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Review

Where Is the Peri-Urban? A Systematic Review of Peri-Urban Research and Approaches for Its Identification and Demarcation Worldwide

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Abstract: Metropolitan areas worldwide have grown rapidly and are usually surrounded by peri-urban zones that are neither urban nor rural. Despite widespread use of the term 'peri-urban', physical determination of these spaces is difficult due to their transient nature and multiple definitions. While many have identified peri-urban areas regionally or globally, questions persist on where exactly the peri-urban is located, and what are the most apt methods to delineate its boundaries. The answers are pertinent towards framing targeted policies for governing the dynamic socio-spatial transformations in these zones. This paper reviews peri-urban research over the last 50-plus years to discern the existing methodologies for its identification/demarcation and their applications. For this, a total of 3124 documents on peri-urban studies were identified through keyword searches in Scopus and Google Scholar databases. Thereafter, 56 documents were examined that explicitly dealt with demarcating peri-urban zones. Results reveal that there is no standout/generalized method for peri-urban demarcation. Rather, these approaches are geographically specific and vary across developed and developing countries, due to differences in land-use patterns, socioeconomic drivers, and political systems. Thus, we recommend developing a 'pluralistic' framework for determining peri-urban boundaries at the regional–global scale to enable better framing of relevant policies.

Keywords: peri-urban growth; peri-urban areas; rural–urban interface; peri-urban demarcation; bibliometric analysis

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1. Introduction

The mixed rural–urban landscape around cities, typically called the 'peri-urban zone', also termed as urban fringe, rurban, or semi-urban [1–3], is denoted by multiple rural-to-urban transformations that create a mosaic-like landscape of urban and rural land-uses, livelihoods, and lifestyles [4–6]. Induced by rural–urban migration and centrifugal processes of urban expansion, which pushes people, businesses, and most natural resource extraction to the city's peripheral areas, the peri-urban zone is a transitional space. While the term peri-urban is currently used globally, the phenomenon, and its dynamics differ from region to region, especially between the Global North and South. From a recent worldwide analysis [7], some key dimensions of difference include: income per head (high to low from the Global North to South), inequality (low to high), rate of urbanization (low to high), rate of peri-urban growth (low to high), and effective governance (high to low).

The shift of the global population from a predominantly rural to urban character has been an important highlight of the 20th century urbanization process. In 1950, only 30% of the world's population lived in urban areas, which has increased to 54% in 2014, and is further projected to rise to 66% by 2050 [8]. Interestingly, most of this population transition will happen in the peri-urban areas of the world's metropolitan cities, and will

predominantly occur in Asian and African cities [9]. Over the last few decades, peri-urban zones have gained increasing attention due to their ongoing population growth, marked industrial expansion, and the large-scale investment in these locales, manifested by inflows of people, capital, labour, and commodities, thereby altering an almost homogeneous community system into a heterogeneous and diverse society [10,11]. This rapid growth of metropolitan peri-urban areas has also induced substantial environmental problems.

The peri-urban has been defined in three different ways, as either a place, a process, or a concept [10]. Recently, Follmann (2022) further identified three conceptual vectors of the peri-urban: territorial, functional, and transitional [6]. Initially, in the 1970s, the term was advanced as a *territorial* concept to define the activities and institutions found within the rural urban interface. Influenced by research on rural–urban interactions [12–15] this approach fore-fronted the *functional* links between cities and their surrounding areas by developing the peri-urban as a multifunctional interface between the city and the countryside [1,16]. Linking this functional understating to rapid urban growth, the peri-urban was gradually morphed into a *transitional* concept, which defined the process of peri-urbanization. The rural–urban interface [17] was seen as a rapidly transforming transitional stage between the rural and urban, with a two-way flow of goods, services, and administrative functions. Halkatti et al. (2003) thus argued that the peri-urban is better understood as a process [18], while policy-framing organizations, such as UN Habitat denote it as the site of 'urban-rural linkages' [19].

The peri-urban is a product of the urbanization wrought by global economic and socio-political functions, and this continuum is derived from the ongoing demographic processes and rural–urban migration. The term 'peri-urban' was used by the Organisation for Economic Co-operation and Development in 2007 to describe urban growth in Europe in the 1980s and denoted a transitional zone that is neither urban nor rural, and is instead defined as a 'grey area' [20]. This peri-urban locale is an unbalanced mixture of rural and urban tracts [21], with the rural–urban interaction being at its peak within it, wherein the mode of rural life and activities are altered rapidly by the intrusion of extensive urban land-uses [22]. Peri-urban areas are thus characterized by some parts being dominated by rural primary activities that change quickly within a short distance to urban residential and commercial areas [23]. However, these zones are highly unplanned, and have inadequate infrastructure services, usually housing middle to low-income residents, and serve as receptacles for the growing rental market [21,22]. Furthermore, according to the nature of change, peri-urban areas can be divided into inner peri-urban zones and outer peri-urban zones [24]. Most current planning and management approaches are thus inadequate in this dynamic rural–urban linkage. While rapid urbanization and the growth of peri-urban areas is a global phenomenon [25], due to geographical conditions, legal and institutional frameworks, spatiotemporal dynamics, and socioeconomic and environmental characteristics, the patterns of peri-urban transformations differ across countries [26–30].

The spatial identification and demarcation of peri-urban areas is difficult due to the complex and diverse nature of rural–urban linkages along city boundaries [31], and, so far, there is no clear definition that is universally applicable for the delineation of peri-urban areas. While many researchers have proposed different methods to classify rural, peri-urban, and urban areas, these identifications vary from region to region and across socio-spatial scales. Moreover, given that the nature, formational aspects, and continued development of peri-urban areas are quite disparate in different regions worldwide, it may be difficult and even impractical to propose a universal method to identify them globally, with considerable doubt if such a method would be optimal given the diverse urban characters and histories. For example, peri-urban development in developing countries is usually typified by rural–urban migration, rapid land transformation, and mixed agricultural and industrial land-use practices, while peri-urban locales in developed nations are characterized as urban well-being and welfare settlements [29]. However, even then, their identification and demarcation are important to promote sustainable urban planning and management, and this need is even more urgent in devel-

oping nations that continue to face unplanned urban growth, land-use conflicts, and its environmental consequences.

Such questions have been addressed by several global databases and urban analysis projects, of which, two are predominant:

(a) Pesaresi et al. (2016) have provided a global classification of inhabited zones by using a combination of census unit data and remote sensing of urban areas [32]. These datasets are referred to as the GHSL (Global Human Settlement Layer). This is also linked with the OECD database of FUA (Functional Urban Areas), based on economic activity and commuting zones [33].

(b) Atlas of Urban Expansion [34] provides detailed analysis of infrastructure, block size, and socioeconomic variables for 121 cities.

Linking these data-driven approaches with further layers of systems analysis, a universal framework has been proposed [7]. This includes:

Functional parameters (land-use, population density, built form, gradients, and gravity fields): these are the tangible qualities, to be seen 'on the map', and hence the primary focus of 'demarcation';

Relationships (proximities, flows, inter-dependencies, and 'urban-rural linkages'): these are based on the demarcations, but do not generally show directly on the map, and may have a very different logic to the simple demarcations;

Dynamic frontiers (change, transition, and disruption): similar to above;

Systemic patterns (agro-urban sprawl, carceral cities, and 'planetary peri-urbanisms'): similar to above

Sectoral layers (social, technical, economic, environmental, political, and cultural systems): each of these may use common demarcations, e.g., social groups, housing markets, commuting zones and eco-region hinterlands but in general, the different layers do not easily match or overlap;

Internal distinctions (e.g., edges, fringes, pockets, clusters, corridors, and hinterlands): these also can benefit with demarcation; however, much of it then depends on the unit scale of analysis;

External/Global distinctions (income, inequality, urbanization, and governance): until now, peri-urban demarcations have not been featured, though some of the results here may contribute towards progress on that.

However, the purpose of the above framework was not to provide a single definition of the peri-urban or such locales, but rather signify the different components of a very diverse landscape. Noting this multiplicity of methods and perspectives, the present study highlights the relevant methods and models that exist in peri-urban research conducted during the previous 50-plus years.

2. Materials and Methods

The present study employs a quantitative review of the Scopus and Google Scholar databases and a qualitative review of some specifically selected research documents. In the first step, Scopus and Google Scholar search engines were used to systematically identify peri-urban research published between 1967 and 2022. We used a search string focusing on the word *peri-urban* in the document title, abstract, and/or keywords. Two different search strings queries were used for this purpose, as denoted below:

- TITLE-ABS-KEY (peri AND urban)
- TITLE-ABS-KEY (peri AND urban) AND (LIMIT-TO (OA, "all")) AND (LIMIT -TO (DOCTYPE, "ar")) AND (LIMIT—TO (SRCTYPE, "j"))

From the Scopus database, 2838 articles were downloaded. Google Scholar was used to examine the databases/documents not covered by Scopus, like project reports, thesis reports, executive summaries, and other non-Scopus listed publications. During this, 286 additional documents were obtained, adding up to a total of 3124 documents published between 1967–2022. After collating the relevant bibliographic information from these documents, VOSviewer software (v. 1.6.18) and RStudio (v. 2021.09.4) were used to create

a bibliometric map of co-authorship, publication countries, keyword co-occurrence, and co-authorship countries, as applied to the main theme, along with cross-table analyses to discern the nature of peri-urban research in the last 50-plus years (Figure 1).

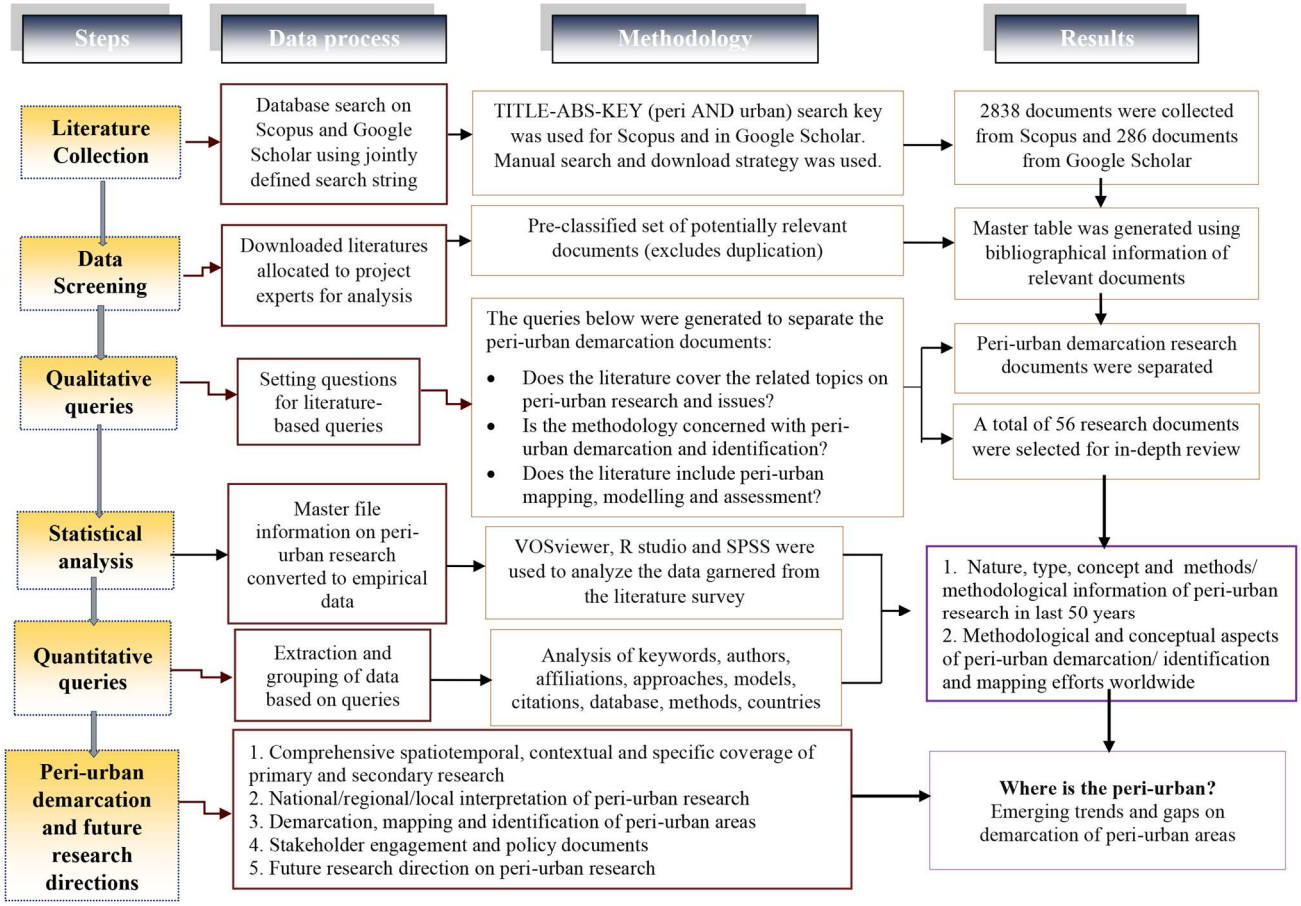


Figure 1. Conceptual framework and flow diagram of the present review of peri-urban research.

The second stage of the review focused on the primary research question of this study: *where is the peri-urban*? A set of qualitative queries were used to identify only those documents among the above database that focus on peri-urban demarcation and identification issues (Figure 1), which led to the extraction of 56 documents. These were assessed in both quantitative and qualitative ways to understand the methods researchers have used to demarcate peri-urban zones worldwide. Of the total reviewed documents, 2633 were research articles, and from these, just 43 discussed peri-urban delineation or identification aspects. Of the reviewed 201 conference papers and 158 book chapters, only two papers and three chapters focused on peri-urban demarcation, respectively (Table 1). Surprisingly, of the 78 review papers on peri-urban research only one discusses peri-urban demarcation, and just 5 out of the reviewed 13 major project reports had assessed peri-urban demarcation issues. These major projects on the peri-urban have been identified based on the respective funder's notification and published reports. The main limitation of our approach was that we only considered research on peri-urban issues published in English, along with using just two search engines and some limited keywords. See the Supplementary Materials section for access details of the prepared database and analysis.

Table 1. Types of documents reviewed in this study.

Document Type	Number of Documents on Peri-Urban Research	Number of Documents on Peri-Urban Demarcation
Research articles	2633	43
Conference papers	201	2
Book chapters	158	3
Reviews	78	1
Project reports	13	5
Books	11	1
Short notes	11	1
Data papers	6	0
Editorials	6	0
Research letters	5	0
Short surveys	2	0
Total documents reviewed	**3124**	**56**

3. Results

3.1. Quantitative Assessment of Peri-Urban Research Documents

Among the 3124 documents published between 1967 to 2022 that dealt with peri-urban research, till 1990, only 56 publications had examined the demarcation of peri-urban areas (Figure 2), and most of these had focused on urban fringe development in European countries or the US. From 1991–2000, 114 publications had analysed peri-urban issues, but these had also largely focused on locales in developed nations.

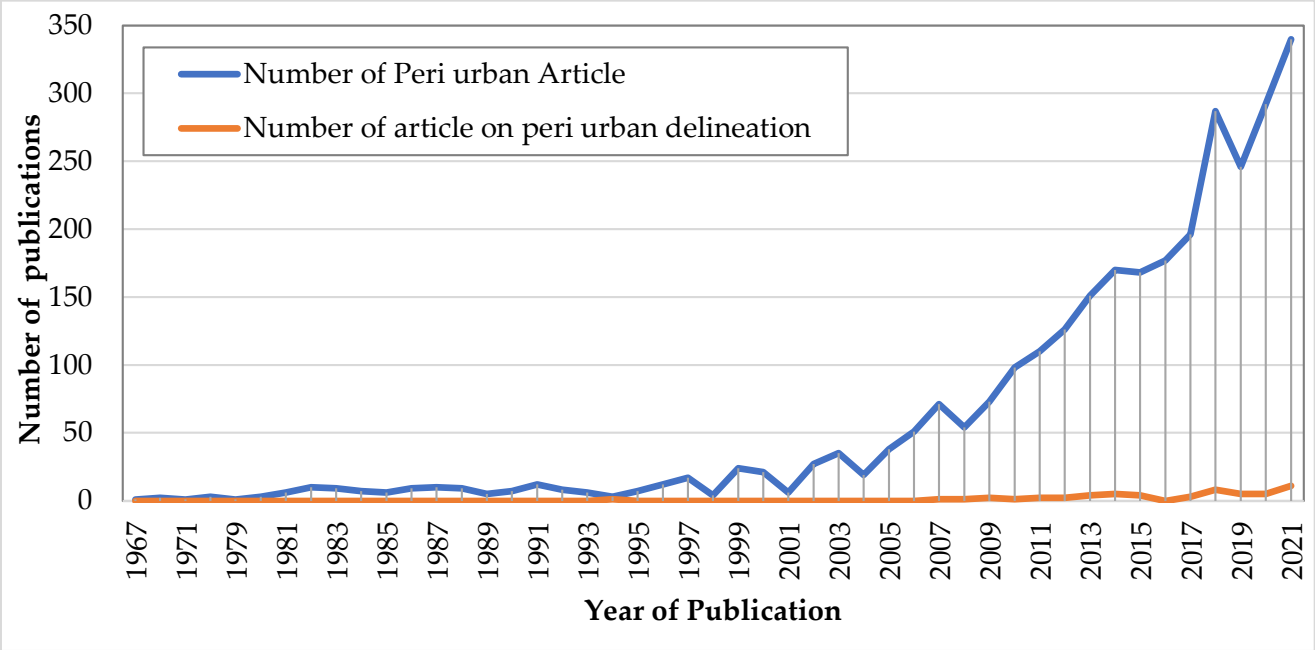


Figure 2. Number of publications on peri-urban aspects from 1967 to 2022.

Peri-urban research received greater impetus in the new millennium due to the spurt in rapid urbanization and sprawl of large cities in developing nations, and the concomitant manifestation of its related environmental and socioeconomic problems. With rural to urban migration becoming commonplace in developing countries, its cities grew markedly

and swiftly into the surrounding peri-urban areas. Between 2001–2010, over 470 published documents dealt with peri-urban issues, while in the last 12 years (2011–2022), this has surmounted to 2263 publications. Interestingly, most of these newer documents highlight peri-urban issues in developing countries, in contrast to the researches done before 2001.

We have also reviewed how researchers from different disciplines have published on peri-urban issues (Figure 3), based on the respective affiliating departments of the first author and corresponding author of each of the examined 3124 publications. In sum, academicians from ten separate disciplines have engaged in peri-urban issues. Among these, 1279 publications (26%) were by environmental science researchers, followed by social sciences (1054 documents, 21%), agricultural and biological sciences (868 documents, 17%), and medicine and health (705 documents, 14%).

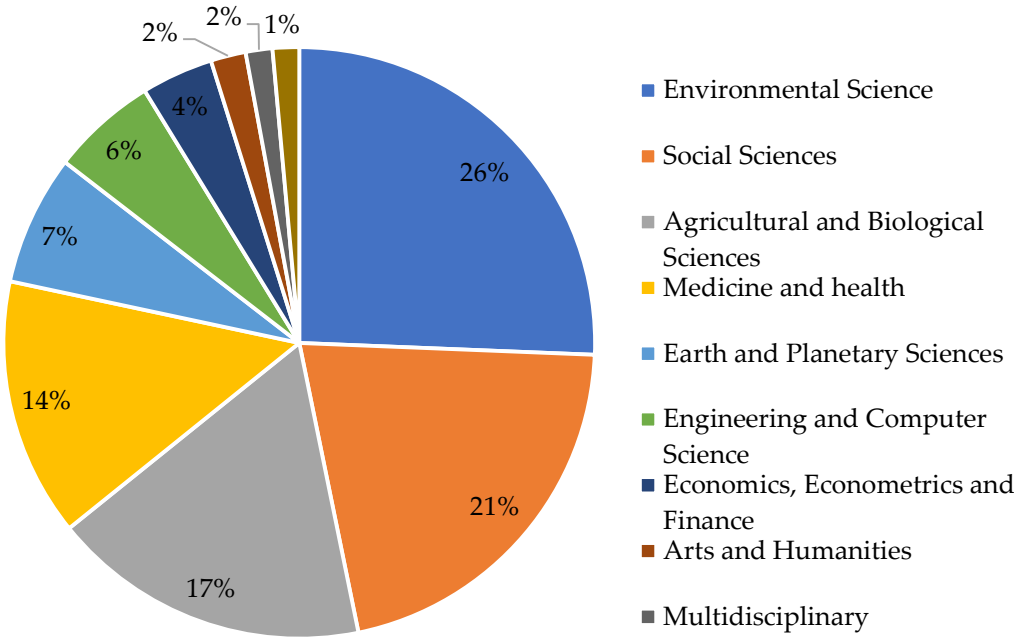


Figure 3. Types of peri-urban publications published by different discipline researchers. (Note: The respective disciplines have been denoted based on the Scopus classification scheme).

In terms of author affiliations and number of articles, the US (398 documents) and UK (309) take the lead in carrying out peri-urban research (Figure 4), followed by India (264), South Africa (223), Australia (213), and China (208). However, publication dates and author affiliations reveal that in recent decades, a greater volume of research has emanated from developing countries. This surmise tallies with the nature and rate of urbanization and peri-urban growth globally [35], which was considerable during 1970–1990 in developed countries, but thereafter became more pronounced in developing nations, particularly after the year 2000. Consequently, it is these developing nations that presently face the bulk of different socio-environmental-economic issues that arise out of city expansion and peri-urban growth, as highlighted by the recent literature.

Of the 56 documents that dealt with peri-urban demarcation/delineation, Europe had the most case studies (16), followed by India (14), Africa (6), Australia (5), Indonesia (3), Malaysia (3), China (2), Vietnam (2), Canada (1), and Central Asia (1). Additionally, six articles investigated peri-urban demarcation worldwide.

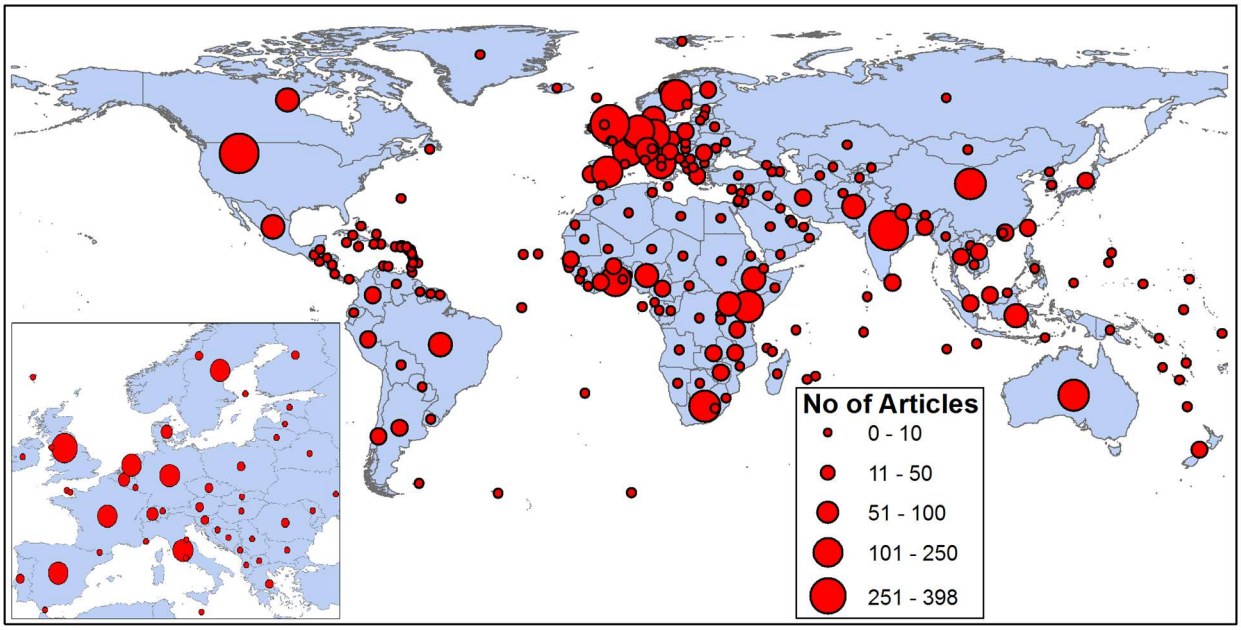


Figure 4. Country- and region-wise distribution of the reviewed documents on peri-urban research.

We also examined the different dimensions, applications, and perspectives of the reviewed documents on peri-urban research (Figure 5). In all, 650 publications focused on peri-urban and environmental issues, 548 examined peri-urban and human/non-human health issues, 428 dealt with the problems of agriculture in peri-urban locales, while 323 documents were on peri-urban social issues. A total of 156 documents were purely focused on the concept and theory of peri-urban areas, with 56 examining peri-urban demarcation/delineation. When the above perspectives and applications of peri-urban research were examined over a 50-plus year timeframe (Figure 6), it became apparent that peri-urban and environmental issues had provided the greatest contribution to research in this domain, despite there being almost no research in this specific category before 1990. Only seven publications had highlighted the above aspect before the year 2000, and between 2001–2010, just 87 documents had delved into it. In keeping with the trends on global urban and peri-urban growth, the research volume in this sub-field has increased exponentially post 2010, with 556 documents highlighting peri-urban and environmental issues thereafter.

Of the 89 documents published before 1990, 26 were on peri-urban theory/concept and social issues, and 32 articles discussed human and non-human health issues in peri-urban areas. With regards to peri-urban demarcation and mapping, out of 56 documents, only one was published before 2000 (in 1994), while 35 were published between 2001–2020. Therefore, 20 articles have dealt with this aspect in the last two years, highlighting its pertinence in current urban research. The overall peri-urban timeframe analysis showed that documents published before 2000 had either discussed theories of peri-urbanization, its concepts, social issues, and the related human/non-human health aspects along with peri-urban agriculture aspects. After 2000, research trends had morphed into a different dimension, mostly focusing on peri-urban land-use change, land transformation, and the impacts of peri-urban growth on the environment, forests, and hydrology.

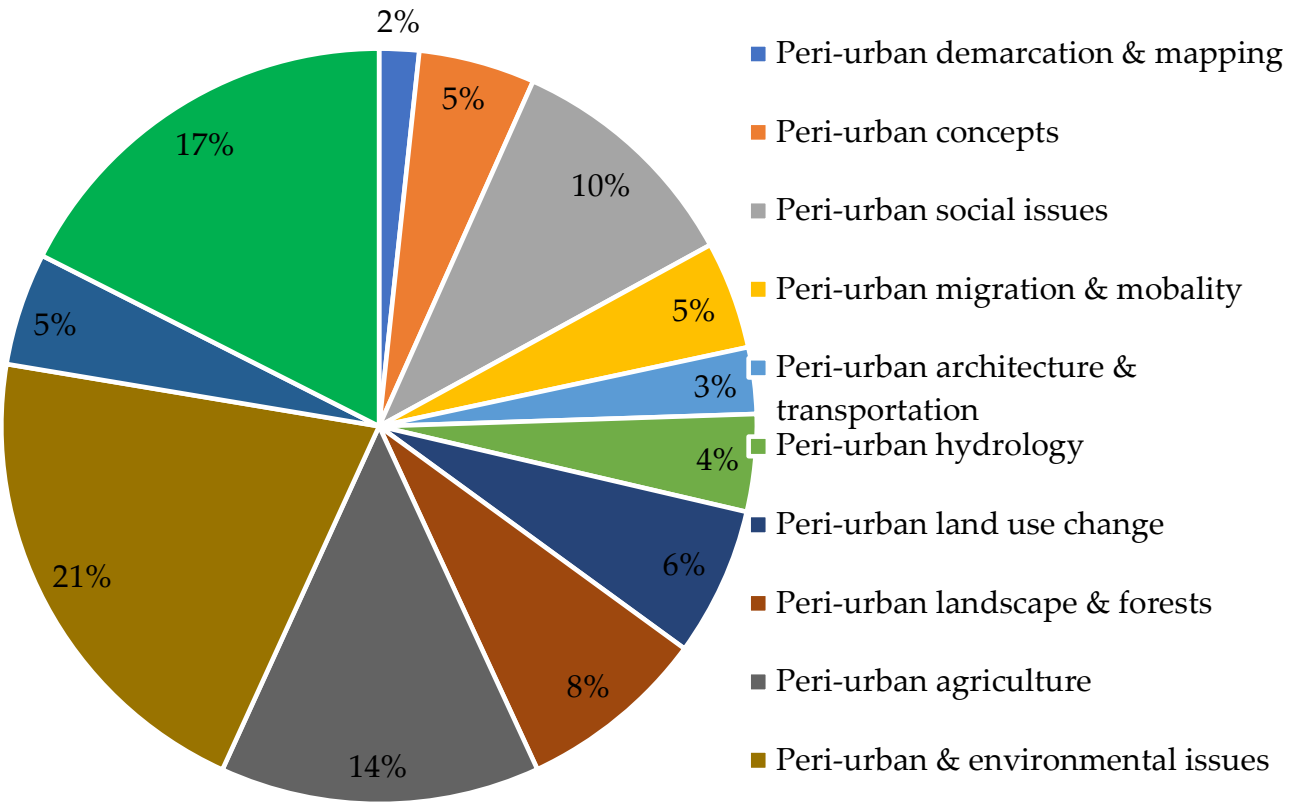


Figure 5. Overall perspectives, dimensions, and applications of peri-urban research.

From the reviewed documents, 12,683 keywords were collated. This was done in VOSviewer from the compiled metadata of the examined documents. Selecting those mentioned at least five times, 1802 keywords were shortlisted (Figure 7). Among these, the term 'peri-urban area' had occurred the most (899 times), followed by 'rural–urban interface' (718), human health (656), population growth (545), urban area (545), land-use change (371), urban population (293), and urban sprawl (254). Alongside these, there were other topical issues or keywords that are in focus at present in peri-urban research, and it is likely that these domains may be future avenues of research. Some of these interlinking keywords are peri-urban growth and environmental monitoring, groundwater, urban planning, governance approach, risk assessment, and peri-urban demarcation.

Then, we examined which publication outlets have covered peri-urban research (Figure 8). The journal *Land Use Policy* has published the highest number of articles on peri-urban issues (61 in all), followed by *Sustainability* (51), *Plos One* (43), *Science Of The Total Environment* (43), and *Acta Horticulture* (40). Temporal variations are apparent again in the publishing trends of peri-urban research in these outlets. While *Land Use Policy* and *Sustainability* display a certain regularity in their publication of peri-urban research, the other notable journals have largely published such articles only after the year 2000. Table 2 lists the ten-most cited articles on peri-urban research so far. Since these have been published at different points of time, the total number of citations received by an article can be higher due to it being published earlier. For this reason, the average citations per year was also computed. Both results reveal that the most cited peri-urban research revolves around its environmental issues, landscape transformation, and impact on agriculture.

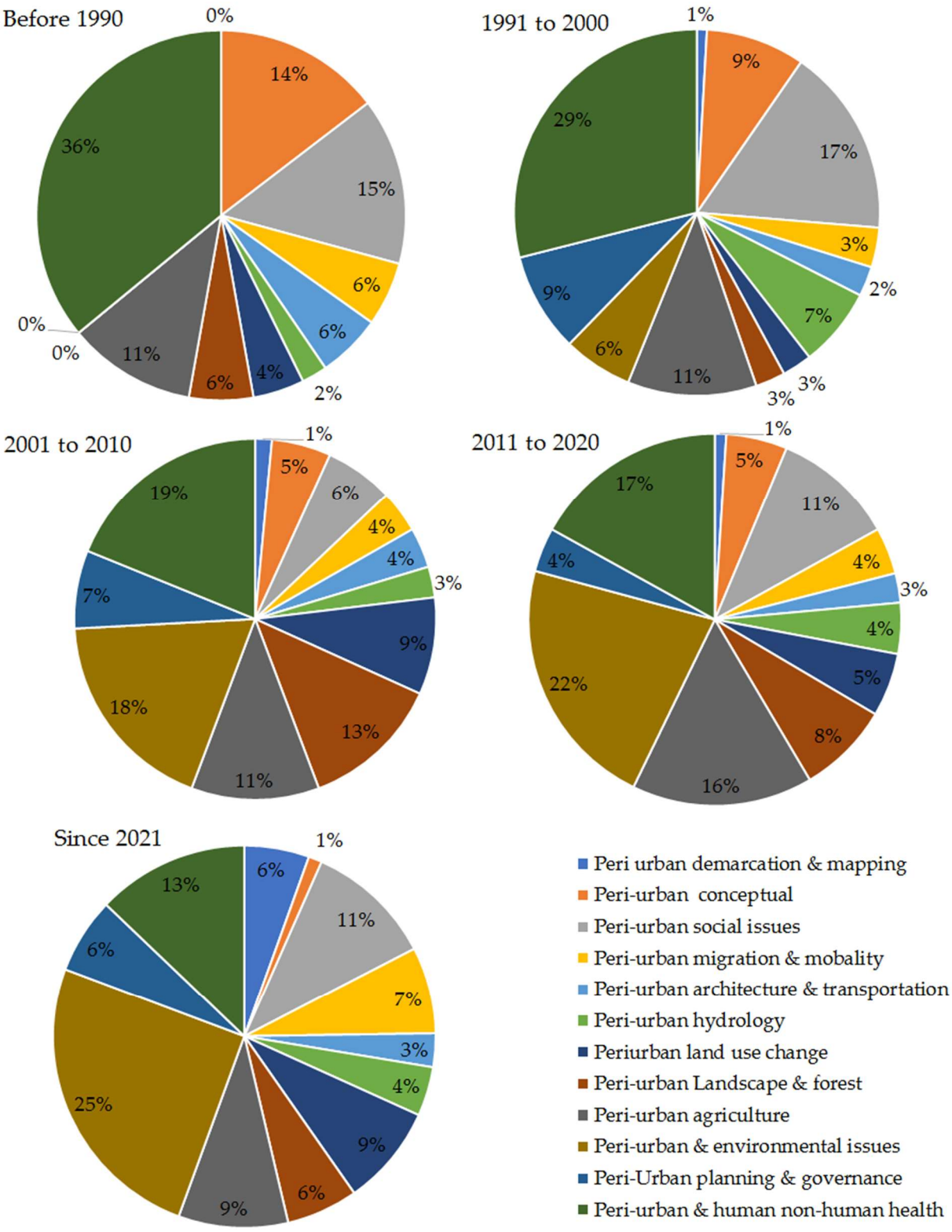


Figure 6. Decade-wise perspectives, dimensions, and applications of peri-urban research.

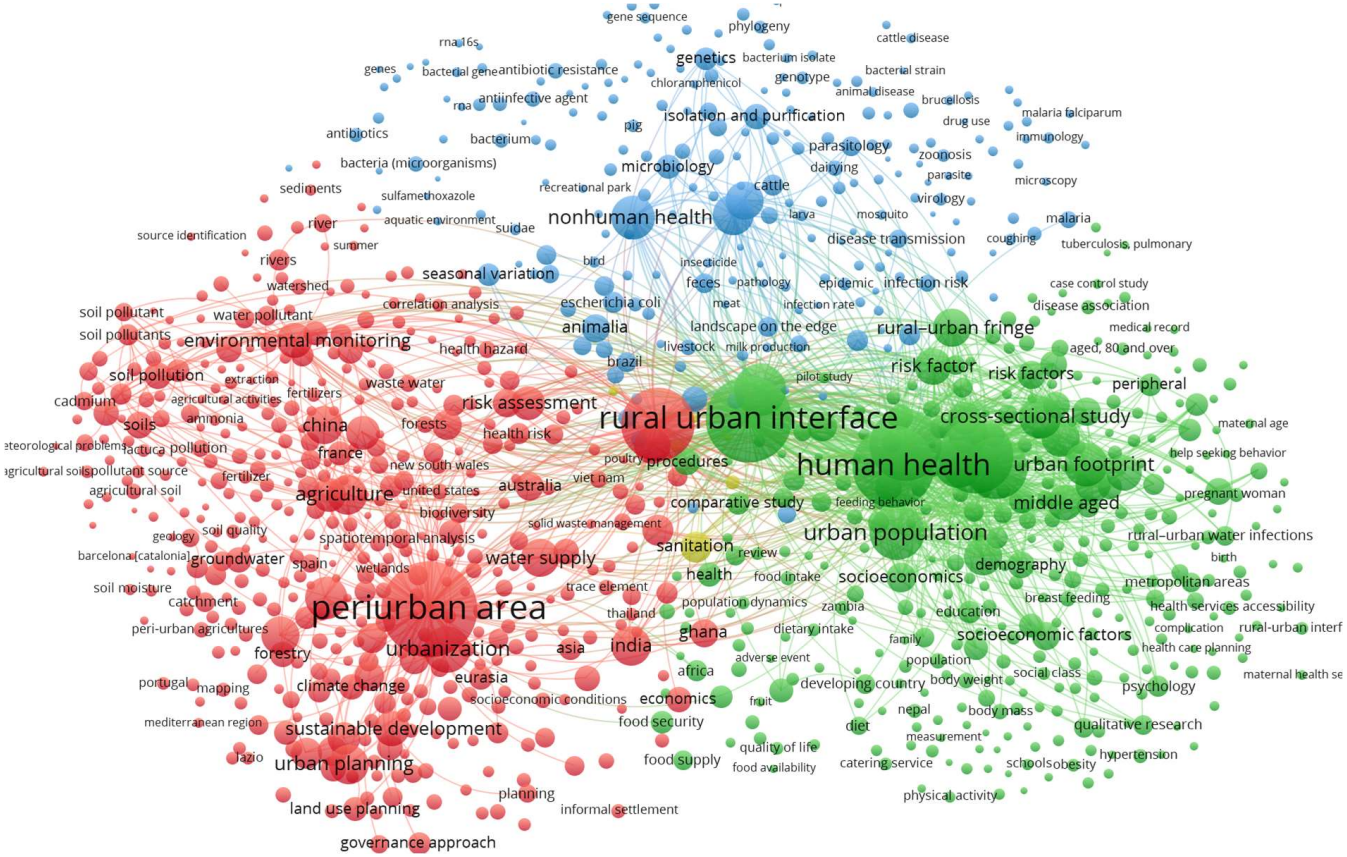


Figure 7. Bibliometric map of keywords co-occurrence with network visualization from 3124 documents on peri-urban studies. (Note: A bigger circle indicates greater occurrence of that keyword while a smaller one indicates lesser examined ideas/concepts. The colours red, green, and blue depict the three major clusters in such research, i.e., peri-urban area, rural–urban interface, and human and non-human health, respectively, and the coloured lines indicate interlinkages between the sub-components of each cluster).

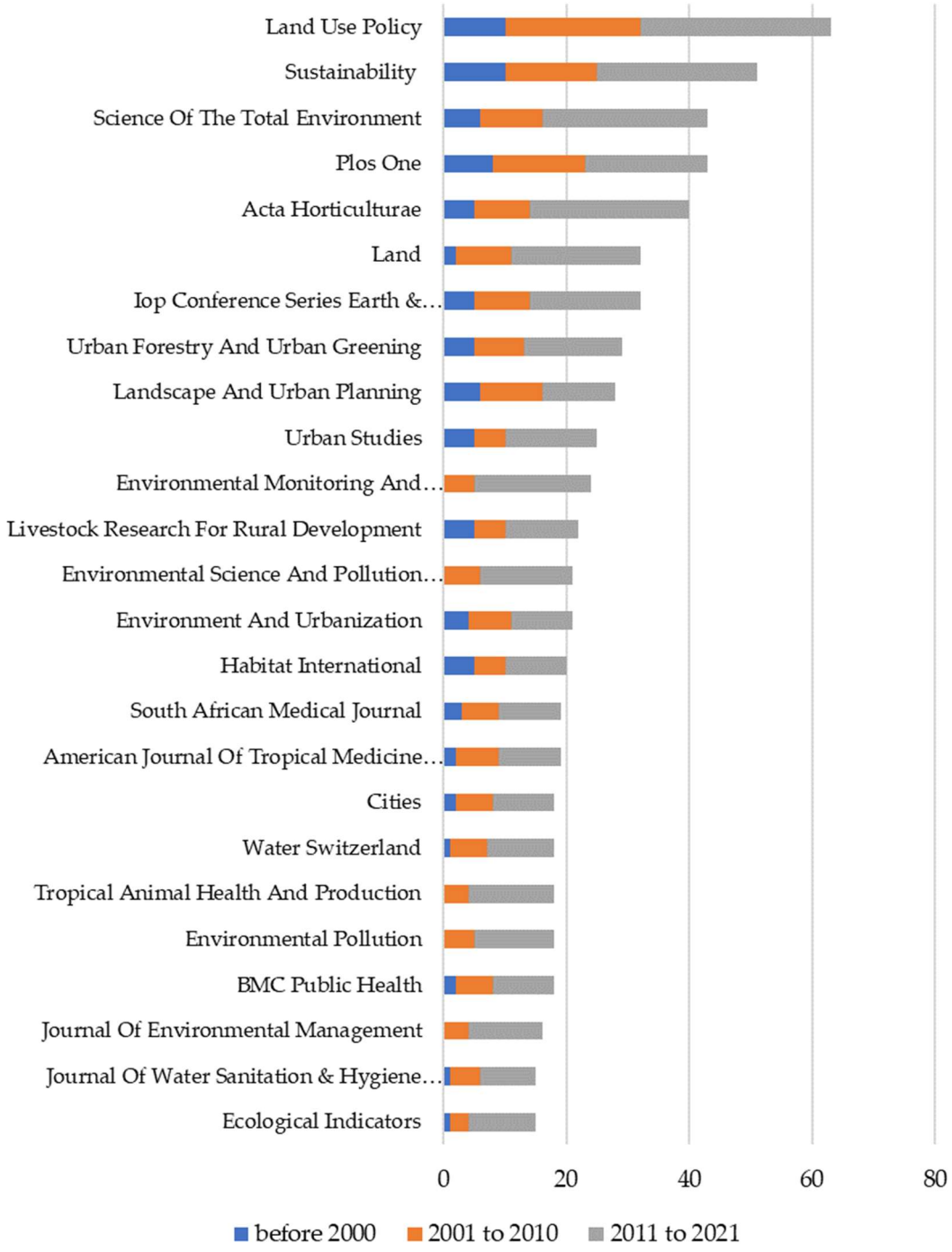


Figure 8. The top 25 Scopus-indexed journals and their number of articles on peri-urban research.

Table 2. The ten most cited articles on peri-urban issues [5,36–43].

Authors	Year	Title	Perspectives	Journals	Cited By	Average Citations per Year
Zasada	2011	Multifunctional peri-urban agriculture: A review of societal demands and the provision of goods and services by farming [36]	Peri-urban agriculture	Land Use Policy	413	34
Carrus et al.	2015	Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas [37]	Peri-urban landscape & forests	Landscape and Urban Planning	377	47
Allen, A.	2003	Environmental planning and management of the peri-urban interface: Perspectives on an emerging field [5]	Peri-urban & environmental issues	Environment and Urbanization	374	19
Schneider, A.	2012	Monitoring land cover change in urban and peri-urban areas using dense time stacks of Landsat satellite data and a data mining approach [38]	Peri-urban land use change	Remote Sensing of the Environment	310	28
Miller et al.	2014	Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover [39]	Peri-urban hydrology	Journal of Hydrology	276	31
Simon	2008	Urban environments: Issues on the peri-urban fringe [40]	Peri-urban & environmental issues	Annual Review of Environment and Resources	232	15
Wu et al.	2013	Informality and the development and demolition of urban villages in the Chinese peri-urban area [41]	Peri-urban social issues	Urban Studies	228	23
Duvernoy et al.	2018	Pictures from the other side of the fringe: Urban growth and peri-urban agriculture in a post-industrial city (Toulouse, France) [42]	Peri-urban agriculture	Journal of Rural Studies	199	40
Zhu et al.	2012	Assessment of spectral, polarimetric, temporal, and spatial dimensions for urban and peri-urban land cover classification using Landsat and SAR data [43]	Peri-urban land use change	Remote Sensing of Environment	195	18
Aguilár et al.	2003	Globalization, regional development and mega-city expansion in Latin America: Analyzing Mexico City's peri-urban hinterland [4]	Peri-urban land use change	Cities	187	9

Note: The citations are as per Google Scholar records of July, 2022.The average number of citations per year has been calculated as the total citations received by an article divided by the period of time from its year of publication till 2022, with the figure rounded off to the nearest whole number). The number in [] at the end of the article title denotes its position in the reference list of this paper.

3.2. Concept of Peri-Urban Demarcation

Conceptually, peri-urban areas are an imaginary location comprised of two dynamic boundaries. The inner boundary is located at the edge of the urban area while the outer one is situated within the rural landscape [44]. Interestingly, this inner boundary is similar to its adjacent urban locales, whereas the outer boundary largely resembles its contiguous rural landscape [45,46]. Demarcation of the exact locations of these boundaries and the delineation of peri-urban areas is, however, conceptually and methodologically complex [31].

As indicated above, the large majority of the existing peri-urban literature either completely avoids the question of spatial demarcation of peri-urban areas or takes a pragmatic approach to identifying it [6]. Such pragmatic inquiries in peri-urban issues subsume all kinds of spaces around the city as peri-urban areas (including suburban, fringe, rurban, and other such locales). In contrast, several studies have tried to spatially demarcate peri-urban zones based on either socioeconomic structures [47–49] or through land-use change analysis [50,51]. However, peri-urban areas are very dynamic and vary across places and regions. Therefore, existing studies have highlighted that their demarcation should be based on land-use change data, incorporation of environmental parameters, socioeconomic data, information on migration and number of daily commuters (including travel times), housing conditions and affordability, and related cultural attributes [31,52,53]. The sharp diversities in the nature and history of urbanization worldwide, especially in the post-modern age, have fostered marked differences in rural and urban cultures and socioeconomic conditions between developed and developing countries. For this reason, peri-urban growth in the Global North is considered as an indicator of urban welfare and well-being [29], whereas in the Global South, it is often negatively connoted as a (planning) challenge [6]. Thus, the usual peri-urban demarcation methodologies in the Global North cannot be simply replicated elsewhere as the respective patterns of peri-urban growth can be quite different.

Thus, the prime question in peri-urban research over the last three to four decades has been that if these areas do indeed exist, then where are they located? Furthermore, are there any methods to succinctly identify these locales? After the influx of quantitative methods in urban studies along with the advent of remote sensing and GIS-based techniques, the identification and mapping of peri-urban zones obtained further momentum. Thus, a range of quantitative, qualitative, and mixed methods have been used to demarcate peri-urban areas globally, but these are very diversified and often regional in character. Due to continued expansion of cities beyond their original municipal boundaries, peri-urban demarcation and mapping has also assumed importance in urban governance and policy framing by the local administrative authority. Thus, practically, urban planners and management bodies seek to identify peri-urban areas and its location beyond existing city limits. However, the methods of such identification are not uniform in nature across the world.

3.3. Approaches and Methodologies for Demarcation of Peri-Urban Areas

This plurality of multiple concepts, along with contradictions as to what creates and manifests peri-urban locales, and the nature and meaning of the processes operative therein, imbue confusion with regard to the correct definitions and understanding of this phenomenon. Moreover, these terms can be diversely used to denote a range of contiguous peri-urban areas having a predominant urban nature, intermediate peri-urban zones that show a transitional nature between the city and village, or the rural peri-urban tract having a predominantly rural character [3]. Thus, the rural–urban interface dichotomy is one of the most important issues in 21st century urban planning, policy-making, and management approaches.

Given that the trend of future population growth worldwide is towards the peri-urban zones of major cities and towns, the conceptual literature and hypotheses based on peri-urban research has grown significantly in the last two decades. Despite this, peri-urban areas still do not have any clear boundaries geographically and conceptually [54], as there

are no adequate or accurate methods for its spatial demarcation or the identification of its multi-dimensional facets. As there are no well-recognized and suitable methods for peri-urban delineation, we have critically reviewed 56 documents specifically dealing with this issue to discern how researchers have used different databases, indicators, models, and methodologies in this regard. Since peri-urban occurrence and demarcation is also context specific given the nature and history of urbanization in a region, we have discussed such studies from each of the major geographic regions.

3.3.1. Peri-Urban Demarcation Studies in Europe

Errington (1994) presented some early maps distinguishing different peripheral developments along the edges of European cities [55]. The integration of remote sensing data and GIS methods for this purpose was initially undertaken by Banzhaf et al. (2009) to chart peri-urban development around Leipzig [56]. Piorr et al. (2011) first classified rural–urban regions at the pan-European level as part of the PLUREL project [20], which defined such locales as 'discontinuous built development, containing settlements of less than 20,000 people, with an average density of at least 40 persons per km^2 (averaged over 1 km^2 cells). These peri-urban areas were identified from the 'urban fringe' and 'urban periphery' classes, based on their spatial classification as the 'rural–urban region' (RUR) [20,36,57].

Haase et al. (2013) have demonstrated various tools for modeling and assessing peri-urban land-use futures in cities across Europe (EU27) [58]. Diti et al. (2015) proposed an agri-environmental and socioeconomic component-based method to quantify and differentiate peri-urban areas from rural expanses and urban tracts in the Emilia-Romagna region of Italy [59]. Poursanidis et al. (2015) used object-based image classification for land cover change analysis in urban and peri-urban zones of Rafina Municipality in Attica, Greece [60]. Cusin et al. (2016) developed a multi-scale statistical approach using French population census data from 1968–2011 to demarcate peri-urban areas across France and gauge their temporal changes [61], defining such locales as discontinuous sub-urbanized spaces having a mixed rural–urban interface. Gonçalves et al. (2017) denoted peri-urban areas using a transdisciplinary approach and identified their typologies in the Lisbon Metropolitan Area [54], based on the assumption that more than one type of peri-urban tract can exist around an urban core. Therefore, linking the physical, economic and social aspects of these locales was deemed to be paramount for capturing the intrinsic variability and complexity of the peri-urban character therein.

Goerlich Gisbert et al. (2017) used a cluster-based model, demographic information, and high-resolution land-use datasets to delineate urban, peri-urban, and rural areas throughout Spain [62]. Cegielska et al. (2018) employed the satellite image-based Shannon entropy model for demarcating peri-urban zones in Małopolskie Province, Poland [63]. Gajić et al. (2018) proposed a new methodological framework [64] for delineating rural and urban areas using physico-geographical, socioeconomic and functional characteristics along with multivariate analysis techniques (PCA, factor analysis, and cluster analysis) in Serbian cities. Cattivelli (2020) devised a new cluster-based classification approach for demarcating peri-urban areas across Europe [65], using variables highlighted by others previously, such as economic and social indicators, demographic dynamics, and distance and settlement indicators. Salvia et al. (2020) used a long-term (1951–2011) settlement dataset [66], obtained by converting the population census information, to study demographic dynamics and metropolitan growth in rural areas around Athens. More recently, ˇZlender (2021a) has devised a qualitative method using focus groups and interviews to characterize peri-urban landscapes of Ljubljana and Edinburgh [67], alongside developing a spatially explicit method [68] for delineating peri-urban zones in both these cities.

3.3.2. Peri-Urban Demarcation Studies in Australia and the Pacific Islands

Buxton and Choy (2007) demarcated peri-urban locales around two Australian megacities and found that these were not homogenous/static in nature [31]. Furthermore, their dynamicity enabled continued growth of the metropolitan areas. Sutton et al. (2010) used

nighttime satellite images to outline urban, peri-urban, and rural tracts areas throughout Australia [69], eliciting that 82% of Australians are urbanites, 15% lived in peri-urban zones, and only 3% in rural tracts. Sutton (2003) had previously used nighttime images in to demarcate the sprawl line for cities in the American Mid-West [70], further incorporating a population-weighted measure of urban sprawl to identify the peri-urban zone threshold. Mortoja and Yigitcanlar (2021) combined remote sensing data with a fuzzy linear urban membership function (FLUMF) model [71] to map peri-urban growth in the Brisbane Metropolitan Region from 1989–2019. Wang et al. (2022) used cellular automata (CA) models and generalized simulated annealing (GSA) algorithms to simulate urban, peri-urban, and rural land development in southeast Queensland [72], predicting the peri-urban growth likely to occur therein by 2031 and 2041.

3.3.3. Peri-Urban Demarcation Studies for Asian Cities

Samat et al. (2011) undertook satellite image and CA-based land-use change mapping in peri-urban areas of Seberang Perai region in Penang State, Malaysia [73]. Dutta (2012) used the Indian population census data and satellite images over a 20-year timeframe for mapping urban and peri-urban dynamics in Lucknow [74]. Follmann et al. (2018) proposed a multi-temporal transect model to identify peri-urban developments in Faridabad [75]. Shi et al. (2012) devised the Landscape Expansion Index (LEI) to demarcate peri-urban areas and chart urban growth patterns and processes in Lianyungang City, China [76]. Vishwanath et al. (2013) used a demographic mapping and visualization-based approach to identify the urbanization occurring beyond municipal boundaries in Indian cities [77], linking these peri-urban areas with the ongoing economic growth/development. Saksena et al. (2014) combined the national census of Vietnam with remote sensing data in an indicator-based quantitative model to classify rural and urban areas in that country [78]. They discerned that approximately 7% of Vietnam's total area was comprised of peri-urban locales, and 13% (>11 million people) of Vietnam's population lived within them.

Banerjee et al. (2014) used a process-based economic model [79], containing several demographic and socioeconomic indicators to demarcate peri-urban tracts of the Greater Hyderabad metropolitan area. Kontgis et al. (2014) used census data and Landsat images of 1990–2012 to enumerate urban and peri-urban zones in the Greater Ho Chi Minh metropolitan area [80]. Hoffmann et al. (2017) constructed a simple index of urbanization for the rural areas of Greater Bangalore using satellite images to build density and distance based on indices of clustering in the rural–urban interface [81]. Arif and Gupta (2018) prepared a peri-urban index for Burdwan [82], using eight parameters derived from three sets of determinants (demographic, occupational structure, and infrastructure). Danielaini et al. (2018) have tried to provide more accurate definitions of the rural–urban zone and guidelines for peri-urban delineation via a case study of the Cirebon Metropolitan Region in West Java [83]. They used eleven social, economic, and spatial variables that were directly or indirectly related to the ecohydrological settings of these locales, incorporating both GIS and statistical techniques to denote eight classes of rural–urban interfaces which provide a suitable framework for the delineation of peri-urban areas.

Rukmana and Widyastuti (2018) used a descriptive quantitative method to identify rural–urban interactions in the Sidoarjo district of East Java [84]. Maithani et al. (2018) used a Weights of Evidence (WoE) based CA model to simulate peri-urban growth of Dehradun [85] while Mustak et al. (2018) incorporated the analytical hierarchy process and coupled fuzzy membership functions with satellite images to identify the rural–urban fringe around Raipur [86]. Dutta and Das (2019) combined demographic and socioeconomic data from India's census with satellite images via PCA and cluster analysis for English Bazar in West Bengal [87]. Tiwari (2019) has used several socioeconomic indicators for delineating the peri-urban areas of five major Indian cities [88]. The use of urban sprawl metrics (USM) to characterize city expansion in India and document changes in the peri-urban zone has also been attempted for large cities, such as New Delhi [89] and Kolkata [90,91], discerning how land-use changes have related to alterations in the ambient land surface

temperature [92] and charting the transformation pathways of such large metropolises [93]. Further approaches to classifying and demarcating peri-urban areas using USM (e.g., noting the nature of alteration in each USM class) can potentially elicit fruitful results.

Hui and Wescoat (2019) used field-based data, Census of India's water and sanitation data and GIS mapping to identify four main peri-urban patterns in Pune district [94]. Xia et al. (2020) prepared a framework for charting future city growth and potential peri-urban zones via a multi-scale urban growth model in the Yangtze River Middle Reaches megalopolis [95]. Mondal and Sen (2020) and Mondal and Banerjee (2021) both used socioeconomic and land-use characteristics to map peri-urbanization around Kolkata [96,97]. Dutta et al. (2022) proposed a clustering methodology using 11 sets of demographic and socioeconomic variables to identify peri-urban areas of Chandigarh [98]. Liu et al. (2022) have recommended nature-based solutions for the problems arising out of urban expansion and identified peri-urban growth and integrated ecosystem services in Hohhot, Inner Mongolia [99].

3.3.4. Peri-Urban Demarcation Done for African Cities

Makita et al. (2010) have used socioeconomic and demographic factors to highlight the rapid rural changes occurring due to peri-urban growth around Kampala [100]. Amoateng et al. (2013) linked physical city development with peri-urban growth [101], whereas Afriyie et al. (2014) utilized field-based datasets along with livelihood indicators and satellite images to demarcate the peri-urban areas of Kumasi in Ghana [102]. Another important and recent case study on classifying and mapping peri-urban areas of rapidly growing, medium-sized Sub-Saharan cities was done in Ghana by Karg et al. (2019). It used a quantitative and multi-dimensional methodology incorporating three core elements—urbanicity index, livelihoods and access to urban services—and land-use dynamics [103]. To fulfil this objective, they collected data via an extensive household survey, extracted pertinent information from satellite images and prepared various secondary layers at different spatial scales. Their findings reveal that the peri-urban zone consists of the space between the inner peri-urban and outer peri-urban areas. Bogaert and Halleux (2015) used a landscape ecology-based approach to identify peri-urban zones of Central African cities [104]. Wolff et al. (2021) used a mixed methods approach in combining expert interviews with geospatial data analysis to identify the urban-rural gradient in Dar es Salaam by incorporating satellite images, OpenStreetMap data, building density, proximity to environmental features, and other socioeconomic variables [105].

3.3.5. Peri-Urban Demarcation Studies in North and South America

Balk et al. (2018) used the time-series information available from the Global Human Settlement Layer (GHSL) from 1990–2010 along with census-designated urban blocks to discern consistent urban proxies in the US [106]. They proposed that urban tracts be denoted as those locales that have >50% built-up area, and if people living therein reside within the census boundary. Conversely, peri-urban areas should have 30% of the census-designated urban population and fewer built-up areas. Czekajlo et al. (2021) have combined 33 years of Landsat images (1984–2016) with multi-temporal census data to map peri-urban land-use transitions across 18 major Canadian cities [107].

3.3.6. Peri-Urban Demarcation in a Global Case Study Scenario

Weller et al. (2019) assessed 423 cities worldwide to identify their respective degrees of peri-urban growth and its direct conflicts with the ambient habitats and endangered species [108]. Li et al. (2020) prepared a dataset of global urban boundaries and measured the growth of the world's important cities using CA-based urban growth models and the Global Artificial Impervious Area (GAIA) dataset [109]. Mortoja et al. (2020) and Ahani and Dadashpoor (2021) both undertook a systematic review of the relevant literature to understand the existing approaches and methods for demarcating peri-urban areas across the world [49,110]. Mortoja and Yigitcanlar (2022) used night-time light data and Landsat

images to explore urban growth patterns over 30 years in a comparative case study between the Dhaka Metropolitan Development area and large urban centres in Australia [111]. For this, they used the Land Change Modeller (LCM) tool and fuzzy linear urban membership function set (FLUMFS) to demarcate peri-urban zones.

3.3.7. Peri-Urban Demarcation Methods Used in Major Research Projects

Peri-urban growth rate in the Global South has been more rapid compared to the Global North, which is reflected in their respective trajectories of change over time and in their inherent characteristics (Table 3). Furthermore, the difference between 'global south and north' (or, 'developing vs. developed') in the peri-urban profiles, is profound. However, there are many shades and nuances between, and experience on the ground shows that both features may co-exist in close proximity. This example table (Table 4) from the Peri-cene project [7], includes the general fields of (a) income/development level, and (b) peri-urbanization (defined as population and/or land area. These are then combined with (c) the climatic type and typical impacts of climate change. Table 4 shows eight 'peri-eco-urban' combinations, at a general level, as a guide for further investigation. Thus, it is quite difficult to frame a spatial classification of peri-urban zones globally due to the diverse and disparate methods and datasets used in such studies in different locations (Figure 9). We have reviewed five major research projects (denoted as such on the basis of the respective funding agency's reports and related documents) that have dealt with peri-urban demarcation methods worldwide (Table 5). All of them have used either a population census or a socioeconomic indicator-based methodology or employed raster land-use datasets to map and model changes in peri-urban areas [20,57,61,112]. Thus, only a few studies exist on the delineation and mapping of peri-urban locales throughout the world. PCAT, under the Peri-cene Project, is a visualization tool that highlights peri-urban zones for 24 million-plus cities across the world. However, this project also has some ambiguities in its adopted method of peri-urban boundary demarcation [7].

Table 3. Comparison of peri-urban area characteristics across the Global South and Global North.

Global South	Global North
Faster and relatively more haphazard growth of peri- urban areas, which is linked with the concomitant economic development and social change.	The planned growth of peri-urban areas is linked with social well-being and a better way of living.
Much of the peri-urban growth has happened after the year 2000.	Maximum peri-urban growth occurred during 1970 to 2000. Spatial expansion of peri-urban locales still carries on, but at a slower pace than that in developing nations.
Lower cost region (in terms of living expenses and land value) in comparison to inner city zones.	Higher cost region in comparison to inner city zones.
Mostly for industrial and corporate setups and in a few cases is also used for residential purposes	Most of the peri-urban expansion has occurred for residential purposes.
Illegal land encroachment, high-density peri-urban development with inadequate provisions of infrastructure and services	Relatively larger areal coverage of peri-urban zones and smaller population size.
Remote sensing data and GIS modelling are frequently used to identify such peri-urban areas, with such studies commencing more recently.	Much more qualitative research has been conducted to examine peri-urban issues, with many RS-GIS based studies having already been conducted previously.

Note: The above differences are what we consider to be the general or usual ones between peri-urban areas in the Global South and Global North based on the research in this domain. There can, of course, be case to case and location or context specific variations from these mentioned differences.

Table 4. Types of peri-urban (P-U) development in various climatic settings and their typical policy pathways/agendas.

Development Type	Climatic Type	Examples	Typical Direct Climate Impacts	Typical Policy Pathways and Agendas
Lower income—rapid P-U growth	Hot/wet climates:	Dhaka, Surabaya, Chennai, Bangkok	Floods, cyclones, heat, sea level	Governance, flood, sea levels, food, livelihood
Lower income—rapid P-U growth	Hot/dry climates:	Mexicali, Cairo, Johannesburg	Drought, heat, (flood)	Governance, water, heat, landscape, social resilience
Lower income—slower P-U growth	Hot/wet climates:	Kumasi, Changsha,	Flood, drought, heat	Governance, flood, food, urban-rural links, eco-urban
Lower income—slower P-U growth	Temperate/dry climates:	Santiago, (Belo Horizonte)	Flood, drought, heat	Governance, flood, water, heat, landscape, social resilience
Higher/mid income—rapid P-U growth	Temperate/wet climates:	Helsinki (Guangzhou)	Flood, ecosystems	Flood, eco-peri-urban, infra-structure, ecosystems, governance
Higher income—rapid P-U growth	Temperate/dry climates:	Melbourne, San Diego	Wildfire, drought, heat, flood	Wildfire, water, flood: landscape, eco-peri-urban, governance
Higher income—slower P-U growth	Temperate/wet climates:	Toronto, Manchester, (Tokyo)	Flood, heat, ecosystems	Landscape, flood, eco-peri-urban, governance
Higher income—slower P-U growth	Temperate and hot/dry climates:	Granada, Naples, (Doha),	Drought, heat, flood, sea level	Landscape, water, heat, flood, livelihood, social resilience, governance

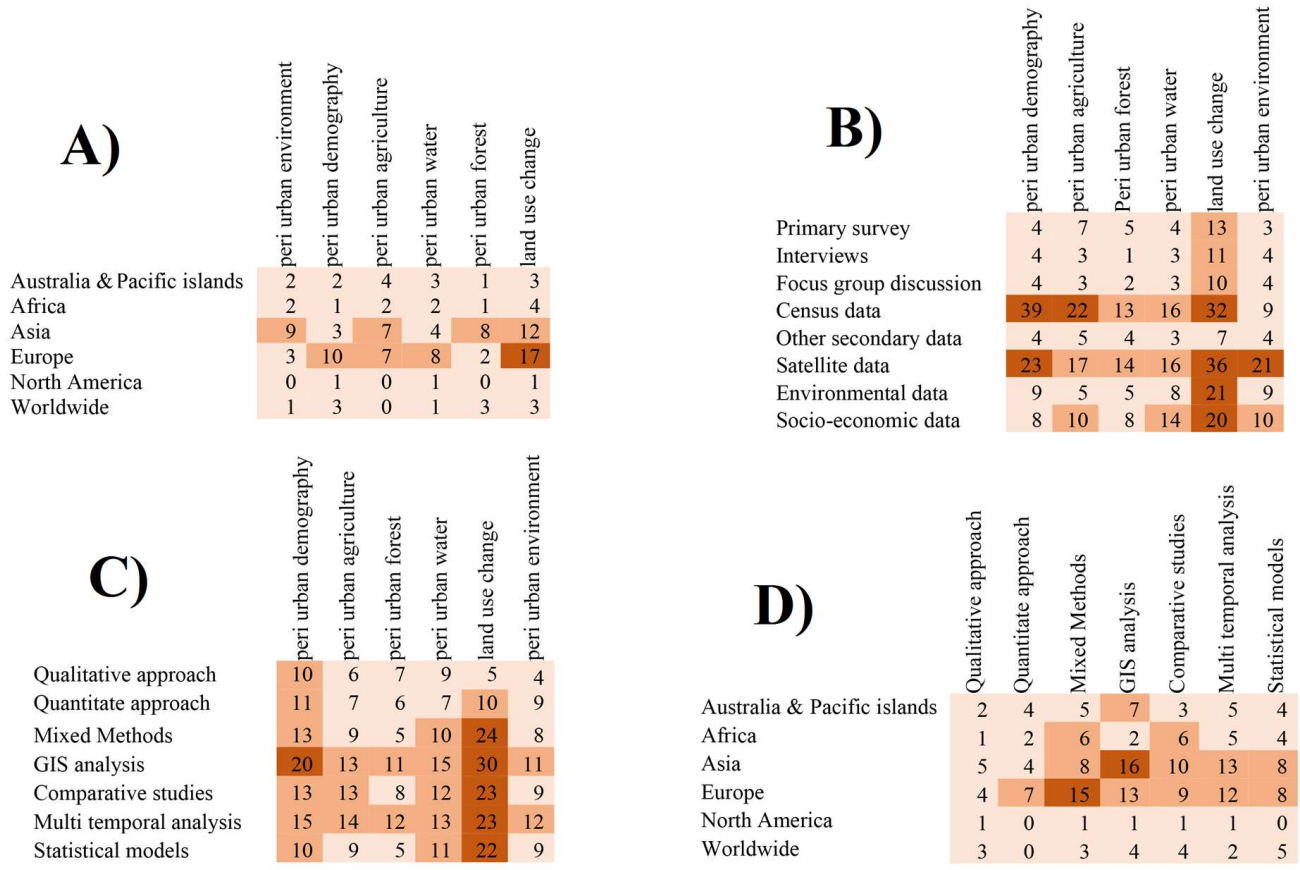


Figure 9. (**A**) Perspectives of peri-urban demarcation in different geographic regions, (**B**) Perspectives of peri-urban demarcation and the databases used, (**C**) Methods related to targeted peri-urban applications, and (**D**) Approaches used to demarcate peri-urban areas in different regions.

Table 5. Notable research projects dealing with peri-urban demarcation and mapping.

Year	Project Title	First Author/Editor	Co-Authors/Co-Editors	Affiliated Institution	Study Area	Secondary Data Used	Geospatial Data	Methodology	Models	Indicators Used
2015	The Peri-urban Question: A Study of Growth and Diversity in Peripheral Areas in France	François Cusin	Hugo Lefebvre and Thomas Sigaud	Université Paris-Dauphine, Sciences Po University Press	Cities in France	French censuses 1968 to 2011	No	Statistical methods for peri-urban zonation	Population zonation	INSEE's urban area zoning classification
2009	On the Edge of Sustainability: Perspectives on Peri-urban Dynamics	Fiona Marshall	Linda Waldman, Hayley MacGregor, Lyla Mehta and Pritpal Randhawa	STEPS Centre, University of Sussex	Worldwide	Define a conceptual method on the peri-urban delineation	Peri-urban sustainability dimensions	Qualitative and quantitative research methods	Indicator based assessment	Several indicators of water and environmental sustainability
2011	Peri-Urbanisation in Europe: Towards European Policies to Sustain Urban-Rural Futures	Annette Piorr	Joe Ravetz and Ivan Tosics	The University of Copenhagen, Danish Centre for Forest	Across Europe	Land cover and population change-based approach	From Global level scenarios down to the European level up to the years 2025 and 2050	Raster grid-based data model that quantifies the trends, risks and potentials for peri-urban regions	Multi-level Indicator based assessment	Several socioeconomic and land cover indicators
2010	Relationships between Urban-Periurban-Rural Regions: First findings from the EU-Project PLUREL	Tanja Tötzer	NA	Systems research, Vienna	Across Europe	Land cover and population change-based approach	From Global level scenarios down to the European level up to the years 2025 and 2050	Raster grid-based data model that quantifies the trends, risks and potentials for peri-urban regions		Land use and land cover-based indicators
2022	Peri-cene– Geospatial Analysis (global assessment & interactive tool on peri-urbanization and climate risk)	Joe Ravetz	Nuno Pinto, Mehebub Sahana and A Ramachandran	University of Manchester, United Kingdom	24 cities world-wide	Census 2001 and 2011	GHSL Human settlement layers data	FUA/non-FUA based analysis	Raster grid-based data model	Population density, population potential and built-up density
2006	The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use	Duncan McGregor	Duncan McGregor and David Simon	Royal Holloway, University of London, UK	Over the world	Over 20 chapters have used different socioeconomic data bases over the world	Few chapters used geospatial data	Qualitative and quantitative research methods	Various models: socioeconomic, demographic and geospatial models	Environmental, socio -economic, demographic, agricultural

Note: The affiliating institution of the first author is usually listed.

3.4. Continuing Remote Sensing Approaches in Peri-Urban Demarcation and Assessment

Peri-urban research has been greatly furthered using satellite-based remote sensing, especially since the beginning of the 21st century. Figure 9B depicts that this approach has been one of the most adopted among the articles reviewed in this study. The usual peri-urban applications have employed myriad remote sensing datasets. In addition to the articles considered in this study, multiple other studies have demonstrated the use of Landsat images to examine peri-urban growth via change detection and derived indices (e.g., [113,114]), primarily due to the long-term availability of this medium resolution data. Furthermore, there are several studies that have used higher resolution images from SPOT, Sentinel-2, Ikonos, GeoEye, and Quickbird satellites for assessing relevant environmental issues in peri-urban locales [74,115–117]. Such monitoring has received greater impetus through the use of night-time [118], hyperspectral [119,120], and microwave imagery [121–123], declassified aerial photos [124,125], the Google Earth platform [75], and terrestrial and airborne Light Detection and Ranging (LiDAR) point clouds and Simultaneous Localisation and Mapping (SLAM) technology [126–130]. Newer methods of object-based image analysis (OBIA) and classification [131], big data analysis [132], and advanced machine learning techniques [133–135], have enabled swifter and more detailed and diversified data capture and extraction in peri-urban environments from remotely sensed datasets. Thus, it is quite apt to surmise that remote sensing and satellite image-based assessments will continuing to provide great insights into peri-urban transformation and environmental issues, and engage with its related issues of sustainability and management.

3.5. Remote Sensing Observations on Land, Ecology and Environment in Peri-Urban Areas

With unprecedented and unregulated growth occurring in urban and peri-urban areas across the world, the land-use character within and around such places are extremely dynamic, with fast-changing ecological characteristics and functions. Remote sensing and GIS-based techniques are considered as ideal tools to analyse such urban and peri-urban environments, their dynamicity, and the altered nature of the neighbourhoods therein, and, furthermore, for relating these aspects with issues of urban development, environmental change monitoring, and modelling. Additionally, the unprecedented and quite unrelenting physical expansion of (especially large) cities continually push the peri-urban interface further outward, making this the most dynamic entity. Failures in acknowledging and mapping such dynamicity could restrict endeavours to achieve urban and regional sustainability. Thus, we believe that the use of large spatio-temporal geospatial datasets and Big Data to gauge the expansion of peri-urban areas, together with their effect on the urban environment's sustainability and livability are important considerations towards framing better policies for managing such locales. The peri-urban interface, i.e., the area between and around cities, shows the extended footprint of human settlements and often bears major consequences of ecological alteration and societal-climate-environmental interactions. Thus, the role of remote sensing observations and geospatial modelling is very necessary to track land, ecology, and environmental changes in the peri-urban areas and suitably inform sustainable and green urbanization frameworks for future urban growth.

3.6. Indicators and Criteria for Peri-Urban Demarcation

Over the last two to three decades, peri-urban zones have become an important arena of research for academicians, urban planners, and policymakers. Even then, there is a scarcity of secondary data from government sources at the regional and national level for analysing peri-urban locales in different parts of the world along with a lack of homogeneity in data standards and temporality, which precludes any detailed comparative analysis. Thus, various studies have perforce used different kinds of indicators to demarcate peri-urban zones, which are also partly governed by the local or region-specific urbanization character. The standout and most used datasets and methods used in these are represented via respective heat maps (Figure 10).

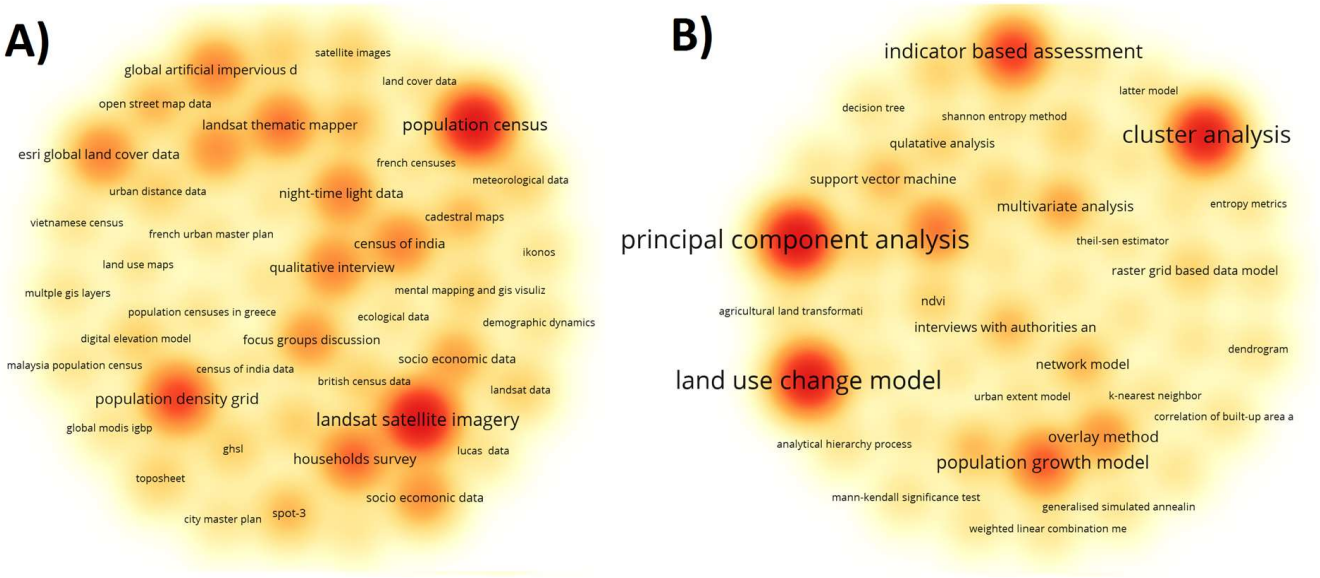


Figure 10. Heat map of the databases (**A**) and models (**B**) used by different studies for demarcating peri-urban areas.

The present review has summarized a list of the most important indicators used for peri-urban demarcation. The most common and important indicator towards this has been rapid population growth and, in a few cases, the rate of population growth of the peri-urban zone is seen to be higher than that of the core urban area. Other important indicators of peri-urban demarcation are land fragmentation and urbanicity. Many researchers have used these parameters as part of land-use change models and satellite image (mostly from the Landsat series) based assessments [49]. However, peri-urban demarcation from only satellite images is biased, being bereft of the importance of socioeconomic factors that fuel such growth and which should necessarily be taken into cognizance. Thus, the third group of important and quite popular indicators are the relevant socioeconomic parameters, which have been used by many to map peri-urban zones (Table 6).

On the basis of this review and the raft of indicators that have been most employed in peri-urban research, we have identified potential areas where such studies can be applied towards meeting planning and policy guidelines. However, it should be noted that the exact remit and contours of these applications and how peri-urban research and mapping can be incorporated within the policy frameworks shall differ based on the intended targets and stakeholder requirements (e.g., [136]). These applications can be grouped into three principal groups: land-use planning, environment/climate/farm policies, and socioeconomic aspects of urban and rural areas. They can potentially range from provision of essential civic services, landscape design, transportation management to fostering a sense of place or a certain cultural milieu and providing better governance structures in such in-between places that often have overlaps of rural or urban administration, or exhibit urban characteristics in administered ruralscapes (cf. [89]).

Table 6. List of indicators used in different studies for the identification of peri-urban areas and their potential applications.

No	Indicator Category	Number of Sub-Indicators	Indicator Used in Peri-Urban Research			Potential Applications of Peri-Urban Research and Policy		
			Local Case	Regional	Global	Land Use Planning	Environment/Climate/Farming	Socioeconomic Urban & Rural
1	Population	32	Y	Y	Y	Y		Y
2	Urbanicity	6	Y	Y	Y			Y
3	Accessibility	8	Y	Y	Y	Y		Y
4	Service	12	Y	N	N	Y		Y
5	Proximity	4	Y	Y	Y	Y		Y
6	Agricultural intensification	13	Y	Y	Y		Farming	
7	Mobility	7	Y	Y	Y	Y		Y
8	Economic indicators	45	Y	Y	N			Y
9	Social indicators	26	Y	Y	N			Y
10	Demographic features	13	Y	Y	Y			Y
11	Occupational structures	8	Y	N	N			Y
12	LULC based indicators	16	Y	Y	Y	Y	Y	
13	Infrastructure	8	Y	Y	N	Y	Energy, water	
14	land suitability indicators	14	Y	Y	N		Farming	
15	Landscape metric indicators	28	Y	Y	N		Landscape	
16	Identities and lifestyle	15	Y	Y	N			Cultural
17	Physical growth	12	Y	Y	Y	Y	Y	
18	Policy and governance	27	Y	Y	Y	Y		Government & governance
19	Network and time	12	Y	Y	N	Y		Transport, mobility
20	Well-being indicators	10	Y	N	N			Social, cultural, health

Note: The potential applications of peri-urban research are as ascertained by the authors on the basis of this review.

Rural–urban mobility and policy and governance aspects/factors are also notable indicators for peri-urban delineation. Such zones face high mobility into them from either the surrounding rural tracts or from the core city. Some indicators that have been used to assess this are network and time, well-being parameters, occupational structures, identities, lifestyle and infrastructure. However, most of these were used for regional scale or city-specific peri-urban demarcation. At the national or state level, peri-urban demarcation has been primarily done using either demographic and socioeconomic parameters or assessment of land-use and land cover (LULC) changes. These two methods also make possible global-scale or intra-country level peri-urban mapping since the required datasets are largely available from respective national census, satellite image repositories, or other gridded/raster datasets, as is reflected by the heat maps.

This paper contributes to a holistic understanding of the nature of peri-urban research conducted over the last 50 years. In particular, it highlights the prevalent issues around peri-urban identification and demarcation, in a global context, with the existing differences between Global North and Global South countries. We have also indicated the future directions of peri-urban studies and denoted the major methodological gaps currently in peri-urban demarcation, which can better inform subsequent analyses. Debate and research on the 'peri-urban' and associated concepts is likely to continue in the foreseeable future. Any research outlook might be structured in terms of the previous 'universal framework (see Section 1), and its application to the demarcation question (Section 2). Drawing on these results we might conclude that the 'functional demarcation' is well advanced, especially with advances in remote sensing and related data analytics. However, it can be argued that such functional patterns are shaped and driven by other layers of reality–, i.e., 'relationships, dynamics, systems, and internal/external distinctions'). In this case, these results are hopefully a first solid step on a much longer journey.

The present study has some limitations. This review has only considered the peri-urban literature published in English, which can induce a certain bias in the derived surmises. We used two search engines, i.e., Google Scholar and Scopus, and limited keywords that may have precluded other studies from being incorporated. Our manual search in Google Scholar may have missed some additional documents. Furthermore, we have considered only 13 major research projects while there may exist further such studies that were not included. Nevertheless, we believe that the work highlights the most important aspects related to peri-urban zone identification and mapping and, thus, contributes to a better understanding of the research field.

4. Conclusions

Accelerated urbanization, especially in the Global South, has been a notable phenomenon in recent decades, with its attendant physical, social, economic, and environmental consequences, making their management important, but quite challenging [137–139]. As products of city growth occurring within the global economic and socio-political scenario, peri-urbanization creates complex ecosystem interactions. Our extensive review has revealed the nature of peri-urban research worldwide and shown how researchers have used different methodological approaches to demarcate such zones. There have been three important phases of peri-urban research, the first concerning its conceptualization during 1970–1990, the second when it was regarded as a process of urban growth and land transformation during 1990–2010, and the third phase after 2010 when these locales are regarded as environmentally sensitive areas. Thus, researchers have mapped this space to discern its character and dynamicity and we have reviewed these methods, surmising that there is, as of yet, inadequate research on this issue with the lack of a general method that can be widely applied for peri-urban demarcation globally [140,141]. Instead, the methods used so far are either quite region-specific or only city-based assessments.

There are two main caveats to this research so far. One is about terminology: while the main search process was focused on the term 'peri-urban', there are many related terms. Searches for urban 'sprawl, interface, edge, fringe or hinterland', or related issues such as

'aerotropolis' [142] may produce overlapping or rather different results. Another caveat follows from the highly diverse and contested landscape/domains of concepts like urban, urbanist, urbanism, and so on. Just as these terms have many layers and nuances, the concept of what constitutes the peri-urban likewise may span from technical analysis to socio-cultural-structural perspectives.

Peri-urban development is directly linked with the occurrence of urban sprawl and land-use change in the urban fringe [143]. Peri-urban areas are characterized by untheorized and non-continuous built-up development. Furthermore, peri-urban zones form along the urban fringe due to the readier availability of land at comparatively nominal cost [144]. These areas are mostly low-density residential locales with usually segregated socioeconomic classes and ethnicities [22]. The outer peri-urban development is typically a leapfrogging manifestation of built-up tracts within farmland expanses and is characterized by low-density, non-contiguous, and automobile-dependent societies [105,145]. An improvement in transport facilities helps to reduce travel time to the nearby metropolis and facilitates urban decentralization, allowing the city to spread out within the lower land value tracts [144,146]. Thus peri-urbanization actually proceeds via land fragmentation, through the continuous, albeit non-contiguous, transformation of non-urban sites into built-up pixels and the concomitant conversion of predominantly ruralscapes into more urban locales [147]. This peri-urban interface also becomes a new economic space and, especially in developing countries, provides opportunities for industrial investment [2], which augment and accelerate the ensuing land transformations. Due to continued peri-urban growth, the boundaries of these zones are not static, neither are the spaces within them homogenous throughout. These aspects further differ from developed (low density built-up and less peopled) to developing nations (comparatively higher density built-up with a burgeoning population). Such variations also occur due to differences in local socioeconomic and political systems, governance frameworks, and institutional factors. Despite the difficulties and ambiguities in delineating peri-urban areas, the common attributes that persist in all such zones mark them out as transitional areas with moderate settlement density and constrained infrastructural facilities and services, social, and environmental crises and high natural habitat degradation rates [148].

In an era of climate change and heightened threat of natural hazards, peri-urbanization is an important challenge for both developed and developing nations, particularly in terms of environmental management and equitable access to civic amenities [71,149–154]. Given the aforementioned problems that often plague these locales, they are now mostly examined through the lens of the UN sustainable development goals [155]. For this, the proper identification and accurate demarcation of peri-urban areas is crucial to enumerate the urban footprint, carbon budget, and future climate change impacts. Furthermore, determining their socioeconomic character and distinguishing the requirements of peri-urban zones in developing nations from those in developed countries through proper indicator-based assessments is another urgent demand. Therefore, urban planners and policymakers should consider peri-urban zones not just as a concept or process, but also delve into the specific methods required to demarcate them succinctly and engage in targeted discussions on sustainable development agendas framed especially for these locales and their neighbourhoods.

Supplementary Materials: The datasets prepared and information generated from them in this study are publicly shared on the University of Manchester's official website datafile portal at: https://www.research.manchester.ac.uk/portal/en/researchers/mehebub-sahana(e6116fb8-31a7-4c83-a3ab-fbbfea3f36bb)/datasets.html (accessed on 25 May 2022)

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