration of tourism perspectives restricts the ability of climate research to fully capture human-environment interactions and to develop adaptation strategies that reflect real management challenges in PAs (Lehikoinen et al., 2021).

Thus, this short communication presents a preliminary framework developed within the PACT-VIRA project (Marković Vukadin et al., 2025), with the main aim of identifying patterns, methodological synergies, and

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gaps in the use of multi-, inter-, and transdisciplinary approaches for assessing climate change impacts in PAs, with a focus on the underrepresentation of tourism dimensions by using systematic review. To provide a clearer analytical structure and to address the gaps identified in previous studies, this short communication is guided by the following research questions:

RQ1: To what extent do existing studies on climate change in protected areas apply multi-, inter-, and transdisciplinary approaches?

RQ2: How, and to what degree, is tourism—especially nature-based tourism—integrated within these approaches?

RQ3: What key components should a preliminary transdisciplinary framework include to enhance climate change assessment and adaptive management in protected areas?

2. Rationale for a multi-, inter-, and transdisciplinary approaches

PAs support biodiversity and key ecosystem functions yet face growing climate-related ecological and socio-economic pressures (Bruno et al., 2018). Responding to these challenges requires distinguishing multi-, inter-, and transdisciplinary approaches (Alvargonzález, 2011; Zabaniotou et al., 2020) (Tab. 1).

Table 1
Defining multi-, inter-, and transdisciplinarity

Dimension	Multidisciplinary	Interdisciplinary	Transdisciplinary
Definition	Collaboration between disciplines addressing a common topic; each remains within disciplinary boundaries	Integration of concepts, methods, and theories across disciplines to develop a unified understanding	Co-creation of knowledge beyond academia, involving researchers and non-academic stakeholders
Knowledge integration	Low	Moderate to high	Very high
Research focus	Parallel contributions	Holistic system understanding	Transformative problem-solving
Participants	Academics	Academics across disciplines	Academics, policymakers, communities, practitioners
Outcome	Broader perspective, fragmented understanding	Coherent framework	Practical solutions, social innovation, mutual learning

Source: authors adapted from: Stock & Burton, 2011; Zabaniotou et al., 2020.

Traditional ecological or climate-focused approaches alone cannot fully capture human-environment interactions in PAs. Integrating natural sciences with social sciences (tourism, governance, economics) enables a holistic assessment of vulnerability and resilience (Rannow et al., 2014; Intergovernmental Panel on Climate Change [IPCC], 2019). Socio-economic integration and stakeholder participation further strengthen the legitimacy and adaptive capacity, particularly in NBT contexts (Scott et al., 2012).

Transdisciplinary approaches address key challenges in PA climate change research, including the need to integrate diverse datasets (e.g., climate projections, ecological trends, tourism metrics) (Yasmeen et al., 2024), combine quantitative and qualitative methods to capture both biophysical and social dimensions of change (Scott et al., 2012), and develop adaptation strategies that are scalable and tailored to local ecological and community contexts (Sun et al., 2024; Volgger & Pechlaner, 2014).

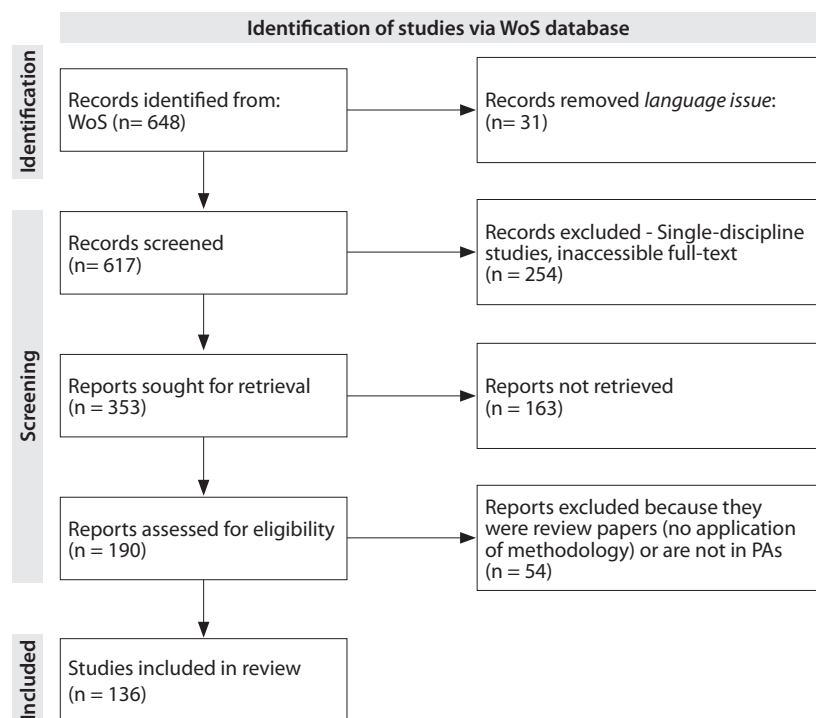
3. Methodology

A systematic literature review guided by PRISMA was conducted to assess the integration of multi-, inter-, and transdisciplinary approaches in climate change research on PAs. The Web of Science database was searched for English-language, peer-reviewed articles (2010–2025) using: ("climate change" OR "climate

variability" OR "climate vulnerability" OR "climate resilience") AND ("protected area*" OR "national park*" OR "marine reserve*" OR "nature-based tourism" OR "eco-tourism") AND ("multidisciplin*" OR "interdisciplin*" OR "transdisciplin*" OR "integrated approach*" OR "co-production" OR "participatory research").

A comprehensive literature search was undertaken to identify studies addressing the impacts of climate change on PAs, with a focus on integrative and cross-disciplinary approaches. Studies limited to a single disciplinary perspective were excluded to ensure the inclusion of research that incorporated ecological, social, and policy dimensions. The preliminary search yielded 648 records, and 31 non-scientific or non-English entries were removed (Fig. 1). 617 titles were screened, retaining only studies addressing at least two core themes: climate change, conservation, PAs, NBT, management, or resilience, which resulted in 264 exclusions. The remaining 363 abstracts were assessed, and 163 studies were excluded for being single-disciplined or lacking accessible full texts. 190 articles proceeded to full-text review, during which 54 studies were removed, primarily because they were review papers rather than original research. In total, 136 studies were included in the final synthesis. Abstracts and full papers, with a focus on methods sections, were then independently assessed by all authors. To characterize how studies integrated multiple disciplines, each article was categorized as multi-, inter-, or transdisciplinary based on explicit criteria (Fig. 1). Multidisciplinary studies involved parallel disciplinary contributions that retained separate concepts and methods, whereas interdisciplinary studies integrated theories, concepts, data, or methods from two or more disciplines into a shared analytical or methodological framework. Transdisciplinary studies went beyond academic collaboration by actively involving non-academic stakeholders (e.g., PA managers, policymakers, local communities) in problem framing, knowledge production, and results interpretation with an emphasis on co-producing actionable solutions. Each study was assigned to the category chosen by the majority of reviewers, and these assignments were used to calculate the final counts for each category.

Figure 1
PRISMA flow chart



The extracted variables included: year, geography, PA type, integrative approach, disciplinary combinations, and methods used, as well as tourism integration in research. Quantitative and qualitative analyses were used to identify trends, gaps, and methodological patterns in integrative research. This review was limited by potential publication bias, language restrictions (English-only sources), and the possibility of omitting relevant grey literature or unpublished studies, which may have constrained the comprehensiveness of the findings.

4. Results and discussion

In response to RQ1, the PRISMA-guided review and expert evaluation of 136 peer-reviewed papers reveal a growing shift from multidisciplinary toward inter- and transdisciplinary approaches in PA climate change research. Among these, 21 studies were identified as adopting a multidisciplinary approach, 69 as interdisciplinary, and 37 as transdisciplinary in scope. However, within the subset of papers only 15 approx. 11% explicitly focused on NBT, only 4 demonstrated a predominantly multidisciplinary design, 6 applied an interdisciplinary framework, and 5 employed a transdisciplinary orientation. This distribution indicates that tourism studies remain markedly underrepresented in holistic research efforts addressing the impacts of climate change on PAs. The limited integration of tourism perspectives, particularly in transdisciplinary contexts, suggests that the sector's potential contributions to co-produced climate adaptation knowledge and practice remain insufficiently explored.

The reviewed literature demonstrates a marked evolution from multi- toward inter- and transdisciplinary approaches in socio-ecological and environmental research, reflecting the growing complexity of climate change, biodiversity loss, and human–environment interactions. Across this continuum of integration, disciplines from the natural sciences (ecology, hydrology, climatology, forestry, geomorphology) frequently intersect with those from the social sciences and humanities (sociology, economics, anthropology, governance studies), producing increasingly holistic frameworks for addressing environmental and conservation challenges (Heinrich et al., 2018).

4.1. Integration patterns and methodological synergies

Research on climate change in PAs increasingly relies on multi-, inter-, and transdisciplinary approaches to address the complex interactions between ecological systems, human communities, and governance structures. These approaches vary in depth of integration, ranging from multidisciplinary analyses, where disciplinary contributions are largely parallel, to transdisciplinary studies, which co-produce knowledge with stakeholders and inform context-specific adaptation strategies (Cumming et al., 2023; Rivers et al., 2023).

Natural science disciplines form the foundation for multi- and interdisciplinary studies assessing climate impacts using field observations, remote sensing, GIS, and phenological and dendroecological data (Klosterman et al., 2018; Richardson, 2023). Integrating these methods with climate modelling and hydrological scenarios helps evaluate species distributions, habitat vulnerability, and quantification of climate-driven risks to biodiversity and ecosystem services, forming the basis for informed conservation planning (Symstad et al., 2017; Blondin et al., 2022).

Social science disciplines capture the human dimensions of climate change impacts through surveys, interviews, participatory mapping, and the integration of local and Indigenous knowledge (Cradock-Henry et al., 2021; Gómez-Ruiz et al., 2022). Interdisciplinary studies link these insights with ecological data to understand tourism dynamics, community resilience, and adaptation strategies, with multidisciplinary approaches still dominant in isolated PAs and interdisciplinary frameworks increasingly applied in marine protected areas and rural contexts (Yeboah-Assiamah et al., 2018; Petrisor et al., 2020; Yang et al., 2025).

Transdisciplinary studies extend this integration by engaging stakeholders, policymakers, and local communities in the co-production of knowledge, scenario planning, and governance processes, and are mostly in place

in suburban PAs or those with a high density of tourism and population. Examples include participatory restoration and co-management initiatives in marine and terrestrial PAs (Rivers et al., 2023; Gómez-Ruiz et al., 2022).

Analytical and computational methods, including ecological and climate modelling, GIS, and remote sensing, are central for assessing habitat vulnerability, biodiversity shifts, and integrating socio-economic data to inform adaptive management and climate resilience in PAs (Tab. 2) (Miller et al., 2017; Olivares-Aguilar et al., 2022; López-Juambeltz et al., 2020; Vieira et al., 2021).

Table 2
Overview of main features of multi-, inter- and transdisciplinary studies

Approach	Core disciplines	Methods/ techniques	Climate change integration in PAs	Examples
Multidisciplinary	Natural sciences (Ecology, Forestry, Hydrology, Climatology)	Field surveys, dendroecology, and remote sensing	Identifies biophysical impacts; limited socio-economic or participatory integration	Benito et al., 2022; Vieira et al., 2021
Interdisciplinary	Natural sciences + Social sciences (Anthropology, Economics, Planning)	Field surveys, participatory mapping, GIS, scenario modelling	Links ecosystem vulnerability with community adaptation and tourism impacts	Miller et al., 2017; Yang et al., 2025
Transdisciplinary	Ecology + Social sciences + Stakeholders' involvement	Participatory restoration, co-management, policy engagement	Co-produces actionable climate adaptation strategies; integrates ecological, social, and governance insights	Gómez-Ruiz et al., 2022; Rivers et al., 2023; Yeboah-Assimah et al., 2018

Source: Authors' synthesis based on the reviewed literature.

4.2. Tourism integration within climate and conservation research

Aligned with RQ2, tourism emerges as significantly underrepresented in climate-PA research, despite its central influence on ecological pressures, visitor dynamics, and community livelihoods. Existing studies tend to focus on tourism only indirectly (Rivers et al., 2023), primarily through ecosystem services valuation, visitor pressures, or socio-economic vulnerability, while comprehensive analyses linking tourism dynamics with climate modelling, governance processes, and stakeholder co-production remain extremely rare (Lehikoinen et al., 2021). This underrepresentation is problematic because tourism directly influences ecological stress, financial sustainability, and local community livelihoods, making its omission a significant gap in efforts to develop integrated climate adaptation strategies for PAs.

Tourism research is underrepresented in explicitly transdisciplinary frameworks, though it appears consistently in interdisciplinary contexts, particularly in studies of marine and coastal socio-ecological systems. Tourism commonly intersects with ecology, economics, and social sciences in evaluating ecosystem services, livelihood impacts, and stakeholder perceptions. However, few studies integrate tourism data with ecological modelling or policy co-production processes (Booth et al., 2022; Gatti & Brownlee, 2024; Dube & Nhamo, 2020). This partial integration limits tourism's contribution to broader resilience and adaptation agendas. Strengthening the linkage between tourism geography, climate modelling, and governance studies could help mainstream tourism within socio-ecological resilience frameworks. Doing so would enhance the capacity to assess tourism's role in both mitigating and adapting to climate change impacts within PAs (Miller et al., 2017; Gómez-Ruiz et al., 2022). Strengthening tourism integration within multi-, inter-, and transdisciplinary approaches is therefore essential for building a more complete socio-ecological understanding of climate risks and resilience in protected areas.

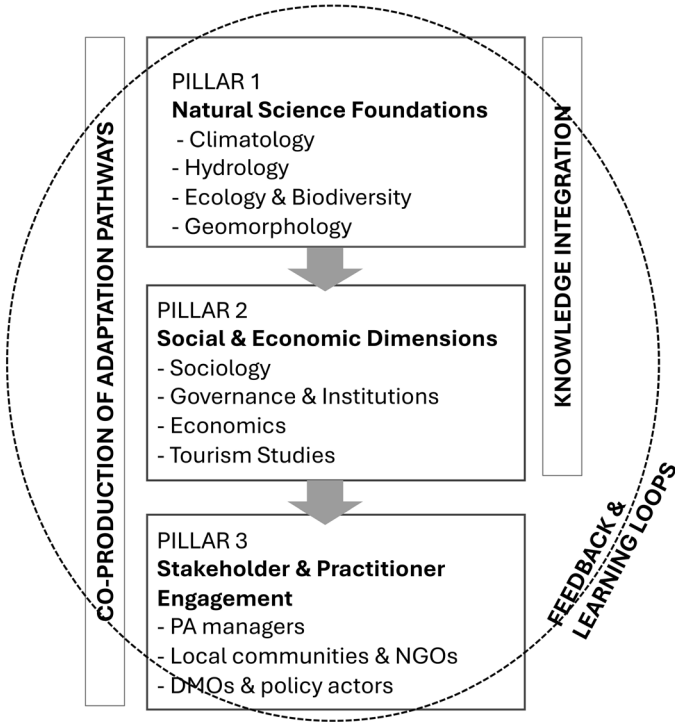
4.3. Integrating diverse disciplinary knowledge in protected areas

To address RQ3, insights from the reviewed literature and the PACT-VIRA project highlight the essential components of a transdisciplinary framework capable of capturing the complexity of climate impacts and informing adaptive PA management.

The PACT-VIRA methodology exemplifies this approach by combining expertise from climatology, hydrology, ecology, biology, tourism studies, economics, geography, and local knowledge to co-produce actionable insights for adaptive management (Marković Vukadin et al., 2025). Climatology and hydrology provide critical data on climate elements, water availability, and hydrological vulnerabilities crucial for modelling ecosystem responses and climate risk scenarios. Ecology and biology assess species distributions, habitat sensitivity, and biodiversity impacts. Tourism studies evaluate visitor behaviour and socio-ecological trade-offs, while economics and geography contribute spatially explicit socio-economic assessments, ecosystem and mapping services under changing climatic conditions. Local and Indigenous knowledge ensures contextual relevance, capturing community perceptions, traditional practices, and adaptive strategies not evident in scientific data. Integrating these diverse knowledge domains through iterative, participatory processes enables the co-production of climate adaptation strategies that are scientifically robust, socially acceptable, and practically implementable. Applying such frameworks enhances resilience assessment and increase methodological impartiality and minimises potential biases in data selection and interpretation.

Building on the synthesis of 136 studies and the methodological experience of the PACT-VIRA project, we explicitly outline a preliminary transdisciplinary framework designed to guide integrative climate research in protected areas. The framework (Figure 2) consists of three core pillars and three integrative processes, reflecting the main pathways through which disciplinary knowledge and stakeholder input are combined. Pillar 1 includes climatology, hydrology, ecology, and geomorphology, which provide baseline information on climate trends, ecosystem sensitivity, and biophysical thresholds relevant to PA management. Pillar 2 encompasses sociology, anthropology, economics, governance, and tourism studies. It captures human–environment interactions, livelihood dependencies, visitor dynamics, and institutional contexts. Last pillar (3) includes PA managers, local communities, tourism operators, NGOs, and policy actors. Their practical knowledge and value priorities shape feasible adaptation options.

Figure 2
Preliminary transdisciplinary framework for assessing climate change impacts in protected areas



Across these pillars, the framework operates through **three key integrative processes**:

1. Knowledge integration, where ecological and climatic data are aligned with socio-economic indicators and tourism-related information to generate a shared understanding of vulnerabilities and trade-offs.
2. Co-production of adaptation pathways, involving iterative dialogue between scientists and stakeholders to define risks, priorities, and feasible management interventions.
3. Feedback and learning cycles, where scenario testing, monitoring results, and stakeholder feedback continuously refine adaptation strategies and governance arrangements.

Together, these components create an operational structure for transdisciplinary climate research in PAs, ensuring that assessments are scientifically robust, socially grounded, and management oriented.

5. Conclusion and future research directions

This short communication responds to the three guiding research questions. In relation to RQ1, the review shows growing but uneven adoption of multi-, inter-, and transdisciplinary approaches, with fully co-produced transdisciplinary studies remaining limited. Addressing RQ2, the analysis confirms that tourism is insufficiently integrated into climate-PA research despite its central role in shaping ecological pressures, revenues, and community livelihoods. In response to RQ3, we propose a preliminary transdisciplinary framework that integrates natural and social sciences with stakeholder knowledge, offering a pathway for more actionable and inclusive climate adaptation strategies. Strengthening these dimensions is essential for advancing effective, tourism-informed climate planning in protected areas.

Despite the growing adoption of multi-, inter-, and transdisciplinary approaches, critical gaps remain. Transdisciplinary approaches offer the greatest potential for actionable climate adaptation, yet fully co-produced studies remain rare. Many efforts are confined to interdisciplinary frameworks that link ecological and social data but lack stakeholder or policy engagement in iterative scenario development, limiting practical applicability (Cumming et al., 2023; Rivers et al., 2023). Fully transdisciplinary implementation is especially limited in studies incorporating tourism, stakeholder co-production, and iterative governance processes.

Key research gaps include insufficient integration of ecological, climatic, and socio-economic data, limited participatory approaches, and the underrepresentation of tourism in socio-ecological resilience planning. Future research should prioritise methodological innovation, expand transdisciplinary collaboration, and embed tourism within adaptive frameworks to enhance PA management, support sustainable NBT, and strengthen ecosystem resilience under climate change. For PA managers and tourism stakeholders, the framework recommends integrating climate, ecological, and tourism monitoring; linking tourism data with climate indicators to anticipate impacts; applying adaptive visitor management; and co-producing adaptation plans with communities, operators, and NGOs.

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Declaration of Competing Interests

The authors declare that they have no known competing interests that could have appeared to influence the work reported in this paper.

References

- Agulles, M., Melo-Aguilar, C., & Jordà, G. (2022). Risk of loss of tourism attractiveness in the Western Mediterranean under climate change. *Frontiers in Climate*, 4, Article 1019892. <https://doi.org/10.3389/fclim.2022.1019892>
- Alvargonzález, D. (2011). Multidisciplinarity, interdisciplinarity, transdisciplinarity, and the sciences. *International Studies in the Philosophy of Science*, 25(4), 387–403. <https://doi.org/10.1080/02698595.2011.623366>
- Arabadzhyan, A., Figini, P., García, C., González, M. M., Lam-González, Y. E., & León, C. J. (2021). Climate change, coastal tourism, and impact chains – A literature review. *Current Issues in Tourism*, 24(16), 2233–2268. <https://doi.org/10.1080/13683500.2020.1825351>
- Belsoy, J., Korir, J., & Yego, J. (2012). Environmental impacts of tourism in protected areas. *Journal of Environment and Earth Science*, 2(10), 64–73.
- Benito, X., Benito, B., Vélez, M. I., Salgado, J., Schneider, T., Giosan, L., & Nascimento, M. N. (2022). Human practices behind the aquatic and terrestrial ecological decoupling to climate change in the tropical Andes. *Science of the Total Environment*, 826, Article 154115. <https://doi.org/10.1016/j.scitotenv.2022.154115>
- Blondin, H. E., Armstrong, K. C., Hazen, E. L., Oestreich, W. K., Santos, B. S., Haulsee, D. E., Mikles, C. S., Knight, C. J., Bennett, A. E., & Crowder, L. B. (2022). Land-dependent marine species face climate-driven impacts on land and at sea. *Marine Ecology Progress Series*, 699, 181–198. <https://doi.org/10.3354/meps14174>
- Booth, H., Mourato, S., & Milner-Gulland, E. J. (2022). Investigating acceptance of marine tourism levies, to cover the opportunity costs of conservation for coastal communities. *Ecological Economics*, 201, Article 107578. <https://doi.org/10.1016/j.ecolecon.2022.107578>
- Bruno, J. F., Bates, A. E., Cacciapaglia, C., Pike, E. P., Amstrup, S. C., van Hooedonk, R., Henson, S. A. & Aronson, R. B. (2018). Climate change threatens the world's marine protected areas. *Nature Climate Change*, 8(6), 499–503. <https://doi.org/10.1038/s41558-018-0149-2>
- Cradock-Henry, N. A., Diprose, G., & Frame, B. (2021). Towards local-parallel scenarios for climate change impacts, adaptation and vulnerability. *Climate Risk Management*, 34, Article 100372. <https://doi.org/10.1016/j.crm.2021.100372>
- Cumming, G. S., Adamska, M., Barnes, M. L., Barnett, J., Bellwood, D. R., Cinner, J. E., Cohen, P. J., Donelson, J. M., Fabricius, K., Grafton, R. Q., Grech, A., Gurney, G. G., Hoegh-Guldberg, O., Hoey, A. S., Hoogenboom, M. O., Lau, J., Lovelock, C. E., Lowe, R., Miller, D. J., ... Wilson, S. K. (2023). Research priorities for the sustainability of coral-rich western Pacific seascapes. *Regional Environmental Change*, 23(2), Article 66. <https://doi.org/10.1007/s10113-023-02051-0>
- Dube, K., & Nhamo, G. (2020). Tourist perceptions and attitudes regarding the impacts of climate change on Victoria Falls. *Bulletin of Geography. Socio-economic Series*, (47), 27–44. <https://doi.org/10.2478/bog-2020-0002>
- Duncanson, L., Liang, M., Leitold, V., Armston, J., Krishna Moorthy, S. M., Dubayah, R., Costedoat, S., Enquist, B. J., Fatoyinbo, L., Goetz, S. J., & Gonzalez-Roglich, M., Merow, C., Roehrdanz, P. R., Tabor, K., Zvoleff, A. (2023). The effectiveness of global protected areas for climate change mitigation. *Nature Communications*, 14(1), Article 2908. <https://doi.org/10.1038/s41467-023-38073-9>
- Gatti, E., & Brownlee, M. (2024). Outdoor recreationists' engagement with weather: The weather-outdoor recreation process model. *Journal of Outdoor Recreation and Tourism*, 45, Article 100707. <https://doi.org/10.1016/j.jort.2023.100707>
- Gómez-Ruiz, P. A., Betancourth-Buitrago, R. A., Arteaga-Cote, M., Carbajal-Borges, J. P., Teutli-Hernández, C., & Laffon-Leal, S. (2022). Fostering a participatory process for ecological restoration of mangroves in Pantanos de Centla Biosphere Reserve (Tabasco, Mexico). *Ecosystems and People*, 18(1), 112–118. <https://doi.org/10.1080/26395916.2022.2032358>
- Heinrich, I., Balanzategui, D., Bens, O., Blasch, G., Blume, T., Böttcher, F., Bork, E., Brademan, B., Brauer, A., Conrad, C., Dietze E., Dräger, N., Fiener, P., Gerke, H. H., Güntner, A., Heine, I., Helle, G., Herbrich, M., Harfenmeister, K., ... & Wilken, F. (2018). Interdisciplinary geo-ecological research across time scales in the Northeast German Lowland Observatory (TERENO-NE). *Vadose Zone Journal*, 17(1), 1–25. <https://doi.org/10.2136/vzj2018.06.0116>
- Intergovernmental Panel on Climate Change. (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. <https://www.ipcc.ch/srccl/>

- Klosterman, S., Melaas, E., Wang, J. A., Martinez, A., Frederick, S., O'Keefe, J., Orwig, D.A., Wang, Z., Sun, Q., Schaaf, C., Friedl, M., & Richardson, A. D. (2018). Fine-scale perspectives on landscape phenology from unmanned aerial vehicle (UAV) photography. *Agricultural and Forest Meteorology*, 248, 397-407. <https://doi.org/10.1016/j.agrformet.2017.10.015>
- Lehikoinen, P., Tiusanen, M., Santangeli, A., Rajasärkkä, A., Jaatinen, K., Valkama, J., Virkkala, R., & Lehikoinen, A. (2021). Increasing protected area coverage mitigates climate-driven community changes. *Biological Conservation*, 253, Article 108892. <https://doi.org/10.1016/j.biocon.2020.108892>
- Lindberg, K., Forbord, M., & Sivertsvik, R. M. (2021). Nature-based tourism and community resilience. In P. Fredman & J. V. Haukeland (Eds.), *Nordic Perspectives on Nature-based Tourism* (pp. 64-79). Edward Elgar Publishing. <https://doi.org/10.4337/9781789904031.00013>
- López-Juambeltz, F., Rodríguez-Gallego, L., Dabezies, J. M., Chreties, C., Narbondo, S., & Conde, D. (2020). A GIS-based assessment combined with local ecological knowledge to support the management of *Juncus acutus* L. spreading in the floodplain of a protected coastal lagoon. *Journal for Nature Conservation*, 57, Article 125891. <https://doi.org/10.1016/j.jnc.2020.125891>
- Marcos, C., Díaz, D., Fietz, K., Forcada, A., Ford, A., García-Charton, J. A., Goñi, R., Lenfant, P., Mallol, S., Mouillot, D., Pérez-Marcos, M., Puebla, O., Manel, S., Pérez-Ruzafa, A. (2021). Reviewing the ecosystem services, societal goods, and benefits of marine protected areas. *Frontiers in Marine Science*, 8, Article 613819. <https://doi.org/10.3389/fmars.2021.613819>
- Marković Vukadin, I., Ložek, F., Krešić, D., Borović, S., Pola, M., Terzić, J., Urumović, K., Srnc, L., Lisko, T., Havrle Kozarić, I., Duplić, A., Kirin, T., & Fabrio Čubrić, K. (2025). Integriranje različitih znanstvenih pristupa za upravljanje turizmom otpornim na klimu u zaštićenim područjima [Integrating diverse scientific approaches for climate-resilient tourism management in protected areas]. In D. Špoljarić Maronić, V. Rožac, I. Bašić, & S. Ozimec (Eds.), *14. međunarodni simpozij Kopački rit: Jučer, danas, sutra – zbornik sažetaka* (pp. 188–191). Javna ustanova Park prirode Kopački rit.
- Melillo, J. M., Lu, X., Kicklighter, D. W., Reilly, J. M., Cai, Y., & Sokolov, A. P. (2016). Protected areas' role in climate-change mitigation. *Ambio*, 45(2), 133-145. <https://doi.org/10.1007/s13280-015-0693-1>
- Michailidou, A. V., Vlachokostas, C., & Moussiopoulos, N. (2016). Interactions between climate change and the tourism sector: Multiple-criteria decision analysis to assess mitigation and adaptation options in tourism areas. *Tourism Management*, 55, 1-12. <https://doi.org/10.1016/j.tourman.2016.01.010>
- Miller, D. C., Rana, P., & Wahlén, C. B. (2017). A crystal ball for forests? Analyzing the social-ecological impacts of forest conservation and management over the long term. *Environment and Society*, 8(1), 40-62. <https://doi.org/10.3167/ares.2017.080103>
- Njoroge, J. M. (2015). Climate change and tourism adaptation: Literature review. *Tourism and Hospitality Management*, 21(1), 95-108. <https://doi.org/10.20867/thm.21.1.7>
- Olivares-Aguilar, I. C., Sánchez-Dávila, G., Wildermann, N. E., Clark, D., Floerl, L., Villamizar, E., Matteucci, S. D., Muñoz Sevilla, N. P., & Nagy, G. J. (2022). Methodological approaches to assess climate vulnerability and cumulative impacts on coastal landscapes. *Frontiers in Climate*, 4, Article 1018182. <https://doi.org/10.3389/fclim.2022.1018182>
- Petrișor, A.-I., Hamma, W., Nguyen, H. D., Randazzo, G., Muzirafuti, A., Stan, M.-I., Tran, V. T., Aștefănoaiei, R., Bui, Q.-T., Vintilă, D.-F., Truong, Q. H., Lixăndroiu, C., Țenea, D.-D., Sîrodoev I., & Ianoș, I. (2020). Degradation of coastlines under the pressure of urbanization and tourism: Evidence on the change of land systems from Europe, Asia and Africa. *Land*, 9(8), Article 275. <https://doi.org/10.3390/land9080275>
- Rannow, S., Macgregor, N. A., Albrecht, J., Crick, H. Q. P., Förster, M., Heiland, S., Janauer, G., Morecroft, M. D., Neubert, M., Sarbu, A., & Sienkiewicz, J. (2014). Managing protected areas under climate change: Challenges and priorities. *Environmental Management*, 54(4), 732-743. <https://doi.org/10.1007/s00267-014-0271-5>
- Richardson, A. D. (2023). PhenoCam: An evolving, open-source tool to study the temporal and spatial variability of ecosystem-scale phenology. *Agricultural and Forest Meteorology*, 342, Article 109751. <https://doi.org/10.1016/j.agrformet.2023.109751>
- Rivers, N., Strand, M., Fernandes, M., Metuge, D., Lemahieu, A., Nonyane, C. L., Benkenstein, A., & Snow, B. (2023). Pathways to integrate Indigenous and local knowledge in ocean governance processes: Lessons from the Algoa Bay Project, South Africa. *Frontiers in Marine Science*, 9, Article 1084674. <https://doi.org/10.3389/fmars.2022.1084674>

- Scott, D., Gössling, S., & Hall, C. M. (2012). *Tourism and climate change: Impacts, adaptation and mitigation*. Routledge. <https://doi.org/10.4324/9780203127490>
- Stock, P., & Burton, R. J. F. (2011). Defining terms for integrated (multi-inter-trans-disciplinary) sustainability research. *Sustainability*, 3(8), 1090-1113. <https://doi.org/10.3390/su3081090>
- Sun, L., Booth, A., & Sworn, K. (2024). Adaptability, scalability and sustainability (ASaS) of complex health interventions: A systematic review of theories, models and frameworks. *Implementation Science*, 19(1), Article 52. <https://doi.org/10.1186/s13012-024-01375-7>
- Symstad, A. J., Fisichelli, N. A., Miller, B. W., Rowland, E., & Schuurman, G. W. (2017). Multiple methods for multiple futures: Integrating qualitative scenario planning and quantitative simulation modeling for natural resource decision making. *Climate Risk Management*, 17, 78-91. <https://doi.org/10.1016/j.crm.2017.07.002>
- Vieira, L. R., Vieira, J. G., da Silva, I. M., Barbieri, E., & Morgado, F. (2021). GIS models for vulnerability of coastal erosion assessment in a tropical protected area. *ISPRS International Journal of Geo-Information*, 10(9), Article 598. <https://doi.org/10.3390/ijgi10090598>
- Volgger, M., & Pechlaner, H. (2014). Interdisciplinarity, transdisciplinarity and postdisciplinarity in tourism and hospitality education. In D. Dredge, D. Airey, & M. J. Gross (Eds.), *The Routledge handbook of tourism and hospitality education* (pp. 85-102). Routledge.
- Xu, W., Xiao, Y., Zhang, J., Yang, W. U., Zhang, L. U., Hull, V., Wang, Z., Zheng, H., Liu, J., Polasky, S., Jiang, L., Xiao, Y., Shi, X., Rao, E., Lu, F., Wang, X., Daily, G. C., & Ouyang, Z. (2017). Strengthening protected areas for biodiversity and ecosystem services in China. *Proceedings of the National Academy of Sciences*, 114(7), 1601-1606. <https://doi.org/10.1073/pnas.1620503114>
- Yang, M., Qiu, J., Luo, S., Zhang, S., Xie, J., Liu, L., Wang, Z., & Zheng, Y. (2025). Evidence on how planning and design contribute to building a habitat security space: A multidimensional exploration. *Environmental Research Communications*, 7(9), Article 092002. <https://doi.org/10.1088/2515-7620/ae07a7>
- Yasmeen, K., Malik, M., Yasmeen, K., Adnan, M., & Al Bimani, N. M. (2024). Bridging the nexus: A comprehensive review of tourism, technology and climate change—uncharted territories and future avenues. In A. I. Hunjra & A. Sharma (Eds.), *The Emerald handbook of tourism economics and sustainable development* (pp. 1–19). Emerald Publishing Limited. <https://doi.org/10.1108/978-1-83753-708-220241001>
- Yeboah-Assiamah, E., Muller, K., & Domfeh, K. A. (2018). 'Complex crisis' and the rise of collaborative natural resource governance: Institutional trajectory of a wildlife governance experience in Ghana. *Environment, Development and Sustainability*, 20(5), 2205-2224. <https://doi.org/10.1007/s10668-017-9985-x>
- Zabaniotou, A., Syrgiannis, C., Gasperin, D., de Hoyos Guevera, A. J., Fazenda, I., & Huisingsh, D. (2020). From multidisciplinary to transdisciplinarity and from local to global foci: Integrative approaches to systemic resilience based upon the value of life in the context of environmental and gender vulnerabilities with a special focus upon the Brazilian Amazon biome. *Sustainability*, 12(20), Article 8407. <https://doi.org/10.3390/su12208407>

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