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LETTER

A multi-site assessment of nature's contributions to people in Mediterranean region

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Abstract

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services concept of nature's contributions to people (NCP) offers an inclusive framework for assessing how nature supports life and livelihoods in ecosystems. This study assessed trends of 18 NCPs, identified key drivers of change, and highlighted critical trade-offs and transformative actions required across critical agricultural catchments. We conducted a standardized expert questionnaire on eight catchments across the Mediterranean region, where water issues represent a key common driver of change, to gather qualitative assessments of NCP trends over the past decade. Our analysis revealed a widespread decline, particularly in regulating NCPs. This decline was mainly driven by agricultural intensification, urbanization, and climate change, resulting in important trade-offs where stable food production is threatening other NCPs. These findings show the Mediterranean's acute vulnerability of agricultural areas that rely on threatened water resources and demonstrate the urgent need for transformative adaptation pathways to secure the region's nature and human well-being.

1. Introduction

The Mediterranean region is widely recognized as a cradle of civilizations and a biodiversity hotspot, yet it is currently facing severe environmental stress (Dean *et al* 2024). While the region possesses a unique climate and a rich history of human-nature interactions, ecosystems such as wetlands, coastal lagoons, and pastoral lands are increasingly vulnerable to anthropogenic pressures, including climate change, pollution, and habitat destruction (Lacoste *et al* 2023, Dean *et al* 2024). These cumulative pressures threaten the ecological integrity of the Mediterranean and the well-being of the populations that rely on it. Understanding the interactions between nature and society is necessary to address these challenges. As recent advances in integrated ecosystem assessments emphasize the necessity to balance ecosystem multifunctionality with sustainable conservation strategies, holistic assessment frameworks, as used in this study, can maximize the synergistic co-benefits of ecological restoration, ecosystem services (ES), and sustainability (Li *et al* 2026a).

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The concept of ES, popularized by the Millennium Ecosystem Assessment (2005), provided a foundational framework for understanding the benefits people obtain from ecosystems, categorized as provisioning, regulating, cultural, and supporting services. However, to better embrace diverse worldviews and knowledge systems, particularly those of indigenous peoples and local communities, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) evolved this concept into 'Nature's Contributions to People' (NCPs). The NCP framework is defined as 'all the contributions, both positive and negative, of living nature to people's quality of life' (Díaz *et al* 2015). It is organized into 18 categories across three broad groups: regulating, material, and non-material contributions, offering a more nuanced and culturally inclusive lens (IPBES 2019).

Global and regional assessments indicate that nature is deteriorating at unprecedented rates, with regulating and non-material NCPs declining in parallel with biodiversity loss, with grave impacts on people (IPBES 2019, Cimatti *et al* 2023). The IPBES Global Assessment Report revealed that around 1 million animal and plant species are threatened with extinction, and 14 of the 18 categories of NCPs assessed have declined since 1970. This assessment concluded that the world is on an unsustainable path and that achieving sustainability goals requires 'transformative changes across economic, social, political and technological factors' (IPBES 2019).

Further spatially explicit global research has reinforced these findings. A study by Liu *et al* (2023) assessed all 18 NCPs globally, finding that 11 of them declined between 1992 and 2018, primarily due to the loss of natural ecosystems. They noted that the relationships between regulating and material NCPs often involve trade-offs. For instance, increasing material contributions such as food production can lead to a decrease in regulating contributions such as water quality regulation and habitat maintenance. Transitional climate areas, like many parts of the Mediterranean, were identified as particularly vulnerable, exhibiting strong trade-off relationships. Furthermore, specific Mediterranean ecosystems are witnessing declines in functionality due to resource exploitation and pollution, highlighting the urgent need for integrated conservation planning which accounts for these spatial discrepancies and cumulative pressures (O'Connor *et al* 2021, Lacoste *et al* 2023).

Despite these insights, significant knowledge gaps remain at regional and sub-regional levels. Our hypothesis is that when high resolution environmental monitoring is unavailable or fragmented, coordinated, multi-site assessments using a consistent qualitative methodology can effectively improve our understanding of NCP trends in specific socio-ecological contexts, particularly in vulnerable hotspots such as the Mediterranean region. Such research is relevant for developing place-based and effective management strategies and policies.

This study aims to address this gap by providing a multi-site assessment of the status and trends of all 18 NCPs across eight demonstration sites within the Mediterranean region. Using an expert-based data collection questionnaire (with 24 experts), we, (i) assess the perceived trends of NCPs over the past decade, (ii) identify the key drivers of change and the critical trade-offs between NCPs, and (iii) discuss the policy implications for developing transformative adaptation pathways to enhance NCPs in intensively managed agroecosystems.

2. Methods

2.1. Conceptual framework

This assessment is grounded in the IPBES's NCP framework, which models the interactions between nature, anthropogenic assets, governance, drivers of change, NCPs, and human quality of life. We assessed all 18 NCPs identified by Díaz *et al* (2018), which are organized into three groups:

- **Regulating NCPs (NCP1 to NCP10):** Regulation of environmental processes such as climate, air and water quality, pollination, and hazards.
- **Material NCPs (NCP11 to NCP14):** Tangible goods from nature, including food, energy, materials, and medicinal resources.
- **Non-material NCPs (NCP15 to NCP18):** Non-physical benefits supporting psychological and cultural well-being, such as recreation, identity, and inspiration.

2.2. Study areas

This study was conducted across eight demonstration sites (basins, catchments, or aquifers): Bode (Germany), Agia (Greece), Arborea (Italy), Mujib River (Jordan), Sebou (Morocco), Jucar-Albufera Natural Park (Spain), Medjerda (Tunisia), and Konya (Türkiye). These sites were selected to represent

a range of socio-ecological contexts, including intensively managed agricultural catchments, coastal zones affected by tourism and urban development, and transboundary river basins facing significant water management challenges, across a gradient of aridity and human development.

2.3. Data collection

NCPs were assessed through a standardized data collection questionnaire distributed to 24 experts within the OURMED Project[9] teams at each site, as follows: Bode, Germany (2 experts); Agia, Greece (3); Arborea, Italy (4); Mujib River, Jordan (1); Sebou Basin, Morocco (3); Jucar Basin, Spain (2); Medjerda, Tunisia (2); and Konya, Türkiye (6). Experts are part of the OURMED project and have conducted extensive fieldwork in the assessed sites (including direct observation, desk research, stakeholder engagement, monitoring, data analysis, and modelling), possessing in-depth knowledge of these sites. Notably, many of these experts had prior engagement and had conducted research before the project began, and as part of their roles within the project, all experts were in close, ongoing contact with local stakeholders and governmental agencies.

For each NCP, experts were asked to assess (i) the relevance of the NCP to local water management and its context, supported by specific examples, and (ii) its trend over the last 10 years, rated on a simple three-point scale (ameliorated, did not change, deteriorated) and accompanied by a detailed description of the observed changes and their underlying drivers. The expert judgements are based on direct and indirect observations from their extensive fieldwork, existing empirical monitoring data collected as part of the broader OURMED project, and their interactions with other stakeholders during various stages of project. The questionnaires were filled collaboratively by each team, and an agreed-upon final assessment is reported for each NCP category. Responses were synthesized across all eight sites and thematically analysed to identify recurring patterns and pressures.

3. Results

3.1. General trends: a pattern of decline

A striking trend across the majority of the demonstration sites was the marked deterioration of regulating NCPs over the last decade, in contrast to more varied trends for material and non-material NCPs (figure 1). This overall decline in regulating NCPs signals increasing environmental stress and a reduced ecosystem capacity to deliver essential, often overlooked, benefits to people. The assessment revealed a consistent and widespread decline in this category (table S1). For example, Habitat Creation and Maintenance (NCP1), a foundational service, has deteriorated in seven of the eight sites, with notable examples including extensive forest dieback in Germany's Bode Basin and wetland loss in Morocco's Sebou Basin. This widespread habitat degradation was a primary driver of declines in Pollination and Seed Dispersal (NCP2), which deteriorated in six sites due to habitat loss and increased pesticide use. Furthermore, the Regulation of Freshwater Quality (NCP7) and Formation and Protection of Soils (NCP8) showed declining trends across most sites, primarily driven by agricultural runoff and intensified land use. This loss of ecosystem resilience is also evident in the weakened capacity for the Regulation of Hazards and Extreme Events (NCP9), a common theme in Germany, Greece, and Tunisia.

Trends for material contributions varied, showing significant trade-offs between production and environmental conditions. Energy (NCP11) improved in five sites, following increasing investments in renewable energy sources such as small hydropower plants and biogas. Food and Feed (NCP12) presents a variable pattern: while it declined in five sites due to water scarcity and soil degradation, it increased in Italy and Türkiye. These increases coincided with declines in other NCPs, demonstrating a trade-off where higher agricultural output corresponds with the degradation of regulating services necessary for long-term sustainability (see table S1).

In contrast to the decline in regulating services, some non-material contributions have improved over the past decade. This is most notable for Learning and Inspiration (NCP15), which has generally improved in five of the eight demonstration sites (Bode, Agia, Arborea, Mujib, and Sebou). These positive changes are often the result of enhanced research and monitoring capabilities, as well as the growth of eco-tourism initiatives (as in the cases of Arborea and Mujib River) that foster a greater appreciation and understanding of the natural environment. This suggests that while the functional aspects of these ecosystems are under threat, their value for education, recreation, and inspiration is increasingly being acknowledged and developed.

[9] Sustainable water storage and distribution in the Mediterranean project OURMED, by Partnership for Research and Innovation in the Mediterranean Region (PRIMA), Award ID: 2222.

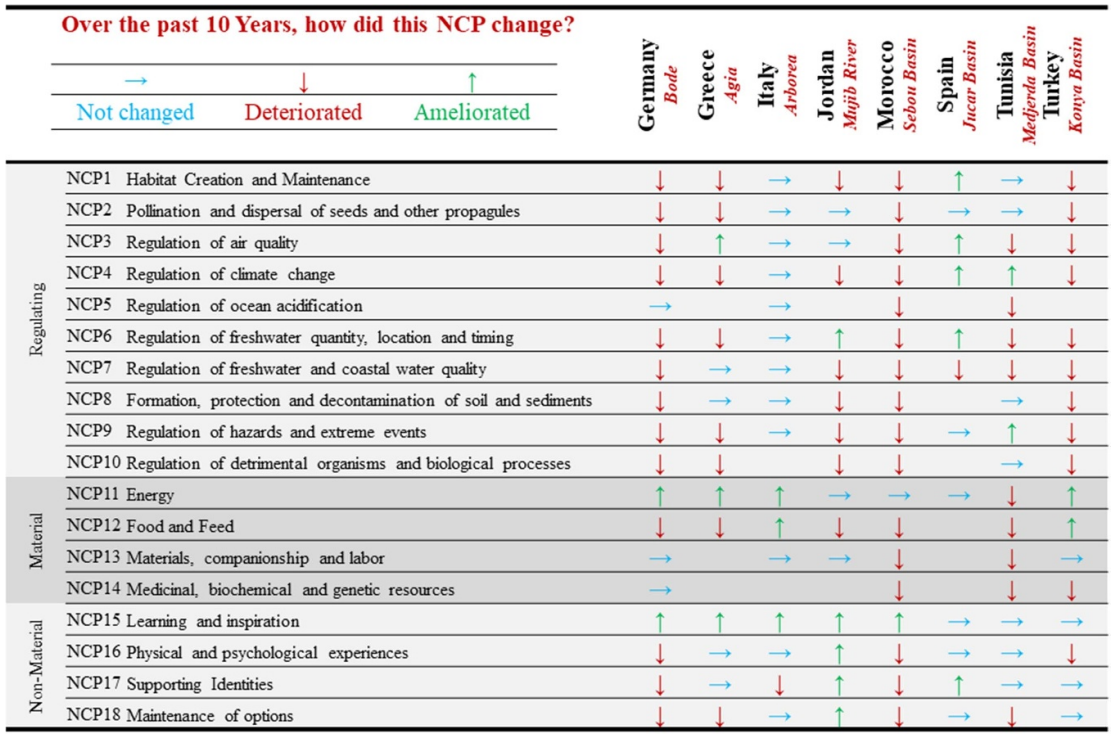

Figure 1. Trends in all relevant NCP categories for the eight demonstration sites. Categories deemed 'not relevant' for a specific site are represented as blank spaces, while those with relevance to the site are populated with trend arrows.

3.2. Common issues and key drivers of change

Despite their differences, the demonstration sites share common environmental challenges, largely driven by similar anthropogenic pressures. Agricultural intensification is the most pervasive driver, with intensive dairy farming causing nitrate pollution of groundwater in Arborea Basin and irrigated agriculture expansion and agrochemical use drive soil salinization, water pollution, and biodiversity loss in the Medjerda and Konya Basins.

Water scarcity and water management issues are critical across southern Mediterranean sites, from groundwater depletion in Konya to allocation conflicts between agricultural, domestic and industrial users in the Sebou Basin and Agia Aquifer. Even the Bode Basin has experienced prolonged droughts that have stressed water availability and quality (Kong *et al* 2022, Musolff *et al* 2024), while these challenges are further exacerbated by ageing infrastructure and fragmented governance in Morocco, Tunisia, and Greece. Such deteriorations in freshwater-related NCPs significantly influence overall ecosystem functioning (Zhang *et al* 2025).

Climate change acts as a threat multiplier across all sites, with increased drought and flood frequency driving forest dieback in Germany, worsening water scarcity in Tunisia, and reducing the water retention capacity of Agia Lake. Urbanization and land-use change contribute to habitat loss and pollution in the Sebou Basin, while in Agia, conversion of agricultural land to urban development and photovoltaic installations are causing irreversible loss of productive agricultural land and critical habitats. As also highlighted by Yan *et al* (2026), such land-use changes and intense landscape transformations, coupled with other types of anthropogenic pressures, are major drivers of declining ecosystem functioning and reduced NCP delivery across several of the demonstration sites.

4. Discussion

4.1. The eroding foundation of well-being

Our multi-site assessment reveals that the deterioration of NCPs across the Mediterranean basin strongly mirrors alarming global trends (Brauman *et al* 2020), but is characterized by distinct, acute regional vulnerabilities. The widespread ecological decline observed across the study sites is heavily driven by the competing demands of agricultural intensification and international supply chains (Marques *et al* 2024).

These macroeconomic pressures frequently degrade foundational resources and threaten highly sensitive ecosystems where accumulated anthropogenic pressures severely limit ecological functioning.

The decline of several NCPs directly affects ecosystem stability. The reduction in Habitat Creation and Maintenance (NCP1) across seven sites corresponds with loss of biodiversity and drives cascading losses in Freshwater Quality (NCP7) and Hazard Regulation (NCP9), threatening water availability, agricultural sustainability, and community safety across the study basins. Furthermore, the socio-cultural impacts of these environmental shifts are profound and cannot be ignored in regional policy. The decline of traditional practices alters the physical landscape while deeply eroding the non-material NCPs valued by local communities (Quintas-Soriano *et al* 2023). Addressing these declines requires recognizing the links between cultural landscapes, tourism, human well-being, and sustainable regional development, as recent evidence demonstrates that cultural ecosystem assets and cultural-tourism integration are vital for contributing to community well-being and long-term regional sustainability (Lu and Yoon 2026).

4.2. Key drivers and trade-offs

The increase in material NCPs such as Food and Feed (NCP12) in Arborea (Italy) and the Konya Basin (Türkiye), alongside the decline in nearly all regulating NCPs in those areas, illustrates the trade-offs inherent in current management paradigms. The pursuit of maximizing agricultural output has created a vicious cycle of groundwater depletion (Konya), soil degradation and reservoir siltation (Medjerda), and water pollution from nutrient loading (Arborea), undermining the very natural resource upon which production depends. Understanding these trade-offs is further supported by recent advances in research on ecological connectivity and land use, which demonstrate that maintaining ecological integrity under increasing anthropogenic pressures is essential for habitat maintenance, biodiversity conservation, and overall ecosystem resilience (Li *et al* 2026) Urbanization and infrastructure development, particularly in the Sebou and Agia basins, represent another major driver, leading to irreversible habitat loss and the degradation of the cultural and aesthetic landscapes that are central to non-material NCPs.

Crucially, our findings highlight the complex spatial and policy trade-offs across the Mediterranean. High-biodiversity areas play a critical role in maintaining regulatory NCPs such as air and water quality, particularly under impending climate change scenarios (Cimatti *et al* 2023). When balancing conservation priorities, our results align with O'Connor *et al* (2021), indicating that prioritizing biodiversity conservation generally secures NCP provision better than focusing only on the service output. Thus, protecting irreplaceable and highly diverse Mediterranean ecosystems yields vital co-benefits for human populations.

4.3. Methodological strengths and limitations

The use of a qualitative expert assessment provided rich, context-specific insights that would be difficult to obtain through quantitative methods alone. Specifically, while quantitative biophysical monitoring is invaluable for providing precise empirical measurement, it often suffers from data gaps, particularly in complex or under-resourced environments where long-term baseline datasets are absent or incomplete. Furthermore, purely quantitative metrics often fail to capture critical context and intricate socio-cultural drivers of ecosystem change. The holistic and flexible approach adopted in this study is adaptable to diverse scales and captures the perceptions of those most familiar with local social-ecological systems, aligning with the IPBES's emphasis on incorporating diverse knowledge systems. However, this methodology has limitations. The findings are based on expert judgement, which introduces subjectivity. While our standardized framework minimizes variation in responses, the results are not a substitute for quantitative biophysical monitoring. Rather, they serve as a rapid, multi-site diagnostic tool to prioritize areas for detailed research and policy action, inspiring a sustainable future vision. Future studies would benefit from integrating qualitative expert knowledge with quantitative indicator-based assessment frameworks, ecological network analysis, and other complementary approaches. For instance, the integrated approach used by Zhi *et al* (2026) that combine ecological network analysis with social network analysis, has proven effective in unveiling both critical metabolic nodes and stakeholder priorities, thereby providing a more holistic ecosystem assessment.

4.4. Pathways for transformation

The observed decline in NCPs shown in this study indicates that business-as-usual is not a sustainable option for intensively managed agricultural systems where water resources management is critical for their sustainability. Achieving regional sustainability goals requires transformative change (IPBES 2019). Traditional, top-down conservation and agricultural policies are insufficient to manage the trade-offs

between extraction and regulation. By adopting knowledge coproduction frameworks and actively valuing local perspectives and traditional practices (Vallet *et al* 2023), policymakers can design more equitable, context-specific interventions. Our findings point to several key leverage points for transformative change:

i. **Reforming harmful subsidies:** The current economic incentives that encourage unsustainable water use and agricultural intensification must be reformed (Sundrum 2024). Shifting subsidies toward practices that enhance regulating and non-material NCPs, such as agroecology, water conservation, and habitat restoration, is critical.

ii. **Integrated governance:** Cross-sectoral approaches to governance are essential. Water, agriculture, energy, and tourism policies must be co-developed within an integrated landscape and seascape planning framework that explicitly manages trade-offs and seeks synergies among NCPs.

iii. **Strengthening local stewardship:** The positive expert assessment of the potential for interventions to improve NCPs highlight the value of site-specific options. Empowering local communities and recognizing their knowledge in the governance of natural resources can lead to more effective and equitable outcomes, particularly for non-material NCPs that are deeply rooted in local culture and identity (Belete *et al* 2024, Denning 2025).

iv. **Investing in nature-based solutions:** The potential for sustainability projects to ameliorate NCPs underscores the value of investing in nature-based solutions (Belete *et al* 2024). Restoring wetlands and forests to enhance water regulation, implementing green infrastructure in urban areas, and creating well-managed protected areas can provide cost-effective, long-term benefits for both nature and people.

5. Conclusion

This study provides one of the first coordinated, multi-site assessment of NCPs across the Mediterranean basin, revealing a widespread and severe pattern of decline. The erosion of regulating NCPs, often traded off for short-term stability in material production, threatens the long-term ecological resilience and human well-being of the region. The trends we have identified are not merely environmental issues; they are fundamental challenges to the future of food security, water availability, cultural heritage, and economic prosperity in the Mediterranean. Reversing this trajectory requires urgent and concerted efforts to foster transformative change, shifting from sectoral, production-focused management towards integrated, sustainable stewardship of the rich natural heritage that defines this vital region.

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Supplementary Data available at https://doi.org/10.1088/2515-7620/aeaad3/data1.

Ethics statement

All individuals involved in the data gathering process participated with open knowledge and explicit consent, fully agreeing to contribute to the research. The data collected was strictly related to the project parameters, and no personal or personally identifiable information was gathered at any stage.

Conflict of interest

The authors declare no conflict of interest.

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