# REVIEW

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# The influence of urbanization on local ecological knowledge: a systematic review



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## Abstract

Urbanization is a complex and multifaceted process studied across various scientific disciplines. However, in ethnobiology, research on the impacts of urbanization on local ecological knowledge (LEK) often lacks standardization and tends to focus primarily on local scales. This study aims to systematically characterize how researchers address urbanization in ethnobiology and assess its effects on LEK globally. We conducted a systematic review using the PRISMA protocol and selected 66 studies from the Web of Science and Scopus databases for analysis. Our findings reveal that researchers often do not adopt a consistent definition of urbanization, frequently framing their study areas within a simplistic urban–rural dichotomy. Although some studies used urbanization indicators, our qualitative analyses, including a correlation matrix, showed that these indicators were largely independent of each other. Additionally, principal component analysis (PCA) with clustering identified four groupings among the indicators, yet with low correlations between them. A *t* test analysis of the 66 papers shows that urbanization generally has a negative impact on LEK. Based on these findings, we emphasize the critical need for standardized urbanization indicators in ethnobiological studies and propose a new approach for characterizing urbanization, which will enhance the precision and relevance of future research in this field.

Keywords Local ecological knowledge, Ethnobiology, Urban-rural dichotomy, Urbanicity

## Introduction

In recent decades, our planet has undergone major transformations in the environmental, social, technological, and economic spheres. In this dynamic scenario, urbanization stands out as a key factor, driving global, regional, and local changes [1]. Urbanization is not a homogeneous process, and its different forms generate different

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Overall, urbanization is commonly considered a transitory social process, in which human populations from rural areas migrate to and concentrate in environments identified as urban [3-5]. It is a complex and multifaceted phenomenon, involving not only population growth and density but also socioeconomic, cultural, political, and ecological aspects [1, 6-8].

Research is being carried out in the field of ethnobiology to understand the effects of urbanization on the



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dynamics of local ecological knowledge (LEK) [9-12]. Most of the ethnobiological evidence linking urbanization with LEK comes from studies investigating the role of medicinal plants in local medical systems. However, the results obtained do not converge on a single trend arising from this interaction [13, 14]. A recent study highlighted how LEK can behave in the face of urbanization [14] a) be transformed: when new knowledge is integrated, and other knowledge falls into disuse; b) be expanded: when new experiences are incorporated; c) remain constant: when it does not change. At the same time, there is a general tendency for urbanization to have a negative effect on knowledge, leading to loss of information [14]. However, this may be a hasty conclusion, since studies linking urbanization to the dynamics of LEK lack standardized methodologies to define and measure urbanization [10, 12].

Ethnobiological studies examining the effects of urbanization on local ecological knowledge (LEK) often face a significant theoretical challenge: the absence of a clearly defined concept of urbanization. Most research in this area tends to rely on the simplistic urban–rural dichotomy to classify regions as more or less urbanized, rather than engaging with a more nuanced understanding of urbanization [15–18].

Additionally, studies that adopt this urban-rural dichotomy often fail to measure the degree of urbanization in the research areas. Conversely, some studies demonstrate a more in-depth understanding of urbanization, reflected in the diverse factors used to measure it. These factors include demographic aspects [19–21], infrastructure [20, 22] or distance from urban centers [23–25], and other relevant indicators. The lack of standardization in these methodologies can lead to misinterpretations about the real effects of urbanization on local ecological knowledge [14]. Therefore, ethnobiological studies must adopt more consistent methodological approaches to investigating the role of urbanization in the dynamics of LEK.

Although some studies have analyzed the effects of urbanization on LEK, they have typically been conducted on local scales [9, 10, 22, 26]. This localized focus highlights the need to systematize data from the scientific literature at a global level to identify overarching trends, knowledge gaps, and future research opportunities. Such a global perspective is crucial for enhancing our understanding of the complex interactions between human populations, natural resources, and urbanization.

Considering this, our work seeks to address the following key questions:

1. How are ethnobiological studies characterizing urbanization, and what are the main global trends?

- 2. What concepts of urbanization are being adopted in ethnobiological research?
- 3. Which urbanization indicators are assessed in ethnobiological research, and which are most measured?
- 4. What are the effects of urbanization on LEK?

By answering these questions, we aim to provide a comprehensive overview that can guide future research in this important field.

#### **Material and methods**

We conducted a Systematic Review (SR) to explore how ethnobiological studies have addressed the relationship between urbanization and its effects on local ecological knowledge (LEK). To ensure a rigorous and transparent process, we adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines throughout the development of this study [27].

#### **Research strategy**

We selected the Scopus and Web of Science search platforms for our research, due to their extensive coverage of scientific studies in the field of ethnobiology. We used the following combination of keywords as search strategy: ethnobiology OR ethnobotany OR ethnozoology OR ethnoecology OR "local ecological knowledge" OR "traditional ecological knowledge" OR "indigenous knowledge" OR "medicinal plants" OR "food plants" OR firewood OR coal OR "religious plants" OR "non-timber resources" AND urbanization OR urban. Once we got the results of this search, we activated the automatic filters in each database: (a) open access publications; (b) time frame from 2000 to 2022; and (c) original papers.

#### Screening and eligibility criteria

First, we reviewed the titles and abstracts of the sampled papers, applying specific inclusion criteria to select relevant studies. To be included, studies needed to link knowledge, use, or consumption of natural resources with urbanization (or urban centers) or involve the urbanrural dichotomy. We excluded papers based on the following criteria: (a) review articles; (b) grey literature, such as theses, dissertations, committee reports, government reports, conference papers, and ongoing research; (c) studies that did not directly assess local ecological knowledge, meaning they did not conduct interviews or monitor the use of natural resources; and (d) papers that addressed migration, even from rural to urban areas, as we could not determine whether the effects on local ecological knowledge were due to urbanization or migration.

#### Data analysis

We conducted searches on the selected platforms between October 2022 and January 2023. The titles of the papers retrieved from each database were organized in an MS Excel spreadsheet, allowing us to identify and exclude duplicates. We then read each of the papers in full and systematically extracted key information from each, including: title; authors; year of publication; journal; objectives; guiding questions; hypotheses; predictions; the concept of urbanization adopted; whether urbanization was measured, and the methods used; the natural resource(s) addressed in the research; field of study; country and continent where the study was conducted; sample type; total sample size; sampling stratification; urban variables analyzed; ethnobiological variables analyzed; and study results.

We classified the studies included in the systematic review based on their level of bias. To assess bias, we analyzed the samples from each article following the protocol proposed for ethnobiology [28], and categorized them as low, moderate, or high risk of bias. Since only a few papers were classified as low bias risk, we decided to include the entire set of studies in our analysis. Retaining studies with moderate or high bias risk is a common practice in systematic reviews and metaanalyses when the total number of papers is limited [28-30].

To address our research questions, we classified the selected papers into two groups based on whether they used urbanization indicators. This classification enabled a more comprehensive analysis, helping us identify which factors are tested in relation to local ecological knowledge (LEK) and how urbanization effects are studied. Table 1 shows the methodological procedures for each scientific question to be answered.

All analyses were conducted in the Python 3 environment. We employed the 'sklearn.decomposition' library for principal component analysis (PCA) and used 'sklearn.cluster' for KMeans clustering. Additionally, we utilized 'scipy.stats' for statistical tests and analyses. These tools enabled us to perform detailed multivariate analyses and extract meaningful insights from the data.

Table 1 Methodological procedures used to answer each of the scientific questions in this systematic review

Scientific questions	Methodological procedures
1. How are ethnobiological studies that address urbanization character- ized, and what are the main trends at a global level?	We quantified the number of papers published each year, categorizing them by publication journal and country where each study was con- ducted. We then analyzed all the papers for the potential risk of bias due to the quality of the sample; and examined the categories of the use of natural resources and the specific aspects of local ecological knowledge addressed in each study. This approach allowed for a comprehensive analysis of how the theme of urbanization is being addressed in the field of ethnobiology, revealing global trends
2. What is the concept of urbanization adopted in ethnobiological research?	We searched each article for an explicit concept of urbanization
3. Which urbanization indicators are assessed in ethnobiological research, and which are commonly used?	We identified and quantified the urbanization indicators used in the papers and subsequently created a correlation matrix based on the binary pres- ence of these indicators (0 for absence and 1 for presence). We established an absolute correlation threshold of 0.2; thus, pairs with absolute values below this threshold were considered to exhibit low correlation. To further explore the relationships among these indicators, we conducted a Prin- cipal Components Analysis (PCA) with clustering. This approach allowed us to identify the most frequently associated urbanization indicators and provided a clearer understanding of the differences and similarities across the studies. It is important to note that this analysis focused solely on papers that included urbanization indicators
4. What are the effects of urbanization on LEK?	We performed a simple counting analysis to assess the effects of urbanization on local ecological knowledge (LEK). In this approach, we assigned specific values to the results of the studies: + 1 for a positive effect, $-1$ for a negative effect, and 0 for a neutral effect. For instance, if a rural community exhibited superior knowledge compared to an urban community, we assigned a value of + 1. Conversely, if an urban community demonstrated superior knowledge, we assigned a value of $-1$ . A value of 0 was used when there were no significant differences observed. Following this counting process, we conducted a t-test to evaluate the overall effect of urbanization on LEK. This statistical test helped us determine whether the impact of urbanization was predominantly negative or positive

#### Results

# How are ethnobiological studies characterizing urbanization, and what are the main global trends?

Our search of the databases returned 16,352 studies related to the chosen keywords (see Fig. 1). We excluded 12,368 studies using the automatic filters described under "Research Strategy" in the Materials and Methods section. During the title and abstract review, we excluded 3,719 studies based on eligibility criteria and 63 as duplicates. We then reviewed 203 studies in full, excluding 136 based on eligibility criteria. Ultimately, we included 66 papers in this systematic review (see Additional file 1): 17 were exclusive to Scopus, 23 were exclusive to Web of Science, and 26 appeared in both databases.

Although we focused our systematic review on the last 23 years (2000–2022), we observed a notable increase in studies on the subject starting from 2011. Particularly, the years 2020, 2021, and 2022 saw a higher concentration of publications, with 9 papers in 2020, 9 papers in 2021, and 12 papers in 2022.

The journals with the highest number of papers selected for this systematic review, along with their

respective impact factors (IF), are: *Journal of Ethnobiology and Ethnomedicine* (IF=3.6) with 16 papers, *Acta Botanica Brasilica* (IF=1.395) with 5 papers, *Ethnobiology and Conservation* (IF=1.54) with 4 papers, *Ethnobotany Research and Applications* (IF=2.17) with 3 papers, *Botanical Sciences* (IF=0.94) with 3 papers, and *PLOS ONE* (IF=3.752) with 2 papers.

South America leads in the number of studies on the role of urbanization related to local ecological knowledge (LEK), with a total of 30 papers. Brazil stands out as the country with the highest number of studies, contributing 21 papers (Fig. 2).

When analyzing the 66 selected papers for sample selection quality, as proposed by Medeiros [28], we found that 80.31% of the papers had a high risk of bias, 16.66% had a low risk of bias, and 3.03% had a moderate risk of bias (see Additional file 2). The primary reason for classifying studies as high bias risk was the lack of information on the universe or sample details, including the number of individuals, heads of households, or households.

The selected studies primarily focused on local ecological knowledge related to plants (76%), followed by



Fig. 1 Flowchart summarizing the selection of ethnobiological studies on urbanization and Local Ecological Knowledge. Format proposed in the PRISMA protocol



Fig. 2 Countries in which the studies analyzed in this review were carried out

knowledge about animals (14%), and other topics, such as ecological interactions, land use, and environmental perception (11%). We identified and classified the purposes for which the resources were used in the 66 selected papers into categories, such as food, fuel, commerce, construction, medicinal, ritualistic, ornamental, and others (Table 2). Notably, some papers addressed multiple categories, resulting in multiple counts for the same study. The medicinal category had the highest number of studies, with 28 papers examining the effects of urbanization on natural resources used for medicinal purposes.

We identified the aspects of LEK investigated in the studies as follows: knowledge: when the variables analyzed indicate the number of citations and the frequency of citation of a species; consumption: when the variable was the quantification of the consumption of a species; use: when the variable analyzed is the diversity of the species used, without quantification; recognition: when the variable analyzed was the ability to recognize the resources through visual stimuli; and environmental perception of the environment. It is important to mention that there were papers that assessed the LEK aspects together (Table 2). Among these aspects, knowledge was the most

frequently analyzed in relation to urbanization, appearing exclusively in 42.2% of the papers across all categories of use (Fig. 3).

# Which concept of urbanization is adopted in ethnobiological research?

Out of the 66 selected papers, only two provided a definition for urbanization. The concepts are detailed in Table 3 below:

## What are the urbanization indicators assessed in ethnobiological research, and which are commonly measured?

Out of the 66 papers analyzed, 36 used the terms "rural" and "urban" to distinguish the studied areas. These papers did not provide any metric to measure the degree of urbanization in the regions they analyzed.

Out of the 66 papers analyzed, 29 used urbanization indicators, revealing a total of 28 distinct indicators (see Additional file 1). Urbanization indicators were defined as the variables used to characterize urbanization in the studies. Most of these 29 papers used only one indicator each, such as those by Ávila et al. [10], Bortolotto et al. [32], Collier et al. [31], Ávila et al. [33], **Table 2** Category of use and aspects of KEL observed in thepapers analyzed, with the number of occurrences of the aspectsin each category. The numbers refer to the quantity of papers inwhich each category of use and aspect of LEK was found

Categories of use	Aspects of analyzed local ecological knowledge				
Food (20)	Knowledge (11)				
	Knowledge and consumption (04)				
	Knowledge and use (02)				
	Consumption (02)				
	Recognition (01)				
Fuel (20)	Knowledge (05)				
	Consumption (12)				
	Environmental perception (01)				
	Recognition (01)				
	Use (01)				
Commerce (03)	Knowledge (03)				
Construction (05)	Knowledge (04)				
	Recognition (01)				
Medicinal (28)	Knowledge (19)				
	Knowledge and use (08)				
	Recognition (01)				
Ritualistic (04)	Knowledge (03)				
	Recognition (01)				
Ornamental (04)	Knowledge (03)				
	Recognition (01)				
Others (18)	Knowledge (11)				
	Knowledge and environmental perception (05)				
	Environmental perception (02)				

Doumecq et al. [34], Gandolfo and Hanazaki [35], Kang et al. [36], Lautenschläger et al. [24], Peroni et al. [37], Santoro et al. [25], Sousa et al. [38], Towns et al. [39],

Valadares et al. [40], Vitasović-Kosić et al. [21], and Wayland and Walker [41]. The paper by Boillat et al. [19] used the maximum number of indicators, totaling eight. The most frequently used indicators were "distance to urban center," mentioned 13 times; "demographic density," mentioned 8 times; "population size," mentioned 7 times; "economic activities," mentioned 5 times; and "access to roads," mentioned 4 times (Fig. 4).

We analyzed the indicators in the articles to assess their independence. We computed Pearson correlation coefficients for each pair of indicators to measure their linear relationships and compiled these coefficients into a matrix. This matrix revealed that 83.10% of the variable pairs have absolute correlation coefficients below 0.2, indicating weak linear associations among most variables. This finding suggests that the indicators are largely independent, providing a broad range of information with minimal strong correlations.

Next, we applied principal component analysis (PCA) to further explore the data structure (Fig. 5) (see Additional file 3). The analysis showed that the first component explains 18.83% of the total variance, while the second component accounts for 14.86%. Together, these components capture 33.69% of the total variance, offering a significant but partial view of the data. This result emphasizes the need to consider additional components for a more comprehensive analysis of the urbanization attributes in the articles.

In Cluster 1[22, 31, 33–37, 39, 41–43], urbanization is defined primarily through a focus on infrastructure and population growth. Articles in this cluster highlight infrastructure presence, population growth rates, and general access to services as key indicators. While access to education and communication is mentioned,



Fig. 3 Bar chart showing the percentages at which aspects of local ecological knowledge were assessed in the analyzed studies. EP stands for Environmental Perception. LEK is local ecological knowledge

### Table 3 Concepts of urbanization in the papers selected for the Systematic Review

Titles of the studies	Concepts
How does urbanization affect perceptions and traditional knowledge of medicinal plants [9]?	"Urbanization is a complex economic process that involves social and environmental changes that occur over short periods and often modify cultural patterns."
Integrated approach to the understanding of the degradation of an urban river: Local perceptions, environmental parameters and geoprocessing[31]	"Urbanization is a multidimensional global process linked to the continuous growth of the human population and changes in land use, a quick and dynamic process that can be difficult to predict."



Fig. 4 Histogram with the frequencies of indicator usage in the analyzed articles

it is secondary to the emphasis on infrastructure and growth.

Cluster 2 [19, 44] defines urbanization mainly by high population density and access to services. The articles in this cluster prioritize education and healthcare services as central to urban development. They also address economic activity and economic inequality, as reflected by the Gini coefficient, indicating its importance in urbanization measures. The significant distance from urban centers suggests a more established urban environment with a defined urban core.

In Cluster 3 [9, 10, 20, 23–25, 32, 38, 41, 45–47], urbanization is characterized by moderate access to essential services, such as education and healthcare. The articles emphasize distances to these services and urban centers, indicating a more dispersed urbanization pattern. Lower population density and notable geographic isolation suggest a less developed urban area compared to Cluster 2, with a focus on more distributed urbanization indicators.

Cluster 4 [48–50] highlights urbanization through a focus on road access, infrastructure development, and the percentage of urban area. The articles emphasize roads and

infrastructure as central measures of urbanization. High urban area percentages, economic activity, and the presence of artificial lakes are also key indicators. This cluster represents a well-developed and interconnected urban environment with balanced urbanization indicators.

#### What are the effects of urbanization on LEK?

The *t*-test result showed that urbanization negatively affects local ecological knowledge  $(t = 6,887, p = 3,5978 \times 10^{-9})$ . Such a low *p* value suggests high statistical significance. This means that it is highly unlikely that the observed results have occurred by chance, strengthening the confidence in the difference that was found. This finding implies that there is a tendency for urbanization to have a negative impact on LEK if it increases.

#### Discussion

# Characterization and global trends in ethnobiological studies on urbanization

When analyzing the geographical distribution of the studies, we observe that the main countries addressing



Fig. 5 PCA scatterplot with clustering

urbanization are predominantly in less industrialized regions, including Brazil, Argentina, Mexico, and China. Except for a few studies from European countries, most of the research originates from countries with lower human development indices [51]. Studies conducted in Europe predominantly focus on understanding how urbanization affects the consumption of forest fuels [52–54]. In contrast, research from less industrialized regions places greater emphasis on understanding how urbanization affects knowledge about plants used for food and medicinal purposes [9, 10, 25, 33, 37, 55–58]. This discrepancy points to a clear differentiation in the focus of research between the regions, possibly influenced by

the different socioeconomic and environmental realities faced by each one, and by the different urbanization processes that each region presents [1].

A study on the growth of ethnobiological research in Latin America revealed findings that align with our own, identifying Brazil, Mexico, Peru, and Argentina as the foremost contributors in terms of publications in the field [59]. This surge in research output is credited to the presence of academic institutions that actively foster ethnobiology through dedicated courses, programs, Latin American ethnobiological societies, and scientific conferences, all of which enhance scholarly discourse in the area. Additionally, these countries are prominently featured in another systematic review, which highlights the significance of the biocultural approach prevalent in Latin American ethnobiological studies. This approach is crucial for bridging local knowledge with scientific inquiry, further strengthening the integration of diverse knowledge systems [60].

Our results reveal a widespread sampling issue in the analyzed papers, which hampers our ability to identify clear global trends regarding the effects of urbanization on local ecological knowledge (LEK). A study that examined bias risks in ethnobiological research on medicinal plants in Brazil reported similar findings, noting a high proportion of studies with significant sampling problems and classified as high bias risk [28]. However, it is important to note that high or moderate bias risk classifications do not always indicate genuine sampling problems. Often, these issues arise from a lack of detailed information on the sampling universe or sample size [28, 61]. Our results support this observation, as many papers lacked detailed information about the sampling universe or sample size, resulting in high bias risk classifications. Providing a more thorough description of the experimental design in these studies could address these issues, reducing doubts and subjectivity [28, 62]. Clarifying these aspects would offer a more robust foundation for evaluating the impact of urbanization on LEK, leading to a more reliable and comprehensive understanding of this complex relationship.

We also found another trend in ethnobiological studies, the concentration mainly on assessing the knowledge about medicinal plants in the face of urbanization [38, 39, 41, 63], with little interest in understanding how urbanization affects the use and consumption of other biodiverse resources. Although this is a common approach in ethnobiology in general, it is also worrying, since an individual might remember and even mention beneficial natural resources when questioned or in response to some sensory stimulus [64]. However, the effective use and consumption of these resources can decline in the face of the sedentary lifestyle that urbanization often foments, resulting in, for example, the increased consumption of processed foods [65, 66], the use of modern fuel sources [2] and the preference for using industrialized medication instead of medicinal plants [13].

#### The concepts of urbanization in ethnobiological research

Our findings reveal a significant gap in ethnobiological studies focusing on urbanization regarding the precise definition of the term. Researchers often treat urbanization as a well-established concept without requiring a formal definition. However, it is important to acknowledge that different interpretations of urbanization emerge, reflecting the various facets of the concept [9, 26, 31, 67, 68].

The papers that provided explicit definitions of urbanization agree on its characterization as a complex economic process marked by rapid social and environmental changes. They describe urbanization as a consequence of continuous population growth, which alters both human lifestyles and land use patterns [9, 26, 31]. In the Hussain and Imitiyaz study [6], the authors conceptualize urbanization as a complex social phenomenon encompassing multiple dimensions that can be analyzed from various perspectives. This inherent complexity contributes to the interdisciplinary nature of urbanization studies, leading to a range of definitions and interpretations of the term [6, 9, 31].

Although most of the papers analyzed did not present a concept for urbanization, they presented two strands to characterize their areas of interest. The first strand addresses the absence of urbanization indicators, where the authors decided to focus merely on the urban-rural dichotomous classification. The use of this categorization, which separates urban and rural areas, is probably associated with previously established spatial limitations, reflecting the preference for an easy-to-understand classification, which considers the typical characteristics expected in each of these distinct regions [69-71]. Urban areas tend to have a high population density, with a notable concentration of buildings, advanced infrastructure and a diversity of industrial, commercial and service activities [6, 72]. In contrast, rural areas are distinguished by their lower population density, characterized by the presence of open spaces and the predominance of agriculture, livestock and extractive activities [6, 72]. Countries such as Brazil, the UK and South Africa use this dichotomy for the political and administrative delimitation of their territories [6, 72].

Nevertheless, it is crucial to emphasize that the application of the dichotomy between urban and rural presents significant limitations [73], and its use may have scientific implications in studies exploring urbanization's impact on local ecological knowledge. This is due to the fact that this dichotomy establishes a clear opposition between the two poles, strictly outlined and mutually exclusive. However, it is possible to observe situations in urban areas that exhibit characteristics similar to rural ones, just as rural areas may present attributes considered urban, such as access to mobile and internet services, even in regions officially designated as rural [10, 72]. Despite the dichotomy that is very common in ethnobiological studies, the complexity that urbanization represents for the present requires more comprehensive and updated approaches if the intention is to represent it in studies.

The second strand observed to characterize the study areas of the analyzed papers addresses the use of urbanization indicators. Even without an explicit concept of what the authors considered urbanization (except for the studies of Arjona-García et al. [9] and Collier et al. [31]), it is clear that there is an intrinsic understanding that urbanization can be measured by some factors [19, 23, 47–49], which will be discussed in the next topic.

Urban ethnobiology focuses on understanding the dynamics of knowledge in urban contexts, encompassing both traditional elements—such as family practices—and new practices and knowledge systems. These emerge from the interactions between local populations and immigrant groups, creating a multicultural landscape unique to urban settings [74]. Urban ethnobiology has significantly advanced the theoretical and methodological understanding of local ecological knowledge in urban and peri-urban environments [74–77]. However, this field often overlooks the full range of the urban–rural continuum, leaving rural LEK dynamics underexamined [78].

Recent research in urban ethnobiology introduced the term **rurbanity** to describe the transitional spaces between urban and rural areas [79]. This interdisciplinary concept suggests that while urban and rural areas remain distinct, they coexist and interact within the same geographic space [80]. Rather than viewing urbanization as a one-way process in which rural areas inevitably become urbanized, rurbanity highlights a continual interaction between the two, where rural characteristics can influence urban areas, resulting in a hybridized space that reflects both influences.

Another relevant concept, widely used in public health studies, is **urbanicity** [73, 81, 82]. Urbanicity refers to the presence of typical urban attributes, which can also appear in non-urban areas at particular times [73, 83]. This concept recognizes the fluid transitions between rural and urban environments, moving beyond strict geographical boundaries and acknowledging various degrees of urbanization.

Both **rurbanity** and **urbanicity** offer valuable frameworks for ethnobiological research. Urbanicity provides a more comprehensive approach, capturing the full spectrum of the urban-rural continuum, while rurbanity focuses more specifically on peripheral, transitional areas often defined by geography or socioeconomic factors [79]. Urbanicity's multidimensional approach, which includes social, physical, and infrastructural aspects like access to commercial and health services, further enhances its utility in examining how urbanization impacts local ecological knowledge [84]. This broader scope makes urbanicity particularly effective for understanding the interplay between urban and rural influences on knowledge systems.

# Urbanization indicators evaluated in ethnobiological research

We found a variety of indicators that characterize urbanization in the analyzed studies, and from this it was possible to perform multivariate analyses, which mainly showed us that the understanding of urbanization of the papers is evidently heterogeneous. That is, despite the formation of groupings in the PCA, most indicators have a low relationship between them. This low relationship suggests that a more integrated, possibly multidimensional approach may be more appropriate to capture the true complexity of urbanization.

The most used urbanization indicators deal mainly with demographic, infrastructural and economic aspects. Within the demographic aspects were used mainly population size [19–21, 23, 44–48] and demographic density [19–21, 23, 44–48]. The use of these indicators is fully justified, since urban or highly urbanized areas are characterized by a significant concentration of people in restricted spaces [6]. However, even areas with low demographic density and small population size may have characteristics of urban areas [72].

The structural aspects most associated with urbanization were distance, time and access to the urban center, access to healthcare services, education, electricity, roads and access to the public transport system. Among these, the distance to the urban center is the most used indicator [10, 19, 23, 40, 44, 47]. However, this indicator has limitations since a greater distance may indicate less access to urban centers. However, if a distant rural community has access to an efficient transportation system, the frequency of commutes to urban centers may be higher than to a community closer to the urban area. Thus, the relevance of this indicator could be expanded if it adopted a multidimensional approach, encompassing elements such as distance, transport system, existence of paved roads, among others [19, 47].

It is necessary that the indicator of economic activities be multidimensional. Historically, rural areas are associated with primary economic activities, while urban areas relate to secondary and tertiary activities. On the other hand, a new set of activities beyond the primary has been observed in rural areas [1, 20]. This phenomenon includes the appreciation of countryside regions, motivated by factors such as abundant biodiversity, picturesque landscape heritage and a better quality of life [72].

Urbanization can be understood as a complex phenomenon, which encompasses a wide range of transformations in socioeconomic aspects, in access to essential goods and services, and in the relationships of human populations with the natural environment [6, 9, 31]. Given this complexity, the most appropriate approach to examine urbanization in the context of ethnobiology would be one that encompasses the social, environmental and infrastructural aspects of the studied regions. An effective approach is the adoption of **urbanicity**. As discussed earlier, urbanicity offers a multidimensional framework that integrates social, physical, cultural, and environmental dimensions [84]. This concept resonates with the way ethnobiologists have come to understand urbanization, as the urbanization indicators examined here align closely with the principles of urbanicity. Furthermore, the most frequently employed urbanization indicators in ethnobiological research already fit within the various scales of urbanicity developed by public health scholars[73, 84, 85]. These scales can be seamlessly adapted for use in ethnobiology to assess the urbanicity of the studied areas, enhancing the accuracy and depth of such analyses.

#### The effect of urbanization on the LEK

Our results showed that, in general, urbanization has a negative effect on local ecological knowledge, corroborating the consolidated view that urbanization leads to losses in the LEK [13, 14]. However, this finding may have some implications. The absence of a standardization in ethnobiological studies exploring urbanization [14], as discussed throughout this paper, is one of them. Other implications include variations in the behavior of different types of LEK in the face of urbanization and in the various aspects of the LEK addressed in the analyzed papers, both of which require greater attention.

We observed a trend in ethnobiological studies, where there is a strong emphasis on people's knowledge about natural resources, while the understanding of the use and consumption of these resources has been largely neglected in the face of urbanization. This trend raises scientific concerns, since the LEK is susceptible to a variety of changes arising from the urbanization process.

It is already widely accepted that the LEK has its own dynamics and that it is changeable [86, 87], and therefore each form of knowledge (such as medicinal plants, edible plants, knowledge and use of animals, among others) reacts differently to urbanization [14]. Based on these understandings, it is possible to observe that knowledge about medicinal plants can be influenced both positively and negatively by urbanization [13]. The harmonious coexistence between local medical systems and biomedicine, including the use of medicinal plants and conventional medicines, presents a positive and complementary character, showing that even local specialists, such as "raizeiros" and "rezadores" ("rooters" and "prayers"), value traditional healthcare practices even in the face of urbanization [13, 25, 64, 88–92]. On the other hand, urbanization can have a negative impact on the LEK on medicinal plants, since urban processes such as the reduction of forested areas and undervaluing of LEK can lead to harmful changes to local medical systems [9, 13]. These processes drive the use of biomedicine, which can impair knowledge about medicinal plants and hinder their identification, recognition, management and preservation [9].

As the urbanization process is linked to the loss of forested areas, human populations living in more urbanized regions tend to have little or no contact with forest resources, as they are far from forest areas [9, 10, 22]. This limited contact with natural resources can cause changes in the LEK, leading communities to know less and less about useful species, especially the youth [38]. In addition, urbanization correlates with an increase in the use of exotic resources, which become predominant in vegetable gardens and backyards of urbanized communities, ensuring food security and access to medicinal plants [33, 37, 65, 89]. Nonetheless, it is worth noting that the knowledge and use of exotic resources is also present in rural area [34, 93]. In the study conducted by Doumecq et al. [34], the authors found evidence of the use of exotic woody resources by communities in less urbanized areas, given the prohibition of extraction of native woody resources in protected areas for conservation in Argentina. In other studies, they show evidence that most of the plants cited and used for the manufacture of home remedies were not native, both in rural areas and in urban areas, even without the context of legal restrictions [56, 94].

Another aspect to be considered in the context of the implications of the negative impact of urbanization on the LEK is the presence of sampling errors in ethnobiological studies. When the sample is not representative of the sampling universe, it becomes unfeasible to generalize the results to the entire population under study. Considering that a significant portion of the papers analyzed suffer from this sampling problem, it is essential to recognize that the results of our test cannot be extrapolated to a precise understanding of the effect of urbanization on the LEK.

#### Conclusions

As we have seen, several trends are emerging to understand how urbanization can affect LEK and how these ethnobiological investigations lack uniformity in their methodologies, which limits our ability to infer on the real effects of it on the LEK.

Since there is no universal agreement on the concept of urbanization due to its complexity and various dimensions, we conclude that the best approach to deal with

urbanization in ethnobiological studies is to use the terminology urbanicity to address the theme of urbanization in ethnobiology. Urbanicity offers a more dynamic perspective by analyzing the level of urbanization in a continuous and contextual manner. This approach considers a wide range of social and infrastructural factors, which are also present in non-urban areas, and can shape local ecological knowledge. By investigating the relationship between urbanization and LEK through the lens of urbanicity, researchers can identify how this knowledge adapts, revealing the processes of resistance or resilience within socio-ecological systems that preserve traditional practices in the face of change. This perspective acknowledges that even in areas that appear rural, interactions with the urban environment may influence LEK without necessarily erasing it.

The multidimensional nature of urbanicity, which encompasses social, environmental, and service-related factors, provides significant advantages for ethnobiological research exploring the impacts of urbanization on LEK. This holistic view enables a deeper understanding of how urban influences intersect with traditional knowledge systems, offering valuable insights into the adaptability and persistence of these practices. First, by adopting the term "urbanicity," we believe that researchers can evoke a more comprehensive and holistic understanding of the influence of urbanization on local ecological knowledge. This allows researchers to take into consideration not only demographic and infrastructural changes, but also socio-cultural transformations that accompany urbanization. In this way, urbanicity offers a more complete means to examine how relationships between human populations and the natural environment are affected, giving room to investigate the complex interactions and cultural adaptations that arise in this context. Besides that, the application of the urbanity concept can facilitate the comparison and analysis of ethnobiological studies in different regions and contexts. By defining and measuring the elements of urbanicity, researchers can establish clearer and more standardized criteria for assessing the extent and effects of urbanization. In turn, this enables the construction of a solid basis for the comparison of results between different populations and environments, contributing to the development of a more cohesive and reliable body of knowledge about the impacts of urbanization on the LEK.

As for how to measure urbanicity, we recommend that future research develop a new method for this purpose. This method should cover all the aspects previously mentioned, considering that only the presence or absence, access and distance to services are not sufficient to determine the urbanicity of a community. Moreover, it is critical to understand that urbanicity is dynamic and subject to change over time, whether positive (such as the development of new paved roads) or negative (such as the loss of health services in a community). We believe that in this context, an urbanicity scale for ethnobiology should encompass the urbanization indicators presented in this review and be sufficiently well constructed to predict the urban/rural dichotomy, that is, by varying the main dimension studied, the urbanicity index should experience a continuous transition from a minimum plateau of urbanicity (rural) to reach the plateau of maximum urbanicity (urban). In this way, it will be possible not only to compare future investigations in ethnobiology about variations in urbanicity, but also to characterize previous studies.

It is crucial that ethnobiologists establish transparency regarding data sampling procedures in their studies, considering the fundamental principle of replicability in science and broad trend investigation. In addition, it is of paramount importance that these researchers manifest a greater interest in exploring diverse LEK approaches to useful natural resources. This is justified by the fact that the LEK associated with each resource may exhibit particular dynamics, possibly resulting in distinct behaviors in the face of urbanicity.

By combining the diversity of approaches found in ethnobiological research with the adoption of the concept of urbanicity and the creation of an appropriate measurement scale, we will be able to achieve more uniform standards in ethnobiological studies, allowing for a less biased assessment of the real effects of urbanicity on local ecological knowledge.

#### Limitations of the study

This systematic review is the result of an effort to synthesize information from studies on the role of urbanization in local ecological knowledge. However, it has some limitations:

- We chose to use open access papers due to accessibility and the potential to avoid publication bias.
- We did not restrict the search to any specific language in order to avoid bias in the results, but we were aware of the possibility of finding papers in languages that we did not master, which would require hiring translators.
- 3. We set a time frame (2000–2022) ensuring that a considerable volume of recent data could be accessed.
- 4. Some important studies may have been excluded from this research due to the systematic protocol inherent to this type of review, which was strictly followed to determine the works included in the analysis. Future systematic reviews should explore

the topic with greater attention to local and regional nuances and patterns.

5. We acknowledge that quantitative analyses may not fully capture the complexity of the relationship between urbanization and local ecological knowledge. Therefore, we recommend that future studies integrate both quantitative and qualitative approaches, allowing for a more nuanced examination of conceptual and methodological variations across the different disciplines addressing urbanization.

We believe that these choices and limitations, while present, do not materially compromise the integrity and validity of the review.

#### Abbreviations

IF	Impact Fac	tors					
LEK	Local Ecological Knowledge						
PCA	Principal Component Analysis						
PRISMA	Preferred	Reporting	Items	for	Systematic	Reviews	and
	Meta-Analyses						

#### Supplementary Information

The online version contains supplementary material available at https://doi. org/10.1186/s13002-024-00747-z.

Additional file 1.

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#### Author contributions

J.M.L.R., A.L.B.N. and M.A.R. conceived the idea and designed the study. J.M.L.R. performed analysis and interpretation. J.M.L.R., A.L.B.N. and M.A.R. wrote and revised the manuscript. All authors read and approved the final manuscript.

#### Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the repository: https://docs.google.com/spreadsheets/d/1M\_3eqY-efnTc YRMIXagzI8J-3XVV4bWJ/edit?usp=sharing&ouid=10814028562456436931 6rtpof=true&sd=true

#### Declarations

Ethics approval and consent toparticipate Not applicabe

#### **Consent for publication**

Not applicabe

#### **Competing interests**

The authors declare no competing interests.

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