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REVIEW

Nature's contribution to people provided by pastoral systems across European, African, and Middle East Mediterranean countries: trends, approaches and gaps

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Abstract

Mediterranean pastoral systems are providers of a wide array of Nature's Contribution to People (NCP). They are 'complex systems' characterized by limited resources and socio-economic dynamics currently threatened by climate and social changes. Despite a growing number of scientific articles dealing with NCP, there is a high risk that the existing literature has left out the complexity of such systems. In the light of ongoing social, economic, and climatic changes in the Mediterranean basin, neglecting the complexity of pastoral systems can lead to significant research biases, missing the priorities affecting the stability and continuity of such systems. A combination of frameworks of analysis provided by the Millennium Ecosystem Assessment and by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services was applied to understand if and to what extent the complexity of Mediterranean pastoral systems has been considered in the available literature. Most of the 126 papers report studies conducted in the European Union zone (102 papers), with the majority in Spain (50). Fewer studies have been conducted in the Middle East (15 papers) and Africa zones (9 papers). Despite results confirming the importance of pastoral systems as providers of NCP, most of the eligible papers focused on regulating NCP. A lack of a multisectoral approach and integration of knowledge suggests that the complexity of Mediterranean pastoral systems has been overlooked by researchers. The creation of 'hybrid knowledge' bridging the expertise of different stakeholders could be the key ingredient to properly address the complexity of Mediterranean pastoral systems.

Highlights

- Mediterranean (Med) pastoral systems are providers of NCP
- Literature on Med-pastoral systems is focused on regulating NCP
- Literature on Med-pastoral systems is biased towards EU
- The complexity of Med-pastoral systems is overlooked in the literature
- Med-pastoral systems require a multiscale, multisectoral, and integrated analysis

Keywords Biodiversity · Ecosystem services · Extensive grazing · Grasslands · Millennium Ecosystem Assessment

Introduction

Pastoralism has a rich history of shaping landscapes, dating back 7000 years in Europe and up to 9000 years in northeast Africa (Dong et al. 2016; Starrs 2018). Today, an estimated 200 to 500 million pastoralists inhabit the world, utilizing 25% of the Earth's land (Niamir-Fuller 2016). These pastoral systems offer sustainable and viable livelihoods,

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contributing public goods and services like landscape maintenance, cultural preservation, and food security (Oteros-Rozas et al. 2014; Niamir-Fuller 2016; Varela et al. 2018). Furthermore, pastoralists possess specialized knowledge for thriving in uncertain environments (Davies et al. 2016; Herrero et al. 2016; Nori and Scoones 2019),

In the Mediterranean, traditional pastoral systems play a vital role in modifying and preserving landscapes, supporting agriculture, and fostering local cultures (Fernández-Giménez 2015; Ocak 2016). They are considered an efficient form of natural resource and land management in semi-arid contexts such as the Mediterranean region (Davies and Hatfield 2007; Bonfoh et al. 2016). The adaptability and flexibility of pastoral systems enable them to utilize unevenly distributed natural and economic resources across space and time (Krätli and Schareika 2010; Krätli et al. 2013; Rueff and Rahim 2016). This is the case, for example, with pastoral systems found in Mediterranean mountainous areas such as the Pyrenees, Alps, Apennines, Taurus, and Anti-Lebanon mountains, often managed through transhumance practices (United Nations 2017; Francioni et al. 2019a; Tesei et al. 2020; Dean et al. 2021).

The Mediterranean basin also faces significant challenges, such as land abandonment and intensification (Fadda et al. 2008; Caballero and Fernández-Santos 2009), with relevant implications for wider environmental issues, including biodiversity conservation and soil carbon stocking (Caballero et al. 2009; Francioni et al. 2019a). Climate and environmental pressures, as well as socio-economic and political marginalization, further complicate the situation (Plieninger et al. 2015; Ouedraogo and Davies 2016; European Commission 2019).

While pastoral systems have the potential for sustainability and adaptability, they are declining globally due to various factors like changes in land use, climate, and socio-economic conditions, as well as inadequate support policies (Morton 2010; Aryal et al. 2014; Porqueddu et al. 2016; López-i-Gelats et al. 2016; Sendyka and Makovicky 2018). This decline is particularly evident in the Mediterranean region (Koniak et al. 2011; Bernués et al. 2014). Negative narratives portraying pastoral systems as ecologically destructive and economically unviable contribute to their marginalization and lack of support from institutions (Morton 2010; López-i-Gelats et al. 2016; Scoones 2021). These narratives fail to recognize the adaptability and efficiency of pastoral systems leaving them marginalized and disadvantaged (Caballero and Fernández-Santos 2009; Eloit 2016; Herrero et al. 2016; Ouedraogo and Davies 2016).

Despite their decline and negative narratives, pastoral systems provide a wide array of goods and services, commonly referred to as 'ecosystem services' defined as 'the benefits that ecosystems provide to human well-being' in the Millennium Ecosystem Assessment (MEA) (Alcamo et al. 2003; MEA 2005). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has updated the ecosystem services framework into Nature's Contributions to People (NCP) concept, emphasizing cultural aspects and local knowledge of stakeholders (Díaz et al. 2018), which are crucial in analyzing complex socio-ecological systems like pastoral systems (Caballero et al. 2009; Ostrom 2009; D'Ottavio et al. 2018). The NCP concept extends the ecosystem services framework by integrating social sciences more comprehensively into the existing economic and ecological dimensions of ecosystem services.

Pastoral systems can be defined as an 'adaptive network of biophysical and social flows generated and maintained by the movement of shepherds and livestock' (Oteros-Rozas et al. 2012). These systems arise from the interaction of humans and natural resources (Díaz et al. 2018; Dean et al. 2021). Pastoral systems are 'complex systems' because they involve various stakeholders, including not only farmers and shepherds but also others such as citizens, hunters, environmentalists, landowners, policymakers, and institutions. Each stakeholder brings their perspective with diverse priorities, and they can influence the systems through practices that evolve with their changing understanding. The stakeholders' changes in understanding emerge from learning processes resulting from (i) the feedback of their practices on the management of livestock and forage resources; (ii) their comprehension of the influence of ecological constraints on biophysical processes; and (iii) the social learning processes arising from local learning opportunities, such as formal and informal pastoral institutions governing the management of common lands (Ison et al. 2007; Steyaert and Jiggins 2007; Caballero et al. 2009). From this perspective, biodiversity and related NCP emerge from the interaction between ecological factors, livestock and forage resources, and pastoral management practices. These practices can be applied at various spatial scales (e.g. field, farm, landscape) and temporal scales (e.g. short and long term), generating synergies and trade-offs among NCP (Alcamo et al. 2003; MEA 2005; Díaz et al. 2018).

The expected drivers of change (climate, social, and economic) in the Mediterranean basin, considered a 'hotspot of changes' (Zittis et al. 2019), increase uncertainty regarding the quantity, quality, and variety of NCP. Therefore, an analysis of the knowledge status related to the complexity of these systems is urgently needed to avoid future biases in research. Based on available literature (D'Ottavio et al. 2018; Manzano et al. 2021; Dean et al. 2021), pastoral systems in the Mediterranean may not have been analyzed as complex systems: for example, NCP analyzed individually; NCP analyzed with others from the same group; few NCP studied together; non-material NCP poorly studied despite being considered the most relevant for local and general stakeholders (Bernués et al. 2014). Should this be the case,

future research might be biased and may not address either the drivers of change or the effects of these changes on NCP that are relevant for stakeholders.

Given the complexity and diversity of pastoral systems, a multiscale, systemic, and multidisciplinary approach, along with local knowledge integration, is necessary to understand their multidimensional nature and address non-material (cultural) NCP, like learning and inspiration by landscapes (Rivera-Ferre et al. 2013; Costanza et al. 2017; Díaz et al. 2018; Manzano et al. 2021).

This paper aims at identifying whether and to what extent the complexity of pastoral systems in the Mediterranean is acknowledged in the literature. This will be done by characterizing the manner in which the NCP have been assessed, considering it as an indicator of the method's effectiveness for analyzing system complexity. The literature has been analyzed through the MEA and IPBES concepts with particular focus on the application of the multiscale and multisectoral approach, together with the incorporation of different types of knowledge within the case studies (Alcamo et al. 2003; MEA 2005; Díaz et al. 2018). These concepts were considered indicators of the complexity of the pastoral systems and of their multifunctionality (D'Ottavio et al. 2018) and complexity (Dean et al. 2021). This will allow for an examination of whether pastoral systems are genuinely studied as complex systems or, as claimed by Manzano et al. (2021), whether there is a lack of holistic thinking in the scientific literature when considering pastoral systems. Moreover, it will highlight potential knowledge gaps in the study of pastoral systems in the Mediterranean, which can be addressed in future research.

Materials and methods

Literature review

Following the works of Rudel (2008) and Young et al. (2006), a combination of a systematic review and meta-analysis was conducted with the methodology of qualitative comparative analysis (QCA), which is increasingly being used in the environmental global change field (van Vliet et al. 2012; Lugnot and Martin 2013; López-i-Gelats et al. 2016). The QCA allows for the identification of trends within the literature through an iterative process of reading and re-reading and coding and re-coding. This process is used in this study to conduct a qualitative meta-analysis to identify and characterize the existing knowledge in the specialized literature on the NCP considered as indicators of pastoral system complexity. The literature was analyzed with respect to the application of the MEA and IPBES key elements, with a focus on the application of the multiscale and multisectoral approach, together with the incorporation of different types of knowledge in the analysis of the case studies (MEA 2005; Díaz et al. 2018). The Web of Science™ search engine was used to identify potential literature for a systematic review. A custom operator string was created on 19/05/2022 to identify academic articles written in English between the years 2003 and 2022:

TS= ((grassland* OR rangeland* OR shrubland* OR scrubland*) AND (grazing OR pastoral) AND (livestock OR horse* OR sheep OR cattle OR goat*) AND Mediterranean).

From this search, 346 scientific papers were obtained with a steadily increasing trend from 2002 to 2022. These papers were then screened against the following inclusion criteria:

a. Contextualization of the study within the scope of a pastoral system
b. Presence of experimental data
c. Analysis of NCP provided by pastoral systems

Following these criteria, literature reviews, meta-analyses, and studies set on experimental farms or research facilities without any linkages with pastoral systems were excluded from the analysis.

The 346 papers were screened using a two-part process. Part 1, Initial screening, involved the division of papers between all the authors. To ensure agreement, 42 of these papers were randomly assigned to one of the co-authors, guaranteeing that each paper underwent review by at least 2 co-authors. Through this process and according to the review criteria, 184 papers were excluded from the analysis, leaving 162 papers remaining. Part 2, Secondary screening, required the validation of agreement of the remaining 162 articles. All 162 articles were subjected to a full reading by the lead authors of the article, after which a further 36 articles were excluded. According to the review criteria, 220 papers were excluded. The remaining 126 papers were analyzed and coded in a dummy variable database that classifies data into five broad categories and several subcategories (i.e. 0 or 1, indicating the absence or presence of a feature):

1) Article information (authors, year of publication, title, journal).
2) Climate type, defined according to Köppen-Geiger classification (Kottek et al. 2006).
3) Type of grazing system (pastoral, agro-pastoral, silvo-pastoral, agro-silvo-pastoral):
    a Grazing animals (sheep, goats, cattle, horses, donkeys, camels, pigs)
    b Mobility method: systems with mobility (nomadic, regional transhumance, local transhumance) or sedentary systems

c Use of mountains in the grazing system operation (yes/no)
d Forage resources (natural and/or semi-natural grasslands, temporary grasslands, shrublands, woodlands, deserts as defined by Allen et al. 2011)

4) Analyzed NCP categorized into three groups (regulating, material, and non-material NCP) following the IPBES framework (Díaz et al. 2018).
5) Application of the MEA-IPBES principles:

a Adoption of spatial scale (field, farm, landscape, and system scale) and temporal scale (short-term: up to 5 years; medium-term: from 6 to 10 years; long-term: over 10 years)
b Use of multisectoral approach (which NCP are analyzed together with which and how many other NCP)
c Incorporation of different types of knowledge through the inclusion and integration of different approaches

Pastoral systems were defined according to Allen et al. (2011) as follows: (i) pastoral system, *sensu stricto* (pastoralist, all-year-round grazing): system in which natural and/or semi-natural permanent grasslands are exploited throughout the whole year; (ii) agro-pastoral system (all-year-round grazing or semi-year-round grazing): system in which natural and/or semi-natural permanent grasslands are exploited in combination with other resources such as fodder crops (i.e. temporary pastures/meadows) and others (i.e. crop residues, fallow) during the whole year (all-year-round grazing) or a part of the year (semi-year-round grazing); (iii) silvo-pastoral system; and (iv) agro-silvo-pastoral system: systems in which trees/shrubs are deliberately integrated with forage crops (i.e. silvo-pastoral) or other crops (i.e. agro-silvo-pastoral) on the same land management unit (i.e. agroforestry systems).

With respect to the mobility method: (i) nomadic refers to 'a reliance on pastoral economic activities, with patterns of high mobility and the changing of dwellings throughout the year' (Miller et al. 2018). This periodic and seasonal movement, normally carried out on foot, is free between two or more macro-areas within a territory (even very large), depending on the opportunities and management needs of the animals reared (i.e. forage, water); (ii) regional transhumance is the movement of domesticated animals over substantial distances between two macro fixed grazing areas, depending on the seasons (i.e. mountain pastures in summer and lowlands in winter). This movement occurs traditionally over multiple days on foot, but can be also done by vehicle, depending on the local context; (iii) local transhumance is the movement of domesticated animals over relatively shorter distances; iv) sedentary systems are those that do not utilize the seasonal movement of livestock to take advantage of resources but remain within a grazing area throughout the year.

Among the NCP provided by pastoral systems, the following were analyzed in detail: (i) regulating NCP: habitat creation and maintenance; pollination and dispersal of seeds and other propagules; regulation of climate; regulation of freshwater quantity, location, and timing; formation, protection, and decontamination of soils and sediments; regulation of hazards and extreme events; (ii) material NCP: food and feed; medicinal, biochemical, and genetic resources; (iii) non-material NCP: learning and inspiration; physical and physiological experiences; supporting identities (Díaz et al. 2018).

Subdivision of the study area into three zones

The Mediterranean basin is the biogeographic zone surrounding the Mediterranean Sea that spans across three continents, more than 20 countries and many more cultures (Blondel 2006). All countries in the Mediterranean basin share features such as a wide variety of landscapes and similar climate characterized by hot, dry summers and cool, wet winters. Pastoral systems are present in each of these countries and have a long history of land management and maintenance as food production systems (López-i-Gelats et al. 2011; Ocak 2016; Guadilla-Sáez et al. 2019). For this analysis, it has been broken into three zones (Figure S1) selected according to socio-political, geographical, and cultural criteria to highlight similarities and differences of pastoral systems: (1) the Mediterranean European Union zone (EU) (Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia, Spain, plus Portugal); (2) Mediterranean Middle East zone (Israel, Jordan, Lebanon, Palestine, Syria, and Turkey), and (3) the African Mediterranean zone (Algeria, Egypt, Libya, Morocco, and Tunisia). None of the selected papers carried out studies in the non-EU zone despite the presence of pastoral systems in Bosnia and Herzegovina, Montenegro, or Albania (Caballero 2015).

Europe provides for specific features, as it is made up of industrialized countries, which share a Common Agricultural Policy (CAP) (European Commission 2019). The CAP offers financial support to the agricultural sector, including specific programs and payments aimed at promoting environmentally sustainable practices (European Commission 2019; O'Flanagan et al. 2019; Nori 2022a). The Mediterranean Middle East zone comprises independent countries in Western Asia, exhibiting a mix of industrialized and industrializing nations. All countries analyzed in the Middle East are not part of any supranational agricultural policies and instead create and use their own national agricultural policies, though significant similarities and common patterns exist (Nori 2022b). The African Mediterranean zone consists of several countries in North Africa, characterized by a broadly similar arid/semi-arid climate and can be classified as industrializing countries. The North African

Table 1 Distribution and characteristics of the pastoral systems for each zone

Zone	Grazing systems	Distribution[a]	Livestock species[b]				
		% within each zone	Sheep	Goats	Cattle	Horses	Pigs
EU	Pastoral	28	53	14	19	14	.
	Agropastoral	21	55	21	24	.	.
	Silvopastoral	32	36	30	27	5	3
	Agrosilvopastoral	19	37	20	24	6	14
Middle East	Pastoral	40	.	29	71	.	.
	Agropastoral	13	50	.	50	.	.
	Silvopastoral	47	9	45	45	.	.
	Agrosilvopastoral	.	.	.	.	.	.
Africa	Pastoral	67	56	33	11	.	.
	Agropastoral	22	50	50	.	.	.
	Silvopastoral	.	.	.	.	.	.
	Agrosilvopastoral	11	33	33	33	.	.

Zone	Grazing systems	Mobility method[b]				Mountains[b]	
		Nomadic	Regional Transhumance	Local T ranshumance	Sedentary	Yes	No
EU	Pastoral	.	21	27	52	85	15
	Agropastoral	.	24	28	48	79	21
	Silvopastoral	.	8	24	68	67	33
	Agrosilvopastoral	.	23	19	58	66	34
Middle East	Pastoral	.	.	.	100	67	33
	Agropastoral	.	.	.	100	.	100
	Silvopastoral	13	.	13	75	75	25
	Agrosilvopastoral	.	.	.	.	.	.
Africa	Pastoral	22	33	11	33	60	34
	Agropastoral	.	.	50	50	.	100
	Silvopastoral	.	.	.	.	.	.
	Agrosilvopastoral	.	.	100	.	100	.

Table 1 (continued)

Zone	Grazing systems	Forage resources[b]					
		Natural grasslands	Semi-natural grasslands	Temporary grasslands	Shrublands	Wood-lands	Deserts
EU	Pastoral	11	53	3	21	13	.
	Agropastoral	13	44	3	34	6	.
	Silvopastoral	5	14	.	12	69	.
	Agrosilvopastoral	2	16	7	30	45	.
Middle East	Pastoral	13	13	.	63	13	.
	Agropastoral	.	50	.	50	.	.
	Silvopastoral	.	.	.	30	70	.
	Agrosilvopastoral	.	.	.	.	.	.
Africa	Pastoral	11	11	.	56	11	11
	Agropastoral	33	.	.	67	.	.
	Silvopastoral	.	.	.	.	.	.
	Agrosilvopastoral	.	.	.	50	50	.

[a]Percentage of the total number of papers for each zone
[b]Percentage of the attributes of each system characteristic (livestock species, mobility method, use of mountains, forage resources) in each grazing system

countries under examination in this study are also members of the African Union, which has a specific policy for pastoral systems known as the 'Policy Framework for Pastoralism in Africa'. This framework, adopted in 2011, is designed to integrate pastoral systems into development policies (Bonfoh et al. 2016). They are also countries where climate and social changes and the decline of traditional governance systems threaten pastoral systems (Kreuer 2011; El Aich 2018).

Results

Geographical and climatic distribution of the case studies

The selected 126 papers were unevenly divided between the three different zones (81% in EU, 13% in the Middle East, and 5% in Africa) (Figure S2), with the majority under 'Mediterranean climates characterized by hot summers' (Figure S3). Half of the EU papers stem from Spain, while almost all of the Middle East papers carried out studies in Israel (15 papers out of 17).

Main characteristics of the pastoral systems

Most papers focused on pastoral systems (*sensu stricto*). EU papers evenly covered all grazing systems. Middle East papers primarily examined pastoral and silvo-pastoral systems, with minimal attention to agro-pastoral systems. Africa papers predominantly addressed pastoral systems, with no representation of silvo-pastoral systems (Table 1). Sheep, goats, and cattle dominated, but some relevant differences emerged among the three zones and pastoral systems (Table 1). Nomadic systems were poorly represented, and only in the Middle East and Africa. Short distance-transhumance was analyzed in all three zones with the EU showing an equal distribution among grazing systems. Long distance-transhumance was evenly represented among pastoral, agro-pastoral, and agro-silvo-pastoral systems of the EU but was limited to pastoral systems in Africa papers. Most of the papers were linked to the use of mountains in all zones except for agro-pastoral systems of Middle East and Africa. In general, woodlands, shrublands, and semi-natural grasslands were the most represented forage resources (Table 1).

Analysis of Nature's Contribution to People

Nature's Contribution to People groups studied in each zone

The selected 126 papers resulted in a total of 348 NCP being analyzed due to the multiple occurrences of different NCP within single papers (Table 2). If analyzed by NCP groups, most papers dealt with regulating NCP (53% of the total number of the analyzed papers, Figure S4), with 'habitat creation and maintenance' as the most studied in all the zones (Figure S5-A). Concerning material NCP (26% of the total number of the papers), 'food and feed' was more commonly found than 'medicinal, biochemical and genetic resources' in EU and Africa papers, while Middle East papers showed a more balanced representation of material NCP (Figure S5-B). Non-material NCP were analyzed by 21% of the total number

of the papers, with 'physical and physiological experiences' as the most studied in all the zones (Figure S5-C).

The least represented NCP in the analysis were 'regulation of climate' (analyzed only by 4% of Africa papers) and 'regulation of freshwater quantity, location and timing' (analyzed only by 2% of EU papers) (Table 2, Fig. 1, and S4).

Application of Millennium Ecosystem Assessment–Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services principles

Application of multiscale approach

Spatial scale Most of the studies were conducted at the landscape scale (66% of the total number of the analyzed papers) in all the zones (Fig. 2A), mainly for the analysis of regulating NCP (e.g. Bernués et al. 2005). Most of the studies carried out at the field scale analyzed regulating NCP but surprisingly, no studies emerged for 'climate regulation'. Instead, the farm scale was mainly adopted for the analysis of material NCP (e.g. Delgado-Pertíñez et al. 2013). Only two papers adopted a multiscale approach within the same case study, combining a field and a landscape scale (e.g. Iglesias et al. 2016 and Godinho and Rabaça 2011).

Temporal scale Different temporal scales were represented in all zones, with a general prevalence of short- and long-term scales (Fig. 2B). Short-time scale was mostly used for regulating NCP and material NCP (e.g. Mancilla-Leytón et al. 2013; Delgado-Pertíñez et al. 2013). Studies carried out on a medium-term scale involved mainly regulating NCP and, in particular, 'Habitat creation and maintenance' (e.g. Lasanta et al. 2016). Studies carried out on a long-term scale were again mostly used for regulating NCP, which included studies on insects (Fadda et al. 2008; Numa et al. 2012; García-Tejero et al. 2013), studies on the effect of different grazing intensities on plant species (De Bello et al. 2007; Tárrega et al. 2009), and the reduction of wildfires (Osem et al. 2011; Ruiz-Mirazo et al. 2012). Some case studies combined different timescales for the analysis of regulating NCP over the short and medium term (Schoenbaum et al. 2009) or short and long term (Fadda et al. 2008; Tárrega et al. 2009).

Application of multisectoral approach

About 25% of the papers analyzed only one NCP (e.g. habitat creation and maintenance in de Bello et al. 2007; Fadda et al. 2008; Tárrega et al. 2009), about 46% two or three NCP simultaneously (e.g. Ruiz-Mirazo et al. 2012; García-Tejero et al. 2013), and about 33% a bundle of NCP (e.g. Koniak et al. 2011). Bundles of NCP emerged in 36 papers, of which 18 analyzed 4 NCP (e.g. Coiffait-Gombault et al. 2012), 12 analyzed 5 NCP (e.g. Henkin et al. 2007), and 6 papers analyzed 6 NCP (e.g. Nadal-Romero et al. 2018) (Fig. 3).

Regulating NCP were generally analyzed with other NCP from the same group in the EU papers (Figure S6). For example, Schoenbaum et al. (2009), investigating the effect of summer sheep grazing on wheat stubble, covered 4 out of 6 NCP within the group. Conversely, in the Middle East and Africa zones, a lower level of NCP integration emerges, along with the fact that some NCP are not analyzed at all (Figure S6).

Material NCP were analyzed mostly with 'habitat creation and maintenance' in the EU (e.g. Bernués et al. 2005) and Middle East papers (e.g. Schoenbaum et al. 2009), while the Africa papers showed the highest level of multisectoral analysis, even if this is the result of only one paper on the pastoral systems of Atlas Mountains (El Aich 2018) (Figure S7).

Non-material NCP were mainly analyzed with 'habitat creation and maintenance' and with 'food and feed' in all the papers of EU and Africa. In general, non-material NCP appear to be the most multisectoral group of NCP (Figure S8).

Incorporation of different types of knowledge

The papers mainly fall into ecological and agricultural categories in all the zones (Fig. 4) as found in Greece (Ainalis et al. 2006) and France (Fadda et al. 2008) for EU, in Turkey (Türkoğlu et al. 2016) for Middle East, and in Tunisia (Tarhouni et al. 2017) for Africa. The anthropological, geological, and social approaches were all better represented in Africa than in any other zone of the Mediterranean basin (Fig. 4).

Agricultural and ecological approaches were highly integrated, particularly in the EU and Middle East (Fig. 5). Economic approaches primarily integrated with ecological and agricultural approaches, especially in EU and Middle East papers. Geological approaches were commonly paired with ecological approaches in EU papers and agricultural approaches in Africa. Sociological approaches were absent in Middle East papers and had limited integration overall. Anthropological approaches appeared only in Africa papers, generally exhibiting low integration with other approaches (Fig. 5).

Discussion

This review has allowed us to explore whether the complexity of pastoral systems has been taken into account by examining how NCP have been examined in different case studies. The framework utilized in this analysis enabled us to investigate whether multiscale and multisectoral approaches emerge in these studies, along with the integration of knowledge from various sources (Peterson et al. 2018; Kadykalo et al. 2019; Dean et al. 2021).

Table 2 Nature's contribution to people (NCP). Each paper can deal with more than one NCP. EU = European Union zone; ME = Middle East zone; AF = Africa zone

NCP group	NCP	Description	Total	EU	ME	AF
Regulating	Habitat creation and maintenance	Formation and production of ecological conditions for living beings of direct or indirect importance to humans (e.g., growing sites for plants, nesting sites for animals)	110	89	15	6
	Pollination and dispersal of seeds and other propagules	Facilitation by animals of pollen movement among flowers and dispersal of seeds, larvae, or spores	13	10	3	0
	Regulation of climate	Climate regulation by ecosystems through emissions of greenhouse gases and/or carbon sequestration. Effects on biophysical feedback from vegetation cover to the atmosphere (e.g., albedo, evapotranspiration)	2	1	0	1
	Regulation of freshwater quantity, location, and timing	Regulation of the flow of surface and groundwater used for drinking, irrigation and as support for non-material services	5	5	0	0
	Formation, protection and decontamination of soils and sediments	Formation and long-term maintenance of soil structure and processes by plants and soil organisms (e.g., protection of soil from erosion, nutrient cycling)	36	28	2	6
	Regulation of hazards and extreme events	Reduction of the impacts on humans or their infrastructure caused by floods, fires, landslides, avalanches	20	15	5	0
Material	Food and Feed	Production of food from wild, managed, or domesticated organisms (e.g., meat, dairy products, edible crops or wild plants, mushrooms, honey); Production of feed (forage and fodder) for domesticated animals	63	52	6	5
	Medicinal, biochemical, and genetic resources	Production of materials derived from organisms (plants, animals, fungi, microbes) used for medicinal, veterinary, and pharmacological (e.g., poisonous, psychoactive) purposes	27	20	6	1
Non-material	Learning and inspiration	Provision by landscapes, habitats, or organisms of opportunities for education, acquisition of knowledge and development of skills for well-being, information, and inspiration for art and technological design	8	6	1	1
	Physical and physiological experiences	Provision by landscapes, habitats, or organisms of opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism, and aesthetic enjoyment based on the close contact with nature (e.g., hiking, recreational hunting and fishing, birdwatching)	44	36	6	2
	Supporting identities	Landscapes, habitats, or organisms for religious, spiritual, and social-cohesion experiences (e.g., cultural, sacred and heritage landscapes, sounds, scents, and sights associated with childhood experiences, iconic animals, trees, or flowers)	20	16	2	2
Total N. of NCP			348	278	46	24

Representation of Mediterranean pastoral systems in the available literature

The search string reveals an increasing trend in studies conducted in the Mediterranean basin over the years, yet not all countries (Figure S2), and pastoral systems (Table 1) are comprehensively represented. This lack of studies could stem from two possible reasons. The first suggests a methodology limitation, particularly in the non-EU zone, potentially due to the English language criterion. This may exclude valuable non-English publications in languages like French, prevalent in North Africa, or national languages in Eastern Mediterranean

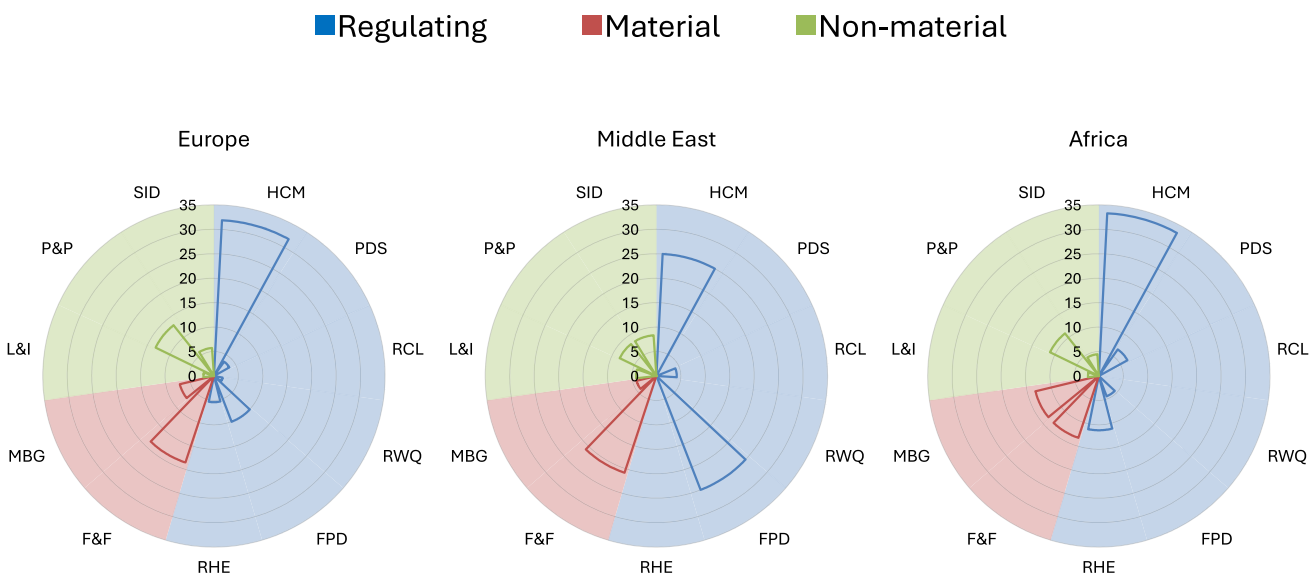

Fig. 1 Percentage of findings for each NCP belonging to the three groups per zone. Each petal represents the percentage of the total number of papers dealing with each NCP. Regulating NCP: habitat creation and maintenance (HCM), pollination and dispersal of seeds and other propagules (PDS), regulation of climate (RCL), regulation of freshwater quantity, location, and timing (RWQ), formation, protection, and decontamination of soils and sediments (FPD), regulation of hazards and extreme events (RHE). Material NCP: food and feed (F&F), medicinal, biochemical, and genetic resources (MBG). Non-material NCP: learning and inspiration (L&I), physical and physiological experiences (P&P), supporting identities (SID)

countries. The second hypothesis proposes a varying commitment of countries' scholars in agriculture-oriented research, potentially justifying the apparent lack of studies. The heavy bias towards Spain might be attributed to its longstanding tradition of studying pastoral systems with its history of drove roads (in Spanish *Cañadas*) which to this day are considered a national infrastructure (Oteros-Rozas et al. 2014; Starrs 2018). However, drove roads (in Italian *Tratturi*) were present also in Italy (Mastronardi et al. 2021), and as noted by Dean et al. (2021), support the hypothesis of differing commitment among researchers, especially in the EU context.

Pastoral systems are defined by an efficient and effective use of resources (Krätli and Schareika 2010; Krätli et al. 2013; Rueff and Rahim 2016). In the EU zone, the even proportion of pastoral systems typology might reflect the utilization of different fodder resources. These include permanent grasslands (e.g. Francioni et al. 2019b), temporary crops (e.g. Budimir et al. 2018), and wooded pastures such as in Dehesa systems in Spain (e.g. Tárrega et al. 2009). The most common grazing system found in the Africa zone was pastoral, which is not surprising given the vast rangeland plains combined with pastoral traditions and the socio-economic conditions associated with nomadism (Dong et al. 2011; Holechek et al. 2017).

Some authors (e.g. Briske et al. 2020) emphasize the importance of transforming rangeland social-ecological systems to optimize combinations of NCP, addressing global citizens' needs while enhancing the well-being of millions

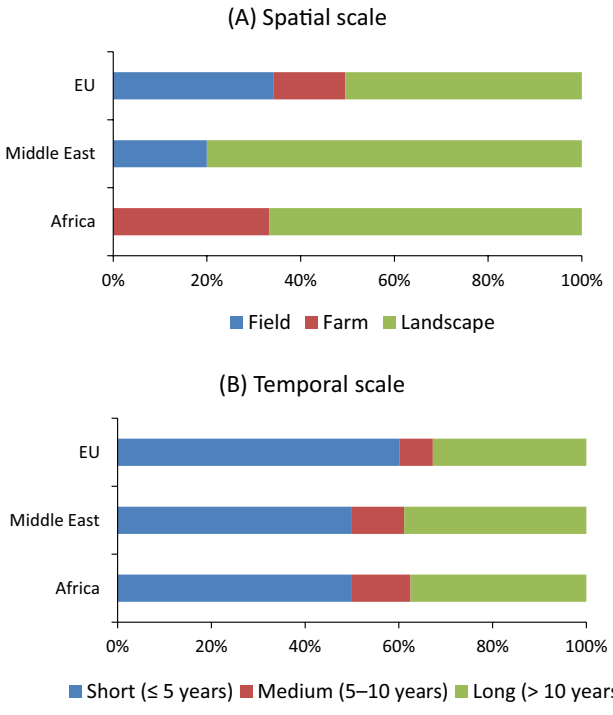

Fig. 2 Spatial and temporal scale adopted within the papers for each zone. Each bar reports the % of the total number of papers for each zone

relying on material NCP. These considerations are particularly relevant in more complex systems, such as agro-silvo-pastoral systems, which require diverse approaches to analyze their multifunctionality. This paucity of studies or their total absence in the Middle East (Table 1) may be a symptom of the simplification of pastoral systems throughout the Mediterranean, as seen in Greece (Kizos et al. 2014), where pastoral systems are not recognized for their complexity, or in any case not analyzed by researchers because they are too complex (Caballero et al. 2009).

Livestock distribution underscores the significant role of sheep, goats, and cattle in Mediterranean pastoral systems. A study by Rossi (2017) revealed that Spain, France, and Italy contributed 39% to European sheep and goat meat production. With the UK's departure from the EU, this percentage is expected to rise substantially. Cattle-based systems dominate the Middle East due to the prevalence of papers from Israel, where cattle farming is more significant than small ruminant farming. Conversely, in Jordan, Palestine, and Lebanon, cattle farming is much less present compared to sheep and goat farming. In Syria and Turkey, the sheep and goat farming sector is also highly developed (FAO 2020). On the other hand, it is true that in all these countries, the systems based on small ruminant husbandry are not analyzed. Systems based on cattle are less prevalent, especially in African papers, where they may be associated with non-sedentary systems (Holechek et al. 2017), and in that case, may be more difficult to study. The pig population in Middle Eastern countries, except for Israel, is exceptionally low (FAO 2020), primarily due to cultural, religious, and legislative reasons. Free-range pig farming systems are absent in the Middle East, including Israel (Ben-Dov et al. 2014), potentially explaining the absence of papers on these systems. While the low values found for horses and pigs (only present in the EU papers) were expected, the absence of papers analyzing systems based on camelids for the Middle East and Africa is surprising. Camels and camelids have drastically declined in numbers in the Middle Eastern countries during the last century. Nowadays, only a few hundred still exist in most of these countries, with the exception of Jordan and Syria (FAO 2020). In Algeria, the camel population is approximately 417,000, constituting 30% of the cattle herd number, primarily raised in extensive systems and likely showing an increase over the last decade. Camels and camelids are important from a socio-cultural perspective, but as indicated by some authors, they are affected by issues such as rangeland degradation, lack of experienced shepherds, and expensive feed inputs (Bedda et al. 2019; Bourbouze et al. 2010). Research on camels primarily focuses on material NCP (e.g. meat, milk, and skin) rather than analyzing the entire socio-ecological system. This is not surprising, given the difficulty of conducting studies in desert areas and inaccessible sites.

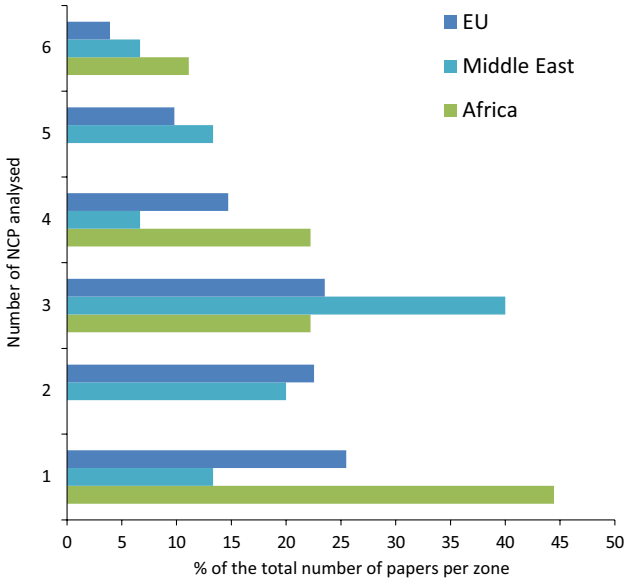

Fig. 3 Number of NCP analyzed (n=126) in the different zones (European Union zone = 102 papers; Middle East zone = 12 papers; Africa zone = 9 papers)

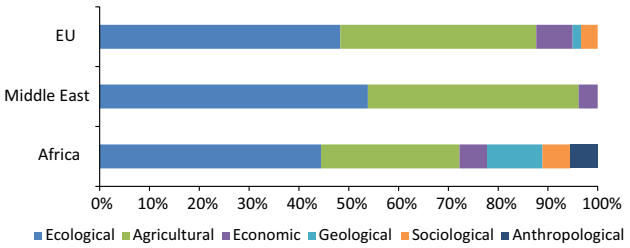

Fig. 4 Approaches used in the analysis of the case studies for each zone. Each bar reports the % of the total number of papers for each zone

Sedentary systems prevail across the Mediterranean basin (Fig. 2). EU papers suggest that sedentary systems align with well-established and strictly enforced land governance, featuring private, public, or common land with rigorous regulations on access. Transhumant systems are prevalent in Spain and France, but less so in Italy and Greece, despite the shared historical practice of transhumance in these four countries that persists today (Caballero et al. 2009; Huyghe et al. 2014). Sedentary systems dominate both the Middle East and Africa zones. In the Middle East, where most case studies focus on Israel (Figure S2), the extracted papers likely report the reality where the systems are intensive and, consequently, sedentary (e.g. Henkin et al. 2015). In the case of Africa, the limited eligible papers could reflect the observed dynamics, where sedentary systems outnumber all others, even in one of the oldest homes of nomadic pastoralism (Dong et al. 2016; Holechek et al. 2017). This

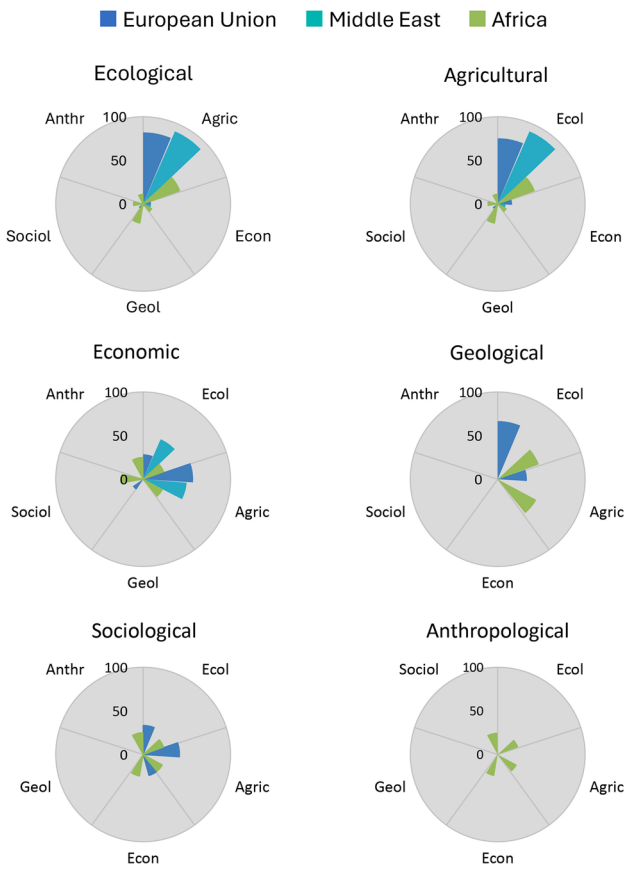

Fig. 5 Integration of approaches used in the analysis of case studies within the papers for each zone. Each petal reports the % of the total number of papers for each zone

could be because of land management practices, sedentarisation policies, or a symptom of the rural exodus to urban areas (Davies and Hatfield 2007; Plieninger et al. 2014; Ouedraogo and Davies 2016). The acknowledged relevance of nomadic systems in the African continent (Dong et al. 2016) and its low proportion in the study might be a symptom that pastoral systems in Africa are being 'simplified' or neglected as governments try to enforce sedentarisation on nomadic populations (Zinsstag et al. 2016; Niamir-Fuller and Huber-Sannwald 2020). The small number of papers analyzing nomadic systems contradicts the initial assumption that these systems would be well-represented. Nomadic cultures were expected to play a significant role in the zone, given their historical, cultural, and economic importance (Davies and Hatfield 2007).

Mountains typically represent a major resource asset for pastoral systems both globally and in the Mediterranean region (Montero et al. 2009), as confirmed by this study for most zones. Mountains and pastoral systems can claim a mutually beneficial symbiotic relationship (Caballero et al. 2009). While mountains provide natural resources for pastoral systems, these, in turn, provide numerous NCP (Fernández-Giménez and Estaque 2012; Huyghe et al. 2014; Ocak 2016). Many NCP such as fire prevention (Bernués et al. 2005), biodiversity conservation (Tesei et al. 2020), and landscape management (Lasanta et al. 2016) are directly related to the grazing system in mountains (Fernández-Giménez 2015; Varela et al. 2018). In the EU context, mountains are featured in 74% of the analyzed case studies (Table 1), indicating that the eligible papers provide a representative sample of the European situation. Here, the CAP plays a crucial role in sustaining pastoral systems. Pastoral activities in European mountain systems contribute significantly to maintaining biodiversity and NCP, serving as a cornerstone for CAP payments (European Commission 2019; Nori 2022a). This is the case, for example, in the Pyrenees (Liechti and Biber 2016; O'Flanagan et al. 2019). However, the situation is less clear for the Middle East and Africa due to the limited number of eligible papers. In the case of the Middle East, the data is notably biased towards Israel, where high mountains are only present in the northeast. Nevertheless, in these two zones, the importance of mountains sometimes emerges, as highlighted by Glasser et al. (2012) in Israel, El Aich (2018) in Morocco, and Belgacem et al. (2013) in Tunisia.

In the EU, grazing systems are categorized as 'pastoral + agro-pastoral' and 'silvo-pastoral + agro-silvo-pastoral' due to the prevalent use of semi-natural grasslands and shrublands/woodlands, respectively. Despite numerous EU papers, there is a notable absence of studies on agro-pastoral systems employing mobility and temporary forage resources, such as transhumant systems in central Italy, which are vital for NCP provision (e.g. Budimir et al. 2018; Francioni et al. 2020). In the Middle East, except for Turkey, where temporary grasslands are limited, systems rely mainly on rangelands and cereal stubbles in lowlands (Porqueddu et al. 2016). In Israel, cattle-based pastoral and agro-pastoral systems predominantly utilize shrublands and grasslands, even in lowlands. Despite common transhumance practices in the Middle East, studies focusing on mobile systems are lacking, unlike in Africa (Table 1).

Bias in the analysis of nature's contribution to people

While all the NCP groups are represented within each zone, regulating NCP are overrepresented. This is likely connected to the significance of biodiversity in the various pastoral systems, especially in the Mediterranean, recognized as a global biodiversity hotspot (United Nations 2017).

Within regulating NCP, a low number of 'climate regulation' NCP emerged, suggesting a lack consideration of the strong roles of global change (e.g. climate, social, economic) affecting the Mediterranean pastoral systems. This indicates a need for more availability of data on mitigation and/or adaptation strategies. Considering the potential for droughts and fires in the Mediterranean basin (Camarero et al. 2018),

the potential impact of pastoralism to prevent or control extreme climate events should be of great significance to many Mediterranean countries. This has been highlighted, for example, through the grazing of the firebreaks in the south of Spain and the reduction of biomass in Mediterranean systems (Oteros-Rozas et al. 2014; Varela et al. 2018; Niamir-Fuller and Huber-Sannwald 2020). Even more surprising is the very low number of papers that analyze climate regulation NCP (one paper for the EU and one for Africa) (e.g. Vigan et al. 2017).

We expected that 'food and feed' would be among the most common material NCP found in the eligible papers, as pastoral systems are primarily food production systems, which, in turn, develop over time to create all other NCP. Indeed, 'food and feed' NCP emerged (e.g. Delgado-Pertíñez et al. 2013). Food and feed was the most commonly found NCP within the literature, due to pastoral systems being food production systems. The selected papers enhance the understanding of the effect of diet selection, intake rates, and management practices of ruminant extensive farming systems on food (Ruiz et al. 2009; Mancilla-Leytón et al. 2013). This is noteworthy, especially given the anticipated shift towards diets with low environmental impact and improved food safety systems in the future. In the food market, consumers prioritize sustainability, authenticity, responsibility, personalization, and health and wellness (Poore and Nemecek 2018). In this context, extensive pastoral systems can play a significant role in producing high-quality products, particularly rich in antioxidants, healthy fats, and fat-soluble vitamins (D'Ottavio et al. 2018), which should be the focus of future research.

Within non-material NCP, an unequal distribution of findings emerges towards the 'physical and physiological experiences', mainly linked to the aesthetic value of landscapes (Table 2). Pastoralism is an important form of cultural identity that is linked to a sense of place, tradition, and heritage (Dong et al. 2016; Ouedraogo and Davies 2016; Zinsstag et al. 2016). This result is supported by Dean et al. (2021) who found that non-material NCP was the second most prominent NCP group globally. Here, this apparent lack of attention to non-material NCP in the analysis of Mediterranean pastoral systems in the EU may be a drawback of the CAP, as support for preserving indigenous and local knowledge is still limited, even though traditional farming practices are key in maintaining biodiversity-rich landscapes (Simoncini et al. 2019).

The results indicate balanced attention to the groups of NCP across the three Mediterranean zones (56%, 26%, and 21% for regulating, material, and non-material NCP, respectively). This confirms observations made by other authors. For example, D'Ottavio et al. (2018) found that regulating services (classified according to the MEA 2005) were among the most studied, while cultural services were among the least studied. Interestingly, despite cultural services being considered the most relevant for local and general stakeholders (Bernués et al. 2014), they received comparatively less attention. In this context, the bias towards regulating NCP might be attributed to the predominant use of ecological and agricultural approaches in analyzing pastoral systems in the Mediterranean, with less attention given to social or economic approaches (Fig. 5). This confirms that pastoral systems are rarely studied in a complex manner and are instead studied in terms of a few easily measured variables (Manzano et al. 2021).

Application of the Millennium Ecosystem Assessment–Intergovernmental Science-Policy Platform on Biodiversity and nature's contribution to people principles

Application of multiscale approach

The landscape scale was extensively utilized, primarily for analyzing regulating NCP. This is a positive outcome, potentially avoiding spatial scale mismatches, particularly for some regulating NCP. Spatial scale mismatches have historically hindered achieving environmental goals, such as biodiversity conservation (e.g. Falco et al. 2021) or landscape preservation (e.g. Lindborg et al. 2017). In pastoral systems, spatial scale mismatch is likely, given that many biophysical processes (e.g. soil erosion, water pollution, biodiversity losses) occur at the landscape scale which is the basis for land policies like agri-environmental measures in EU Rural Development Programmes (Toderi et al. 2017).

Regarding the temporal scale, the short-term scale may be suitable for some NCP (e.g. primary production in 'food and feed'), but for others, larger scales of analysis (i.e. medium or long-term) are necessary, as in the case of carbon dynamics, which received limited attention (only two out of 126). Given that the Mediterranean basin is recognized as a climate change hotspot (Lionello and Scarascia 2018), having insights into changes in forage production/quality is crucial for establishing adaptation strategies and preventing the collapse of pastoral systems.

Ecosystems vary significantly in space and time, and relying solely on single space or time measurements may lead to spatial scale mismatches (e.g. implementing irrational agri-environmental measures for biodiversity conservation in protected areas) (Toderi et al. 2017) or time scale mismatches (e.g. providing climate-mitigation guidelines for permanent grasslands based on short-term CO_2 dynamics) (Francioni et al. 2019b; D'Ottavio et al. 2023). Only two of the papers combined both field and landscape scales (Godinho and Rabaça 2011; Iglesias et al. 2016) while three papers combined different temporal scales (Fadda et al. 2008; Tárrega et al. 2009; Schoenbaum et al. 2009). This might display a

lack of consideration for the impact of pastoral systems across scales by the majority of researchers and supports the argument of Manzano et al. (2021) concerning pastoralism that is being largely overlooked in international sustainability forums and agendas. This hypothesis is supported by the fact that the few studies that analyzed multiple temporal scales have examined mainly regulating NCP *per se* and not as a bundle of NCP (Fadda et al. 2008; Tárrega et al. 2009; Schoenbaum et al. 2009). This highlights the necessity for multiscale and multisectoral approaches in analyzing pastoral systems. Such studies would enhance acceptance, and provide more data for researchers and policymakers, ensuring the sustainability of complex production systems amid a general downward trend exacerbated by climate change.

Application of multisectoral approach

Very few papers have adopted a multisectoral approach (Fig. 5 and Figures S6–8), revealing a gap in the literature on the complexity of pastoral systems. A multisectoral approach would significantly improve the situation. In this regard, integrating agronomic and social approaches, incorporating local farmers' knowledge, could enhance not only forage or meat production but also preserve the aesthetic quality of the landscape. Material NCP, especially 'food and feed', received adequate attention, yet integrating them with system features is crucial for realizing the full potential of pastoral systems. 'Physical and physiological experiences' were the most studied non-material NCP (Table 2, Fig. 1) and showed significant connections with other NCP groups (Figure S8). This is an encouraging result as it highlights the strong linkage with people as it has been shown that the aesthetic value of the landscape has a very high appreciation among stakeholders (Bernués et al. 2014).

Pastoral systems play a key role in the provision of a wide array of NCP (D'Ottavio et al. 2018) with emphasis on cultural NCP when social sciences are incorporated into the framework of analysis, highlighting one of the key differences between the NCP and ecosystem service frameworks (Dean et al. 2021). This idea is supported by a recent publication by Manzano et al. (2021) which shows that pastoral systems suffer from a lack of holistic thinking by academics. Indeed, focusing on only a few NCP or on only one scientific perspective as found in this analysis (Table 2 and Figs. 4 and 5), the risk of ignoring the potential cascading interactions among NCP and between scales is high.

Incorporation of different types of knowledge

Hybrid knowledge can be defined as a combination of scientific, land users, and policy makers' perspectives, leading to a more valuable and meaningful assessment of global changes (Thomas and Twyman 2004). Integrating hybrid knowledge in future studies could enable a comprehensive analysis of pastoral systems, fully recognizing their complexity (Young et al. 2006; Steyaert and Jiggins 2007; Akpo et al. 2015). However, from the analysis of the papers, a true hybrid knowledge never emerges. The studies primarily focus on agricultural and ecological approaches, often combined, but with limited integration of other perspectives. As a result, there is an imbalance in knowledge availability, with regulating NCP prevailing over others. This lack of integration hinders a complete understanding of all the components of pastoral systems and their potential interactions, putting at risk the ability to address stakeholders' priorities, which are crucial for the system's sustainability.

To effectively address complex systems, resolving these issues requires transdisciplinary scientific knowledge (e.g. involving agronomists, botanists, animal scientists) integrated with the knowledge of policymakers, farmers, and other relevant stakeholders. Including local knowledge leads to the development of site-specific, shared, and successful options (measures, actions, strategies, or interventions) that can address stakeholders' priorities. These options are site-specific because they are tailored to the local characteristics of the system, including ecological, sociological, institutional, and productive aspects. In the case of landscape-scale issues (e.g. biodiversity conservation, wildfire risks, aesthetic value of the landscape), such options can overcome scale mismatch problems (Toderi et al. 2017) often encountered in pastoral systems. The formation of hybrid 'scientific-local' knowledge in the analysis of NCP is crucial because it can enhance research findings and facilitate their adoption by stakeholders (Alcamo et al. 2003).

Caveats and limitations

Our research excluded many papers because the necessary information was not available within the articles, such as the grazing systems or the mobility methods.

Publication bias could also be an issue, that certain topics which report significant differences are more often published than studies that find no significant differences. EU pastoral systems in our analysis are heavily influenced by Spain as it is the individual country with a very high number of studies compared to the others that may have unduly affected the outlook of the EU pastoral system in the analysis. This is also the case with the Middle Eastern pastoral systems as almost 90% of the few eligible papers are from Israel.

As the study only included articles that were published in English, this can be considered a major limiting factor of the study. There are almost certainly relevant papers to be found in other languages outside of English, particularly in French as it is the most common language of publication in the African Mediterranean. Equally, there is a wide range of languages in the Eastern Mediterranean and in the non-EU

zone which may have limited the representation of countries in the analysis.

Conclusion

This study has confirmed the importance of pastoral systems as providers of a wide array of NCP across the Mediterranean basin. However, it has also highlighted that regulating NCP were the most studied throughout the analyzed literature. The little attention that pastoral systems have received as providers of all the other NCP highlights the need to broaden research to different aspects besides 'habitat creation and maintenance'.

This study highlighted a low level of integration between the different NCP, especially between those belonging to different groups. Nevertheless, a good level of application of both temporal and spatial scales of analysis was used in the analyzed papers. Both multisectoral and multiscale approaches are essential for the study of pastoral systems, as without the inclusion of diverse narratives, these would be otherwise viewed only in terms of a few variables, and their complexity will continue to be ignored. The hybrid MEA-IPBES framework has the potential to embrace the complexity of pastoral systems, but the lack of multisectoral approaches, along with the absence of hybrid knowledge, demonstrates that their complexity was not fully taken into account. If studies continue to ignore the multisectoral dimension of NCP, much of the pastoral system's complexity will remain unacknowledged. This, in turn, has the potential to increase the vulnerability of pastoral systems, as inappropriate policymaking could take place based on simplistic narratives. The case applies, for instance, when looking at Middle East and Africa, where the focus on sedentarisation and intensification has significantly influenced and biased research and investment efforts, resulting in a poor understanding of more extensive pastoral systems and the recognition of the NCP provided. One of the key ingredients for analyzing and supporting pastoral systems, taking into account their complexity, would be the inclusion of different types of knowledge by different stakeholders, resulting in hybrid knowledge. This hybrid knowledge should be used to deeply understand the components of the system and the interactions that exist between them, whether they are socio-economic, ecological, or productive. Hybrid knowledge is essential for co-designing strategies, interventions, and measures that support the sustainability and continuity of pastoral systems.

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Data Availability Data will be made available on request.

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