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Web-based participatory mapping in informal settlements: The slums of Caracas, Venezuela

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ABSTRACT

This article explores the potential of web-based participatory mapping tools for urban planning purposes and spatial information creation in informal settlements, i.e. the slums (barrios) of Caracas, Venezuela. While an increasing use of mapping tools is found in developed countries, fewer applications are found in informal settlements of developing countries, due to issues of high informality, illegality, and a lack of information, human and financial resources. In the context of course-based mapping activities directed to neighbourhood Sector-level planning officers and action research, this study has employed a two-tier approach (planning officials doing the mapping and eliciting complementary information from the population) to online participatory mapping (Google My Maps) for urban planning purposes in the barrios of Caracas. Our efforts aimed mostly at identifying and mapping public facilities, and planned and under-construction public works. This research aims to show the potential contribution of such tools to planning informal settlements and creating locally-produced spatial information. The outcomes of the mapping courses have already proven to be useful for planning public projects across Sectors and Communes, mutual consideration of their priorities in the preparation of two-year development plans, and for increased awareness of local residents of communal councils.

1. Introduction

The development and use of computer technologies in planning began in the 1960s with efforts to develop computerized models of the city (Klosterman, 1997 and 2012). Application of computer technologies to urban planning has evolved over the years together with the shifting perspectives of urban planning from expert-oriented planning to greater public involvement (Foth, Bajracharya, Brown, & Hearn, 2009). Currently, Information and Communication Technologies such as Web 2.0, blogs, new media, and mobile applications are changing the practice of urban planning, witnessed by the emergence of new forms of e-planning, e-governance and e-participation (Evans-Cowley & Hollander, 2010; Goodchild, 2007; Jones, Layard, Speed, & Lorne, 2015; Scattoni et al., 2014; Silva, 2010, 2013; Williamson & Parolin, 2013). However, despite the increasing number of experiences with ICT in urban planning, the use of internet-based tools in planning exercises is less marked compared to the everyday use of technology in public administrations (e-forms, e-payments, and so on).

Common geo-information and web mapping applications for participatory mapping concern interfaces such as Google Maps, Google Earth and OpenStreetMap (OSM).[2] Various examples and widespread use of such tools are found in western European countries, the USA and Australia (Brown & Kyttä, 2018). However, their use is much more limited in developing countries with fewer examples available in the literature (e.g. Panek, 2015; Panek & Sobotova, 2015). Other examples of geo-information tools application in developing countries and informal settlements are mostly based on traditional GIS software (see e.g. Abbott, 2001, 2002b, 2003; Carazzai, 2002; Muthoka Mbathi, 2011). In this article, we set out to explore the application of common web mapping interfaces in the context of resource-poor informal settlements for the case of the slums (*barrios*) of Caracas, Venezuela. The barrios of Caracas present the same characteristics of high informality and illegality of residential areas, lack of infrastructure, public space and facilities as other informal settlements across the world (AlSayyad, 1993; Garstka, 2009; Van Ballegooijen & Rocco, 2013; Chiodelli, 2016). Over 1,25 million people live in Caracas' barrios, representing 60 per

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[2] An increasing number of mapping applications has been specifically designed for community-based and participatory mapping purposes, and are available on the market. Examples are Carticipe, Commonplace, Emotional Maps, Maptionnaire). For a full review of such applications, see Falco and Kleinhans (2018a).

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cent of the total population, with no functioning legal and regulatory framework in terms of land use planning and housing (Gran Misión BNBT, 2016). In this regard, following the National Government guidelines as elaborated by the Foundation "Gran Misión Barrio Nuevo Barrio Tricolor",[3] Caracas' slums were divided into a three-tier system of population ascending spatial entities according to the new socio-political organization based on the 2010 popular power laws (Massey, 2009; Sánchez-Falcón, 2011) (see Fig. 1 in section 3):

- 1,279 Communes (Comunas) with an average population of 1,000;
- 132 Slum's Sectors (Sectores) with an average population of 9,600;
- 13 Slums' Corridors (Corredores) with an average population of 96,000.

As Abbott (2001: 267) underlines, informal settlements represent major challenges for developing cities since "they can be viewed as holes within the urban cadastre." The same applies to online maps, for example Google Earth, Google Maps and OSM (see e.g. Panek & Sobotova, 2015). In the context of Caracas' slums, characterized by informality, uncertainty and lack of information and other resources, the preparation of a corridor-wide land use plan is challenging due to the multiple informal social situations and realities that greatly complicate the access to and accuracy of information. Plans already exist at the intermediate Sector level, which mainly set out the priorities in terms of infrastructure needed in the near future. However, no land use plans are available at the corridor level as this has been recently introduced as a new spatial level by the Foundation "Gran Misión Barrio Nuevo Barrio Tricolor" with the purpose of tackling issues of the slums. The corridor level is not part of the 2010 popular power laws and more recent planning regulations, and it has been only recently adopted for practical planning purposes. This situation makes it extremely complicated to coordinate the priorities and plans for the different Sectors within one corridor. Even at the lower scale of communes, "communal councils show very little capacity for planning or integrating projects beyond their micro-level (sub) neighbourhood level" (Martin, 2017, p. 201). In the context of this complex governance and lack of resources, we seek to answer the following question: How can web-based mapping technologies be harnessed to fill the spatial information gap at the corridor level and thus support corridor-wide planning of the slums?

The research project underlying this article intended to fill the spatial-information gap that exists at the corridor level by means of employing a user-friendly online tool (Google My Maps) to produce spatial information at the intermediate sector level for all sectors of a corridor. The idea was to create a general map for the corridors that was not previously available. Considering the scarcity of information, human and financial resources, a full-scale bottom-up mapping approach (from communes to sectors) was not feasible. The project therefore adopted a two-tier structure, that enabled planning officials to efficiently elicit information on communal level. More specifically, Google My Maps was used to collect spatial information in the context of training sessions for planning officials at the *sector* level. Following these mapping sessions, face-to-face workshops with the population at the *communal* level were held to collect qualitative data supplementing the mapping information. This approach yielded a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) concerning the domains of education, safety, health, poverty, employment, quality of public services, and public transport.

In this article, we deal with the first part of the project: the use of the mapping tool and collection of spatial information. For reasons explained in section 5, we focus on the examples of the Corridors Catia-Sur and 23 de Enero-San Juan to demonstrate the outcomes of web-based participatory mapping efforts. In this way, we attempted to establish shared priorities among the different sectors that fall within the two corridors and to create examples for more exhaustive maps and plans for the slums of Caracas. In the context of this article, our aim is to show the potential contribution of such tools within a two-tier approach to planning informal settlements and creating locally-produced spatial information previously unavailable.

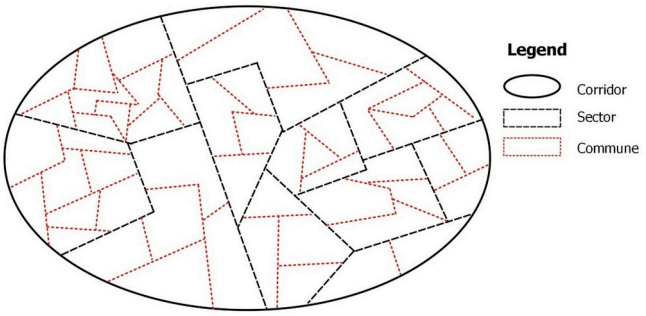

Fig. 1. Schematic Representation of the three-tier system involving Corridors, Sectors, and Communes.

The article is structured in six parts: Firstly, in section 2, we briefly review the web-based participatory mapping literature with a focus on the use of web mapping tools in developing countries and resource-poor contexts. In section 3 we concisely present the specificities of the planning process in Caracas' slums so as to clarify the context for readers and pave the way for the explanation of the tools used, the goals and results of this work. We then move on to describe the methodology for the production of spatial information in section 4. Section 5 deals with the results of the web-based participatory mapping efforts while section 6 discusses advantages, contribution, and limitations of our approach and provides concluding remarks.

2. Web-based participatory mapping and the opportunities/challenges in developing countries

The use of web-based applications for the engagement of multiple stakeholders in planning and mapping processes has accelerated in the last decade. Applications range from well-known Public Participation GIS (PPGIS) and Participatory GIS (PGIS) to online collaborative mapping tools, Volunteered Geographic Information (VGI), social media in neighbourhood planning, and various simulation software (Goodchild, 2007; Pettit et al., 2015; Foth et al., 2009; Brown & Kyttä, 2014; Pelzer & Geertman, 2014; Schmidt-Thomé, 2014; Falco, 2016, Falco & Kleinhans, 2018a; Panek, 2018; Kahila-Tani, Kyttä, & Geertman, 2019). The increasing application of such Web 2.0 technologies has been coined 'neo-geography', which Wilson and Graham (2013, p. 4) have defined it as "digitally mediated social practices through explicitly spatialized data/code practices." Along this line, geo-participation can also be considered an umbrella term to include practices that use spatial tools, both analogue and technology-mediated, in order to involve citizens in public participation exercises (Panek, 2016). Zhang (2019) classifies geo-participation in three subcategories: i) consultative (PPGIS, PGIS, geo-questionnaires); ii) transactional (OSM and participatory open data); iii) passive (social sensing). PGIS and PPGIS applications are increasingly dominated by technology-mediated and web-based mapping techniques (Corbett et al., 2006; Brown & Kyttä, 2014). According to Corbett and Keller (2005: 92), "PGIS evolved through a realization that GIS was failing to serve society as a whole." PGIS was therefore defined as a practice in its own right which facilitates the representation of local people's spatial knowledge (Corbett et al., 2006).

[3] This could be translated as: Great Mission New Tri-colour Slum. Tricolor refers to the Venezuelan flag: yellow, blue and red. Mission refers to the type of association, namely a foundation with its own mission to transform the habitat of all slums across the country. It is to note that "Missions" and "Great Missions" are generally Federal-Government funded programs which provide funding to which Communes can apply for new projects.

PGIS and PPGIS include technologies to support public participation in a variety of contexts (land use, landscape, environmental planning) with the aims of inclusion and empowerment of the general population to inform the planning process (Babelon, Stahle, & Balfors, 2017; Brown & Kyttä, 2018; Panek, 2015). Brown (2012) states that collection of spatial data in PPGIS methods is public agency-driven as opposed to VGI where citizens and individuals voluntarily contribute their knowledge and information about a specific part of the city (Adams, 2013; Coleman, Georgiadou, & Labonte, 2009; Goodchild, 2007).

Many authors (e.g. Aitken, 2014; Elwood, 2002; Goodchild, 2007; Slotterback, 2011) have identified advantages linked to digital participatory mapping technologies in planning. Benefits include empowering of local citizens; promoting dialogue between citizens and planning professionals; democratizing of GIS; collecting feedback and information useful for the planning process; increasing the number of participants and opening new channels for participation. On the other hand, difficulties and challenges to the adoption of digital mapping technologies in planning can be disempowering and are linked to requirements in terms of human capital, hardware and software costs, expert-based nature of technology with lack of user friendly applications, keeping up with technology advancement, programming skills, and the digital divide in general (Aggett & McColl, 2006; Corbett & Keller, 2005; Falco & Kleinhans, 2018b; Göçmen & Ventura, 2010; Norris, 2001; Rybaczuk, 2001; Slotterback, 2011). The result of these difficulties and challenges is that the full potential of digital participatory mapping tools can often only be unleashed in resource-rich contexts in which both citizens and planning professionals are able to deal effectively with the aforementioned challenges.

In challenging urban contexts such as those represented by informal settings and slums in developing countries, the disadvantages of and challenges to geo-information mapping tools may be exacerbated due to social, political and economic reasons. Lack of reliable data and information as well as lack of (up to date) maps characterize informal settlements (Abbott, 2003; Muthoka Mbathi, 2011; Panek & Sobotova, 2015; Warren, 2010), making planning of such settlements even more arduous. The application of geo-information tools in informal settlements has not been as widespread as in more developed contexts. However, there are significant cases of participatory mapping projects in informal settlements, such as the two projects carried out in the slum of Kibera, Nairobi (Map Kibera Project and Map Kibera) (Hagen, 2011; Marras, 2012; (MKP, 2019); (MKP, 2019)). Panek and Sobotova (2015) have analysed the differences between the two projects in terms of mapping technologies (QGIS, GPS, and OpenStreetMap) and engagement of the local population. Panek and Sobotova (2015) highlight that Map Kibera appears to be more sustainable in the long run as a consequence of more direct and sustained community development approach. Other interesting projects include the informal settlements of Karachi, Pakistan, and Lima, Peru. In Karachi, participatory mapping was employed to map and improve sanitation infrastructure, services, and house upgrading initially hampered by a lack of maps (Hasan, 2006). According to Hasan (2006) the mapping efforts had a great impact on infrastructure planning and investment, including impact on local government's strategy to plan and manage infrastructure. In Lima, a new approach to participatory mapping was employed, using balloons and kites as low-cost aerial imaging techniques for mapping (Warren, 2010). This study (Warren, 2010) underlines the empowering and facilitating role of low-cost participatory mapping in self-determination for small communities.

The use of participatory geo-information tools in informal settlements is seen as a potential solution to the lack of information that planners need to overcome (Abbott, 2002a, 2003; Muthoka Mbathi, 2011).The aforementioned examples show that geo-information tools are employed along with wider mapping approaches characterised by an emphasis on offline data collection methods, training and bottom-up community development. This article reports the use of web-based participatory mapping techniques in mapping training sessions to map spatial attributes and create spatial knowledge for planning at the corridor level in a challenging informal context where (even) bottom-up community development was not feasible. In the next section we therefore briefly review the reform process Venezuela has gone through and discuss the planning framework as a prerequisite to understanding the difficulties to plan for the barrios of Caracas.

3. Context: planning Caracas' slums

Venezuela has been engaged in a continuous process of substantial political and legal changes since the approval of the new Constitution in 1999. The so-called "XXI Century Socialism" political current (Dieterich, 2005; Ramirez Montañez, 2017) was founded on Doreen Massey's concept of power-geometries (2005), or as former President Chavez called it "*nueva geometría del Poder*", as one of the five pillars of the new ideological current (Massey, 2009). The new current aimed to implement a decentralization process (mainly in terms of budget and powers to plan and implement micro-projects such as retaining walls, staircases and sewers) through a bottom-up structure of the State and establish a new participatory democracy (Banko, 2008; Rodríguez-Zerpa, 2009). After the approval of the new Constitution, the laws related to city planning have changed in many ways. Specifically, in 2002 when Urban Land Committees were established, and in 2006 with the "Ley Orgánica de los Consejos Comunales" (Fundamental Law of Communal Councils), and 2009/2010 with the establishment of 14 controversial laws known as the "laws of popular power" (Sánchez-Falcón, 2011). These laws defined a new bottom-up structure of spatial governance based on communal councils at basic spatial level of Communes. Communal councils represent the basic planning level where citizens participate and are entitled to prepare a community plan for their Comuna (commune). As López-Valladares (2008) and Rojas López and Pulido (2009) emphasise, Communal Councils (CCs) have been established in 2006 as a specific spatial organization, functioning as the basic building block (Rodríguez & Lerner, 2007) for the Comprehensive National Planning System. This step has divided the public opinion into those who think that CCs are a new form of direct democracy and those who argue that they are a threat to constituted representative power because of budget provisions and planning-implementation powers (Goldfrank, 2011).

Within this framework, however, the laws that introduced the different plans and legal mechanisms to regulate land uses pre-date the 1999 Constitution and are still in place. As far as slums are concerned, the 1987 "Ley Orgánica de Ordenación Urbanística" (Urban Planning Law) recognized slums for the first time as "non-controlled settlements" and provided that they should be included in the city-wide Local Urban Development Plan (LUDP) and subsequently in a Special Plan for slum areas only, with detailed and strict requirements. A remarkable example of a special plan is the plan prepared within the program "Physical Rehabilitation of Caracas' Slums" (1999–2007) by Teolinda Bolívar, Josefina Baldó and Federico Villanueva after a comprehensive research on Caracas' slums (Baldó & Villanueva, 1998; Bolívar and Baldó, 1996). Despite the comprehensive research and program, the plan was ultimately cancelled due to the "sad paradox" of legality (Vallmitjana, 2002), which meant trying to plan and act legally in a territory built on the basis of informality and illegality.

A radical position to bypass the 1987 Urban Planning Law and implement a more decentralized system was introduced in 2002 through the "Urban Land Committees" and the "Special Law of Comprehensive Regularization of the Land Tenure of the Urban Popular Settlements". This special law establishes that any group of a maximum of 400 families that share an area can be organized, at the scale of Communes,[4] into an "Urban Land Committee" (ULC) with the objective to regulate land tenure and property. However, in order to do so, ULCs

[4] Potentially, every commune has its own ULC.

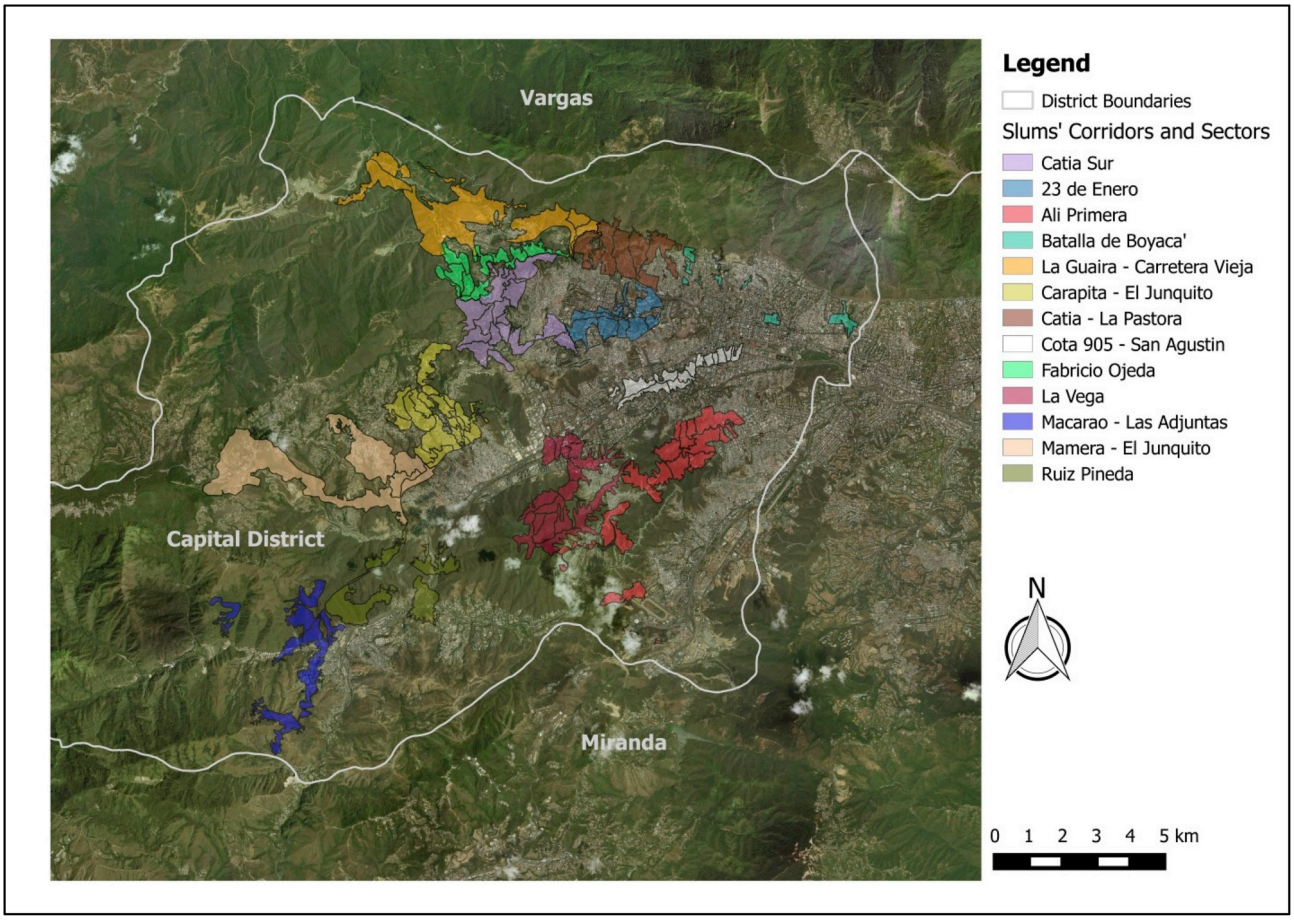

Fig. 2. All 13 slum corridors within the Capital District of Caracas.

do not need to elaborate any plan and are allowed to work independently of the Municipal Government. An ULC only reports to the National Institute of Urban Land (also created in the 2002 special law), which results in a fluid interaction among Committees at the national and communal levels but in isolation from other municipal and sub-municipal government institutions such as those of sectors and corridors (Antillano, 2005), since the latter have never been introduced by planning laws.

This resulting isolation of ULCs from municipal and sub-municipal government institutions is crucial to understand the reasons behind the lack of information and coordination to produce a wider plan at the corridor level with a coherent strategy rather than a set of single actions. Through participatory mapping exercises and digital tools, we aimed to overcome the lack of spatial information at the Corridor level and contribute useful knowledge to all stakeholders involved (Municipality, communal councils, sectors, and committees). This corridor-level information proves to be essential especially on two levels: i) for the municipality, since the city cannot plan at the micro-level of communes with an average population of 1,000; ii) for the communal councils and sectors as they will be able to plan taking into account the interventions and projects of neighbouring communes and sectors (Fig. 1).

4. Methodology

We have employed an action research approach as one of the authors was employed in the urban planning department of Caracas' municipality. The approach included web-based participatory mapping courses to train municipal officers at the sector level, and workshops with the population of communes (Picture 1). The courses and training with the mapping technology, Google My Maps,[5] took place in June and July 2016. During the courses, officers of the Sector level could familiarise with the tool and learn the basic operations, enabling them to map attributes such as public facilities, public space, projects and works within the respective corridors and sectors. Generally, three to four officers per corridor joined the participatory mapping training courses with a total number that varied between 40 and 45 participants across all corridors. We employed a mix of points and polygons[6] geometries in the participatory mapping efforts, bearing in mind the potential advantages of both as discussed by Brown and Pullar (2012) (e.g. stronger external validity for points attributes but a higher sampling effort compared to polygons). It is fundamental to mention that the Sectors' offices are located within the slums' areas, which allows the officers to

[5] Initially, we tried to explore whether it would be possible for the participants to use OSM. However, OSM was less appropriate and we encountered some resistance and difficulties related to less experience and familiarity with OSM. Google My Maps allows users to create up to ten new layers while mapping which was very useful to map categories of services and projects. However, an objective of our work is to include all the mapped information in OSM. We are currently trying to upload the information as a batch file following this guide (https://www.geofabrik.de/data/geofabrik-osm-gis-standard-0.7.pdf).

[6] We did not include lines mainly for a major reason: one of the criteria for funding allocation for project implementation under the Gran Misión Barrio Nuevo Barrio Tricolor is based on square metres of area which can be calculated only through polygons.

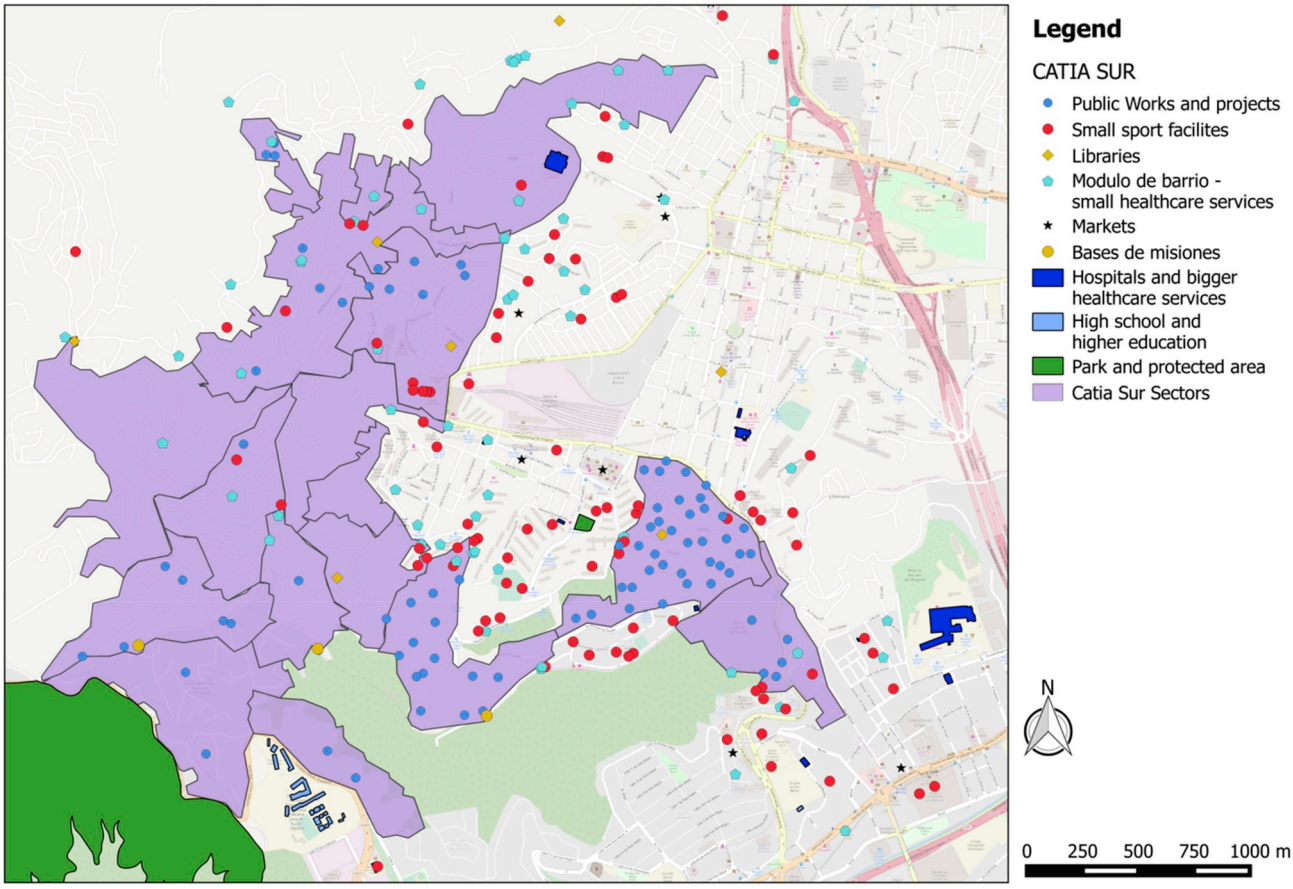

Fig. 3. Results of web-based participatory mapping in Corridor Catia Sur.

have direct contact with the population and understand their needs and priorities.

Google My Maps was chosen because it is one of the most widespread, simplest and freely available mapping options and allowed us to export all information and spatial attributes to KML format to be used at a later stage in GIS software (for which purpose we employed QGIS). After the participatory mapping courses with the Sector officers were completed (see below), the resulting spatial data was checked to reduce inaccuracies such as double mapping of features, incomplete polygons, and missing information.

The workshops with the population of communes took place from October 2016 onwards. Two workshops per Corridor were held to get more insights into the state of the slums. A SWOT approach was employed in the discussion with the population to determine perceived Strengths, Weaknesses, Opportunities and Threats regarding the domains of education, safety, health, employment, quality of public services, and public transport. The information collected through the SWOT approach contributed to the understanding of the slum areas by sector officers and definition of planning priorities. The workshops did not include a participatory mapping component for a major reason: it would have required training of citizens and availability of much greater resources in terms of personnel and hardware. However, the location of the Sectors' offices within the slum areas facilitates direct contact with the population and enabled sector officers to use information formed through direct contact with the wider population during the participatory mapping training sessions. For this reason, in the next section we focus on the results of the participatory mapping training sessions only with the officers at the Sector level. Results are summarised for the corridors of Catia Sur and 23 de Enero-San Juan as the two most successful corridors in terms of quality of mapping, amount of collected data, and number of participants in the workshops.

5. Results: the creation of spatial knowledge in informal settlements

The web-based participatory mapping efforts through Google My Maps allowed the training session participants to produce online maps for all the 13 Slums' corridors of Caracas, each one including several sectors. This enabled us to collaboratively produce for the first time ever maps containing all sectors within one single corridor, which had never been produced before as sectors were generally mapped independently of one another, not allowing for planning and considerations at the wider corridor scale. In total, over 4,000 features were mapped, producing a great amount of spatial information and knowledge in the slum areas. Specifically, the mapping efforts focused on categories such as: public spaces, education and schools, main public works and projects, both planned and under construction, public facilities such as hospitals and smaller health clinics, parks, theatres and museums, markets, etc. Moreover, the training participants were able to map all slums' corridors and their sectors as shown in Fig. 2 and their location within Caracas (Capital District).

The results of the mapping efforts at the corridor level are of extreme interest for all corridors since they show location of micro-projects in the barrios; e.g. health services, education, and sport facilities. In this section we present the results for two specific Corridors (Catia Sur and 23 de Enero) representative of the best results achieved in terms of number of mapped features, participation and engagement of the responsible coordinators for the sectors as well as workshops with the population. We also discuss the main challenges we faced in all corridors which represent major constraints to mapping.

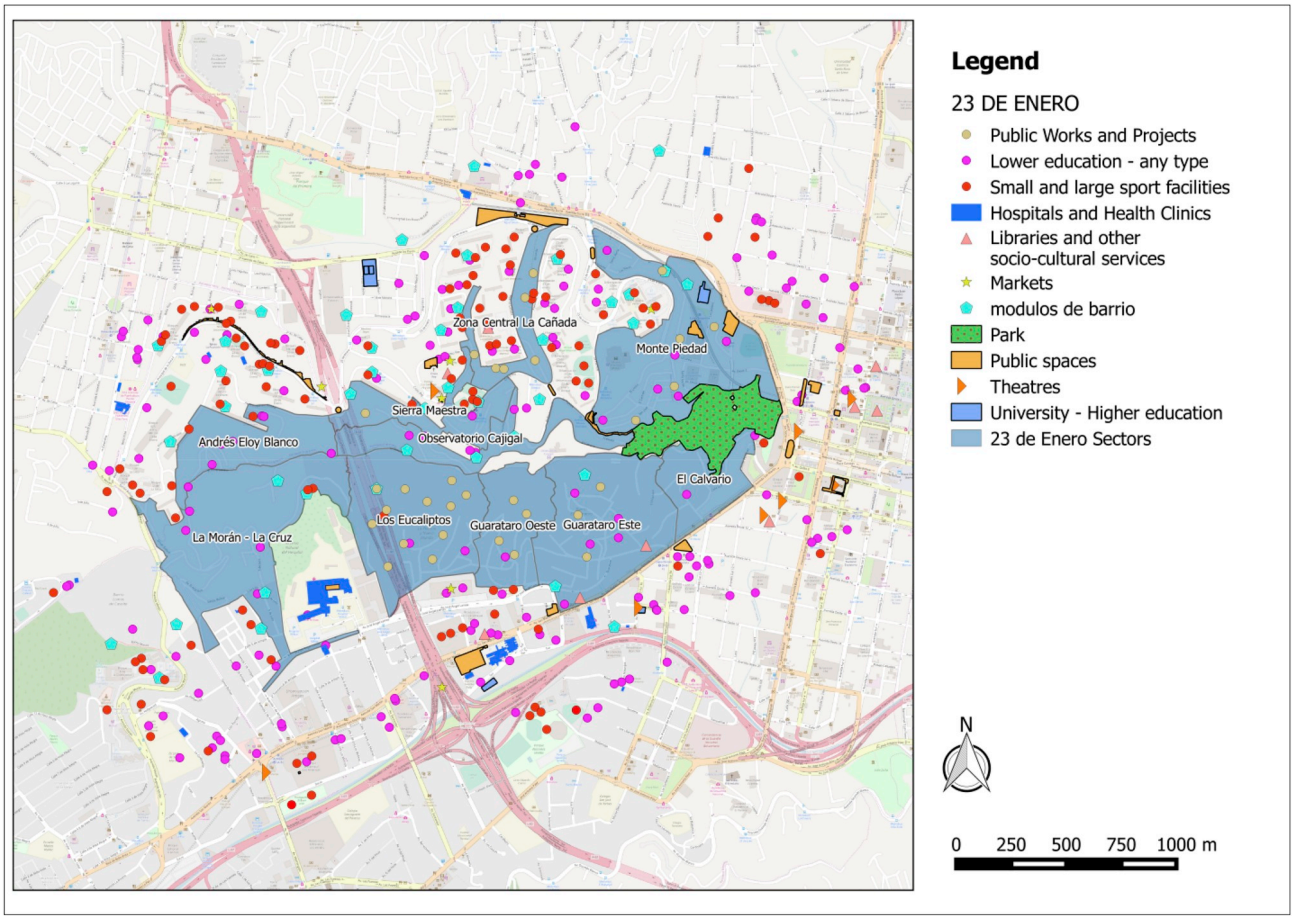

Fig. 4. Results of web-based participatory mapping in Corridor 23 de Enero-San Juan.

5.1. Participatory mapping in Catia Sur

Catia Sur is the second largest slum corridor of the city in terms of population with roughly 150,000 inhabitants. As most of the slums of Caracas, a great part of Catia Sur is located in the hilly part of the city while a large number of services are often concentrated in the lowest parts of the hill with better accessibility. Due to its size (roughly 4.7 Km^2), this corridor shows a great diversity in terms of living conditions and housing types. However, in general terms, the more up the hill or the farther away from an access road, the more precarious the housing and living conditions are.

Fig. 3 shows the results of the participatory mapping process for the corridor of Catia Sur. In total, 298 features were mapped for the corridor of Catia Sur with a focus on categories such as sport, large and small healthcare services (the latter are *modulos de barrio*), libraries, markets, *bases de misiones* (logistic centres to eradicate poverty in the slums and support the population in terms of education, health, and food), and public works and projects.

Public works and projects include projects that have either been completed or are under construction/planned, with some difficulty to clearly distinguish these two categories, mostly due to construction schedules that divide public works into several phases. Public projects include several types of projects, such as: new housing, refurbishment of *modulos de barrio* (known as Barrio Adentro defined as basic healthcare facilities) and education facilities, construction of new *bases de misiones* (which denote places with difficult access were services had to be compacted into a single intervention), resurfacing of roads, stairs and sidewalks. Strikingly, the majority of public works and projects are executed and planned for the sectors closer to the formal (as opposed to informal) areas of the city such as La Silsa, Nazareno and La Moran (see Fig. 3 above). It is also evident that for certain categories (e.g. sport facilities and *modulos de barrio*) it was easier to map existing facilities just outside the corridor's boundaries than within the corridor and sectors due to high informality within the slum areas. In the case of

Picture 1. Workshops with the population of the Communes. Source: Authors.

Picture 2. Corridor 23 de Enero-San Juan. Source: Authors.

Catia Sur, there is a lack of schools within the corridor's boundaries, which instead are mainly located in the formal and built-up areas with one major exception: the comprehensive institute to the south of the corridor just outside the sector Antonio Jose de Sucre. This is in contrast with the results of the participatory mapping process for the Corridor 23 de Enero for which education facilities were the most mapped features (Fig. 4).

5.2. Participatory mapping in 23 de Enero-San Juan

The Corridor 23 de Enero - San Juan is the third largest corridor of the city (about 2.3 Km^2) with a population of roughly 130,000 inhabitants. It is one of the most consolidated slums of the city as it is located within the area of 23 de Enero (a social housing project from the 1950s) and San Juan, one of the oldest populated areas of the city (Picture 2). Again, it developed along the hilly terrain between the San Juan and the social housing project 23 de Enero.

With regard to this corridor, a total of 447 features were mapped (Fig. 4). In this case, however, a great majority of all mapped features fall outside the boundaries of the Corridor itself. This denotes two major issues. Firstly, the difficulty in mapping features within the slum areas. Secondly, the major difference in terms of number of facilities between the slum areas and the formal city, as is the case for Catia Sur. A striking difference between formal and informal areas is related to education (mostly primary and secondary schools) and sport facilities with an almost total lack within the boundaries of the slum's corridor and great availability in the formal areas of the city. As far as public works and projects are concerned, 31 projects were mapped compared to the 84 in Catia Sur. These again concern refurbishment of small health services, resurfacing of roads, construction of new housing as part of a national program (see Martin, 2017), and improved safety against landslides with new retaining walls. Most specifically, 19 of the 31 public projects are located in the sectors of Los Eucaliptos, Guarataro Oeste and Guarataro Este in the southern part of the corridor (see Fig. 4).

6. Discussion and conclusions: major mapping challenges and ethical issues

The application of digital participatory mapping techniques yields great potential for slum areas, both in terms of planning and community empowerment (Panek & Sobotova, 2015). In our case, the use of Google My Maps for the slum areas and informal settlements of Caracas has produced a great amount of spatial information which is able to reduce the spatial knowledge gap and form the basis for planning efforts that will take place at the corridor level and include all sectors of a corridor. Our efforts have been aimed mostly at identifying and mapping public facilities (e.g. schools, libraries, health services, green areas), public projects and works to improve planning across sectors and communes and the mutual consideration of their priorities in the preparation of development plans. This will be favoured by the mapping of the contextual environment and the relationship of the sectors with the areas immediately surrounding the slum's boundaries. The case of the corridor 23 de Enero-San Juan shows extremely well the gap in the availability of public facilities between the slum areas and areas outside the slum boundaries. Mapping the spatial attributes of the corridor, including the immediate adjacent area, has great potential to inform and benefit the planning process and priorities. In the Catia Sur corridor, the results of the participatory mapping courses show a great imbalance between the sectors of the corridor in terms of planning and construction of public projects and works. However, during our participatory mapping courses, we faced various challenges. We discuss these here along with ethical issues which relate to our experience and concern participatory mapping in general. We must state that our project was the only one in Caracas, and most likely in the whole

country, which tried to use municipal resources to produce a plan at the corridor level, for all corridors, by means of training professionals whose office was located in the barrios. Both at the municipal and the national level, funds for barrios are generally used to design and implement projects and services. The challenges we faced fall mainly within four categories: (1) administrative level of government responsible for a particular corridor, (2) political decisions (linked to administrative responsibility), (3) lack of staff and difficulty to retain them within the barrios, and (4) responsibilities and duties of professionals involved. As far as the *administrative responsibility* is concerned, corridors and sectors in Caracas fall either under the municipal administration or the national government jurisdiction, specifically the Government of the Capital District (GCD). This split responsibility made it harder to collaborate with those sectors (even within the same corridor) which fall under the GCD administration. While the municipal government decided to use the funds for barrios to employ professionals to map and produce a plan at the corridor level, the GCD used the funds to directly implement public projects as it is generally done. These parallel political decisions produced an imbalance in availability of human resources and personnel for some sectors and corridors. This added up to the existing challenges to employ professionals who are willing to work in the challenging context of the barrios, and retain them there. While we were generally able to involve two professionals per corridor, the corridors under the municipal administration employed more professionals at the sector level, allowing us to produce higher quality maps, such as in the case of the two corridors we have discussed above. We tried to overcome the lack of personnel by asking sector professionals employed by the municipality to help with the mapping of the remaining sectors, even within the same corridor, which fell under the GCD jurisdiction and therefore lacked resources. However, this proved difficult as it added work burden and responsibilities on professionals who were reluctant to take on more responsibilities and duties for other sectors than the one they worked in.

Along with these challenges, we faced ethical issues which are common in participatory mapping practice, regardless of whether it is carried out with or without technology. Already in 1998, Abbot et al. (1998) exposed risks of visualizing place-specific local knowledge without ensuring sufficient control of the process and outputs. Corbett and Keller (2005) noted that participatory mapping can be disempowering or even marginalizing due to the complexity of technology and issues related to data inaccessibility. Chambers (2006) warned against ethical issues related to raising expectations, extracting information only for outsiders and powerholders. Dunn (2007) explored aspects of control and ownership of spatial information and representation of local knowledge. Rambaldi, Chambers, McCall, and Fox (2006) discuss ethical issues around 'who' and 'whose' questions. Who participates, who is empowered or excluded, who owns the data and output, decides, controls, understands and has access to the information? Whose problems, perspective, trust, logic, sense of place, priorities? We also faced these issues during our mapping efforts and some of them represent limitations for our study. We tried to bear in mind people's problems, priorities and perspectives even though planning professionals were in charge of the mapping and the logic may not have been that of the resident population. We also paid attention to the 'who' questions and tried to involve the local population through the workshops. The information produced is available to them and has already proven to be useful for short-term projects. However, many residents (among those who did not participate in the workshops) are not aware of this and remain, to a certain extent, excluded and disempowered. Similar issues remain around who owns the data, the maps and the output (the public agency), and subsequently decides - mostly the public agency through funding allocation criteria.

Despite the challenges and ethical issues we faced, the contribution of our study proves to be valuable to the wider population of the slums. Above all at the lowest level of communes and communal councils, as citizens are now aware that this information exists, can be accessed and used for planning purposes through the Sectors' officers. In fact, the information produced during the mapping courses has already proven to be useful in the months following the courses. We have observed that short term two-year plans have been produced on the basis of the new maps to set the priorities in terms of infrastructure projects within the slums (e.g. retaining walls, stairs, roads).

Apart from a practical contribution to this situation of complex governance and lack of resources, we sought to answer the question of how web-based mapping technologies can be harnessed to fill the spatial information gap at the corridor level and thus support corridor-wide planning of the slums of Caracas. In line with the literature on web-based mapping technologies that has identified several (community) benefits, we have shown how a two-tier approach consisting of online mapping technologies and offline interaction with the local population can be harnessed not only to map physical features of the slums, but to produce local spatial knowledge in informal and resource-poor contexts which proves to be useful in planning at a wider scale. This provides some evidence that in cases where a fully bottom-up mapping approach is not feasible in terms of information, human and financial resources, a two-tier approach is able to produce valuable information to determine spatial priorities and plan infrastructure projects at a higher level than the commune.

While seemingly counterintuitive, we have found that offline ways of eliciting spatial information on public facilities through SWOT workshops with *residents* of the communes are a reasonably effective way to elicit the required information under conditions of poverty, low educational levels and lack of access to digital means of communication. Training the general population to use tools such as Google My Maps and directly enter their observations would have required significant resources which are lacking in the context of Caracas. Instead, a training effort through sessions targeted at planning *professionals* enabled them to enter data and information formed through direct contact with the population as the offices are located within the slums' areas. Hence, as an answer to the research question, we conclude that filling the spatial information gap at corridor level was possible through an approach in which planning officials initiate the mapping with web-based tools and subsequently enrich the data with bottom-up, offline qualitative information from the communes.

Much literature on VGI and PPGIS underlines its *direct* participatory potential (e.g. Babelon et al., 2017; Brown & Kyttä, 2014; Nummi, 2018; Sieber, Robinson, Johnson, & Corbett, 2016). However, our article contributes to the wider literature by revealing how the interests of target communities in resource-poor situations can be best served with an *indirect*, two-tier approach which is sparked off by planning professionals who perform mapping exercises on the basis of crowdsourced data from workshops on-the-ground and other effective offline community-based data collection methods.

Obviously, this study has some limitations. Firstly, and most clearly, the impossibility of getting the wider population involved in the participatory mapping efforts due to lack of both human and financial resources. In spite of this, however, the courses with the Sector officers were able to produce a great amount of spatial information for the slums due to the fact that offices are located within the slums' areas. Secondly, ethical issues remain relatively to ownership of data and maps, mapping logic, and access to data. Thirdly, in terms of producing relevant information for planning processes at the corridor level, the impossibility to map major land uses within the slums. Due to the informal and illegal character of slum settlements, it was impossible to define land uses within the slums areas. However, future participatory mapping research could try to overcome this limitation and define major land uses within slums areas through a stronger interaction between the local population and planning officials. This would allow the production of valuable information for the formal and institutional planning processes.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.habitatint.2019.102038.

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