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Evolution of research on ecosystem services in the era of ecological economics: The case of Moroccan research on wetlands

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ABSTRACT

Ecological economics has become an essential discipline for tackling the world's ecological crises. It emphasizes the importance of finite natural resources, ecosystem services and economic and social sustainability. Researchers have integrated these environmental limits into economic decision-making, emphasizing the need for sustainable resource management to preserve ecosystems over the long term. This analysis combines a critical review of theories on the evolution of the concept of ecological economics with a bibliometric analysis of Moroccan scientific research on wetland ecosystem services. The latter was achieved by gathering 114 Moroccan articles on ecosystem services and 15 articles on Moroccan scientific research on wetland ecosystem services, all peer-reviewed and sourced from the Scopus database. The results indicate that studies on this subject are increasing in parallel with developments in the ecological economy. Understanding these trends and limitations is essential to guide future research on ecosystem services and wetland management.

1. Introduction

Ecological economics disrupts traditional economic models by highlighting the limits of infinite growth and emphasizing the crucial importance of ecosystem services in the face of natural resource scarcity[1]. Research on these services, particularly in wetlands, is of major importance for the preservation of biodiversity and human well-being [2]. Despite everything, the work done on this subject in Morocco remains little known on an international scale.
This study is part of a broader approach aimed at highlighting the essential role of ecological economics in the sustainable management of natural resources and increasing the visibility of Moroccan scientific research in this field. By scrutinizing the evolution of ecological economics and its application to the study of ecosystem services, particularly in wetlands, we challenge traditional economic models. Predecessors such as Herman Daly advocate for a balanced economy, where growth is constrained by the capacities of ecosystems, while others, like Nicholas Georgescu-Roegen, focus on entropy within economic systems. The differences of opinion regarding the integration of these ecological limits into our economic systems highlight the imperative of sustainable management of natural resources for a viable long-term economy.
Ecological economics challenges traditional economic models and focuses on how human activities interact with ecosystems and the physical limits of the planet[3].
She proposes to rethink economic growth by taking into account the essential ecosystem services for the Sustainability of Human societies. This study merges a critical analysis of the evolution of theories in ecological economics with a bibliometric evaluation of Moroccan scientific research on ecosystem services, with a particular focus on wetlands.

2. Materials and Methods

Based on specific criteria such as title, abstract, keywords, and publication years, this analysis examined 114 Moroccan articles on ecosystem services, as well as 15 articles specifically focused on Moroccan scientific research related to wetland ecosystem services. These peer-reviewed articles were evaluated using the Scopus database. The following equations were applied to filter the results:

Equation 1: 15 document results:
TITLE-ABS-
KEY (ecosystem AND services AND wetlands AND morocco)

Equation 2: 114 document results:
TITLE-ABS-
KEY (ecosystem AND services AND morocco)

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Namely, Equation 1 was applied for articles on ecosystem services in Moroccan wetlands, and equation 2 for ecosystem services in Morocco, with a search period extending from 2008 to 2023 for the first equation and from 1998 to 2023 for the second equation. The final results were selected on the basis of criteria such as titles, abstracts, keywords and years of publication. This methodical approach provides a detailed and insightful overview of ecological economics and ecosystem services research in Morocco.

3. Results and discussion

3.1 Notion and typology of ecosystem services

The German biologist Ernst Haeckel coined the term ecology in 1866. According to Mooney and Ehrlich (1997), the first articles to include basic ecological foundations date from works published in the 1880s and 1890s. Tansley first used the concept of ecosystem in 1935. Ecosystems are essential to human viability, since they create a favorable environment for life, and provide goods and services for human beings. Nature, with its physico-chemical, ecological and biological richness, is considered a heritage and a productive natural capital that provides human beings and ecosystems with benefits on the scale of production and consumption [4]. Ecosystem services refer to the benefits that ecosystems provide to human beings and to nature itself [5]. Daily emphasizes the distinction between ecosystem services as processes and as goods provided by ecosystems [6]. They include the conditions and processes by which natural ecosystems support and satisfy human life, encompassing biodiversity, production of goods such as fish, water, timber, fuels and pharmaceuticals, as well as life-support functions such as purification, recycling and renewal, along with cultural and aesthetic benefits[7]. On the other hand, Costanza considers goods and services as one group under the term “ecosystem service”. Although not explicitly stated in the MEA report, this idea is implied through the recurrent use of the term “ecosystem goods and services”. By grouping these two aspects under the term “ecosystem service”, we recognize the interconnected and interdependent nature of the goods and services provided by ecosystems [3]. There are several typologies of the ecosystem service, determined according to a number of factors and parameters. Of paramount importance is the one that detects the concept of ecosystem service according to the benefits it provides to the ecosystem and to humanity [3], [8], [9], [10].

The MEA proposed a classification of ecosystem services in 2005 to raise society's awareness of the multiple benefits we derive from the ecosystems around us [2]. This classification identifies four main categories of ecosystem services:

- Supply or production services, which encompass the direct services we use every day. These include the production of food [11], building materials and energy from ecosystems [12]. These services are essential to our survival and well-being [13].
- Regulating services, which refer to the ability of ecosystems to regulate other environments or processes. This can include climate and flood regulation, water purification [14], plant pollination and disease regulation [15]. These services play a vital role in maintaining the balance and health of ecosystems.
- Cultural services are another important category of ecosystem services [16]. They refer to the non-material benefits we derive from ecosystems, linked to our cultural, spiritual and recreational needs [17]. These can include aesthetic appreciation of landscapes, outdoor recreational activities, cultural and historical links, and symbolic and spiritual values associated with ecosystems [18].
- Sustaining or supporting services, which are fundamental to the production of other ecosystem services. They have indirect long-term effects on ecosystems, such as soil formation, nutrient cycling and photosynthesis and biomass production. Although less perceptible, these services are essential for maintaining the health and resilience of ecosystems [19].

The TEEB study identified habitat-related services as an essential category of ecosystem services. The latter play a crucial role in biodiversity conservation by providing essential habitats for animal species [15]. Habitats provide suitable conditions for reproduction, foraging, shelter and migration, and are particularly important for migratory species. Protecting these habitats, helps preserve the genetic diversity of species and maintain healthy populations, which is essential for the stability of ecosystems. Habitat protection is also of economic importance, as many migratory species have commercial value in other regions. Thus, preserving these habitats supports local economic activities and preserves the livelihoods of the communities that depend on them [20].

3.2 Wetlands

Wetlands are unique ecosystems at the interface between aquatic and terrestrial environments [21]. They include a wide range of habitats such as estuaries, lagoons, ponds, marshes, peat bogs, wet meadows and mangroves. This diversity of environments creates specific ecological conditions that favor a wide variety of species and ecological processes [22]. Worldwide, around 54% of wetlands are permanent and 46% are seasonal. A further 92.8% are inland systems and 7.2% are marine and coastal systems. Europe is home to around 12.5% of the world's wetlands, underlining their importance for biodiversity and water quality. The preservation and careful management of these ecosystems is essential to safeguard their ecological services [21]. According to the 1971 Ramsar Convention, a wetland is defined as an area of marsh, fen, peatland or water, whether natural or artificial. In addition,

it can be either permanent or temporary, and with stagnant or flowing water which, in turn, can be fresh, brackish or salt. This definition also includes bodies of marine water whose depth at low tide does not exceed six meters, and shows the diversity of wetland types that exist around the world. It encompasses mangroves [23], marshes, bogs, fens, ponds, lagoons, estuaries and even shallow coastal waters. This reflects the variety of ecosystems and habitats that wetlands provide, as well as their importance as reservoirs of biodiversity.

3.3. Economic ecology

In the 20th century, ecology and economics became autonomous disciplines. However, they share common interests [24]. Ecological economics emerged within this rapprochement, seeking to integrate ecological principles and environmental realities into economic frameworks [25]. It recognizes that economic activities depend on the natural resources and ecosystem services provided by nature [25], and seeks to assess and integrate the value of these services into economic decisions. Ecological economics aims to promote sustainability and responsible resource management by integrating ecological concepts into economic models. In doing so, it seeks to facilitate more informed decision-making and find sustainable solutions to environmental and economic challenges. The ecological economy thus represents an important attempt to reconcile ecological and economic perspectives for a more balanced and sustainable development [3], and [26].

The economic value of ecosystem services measures the well-being and benefits that people derive from ecosystem service (production, consumption, etc.). This value is classified according to the development of economic ecology on the time axis. Classical economics considers natural resources as use values and recognizes their contribution to services rendered, although their economic value is not taken into account. In the 19th century, the economic approach evolved towards exchange value and the substitutability of natural resources [24]. Neoclassical economics focuses on exchange values rather than nature and physical resources [24]. Money is used as a measuring instrument in social contexts to assess social well-being, and resource scarcity is often conceptualized in monetary terms. Environmental economics has developed techniques for valuing non-market ecosystem services in order to integrate them into economic decision-making, thus filling the gaps left by economics [24]. The controversy over substitutability and value in ecological economics raises debates over the monetary valuation of ecosystem services and environmental impact Turner (1999). The boundary between environmental economics and ecological economics is controversial, but both fields contribute to the understanding of environmental issues [27], and [24].

3.4. Evolution of the theory of ecology economical

The theory of Thomas Malthus, presented in his 1798 work "An Essay on the Principle of Population," highlights the tensions between population growth and the planet's limited resources. According to Malthus, the population tends to grow exponentially, while the available resources increase linearly, which inevitably leads to crises of overpopulation and food shortages. To develop the current of ecological economics based on Malthus's ideas, it is emphasized to explore how these concepts can be applied to our current understanding of environmental challenges and economic sustainability, focusing on responsible resource management and informed decision-making to ensure a viable future for generations to come [7].

On the other hand, in his 1890 work titled "Principles of Economics," Alfred Marshall drew attention to the concepts of sustainability and resource scarcity, which influenced the economic discussions of his time. He emphasized the need to consider limited resources and the effects of economic activities on the environment, thus laying the groundwork for the movement of ecological economics. Marshall's ideas helped to understand that economic analyses should encompass environmental and social considerations, leading to a more holistic approach to sustainable economic practices. This has encouraged a shift towards a comprehensive understanding of the coexistence of economic activities with natural resources and the environment. Marshall's work paved the way for the integration of environmental and social concerns into economic studies and raised awareness of the need for a balanced and sustainable economic approach [28].

In an economic opinion that is open to the views of environmentalists, Frederick Soddy, a British chemist, questioned the idea of infinite economic growth in his 1920 book. He emphasized the distinction between material wealth, which includes energy and natural resources, and monetary wealth. Soddy introduced the concept of physical economy, highlighting the importance of considering the limits of the biosphere in economic activities. His approach has influenced the development of ecological economics by emphasizing the need to consider the physical limits of the planet in economic models. This has paved the way for reflection on a sustainable economy focused on the preservation of natural resources and the environment for future generations. Soddy's ideas continue to inspire more balanced development strategies that respect planetary boundaries.

Nicholas Georgescu-Roegen, an eminent Romanian economist of the 20th century, introduced the concept of entropy in economics in his 1971 work titled "The Entropy Law and the Economic Process." He emphasized the essential link between economic processes and the laws of thermodynamics. Georgescu-Roegen stated that economic production is limited by thermodynamic constraints, particularly the irreversibility of energy consumption processes and the accumulation of entropy in the system. This perspective has profoundly influenced the field of ecological economics by highlighting the

importance of considering the physical limits of the planet and energy constraints in our economic systems. Georgescu-Roegen's contribution has thus enriched our understanding of the interactions between the economy and the environment, has promoted a more sustainable, and balanced vision of economic development.

The creation of the Society for Ecological Economics (SEE) in 1988, driven by researchers such as Robert Costanza and Herman Daly, is a remarkable initiative. Its main goal is to promote an interdisciplinary approach to economics that fully integrates ecological limits. This organization aims to develop economic models that consider environmental constraints, in order to promote sustainable management of natural resources while balancing economic, social, and ecological dimensions. Several researchers have contributed to the evolution of this field by proposing theories and solutions to integrate ecological concerns into economic decision-making.

Jiang and Cui focus on environmental sustainability in China, analyzing the impact of urbanization and development on ecosystems and ecosystem services in eastern China. Their theory advocates the idea that economic decisions should take into account ecosystem services and promote sustainable economic growth [29].

Robert Costanza is a pioneer of ecological economics; he developed tools to assess the economic value of ecosystem services, thereby demonstrating the economic importance of nature. He supports the integration of the economy into the biosphere and the inclusion of ecological costs in economic models [3]. Then Bai focuses on wetlands and the economic policies that influence their degradation. He proposes solutions to restore ecosystem services in these areas, emphasizing the importance of incorporating environmental costs into economic growth models [30]

On the other hand, Smith is interested in aquatic ecosystems and the impact of climate change on these ecosystems. He emphasizes the importance of considering ecosystem services in the management of water resources and adjusting economic policies to reduce negative impacts on these systems.

Thus, Ouyang has conducted research on the management of ecosystem services and promotes an approach where these services are mapped and assessed to influence national economic decisions. He emphasizes the need to integrate economic and conservation goals to strengthen the connection between economic prosperity and ecosystem health. Mitsch is a specialist in wetlands who has advocated for their recognition as vital ecological systems. He promotes the use of nature-based solutions to address environmental issues and asserts that wetlands can provide economic benefits while offering crucial ecosystem services. In addition, Li explores the impacts of urbanization on ecosystems and proposes solutions to integrate ecological principles into urban development strategies. He advocates for the creation of eco-friendly cities where biodiversity is promoted and negative impacts on ecosystems are minimized.

Finally, James Lovelock is known for his Gaia theory, which suggests that the Earth operates in a cooperative manner. His work highlights the importance of cooperation and harmony between ecological and economic systems to preserve the environment.

3.5. The evolution of Moroccan scientific research on the ecosystem services of wetlands in the era of ecological economics

The bibliometric analysis of scientific publications on ecosystem services in Morocco reveals a notable increase in production between 1998 and 2023, peaking in 2023 with 114 documents published (**Fig. 2.**).

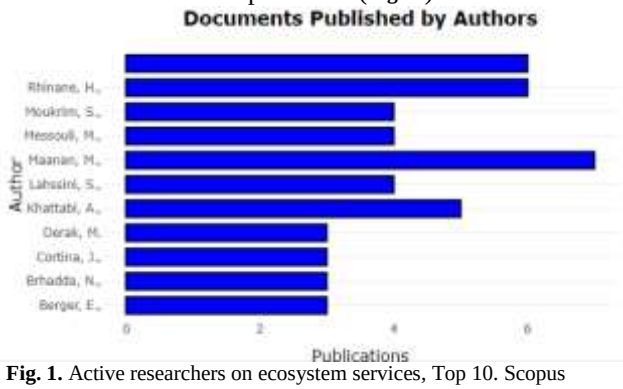

Fig. 1. Active researchers on ecosystem services, Top 10. Scopus database, selection of 114 documents.

This trend underscores a growing interest in ecological economics and ecosystem services. Regarding the ecosystem services of wetlands, Moroccan scientific publications, which began in 2009, show moderate growth, with only 15 articles recorded up to 2023.

The topics covered, such as biodiversity, ecotourism, and the economic evaluation of ecosystem services (Table 1), indicate a multidisciplinary approach. Studies like those by Choukrani on seasonal wetlands in Gharb and Ait Kacem on blue carbon stocks in the Moulay Bousselham lagoon highlight the importance of quantifying economic benefits. Furthermore, the integration of technology, as illustrated by Fathi (2023) through remote sensing, enhances natural resource management. However, the impact of these works remains limited, with a low number of citations, suggesting that Moroccan research, while relevant, is still underrepresented internationally and requires greater visibility.

Additionally, the analysis of publications (**Fig. 1.**) by author shows that Maanan, M. is the most prolific with 7 articles, followed by Rhinane, H. with 6 publications. Other researchers like Khattabi, A., Lahssini, S., and Messouli, M. each contributed with four publications, while Aydda, A. also stands out with three publications. This distribution reveals an active research community, though some authors are distinguished by a higher scientific output.

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Table 1
Number of Moroccan documents have been published on the ecosystem services of wetlands during the era of economic ecology.

Document title	authors	Source	Year	Citations
Biodiversity assessment and ecotypology of the Taanzoult plain running water (Aguelmam Sidi Ali, Morocco)	Sammoudi, Rachid	Scientific African	2023	0
Ecotourism in Morocco: Review of the Current Situation, Natural Potential, Cultural Diversity, Obstacles and Recommendations for Future Research	Chellik, Soukaina	Tropical Journal of Natural Product Research	2023	0
Remote Sensing at the Service of Wetlands Mapping: A Case of the Lower Loukkos Complex (North-West Morocco)	Fathi, Badreddine	Ecological Engineering and Environmental Technology	2023	0
Contrasting views of ecosystem services in seasonal wetlands of Gharb, Morocco (Visions contrastées des services écosystémiques des zones humides saisonnières du Gharb, Maroc)	Choukrani, Hajar	Cahiers Agricultures	2023	1
The Economic Benefit of Coastal Blue Carbon Stocks in a Moroccan Lagoon Ecosystem: a Case Study at Moulay Bousselham Lagoon	Ait Kacem, Hicham	Wetlands	2022	5
A new approach to mapping cultural ecosystem services	Mouttaki, Ikram	Environments - MDPI	2021	11
The value of carbon sequestration and storage in coastal habitats areas in North West of Morocco	Ait Kacem, Hicham	E3S Web of Conferences	2021	1
Groundwater-dependent ecosystems in the Souss-Massa river region: An economic valuation of ecosystem services	Hirich, Abdelaziz	Handbook of Environmental Chemistry	2017	5
Study of structure dynamic Mytilusgalloprovincialis in the atlantic coastline rabat-sale	Khamar, Mohamed	Der Pharma Chemica	2016	0
Combining vulnerability analysis and perceptions of ecosystem services in sensitive landscapes: A case from western Moroccan temporary wetlands	Bouahim, Siham	Journal for Nature Conservation	2015	30

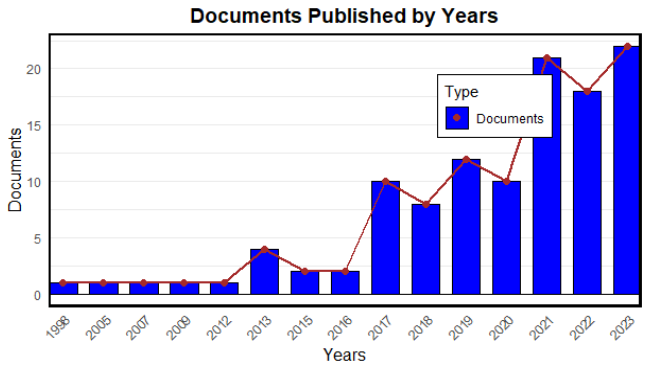

Fig. 2. Documents published by year. Source: Scopus database, selection of 114 documents.

A network of related concepts focused on the main idea of ecosystem services is demonstrated by the second study on ecosystem services in Morocco's wetlands (**Fig. 3.**). Six keyword collections with a total link strength of 1779 have been identified by the researchers. The relationships between multiple topics, notably wetlands, biodiversity, climate change, Moroccan-specific interests, and cultural services, are represented by this complex network. The figure's various colors show how research objectives have changed over time, and the lines joining the nodes show how strong the links are. Notably, the picture shows how issues like wetlands and biodiversity are frequently interlinked. Important insights into the interdependencies of several ecosystem service components are provided by this visual portrayal. It can be used as a reference by researchers and decision-makers to identify priority areas for further study.

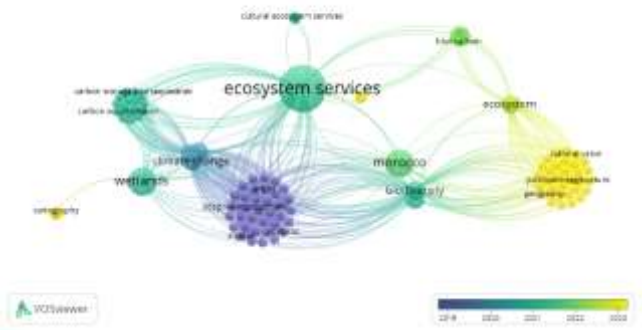

Fig. 3. Co-word map network visualization of Moroccan research at ecosystem services wetland. Source: Scopus database, selection of 15 documents.

3.6. Limitations

The theories of prominent researchers in ecological economics, including Jiang, Cui, Costanza, Bai, Smith, Ouyang, Mitsch, Li, Lovelock, and Daly, provide diverse perspectives on the subject. However, it is essential to recognize that each approach has its own set of constraints and obstacles that must be addressed. By carefully examining these limitations, such as the need for broader global application, the challenges of quantifying ecosystem services, the difficulties in implementing proposed solutions, and potential conflicts between ecological and economic goals, we are encouraged to critically reflect on how these theories can be improved and refined. Adopting a more comprehensive approach and seeking practical solutions that consider local realities, as well as political and social issues, can help lay a stronger foundation for a sustainable and balanced ecological economy.

Moroccan research on ecosystem services suffers from several gaps, including low international visibility and a high number of publications with few citations. Additionally, the lack of comprehensive data, funding challenges, and insufficient international collaborations limit the scope and impact of the work. Improving the integration of various disciplines is crucial for better understanding the complex relationships between ecosystems and local communities.

4. Conclusion

The concept of ecological economics challenges traditional economic models by highlighting the physical limits of the planet and the importance of ecosystem services. This approach encourages responsible management of natural resources and consideration of environmentally friendly economic alternatives. Scientific research conducted in Morocco on ecosystem services reflects a growing interest in ecological economics, but it still has limited impact due to a lack of international recognition. It is essential to better disseminate this work to effectively contribute to the sustainable management of ecosystems. Ecological economic theories offer various perspectives on the subject, but it must be acknowledged that each approach has its own constraints and challenges. By carefully examining these limitations, such as the need for broader global application, the challenges of quantifying ecosystem services, the difficulties in implementing proposed solutions, and the potential conflicts between ecological and economic goals critical reflection on improving and refining these theories is possible. Adopting a more holistic approach and seeking practical local solutions can contribute to a sustainable and balanced ecological economy.

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