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ORIGINAL ARTICLE

Diverse values of nature can drive transformative change in the WEFE nexus governance in Mediterranean countries

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Abstract

The water–energy–food–ecosystem (WEFE) nexus has emerged as a useful concept to describe and address complex interdependencies in natural resource governance. However, most existing research predominantly emphasizes biophysical and economic dimensions, overlooking the social and cultural dimensions of the nexus and how communities perceive and value these interconnections at diverse local scales. This study aims to bridge this gap by integrating the Diverse Values of Nature framework (IPBES) and the Human–Nature Connectedness (HNC) framework into WEFE nexus research, to explore how communities relate to WEFE systems and how these relations influence and shape the perception of well-being and sustainable natural resources governance. We conducted 110 semi-structured interviews across seven Mediterranean case studies (Spain, Portugal, Morocco, Tunisia, Jordan, and Italy), focusing on agricultural actors. The interviews were analyzed to identify value types (instrumental, intrinsic, and relational), HNC dimensions (material, experiential, cognitive, emotional, and philosophical), and links to diverse components of human well-being, which local actors associated with their WEFE nexus systems across the seven case studies. Results reveal that instrumental values dominate across the analyzed case studies, while intrinsic and relational values also play a crucial role in shaping governance priorities. In addition, the emotional and philosophical dimension of HNC emerged as key leverage points for governance transformations of the WEFE nexus. Additionally, case-specific contrasts and variations (e.g., varying levels of emotional bonds attached to diverse WEFE nexus systems) highlight the important need for applying context-sensitive and place-based approaches. Based on these findings, we argue that integrating non-monetary values, context-sensitive approaches, and human–nature relationships into WEFE governance could be essential for recognizing and supporting diverse worldviews, local knowledge systems, and cultural identities. This study contributes to advancing nexus thinking by demonstrating how social values and human–nature connections, not just monetary or biophysical trade-offs, in systems can inform transformative changes in WEFE nexus approaches and natural resource governance. This study advances nexus thinking beyond technical efficiency, advocating for inclusive, adaptive, and equity-centered approach.

Keywords Human–nature connectedness · Non-monetary values · Transformative governance · Sustainability · Leverage points · Mediterranean region

Introduction

Social–ecological systems are complex adaptive systems where ecological dynamics are deeply interconnected with social change (Fischer et al. 2015). As society navigates these complexities, the water–energy–food–ecosystem (WEFE) nexus has emerged as a critical framework for understanding and managing these interdependencies (Canessa et al. 2022). Nexus thinking promotes integrated

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resource management by emphasizing synergies and trade-offs across the use of water, energy, food, and ecosystems to achieve sustainable outcomes (Sambo et al. 2024). Changes in the spatial or temporal dynamics of any WEFE component can trigger cascading effects in others, creating both opportunities for synergy and risks of conflicts at multiple scales (Schlemm et al. 2024; Farmandeh et al. 2024). Understanding these interactions at both global and local levels therefore remains a priority in the global development agenda and the sustainable development goals (SDGs) (López-Rodríguez et al. 2024; Bidoglio et al. 2024). Nonetheless, implementing the WEFE nexus approach remains challenging due to spatial, temporal, institutional, and jurisdictional barriers that complicate cross-sectoral governance (Zhang et al. 2018). Existing research has predominantly focused on the economic and instrumental dimensions of the nexus, prioritizing resource optimization and market efficiencies. This emphasis often comes at the expense of a more holistic and ecosystem-centered perspective (Schlemm et al. 2024). Notably, many studies reduce the concept to the WEF nexus (water–energy–food), neglecting the crucial ecosystem component that underpins and regulates the entire system (Martinez-Hernandez et al. 2017; Liu et al. 2019; Sambo et al. 2024). In this study, we explicitly use the WEFE nexus to emphasize the role of ecosystems. Ecosystems provide essential services that sustain the ecological functioning of water, energy, and food systems (Burkhard and Maes 2017).

Over the past decade, most WEFE nexus research has been quantitative, focusing primarily on assessing biophysical resource flows across sectors (Albrecht et al. 2018). At the same time, a growing body of qualitative research has emerged, emphasizing actor engagement and the integration of social dimensions into WEFE nexus approaches (Kropf et al. 2021). Qualitative studies have employed diverse mixed-method techniques to explore these social dynamics, including: Delphi and focus group methods to identify the relationships between different WEFE sectors and key actors (Smajgl et al. 2016); actor analysis using causal loop diagrams and participatory processes to compare actor perspectives, enhance engagement, and foster knowledge co-production (Howarth and Monasterolo 2016; Halbe et al. 2015); and participatory workshops designed to involve key actors in decision-making, facilitating dialogue between conflicting interests to achieve shared environmental and landscape policies (de Strasser et al. 2016). These qualitative approaches contribute to a more inclusive and context-specific understanding of the WEFE nexus, bridging the gap between technical assessments and actor-driven governance.

Despite growing recognition of the WEFE nexus as a framework for integrated resource management, research on its social dimensions, including how people perceive nexus interdependencies, their mental models, values, and preferences, remains underexplored (IPBES 2022; Kropf et al. 2021; Albrecht et al. 2018). Many nexus studies predominantly focus on technical, biophysical, and economic assessments, often neglecting diverse value types toward nature, instrumental, intrinsic, and relational, and their role in shaping human–nature interactions (Riechers et al. 2025; El Ghafraoui et al. 2023; Ortiz-Przychodzka et al. 2023). Relational values encompass meaningful, often reciprocal human relationships with nature and among people through nature. They are frequently tied to specific landscapes, places, species, or ecosystems (Chan et al. 2018, 2020). These values do not exist in nature per se but emerge from people's interactions with it and each other through nature. They are context dependent and place based, reflecting complex human–nature relations linked to quality of life, sense of community, responsibility, and care for nature. Relational values include a sense of place, a sense of identity, environmental cohesion, and stewardship (McGregor 2010; Kimmerer 2011; Riechers et al. 2025). Additionally, the influence of Human–Nature Connectedness (HNC) on these values is rarely considered within nexus governance, limiting a holistic understanding of how individuals and communities perceive, experience, and engage with water, energy, food, and ecosystems beyond monetary or market-based considerations. Addressing this gap is crucial for developing more inclusive, participatory, and sustainable WEFE governance strategies that recognize the social, cultural, and ethical dimensions of resource management (Otamendi-Urroz et al. 2023).

The need for a value-inclusive nexus approach is particularly relevant in the Mediterranean region, where human societies and ecosystems have co-evolved over centuries, creating an exceptional ecological and cultural diversity (Blondel 2006). However, despite being a biodiversity hotspot, the Mediterranean is one of the most vulnerable regions globally due to climate change, land-use transformation, and resource overexploitation (IPCC 2021). These pressures threaten critical ecosystem services, intensifying the challenges of maintaining water availability, food security, and energy sustainability (FAO & ITPS 2015). Projections indicate escalating water demands, decreasing rainfall, rising temperatures, and prolonged droughts (Canessa et al. 2022), exacerbating social–ecological conflicts over resource allocation. Given these dynamics, governing the WEFE nexus in the Mediterranean requires a paradigm shift, one that integrates actor values, traditional ecological knowledge, and social perceptions into policy and decision-making. Adopting an integrated resource management approach, informed by local perspectives, diverse value systems, and participatory governance, is essential to navigating the increasing complexity of social–ecological transformations in the face of climate change, environmental degradation, and socio-political pressures (Cramer et al. 2018; Rockström

et al. 2023). A more socially responsive nexus framework can enhance resilience, promote just resource distribution, and foster adaptive governance mechanisms that reflect the lived realities of communities across the Mediterranean and beyond.

Within this context, this study focuses on broadening the scope of WEFE nexus research by incorporating diverse value perspectives, particularly those extending beyond economic considerations. It adopts two complementary frameworks: the Diverse Values of Nature framework (Chan et al. 2018; IPBES 2022; Pascual et al. 2023) which categorizes values into instrumental, intrinsic, and relational dimensions, and the Human–nature Connectedness (HNC) framework (Ives et al. 2018). The HNC framework sheds light on the key factors shaping human–nature relationships, including material (extraction and consumption of resources), experiential (direct interaction with nature), cognitive (values, attitudes, and knowledge about nature), emotional (affective bonds with nature), and philosophical (deep-seated worldviews about nature) dimensions (Schultz 2002; Ives et al. 2018).

To the best of our knowledge, no prior study has applied the HNC framework to examine people's connectedness to nature within WEFE nexus systems. Additionally, drawing from the value types outlined by the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2022), instrumental, intrinsic, and relational values, our study seeks to uncover how the WEFE nexus contributes to local actors' well-being beyond standard economic valuation. By integrating both perspectives within the nexus thinking, this study aims to explore how local actors, especially farmers and actors from the agricultural sector, in seven Mediterranean case studies perceive the various benefits of the WEFE nexus and how these relate to human well-being through human–nature connection processes (López-Zayas et al. 2024). Furthermore, by combining the HNC framework with the value of nature types within the WEFE nexus approach, this study aims to reflect and point out how different dimensions of HNC, together with the multiple values that sustain those dimensions, shape how people relate to and interact with WEFE nexus components (Lehnen et al. 2022). (Fig. 1). This integrated perspective helps uncover how values and connections to nature can drive shifts in resource management, governance, and policy, ultimately leading to more sustainable and inclusive WEFE nexus approaches. Specifically, this research addresses the following key questions: (i) What types of values are associated with the WEFE nexus beyond conventional market-based considerations? (ii) How do these values relate to different dimensions of human well-being? (iii) Which dimensions of human–nature connectedness play a significant role in shaping WEFE values?

This study provides valuable insights for the WEFE nexus literature by directly integrating and combining diverse frameworks into the WEFE nexus approach, encompassing the Human–nature Connectedness (HNC), the multiple Values of Nature, and the leverage points perspective, to explore values associated with the WEFE nexus beyond monetary ones. Through cross-comparative case studies in seven Mediterranean countries, it provides empirical evidence that emphasizes the role of non-monetary values and context-specific relationships shaping perceptions of the WEFE nexus. Finally, the study highlights the importance of considering human–nature connectedness and diverse components of human well-being as potential leverage points for advancing transformative governance within WEFE nexus approaches.

The article is organized as follows: next section outlines the theoretical background, describing the approaches applied in this study and how they are integrated. Following section 3 presents the case study areas, interview design, and the methods used for data collection and analysis. Next section 4 details the results, focusing on the diverse values, dimensions of human–nature connectedness, and their links to well-being across the seven case studies. Finally, last section discusses the main findings, highlighting differences among the case studies, key

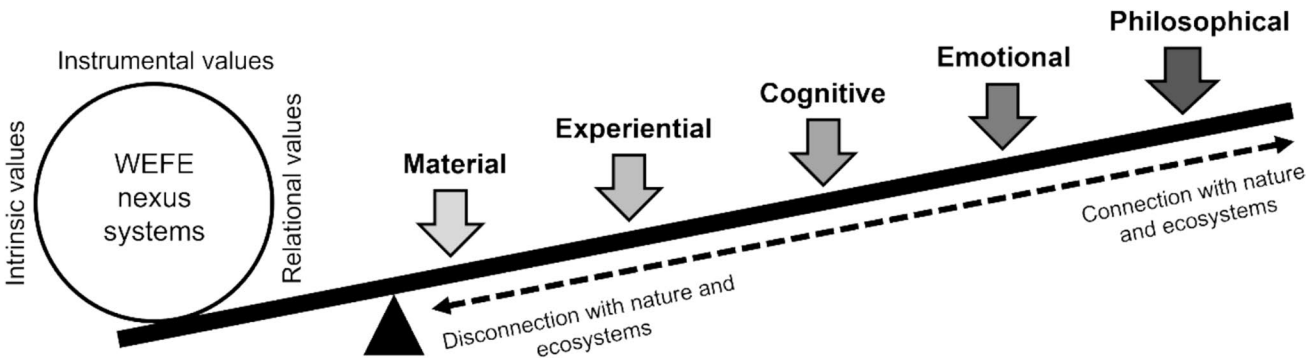

Fig. 1 Application of Human–Nature Connectedness (HNC) and Values of Nature framework within the WEFE nexus approaches

implications, and recommendations for more inclusive and value-oriented WEFE nexus governance.

Theoretical approaches

To deepen the analysis of values within the WEFE nexus, this study integrates three interrelated but different conceptual frameworks: the Diverse Values of Nature, Human–nature Connectedness (HNC), and the Leverage points framework for pathways for sustainability transformations (Table 1). Each of these frameworks offers complementary insights for understanding how local actors perceive and relate to WEFE nexus components, and how these perceptions can inform governance and environmental decision-making.

The *Diverse Values of Nature* framework (IPBES 2022; Chan et al. 2018) distinguishes between instrumental, intrinsic, and relational values people assign to nature. These multiple values help identify the ethical, utilitarian, and socially embedded meanings attributed to water, energy, food, and ecosystems.

The *Human–Nature Connectedness (HNC)* framework (Ives et al. 2018) provides a multidimensional lens for exploring how individuals and social communities connect and relate to nature across material, experiential, cognitive, emotional, and philosophical dimensions. These dimensions capture how people engage with nature physically, emotionally, intellectually, and through their worldviews and values.

The *Leverage points* approach developed by Meadows (1999) identifies specific interventions within systems where small shifts can produce important changes. In this study, we analyze how values and HNC dimensions themselves may serve as shallow (i.e., changing practices) or deep (i.e., changing mindsets and values) leverage points for transformative change in WEFE nexus governance.

While these frameworks and approaches consider different perspectives and point of views, they partially overlap and cross when applied empirically. For instance, a participant quote describing deep emotional attachment to landscape could simultaneously reflect a relational value, an emotional HNC dimension, and a deep leverage point. Similarly, different well-being dimensions may be associated with either instrumental or relational values, depending on the context. We acknowledge these overlaps among the frameworks not as contradictions, but as opportunities for deeper and richer understanding and interpretation.

By combining these approaches, this study aims to move beyond narrow analyses confined to a single framework of the WEFE nexus. Integrating the lenses of values, connectedness, and transformation enables a deeper understanding of what local actors value, how they relate to these values, and which aspects of these relationships may support meaningful shifts in WEFE nexus systems. This multidimensional approach reveals "bundles" of values, connections, and well-being perceptions that would likely remain hidden if only one framework were applied.

Methods

Case studies' description

Our case studies include seven countries across the Mediterranean Basin: Spain, Portugal, Lebanon, Morocco, Jordan, Italy, and Tunisia (Fig. 2). The seven case studies were selected for their relevance to the food sector within diverse WEFE nexus social–ecological systems. Together, they represent a broad spectrum of agricultural and social–ecological contexts across the Mediterranean Basin, each facing specific pressures on water, energy, food production, and ecosystem management, as well as climate-related constraints (Iglesias and Garrote 2015). Despite this diversity, the case studies also share interconnected challenges, including water scarcity, agricultural intensification, and ecosystem service degradation. These factors make them particularly suitable for examining how agricultural stakeholders in different contexts perceive and value the multiple dimensions of the WEFE nexus.

The Axarquía case study (Spain). Located in Málaga, Southern Spain, the Axarquía region spans 1023.51 km^2 and is characterized by mountainous terrain and limited water resources. Agricultural expansion, particularly in subtropical crops like avocados and mangoes, has intensified water scarcity. The La Viñuela reservoir, the region's main water source, has reached historic lows, holding only 12% of its capacity. The situation is worsened by small river basins, insufficient large-scale storage, and increasing reliance on private reservoirs, desalination, and wastewater treatment. Rising water demand from agriculture, population growth, and urban development has created a pressing water management crisis (Junquera et al. 2024).

The Beqaa Valley case study (Lebanon). As Lebanon's main agricultural hub, the Beqaa Valley contains 55% of the country's irrigated land and produces 42% of its crops, including cereals, legumes, and vegetables. However, semi-arid conditions and heavy reliance on groundwater have led to overextraction, surpassing natural recharge rates. The region also faces increasing environmental stress due to ongoing governmental and economic crises, further complicating sustainable water management (Khalil 1989; Halwani and Halwani 2022).

Table 1 Summary of the main characteristics, operationalization, and overlaps across the frameworks integrated in this study

Framework/approach	Key dimensions	Operationalization in the study	Conceptual overlaps and cross-links
Diverse Values of Nature (IPBES 2022; Chan et al., 2018)	Instrumental value Intrinsic value Relational value	Coded open-ended interview responses about the perceived importance of water, energy, food, and ecosystems. Participants explained *why* each component of the WEFE nexus was important	Instrumental values often link with material HNC and well-being dimensions like economic security or livelihoods Relational values often co-occur with emotional or philosophical HNC, and with social relations or identity dimensions of well-being Value types often can represent leverage points in the system (e.g., value shifts = deep levers)
Human–Nature Connectedness (HNC) (Ives et al. 2018)	Material Experiential Cognitive Emotional Philosophical	Used Likert-scale ratings and open-ended justifications for connection to WEFE components. Responses coded into HNC dimensions	HNC dimensions often overlap with values (e.g., emotional bonds with land = relational value) Philosophical/emotional HNC can be linked to deep leverage points Material/cognitive HNC can be linked to shallow–mid leverage points Some quotes of participants can reflect multiple HNC dimensions simultaneously
Leverage points (Meadows 1999; Chan et al. 2020)	Shallow Deep	Used as an analytical lens in discussion to interpret which values and HNC dimensions function as diverse system levers	Relational and intrinsic values often relate to deep leverage points (e.g., sense of responsibility, ecological ethics, social cohesion) Cognitive and material HNC represents more shallow/mid-level levers (e.g., knowledge, cognitive understanding) Well-being dimensions like agency or social cohesion can align with deeper leverage points
Human well-being dimensions (López-Zayas et al. 2024)	Social relations Economic/physical security Agency and political voice Education Ecosystems Health	Interview responses mapped to 9 adapted well-being categories. Links established via thematic coding of values and HNC responses	Specific well-being dimensions can be tied to value types (e.g., income = instrumental; identity = relational) Some well-being outcomes (e.g., agency, health) reflect transformation and connect with deep levers in the system Many well-being dimensions (e.g., social relations) intersect with both HNC and value frameworks

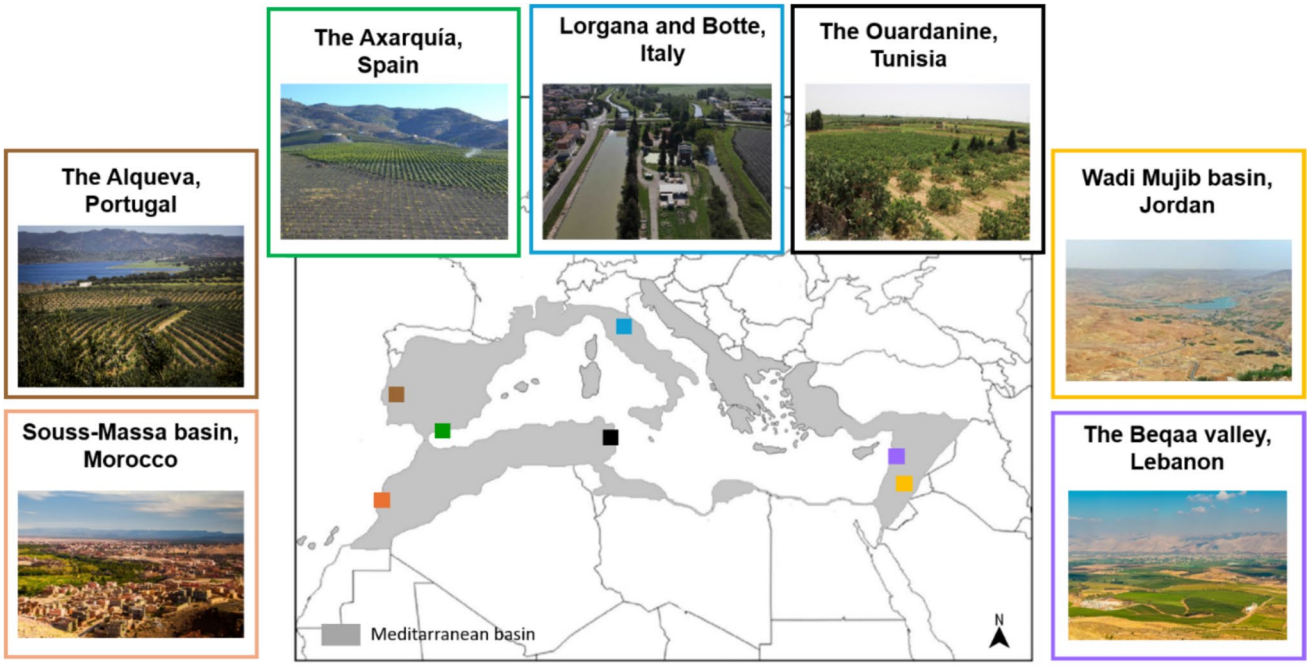

Fig. 2 Study area and localization of the seven case studies in the Mediterranean Basin

The Alqueva irrigated area in Alentejo region (Portugal). The Alqueva Multi-Purpose Project on the Guadiana River includes a large-scale dam (4150 hm^3 capacity), irrigation channels, and hydropower plants. It has transformed the Alentejo region by increasing water availability, shifting traditional cereal steppes to permanent crops like olive groves, vineyards, and almond orchards through intensive irrigation. While benefiting farmers and consumers of olive oil, nuts, and wine, agricultural intensification and climate change have led to severe environmental and socio-economic issues. Challenges include water scarcity, soil degradation, biodiversity loss, chemical imbalances in surface waters, and the decline of traditional ecosystems like the Montado (Morgado et al. 2022).

The reclaimed water irrigated area of Ouardanine (Tunisia). Located in Monastir Governorate, Tunisia, Ouardanine has faced aquifer salinization, prompting farmers to adopt secondary treated wastewater for irrigation since 1996, later upgraded to tertiary treatment in 2022. Reclaimed water has improved the landscape by reducing effluent discharge into the Guelta stream, creating jobs and enhancing community welfare (Mahjoub et al. 2017). With one of Tunisia's highest levels of farmer acceptance of reuse and agricultural intensification, the practice has yielded economic, environmental, and social benefits (Mahjoub et al. 2022). However, reliance on electricity for irrigation and the low water governance remain a challenge, as power cuts during peak hours' consumption leads to disruption of the water supply which may result in conflicting relations among the community.

Lorgana and Botte irrigation district (Italy). Lorgana and Botte irrigation district is an area of about 24,500 ha falling within the Renana Land Reclamation Consortium (CBR) area, which collectively manages 3419 km^2, including the Metropolitan City of Bologna. The region has a subcontinental temperate climate, with hot, humid summers and cold winters. Irrigation in the area takes place through artificial channels and pressure pipelines that have the function of conveying water to the farms and collecting drainage water and discharging it into water bodies. It is an important agricultural area with main crops such as cereals, legumes, and industrial crops. The selected area is characterized by clear water inputs and outputs and the presence of a large area (1.300 ha) of wetlands, which have an important environmental function. Moreover, different sewage treatment plants discharge their effluents into the irrigation network, representing a case of indirect water reuse.

Wadi Mujib Basin (Jordan). Located in central Jordan, Wadi Mujib Basin covers 6727 km^2, making it one of the country's largest basins. It is crossed by Wadi al Walah and Wadi Mujib, which merge into the Mujib River near the Dead Sea. The region has an arid to semi-arid climate, with summer temperatures exceeding 40 °C and winter nights dropping below 10 °C. Key industries include phosphate mining in the upper basin and potash production along the Dead Sea. The area also hosts two major protected zones: the Dead Sea Biosphere and Mujib Biosphere Reserve. Climate

change has led to irregular rainfall and more extreme weather events, exacerbating land degradation. The Walah Dam, built in 2003, is a crucial water source, but much of the basin's water is diverted to Amman for drinking purposes (MWI 2016). Hydroponic farming, powered by solar energy, offers a sustainable alternative to traditional agriculture, requiring minimal water and land while reducing pesticide use (Al Naber and Molle 2017).

Souss-Massa Basin (Morocco). Located in western Morocco, the Souss-Massa Basin spans 27,000 km^2, with 21% plains and 79% mountains. It is bordered by the Anti-Atlas to the south, the High Atlas to the north, the Siroua Massif to the east, and the Atlantic Ocean to the west. The semi-arid Mediterranean climate is influenced by the ocean, the Canary Current, and the Sahara. Water availability fluctuates due to climate change, with surface water quality deteriorating downstream of urban areas. The basin contains key aquifers, essential for ecosystems and agriculture. Despite limited fossil resources, the region has high solar energy potential. Agriculture, particularly citrus and early vegetable production, is the main economic driver, contributing over 74% of the total economic value. However, irrigation is highly water- and energy-intensive, posing sustainability challenges.

Interview design and social sampling

For data collection, we use in-depth semi-structured interviews with local actors in each of the seven Mediterranean case studies. The interviews were conducted in the local languages of each case study, including Portuguese, Spanish, Arabic, Italian, and local dialects. The social sample was carefully designed and focused to capture the perspectives of local people with potential direct or indirect connections to the WEFE (water–energy–food–ecosystems) nexus at a local scale. The interconnections and interdependencies among water–energy–food–ecosystems are especially pronounced in the agricultural sector, where all dimensions of the Nexus are deeply interconnected in practical and context-specific terms. For this reason, our focus was primarily on actors from the agricultural sector, encompassing key local actors such as farmers, agricultural businesses, cooperatives, and water companies linked to agriculture. Participants meeting these criteria were selected in each case study, where in-depth, face-to-face interviews were conducted with the assistance of local actors. The number of semi-structured interviews (ranging from 11 to 21 per case study) was chosen to balance cross-case comparability with the depth required for qualitative analysis. This approach is consistent with established qualitative research standards and aligns with thematic saturation criteria for case study research (Guest et al. 2006).

The interview outline was organized into several sections to gather information on: (i) the diverse values agricultural local actors associate with the WEFE nexus, including potential links to human well-being dimensions; (ii) human–nature connectedness (HNC), referring to participants' perceptions of material, experiential, cognitive, emotional, and philosophical dimensions that explain their connection (or disconnection) processes to the WEFE nexus; (iii) sociodemographic data of participants, such as age, gender, education level, and occupation (Appendix 1). The interviews included both yes/no and open-ended questions, allowing participants to express their opinions freely and provide examples. The interview template was adapted to suit different local contexts, with terminology adjusted to minimize biases arising from varying interpretations of terms across regions. These adjustments were developed collaboratively with the local moderators responsible for conducting the interviews and tested with them to ensure clarity and comprehension for participants. Interviews were conducted across seven case studies between July and October 2024, resulting in a total of 110 interviews. All interviews were recorded, transcribed, and subsequently translated into English for further analysis.

Data analysis

The data collected from interviews in each case study were systematically entered into an Excel database to facilitate subsequent analysis. To assess the diverse values associated with the WEFE nexus, participants were asked to indicate whether they perceived water, energy, food, and ecosystems in their region as important and explain why. Responses to the open-ended "why" question were categorized based on the types of values expressed, following the frameworks of Arias-Arévalo et al. (2018) and IPBES (2022), and adapted to the WEFE nexus context. The values were classified into: (i) instrumental values, reflecting the utility and direct benefits of nature, such as economic benefits people obtain from WEFE nexus components; (ii) intrinsic values, representing the inherent worth of nature, including ethical and moral considerations they associate with WEFE nexus; (iii) relational values, emerging from human–nature relationships, encompassing principles, virtues, and responsibilities that local people identify within the WEFE nexus social–ecological system. The frequency of responses associated with each value type was calculated and visualized using a bar graph.

To explore the potential relationships between human well-being and the perceived WEFE nexus values, participants were invited to express their views on various statements reflecting different WEFE nexus values and to freely explain their agreement or disagreement with those statements. The open-ended responses to these statements were

reclassified into nine components of human well-being, based on the categories used in López-Zayas et al. (2024) and adapted for this study. The categories included: quality of life, education, physical and economic security, material standards of living, leisure and other outdoor activities, agency and political voice, health, social relations, and ecosystems. The percentage of responses corresponding to each human well-being dimension was calculated for each case study, providing insights into the perceived links between WEFE nexus values and human well-being.

Finally, the five dimensions of HNC associated with the WEFE nexus were explored by asking participants to respond to specific statements (one for each HNC dimension). Importance was assessed using a ranking scale ranging from "Nothing" to "Everything" (equivalent to a Likert scale from 1 to 5). The relative frequencies of responses for each HNC dimension were calculated and presented using a Nightingale diagram, created with the Excel plug-in Kutools. Qualitative content analysis was then performed on the "why" responses to identify key examples corresponding to each HNC dimension, enriching the understanding of how people perceive and describe their connections to the WEFE nexus.

Results

Sociodemographic characterization of the social sampling

A total of 110 in-depth interviews were conducted across seven Mediterranean countries. Of these, 19% ($n=21$) were conducted respectively in Jordan and Morocco, 13.6% ($n=15$) in Italy and Portugal, and between 12.7% and 10% in Spain, Lebanon, and Tunisia, respectively ($n=14$, 13, and 11). The sample revealed a clear gender imbalance, with males comprising 71.9% ($n=79$) of participants and females 28.1% ($n=31$). Most participants were aged between 31 and 55 years (59%, $n=65$), followed by those aged 18–30 years (21.8%, $n=24$), and a smaller group over 55 years old (18.2%, $n=20$). The majority of participants had a university education (64.5%, $n=71$), while 30% ($n=33$) had a non-university education, and 3.6% ($n=4$) had no formal education. All the people interviewed were local actors engaged directly or indirectly with the agricultural sector, including farmers, agricultural entrepreneurs, members of agricultural cooperatives, and representatives of local irrigation and water companies across the seven case studies. Table 2 provides a detailed description of the main sociodemographic characteristics of the respondents.

Values associated with the WEFE nexus

Instrumental values were the most frequently mentioned by local respondents (69% of total responses). However, intrinsic and relational values were also recognized across the seven Mediterranean case studies, with intrinsic values emerging as the second most frequently mentioned (37%), whereas relational values were the least frequently mentioned (28%) (Fig. 3).

This distribution of value types varied across the seven case studies, with *instrumental values* dominating in most regions. For example, in all case studies more than 50% of responses attributed instrumental values to the WEFE nexus.

Table 2 Sociodemographic characterization of the social sample

Sociodemographic variables	Categories	Number of respondents	% of respondents
Country	Lebanon	13	11.8%
	Portugal	15	13.6
	Spain	14	12.7
	Tunisia	11	10.0
	Morocco	21	19.1
	Jordan	21	19.1
	Italy	15	13.6
Gender	Female	31	28.18
	Male	79	71.81
Age	18–30 years	24	21.81
	31–55 years	65	59.0
	> 55 years	20	18.2
Educational level	No university	33	30.0
	University	71	64.5
	No studies	4	3.6
Total number of respondents	$N=110$		

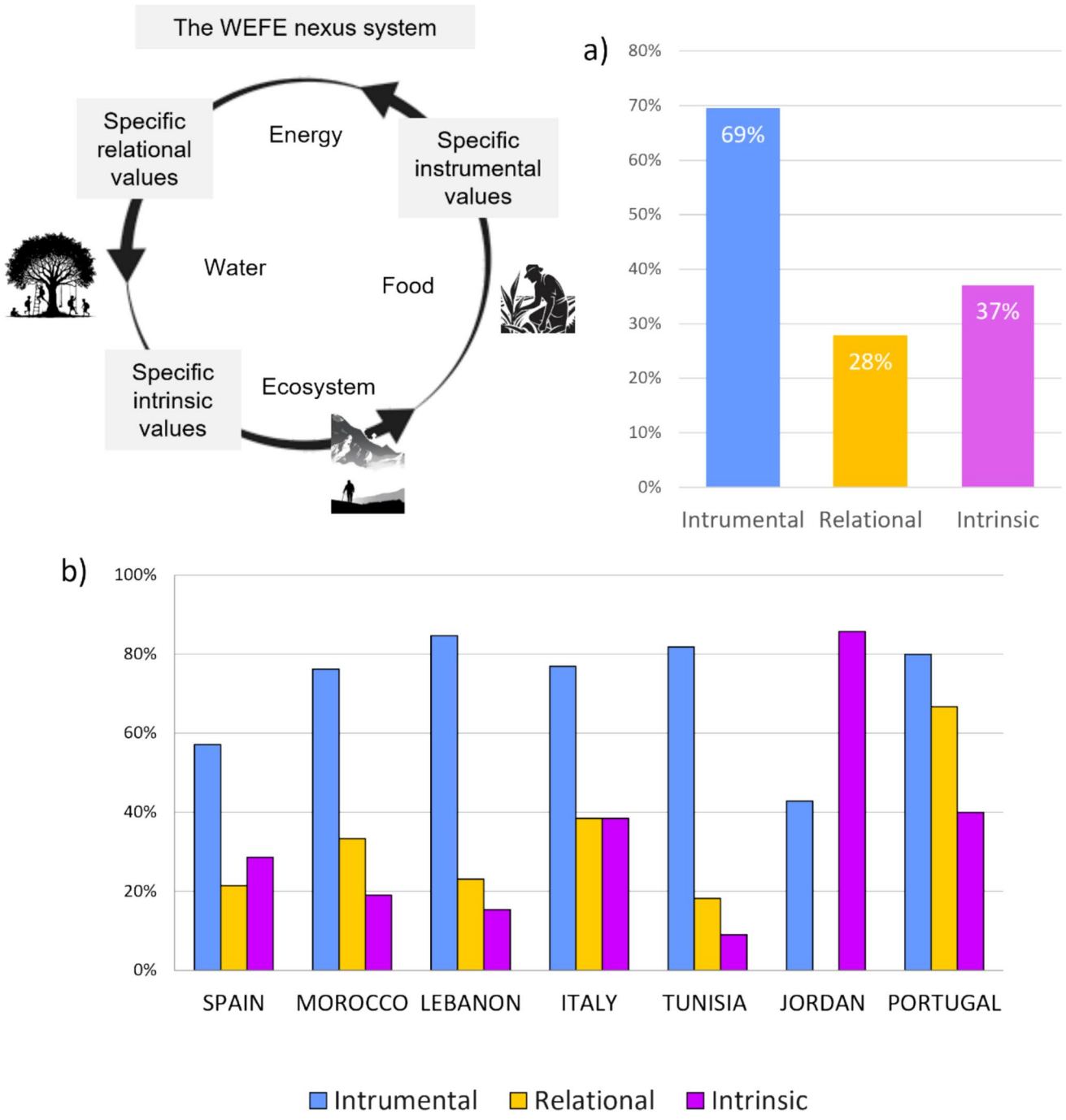

Fig. 3 Instrumental, intrinsic, and relational value types associated with the WEFE nexus: (**a**) across all seven case studies and (**b**) presented separately for each case study. Figure adapted from Geissberger and Chapman (2023)

In Jordan, however, only 43% of responses identified instrumental values. Examples of instrumental values include the dependence on and utility of water, energy, food, and ecosystem components for economic benefits, production capacity, and local development. For instance, respondents noted: *"Because we live off the land, we must ensure that there is no lack of resources"* (respondent from Spain); *"They are the basis of all production processes and are part of everyday life"* (respondent from Italy)*; "These components are connected and important. They help us achieve abundant production and improve the living standards of the local community"* (respondent from Tunisia); *"It is the foundation of everything and supports economic development"* (respondent from Jordan).

In contrast, Jordan had the highest proportion of responses attributing *intrinsic values* to the WEFE nexus (86% of responses), compared to 40% in Portugal, followed by Italy, Spain, Morocco, and Lebanon. Tunisia recorded the lowest proportion of responses (9%). Intrinsic values expressed by local people emphasized the fundamental importance of WEFE components for life, ecosystems, and biodiversity: *"Without them, we would not have the kind of life we have"* (respondent from Spain); *"It is the foundation of life and diversity"* (respondent from Jordan).

Relational values were the least frequently mentioned type (28% of total responses). They were mentioned in all case studies except in Jordan, where responses predominantly reflected intrinsic values, highlighting strong moral and ethical attachments to nature rather than social or place-based connections. They were most cited in Portugal (67%), followed by Italy (38%), Morocco (33%), Spain (21%), Lebanon (23%), and Tunisia (18%). Among the main reasons local respondents associated relational values with the WEFE nexus, there was the importance of WEFE components for communities, families, ecosystems, traditions, and sustainable practices for the local actors, such as: *"We have a deep-rooted connection to this land because it has been passed down through generations"* (respondent from Portugal); *"Food plays a cultural role, bringing people together"* (respondent from Lebanon); *"We've always been taught to look at our land and understand what we can produce for both livelihood and service to others"* (respondent from Portugal).

Relationships between human well-being and the WEFE nexus

We identified diverse patterns of relationships between the values associated with the WEFE nexus and components of human well-being (Fig. 4). The results revealed that the nine components of human well-being were mentioned differently across the seven case studies, highlighting contextual, location-specific connections between the WEFE nexus and human well-being. In the Moroccan case study, all nine dimensions of well-being were mentioned, followed by Jordan with eight dimensions; Spain, Lebanon, and Portugal with seven; and Tunisia with six.

Across all case studies, the "Social Relations" dimension of human well-being was the most frequently linked to the WEFE nexus at local scales. It was mentioned by more than 50% of respondents in all case studies (except in Italy, where 46% mentioned it). Examples of responses include aspects related to a sense of place, a sense of community, and social interactions: *"I enjoy the Sierra Tejeda, it's super important for me. I identify myself with the olive groves of the Axarquia"* (Spain); *"As people of the Sous*

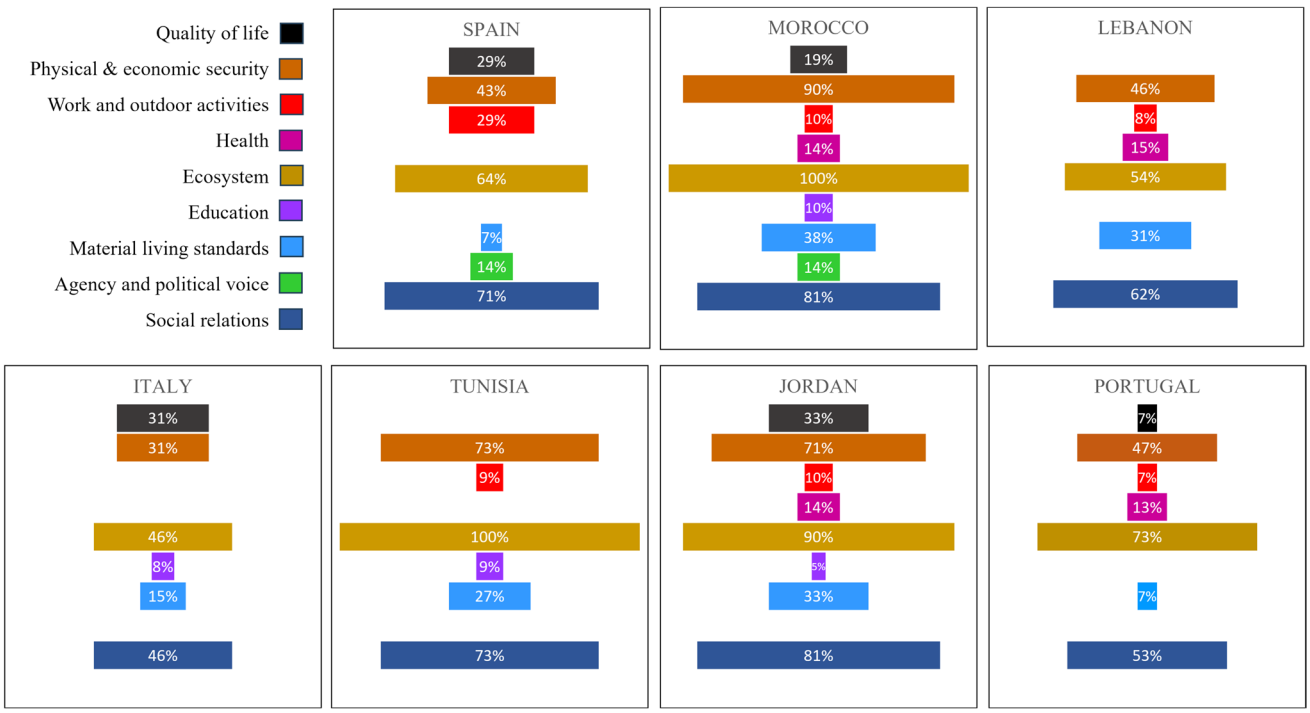

Fig. 4 Percentage of responses referencing various values associated with different dimensions of human well-being linked to the WEFE nexus, categorized by case studies. Each color represents a specific dimension of human well-being. Human well-being dimensions were adapted from López-Zayas et al. (2024)

Massa region, we have a strong identity and cultural heritage that is linked to the land and nature" (respondent from Morocco)*;* or *"As Amazigh people we have a strong identity and a strong cultural patrimony that is linked to the land and nature. A lot of proverbs show this attachment to the land and the importance of water"* (respondent from Morocco).

The "Ecosystem" dimension was the second most frequently mentioned across the case studies. In Morocco and Tunisia, all respondents (100% of responses) referred to this dimension, followed by Jordan (90%) and Portugal (73%). This dimension reflects the critical role of ecosystems in maintaining balance and supporting livelihoods, linked to landscape elements, together with a clean environment and cultural heritage: *"I believe that the interconnectedness between water, energy, food, and the land is something that we must respect, not only because it's important for human use but also because between these elements there is a natural balance that we cannot afford to neglect. Each element has a vital role in sustaining the ecosystems around us and ensures that humans and the environment can coexist"* (respondent from Morocco).

The "Physical and Economic security" dimension was also widely linked to WEFE values, appearing in all case studies. It was most frequently mentioned in Morocco (90% of responses), Jordan (71%), and Tunisia (73%). Examples refer to security and economic benefits derived from the WEFE nexus: *"These components are connected to my source of income, which is agriculture"* (respondent from Tunisia); *"My region is rich in these elements that help the people live better and discover many new things about it. Moreover, the interaction of these elements creates new opportunities for work and socialising"* (respondent from Italy).

The "Material Living Standard" dimension appeared in all case studies, with the highest frequency in Morocco, Lebanon, and Jordan (30–40% of responses), followed by Tunisia, Italy, Spain, and Portugal (20–7%). This dimension includes aspects related to private and public services: *"Availability of job opportunities, food, and comfortable living"* (respondent from Jordan); *"Thanks to agriculture, there are more jobs and better working conditions, which allows us to have a higher quality of life and to prosper economically"* (respondent from Portugal).

The "Leisure and Outdoor Activities" dimension was identified in six case studies, ranging from 29% of responses in Spain to 9–10% in Morocco, Jordan, Portugal, and Tunisia. This dimension was not mentioned at all in the Italian case study. Examples are: *"I enjoy the WEFE components through tourism and recreational trips"* (respondent from Jordan); *"I grew up spending a lot of time in nature. I love the indigenous species in Lebanon, including working with native grape varieties. I also enjoy spending time with my family in nature, which strengthens my connection to the environment and my culture"* (respondent from Lebanon).

The "Health" dimension was associated with WEFE values in Morocco, Lebanon, Jordan, and Portugal, with approximately 15% of respondents mentioning it. Examples of the Health dimension are: *"Nature provides relaxation and calmness for the soul"* (respondent from Jordan); *"Because I produce good and healthy food first, and then, I am indirectly benefiting economically"* (respondent from Lebanon); *"Nature has always existed; it is up to us to adapt and acclimatize in a healthy way to ensure its sustainability. We must respect nature and production factors to live better and value them efficiently and rationally"* (respondent from Morocco).

The "Education" dimension was observed in Morocco, Italy, Tunisia, and Jordan, with low response rates, peaking at 10% in Morocco. This dimension includes aspects related to learning from nature and raising children, such as: *"Without the availability of these elements, we wouldn't be able to live in a region where we build our lives and educate and raise our children"* (respondent from Tunisia).

Finally, the "Agency and Political Voice" dimension was the least frequently linked to the WEFE nexus, mentioned only in Spain and Morocco, with 14% of responses: *"[…] Although they are in some areas starting to disappear, local farming methods, water conservation techniques, and land management practices are all designed to work with nature rather than against it and that nature has the right to exist, evolve, and regenerate"* (respondent from Morocco).

The Human–Nature Connectedness dimensions associated with the WEFE nexus

The results revealed a diversity of perceived importance of the different dimensions of Human–Nature Connectedness (HNC) linked to the WEFE nexus across the seven case studies. In general, respondents gave the highest value of importance (corresponding to the level 5 "high importance") to the philosophical dimension (89% of responses), followed by the material (32%), experiential (29%), and emotional (27%) dimensions (Fig. 5). The cognitive dimension was chosen by 24% of respondents as very high importance (level 5 of the Likert scale) and 24% as medium–low importance (level 3–2 of the Likert scale), making this dimension the one where respondents associated lower importance. In addition, the material and emotional dimensions also showed medium–low values of importance (21% of responses, level 3–2 of the Likert scale).

In the *material dimension*, perceptions of importance varied across the seven countries. Tunisia placed the highest emphasis: 73% considering material aspects very important, though 9% rated them as of very low importance. Italy also showed strong recognition. All respondents rated this

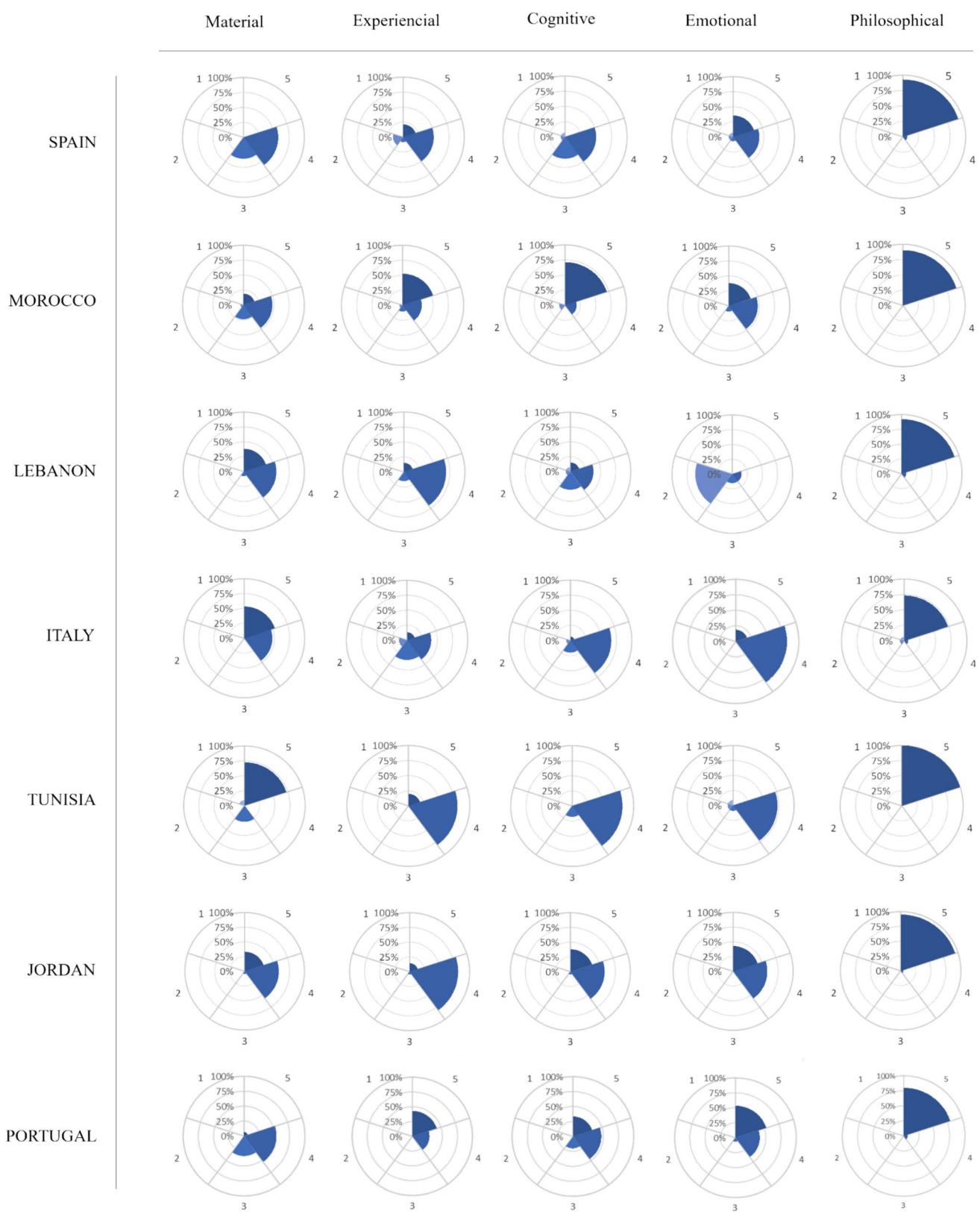

Fig. 5 Description of the five dimensions of HNC (material, experiential, cognitive, emotional, and philosophical) evaluated on a Likert scale from 1 to 5 for each case study. Each level represents a specific scale of values as follows: for the material dimension, 1 = nothing and 5 = everything; for experiential and emotional, 1 = very negative and 5 = very positive; for cognitive, 1 = very little and 5 = very much; and for philosophical, 1 = not important and 5 = very important

dimension as either highly important (53%) or important (47%). Lebanon and Jordan leaned toward high importance, with the majority assigning either the highest or second-highest ratings. In contrast, Spain and Portugal held more moderate views, with most respondents rating material aspects as important or neutral and very few assigning them the highest importance. Morocco presented a balanced distribution, with responses spread across high, moderate, and low importance levels. Overall, Tunisia and Italy assigned the greatest significance to material aspects, while Spain and Portugal displayed a more reserved perspective. Examples of statements related to the material dimension are: *"We consume all region's products to encourage others to use them and to convince them that they are healthy and consumable, even if they are irrigated with treated water"* (respondent from Tunisia); *"We are one of the main agricultural regions of the country, thanks to the great diversity of local products, fresher, of better quality, this stimulates the local economy while preserving our traditions"* (respondent from Spain).

In the *experiential dimension*, most respondents assigned high importance, with over 70% giving positive or very positive ratings across all surveyed countries. Morocco and Portugal stood out with the highest "very positive" ratings (53% and 64%, respectively), followed by Tunisia and Jordan, where the majority rated it positively, though with fewer "very positive" responses. In Spain and Lebanon, responses leaned positive, though Spain showed a slightly broader distribution, with 17% assigning a negative rating. Italy exhibited the most diverse responses, with lower "very positive" ratings (13%) and a higher proportion of neutral (33%) and negative (13%) evaluations. Overall, the dimension was highly valued, especially in Portugal, Morocco, and Tunisia, while Italy and Spain displayed more varied perceptions. Some examples of the experiential dimension are: "*I still appreciate what's offered. I have good feelings towards it. It keeps giving us, nature is very generous*" (respondent from Lebanon); "*It gives me peace, beauty, and a sense of belonging*" (respondent from Portugal); *"It is a landscape that does not correspond to its habitat, it has been heavily modified since the 1960s"* (respondent from Spain); *"I believe that unfortunately my region is very overexploited from a natural point of view"* (respondent from Italy).

In the *cognitive dimension*, perceptions of importance varied across countries, with some emphasizing its significance while others maintained a more balanced view. Morocco placed the highest value on this dimension, with 71% rating it as "very much" and 19% as "quite a bit". Jordan followed closely, with similar high ratings. Tunisia and Italy also recognized its importance, though in Italy, only 7% selected the highest rating, while most rated it as "quite a bit". Portugal showed a similar trend, with a mix of strong and moderate importance ratings. In contrast, Spain and Lebanon displayed more varied perspectives, with a significant proportion of neutral and lower ratings. Overall, Morocco, Jordan, and Tunisia assigned the greatest importance to the cognitive dimension, while Spain and Lebanon exhibited more diverse views. Respondents acknowledge the cognitive dimension by stating the level of knowledge they have of their region, examples of these statements are: *"I know how landscape works, because I've lived here since I was born and because I work in an agricultural co-operative, specifically a wine co-operative, so I observed the functioning and mechanisms from it" (Respondent form Portugal)*; "*I am knowledgeable because I work in this field, but I can still learn more"* (respondent from Tunisia).

In the *emotional dimension*, most countries showed predominantly positive responses, with some exceptions. Portugal, Jordan, and Morocco had the highest "very positive" ratings (53%, 43%, and 38%, respectively), reinforced by strong "positive" perceptions. Italy also showed a highly positive outlook, with 87% rating it as positive and 20% as very positive. Spain and Tunisia followed a similar trend, though with more varied responses, including some neutral and negative ratings. While emotional and philosophical connections were widely appreciated in most countries, the emotional dimension was less emphasized in Lebanon, which stood out as an outlier, with 62% of respondents rating this dimension negatively and only 15% giving it a positive evaluation. Overall, Portugal, Jordan, and Italy had the strongest positive perceptions, while Lebanon displayed a predominantly negative assessment. Examples of emotions that respondents expressed were: *"Diverse, vibrant, attractive, the most suitable environment for agriculture"* (respondent from Jordan); *"Freedom, countryside, good food. Because we look and we have a brutal freedom, anywhere, we look and we only see the blue sky […]"* (respondent from Portugal); "*Available but not sustainable, precious, rare"* (respondent from Lebanon).

In the *philosophical dimension*, the majority of respondents across the seven case studies considered it highly important, with over 90% assigning it the highest rating in most countries. Exceptions were found in Portugal, where 80% rated it as highly important while 7% considered it important, and in Italy, where 73% assigned the highest value, 7% rated it as important, and 14% considered it of low importance. The main arguments for valuing this dimension were linked to eudaimonic stewardship, emphasizing the necessity of nature for a good life, such as: *"It is fundamental to my well-being"* (respondent from Spain); *"Nature is central to our life and I feel a deep sense of responsibility to protect and preserve it for future generations"* (respondent from Morocco); *"It is a reflection of who I am"* (respondent from Lebanon); *"I see nature as my psychologist. Without regular time spent in nature, I feel that I am missing something essential in life"* (respondent from Portugal).

Discussion

Nature's values in the WEFE nexus and well-being

Our findings show that local actors interpret the WEFE nexus not only through instrumental lenses (e.g., food, irrigation), but also through intrinsic and relational values. These are rooted in moral, cultural, and place-based attachments, shaping how communities understand and interact with the WEFE system. A close examination of the seven Mediterranean case studies reveals significant contextual variation. Thereby, the predominantly technical and quantitative focus of WEFE research and policy is challenged, which often overlooks the social and cultural dimensions of environmental decision-making. Recognizing this spectrum of values may enhance sustainability, policy relevance, and actor engagement, providing insight into how individuals and societies express the importance of nature beyond mere resource use (Sanya et al. 2025; Schlemm et al. 2024).

The distribution of value types in our study is influenced by shared Mediterranean socio-environmental challenges, as well as by the agricultural focus of our sample. This orientation embeds nexus thinking within the lived realities of food production, irrigation, and landscape stewardship. It often prioritizes water and food, while energy is more implicitly connected to production processes. For example, results highlight how this agricultural lens shapes value assignments to WEFE components, emphasizing tangible benefits such as irrigation water, food production, energy for agriculture, and soil fertility (Al-Zúbi et al. 2024).

Beyond economic reasoning, local actors emphasized intrinsic values, often seen as opposing instrumental values. This reflects the belief that nature has inherent worth beyond human utility, and a moral obligation to protect and conserve ecosystems as life-sustaining entities (Himes et al. 2024; Pascual et al. 2017). In our study, intrinsic values, reflecting biocentric and ecocentric worldviews (King 2006), are also closely tied to cultural heritage and spiritual beliefs, particularly in Jordan and Morocco. For instance, Jordanian respondents' emphasis on intrinsic value may stem from Islamic environmental ethics that stress human responsibility toward nature beyond utilitarian concerns (Sayem 2021). In Italy, a severe 2022 drought and subsequent flooding heightened agricultural actors' sensitivity to ecosystem health, often outweighing economic priorities (Chelli 2023).

Respondents also highlighted relational values tied to sense of place and identity associated with WEFE nexus components. Agricultural actors often emphasized the importance of traditional and ecological knowledge in managing these components. This reflects the central importance of land, ecosystems, and biodiversity in shaping territorial identity (Ortiz-Przychodzka et al. 2023). In both Portugal and Spain, WEFE systems structure daily life and cultural identity, aligning with findings from other studies on rural Spanish communities (López-Moreno et al. 2024; Arias-Arévalo et al. 2018). In Portugal's Alentejo region, for example, relational values expressed by local actors are particularly strong due to their direct and ongoing relationship with the environment. This relationship is rooted in agricultural activities, low population density, and rural traditions such as *cante alentejano*, a UNESCO-recognized cultural heritage (UNESCO 2008). These factors strongly contribute to a sense of belonging and reinforce local identity. Similarly, a Berber respondent in Morocco described a sacred, cyclical connection between agriculture, festivals, and land, emphasizing reverence for nature and sustainable local farming practices rooted in ancestral knowledge: *"I belong to the berber community and as a berber, we, from the inheritance of our ancestors, have a deep reverence to nature and we know that we need to respect her and preserve her. The land, the mountains, the trees, the animals are a part of a sacred landscape. Festivals, celebrations and oral traditions are linked to nature and the agricultural cycle. There is a particular agricultural calendar linked to nature and its rhythm. Nature has its own right to exist beyond its utility for human beings if we want it to be sustainable. […]Although it is in some areas starting to disappear, Local farming methods, water conservation techniques, and land management practices are all designed to work with nature rather than against it and that the nature has the right to exist, evolve, and regenerate"* (Respondent from Morocco). These findings illustrate how spiritual, ethical, and cultural heritage shape distinct relationships to WEFE components. There is thus a need for a comprehensive WEFE nexus framework that integrates philosophical, moral, social, and cultural dimensions. Understanding how values, practices, and well-being interrelate is essential to designing inclusive and responsive strategies for complex social–ecological interactions (Sanya et al. 2025; Riechers et al. 2025).

Our results also show that the WEFE nexus is perceived not only as providing material security but also as being foundational to human well-being. While water, energy, and food security remain core concerns linked to economic benefits, respondents connected these resources to both mental and physical well-being (Fagerholm et al. 2019; Millennium Ecosystem Assessment 2005; Great International 2024). Respondents demonstrated strong awareness of nature's role in sustaining livelihoods, knowledge systems, and traditions, aligning with "nexus thinking" that integrates ecological and social dimensions into sustainable resource management (Sambo et al. 2024).

Across the seven Mediterranean case studies, nearly all nine dimensions of human well-being were associated with WEFE elements, with ecosystem health and social relations among the most commonly cited. This confirms that nexus systems contribute not only to survival and economic benefits, but also to human–nature relationships, social bonds, and cultural identity (López-Moreno et al. 2024). WEFE components were also perceived as vital for health and education, consistent with previous research on well-being and quality of life, which encompasses basic needs, equity, and justice (Millennium Ecosystem Assessment 2005). For instance, in Morocco, a deep cultural appreciation for nature supports management strategies that balance economic needs with long-term environmental resilience was revealed by the results. Similarly, the ecosystem, material, and education dimensions of well-being were strongly perceived as interconnected, as illustrated by direct quotes from respondents in the Tunisian case study. In this context, treated wastewater is the only water resource that ensures food security, and is thus considered the main driver of economic development in the region. For the local community, the availability of treated wastewater enables food production, prevents the discharge of effluents into streams, and thus helps reduce ecosystem pollution and preserve biodiversity. As a result, local communities are very sensitive to nature, as it represents their cherished crops and inherited agricultural land that they seek to preserve for future generations. Raising the next generation in comfort is only possible when a stable income is secured, and that income is directly linked to the availability of treated wastewater.

Place-based approaches and actor engagement within WEFE nexus governance emerge as crucial for capturing how people perceive the relationships between WEFE systems and their well-being (Ortiz-Przychodzka et al. 2023; Fagerholm et al. 2020).

However, a strong awareness of these values does not automatically translate into sustainable behavior within WEFE nexus management. The Jordan case illustrates this attitude–behavior gap, where dominant narratives around water scarcity reflect tensions between external blame and resource mismanagement (Hussein 2018). Cultural priorities such as food self-sufficiency, tribalism, and traditional water rights influence resource allocation, sometimes leading to inefficiencies but also reflecting intertwined instrumental and intrinsic values.

The persistence of the attitude–behavior gap (Yir-Hueih et al. 2023) suggests that individual values must be reinforced by structural conditions that enable long-term change. These findings also prompt broader questions: How is well-being defined across different contexts? Can sustainability be achieved if food and energy production continue at the cost of ecological degradation?

Connectedness to nature in the WEFE nexus: implications for decision-making from a leverage point perspective

Across the seven case studies, respondents reported strong connections to their local WEFE nexus system. This observation contrasts with broader global trends of increasing disconnection from nature, driven by urbanization and technological advancement that reduce direct interactions with nature (Riechers et al. 2022). Such declines in material, cognitive, and emotional ties (Ives et al. 2018; Riechers et al. 2021) have contributed to the misconception that human well-being is independent of ecosystem health (Sambo et al. 2024).

Agricultural actors especially emphasized emotional and philosophical bonds with WEFE systems, valuing them as essential to personal identity, community continuity, and future well-being (Castro et al. 2023). These findings align with research highlighting place attachment, ecological literacy, and lived nature experiences as key to sustaining environmental concern and innovation (de Roo et al. 2021; Ives et al. 2018).

The Leverage points framework (Meadows 1999) helps translate these results into policy-relevant insights. Our findings align with the need to integrate diverse values and evaluations of nature, moving beyond narrow market-based approaches that often ignore intrinsic and relational values (IPBES 2022; Pascual et al. 2023). Achieving transformative change toward more equitable and sustainable WEFE governance requires identify and integrate leverage points capable of triggering systemic shifts (Riechers et al. 2021; Chan et al. 2020; de Strasser et al. 2016).

Transformative change, as defined by IPBES (2019), refers to a fundamental, system-wide reorganization that reshapes technological, economic, and social structures. Applying Meadows' (1999) Leverage points framework, we identify key intervention areas within the WEFE nexus. These areas hold the potential to catalyze deep, systemic transformations (Unai et al. 2022).

Philosophical and emotional dimensions of HNC were most widely emphasized, reflecting deep ethical commitments and affective bonds with nature. These forms of connection offer significant transformative potential when seen through the lens of leverage points. They align with deep leverage points such as values, worldviews, and paradigms, that, when shifted, can trigger wide-reaching change (Ives et al. 2018). Although such shifts are difficult to engineer directly, recognizing their presence within communities provides valuable insight into where and how transformation might take root. In Tunisia, for example, the availability of treated wastewater emerged as a key material driver of economic development. This resource sustains agriculture by enabling a shift from rain-fed to irrigated,

intensive farming, which supports crop diversification, increases yields, and fosters new markets and value chains. It has also promoted job creation and attracted investment to the region, illustrating how shallow levers can catalyze meaningful socio-economic shifts. Similarly, in Portugal's Alentejo region, respondents emphasized how the construction of the Alqueva dam transformed local agriculture, enabling irrigation for crops such as olives, wine grapes, and almonds. Water availability reshaped food production and contributed significantly to improved quality of life, allowing residents to remain in one of the country's poorest and most climatically challenging regions. Over time, these material changes became intertwined with deeper cultural and ecological dimensions, as agricultural practices were increasingly informed by traditional ecological knowledge and a strong sense of place-based identity. This connection fostered the development of sustainable wine cooperatives rooted in local knowledge.

These case studies highlight how shallow interventions, such as improved water access, can trigger broader shifts when embedded in social and ecological contexts (Gianelli et al. 2025). To better understand these dynamics, we apply the human–nature connection (HNC) framework, which considers how different dimensions of value influence transformation potential.

Our findings also reveal important contextual differences in HNC dimensions. In Tunisia and Lebanon, material and experiential connections to nature predominate, reflecting daily dependence on natural resources and pragmatic livelihood concerns. In Lebanon, governance fragmentation and instability heighten resource insecurity, further shaping farmers' practical environmental relationships despite enduring cultural ties. Similarly, in Tunisia, agricultural products irrigated with treated wastewater compete in the local market with those using conventional water, emphasizing the complex interplay between water availability, income, and well-being.

In contrast, in Spain and Portugal, emotional and intrinsic connections are more balanced with instrumental values, underscoring the role of identity and tradition in shaping sustainability perceptions. Across all sites, the cognitive dimension of HNC, related to knowledge and awareness, was generally perceived as less central, suggesting that knowledge-based interventions alone may be insufficient to drive systemic change. Instead, emotional, cultural, and livelihood-based engagements with nature represent critical entry points for participatory governance.

These context-specific variations reinforce the need for localized, adaptive governance strategies that respect diverse value systems and priorities (Castro et al. 2023). Our empirical findings highlight social factors and context-specific entry points for more inclusive WEFE governance, emphasizing the value of integrating diverse human–nature connections and values to shift governance from a technical resource management focus to one embracing social and cultural dimensions (Gianelli et al. 2025).

By activating both shallow and deep leverage points within policy, institutional frameworks, and participatory processes, WEFE governance can foster meaningful, long-lasting transformations, enabling more just and sustainable outcomes across socio-ecological contexts.

Implications for policy and practice

The integration of the Diverse Values of Nature, Human–nature Connectedness, and Leverage points frameworks provides a conceptual foundation for more inclusive, adaptive, and transformative WEFE governance.

While a general pattern emerges in our findings, indicating that multiple dimensions of well-being and multiple value types are associated with the WEFE nexus, significant contextual variation requires tailored approaches. Recognizing and integrating these differences can inform targeted policy interventions that are both socially meaningful and more likely to succeed in the long term (Unai et al. 2022; Visseren-Hamakers et al. 2021).

This has several implications for policymakers and environmental managers: (i) understand local perceptions and values: governance strategies should understand and account for the ways people value and connect to WEFE components and how these relationships influence their sense of well-being; (ii) activate both shallow and deep leverage points: policy interventions should target immediate behaviors and systems (shallow levers), while also addressing deeper structures such as worldviews and values; emotional and philosophical connections to nature can support mindset shifts necessary for transformative change; iii) tailor governance to local contexts: governance approaches must reflect the local values and worldviews communities associate with specific WEFE components; rather than imposing top-down models, policies should build on existing place-based identities, stewardship practices, and emotional attachments to nature.

Beyond these general implications, our findings also allow for case-specific reflections that illustrate how context-sensitive approaches could inform more inclusive WEFE governance across different social–ecological contexts. For instance, in Spain, strengthening water governance to address conflicts arising from subtropical crop expansion is crucial. In Portugal, policies should integrate traditional ecological knowledge from the Montado landscapes. In Italy, improving coordination between irrigation consortia and ecosystem protection is needed to ensure a sustainable trajectory of landscape management. In Tunisia, consolidating wastewater reuse policies can enhance agricultural resilience. In Morocco, cultural values and ecological knowledge should be explicitly recognized and incorporated into water

management policies. In Jordan, hydroponic and solar-based farming practices represent sustainable alternatives that require supportive governance frameworks. Finally, in Lebanon, participatory water allocation schemes are essential to address groundwater overextraction. These tailored recommendations enrich the policy relevance of the study by showing how local values and practices can be leveraged for more adaptive governance in diverse social–ecological contexts.

In Mediterranean regions facing water scarcity, land degradation, and climate challenges, strengthening human–nature relationships supports sustainability while ensuring policies are culturally meaningful, socially legitimate, and ecologically sound (de Roo et al. 2021; Riechers et al. 2025).

At the same time, it is important to recognize that fundamental trade-offs between the use of water, energy, and land resources exist. These trade-offs which also often involve important distributional and economic issues that cannot be addressed through the values alone. Fundamental systemic changes are needed to challenge the underlying paradigm of productivism, reduce the overproduction of food and food losses, and shift unsustainable dietary habits. WEFE governance cannot rely on optimizing these flows or resolving sectoral trade-offs, but it should also engage with deeper questions about justice, ecological limits, and the kind of futures communities envision. Policies that strengthen human–nature relationships and integrate diverse values and relational perspectives are better equipped to navigate these tensions and guide sustainability transitions.

The integrated frameworks used in this study go beyond merely demonstrating that everything is important and instead illustrate the interconnectedness between how people value and connect with nature, how these relationships vary across cultural and ecological contexts, and how such meanings can drive systemic change. Integrating these perspectives provides explanatory power and multidimensional insights that are crucial for transformation-oriented WEFE nexus governance.

Limitations of the study

While this study offers rich empirical insights, it is important to acknowledge several limitations. First, although the interview sample was diverse, it primarily focused on agricultural actors, thereby not capturing the full diversity and complexity of other local actor groups within each case study. This emphasis on agricultural actors stems from the recognition that they maintain complex, daily interconnections with all dimensions of the WEFE nexus. In this context, food is not an isolated element, but one that is deeply intertwined with water, energy, and ecosystems. This agricultural lens should also be kept in mind when interpreting the study's results, as it influenced the thematic focus, particularly the emphasis on food and water over energy and ecosystems.

Second, the sample exhibited a significant gender imbalance, with over 70% of participants identified as male. This disparity reflects socio-economic and cultural norms that limit the visibility and participation of women in rural communities, particularly within Mediterranean agricultural systems. Women's involvement in such research is often shaped by their societal roles, levels of education, and economic activities. This imbalance also has implications for the study's findings, as gender significantly influences values, relationships with nature, and approaches to natural resource governance.

Third, the results cannot be generalized to the entire Mediterranean Basin. They reflect the specificities of the case studies analyzed and illustrate the contextual factors unique to each setting. While the case studies share some environmental challenges, such as water scarcity and agricultural intensification, cross-context qualitative comparisons are complex. These challenges arise partly from translation and interpretation issues across multiple languages and cultural contexts. Despite efforts to co-develop and locally adapt interview instruments with facilitators, nuances in language and meaning may have influenced how values were expressed and interpreted. Additionally, each case study represents a distinct social–ecological system with its own environmental and socio-cultural dynamics. Finally, we would like to recognize our positionality as researchers embedded within academic institutions and international collaborations. This positioning may influence how we frame, interpret, and engage with local actors. We approached these issues critically and reflexively, striving to center participants' voices, co-design instruments with local experts, and triangulate interpretations through cross-team discussions.

Conclusion

Effectively governing the WEFE nexus requires an integrated approach that accounts for the complex interdependencies among resources while recognizing the diverse values and human–nature connections embedded within these systems. Existing WEFE nexus frameworks have predominantly focused on biophysical and economic dimensions. This study underscores the necessity of incorporating instrumental, intrinsic, and relational values alongside the multiple dimensions of Human–nature Connectedness (HNC) within WEFE nexus approaches. Our findings, drawn from diverse Mediterranean case studies, demonstrate that local communities perceive the WEFE nexus as essential not only for economic security, but also for broader well-being dimensions. These include physical health, education, social cohesion, and cultural identity. While instrumental values,

such as the economic benefits derived from water, energy, food, and ecosystems, are widely acknowledged, intrinsic and relational values also play a fundamental role in shaping local perceptions and governance priorities. Importantly, our study reveals a strong local attachment to WEFE nexus components. Respondents emphasized the emotional and philosophical dimensions of HNC, reinforcing the idea that sustainability policies must extend beyond market-based considerations. This recognition is critical in the Mediterranean countries, a biodiversity hotspot facing acute social–ecological challenges, where effective governance must balance competing demands while ensuring equity and long-term resilience. By integrating social and relational dimensions into WEFE nexus governance, policymakers and actors can develop more inclusive, adaptive, and context-specific strategies that align with the lived experiences, values, and well-being priorities of local communities. These insights advance into a holistic nexus thinking, emphasizing governance approaches that move beyond technical efficiency to foster socio-cultural engagement, participatory decision-making, and sustainable resource management in diverse social–ecological landscapes.

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Data availability The data supporting the findings of this study are available in a public repository (ZENODO). Access to the dataset through this doi: https://doi.org/10.5281/zenodo.14961351

References

Al Naber M, Molle F (2017) Controlling groundwater over abstraction: state policies vs. local practices in the Jordan highlands. Water Policy 19(4):692–708. https://doi.org/10.2166/wp.2017.127

Albrecht TR, Crootof A, Scott CA (2018) The water-energy-food nexus: a systematic review of methods for nexus assessment. Environ Res Lett. https://doi.org/10.1088/1748-9326/aaa9c6

Al-Zúbi M, Weston S, Shahid S, Brouziyne Y, Mujtaba I, Naber MA (2024) Conceptualizing the intersection of the Water-Energy-Food-Environment (WEFE) Nexus, human security, and inclusive society: insights from Middle East and North Africa (MENA), Sub-Saharan Africa, and Asia-Pacific regions. International Water Management Institute (IWMI). CGIAR Initiative on Fragility to Resilience in Central and West Asia and North Africa, Colombo

Arias-Arévalo P, Gómez-Baggethun E, Martín-López B, Pérez-Rincón M (2018) Widening the evaluative space for ecosystem services: a taxonomy of plural values and valuation methods. Environ Values 27:29–53

Bidoglio G, Vanham D, Bouraoui F, Barchiesi S (2024) The water–energy–food–ecosystems (WEFE) nexus. In: Encyclopedia of ecology, 2nd edn, vol 4. https://doi.org/10.1016/B978-0-12-409548-9.11036-X

Blondel J (2006) The "design" of Mediterranean landscapes: a millennial story of humans and ecological systems during the historic period. Hum Ecol 34(5):713–729. https://doi.org/10.1007/s10745-006-9030-4

Burkhard B, Maes J (2017) Mapping ecosystem services. In: Advanced books. Pensoft Publishers. https://doi.org/10.3897/ab.e12837

Canessa C, Vavvos A, Triliva S, Kafkalas I, Vrachioli M, Sauer J (2022) Implementing a combined Delphi and focus group qualitative methodology in nexus research designs: the case of the WEFE nexus in Apokoronas, Crete. PLoS ONE. https://doi.org/10.1371/journal.pone.0271443

Castro AJ, Otamendi-Urroz I, Quintas-Soriano C, Suárez Alonso ML, Vidal-Abarca MR, Martín-López B (2023) Repensar la conexión con la naturaleza a través de las emociones. Ecosistemas 32:2502. https://doi.org/10.7818/ECOS.2502

Chan KM, Gould RK, Pascual U (2018) Editorial overview: relational values: what are they, and what's the fuss about? Curr Opin Environ Sustain 35:A1–A7. https://doi.org/10.1016/j.cosust.2018.11.003

Chan KMA et al (2020) Levers and leverage points for pathways to sustainability. People Nat 2:693–717

Chelli G (2023) La siccità del Po nel 2022 è stata la peggiore degli ultimi due secoli. Nature, Italy. https://www.nature.com/articles/d43978-023-00122-8

Cramer W, Guiot J, Fader M, Garrabou J, Gattuso JP, Iglesias A, Lange MA, Lionello P, Llasat MC, Paz S, Peñuelas J, Snoussi M, Toreti A, Tsimplis MN, Xoplaki E (2018) Climate change and interconnected risks to sustainable development in the Mediterranean. Nat Clim Change 8(11):972–980. https://doi.org/10.1038/s41558-018-0299-2

de Roo A, Trichakis I, Bisselink B, Gelati E, Pistocchi A, Gawlik B (2021) The water-energy-food-ecosystem nexus in the Mediterranean: current issues and future challenges. Front Clim. https://doi.org/10.3389/fclim.2021.782553

de Strasser L, Lipponen A, Howells M, Stec S, Bréthaut C (2016) A methodology to assess the water energy food ecosystems nexus in transboundary river basins. Water 8:59

El Ghafraoui Y, Quintas-Soriano C, Pacheco-Romero M, Murillo-López BE, Castro AJ (2023) Diverse values of nature shape human connection to dryland landscapes in Spain. J Arid Environ 216:105023. https://doi.org/10.1016/j.jaridenv.2023

Fagerholm N, Torralba M, Moreno G, Girardello M, Herzog F, Aviron S, Plieninger T (2019) Cross-site analysis of perceived ecosystem service benefits in multifunctional landscapes. Glob Environ Change 56:134–147. https://doi.org/10.1016/j.gloenvcha.2019.04.002

Fagerholm N, Martín-López B, Torralba M, Oteros-Rozas E, Lechner AM, Bieling C, Stahl Olafsson A, Albert C, Raymond CM, Garcia-Martin M, Gulsrud N, Plieninger T (2020) Perceived contributions of multifunctional landscapes to human well-being: evidence from 13 European sites. People Nat 2(1):217–234. https://doi.org/10.1002/pan3.10067

FAO & ITPS (2015) Status of the World's Soil Resources (SWSR). Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils

Farmandeh E, Choobchian S, Karami S (2024) Conducting water-energy-food nexus studies: what, why, and how. Sci Rep 14:27310. https://doi.org/10.1038/s41598-024-79214-4

Fischer J, Gardner TA, Bennett EM, Balvanera P, Biggs R, Carpenter S, Daw T, Folke C, Hill R, Hughes TP, Luthe T, Maass M, Meacham M, Norström AV, Peterson G, Queiroz C, Seppelt R, Spierenburg M, Tenhunen J (2015) Advancing sustainability through mainstreaming a social–ecological systems perspective. Curr Opinion Environ Sustain 14:144–149. https://doi.org/10.1016/j.cosust.2015.06.002

Geissberger S, Chapman M (2023) The work that work does: how intrinsic and instrumental values are transformed into relational values through active work participation in Swiss community supported agriculture. People Nat 5(5):1649–1663. https://doi.org/10.1002/pan3.10531

Gianelli I, Trimble M, Juri S, Pereira LM, González-Mon B, Villasante S (2025) The seeds' substrate: a concept to understand how transformations toward good Anthropocenes can be enabled. Ecol Soc 30(1):38. https://doi.org/10.5751/ES-15792-300138

Great International (2024) Examining the water-energy-food security-ecosystem nexus approach in Nepal: learning from some case studies series 1. Kathmandu

Guest G, Bunce A, Johnson L (2006) How many interviews are enough? An experiment with data saturation and variability. Field Methods 18(1):59–82. https://doi.org/10.1177/1525822X05279903

Halbe J, Pahl-Wostl C, Lange MA, Velonis C (2015) Governance of transitions towards sustainable development: the water-energy-food nexus in Cyprus. Water Int 8060:1–18

Halwani J, Halwani B (2022) Climate change in Lebanon and the impact to water resources. In: Climate change in the Mediterranean and Middle Eastern Region. Springer, pp 395–412

Himes A, Muraca B, Anderson CB, Athayde S, Beery T, Cantú-Fernández M et al (2024) Why nature matters: a systematic review of intrinsic, instrumental, and relational values. Bioscience 74(1):25–43. https://doi.org/10.1093/biosci/biad109

Howarth C, Monasterolo I (2016) Understanding barriers to decision making in the UK energy-food-water nexus: the added value of interdisciplinary approaches. Environ Sci Policy 61:53–60

Hussein H (2018) Lifting the veil: Unpacking the discourse of water scarcity in Jordan. Environ Sci Policy 89:385–392. https://doi.org/10.1016/j.envsci.2018.09.007

IPBES (2022) Summary for policymakers of the methodological assessment report on the diverse values and valuation of nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://doi.org/10.5281/zenodo.6522392

IPCC (2021) Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781009157896

Ives CD, Abson DJ, von Wehrden H, Dorninger C, Klaniecki K, Fischer J (2018) Reconnecting with nature for sustainability. Sustain Sci 13:1389–1397. https://doi.org/10.1007/s11625-018-0542-9

Junquera V, Rubenstein DI, Levin SA, Hormaza JI, Pérez IV, Gavilán PJ (2024) Hydrological collapse in southern Spain under expanding irrigated agriculture: Meteorological, hydrological, and structural drought. arXiv:2408.00683

Khalil A (1989) The society and its environment. In: Collelo T (ed) Lebanon: a country study. Federal Research Division, Library of Congress, Washington DC, pp 39–86

Kimmerer R (2011) Restoration and reciprocity: the contributions of traditional ecological knowledge. In: Egan D, Hjerpe EE, Abrams J (eds) Human dimensions of ecological restoration. Island Press and Center for Resource Economics, pp 257–276

King RJH (2006) Playing with boundaries: critical reflections on strategies for an environmental culture and the promise of civic environmentalism. Ethics Place Environ 9:173–186

Kropf B, Schmid E, Mitter H (2021) Multi-step cognitive mapping of perceived nexus relationships in the Seewinkel region in Austria. Environ Sci Policy 124:604–615. https://doi.org/10.1016/j.envsci.2021.08.004

Lehnen L, Arbieu U, Böhning-Gaese K, Díaz S, Glikman JA, Mueller T (2022) Rethinking individual relationships with entities of nature. People Nat 4(3):596–611. https://doi.org/10.1002/pan3.10296

Liu C, Zhang Z, Liu S, Liu Q, Feng B, Tanzer J (2019) Evaluating agricultural sustainability based on the water-energy-food nexus in the Chenmengquan irrigation district of China. Sustainability 11(19):5350. https://doi.org/10.3390/su11195350

López Moreno S, Castro Martínez A, Otamendi Urroz I, Quintas Soriano C (2024) Análisis de la diversidad biocultural en la cuenca Mediterránea: una revisión sistemática de la literatura. Ecosistemas 33(3):2737. https://doi.org/10.7818/ECOS.2737

López-Rodríguez MD, Jiménez-Aceituno A, Quintas-Soriano C, Requena-Mullor JM, Garau E, Alba-Patiño D, Otamendi-Urroz I, Aguiar APD, Cortés-Calderón S, Castro AJ (2024) Applying the three horizons approach in local and regional scenarios to support policy coherence in SDG implementation: insights from arid Spain. Glob Environ Change 89:102922. https://doi.org/10.1016/j.gloenvcha.2024.102922

López-Zayas C, Castro AJ, Requena-Mullor JM, López-Rodríguez MD, Garau E, Quintas-Soriano C (2024) Emotional attachment and philosophical worldviews explain human connectedness to nature in abandoned rural Spain. Sustain Sci 19:1809–1823. https://doi.org/10.1007/s11625-024-01538-x

Mahjoub O, Jemai A, Gharbi N, Messai Arbi A, Dekhil S (2017) Public acceptance of wastewater use in agriculture: Tunisian experience. In: Hettiarachchi H, Ardakanian R (eds) Safe use of wastewater in agriculture: from concept to implementation. UNU-FLORES.

Mahjoub O, Hettiarchchi H, Gharbi N, Dekhil S, Mekada M, Mekada S, Charfeddine M, Mahjdoub N, Zarga M (2022) Diversity, sustainability, and tradition. In: Bernd MG, Richard E, Doha Z, Peter E, Chrysi L, Richard AB, Natalia G, Cevza Melek K-A (eds) The gateway to the future of the Mediterranean. European Commission, Publications Office of the European Union, Luxembourg, p 224. https://doi.org/10.2760/38718,JRC12640

Martinez-Hernandez E, Leach M, Yang A (2017) Understanding water-energy-food and ecosystem interactions using the nexus simulation tool NexSym. Appl Energy 206:1009–1021

McGregor D (2010) Honouring our relations: an anishnaabe perspective on environmental justice. In: Agyeman J, Cole P, Haluza-DeLay R O'Riley P (eds) Speaking for ourselves: environmental justice in Canada. UBC Press, pp 27–41

Meadows D (1999) Leverage points: places to intervene in a system. The Sustainability Institute, Hartland

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington D.C.

Morgado R, Flores Ribeiro P, Lima Santos J, Rego F, Beja P, Moreira F (2022) Drivers of irrigated olive grove expansion in

Mediterranean landscapes and associated biodiversity impacts. Landsc Urban Plann 225:104429. https://doi.org/10.1016/j.landurbplan.2022.104429
MWI (2016) National Water Strategy of Jordan 2016–2025. MWI, Amman. http://extwprlegs1.fao.org/docs/pdf/jor156264E.pdf
Ortiz-Przychodzka S, Benavides-Frías C, Raymond CM, Díaz-Reviriego I, Hanspach J (2023) Rethinking economic practices and values as assemblages of more-than-human relations. Ecol Econ 211(2):107866. https://doi.org/10.1016/j.ecolecon.2023.107866
Otamendi-Urroz I, Quintas-Soriano C, Martín-López B, Expósito-Granados M, Alba-Patiño D, Rodríguez-Caballero E, García-Llorente M, Castro AJ (2023) The role of emotions in human–nature connectedness within Mediterranean landscapes in Spain. Sustain Sci. https://doi.org/10.1007/s11625-023-01343-y
Pascual U, Balvanera P, Díaz S, Pataki G, Roth E, Stenseke M, Watson RT, Dessane EB, Islar M, Kelemen E, Maris V, Quaas M, Subramanian SM, Wittmer H, Adlan A, Ahn S, Al-Hafedh YS, Amankwah E, Asah ST, Başak Dessane E, Berry P, Bilgin A, Breslow SJ, Bullock C, Cáceres D, Daly-Hassen H, Figueroa E, Golden CD, Gómez-Baggethun E, González-Jiménez D, Houdet J, Keune H, Kumar R, Ma K, May PH, Mead A, O'Farrell P, Pandit R, Pengue W, Pichis-Madruga R, Popa F, Preston S, Pacheco-Balanza D, Saarikoski H, Strassburg BB, van den Belt M, Verma M, Wickson F, Yagi N (2017) Valuing nature's contributions to people: the IPBES approach. Curr Opin Environ Sustain 26:7–16. https://doi.org/10.1016/j.cosust.2016.12.006
Pascual U, Balvanera P, Christie M (2023) Leveraging the multiple values of nature for transformative change to more just and sustainable futures: insights from the IPBES values assessment. Curr Opin Environ Sustain 64:101359
Riechers M, Balázsi Á, García-Llorente M, Loos J (2021) Human–nature connectedness as leverage point. Ecosyst People 17(1):215–221. https://doi.org/10.1080/26395916.2021.1912830
Riechers M, Martín-López B, Fischer J (2022) Human–nature connectedness and other relational values are negatively affected by landscape simplification: insights from Lower Saxony Germany. Sustain Sci 17:865–877. https://doi.org/10.1007/s11625-021-00928-9
Riechers M, Pearson J, Diaz-Cruz N et al (2025) Interplays between relational and instrumental values: insights from research experiences on human–nature relations. Sustain Sci 20:287–298. https://doi.org/10.1007/s11625-024-01559-6
Rockström J, Gupta J, Qin D, Lade SJ, Abrams JF et al (2023) Safe and just Earth system boundaries. Nature 619:102–111. https://doi.org/10.1038/s41586-023-06083-8
Sambo B, Sperotto A, Torresan S, Pittore M, Zebisch M, Critto A (2024) Looking at the water-energy-food nexus through the lens of ecosystem services: a new perspective. Environ Res Lett 19(12):121003. https://doi.org/10.1088/1748-9326/ad96cf
Sanya J, Gross M, Mwampamba TH, Pearson J, Sesabo JK, Riechers M, Kinabo NR, Krail V, Martín-López B (2025) Heterogeneity of demands for nature's contributions to people and nature's values by farmers: insights from the Kilimanjaro social ecological system. Ecol Soc 30(2):25. https://doi.org/10.5751/ES-15961-300225
Sayem MDA (2021) Islam and environmental ethics: a Qur'ānic approach. Islam Stud 60(2):157–172
Schlemm A, Mulligan M, Tang T, Agramont A, Namugize J, Malambala E, van Griensven A (2024) Developing meaningful water-energy-food-environment (WEFE) nexus indicators with stakeholders: an Upper White Nile case study. Sci Total Environ 931:172839. https://doi.org/10.1016/j.scitotenv.2024.172839
Schultz PW (2002) Inclusion with nature: the psychology of human–nature relations. In: Schmuck P, Schultz WP (eds) Psychology of sustainable development. Springer US, Boston, pp 61–78. https://doi.org/10.1007/978-1-4615-0995-0_4
Smajgl A, Ward J, Pluschke L (2016) Water–food–energy nexus–realising a new paradigm. J Hydrol 533:533–540. https://doi.org/10.1016/j.jhydrol.2015.12.033
Unai P, Pamela DM, Sarah ED, Hien TN, Xuemei B, William WLC, Michelle L, Nadja S, Unai P, Pamela DM, Sarah ED, Hien TN, Xuemei B, William WLC, Michelle L, Nadja ST, Robert JS, Hans-Otto P (2022) Governing for transformative change across the biodiversity–climate–society nexus. BioScience 72(7):684–704. https://doi.org/10.1093/biosci/biac031
UNESCO (2008) Cante Alentejano, polyphonic singing from Alentejo, southern Portugal. Intangible Cultural Heritage. https://ich.unesco.org/en/RL/cante-alentejano-polyphonic-singing-from-alentejo-southern-portugal-01007
Visseren-Hamakers IJ et al (2021) Transformative governance of biodiversity: insights for sustainable development. Curr Opin Environ Sustain 53:20–28. https://doi.org/10.1016/j.cosust.2021.06.002
Yir-Hueih L, Min-Han T, Yun-Cih C (2023) Actions speak louder than words: adoption of sustainable farming practices based on an integrated model. J Clean Prod 416:137856. https://doi.org/10.1016/j.jclepro.2023.137856
Zhang C, Chen X, Li Y, Ding W, Fu G (2018) Water-energy-food nexus: concepts, questions, and methodologies. J Clean Prod 195:625–639. https://doi.org/10.1016/j.jclepro.2018.05.194

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