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Ecosystem Services in the Milpa System: A Systematic Review

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Abstract

The Milpa System is a millenary agroecosystem that has played a crucial role in Mesoamerican agriculture for over 9,000 years. This system provides essential ecosystem services such as food production, soil quality restoration and the transmission of ecological knowledge. The objective of this paper is to inventory the potential ecosystem services provided by the milpa system, based on a systematic review of the literature. The review was conducted using the PRISMA methodology, ensuring reproducible and structured research. Despite the milpa system has been vital for Mexican agriculture, there is a significant lack of research on its ecosystem services. Because of this, the review was broadened to involve other types of polyculture agroecosystems that include maize as an integral part of their composition, resulting in the review of 47 articles encompassing 38 ecosystem services. Among these, five Provisioning services were identified, with 32 of the articles mentioning food provision. Twenty Regulation and Maintenance services are mentioned in 24 articles, while Cultural services are the least studied, appearing in only 12 articles. Although there is not enough research done on the potential of the milpa system to provide with ecosystem services, it remains a cornerstone of Mexican agriculture and social identity. Preserving and promoting the milpa system is essential for enhancing agricultural resilience, ensuring food security and conserving biodiversity.

Keywords

Agroecosystem, ecosystem services, milpa system, native maize, sustainability, traditional cultivation

Introduction

The Milpa System (MS) is an ancestral agroecosystem of Mesoamerican origin that plays a crucial role in agriculture. Its approach goes beyond food production by holistically integrating natural and cultural components with the environment (Harguindeguy 2021).

This traditional method of agriculture focuses on the cultivation of maize (*Zea mays L.*) intercropped with various companion plants (Castillo López et al. 2022). With a history of at least 9,000 years, the MS is considered a cornerstone of Mexican agricultural history (Franco and Galindo 2023, Toledo and Barrera-Bassols 2020).

One of the distinctive features of the MS is its biological diversity. The best-known and oldest MS in Mexico is the joint planting of maize with beans (*Phaseolus spp.*) and squash (*Cucurbita spp*.), known as the triada Mesoamericana (Mesoamerican triad). The planting of these three crops in the same field creates an agricultural synergy where each plant performs a specific ecological function: beans fix nitrogen in the soil, improving its fertility, while squash acts as ground cover, helping to retain soil moisture and control unwanted weeds (Sánchez-Velázquez et al. 2023). In some cases, crops such as chili (*Capsicum spp* .) and tomatoes (*Solanum lycopersicum*), as well as fruit and timber trees, are also integrated, contributing to the biodiversity and resilience of the system (Fonteyne et al. 2023).

Rooted in traditions and local knowledge, this system has withstood the test of time by playing a vital role in the food culture and nutritional security of indigenous and peasant communities (Méndez-Flores et al. 2023, Ramírez-Maces et al. 2023, Sánchez Morales et al. 2018). According to Guzmán-Mendoza et al. (2023), the prevalence of the MS in Mexico manifests as a tangible expression of the harmonious interaction between humans and nature, a symbiosis that has shaped agricultural landscapes throughout the country.

The sustainable functioning of the MS largely depends on the ecosystem services (ES) that this agroecosystem continuously provides. ES are defined as the direct and indirect benefits that ecosystems provide to humans (Costanza 2020). The proper functioning of ES is also crucial for the conservation of native maize and other local crops (Alpuche-Álvarez et al. 2019, Berdugo et al. 2019). A review of recent literature indicates little research has been done that summarizes the intersection of ES with the MS, which is important to highlight the need for its protection and conservation. Thus the objective of this review is to present an analysis of the available literature on the provision of ES in polycultures that include maize as part of their structure.

The systematic review positions itself as an essential tool to synthesize existing evidence, identify patterns, and offer recommendations for future research, thus contributing to the understanding and sustainable promotion of this valuable agroecosystem. This methodological approach allows not only for a comprehensive analysis of the relationship between biodiversity and the ES provided by the MS but also provides a solid foundation for the design of sustainable management strategies for agroecosystems which work under a similar principle.

Data resources

Literature Search

This systematic review follows the principles established in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Page et al. 2021), which guided the research team through a clear, transparent, and reproducible sequence, thus facilitating the presentation of the results in this article. The literature search was conducted in October 2023 on the Scopus portal due to its vast collection of scientific literature. The following search terms were used in the title, abstract, and keywords: (“ecosystem services” AND “milpa”) and (“ecosystem services” AND “maize”) for articles published between 2017 and 2023. The results were restricted to publications in Spanish and English. After applying this filter, 8 and 251 results were obtained, respectively, for each search term.

Selection Criteria

The article selection process began with the review of the abstracts of the 259 selected works. The software Abstrackr (Wallace et al. 2012) was used to manage the abstracts review by assigning an equal number of abstracts to two independent reviewers. The reviewers identified the potential relevance of the articles according to the topics addressed in the abstract. Considering the objective of this research, the following exclusion criteria were set at this stage:

- Abstracts focused on monocultures.
- Abstracts focused on crop rotation strategies.
- Abstracts related to agroecosystems that do not include maize.
- Abstracts that do not mention ES in an agroecosystem.

The application of these criteria resulted in a reduced list of articles that were subjected to a thorough review by two independent researchers. The specific objective of the extensive review was to identify the ES present in the studied agroecosystems. The process of the review is presented in Fig. 1.

This extensive review generated the formulation of additional exclusion criteria, this time focusing on the detailed description of ES:

- Lack of specification of ES.
- Presence of biased or tendentious information.
- Poor methodology.
- No identification of ES in milpas or polycultures.

Data Collection

A spreadsheet was created to compile essential information from the articles (i.e., title, journal, authors). In this sheet, each reviewer concisely summarized the content of the documents, including the filling out of the column included to list mentioned ES. Additionally, the number of incidences of each service was recorded. To achieve this, the services described in the various articles were standardized based on the most recent Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin 2018). The CICES classification was chosen because it is an international effort to present a common framework to measure, quantify, and evaluate the provision of ES in different environments. According to this classification, there are three main classes of services: Provisioning, Regulation and Maintenance, and Cultural. Provisioning services are material outputs from the ecosystem and the abiotic environment; Regulation and Maintenance services are ways in which living organisms can moderate or regulate the environment, thus affecting human health, safety, and comfort; finally, Cultural services are intangible, non-consumable benefits that are not subject to competition, which affect people's mental and physical states (Haines-Young and Potschin 2018). In this way, the services described by different authors were placed into broad categories and subsequently into specific classes, to make an equitable evaluation among the different reports.

Data Synthesis

With the information from the analyzed articles, a detailed description of the final products obtained from each ES was prepared. The synthesis was focused on the services mentioned in more than four articles, considering how this value is the median frequency of the total fo mentions in the analyzed documents.In addition to the systematic literature review, a bibliometric analysis was conducted to identify thematic trends in the research area. The bibliometric analysis was performed using the Science Mapping Process. For this study, the implementation for R of Bibliometrix (i.e. Biblioshiny) was used, which facilitated the execution of the science mapping process in the final steps of data analysis and visualization (Aria and Cuccurullo 2017). The choice of this tool was relevant for the literature review, as it provided with an overview of the current state of research in the area and allowed the identification of emerging trends that help to understand the most promising research areas. Moreover, this review aimed to provide a comprehensive view of the challenges associated with the valuation of the ES offered by the MS. To this end, the cascade model developed by Potschin et al. (2016) has been adopted, which considers that the physical structure and biophysical processes of an ecosystem determine its functions. These functions are defined as the crucial ecological interactions that sustain the ecosystem's capacity to provide services. ES, in turn, represents the flow of these functions, ultimately contributing to human well-being. The end of this flow can be interpreted as specific social benefits. This model facilitated the understanding of the multidimensional interconnection of the MS with ES, biodiversity, and human well-being. Additionally, it enabled the understanding of how impacts at a specific level of the cascade could affect the other levels Fig. 2.

Results and Discussion

The annual publication rate of research articles on the analyzed topic showed relative stability. An average of seven articles per year were identified, with two notable exceptions: in 2017, only two were recorded, while in 2021, there was a significant increase, with a total of ten publications. It is noteworthy that more than one-fifth of the articles are published by corresponding authors affiliated with institutions in China (n = 10), closely followed by studies from the United States (n = 9). Corresponding authors from Mexico and

Germany rank third in terms of contributions, with a total of four articles each. Furthermore, examining the geographical distribution of all authors involved in the reviewed articles reveals that Mexican authors constitute the largest group (n = 54), followed by American (n = 47) and Chinese (n = 43) authors Fig. 3 .

The examined studies presented a wide range of ES, highlighting both their diversity and the scarce repetition of themes among them. Some articles even chose to move away from the traditional focus solely on food production, by exploring other types of services more deeply, ranging from cultural aspects to ecosystem regulation. This outlook reflected a growing attention to the diversity of services that agroecosystems can provide.

In 2017, two relevant studies were examined, that mentioned cultural ES and pollination, a regulation service essential for biodiversity and ecosystems stability. In 2018, there was an increase in researcher interest with seven published articles mentioning the importance of maize agroecosystems for sustainable agriculture and how the implementation of polycultures increased yields compared to monocultures. For 2019, seven studies were reviewed, all of which mentioned biodiversity conservation as a significant benefit of polyculture agroecosystems, while three of them also mentioned cultural ES.

The articles published in 2020 mentioned the conservation of traditional agricultural practices as a tool to restore degraded ecosystems and recover the loss of ES, focusing on cultural and regulation services, with an emphasis on pest control. In 2021, there was a higher number of publications compared to the average of the other years analyzed. Although these publications addressed a narrower range of ES, they revealed a broader distribution of services within the three considered categories. In 2022, most studies focused on how polycultures could contribute to food security and climate change mitigation. Finally, in 2023, seven studies were analyzed that explored the relationship between polyculture agroecosystems, food security, increasing yields, and biodiversity conservation as key for agricultural diversity and natural pest control.

Regarding Provisioning ES, the research on polycuture systems has demonstrated how the implementation of such agroecosystems can significantly improve crop yields. Chikowo et al. (2020) made clear the importance of polycultures for increasing yield in areas with limited land, compared to monocultures and added how these systems can improve biodiversity protection and nitrogen fixation in the soil. Hunter et al. (2019) performed a meta-analysis that evidenced that polycultures could positively influence yield by providing multiple ES without compromising food production. These studies complied with the results by Colbach et al. (2018), Li et al. (2023), Sun et al. (2021) and Ulcuango et al. (2021) who concluded that polycultures generated higher food yields and economic gains, with the added benefit of promoting biodiversity conservation.

Daryanto et al. (2020) proposed that polycultures represent a new green revolution focused on sustainability and noted the importance of an agricultural paradigm shift towards their implementation. The studies by Novotny et al. (2021) and Pierre et al. (2022) found this to be true for Mexico, where the milpa had become fundamental in ensuring food security, biodiversity conservation and resilience to climate change. For instance, polycultures in Yucatán not only met the basic needs of more than 50,000 families but also presented yields between 31% and 53% higher compared to maize monocultures (Pierre et al. 2022).

Many studies made the point of mentioning how even though food production is the main goal of these agroecosystems they provided with a broad spectrum of additional ES. Some of the mentioned services include efficient water and soil nutrients use (Drinkwater et al. 2021, Mcharo and Maghenda 2021, Oyeogbe 2021, Pradhan et al. 2018, Shah et al. 2019), microclimate and greenhouse gas emissions regulation (Augstburger and Rist 2020, Rusere et al. 2022), biodiversity conservation (Augstburger and Rist 2020, Li et al. 2019, Sun et al. 2021, Ulcuango et al. 2021) and even cultural ES such as aesthetic beauty, education and recreation (Augstburger and Rist 2020). Delaquis et al. (2018) identified 25 positive impacts when transitioning from monoculture to polyculture, indicating that this transition promoted a balance between productivity, resilience, and environmental health.

Cultural ES provided by polycultures are relevant for their capacity to strengthen cultural identity and the community sense. According to several studies there are objective and subjective values linked to the sense of identity for rural communities that participate in the development of traditional polycultures (Barrasa García 2017, Falkowski and Diemont 2021, Soleri et al. 2022). Nevertheless, this situation was not exclusive to Mexican communities, as Mthembu et al. (2018) discussed, issues such as the need to strengthen social relationships and transmitting knowledge systems that would maintain their traditional crop system are faced by Mexican as well as South African producers. Lastly, Alpuche-Álvarez et al. (2019) argued that maintaining the milpa would not only preserve an agricultural system but also provide a range of cultural services encompassing social identity, physical and mental health, community cohesion, and spiritual and intellectual stimulation.

Falkowski et al. (2019) focused their research on the importance of preserving traditional ecological knowledge applied in milpa agriculture in the Lacandon Jungle through elements like songs, stories, and beliefs, and their relevance within the local culture, which was backed up by similar studies such as Augstburger and Rist (2020) and Falkowski et al. (2020). Vannoppen et al. (2021) focused on the "scenic attractiveness" as a cultural ES, evaluating the impact of maize cultivation and highlighting the improved landscape perception through polycultures and winter cover crops. Lastly, Soto-Pinto and Jiménez-Ferrer (2018) accentuated the cultural aspect of ES in a study for a combination of milpa with the production of timber trees. This combination not only generated aesthetic value but also promoted biodiversity conservation and increased yields by combining food and timber production in one site.

Finally, on the topic of regulation and maintenance ES, several studies mentioned the effects that polyculture agroecosystems had on the regulation of mass flows and extreme events such as underground water recharge and conservation (Hong et al. 2018, Mcharo and Maghenda 2021, Shah et al. 2019, Vignola et al. 2022). van Tuinen et al. (2020) explored the implementation of polycultures with trees to enhance ES, and even though the focus of the study was on the influence of roots on soil microorganisms, they also mentioned wind and erosion control due to presence of trees. Other studies that mentioned the contribution of polyculture to soil quality were made by Pradhan et al. (2018) and Wang et al. (2020) addressing fertility and the contribution of arbuscular mycorrhiza present in these systems. Similarly, Ansari et al. (2022) added composting to the polyculture to help in stabilizing soil properties and improving its fertility. In the same study and others, it was mentioned how polycultures improved the carbon sequestration levels and aided on leveraging the impacts of monocultures (Ansari et al. 2022, Jeswani et al. 2018).

Ajibade et al. (2023) emphasized the need to address the increasing vulnerability of soil to climate change and biodiversity loss. This call was supported by the study of Babu et al. (2023), who, through a three-year experimental analysis, demonstrated that polycultures, particularly the combination of maize with beans and buckwheat, produced a total carbon deposit of over 24.9 and 23.0 tons/ha at soil depths of 0-10 cm and 10-20 cm, respectively. According to these results, this polyculture not only improved agricultural yields but also contributed to other ES, such as carbon sequestration and climate change mitigation. Ma et al. (2023), demonstrated the importance of integrating legumes into maize polycultures with a 36-year mathematical simulation, learning how it could potentially increase soil carbon levels by 7% and reduce nitrogen leaching loss by 41% compared to other monoculture techniques, bringing attention to its economic and yield potential. These results supported the idea that maize polycultures are not only crucial for food security but also necessary for environmental sustainability, in contrast to intensive practices that threaten soil fertility and cause environmental degradation.

As previously mentioned, Augstburger and Rist (2020) studied the ES provided by polycultures from a multidisciplinary approach which allowed them to see the importance of intercropping to biodiversity conservation, idea that was repeated on studies such as Ajibade et al. (2023), Goettsch et al. (2021), Helms et al. (2021), Lami et al. (2023) and Wang et al. (2020) who accentuated the importance of the polycultures such as the milpa system for genetic diversity. Similarly, Landaverde-González et al. (2017) and Dively et al. (2020) advocated for the recovery of traditional crops, including wildflowers to attract pollinators that contribute to maintaining biodiversity and the health and stability of ecosystems.

Pokharel et al. (2023) and Vogel et al. (2023) demonstrated that intercropping for tea plantations with maize, and maize with beans, respectively, promote biological pest control by increasing the presence of pests natural enemies; in addition, improvements in soil quality and resistance to extreme weather conditions were observed. Helms et al. (2021), Ouyang et al. (2020) and Stoltz et al. (2018) stated how the presence of a multilayered crop structure provides with favorable habitats for pest predators, thus enhancing natural pest control. The studies by Otieno et al. (2022) and Lami et al. (2023) were more specific, by focusing on the presence of beneficial arthropods within maize agroecosystems. The results proved that arthropods have a positive role in sustainability by avoiding the need of using synthetic pesticides and improved resilience in the plantation.

Kc et al. (2022) performed a scoping review for ES in the context of agroforestry and changes to landuse in the Himalayas. They mentioned how each type of ecosystem (i.e.

agroforestry, agriculture, forests) performed better or worse in the provision of certain ES. For instance, the provision of food was better with both agriculture and agroforestry, than with forests; but, on the other hand, the risk for erosion, avalanches and landslides was reduced when considering forests and agroforestry, in comparison with agriculture. While these comments may not seem surprising, they highlighted the fact that due to climate change the temperature and precipitation regimes are changing and areas usually reserved for forestry are becoming available for agriculture, endangering the provision of forest-specific ES. The authors concluded that a balanced approach, such as the provided by agroforestry, would enhance some services such as food provision and ecological knowledge, while maintaining others like soil quality, erosion reduction and flood prevention.

Through the systematic evaluation of the articles, a total of 38 different ES were identified, revealing a characteristic pattern in the classification of ES linked to the MS. According to the three CICES categories, most of the identified ES are predominantly grouped in the "Regulation and Maintenance" category, with a total of 20 services documented on 151 occasions. Among these, biodiversity conservation (mentioned in 24 articles) and soil fertility support processes (cited in 23 articles) stood out as the most frequent Table 1.

In the category of cultural services, a total of 13 services were recorded, with 51 mentions. The most notable include aesthetic beauty (mentioned in 9 articles), education, cultural identity, and recreation Table 2.

Finally, concerning "Provisioning" services, five services were identified with 48 mentions, with the provision of plant-based food being the most recurrent. This finding was consistent, given that this study focused on an agroecosystem specialized in food production Table 3. Fig. 4 presents the frequency of mentions for each ES included in the systematic review.

As previously established, this study focuses on describing ES related to the MS, an agroecosystem designed to optimize soil productivity in terms of plant products. Consequently, it is not surprising that the most frequently mentioned ES is food provision, which has been addressed in 32 different studies. Similarly, the next two most mentioned ES are biodiversity conservation and soil fertility, which fall within the "Regulation and Maintenance" category. Biodiversity conservation plays a crucial role in maintaining suitable conditions for plant species that provide food or habitat for animal species acting as pest predators, such as insects and fungi. On the other hand, maintaining soil fertility is vital for the optimal functioning of the milpa, especially when considered as an organic system that avoids the use of agrochemicals for its proper development.

Based on the analysis of the reviewed documents, it can be argued that the provisioning ES contributed by the MS mainly focus on plant production, including plants for food, wood, and medicinal purposes. Conversely, the regulation and maintenance ES of the MS extend to various subsystems or compartments, encompassing soil (e.g., soil fertility and soil biodiversity conservation, as well as erosion control), water (such as water conservation and aquifer recharge), the biosphere (including biodiversity conservation, pest and weed control, and seed dispersal), as well as the abiotic interface surrounding the system (emphasizing carbon sequestration, microclimate regulation, flood mitigation, and wind control). These ES demonstrate the multifunctionality and integral importance of the MS in providing and maintaining essential ES.

The scope of cultural ES encompasses a broad perspective, as it involves human interaction with the environment in two distinct contexts. First, it relates to the active or passive appreciation of the ecosystem's features, including elements such as its aesthetic beauty, potential for tourism, and recreation. Second, it connects to community creation through these experiences, encompassing aspects such as inspiration, the development of campesino identity, and the influence of religious elements.

Following the ecosystem services cascade model proposed by Haines-Young and Potschin-Young (2010), it is observed that the final cultural service provided by the MS depends on how each specific plot is configured. For example, a milpa integrated into an agroforestry system may offer greater aesthetic value compared to an agricultural area that includes cover crops, and even more so in relation to one that only cultivates the basic products of maize, beans, and squash. Similarly, an agroecosystem that has maintained stable food production for a population over several years is more likely to become a reference point for creating a *campesino* identity, an identity rooted in traditional farming practices and community values, as opposed to one that requires constant fertilization and may endanger the health of producers who encounter it. This perspective underscores the interconnection between cultural aspects and the specific configuration of the MS in the provision of ES.

The limitations identified in this study emphasize the lack of research on the MS outside of Mexico, which restricts the generalization of the findings beyond Mexican borders, despite the benefits this agroecosystem offers to both farmers and consumers.

The main limitation lies in the scarcity of publications addressing the relationship between the MS and the ES. To tackle this challenge, we have broadened the scope of the research to include studies focused on ES in agroecosystems in general, and then narrowed down to those involving the production of maize along with additional crops. Although this implies a deviation from the focus of the study, it allowed us to explore a wider range of services that the MS can provide by comparing it with other similar agroecosystems.

The loss of ES dependent on biodiversity could potentially limit access to basic necessities for a healthy life, highlighting inequality in the most vulnerable sectors, especially in areas with high levels of marginalization and poverty.

Cultural ES are the least studied, with only 12 articles mentioning them. In general, other studies indicate that these services are the least researched due to the difficulty in quantifying them. Their study is greatly influenced by the subjectivity of each community and culture, complicating the creation of standardized quantification methods. Even when evaluation tools exist, they are subject to the subjective interpretation and valuation of each community and individual.

Another complication in the quantification of cultural ES lies on their economic valuation, which implies a challenge because these are intangible and often lack direct market value, making the use of economic evaluation tools difficult. However, their conservation is crucial as they contribute to human well-being by providing aesthetic, recreational, and spiritual experiences, and cultural identity through traditional practices, ceremonies, and spiritual connections. They also promote sustainable tourism that benefits both the community and biodiversity. The inclusion of cultural perspectives in ecosystem management and conservation is essential to ensure a sustainable balance between human needs and environmental health.

Considering that the primary objective of the MS is to optimize production primarily for food provision, it is important to point it out as a final service. Thus, the ES refers to a connection of ecosystem events and functions, followed by the valuation of benefits such as the nutritional value of these foods and the economic resources that can derive from selling surplus production. This reflection shows how, in the context of ES, the line between the service and its utilization can be blurred and cause confusion. However, it is important to consider the context in which we are working to more clearly identify the occurrence of the service.

Conclusion

This systematic review provides a comprehensive insight into the current state of knowledge on how diversity in the MS contributes to system health, agricultural productivity, human well-being, preservation of traditions and cultural aspects, as well as resilience to climate change. Through the systematic review of 47 articles collected from the Scopus database, 38 distinct ES were identified, according to the CICES classification.

Food provision stands out as the most mentioned ES, followed by biodiversity conservation and soil fertility. The reported services are predominantly grouped in the category of "Regulation and Maintenance", demonstrating the integral importance of the MS in the provision and maintenance of essential ES. Additionally, cultural ES play a crucial role, connecting aspects such as aesthetic beauty, education, cultural identity, and recreation, highlighting the relevance of cultural aspects and the specific configuration of the MS in the provision of ES.

Despite the scarcity of studies conducted, both outside and within Mexico, that relate the MS and ES, this review provides a solid foundation for understanding the importance of diversity in the MS in the global context. Furthermore, it emphasizes the need to promote sustainable agricultural practices, such as polycultures, to enhance agricultural system resilience and ensure food security and biodiversity preservation in a context of climate change.

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Author contributions

Aline Romero-Natale: Conceptualization, Methodology, Software, Writing - Original Draft, Editing; **Otilio Arturo Acevedo-Sandoval**: Conceptualization, Validation, Writing - Review; **Arturo Sanchez-Porras**: Methodology, Software, Writing - Original Draft, Editing

Conflicts of interest

The authors have declared that no competing interests exist.

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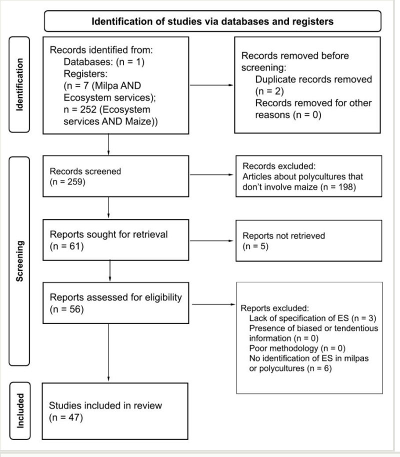

Figure 1.

Flow diagram of the methodology and selection processes used for this systematic review. It follows the template of PRISMA (Preferred Reporting Items for Systematic Reviews).

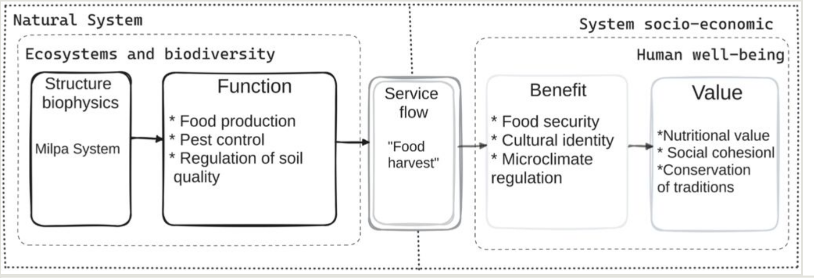

Figure 2.

Ecosystem services cascade model in the natural and socioeconomic context of the milpa system.

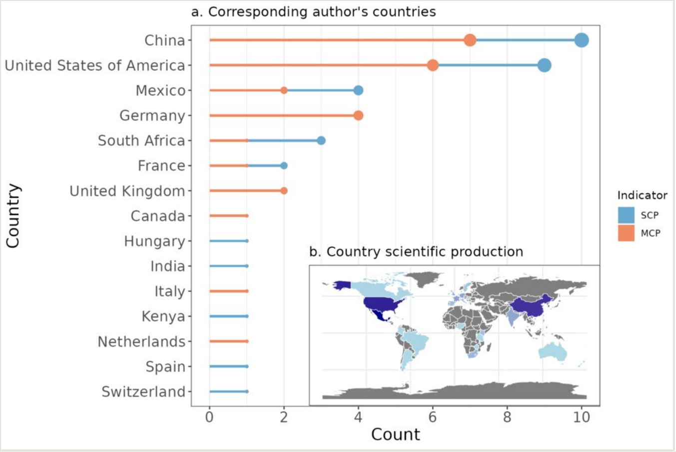

Figure 3.

a) Affiliation country of corresponding authors; SCP indicates Single Country Publications and MCP states Multiple Countries Publications; and b) Geographic distribution of all contributing authors of the reviewed literature.

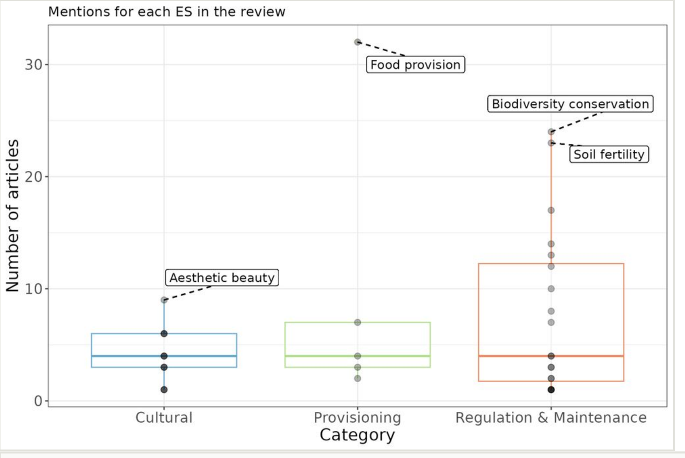

Figure 4.

Number of mentions for each ES in the reviewed literature. The services with higher number of mentions in each category are highlighted.

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Table 1.

Regulation and Maintenance Services in Polyculture Agroecosystems.

CICES Class	CICES Code	Identified Services	Mentions
Control of erosion rates	2.2.1.1	Soil Erosion Control	8
Buffering and attenuation of mass movement	2.2.1.2	Wind Reduction	1
Hydrological cycle and water flow regulation (Including flood control)	2.2.1.3	Drought Regulation	1
		Flood Regulation	2
Pollination (or 'gamete' dispersal in a marine context)	2.2.2.1	Pollination	12
Seed dispersal	2.2.2.2	Seed Dispersal	1
Maintaining nursery populations and habitats (Including gene pool protection)	2.2.2.3	Soil Biodiversity Conservation	3
		Biodiversity Conservation	24
Pest control (including invasive species)	2.2.3.1	Weed Control	13
Disease control	2.2.3.2	Pest and Disease Control	17
Weathering processes and their effects on soil quality	2.2.4.1	Soil Conservation	7
Decomposition and fixation processes and their effects on soil quality	2.2.4.2	Soil Fertility	23
		Nitrogen Fixation	10
Decomposition and fixation processes and their effects on soil quality	2.2.4.3	Carbon Sequestration	14
Regulation of the chemical condition of freshwaters by living processes	2.2.5.1	Water Quality	3
Regulation of chemical composition of atmosphere	2.2.6.1	Atmospheric Oxygen	1
Regulation of temperature and humidity, including ventilation and transpiration	2.2.6.2	Microclimate Regulation	2

Other types of regulation and maintenance services provided by biotic processes	2.3.x.x	Climate Change Mitigation	4
Maintenance and regulation by inorganic natural chemical and physical processes	5.2.2.1	Well Recharge	1
		Water Conservation	4

Table 2.

Cultural Services in Polyculture Agroecosystems.

CICES Class	CICES Code	Identified Services	Mentions
Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	3.1.1.1	Tourism	4
	3.1.1.2	Physical and Mental Health	3
Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	3.1.2.1	Stories	1
Characteristics of living systems that enable education and training	3.1.2.2	Spiritual and Intellectual Stimulation	4
		Education	6
Characteristics of living systems that are resonant in terms of culture or heritage	3.1.2.3	Social Cohesion	3
		Cultural Heritage	4
		Cultural Identity and Values	6
Characteristics of living systems that enable aesthetic experiences	3.1.2.4	Aesthetic	9
Elements of living systems that have symbolic meaning	3.2.1.1	Songs	1
		Cultural Inspiration	1
Elements of living systems that have sacred or religious meaning	3.2.1.2	Religious	3
Elements of living systems used for entertainment or representation	3.2.1.3	Recreation	6

Table 3.

Provisioning Services in Polyculture Agroecosystems.

CICES Class	CICES Code	Identified Services	Mentions
Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	1.1.1.1	Food provision	32
Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing	1.1.1.2	Biomass	7
Cultivated plants (including fungi, algae) grown as a source of energy	1.1.1.3	Fuel (Wood)	4
Cultivated plants for health purposes	1.1.1.X	Medicinal Plants	2
Surface water used as material (non drinking purposes)	4.2.1.2	Water Supply	3