Review [Revisión]

THE SCOPE AND CONSTRAINTS OF HOMEGARDENS FOR SUSTAINABLE DEVELOPMENT: A REVIEW †

[ALCANCES Y LIMITACIONES DE LOS HUERTOS FAMILIARES PARA EL DESARROLLO SOSTENIBLE: UNA REVISIÓN]

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SUMMARY

Background. Considering the current importance of recognizing the potential of traditional agroecosystems, including homegardens in the sustainable development of many rural and urban communities, strategists and scientists around the world are showing increasing interest in their study. **Objective.** Analyze the scientific literature relevant to the scope and constraints of homegardens (HGs), and to identify gaps and research perspectives, especially for indigenous communities in Mexico. **Methodology.** A total of 335 studies published in the last decades (1986-2020) were collected from different databases using predefined keywords. All publications were organized and stored in the Zotero (2018) program. The trends of all the publications were analyzed using NVivo 12 Plus software. **Results.** The number of publications increased from the year 2000. About 70% of the publications analyzed were research articles in english. Of the total studies examined 239 (71.35%) were conducted in different parts of the world, of which 30% from Asia and the remaining 96 (28.65%) from Mexico, primarily in tropics. Most of these studies focused on ecological (62.98%), economic (20.29%), cultural (13.43%), social (7.46%) and multifunctional features (12.23%) of HGs. The same pattern was identified in the case of Mexico, with studies of 10.74%, 5.07%, 5.67%, 0.597%, and 3.58% focused on ecological, economic, cultural, social and the multifunctionality features of HGs respectively. **Implications.** The analysis of the scope and limitations of HGs contributes to identifying the need to carry out transdisciplinary research that reflects their whole dynamics as agroecosystems, in which, in addition to the ecological environment, there are various cultural aspects considered important in the indigenous communities of Mexico. **Conclusions.** The publications emphasized the importance of homegardens to provide multiple ecosystem functions and services to enhance human well-being. However, future research should reevaluate HGs based on a holistic multi-functional agriculture approach to promote them as one of the strategies conducive to improve family well-being. Also, it is suggested to evaluate the degree of sustainability of HGs based on its resilience and adaptation capacity to confront current challenges.

Keywords: agroforestry systems; biocultural heritage; livelihood strategy; multifunctional agriculture; traditional agroecosystems.

RESUMEN

Antecedentes. Considerando la importancia actual de reconocer el potencial de los agroecosistemas tradicionales incluidos los huertos familiares en el desarrollo sostenible de muchas comunidades rurales y urbanas, los estrategas y científicos del todo el mundo están mostrando un interés creciente en su estudio. **Objetivo.** Analizar la literatura científica relevante al alcance y las limitaciones de los huertos familiares (HF), e identificar las brechas y las perspectivas de investigación, especialmente para las comunidades indígenas en México. **Metodología.** Se recopilaron 335 publicaciones de las últimas décadas (1986-2020), de diferentes bases de datos utilizando palabras clave predefinidas. Todas las publicaciones se organizaron y almacenaron en el programa Zotero (2018). Las tendencias de todas las publicaciones se analizaron utilizando el software NVivo 12 Plus. **Resultados.** El número de publicaciones

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aumentó a partir del año 2000. Alrededor del 70% de las publicaciones analizadas fueron artículos de investigación en inglés. Del total de estudios examinados, 239 (71.35%) se realizaron en diferentes partes del mundo, de los cuales el 30% de Asia y los 96 restantes (28.65%) de México, principalmente en los trópicos. La mayoría de estas publicaciones se centraron en las características ecológicas (62.98%), económicas (20.29%), culturales (13.43%), sociales (7.46%) y multifuncionales (12.23%) de los HF. Se identificó el mismo patrón en el caso de México, con estudios de 10.74%, 5.07%, 5.67%, 0.597% y 3.58% enfocados en las características ecológicas, económicas, culturales, sociales y multifuncionales de HF respectivamente. **Implicaciones**. El análisis de los alcances y las limitaciones de los HF contribuye a identificar la necesidad de realizar investigaciones transdiciplinarias que refleje su dinámica total como agroecosistemas en los que, además del medio ecológico, existen diversos aspectos culturales considerados importantes en las comunidades indígenas de México. **Conclusiones.** Las publicaciones enfatizaron la importancia de los HF para brindar múltiples funciones y servicios ecosistémicos con el fin de mejorar el bienestar humano. Sin embargo, las investigaciones futuras deben reevaluar los HF basados en un enfoque holístico de la agricultura multifuncional con el fin de promover estrategias conducentes al mejoramiento del bienestar familiar. Además, se sugiere evaluar el grado de sostenibilidad de los HF en función de su capacidad de resiliencia y adaptación para enfrentar los desafíos actuales.

Palabras clave: sistemas agroforestales; patrimonio biocultural; estrategia de medios de vida; agricultura multifuncional; agroecosistemas tradicionales.

INTRODUCTION

Homegarden (HG) has been identified as the oldest and complex land-use or agroforestry system that has evolved through generations in different parts of the globe, especially in the tropics. It is considered as one of the major forms of sustainable agricultural or food production activity commonly practiced by diverse cultural and ethnic groups of people all over the world primarily for subsistence (Torquebiau, 1992; Kumar and Nair, 2006; Krishnamurthy and Krishnamurthy, 2016; Vibhuti *et al*., 2018).

In Mexico, HGs play a vital role in the lifestyle of the indigenous population of more than 68 ethnic groups (INALI, 2008), distributed throughout the country. Also, it is considered as a sub-system of the traditional agroecosystems that predominate in the rural landscape of the nation as well as it is recognized as an integral part of the family agriculture system that provides food and other basic requirements to many native people in Mexico (Caballero *et al*., 2010; Mariaca, 2012; Ordoñez Diaz *et al*., 2018a; Castañeda-Guerrero *et al*., 2020).

In the last few decades, especially, from the 80's, there are several studies all around the globe that highlight the potential of HGs to contribute to sustainable development. This is mainly due to their ability to manage, use as well as conserve natural resources efficiently compared to commercial agricultural practices and at the same time provide multiple fundamental ecological functions (such as nutrient cycling, photosynthetic route enhancement, resistant to plant diseases) and services (such as food, recreation, habitat) which are primordial for inclusive rural development (Monroy and García, 2013; García-Flores *et al*., 2016a; Krishnamurthy *et al*., 2017; Muhammad *et al*., 2017).

Although the importance of HGs recognized worldwide, on one hand, still these systems have not been given priority in the national or international development agenda as an inclusive development strategy and on the other hand, the management, conservation, and appreciation of agrodiversity associated with these traditional systems in future remains uncertain due to the changing demands and expectations of the growing population regarding food or wealth.

To be specific, currently, traditional practices including HGs are vulnerable and confront series of environmental, economic, and socio-cultural crises such as climate change, loss of biodiversity, the irrational extension of the agricultural frontier, cultural erosion, migration, rapid urbanization, etc. Consequently, endangering the livelihood as well as the sustainability of the local people who depend on them, especially, as recognized in the rural parts of Mexico (Cano-Ramírez *et al*., 2012; Mohri *et al*., 2013, Cano Contreras, 2015; González, 2018; Ordoñez Diaz *et al*., 2018a). Moreover, the accumulated biocultural knowledge transmitted from generation to generation could vanish by disrupting the way of life involved in this kind of traditional practices (Toledo and Barrera-Bassols, 2008; Boege, 2008; Lope-Alzina, 2012; Ordoñez Díaz *et al*., 2018b).

Under these conditions, it is essential to review the current status, importance and persistence of the HGs towards the above-mentioned challenges. In this context, this study aims to gather, systematize, and analyze a wide set of scientific literature relevant to the scope and limitations of homegardens in the sustainable development of peasant families involved in their management as well as to identify existing gaps and study perspectives in this field of research, especially in Mexico.

In summary, the intention of this review is first, to document the current state of homegarden knowledge, and second, to provide compiled information as a basic reference to perform an updated review in the future. For this purpose, an extensive literature review relevant to the present study carried out using Meta-analysis method. Based on the outcome of our analysis, we ultimately discuss, why multifunctional homegardens despite its potential are vulnerable and how to enhance these systems to protect and promote as an alternative strategy for livelihood in the sustainable developmental policy programs.

MATERIALS AND METHODS

A search of publications related to homegardens at a global level was carried out. First, an extensive and systematic literature review was developed on the subject of interest using free or public search engine databases such as ScienceDirect, Google Scholar, Academia, ResearchGate, Scientific Electronic Library Online (SciELO), FreeFullPDF, and CONRICyT (initials in spanish stands for, Consorcio Nacional de Recursos de Información Científica y Tecnológica). The above-mentioned search engines allowed to have access to scientific articles relevant to the theme in different journals such as Agrosystems, Economic Botany, Elsevier, Ethnobotany, Nature, Terra, Tropical and Subtropical Agroecosystems, and the Mexican Science and Technology magazines of CONACYT (initials in spanish stands for, Consejo Nacional de Ciencia y Tecnología).

Second, different combinations of a predefined list of eleven key phrases both in Spanish and English were used: 1) Homegardens + Ecological importance, 2) Homegardens + Economical importance, 3) Homegardens + Sociocultural importance, 4) Homegardens + Multifunctional agriculture, 5) Homegardens + Sustainability, 6) Homegardens + Climate change, 7) Homegardens + Resilience, 8) Homegardens + Agroforestry, 9) Homegardens + Agroecosystems, 10) Homegardens + Mexico, 11) Homegardens + opportunities and limitations.

Third, the search was delimited from January 1986 to January 2020, considering only the published articles in indexed journals. Due to the lack of peer review process, the current study did not consider the valuable information found in "grey literature" (e.g., technical reports, conference abstracts, graduate and undergraduate theses). Fourth, all the publications found in the search were organized in a database according to the title, author, type and year of publication.

Fifth, they were stored in the reference management program called Zotero (2018), in the alphabetical order according to the American Psychological Association (APA 7th edition) standard. Sixth, all the references stored in the Zotero were converted in the RIS (Research Information Systems) format to store as a compiled file in the computer. Seventh, the compiled file was exported to the software program of qualitative research, NVivo 12 plus (QSR International, 1999), where a frequency analysis of words with a minimum of six characters was carried out. This number of characters was selected, since the keywords related to the topics of the publications contain at least six or more characters, for example, Mexico, homegarden.

The word frequency analysis allowed identifying the most representative keywords in all documents, which were detected in the word cloud (Figure 2) according to their dominance of font size, in the first five levels. These keywords allowed selecting the publications that contained three or more keywords in the abstract. Finally, the selected publications were classified based on parameters called nodes or themes. These codifications allowed to evaluate each publication based on its research topic. Also, these results facilitated the focus of the discussions to analyze the publications of homegardens at a global scale including Mexico, and perhaps the most important, they will contribute to strengthening research on home gardens in Mexico as pillars of agricultural sustainability, both ecologically and culturally.

RESULTS AND DISCUSSION

Across the globe, including Mexico, HGs have been studied extensively for different reasons. By analyzing the documented literature by a wide range of disciplines with a distinct research focus in a specific location, this review presents the following synthesis to update knowledge in the homegarden research topic.

Research publications in the homegarden field

The results of this database indicate that more than 70% of the research papers considered in this review were written in English and the rest in Spanish, as well as the type of publications analyzed, were mostly research (267 papers, i.e., 79.7%) and review (35 papers, i.e., 10.44%) articles. The rest of the documents belong either to book or book chapters. Regarding the place of research, more than 239 (71.35%) studies were carried out in different parts of the world, primarily in tropical regions. And the remaining 96 (28.65%) studies were carried out in different states of Mexico. Regarding the number of publications, overall, research studies in this topic is increasing in the last few decades, especially from the 1980s. The summary of all these results is shown below (Figure 1).

Word frequency analysis

The word frequency analysis was conducted based on the criteria of the minimum six characters of words as well as the 500 most frequent words from a total of 335 publications. The results obtained were filtered by deleting the irrelevant or derived or general words such as abstract, according, amount, examine, hypothesis, maximum, etc. The same procedure was applied for the 250, 100 and 50 most frequent words. This procedure facilitated to distinguish between the most and the least frequent words, which in turn simplified to select and compare the most representative keywords relevant to the topic.

Based on the results generated in the different levels of frequency analysis, a total of 22 most frequent keywords with maximum 16 characters were selected that represent 8.8% of the total words: species, homegardens, agroforestry, management, traditional, social, economic, conservation, biodiversity, development, cultural, ecological, knowledge, composition, structure, Mexico, ecosystem, nutrition, livelihood, agrobiodiversity, sustainability, biocultural. Also, a total of five less frequent keywords with maximum 15 characters that represent 2% of the total words: resilience, adaptability, agrodiversity, vulnerability, multifunctional, multipurpose.

The most and least frequent keywords could be differentiated based on the dominance of each word's font size in the following image (Figure 2). Some less frequent words such as resilience, agrodiversity not even shown in the image due to its low rate or rank of frequency. The selected keywords allowed to generate 10 principal themes or nodes (Table 1, Figure 3), which in turn facilitated to codify and then categorize or classify all publications into certain nodes based on their research focus. Many studies belong to more than one category.

The results of the categorized publications on homegarden research around globe indicate that: i) more than 62.98% of the papers were focused on the potential to provide diverse ecosystem services by safeguarding species, structural and functional diversity. Out of which, plant or species diversity issues from ethnobotanical perspective were the most prevalent studies; ii) about 20.29% of the research analyze the role to provide income or savings that helps to meet economic needs of the family through the sale or use of garden products throughout the year; iii) around 13.43% of the studies emphasize the potential to protect cultural diversity by promoting associated traditional ecological knowledge of the native people; iv) even though HGs scope to provide social benefits is higher, the results identified, only 7.46% of the papers encompass the social aspects; v) only, 12.23% of investigations highlight the multifunctionality feature using the holistic approach of sustainable development, i.e., environmental, economic, and socio-cultural functions; and vi) there are very few studies relevant to the assessment of the sustainability of HGs based on its resilience and adaptation capacity which is shown in the graph (Figure. 3).

According to the results obtained in case of Mexico indicate that although majority of studies identified explore the ecological (10.74%), economic (5.07), and cultural (5.67%) aspects of homegardens, there are very few studies (0.597%) given priority to the social relevance (Table 1). Besides, very lower percentage of HG studies considered (3.58%) analyze the multifunctionality character and its contribution to sustainable development. Overall, the classification of the publications based on nodes facilitated to select and compare research focus and findings in the HG field throughout the globe. Also, it allowed us to identify the current status in this field of research, which in turn facilitated to identify gaps and perspectives, especially in Mexico.

Homegarden: A traditional agricultural practice

Several research studies have been carried out in different parts of the world through which different aspects of HGs have been addressed until now, however, most of them remained descriptive. A clarification regarding the origin, definition and general characteristics of this traditional production system is essential to update reader's comprehension relevant to its historical context and biophysical aspects. In this context, as one of the results, the current literature review presents a summary of the overall description of this ancestral land-use practice in the following sections: 1) the concept of HG, 2) historic development of HG, 3) distribution of HG, 4) characteristics of HG, 5) types of HG, and 6) management of HG.

1) The concept of HG

There is a lack of universal term and definition to refer to homegarden (also spelt as a home garden). Numerous studies have been designated HGs using different terms that vary according to the culture, ethnic, language, and dialect of the distinct groups of people living in different geographical locations. For example, there are terms such as mixed-garden horticulture (Terra, 1954), dooryard gardens (Wilhelm, 1975), house garden (Stoler, 1978), home-garden (Wiersum, 1982), kitchen garden (Brierley, 1985),

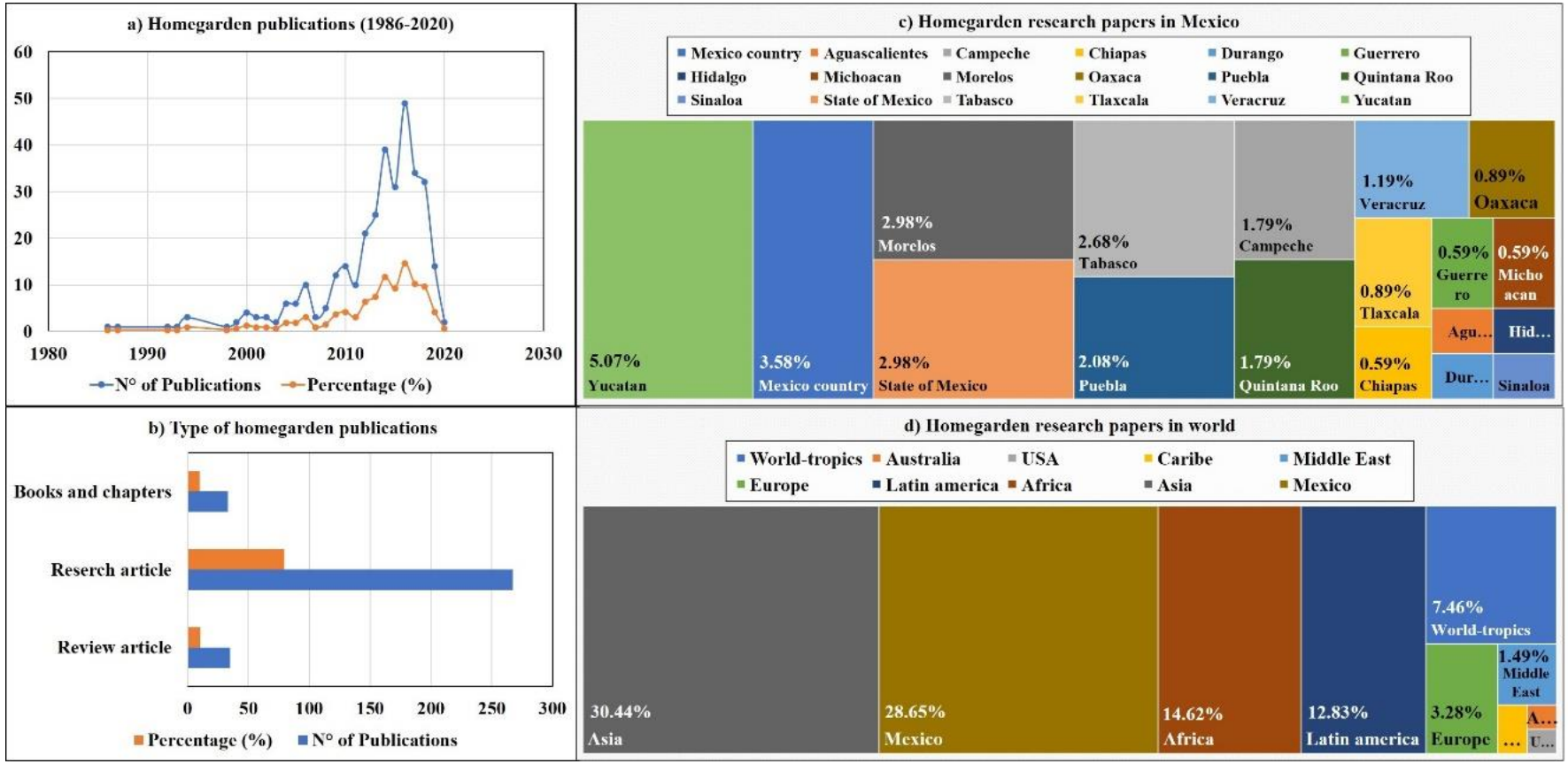

Figure 1. The categorized homegarden publications in the current study were represented in graphs that indicate: a) publications trend from 1986-2020; b) the type of documents considered; c) percentage of studies analyzed in different regions of Mexico and d) percentage of studies reviewed from different parts of globe.

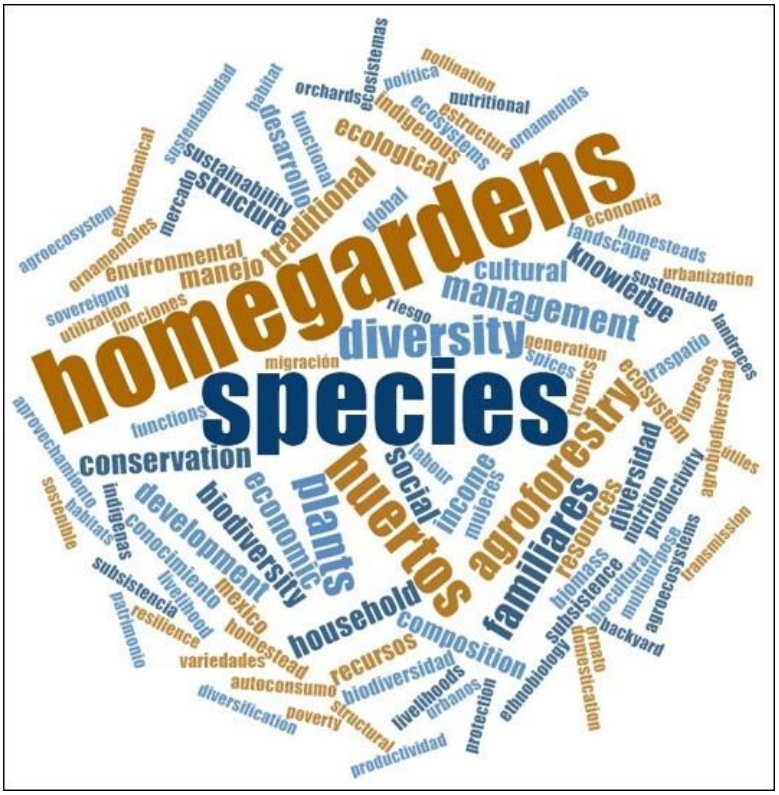

Figure 2. The word cloud of the 250 frequent words generated from the 335 publications could be distinguished based on the dominance of the word's font size.

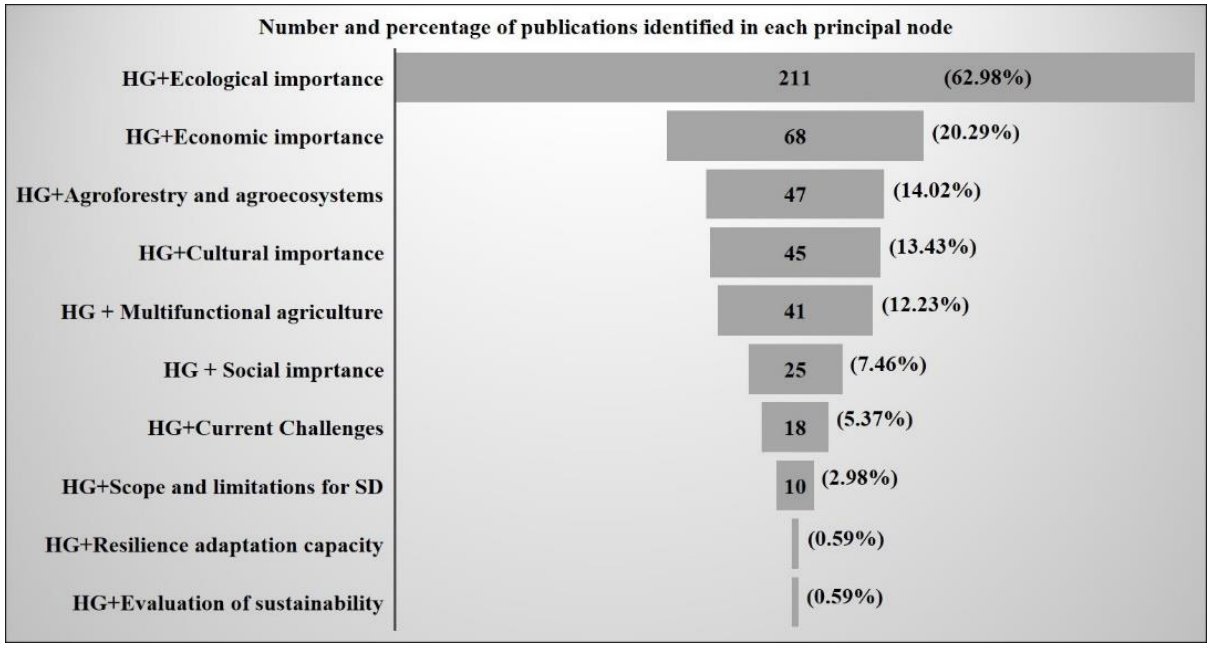

Figure 3. The number and percentage of research papers identified in each principal node determined based on keywords generated from the word frequency test.

household garden (Vasey, 1985), tropical agroforestry homegarden (Fernandes and Nair, 1986), javanese homegarden (Soemarwoto and Conway, 1992), agroforests (Kumar and Nair, 2006), and so on, which were commonly used throughout the world. However, as the term home garden is confused with ornamental

garden around homes, most of the recent literature use the term homegarden to refer the land-use system (Kumar and Nair, 2006; Lope-Alzina and Howard, 2012; Rayol *et al*., 2019).

In Central and South America, names such as *solar*, *patio*, vegetable garden, fruit orchard or tropical fruit homegarden, mixed agroforestry garden, *quintais* or *quintal agroforestal*, *pomares domestics* were frequently used to refer to homegarden (Lok, 1998; Akinnifesi *et al*., 2010; Arias-Reyes, 2012; Rayol and Miranda, 2019). In Mexican rural environment, existing several regional names in the spanish language such as *traspatio* (backyard), *huerto casero* (homegarden), *huerto familiar* (family orchard), and *solar*. Also, there exist several local or colloquial names assigned by the native people that were not well documented in the literature so far (Mariaca, 2012; Duché-García *et al.*, 2017; Delgadillo and Toledo, 2018; Ordoñez Diaz *et al*., 2018a).

Regarding the concept of homegarden, some authors describe it as an integrated agroecosystem located nearby the dwelling place and usually managed with family labour to grow and produce combinations of multipurpose plant and animal species primarily for family consumption (González, 2012; Galhena *et al.*, 2013; Gutiérrez *et al*., 2015; Flota-Bañuelos, *et al.*, 2016; Garcia-Flores *et al.*, 2016a). Others define it as a less complex agroforest system with deliberate management areas of natural resources within the compounds of individual houses that not only mimics epigeal and hypogeal stratification of forest or multilayered ecosystems (Rappaport, 1971; Lope-Alzina and Howard, 2012; Chablé-Pascual *et al.*, 2015; Gbedomon *et al.*, 2015; Thomas and Ravikishore, 2017) but also fulfils different social, economic, environmental and cultural needs of the people (Torquebiau, 1992; Hoogerbrugge and Fresco, 1993; Krishnamurthy *et al.*, 2017; Rosales-Martínez *et al*., 2019).

As homegardens are man-made microenvironment within lager farming systems that includes domesticated plants, and/or animals as well as people some authors consider it as a part of an agro-socio-ecological system with high species and functional diversity (Soemarwoto and Conway, 1992; Linger, 2014; Gutiérrez *et al.*, 2015; González, 2018). According to Mariaca (2012), it is a traditional agroecosystem in which the family unit lives and carries out different agricultural production activities related to the process of selection, domestication, diversification as well as conservation of flora and fauna including fungi. Also, the HGs are one of the most important sites in which peasant families are generating, transmitting and evaluating their agricultural knowledge.

Based on the consensus of various authors, in general, the concept of the operational base of homegarden could be defined as a land-use or agroforestry system that has an intimate association with trees, shrubs, annual crops and/or domestic animals adjoining to the plots of an individual home where ecological interactions take place between an agroecosystem and the household to obtain multiple products and services mainly for the family well-being (Fernandes and Nair, 1986; Soemarwoto, 1987; Torquebiau, 1992; Kumar and Nair, 2006; Mohri *et al*., 2013; González *et al*., 2014; Cano Contreras, 2016; Duché-García *et al*., 2017; Chakravarty *et al*., 2018; Thamilini et al., 2019; Castañeda-Guerrero *et al*., 2020).

2) Historical development of HG

HGs are considered as one of the oldest land use activity next only to shifting cultivation practiced by our ancestors in different cultures of the world (Kumar and Nair, 2004). Historical records based on archaeological evidence or literature references suggest that HG practices seem to have arisen in prehistoric times when hunters and gatherers in their nomadic lifestyle incidentally or parallelly domesticated the wild ancestor of maize (*teosinte*), wheat, squash, and other important plants or fruit trees, at least more than 9,000 years ago (Mohri *et al.*, 2013; González, 2018).

There are many other studies across the globe approximately coincide with the above dates regarding the origin of HGs. For example, Trabanino (2018) indicates that Mesoamerican agroforestry systems such as homegardens are at least 11,000 years older. According to Miller (1992), and Miller *et al.* (2006), hunter-gatherers have occupied the western Brazilian Amazonia around 9,000 years ago and probably performed prehistoric agricultural activities adjacent to dwellings, along with or near rivers in the forest (Lathrap, 1977).

Archaeological evidence from Colombia, Ecuador, Peru, and Mesoamerica confirms that cultivation of native tubers and seed plants was taken place in Amazonia between 10,000 and 8,600 years ago (Piperno and Pearsall, 1998; Piperno *et al.*, 2000; Smith, 2001). A study from Asia (Mohri *et al*., 2013), based on the works of Hutterer (1984) and Terra (1954) indicates that, for instance, javanese homegardens originated in the 7th millennium BC, in Central Java and parts of East Java, expanding to West Java in the mid-18th century. According to Wiersum (2006), the

origin of southeast Asian tropical homegardens might be around 13,000-9,000 BC.

In the case of Mexico, HG and milpa (corn, pumpkin and bean field) agroecosystems are considered as an agro-bio-cultural heritage due to its long history of about 9 millennium (González, 2018) that helped people to develop settlements with sustained annual food production (Angel-Pérez, 2013). Based on the grinding stones and botanical samples found in the state of Chiapas, Acosta Ochoa (2010, 2011) indicate that incipient or dispersed HGs were started at the end of Pleistocene epoch i.e., between 10,000-12,500 years ago. And Smith (1967), suggest that the formation of diversified homegardens (with at least nine tree species), began approximately around 6,000-7,000 BC, which was based on the evidence provided by MacNeish (1967) from the excavations carried out in the Tehuacan valley, in the state of Puebla. Also, Caballero (1992) confirms the vital role of HGs in pre-Hispanic societies such as the mayans, aztecs and totonacs continue to sustain many indigenous communities even after the colonial era. According to Fedick *et al.* (2008) traditional maya homegardens in the Yucatan peninsula dates back at least over three millennia.

Table 1. Percentage of publications in Mexico belong to each node in homegarden research.

No°	Principal nodes	No° of publications in Mexico	% of publications
1.	HG + Multifunctional agriculture (sustainable development or SD)	12	3.582
2.	HG + Ecological importance	36	10.746
3.	HG + Economic importance	17	5.074
4.	HG + Social importance	2	0.597
5.	HG + Cultural importance	19	5.671
6.	HG + Current challenges	3	0.8955
7.	HG + Scope and limitations for SD	4	1.194
8.	HG + Agroecosystems & Agroforestry	14	4.179
9.	HG + Resilience, adaptation capacity	-*	-*
10.	HG + Evaluation of sustainability	1	0.298

*(Publications not available or registered in the current study).

In summary, although the time gap suggested in different studies varies, all the above references invariably conclude that the land-use activity of HG was a millennium practice and originated due to the human perception of germination of some edible seeds or plants left incidentally in the resting places of the groups of nomadic hunter-gatherers at least more than 9,000 or 10,000 years ago.

Moreover, the transformation of the nomads from hunter-gatherer to a farmer not only contributed to establishing early human settlements where a certain plant or animal domestication were carried out adjunct to the dwelling places, primarily for subsistence, but also the development of traditional homegarden practice usually located in the surrounding areas near the individual houses.

Also, certain characteristics (such as location, species diversity, family labor and destination of the products) between prehistoric agricultural activities near early human settlements and HG systems resemble each other. In this context, considering the evidence (based on dating techniques) given by some authors like Abdoellah *et al.* (2006), Miller and Nair (2006), Acosta Ochoa (2010, 2011), Ordoñez Diaz *et al*. (2018a), González (2018), and Trabanino (2018), we could suggest that HGs could be the place where agriculture was born since the cultivation and domestication process of many species in the early human establishments influenced the development of agricultural societies in different parts of the globe. However, in general, this land-use practice has been recognized in the global arena as an important agroecosystem as well as oldest agroforestry system.

3) Distribution of HG

Homegardens are the most widespread use of land in the tropics and subtropics of the world, predominantly in the regions of East Africa, West Africa, South Asia, Southeast Asia, Pacific Islands, as well as Central and South America (Fernandes and Nair, 1986; Agelet *et al*., 2000; Howard, 2006; Kumar and Nair, 2006; Chakravarthy *et al*., 2017). According to Lok (1998), Rebollar-Domínguez *et al*. (2008), Mariaca (2012), Ordoñez Diaz *et al.* (2018a), and González (2018), in Mexico, homegardens are common in both rural and peri-urban areas and distributed mainly in the Central East and Southeast zones (principally in the states of Tabasco, Chiapas, Veracruz, Oaxaca, Puebla, Hidalgo and in the Peninsula of Yucatan). In general, farmers world-wide have developed these systems due to their contribution of ecosystem services which is far from negligible.

4) Characteristics of HG

Homegardens, in general, are distinguished among other agroecosystems due to its unique environmental, economic, social and cultural characteristics. By analyzing several documents, the current study presents the following summary of the list of general key characteristics considered by different authors across the globe to distinguish homegarden from other agricultural systems (Table 2). However, it is important to recognize that even though components of ecological environment such as geological, geographical, climatic and edaphic aspects are instrumental in determining the overall aspects of homegarden, the uniqueness of each homegarden depends mainly on cultural characteristics such as customs, traditions, individual or gender preferences of the members of the family (Smitha *et al*., 2006; Brandt *et al*., 2012; Cuevas, pers. comm., 2019). For instance, each Mexican homegardens has its characteristics that reflect the local environmental conditions as well as world vision of the native people towards the management, use and conservation of species.

5) Types of HG

Homegardens are generally classified based on its environmental, economic and socio-cultural characteristics or variables which mainly depend on the research focus of the study. Variables such as the area or size of the garden, climatic zones, economic conditions of the household were utilized in different studies to classify homegardens (Lok, 1998). For instance, in some parts of South Asia, gardens that contain a link to agricultural and natural landscapes generally located in rural or semi-rural areas of Sri Lanka are classified as Kandayan homegardens or forest gardens (Jacob and Alles, 1987; Perera and Rajapakse, 1991; Pushpakumara *et al.*, 2012).

In Indonesia, traditional Javanese homegardens are also referred as *pekarangan* (Wiersum, 2006). In Vietnam, diverse agri-aquacultural carried out near the domestic dwellings are distinguished as traditional integrated agriculture-aquaculture (IAA) system or *Vuon-Ao-Chuong* (VAC) system, which means Garden-Pond-Livestock pen (Trinh *et al*., 2003). In Mesoamerica, traditional fruit homegarden that contain native fruit trees as a main component of the agroecosystem found generally near the individual home (Sotelo-Barrera *et al*., 2016). Based on the analyses this review presents the following summary of some types of homegardens mentioned in different papers (Table 3).

6) Management of HG

Management of HG varies from place to place according to the ecological environment, cultural and socioeconomic contexts. As work is done manually, human labour is used as the main energy input in these traditional small-scale agroecosystems. And they do not depend on high energy inputs such as chemical fertilizers, pesticides or fuel-powered machinery. Also, very simple tools such as a small hoe, rake, spade, fork, pickaxe, watering hose and stick were used in the garden activities. Many of these tools were built from recycled material available locally. Animals such as cattle, hens found in the homegardens contributed to maintaining the fertility of the soil. Due to these reasons, HGs are generally considered as a sustainable agroecosystem from an ecological point of view. Each HG was maintained by the household members (including men, women and children) and the harvest products are primarily consumed by the family. Majority of the plants grown in homegardens are cultivated (Vogl and Vogl-Lukasser, 2003; Ángel and Méndoza, 2004; Mariaca, 2012; Chávez-García, 2012; Chablé-Pascual *et al*., 2015; Larios *et al*., 2013; Gbedomon *et al*., 2015; Krishnamurthy *et al*., 2017; Castañeda-Guerrero *et al*., 2020). However, some of the plants belong to other management categories: wild, tolerated, protected or fomented, and domesticated species.

Multifunctional role of HG for sustainable development

Many farmers worldwide practice HGs primarily to satisfy their family needs. However, homegardens have a good reputation for providing a series of goods and services that are not always referred to agricultural production. For example, biodiversity conservation, soil fertility, carbon sequestration, gender equity, social cohesion, savings or income from diversified biophysical outputs, and biocultural heritage conservation etc. In other words, HGs can fulfil ecological, economic and socio-cultural functions better than monocultures or other agricultural practices (Fernandes and Nair, 1986; Kumar and Nair, 2006; Lwanga, 2012; Sánchez, 2012; Agbogidi and Adolor, 2013; Mattsson *et al*., 2013; Mohri, *et al*., 2013; Calvet-Mir *et al*., 2015; Vieira *et al*., 2016; Schrader *et al*., 2017; López *et al*., 2019; Rosales-Martínez *et al*., 2019; Abdoellah *et al*., 2020; Castañeda-Guerrero *et al*., 2020). In this context, the following section intends to analyze the ecological, economic and socio-cultural importance of homegardens to have a better understanding regarding its multifunctional feature.

1) The Ecological Importance of HG

Recently, there is growing attention to find ways of reconciling food and agricultural production activities to confront several environmental challenges such as climate change, biodiversity loss, genetic erosion that

Table 2. Summary of the general key characteristics of the land-use system of homegardens (adapted from sources*).

No°	General characteristics of homegardens	Description
1.	Environmental characteristics • Location • Frequency of harvest • Species composition • Structural complexity • Flow of energy • Functional diversity	• Near dwelling or residence areas (which are physically delimited using fences or hedgerows or borders established through mutual understanding) [2, 3, 5, 7, 8, 11, 14] * • Daily and seasonal [2, 3, 5, 6, 14] • Resemble and mimic natural or forest ecosystems ecology [2. 6, 7, 8, 9, 13] • Horizontal and vertical organization [1, 3, 5, 13, 14] • Complex and dynamic interactions [1, 13, 14] • Fulfils multiple social, economic, environmental and cultural functions [1, 9, 10, 13, 14]
2.	Economic characteristics • Capital investment • Income • Destination of products	• Low establishment, labour and input cost [3, 8, 11, 14] • Main or additional income [9, 11, 13, 14] • Family consumption (supplement or main source of living) [3, 5, 11, 14]
3.	Social characteristics • Exchange of additional part-time assistance and products • Labour source • Access	• Generally, with friends and neighbours [4, 7, 8, 14] • Family labour (men, women, and children) [9, 14] • Easy access [8, 11, 14]
4.	Cultural characteristics • Selection of species type • The pattern of plantation design • Type of energy • Type of technology • Degree of management	• Based on cultural and individual preferences or needs (e.g., food, medicinal or other species) [5, 9, 14] • Irregular [3, 5, 14] • Manual using simple hand tools [1, 5, 12, 14] • Simple technology varies according to the world vision of each culture [1, 5, 13, 14] • Wild, tolerated, fomented, cultivated and domesticated [15]

*Sources: 1. Rappoport (1971), 2. Barrera *et al*. (1977); 3. Ruthenberg (1980); 4. Fernandes and Nair (1986); 5. Niñez (1987); 6. García-Flores *et al*. (2016a); 7. Soemarwoto and Conway (1992); 8. Hoogerbrugge and Fresco (1993); 9. Lok (1998); 10. Mendez (2000); 11. Mitchell and Hanstad (2004); 12. Wiersum (2006); 13. Kumar and Nair, (2006); 14. Galhena *et al*. (2013); 15. Larios *et al*. (2013) and Angel-Pérez (2013).

Table 3. Summary of the types of *homegarden* (adapted from different sources*).

No°	Variables or criteria	Types of homegarden
1.	Total, area or size of homegardens	Big or medium or small [5, 8, 9, 11]
2.	The economy of the household	Survival, subsistence, market and budget gardens [5, 10, 12, 14] *
3.	Distribution of homegardens based on: • Ecological zone • Geographical zones	• Tropical or temperate [5, 9, 14] • Rural or peri-urban or urban [5, 9]
4.	Purpose of production activity	Subsistent or semi-commercial or commercial [13]
5.	Species diversity • Species (density) diversity • Management zones	• High or low diversity [1, 2, 3, 6, 7, 8, 9, 10, 11, 13] • Mixed management zones of plants (medicinal, vegetable, ornamental, etc.) and trees (multi-purpose) including habitation areas [8, 9, 10, 13]
6.	Structural diversity (space utilization or division based on management areas)	• Multi-strata homegardens or agroforests [1, 3, 4, 5, 8, 9, 13]
7.	Functional diversity	• Fruit, vegetable, ornamental, handcrafting and mixed production gardens [4, 7, 10, 14]

*Sources: 1. Rappoport (1971), 2. Barrera *et al*. (1977); 3. Ruthenberg (1980); 4. Fernandes and Nair (1986); 5. Niñez (1987); 6. García-Flores *et al*. (2016a); 7. Soemarwoto and Conway (1992); 8. Hoogerbrugge and Fresco (1993); 9. Lok (1998); 10. Mendez (2000); 11. Mitchell and Hanstad (2004); 12. Wiersum (2006); 13. Kumar and Nair, (2006); 14. Galhena *et al*. (2013).

affects human well-being. In this context, traditional homegardens have attracted considerable attention of scientists and developmental strategists due to its potential to provide multiple benefits as well as to contribute to achieving environmental sustainability. During the past few decades, many studies demonstrate the ecological importance of HGs by analyzing its: a) species diversity, b) structural diversity, and c) functional diversity.

a) Species diversity

The composition of HG refers to both biotic and abiotic elements found within the system (Lope-Alzina and Howard, 2012). However, several authors from a wide range of disciplines (ethnobotany, agroecology, anthropology, agroforestry, ethnoecology) principally focus on the richness, frequency, dominance and abundance of plant and animal components in the study of homegardens. Most of the studies demonstrated the high floristic composition of HGs by inventorying species and concluded that HGs are one of the agroforestry or agroecosystems that consists of highly diversified multipurpose species located around homesteads (Fernandes and Nair, 1986; Miller and Nair, 2006; Kabir and Webb, 2007; Kumar, 2011; Rayol *et al*., 2017). Regarding the origin, HGs also consists of many non-native species that varied according to the history (particularly trade) of the region.

Moreover, the potential value of HGs as repositories of biological diversity to conserve many landraces and cultivars, as well as wild and endangered species is recognized worldwide (Watson and Eyzaguirre, 2002; Galluzzi *et al*., 2010; Avila *et al*., 2017). For instance, more than 301 trees and shrubs were reported from the Mayan homegardens of Yucatan, Mexico (Rico-Gray *et al*., 1990, 1991), 419 species belonging to 109 families were reported in Bangladesh (Kabir & Webb, 2007), 186 plant species in the North-East Brazilian urban and suburban homegardens (Akinnifesi *et al*., 2010); 223 plant species with different uses were identified in Campeche, Mexico (Flota-Bañuelos *et al*., 2016), about 357 species belonging to 263 genera and 102 families were found in Totonac homegardens in the state of Puebla, Mexico (Castañeda-Guerrero *et al*., 2020).

However, as HG is a dynamic system with constant changes, the estimated data of species richness in various studies depends mainly on the selected sample size or methodological procedures and variables. For instance, as more HG units are surveyed, high diversity will be reported. Besides, as limited plant specimens were collected to identify their taxonomical characteristics, it is unclear whether standard inventorying procedures were considered to avoid enlisting same species into different ones due to the complication involved in distinguishing between many varieties and local names.

Some studies also analyzed the correlated factors that influence plant species diversity in homegardens. Although personal preferences of the members of the family is the key factor to determine the floristic composition of HGs, a broad range of other variables related to ecological conditions, cultural demands and socioeconomic context also influenced the crop diversity of HGs. For example, a study conducted at a global scale (Padulleés *et al*., 2014) indicates that mean temperature, potential evapotranspiration, the distance between settlements and differences in GDP (Gross Domestic Product) per person, are some important variables that explain the taxonomic dissimilarity between gardens.

Other variables such as population density, garden type, mean annual rainfall, and dominant language of the family also contribute positively (but lesser than above variables), to the species diversity in HGs. Housing or farming age and size (Eichemberg *et al*., 2009) education, gender, homeownership (Yabiku *et al*. 2008; Larson *et al*., 2009; Zhou *et al*., 2009) are some other factors that have a significant influence in determining the types of plants grown by people in their gardens.

Other studies apply the diversity index methods to evaluate the alpha, beta and gamma diversity in HGs. However, in general, most of the HG research that intends to evaluate the role of agrobiodiversity primarily focus on interspecific (variation between species) diversity of plant and animal components, and there is a lack of adequate data analysis on intraspecific (variation within species) diversity.

According to Cuevas (pers. comm of the second author), the comprehensive assessment (not just the measurement) of the existing agrobiodiversity in an agroecosystem (among them the family gardens), requires adjusting the methods (such as Shannon and Simpson index) used to date, since, in this case, the concept of species is insufficient, being essential to consider the infraspecific variants (cultivar, subspecies, race, cultivar). And even within these, those of cultural importance such as flavour, pungency, as well as agronomic importance as susceptibility to Phyto pathological or environmental problems such as resistance to drought should be considered to determine the exact status of agrobiodiversity in a zone.

Regarding fauna, very few domestic species such as chicken, pig, cattle, sheep and goats, dominate the scenario in the HG system and the role of wild or semi-domesticated species also needs to be focused on the research (Ruíz-Nieto *et al*., 2019). Besides, there is not enough research that analyzes the importance of other living components that is associated with agrobiodiversity of homegardens such as fungi and microorganisms (bacteria, algae, lichens, insects etc.).

Moreover, as the potential use of many wild species within HGs have only begun to be documented, further research from ethnoecological and ethnobotanical approaches are required to identify the plant and animal resources to implement a win-win strategy in tackling both livelihood challenges as well as sustainable development constraints.

b) Structural diversity

The structure of HG refers to the spatial organization of all elements within the system. In other words, both horizontal (livestock, buildings, vegetation) and vertical (vegetation) distribution of system's components combine to form the full structure of HG (Rappaport, 1971; Lok, 1998; Lope-Alzina and Howard, 2012; Thomas and Ravikishore, 2017). Many studies are given more emphasis to analyze the vertical strata of HG due to the complexity of its functional dynamics. For example, the vertical height of the vegetation (predominant) component determines the type of interactions (complementary or competitive) among species and allow a good utilization of environmental factors such as sunlight, water and nutrients. A study from India, suggests that existing facilitative mechanism by the main crop (coconut trees) to its intercrops (clove and nutmeg) above the ground, but exploitative mechanism below the ground (Pandey *et al*., 2014).

Also, it has been generally recognized that vertical (height) strata of HGs have the multi-strata or multi-storey pattern (similar to that found in natural ecosystems or forests) with a combination of various plant species of different life forms and heights distributed in different niches (Kumar and Nair, 2006; Pandey *et al*., 2014; Castañeda-Guerrero *et al*., 2020). For instance, according to Fernandes and Nair (1986), Caballero (1992), Lope-Alzina and Howard (2012) most of the HGs are distributed vertically at least with three layers: lower with herbs and food or medicinal plants (0-2 m), intermediate with shrubs or bushes and young low trees (3-5 m) and upper with tall trees (5-10 m). Other studies identified four (Krishnamurthy *et al*., 2017) and six (De Clerck and Negreros-Castillo, 2000) different vertical strata in Mayan-Yucatecan homegardens in the state of Quintana Roo in Mexico.

The horizontal base structure of HGs is characterized by identifying areas with specific use and management that frequently resembles the worldview or cosmos of native people. For example, some areas or zones covered with ornamental, herbs, perennial trees or shrubs, annual crops, uncultivated plants, buildings or dwelling space (Caballero, 1992; Lok, 1998; Mendez, 2000; Lope-Alzina and Howard, 2012).

Furthermore, like species diversity, the structural diversity of homegarden also varies from place to place according to the local ecological, socioeconomic and cultural characteristics. Planting pattern, design and choice of the plants, for example, influence significantly the structural pattern of HGs. According to Vibhuti *et al*. (2018), altitudinal variations and size of HGs determine the planting pattern and plant choices or preferences which in turn are highly linked to aesthetic or cultural values of the HG owners.

In summary, the structural complexity of HG systems has been claimed to play a pivotal role in providing several ecological services and functions. For example, the structural diversity of agroecosystems reducing the risk of crop failure, providing shade to understory plants, protecting soils from erosion or degradation due to heavy rain or wind, increasing the efficiency of resource management and its resilience, etc. (Soemarwoto, 1987; Abdoellah *et al*., 2006; Vlkova *et al*., 2011). However, as it is difficult to separate the species-specific interactions due to the structural complexity of HGs, very few studies intend to understand its mechanism of interactions or the flow of energy in below and above ground (Rappaport, 1971). Also, the functional structure of HGs is not given enough focus to understand well (Wiehle *et al*., 2014). Therefore, more research should focus the functional dynamics of homegardens based on its structural diversity to understand the complexity involved in it to improve the mechanisms of these systems in near future.

c) Functional diversity

HG systems provide a series of advantages in terms of ecosystem services by fulfilling diverse environmental, socio-economic and cultural functions. As the role of economic and socio-cultural importance of HGs are discussed below, this section explores about some ecological functions. For instance, HGs as one of the sustainable family farming system improve fertility and conserve the soil which is the basis for agriculture and forestry production. A study to evaluate the soil chemical properties of homegardens from Eastern Amazon, Brazil concludes that these systems act similarly as the secondary forest in terms of nutrient cycling and conserve the fertility of tropical soils. Thus, it could be recommended as one of the

alternative strategies to restore degraded areas (Thiago *et al*., 2016).

Other studies acknowledge that HG systems serve as a reservoir of genetic diversity, thereby well suited for *in situ* (maintenance of populations in natural surroundings) and *circa situm* (maintenance of populations within altered agricultural landscapes or farm) conservation of potential wild or endangered species for the present as well as future use (Kumar *et al*., 1994; Akinnifesi *et al*., 2010; Galluzi *et al*., 2010; Agbogidi and Adolor, 2013). According to Schrader *et al*. (2017), HGs ensure pollination services through the conservation of species richness and abundance of wild bees which are essential to secure farmers yield of many crops.

Many studies highlighted the potential role of HGs to reduce the global warming by serving as a reservoir of short- and long-term stored carbon in its soil, wood products and vegetation biomass (Saha *et al*., 2009; Mattsson *et al*., 2014; Subba *et al*., 2017; Marambe *et al*., 2018). Some studies showed how the practice of homegardens help to reduce the local rate of deforestation by diminishing the family's livelihood dependency on forest-based products such as firewood, timber, fiber, medicine, animal fodder and shade (Albuquerque *et al*., 2005; Das and Das, 2005; Kehlenbeck *et al*., 2007). Also, HGs provide essential regulating services such as pest regulation, water and nutrient cycling, erosion control.

In general, HGs improve local environmental or climatic conditions and act as a refuge to wildlife as well as provide comfort and security to the family. Moreover, it adds value to the entire landscape as well as to the property itself (Galhena *et al*., 2013; Idohou *et al*., 2014). However, very few studies provide quantitative data regarding the functional dynamics of this complex agroforestry system. Also, the functional equivalence or redundancy (i.e., multiple species representing a variety of taxonomic groups can share similar, if not identical, roles in ecosystem functionality, for example, nitrogen fixers) suggested by Salmerón *et al*. (2017), should be considered in the future research of this ancient land-use practice.

Moreover, it is not well known whether the knowledge of the local people associated with HG practice is still transmitted to the next generation to improve its resilience in the face of current challenges. This is why it is important to understand that although it is essential to measure the so-called biocultural heritage that a peasant family has inherited, it is equally important to consider the degree of appreciation for it, which is evidenced in its daily application.

2) The Economic importance of HG

Several studies recognize that HGs as a source of edible fruit, vegetables, medicines and other products that satisfy many human needs as well as provide food and nutritional security of the owner´s family in different parts of the world. For example, according to (Torquebiau, 1992), in many tropical developing countries, over one-third of the total calories and protein consumption were obtained from the food production of HG systems. Thamilini *et al*. (2019), concludes that families with organized HGs had achieved greater nutrient adequacy by means of higher dietary diversity. Furthermore, it plays an important role in the subsistence economy of the peasant´s families, as the harvest products from HGs either reduce the personal consumption expenses or provide additional or supplementary cash income by selling them in the local market. Sometimes exchanging the production of HG products with the owner's friends and neighbours without ready cash or money also help to save money or labour (Blanckaert *et al*., 2004; Cámara-Córdova, 2012).

Besides, HGs are profitable ventures from the ecological point of view, as many benefits or positive externalities (such as erosion control, carbon sink) of HGs cannot be evaluated using conventional economic approaches such as yield, cost-benefit analysis and net present value (Torquebiau and Penot, 2006). For these reasons, HGs are an effective approach to enhance the livelihood as well as the economy of the people who depend on it.

However, HGs contribution of economic benefits primarily depends on the plants or species that are grown according to the satisfaction of the needs and requirements of the owners of the households. For example, changes in the demand of the market significantly influence the owner's choice of the production as well as its destiny i.e., whether for self-consumption or commercial purpose (Peyre *et al*., 2006). Moreover, without diversifying the horizontal and vertical structure of HGs, profit enhancement cannot be expected.

In other words, as each homegardens are structurally and functionally different from each other, it is important to diversify and add value to HG products to generate income as well as food and nutritional security (Thomas and Ravikishore, 2017). Besides, as the value of many goods and services are difficult to quantify, the amount of income and savings derived from these systems are not exactly presented in many papers.

Therefore, more research is needed to identify the influence of current local trends or societal pressures over the owner's choice of HG management as well as

structural diversification of specialized HG systems to increase economic benefits. Moreover, assessment of the nutritional value of each native species and the evaluation of food security based on access, availability, utilization and market (the four pillars of food security) in different regions, especially among indigenous groups are recommended for further research.

3) The socio-cultural importance of HG

Notable studies acknowledge that HG is a social capital that not only ensures the availability of multiple products but also develops social interactions with neighbours and relatives which in turn strengthen the relationship between them. It also reflects the societal status of the owner by increasing stability as well as the integrity of the households through continuous food supply employment and supplementary cash income throughout the year. Especially, during crisis periods (such as wars, conflicts, natural hazards, pandemic), HGs not only guarantee basic comfort and food security but also act as a safety net in providing alternative livelihood sources to the family (Kabir and Webb, 2008; Buchmann, 2009; Agbogidi and Adolor, 2013; Linger, 2014; Bargali, 2016).

Moreover, HGs are considered as a valuable patrimony to the native people, as it keeps alive the cultural history as well as local knowledge about species management, use and conservation from generation to generation. That's why, it is recognized as a biocultural heritage that reflects the world vision or cosmos of the local indigenous population who experimented and transmitted their knowledge of selection and domestication of plant and animal species over generations (Boege, 2008; Mariaca, 2012; Calvet-Mir *et al*., 2015).

However, although some of these studies focus on sociocultural aspects of HGs, none examines how changes in these aspects impact homegarden systems resilience. Hence, in future, the information regarding sociocultural factors needs to be evaluated then interpreted with caution as they have a significant influence in the variations of the structure and species composition of homegardens as well as management practices, which in turn system's sustainability criteria.

Current status and challenges of HG

Several studies highlight considerably that the millennial practice of homegarden design is the most important component of traditional agroforestry or agroecosystem in many parts of the world, particularly among indigenous people living in rural communities of Mexico. It is also recognized as a multifunctional land-use system that provides numerous (ecological, economic, and socio-cultural) benefits to enhance the livelihood of the local native people throughout the year.

Recently scientists, as well as strategists of developmental programs around the globe, are refocusing their attention towards HGs due to their sustainability and multifunctional role. However, despite worldwide recognition of the importance of HGs, currently, this ancestral practice is confronting enormous challenges. For instance, challenges such as agricultural expansion and fragmentation, climate change, loss of biodiversity, cultural erosion, socioeconomic trends have a significant influence in the future transformation of traditional agroecosystems, particularly homegardens. Even though HG practice have evolved over centuries and survived too many changes until now, however, the agrodiversity associated with these systems remains uncertain.

Many authors have already expressed their concern about the future of this traditional practice. To be specific, questions are already raised whether the shift from subsistence to market-oriented agriculture, rural migration either in pursuit of education or labour, land pressure due to urbanization, lack of interest of the new generations to care the traditional farming systems due to the rapid changes in the pattern of food, environmental and livelihood conditions etc. are threatening the very existence of HGs, particularly at the local scale (Kumar and Nair, 2006; Boege, 2008; Mohri *et al*., 2013; Vogl-Lukasser and Vogl, 2018).

On one hand, modifications in the fundamental structure and functions of the HG system due to above challenges not only compromise its potential (multifunctional and sustainable) role, but also the invaluable biocultural knowledge involved in it. On the other hand, many people in different parts of the world who practice HG are still living under poor conditions and lot of them are forced to abandon this practice in search of alternative options for their livelihood mainly due to the impact of above-mentioned changes. Particularly, the new generations are turning their backs to homegarden practice due to the increasing economic pressure and changes in their lifestyle. Besides, the importance of this inherited practice through different generations is still underestimated and neglected in many places, especially in Mexico (Eichemberg *et al*., 2009; Mariaca, 2012; Ordoñez Díaz *et al*., 2018b).

The above-mentioned status of HG is mainly due to the lack of local government policies or programs to reevaluate and implement HG practice by diversifying or adding value to the products. Also, encouraging owners of the homegardens to manage and conserve this traditional land-use practice by offering economic incentives or payment for environmental services. In

this context, there is an urgent need to stimulate more policies to promote HG as one of the alternative strategies to contribute to achieving the dual goals of sustainable livelihood and environment. Also, the capacity of the HGs to confront current challenges, as well as its sustainability, should be reassessed. However, in situations such as the current pandemic of Covid-19, these systems have become very necessary to achieve food security as well as food sovereignty for millions of people.

Summary of the research gaps and perspectives in the field of HG

Based on the extensive literature analysis this study highlights that although several investigations on HGs have been conducted by a wide range of disciplines in different parts of the globe in the past few decades, there exist many gaps that need to be focused on the future. Most of the HG studies around the globe were conducted intensively in the tropical zone, and scientific data on temperate and semi-arid homegardens are scarce. Most of the investigations until now either describe the biophysical aspects of HGs or analyze the functions based on its ecological attributes such as structure and composition in the selected study area.

Although species diversity in HGs has been extensively inventoried, there is a substantial lack of quantitative data about intraspecific diversity a very important aspect related with the ethnoresource concept involved in the agrobiodiversity as part of the HG. Moreover, the results of interspecific diversity may have biased due to the variations in the selected criteria to assess the species richness. Experimental data evidence still needs to be gathered regarding the role of associated agrobiodiversity (for instance, soil organisms or bees or birds) in the HG systems.

Besides, quantitative data on biogeochemical processes such as the mechanism of nutrient cycling, carbon and water flux, species-specific interactions of above as well as below ground within the system have not been sufficiently addressed up to now. Also, research about the functional equivalence or redundancy of HGs is lacking. As there are very few papers that focus the economic and socio-cultural aspects of HG, future research should assess carefully the positive externalities using alternative socioeconomic approaches from the ecological perspective. And data evidence regarding geographical and regional level comparison as well as extent and distribution of HG practice are still lacking.

Besides, there are fewer investigations that use the holistic approach to figure out the variations and dynamics of this complex agroecosystem. It is also surprising that there is a lack of research to assess the capacity of these systems to resist and adapt current ecological, economic and socio-cultural changes. In this context, the degree of sustainability of HGs based on its resilience towards current challenges needs to be examined using holistic as well as ethnobotanical approaches. As the main intention of this review is to identify the scope and limitations of HG research in Mexico, we infer that the global scenario about the current status as well as gaps and perspectives of HG research also applies to Mexico. Although notable studies were conducted in Mexico, still more interdisciplinary and transdisciplinary research on HG is needed.

Limitations of the current review

Although the main conclusions of this review remain robust, there are some limitations in the current study. An exhaustive literature review was conducted to analyze the current status of homegardens around the world, especially in Mexico. Although there are numerous published documents (including grey literature such as a thesis) in the HG research, we considered only those papers found in the initial results based on the search criteria mentioned earlier. As publications from all geographical and climatic regions were not considered in the present study, the results of this review may not be sufficiently precise.

Also, some research papers referred here were not codified in the current NVivo analysis due to the following two reasons: 1) some of them were not available due to the inaccessibility in the free public search domains, and 2) some papers were found in the later specialized search using some specific keywords to rationalize certain arguments. For example, to analyze the origin and characteristics of HGs. Moreover, regarding the variables used in this review, some of them were selected to match the appropriate pre-determined categories and therefore this classification may be incomplete. Additionally, the results of the word frequency test varied widely based on the applied criteria, which may have biased the results to some extent.

CONCLUSIONS

Many scientists and developmental strategists from different parts of the globe concur that the ancestral practice of homegardens guarantees a low-input sustainable agricultural production without major environmental consequences than other farming systems. Also, it is a multifunctional land-use system that continues to meet the internal needs of the family as well as safeguard agrodiversity. Moreover, it is recognized as a biocultural heritage site, and therefore a valuable patrimony to humanity.

However, despite its potential role to contribute to sustainable development, the current environmental, socioeconomic and cultural challenges are threatening the very existence of HGs. Hence, there is an urgent need to stimulate local government policies to implement and promote HG as a win-win solution to achieve the dual goals of sustainable livelihood and environment.

Besides, although advances made in the HG research worldwide during the past decades, yet there are several research gaps mentioned in the earlier section needs to be focused on the future. Particularly, there has been less research emphasis on measuring agricultural sustainability of HGs from holistic as well as ethnobotanical perspective. Besides, there is a substantial lack of quantitative data about its degree of resilience and sustainability to confront current changes.

As HGs are the most complex and dynamic system compare to monoculture, no proper and widely applicable methodologies are yet available to examine the resilience attribute to evaluate its degree of sustainability for drawing suitable inferences. All the above inferences also apply to Mexico. Thus, it is essential to figure out immediate actions to enhance the resilience of homegardens to confront emerging challenges as well as to conserve the epitome of HG as a valuable patrimony to future generations.

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