Special section: Interconnected Ibero-America: Territorial and Socio-Environmental Challenges
v. 68, p. 541-564, Jul./Dec. 2026 http://doi.org/10.5380/dma.v68i.100950 e-ISSN 2176-9109

DMA Desenvolvimento e Meio Ambiente

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Collaborative mapping as a means for producing data on precarious settlements

O mapeamento colaborativo como forma de produção de dados sobre assentamentos precários

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Article received on **August 21, 2025**

Final version accepted on **April 6, 2026**

Published on **October 28, 2026**

Abstract: This article presents the results of the research "Collaborative mapping as a way of producing data on precarious settlements", which investigates strategies for applying this methodology in these territories. Precarious settlements are predominantly residential areas inhabited by low-income families. They are characterized by poor housing conditions and a historical origin shaped by the strategies these populations use to autonomously meet their housing needs within a context of unequal urbanization. Addressing this reality requires producing comprehensive, high-quality information, which is an essential input for planning social policies and programs. However, existing data for quantifying or characterizing these settlements are often weak and limited. In this context, collaborative mapping emerges as a promising alternative, enabling ordinary citizens to appropriate cartographic tools and directly involve local populations in map production. Therefore, through a literature review, this article examines the characteristics, feasibility, impacts, limitations, and potential of applying collaborative mapping in precarious settlements.

Keywords: collaborative mapping; precarious settlements; data production.

Resumo: O presente artigo apresenta resultados da pesquisa "O mapeamento colaborativo como forma de produção de dados sobre assentamentos precários", que investiga estratégias de aplicação dessa metodologia nesses territórios. Os assentamentos precários são áreas predominantemente residenciais, habitadas por famílias de baixa renda, caracterizadas pela precariedade das condições de moradia e por uma origem histórica marcada pelas estratégias utilizadas pela população de baixa renda para suprir suas necessidades habitacionais de forma autônoma, em um contexto de urbanização desigual. Uma maneira de lidar com tal realidade é produzir informações completas e de qualidade, importante insumo para o planejamento de políticas e de programas sociais. Entretanto, as informações existentes que permitem a quantificação ou a caracterização dos assentamentos são frequentemente frágeis e limitadas. Nesse sentido, o mapeamento colaborativo, no qual cidadãos comuns apropriam-se dos meios de representação cartográfica, incluindo populações locais na produção de mapas, apresenta-se como uma alternativa promissora. Assim, o artigo busca, por meio de uma revisão da literatura, examinar as características, a exequibilidade, os impactos, as limitações e as potencialidades da aplicação do mapeamento colaborativo em assentamentos precários.

Palavras-chave: mapeamento colaborativo; assentamentos precários; produção de dados.

1 Introduction

The history of precarious settlements is inherently tied to the history of capitalism. Although impoverished neighborhoods have existed as long as cities have, the modern concept of the *favela* (slums) as a "squalid and overcrowded" place emerged alongside merchant capitalism in the 16th

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century (UN-Habitat, 2003). The Industrial Revolution triggered a rapid influx of migrants to cities, creating a massive need for housing that the formal market failed to adequately meet (UN-Habitat, 2003). This shift to a new production system consequently generated inequality and insecurity for the urban proletariat. Land became synonymous with exploitable profit, establishing a system where landlords and speculators seeking quick returns subdivided old mansions into tiny units to rent to multiple families, without expanding basic services like water and sanitation (UN-Habitat, 2003). Furthermore, where existing housing was insufficient, low-quality dwellings were rapidly erected on peripheral lands (UN-Habitat, 2003).

In the so-called "Global South", the emergence and constitution of precarious settlements possess unique characteristics that differentiate their territorial dynamics. These are heavily influenced by colonialism and its legacies, which established structural inequalities that shaped urban development and persist today (Ohenhen & Abakporo, 2024). In these countries, this process unfolded primarily from the 20th century onward, driven by rural-urban migration and natural population growth. This generated a demand for housing and infrastructure that government authorities were unable to provide (UN-Habitat, 2003). This was compounded by growing poverty and vulnerability, a lack of affordable housing for low-income populations, inefficient planning policies, and conflict-induced displacement. Together, these factors culminated in a pattern of autonomous home construction outside the formal market. This pattern is characterized by precarity, risk, irregularity, a lack of basic infrastructure, and distance from urban centers (UN-Habitat, 2003; UN-Habitat, 2020; Suhartini & Jones, 2023). Consequently, informal urbanization became the predominant mode of city-building in the Global South, producing precarious settlements with distinct characteristics that nonetheless share a similar historical origin and model of precarity (Suhartini & Jones, 2023).

As in other Global South countries, the Brazilian housing crisis is rooted in the nation's economic and social formation, emerging as the result of a segregating and exclusionary urbanization process (Maricato, 1999). This process, which occurred particularly during the 20th century, retains many roots of Brazil's pre-republican patrimonial and clientelist society, with the occupation of urban land as an intrinsic element (Maricato, 1999).

According to Maricato (1999), this unequal urbanization in Brazil has three main characteristics. First, low-wage industrialization, combined with public policies and private financing that widened inequality, prevented workers from accessing the formal housing market, driving them toward *favelas* and illegal subdivisions built through self-construction (Maricato, 1999). Second, local governments have a tradition of regressive investment. Following real estate market logic, they prioritize high-value areas, inflating land and property prices while intensifying housing shortages and territorial

segregation (Maricato, 1999). Finally, the third characteristic is ambiguous legislation or arbitrary law enforcement. Driven by market forces and relationships of privilege, it permits occupation in devalued areas while restricting it in high-value ones, allowing the private market to appropriate the bulk of public housing subsidies (Maricato, 1999). These inequality-fostering characteristics intensified in the 20th century, particularly during the 1950s and 1960s. An abundance of rural labor migrated to industrial hubs, triggering an urban explosion unmatched by the provision of housing, infrastructure, or urban amenities necessary for a decent quality of life (Ferreira, 2000).

The term "slums" is used globally by UN-Habitat to characterize the various types of precarious settlements resulting from this process, considered the "most visible manifestation of urban poverty in developing countries" (Queiroz Filho, 2015, p. 344). According to this agency, precarious settlements combine several of the following deprivations: inadequate access to safe water, lack of sanitation and other infrastructure, poor structural housing quality, overcrowding, and residential insecurity (Queiroz Filho, 2015).

In Brazil, the Ministry of Cities defines precarious settlements as diverse human settlements fraught with shortages and inadequacies, including *favelas*, tenements (*cortiços*), irregular subdivisions, and degraded housing complexes, among others (Ministério das Cidades, 2010). Furthermore, they are characterized by being predominantly residential areas inhabited by low-income families; presenting precarious housing conditions (land tenure irregularity, lack of environmental sanitation infrastructure, poor access to transport and social amenities, flood-prone or geotechnically hazardous terrain, overcrowding, insalubrity, and structural deficiencies); and sharing the historical origins described previously. These origins reflect the strategies low-income populations use to autonomously meet their housing needs amid the inequalities generated by the urbanization process (Ministério das Cidades, 2010).

More recently, it is understood that the modes of producing and reproducing urban spaces and their segregation mechanisms have evolved alongside a transition in city models. In Brazil, as in much of the Global South, cities are no longer configured as "industrial metropolises" shaped by the hegemony of industrial capital and capital-labor relations. Instead, they have become "financial metropolises" driven by financial capital. In this paradigm, the city is not merely a site of factory production but a productive space in itself, oriented toward profit and capital accumulation, and supported by public policies that foster this model (Carlos, 2020). In these new metropolises, urban land and city-building have become a "lucrative business". Access to urban spaces is dictated by private property logic, and urban design is fragmented by the real estate market and income stratification. Consequently, citizens become consumers of signs and

spectacles, with social relations increasingly mediated by consumption (Carlos, 2020). These characteristics reinforce the segregation inherited from industrial metropolises while creating new mechanisms for segregation and the reproduction of precarious settlements based on a space fragmented and hierarchized by capital. Examples include the proliferation of gated communities protected by walls and fences; the hollowing out and restriction of public spaces, replaced by directed, private consumption spaces where access is mediated by the market; the selectivity of urban mobility, which isolates and immobilizes peripheral working classes; and public policies driven by a State aligned with financial market interests, enacted through evictions and zoning regulations (Carlos, 2020).

Today, living in a *favela* is considered one of the cruelest representations of urban poverty and inequality, characterized by a high concentration of social and economic deprivations (UN-Habitat, 2003). According to the 2024 UN-Habitat report, over 2.8 billion people face some form of housing inadequacy, with 1.1 billion living in precarious settlements, 90% of whom are in Africa and Asia. Regarding the Brazilian context, the 2022 IBGE Census estimated that over 16 million people reside in what are termed Favelas and Urban Communities[1], accounting for 8.1% of the population. Concurrently, the João Pinheiro Foundation, which tracks household figures, estimated a housing deficit of 5,977,317 dwellings in 2023, representing 7.6% of all occupied private households in Brazil. Of these more than 5 million households, 3,665,440 (61.3%) face excessive rent burdens, 1,241,437 (20.7%) are in precarious housing, and 1,070,440 (18.0%) involve involuntary cohabitation (Fundação João Pinheiro, 2023).

One way to address the reality of these settlements is, in the words of Denaldi and Feitosa (2020), to "make them visible". This visibility, achieved through the production of comprehensive and high-quality information, is a critical input for planning social policies and programs, such as *favela* upgrading and land tenure regularization (Denaldi & Feitosa, 2020). Consequently, progress can be made in integrating precarious settlements into the "formal" urban fabric by providing basic infrastructure and improving the quality of the built environment (Colombo, 2019; Denaldi, 2022). Furthermore, the distinct patterns and forms of precarious and irregular territorial occupation require urbanization or regularization interventions that engage with these unique characteristics. This involves

1 "*Favelas* and Urban Communities" is the new terminology adopted by the Brazilian Institute of Geography and Statistics (IBGE) in 2024. These are defined as "popular territories originating from the various strategies used by the population to meet, generally autonomously and collectively, their needs for housing and associated uses (commerce, services, leisure, culture, among others), given the insufficiency and inadequacy of public policies and private investments aimed at guaranteeing the right to the city". (IBGE, 2024, p. 1).

analyzing the feasibility of consolidating the occupation and determining the parameters and strategies to be adopted in these projects (Denaldi, 2022).

However, promoting this visibility faces a major hurdle: the data required to quantify or characterize these settlements are precarious and limited (Cardoso, 2016; Denaldi, 2022). In 1999, Maricato highlighted that:

> There are no reliable overall figures on the occurrence of *favelas* throughout Brazil. Due to methodological flaws or the obvious difficulty in ascertaining land ownership where *favelas* are established, the IBGE presents significantly underestimated data. (p. 10).

The author further noted that "the lack of data, which reveals an ignorance of the subject, is in itself revealing". (p. 10). This problem, pointed out by Maricato (1999) over 20 years ago, persists today. According to UN-Habitat (2015), accurate quantitative and qualitative data on precarious settlements and *favelas* remain limited, leaving the dimensions of residents' lives largely unaccounted for in policymaking and planning. For Denaldi and Feitosa (2020), one factor explaining this limitation is "the reduced institutional capacity of most Brazilian municipalities, which lack updated information and are often unaware of alternatives and strategies to produce it" (p. 356). Moreover, the few available data points are collected by the IBGE Demographic Census, which is prone to undercounting and failing to capture various dimensions of the problem (Cardoso, 2016; Denaldi, 2022). Thus, "the incomplete representation or outright lack of data about a specific territory deprives its residents of the struggle for the right to that location" (Ferreira & Gonsales, 2019, p. 116). It is important to recognize that the problem of data gaps is not uniform across different localities. In many contexts, especially in well-resourced cities, these territories are already at least partially known to public authorities, presenting parallel challenges related to the use, integration, and prioritization of this information.

In an attempt to address this issue, many studies are focusing on developing procedures to detect and characterize precarious settlements using various approaches (Feitosa et al., 2021). In this context, collaborative mapping stands out. Through advances in accessible technology and open data, it has granted the public access to spatial data that was previously restricted to a small group of experts (Verplanke et al., 2016). This type of mapping advocates for the voluntary inclusion of non-specialized local populations in map production. It acknowledges their cognitive, spatial, and environmental expertise, directly involving community members in surveying land use and delineating their territorial boundaries (Herlihy & Knapp, 2003; Acselrad, 2008; Machado & Camboim, 2019). Consequently, several studies have highlighted the potential of collaborative mapping to produce more complete and accurate information.

From this perspective, the current study investigates the application of collaborative mapping in precarious settlements, seeking to understand

how this mapping approach can help improve the described scenario. Initially, we identified the need for a comprehensive review of participatory mapping literature to synthesize its general foundations before analyzing its application in *favelas*, thereby ensuring a more robust and well-grounded study.

2. Collaborative mapping: A comprehensive literature review

Maps are an abstraction of reality, constructed from a viewpoint that frames the real world to describe, define, and symbolically possess it (Acselrad, 2008). Throughout history, cartographic representations have been subordinated to the territorial ambitions of the political systems that demanded and justified them. Initially used to support military tactics, they were mobilized for colonization and territorial domination (Acselrad, 2008; Marino, 2021). In contrast to this dominant dimension, maps have also served purposes of resistance and liberation. This positions cartography within a contested space tied to existing territorial conflicts, driven by the insurgency and aspirations of those historically denied the power to represent their territory (Acselrad, 2008; Marino, 2021). The rise and popularization of this social, politicized cartography has resulted in maps produced by various social groups and used as tools in distinct struggles (Marino, 2021).

In this context, collaborative mapping is defined as a tool for generating geographic information by ordinary citizens who appropriate cartographic means of representation. It includes local populations in map production and challenges the relationship between the power to map and the legitimacy of the subjects of this representation (Acselrad, 2008; Bortolini & Camboim, 2019). This mapping approach develops critical awareness and collective action, as it is guided by the very individuals involved in the issues being mapped. These participants can create their own language by producing terms and definitions that reflect their values; analyze patterns and identify collective knowledge by sharing experiences; and identify the role of institutions and the extent of their power in shaping collective experiences (Moore & Garzón, 2010). Such maps can be developed to describe various dynamics depending on specific demands, including land use and socio-economic activities (Angeluci & Rezende, 2019). Thus, countless new actors are empowered to share their own perceptions of the spaces they inhabit through "alternative" maps, crafted according to individual experiences, shifting ordinary users from a passive position of "consumers" to an active role as potential agents of transformation (Colombo et al., 2019).

To interpret the context surrounding the popularization of this mapping model, Bassani (2019) introduces the concept of the "new status of the map", reflecting its integration into contemporary daily life. The

author emphasizes the new usability conditions of maps, spurred in the 1980s by innovative definitions of "territory" as a space of politics and resistance, marking the emergence of a counter-cartography that confronts concentrated power. Consequently, a more social, progressive, critical, and participatory cartography expanded and democratized. It becomes a socio-political act the moment it is created by agents outside the public administration (Ferreira & Gonsales, 2019; Holanda et al., 2016). Thus, participatory mapping is presented as a new perspective on the functions and methods of mapping, deployed in strategic contexts for mobilizing specific groups (Bassani, 2019).

Further analyzing this context, several authors (Goodchild, 2007; Elwood, 2014; Holanda et al., 2016; Bortolini & Camboim, 2019; Camboim & Paiva, 2021; Rocha et al., 2021) highlight the rise of Web 2.0 and the subsequent emergence of various collaborative mapping platforms. Driven by technological advancements, this Web format emerged in the early 2000s, grounded in the core principle of harnessing collective intelligence (O'Reilly, 2009). According to O'Reilly, new network services rely on open-source "peer-production" (a cooperative system for generating data and services), which allows users to add their own data to existing systems, thereby adding value and knowledge to online resources. Consequently, the user's role expanded: it became possible to build websites populated almost entirely by user-generated content (Goodchild, 2007). This technology gave rise to platforms featuring collaborative mapping tools, such as OpenStreetMap, Wikimapia, Wikicrimes, and Colabre (Bortolini & Camboim, 2019).

Moreover, many cite the dissemination of geospatial technologies as a crucial factor in this popularization. The emergence of widely accessible geospatial technologies over the past two decades has opened unprecedented possibilities in cartography. By appropriating these tools, citizens have assumed an increasingly active role in producing cartographic information (Colombo et al., 2019). Furthermore, this dissemination was driven by the high capillarity and penetration of new communication and information technologies across various sectors of society, fueled largely by the massive number of people with access to mobile phones (Colombo et al., 2019).

The practice of collaborative mapping is understood within two main frameworks: Participatory Geographic Information Systems (PGIS) and Volunteered Geographic Information (VGI). According to Verplanke et al. (2016), these approaches share principles such as capturing undocumented spatial knowledge, prioritizing non-authoritative sources, promoting Citizen Science and counter-mapping, and striving for efficiency. These practices form a logical framework based on community engagement and the elicitation of local knowledge, aiming for its proper documentation and application (Verplanke et al., 2016). Additionally, collaborative mapping

is linked to concepts such as "geographic citizen science", "Geoweb", "crowdsourcing", and "critical GIS" (Elwood, 2014; See et al., 2016; Rocha et al., 2021), cementing its role as a tool for social impact.

3. Methodology

This research is based on a literature review, analyzing published documents addressing collaborative mapping in precarious settlements. To this end, we retrieved studies available in Google Scholar, Scopus, and the CAPES Periodicals portal. To draft the introduction and contextualize the study, in addition to the texts found in these databases, we used data from IBGE, UN-Habitat, other housing research institutions, and official government documents. The database search utilized specific keywords that guided the research, with search strings formatted as follows: ("mapeamento colaborativo" OR "mapeamento participativo") AND ("favelas" OR "assentamentos precários"); ("informal settlements" OR "slums" OR "deprived areas" OR "irregular settlements" OR "precarious settlements" OR "favelas" OR "Shantytowns" OR "Squatter settlements") AND ("collaborative mapping" OR "participatory mapping" OR "citizen mapping").

Furthermore, while reviewing the selected texts, it became necessary to employ a snowballing method to gather additional documents. This method uses reference chains for exploratory purposes, improving topic comprehension and testing the feasibility of a broader study (Vinuto, 2014). More specifically, we used backward snowballing, which involves identifying new articles from the reference lists of previously analyzed papers (Wohlin, 2014). Generally, a primary advantage of the snowball method is its ability to expand a systematic literature review using relevant articles to capture supplementary research, such as "gray literature" (Wohlin, 2014). Gray literature comprises materials not indexed in traditional databases and characterized by a lack of standard bibliographic access (McKimmie & Szurmiak, 2002). Given that collaborative mapping in *favelas* is a relatively new, underexplored, and non-conventional topic in academia, selecting texts also required alternative methods.

Following the literature search via the described processes, the retrieved studies were selected based on a rigorous analysis of their quality and relevance to the research topic. The exclusion criterion involved discarding studies that were not directly related to the research topic, following an analysis of their titles and abstracts, along with a quick skim reading if necessary. Most discarded texts were excluded because they discussed collaborative mapping generally, lacking a focus on its application in precarious settlements.

We included theoretical-conceptual approaches to collaborative mapping in *favelas*, alongside case studies and experience reports. The latter

allowed us to analyze the practical application of the method, enriching the research by exploring aspects of the collaborative mapping process in *favelas* and focusing on the divergences and convergences among different experiences.

Regarding language, the initial research phase included only Portuguese-language studies dealing with Brazilian cases. Subsequently, to compare Brazilian experiences with those from other countries, we included global studies in English, meaning language and country were no longer exclusion criteria.

Google Scholar returned 447 results for the Portuguese search and approximately 2,800 results for the English search. The CAPES Periodicals Portal returned one result for the Portuguese search and zero for the English search. Finally, Scopus returned no results for the Portuguese search and 34 results for the English search. After selecting texts based on the established criteria and adding new papers via snowballing, a total of 38 studies were analyzed. It should be noted that not all read texts were used in drafting this article. To better understand when and where collaborative mapping in precarious settlements has been most widely studied, Table 1 and Figure 1 illustrate the distribution of the analyzed studies by location (noting that some studies analyzed multiple territories) and year:

Table 1 Distribution of analyzed texts by location.

Theoretical-conceptual texts (no specific study territory)	**Brazil (number of analyzed studies per territory)**		**Other countries (number of analyzed studies per country)**	
5	São Paulo, SP	4	Kenya	5
	São Paulo Metropolitan Region, SP	1	Bangladesh	2
	Rio de Janeiro, RJ	3	India	2
	Curitiba, PR	2	Indonesia	2
	Curitiba Metropolitan Region, PR	1	Nigeria	2
	Santo André, SP	1	Pakistan	2
	Salvador, BA	1	South Africa	2
	Teresópolis, RJ	1	Benin	1
	Tefé, AM	1	Colombia	1
	Brazil overall	1	Egypt	1
			Italy	1
			Mexico	1
			Namibia	1
			Peru	1
			Rwanda	1
			Venezuela	1
	Total	**16**	**Total**	**26**

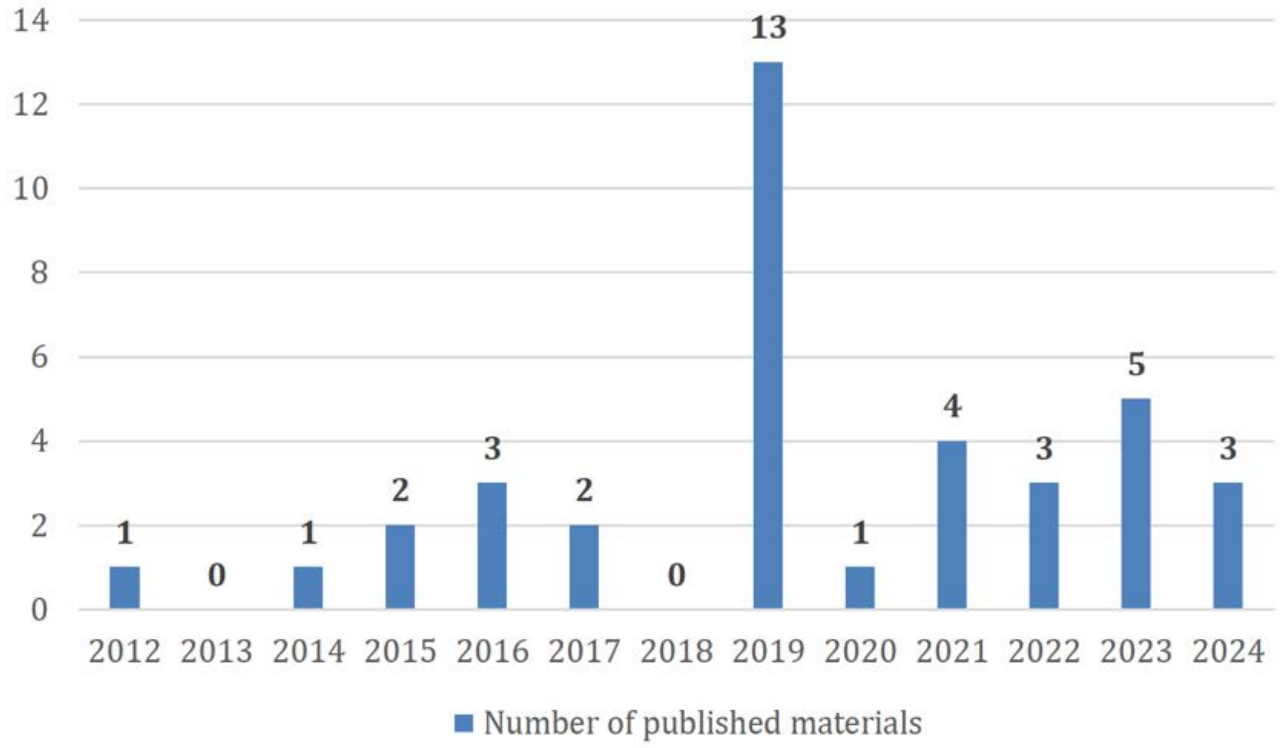


Figure 1
Analyzed publications by year.

Next, we read and analyzed the bibliographic material, extracting and systematizing the information. This process occurred concurrently with the snowball literature search, which required preliminary analysis to select new documents. Finally, the 38 studies were analyzed and compared, identifying convergences, divergences, gaps, and implications for the field. Through this research stage, different categories were identified for analyzing the studies and their content. These categories proved to be an effective format for organizing the content and will serve as the basis for presenting and discussing the results. They are:

(1) Collaborative mapping and its tools;

(2) Methodologies utilized;

(3) Necessary actors;

(4) Location of the mappings;

(5) Advantages and potential; and

(6) Problems and limitations.

4. Results and discussion

4.1. Collaborative mapping and its tools

Collaborative mapping in *favelas* is based on the collection of geospatial data in these socially vulnerable, precarious urban areas, with the active

participation of local actors (Rocha et al., 2021). These thematic or situational maps give a voice to the "rebels" in peripheral populations, prioritizing local and traditional knowledge to describe their struggles and conflicts over urban land use (Angeluci & Rezende, 2019). In these territories, collaborative mapping acts as a methodological toolkit that emphasizes the map as an instrument for understanding how communities use space, empowering them and seeking to resolve territorial management conflicts (Peixoto et al., 2014).

The practice of collaborative mapping in favelas can employ tools that fall into two fundamental groups: analog and digital (Bortolini & Camboim, 2019). Analog tools include paper-printed maps and physical models, among others (Bortolini & Camboim, 2019; Rocha et al., 2021). Such tools prove relatively effective in this type of mapping, primarily because they allow for on-the-spot field notes and map corrections (Bortolini & Camboim, 2019). However, it is crucial to note their limitations: papers are easily lost, locations can be imprecise, updating information when territorial changes occur is difficult, and their use requires intensive labor (Aditya et al., 2019).

Conversely, digital tools are highly relevant in today's information society, characterized by the massive digitization of social life via Information and Communication Technologies (ICTs) (Angeluci & Rezende, 2019). This contemporary society is established within informational territories, understood as the convergence of physical dimensions and electronic flows, within cybercities (Lemos, 2009). In this context, digital mapping offers new ways to strengthen communities by fostering the appropriation of places and territorialities and creating new discourses about urban space (Lemos, 2009).

Regarding digital tools, computers and smartphones equipped with GNSS (Global Navigation Satellite System) receivers stand out. They enable the use of digital mapping software, especially open-source programs, placing maps literally "in the palm of the hand" (Peixoto, 2014; Angeluci & Rezende, 2019; Bortolini & Camboim, 2019; Rocha et al., 2021). Furthermore, the advantage of using smartphones, cameras, and other digital devices lies in their ability to enrich maps with georeferenced photos, videos, and other media (Silva et al., 2024). Among the software used in digital mapping, several programs highlighted in the analyzed studies stand out: Knight Lab, Google Street View, Mapillary, Google Maps, QGIS, ArcGIS, and, most prominently, OpenStreetMap (Peixoto et al., 2014; Angeluci & Rezende, 2019; Colombo, 2019; Rocha et al. , 2021; Raviscioni et al., 2022).

OpenStreetMap (OSM) emerges as a vital and popular program within the digital toolset. OSM is a mapping platform that leverages a collaborative environment to incorporate the local knowledge of individuals, many of whom lack formal academic training, while providing

geographic information that serves as a foundation for other cartographic products (Bortolini & Camboim, 2019). This platform focuses on creating more detailed representations of the Earth's surface. Because its massive user base represents an international effort, it boasts a highly developed database, filling a deep void in the availability of digital geographic information through volunteer forces (Bortolini & Camboim, 2019). When used for collaborative mapping in favelas, it offers distinct advantages: it adapts well to the dynamism of these settlements as a more dynamic form of data production and serves as an interactive cartographic base, helping mappers situate themselves geographically (Bortolini & Camboim, 2019). Moreover, its cartographic base is useful because, by using urban infrastructure references like streets, users can place the produced map in its proper location, generating a georeferenced drawing (Bortolini & Camboim, 2019). Thus, map application users can become producers of geospatial data (Rocha et al., 2021).

4.2. Methodologies utilized

The methodologies employed during collaborative mapping can vary case by case, depending on the residents' needs, the mapping's purpose, situational constraints, and available resources, among other factors. It is understood that "the proliferation of projects involving community participation and their spatial knowledge in creating cartographic documents establishes new needs for cartographic methodologies" (Peixoto et al., 2014, p. 5). Despite these variations, the centrality of the residents' perspectives in map production remains paramount.

Generally, the studies analyzed here are organized into well-defined stages, including: initial planning (defining methods, tools, and objectives); mobilization and participant engagement (workshops, meetings, mediation); data collection (mapping, interviews, questionnaires, visual records); information systematization (reports, spreadsheets, presentations, formatted maps); and, in some cases, field validation, and information systematization. This structure appears, with variations, in practically all the studies.

Another central point is the adoption of different data collection methods combined with collaborative mapping to ensure comprehensive results that capture the social, spatial, and symbolic dimensions of the territories and their inhabitants. Prominent among these methods are administering questionnaires, conducting workshops, capturing images, gathering personal accounts, organizing technical visits, and hosting discussion circles. This combination responds to the limitations and potentials of the territories, enhancing mapping accessibility and accuracy.

Technical and pedagogical mediation is also a recurrent element. Workshops and training sessions are used to teach tool usage and guide data production, proving especially relevant in contexts with varying levels

of technological and cartographic familiarity. This method facilitates the residents' appropriation of collaborative mapping.

4.3. Necessary actors

First and foremost, it must be emphasized that the principal actors in collaborative mapping in favelas are the community residents themselves. As highlighted previously, this mapping relies on eliciting a community's knowledge of their own locality, underscoring the role of "citizens as sensors" (Goodchild, 2007; Angeluci & Rezende, 2019).

Furthermore, several authors have concluded that, alongside the residents, the presence of mediators is necessary (Aditya et al., 2019; Bortolini & Camboim, 2019; Yeboah et al., 2021; Handayani & Dianingrum, 2023; Raviscioni et al., 2022). Mediators are individuals or entities that facilitate access to Geographic Information Systems (GIS), transfer knowledge, and build capacity, thereby improving the accessibility of mapping processes (Robinson et al., 2017). Mediators can be found not only in social movements, universities, or government agencies but also among the residents themselves, often best represented by leaders with strong mobilization and communication skills (Robinson et al., 2017; Bortolini & Camboim, 2019). These mediators can address a difficulty pointed out by Colombo (2019, p. 69): community members do not naturally appropriate the method and the produced data. Instead, it requires "intense communication work to convey the importance of the generated data and explain how to use it in the community's favor", offering guidance and encouragement throughout the process (Colombo, 2019; Handayani & Dianingrum, 2023).

With a purpose similar to that of mediators, Peixoto et al. (2014) argued that the collaborative mapping process in favelas requires the involvement of professionals dedicated to addressing the involved communities' needs. According to these authors, even if cartographic tools are accessible to the community, technical and scientific cartographic knowledge is necessary to make map construction viable (Peixoto et al., 2014). In this sense, beyond cartographic education, there must be a mutual exchange of knowledge and support between local residents and cartography professionals (Peixoto et al., 2014).

Additionally, the importance of university members (both faculty and students) and NGO staff is noteworthy, as these institutions spearheaded most of the initiatives reported in the analyzed studies. According to Barella (2024), such institutions fill the "gray area" left by the government, positioning themselves as key actors in the effort to develop support policies for precarious settlements.

4.4. Location of the mappings

The analyzed studies explored the application of collaborative mapping in the following countries: Brazil (predominantly), South Africa, Bangladesh, Benin, Colombia, Egypt, India, Indonesia, Italy, Mexico, Namibia, Nigeria, Pakistan, Peru, Kenya, Rwanda, and Venezuela. With the exception of Italy, which appeared only once, these are "Global South" countries. Despite varying contexts, they share the same roots of housing precarity, driven by exploitation, inequality, and dependency, which are factors that shaped their unequal urbanization.

Moreover, it was noted that a large portion of the studies were conducted by university faculty and students, which influenced mapping locations, as these primarily occurred in university towns or neighboring cities. A territorial concentration of collaborative mapping experiences is also evident, given that most actions were carried out in favelas located in capital cities or metropolitan areas. Regarding the Brazilian articles, which formed the majority of the analyzed corpus, most experiences took place in the states of São Paulo and Rio de Janeiro.

This concentration of collaborative mapping efforts can be explained by the high density of favelas in these locations, driven by larger populations and the fact that the territorial formation process described in the introduction occurred on a larger scale in these metropolitan regions and states (Observatório das Metrópoles, 2011; IBGE, 2020). Furthermore, the higher level of scientific, technological, and innovation development in these areas can also be cited as a factor driving the concentration of studies and experiences (Rocha & Ferreira, 2004). While this correlation is logical, it must be emphasized that favelas outside these regions have an equal, if not greater, need for data production and planning. Therefore, it is crucial that such actions expand into these territories, as they stand to benefit significantly from these practices and their outcomes.

4.5. Advantages and potential

Generally, collaborative mapping stands out because it mobilizes the local knowledge of individuals who often lack formal academic training, setting it apart from official cartography (Bortolini & Camboim, 2019). According to Ferreira and Gonsales (2019, p. 118), through this mapping, "a greater understanding of the socio-spatial reality of threatened settlements is built in parallel, providing the population with tools to strengthen their struggle for the right to decent housing and the right to the city". Through this experience, participants gain a better understanding of themselves, their territories, and their histories, in addition to developing leadership and technological skills (Silva et al., 2024).

Furthermore, the popularization of technology makes the collaborative mapping process viable (Bortolini & Camboim, 2019). According to

Colombo (2019, p. 64): "Because it relies on low-cost, low-complexity tools, this method can potentially be replicated by any citizen with internet access, thus enabling decentralized, large-scale data production". Thus, with increasingly easy access to the internet and geolocation technologies, this mapping model, which gathers strategic data to support urban transformations in under-resourced areas, becomes widely advantageous and disseminated (Colombo, 2019). Moreover, the technological skills developed through participatory mapping experiences represent a major personal advantage for participants, given the relevance of these skills in career advancement (Silva et al., 2024).

Additionally, the creation of an enriching environment for exchange through the participatory mapping experience is notable (Peixoto et al., 2014). This environment is fostered through interactions between multidisciplinary professionals, who, according to Peixoto et al. (2014), are essential for map production due to their technical expertise, and the territory's inhabitants, who contribute their unique understanding of the space. This knowledge exchange is critical for generating information and establishing methodology during the process, while also enriching the experience and knowledge of both parties (Peixoto et al., 2014).

Regarding its potential, collaborative mapping in favelas is highlighted as an important tool for generating data for state, academic, and non-governmental institutions. It subsidizes civil society actions and urban/social development projects, thereby assisting public administration (Angeluci & Rezende, 2019; Bortolini & Camboim, 2019). Consequently, peripheral communities can achieve more equitable participation in the public sphere during policy formulation and execution (Angeluci & Rezende, 2019). In the words of Colombo (2019, p. 69), this mapping "allows information gaps between 'formal' and 'informal' zones of cities to be filled, thus constituting a first step toward integrating territories stigmatized by socio-spatial marginalization".

Broadly, producing this georeferenced information supports two types of actions aimed at developing informal settlements: infrastructure actions and legal actions (Colombo, 2019). To support infrastructure actions, collaborative mapping generates data that sizes and locates demand, ensuring projects are planned according to social realities (Colombo, 2019). Regarding legal actions, mapping can generate an accurate environmental description of communities, ensuring that land conflict processes are objectively evaluated (Colombo, 2019).

Furthermore, geographic information can be aligned with residents' interests, particularly in land conflicts (Bortolini & Camboim, 2019). This technique is essential for debating and materializing problems, potentials, and proposals, serving as a foundation for participatory diagnostics and planning. Thus, mapping becomes a multidisciplinary

tool for understanding local habitability and vulnerability. It raises awareness about basic rights, promotes social development, and prevents abuses and omissions by authorities (Colombo, 2019; Rocha et al., 2021).

Additionally, successful collaborative mapping experiences can foster a sense of pride in participants, which may spur a lasting interest in similar activities, especially when their right to be heard by policymakers is validated (Silva et al., 2024).

Finally, the potential of integrating collaborative mapping in favelas with other mappings of these areas conducted by different sources should be highlighted (Aditya et al., 2019; Machado & Camboim, 2019; Yeboah et al., 2021; Silva et al., 2024). Silva et al. (2024) demonstrate that combining satellite imagery (acting as a base map) with collaborative mapping allows residents to express their perspectives in a structured manner.

In this vein, Machado and Camboim (2019) investigate integrating collaborative mapping with official urban reference mapping, which is mapping produced by designated public agencies in accordance with specific legislation and technical standards set by the National Cartography Commission. The authors point out that due to low cartographic investment in the country, official reference mapping covers the territory unevenly, whereas collaborative mapping offers a large volume of frequently updated data. Thus, it is shown that:

> The integration of voluntary mapping has the capacity to enrich, update, and complement official mapping. However, it involves several challenges, requiring methods for analysis, compatibility, and the automation of mapping and integration processes, in addition to procedures for documenting collaborative data quality through metadata. (Machado & Camboim, 2019, p. 17).

4.6. Problems and limitations

A primary limitation of using this mapping method is the quality of the data produced, which does not meet strict quality norms and standards during its generation and is created by volunteers lacking cartographic expertise, making it difficult to establish positional and semantic accuracy for this information (Colombo, 2019; Camboim & Paiva, 2021; Santos et al., 2023). This data quality requires careful attention, especially when attempting to use this data as reference spatial information (Camboim & Paiva, 2021). Data accuracy can be further limited by factors such as inconsistent GPS signal quality or restricted satellite image resolution (Colombo, 2019). Moreover, applying mapping within the informal domain can lead to biased data collection, organization, analysis, and results (Silva et al., 2024). It should be noted that in remote collaborative mapping, data quality becomes an even more pressing issue, as data can become highly

inaccurate in areas with complex architecture and extreme building density (Yeboah et al., 2021). According to Colombo (2019):

> Legitimizing alternative data sources, such as maps produced by PGIS, is an erratic process; contact with public authorities or even community lawyers can be contentious, as these actors do not always consider the produced data to be reliable information sources. This latter point is highly critical, as alignment with public authorities is essential for the generated data to have a real impact, leading to positive, transformative actions in urban space (Colombo, 2019, p. 69).

Furthermore, access to the technology involved in the processes represents a structural challenge to applying digital participatory mapping (Angeluci & Rezende, 2019). This challenge is rooted in the digital divide, a participatory gap that creates precarious consumers and elite consumers of this culture, demonstrating that the information society cannot manage its own complexity, thus forming a "digital periphery" (Angeluci & Rezende, 2019). Consequently, the application of digital mapping in these areas is limited by the potential lack of technological knowledge and access to such tools and infrastructure, as frequently seen in favelas where internet and electricity availability is unreliable (Silva et al., 2024).

Additionally, because this mapping often occurs on open-data platforms with unrestricted use, like OpenStreetMap, careful attention must be paid to the security and privacy of the geographic information disclosed. This mapping reveals the locations of sensitive spaces, exposing them to external communities (Bortolini & Camboim, 2019; Silva et al., 2024). This caution should be redoubled when the published data pertains to favelas, which are potential sites of conflict subject to repression (Bortolini & Camboim, 2019). The presence of personal and sensitive information reduces the replicability of the collected data, as it requires confidentiality and/or redaction prior to disclosure (Santos et al., 2023).

Another limitation is that cartographic literacy is rare in these areas, largely due to limited access to education and training (Bortolini & Camboim, 2019). These factors are exacerbated by the rarity of collaborative mapping activities, which have not gained significant traction within the Brazilian institutional sphere (Bortolini & Camboim, 2019; Colombo, 2019). Even when participants are familiar with navigation maps, there is a notable lack of understanding regarding the creation of spatial objects, such as points, lines, and polygons (Silva et al., 2024). This creates a dilemma: the complexity of cartographic tools and concepts hinders accessibility, yet simplifying them may restrict the subsequent usability of the geographic information (Santos et al., 2023).

Moreover, engaging the community in mapping faces challenges like low resident mobilization, often due to a lack of local leadership or

associations to act as references (Bortolini & Camboim, 2019). There are also notable difficulties in residents appropriating the method and the generated data, requiring intense communication efforts to demonstrate its relevance and community benefits (Colombo, 2019). Scientists, conversely, are not always prepared to communicate outside the academic environment, which complicates interactions between actors using different languages and frames of reference (Rocha et al., 2021). This dynamic renders the relationship between residents and mapping coordinators delicate, as residents may be reluctant to share information with outsiders (Silva et al., 2024).

As another limitation, Silva et al. (2024) point to power imbalances that permeate the relationships established during participatory mapping in favelas. These imbalances manifest when socially privileged individuals exert authority in the community, when technological skills are asymmetrically distributed among residents, and during disputes over boundaries and land conflicts triggered by the mapping (Silva et al., 2024).

The difficulty of determining whether collaborative mapping genuinely promotes population empowerment, and what kind of empowerment is promoted, is also considered a methodological limitation (Corbett & Keller, 2005; Corbett et al., 2016). While the term is widely used to justify the success of cartographic interventions, it lacks clear definitions and precise metrics in most studies, leaving few researchers able to establish direct causal links between mapping activities and shifts in social or political power structures (Corbett & Keller, 2005; Corbett et al., 2016). This conceptual vagueness hinders the measurement of a project's success, weakens the ability to communicate real social change resulting from interventions, impairs research transparency and robust findings, widens the gap between technocratic and social focuses, and obscures exactly what the benefits were and who truly benefited from the initiative by relying on generalizations (Corbett & Keller, 2005; Corbett et al., 2016).

Despite all these highlighted limitations, collaborative mapping in favelas remains a potent tool. Its "weaknesses are insignificant when considering what is achieved by confronting the abyssal disparity in access to fundamental rights reproduced daily in Brazil" (Rocha et al., 2021, p. 788). In the words of Colombo (2019, p. 66): "Obtaining imprecise data is far better than having no data at all for substantial portions of Brazilian cities".

5. Conclusion

Based on the analysis of the reviewed texts and implemented experiences, we conclude that collaborative mapping is a highly useful tool for producing data on favelas. It embeds the residents' perspectives in the generated maps and advantageously promotes the visibility of these territories' realities. However, it must be acknowledged that this practice

has limitations and challenges that require consideration. These include uncertainty regarding data quality, barriers to accessing digital tools in digital collaborative mapping, the exposure of sensitive locations on open platforms, the residents' lack of cartographic literacy, community reluctance to engage in projects, power imbalances within established relationships, and ambiguities and gaps in defining empowerment. These aspects represent potential hurdles for collaborative mapping in favelas. They complicate its application, highlight uncertainties in the produced data, and can generate detrimental consequences for the residents themselves. Consequently, mapping action promoters might feel discouraged, official bodies may refuse to accept the produced data for policy planning, and residents may become apprehensive about participating and providing information. Therefore, to manage and potentially overcome these limitations, all actors must recognize them and consider the specifics of each case, keeping in mind that effective solutions are only proposed when the problem is thoroughly understood.

Nevertheless, echoing Colombo (2019) and Rocha et al. (2021), these limitations and weaknesses pale in comparison to the vast data void surrounding these territories. This lack of information actively reproduces existing inequalities, obstructs residents from accessing fundamental rights, and deepens their deprivations. In this regard, we observed that collaborative mapping in favelas is capable of: legitimizing the knowledge of these areas' residents; being potentially replicable by any citizen with internet access, enabling decentralized, large-scale data production; allowing peripheral communities to participate in the public sphere and planning practices; becoming a vital tool for multidisciplinary community assistance; supporting infrastructure and legal actions; instilling a sense of pride in participants; and integrating with mappings produced by other sources. In all the texts analyzed throughout this research, authors highlighted that the advantages offered by this mapping approach far outweigh its limitations, concluding that it serves as a highly relevant device in favela residents' struggle for their territorial rights.

Consequently, collaborative mapping functions as a capable mechanism for producing comprehensive, high-quality information about favelas. This is a critical step in promoting the visibility of these territories and subsequently planning targeted social policies and programs. Ultimately, the incomplete representation that perpetuates the irregularities, precarities, and vulnerabilities of favelas, as detailed in this article's introduction, can be significantly rectified through this mapping approach. While this practice is increasingly utilized for this purpose, it still requires far greater visibility, research, encouragement, and popularization.

Acknowledgments

The authors thank the National Council for Scientific and Technological Development (CNPq) for the Scientific Initiation and Research Productivity fellowships, and the São Paulo Research Foundation (FAPESP) for financial support through the Center for Favela Studies (CEFAVELA), FAPESP grant no. 2022/12259-8.

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