

# Participatory GIS for Urban Sustainability and Resilience: A Perspective of Social Learning and Ecology of Knowledge

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**Abstract** The contemporary urbanization model is characterized by unsustainability and environmental injustice as well as social and cognitive exclusion. The search for sustainability and resilience demands better structures of social inclusion and governance to deal with multi-layer determinants and so, it is imperative to promote social participation in decision-making and urban planning. In this chapter we focus on the potentiality of Participatory Geographic Information Systems (PGIS) in terms of fostering social learning and participation, combining spatial, technical and social knowledge and addressing sustainability and resilience issues. A review of PGIS application research findings showed that 25% of PGIS research is applied to urban studies in general, and to natural disasters in cities, such as floods and landslides. According to the review, the PGIS, through the mapping process, that includes social learning and dialogue and aims to apply the ecology of knowledge concept, presents advantages in social engagement when compared to other social participation tools. It has great potentiality to educate and empower citizens, providing better governance and urban scenarios and, therefore, promoting healthier and resilient cities.

**Keywords** Participatory geographic information systems (PGIS)  
Ecology of knowledge · Social learning · Urban resilience · Sustainability

## 1 Introduction

According to Hoff (2011), GIZ and ICLEI (2014), urban development is founded on inequality and environmental degradation. While a few have access to an abundance of resources, recklessly exploited without any control, the majority of

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the population will have to face or is already facing some kind of shortage related to those very same resources. Disorderly urbanization processes typical of developing countries mean that natural resources are used up in an unsustainable manner, aggravating the situation of degradation and undermining the cities' resilience. Currently more than half of the world population lives in cities and 7 out of every 10 of the planet's 9.6 billion inhabitants will be living in cities by 2050 (WHO 2013). Accordingly, efforts to optimize the cities' resources must be redoubled and strategies must be devised to enhance resilience. To that end it is necessary to establish methodologies and tools to achieve efficient planning and governance.

The current urbanization model has generated significant negative social and environmental impacts with direct implications for the health and wellbeing of the citizens. That process of disorderly growth is even more intense in the central areas of cities which are destined for high-income population groups and their associated concentration of resources, while more peripheral areas of the cities, also densely populated, suffer from the lack of basic infrastructure and health problems stemming from that lack and from poor socio-environmental management processes. In that way the cities are becoming less resilient (Razzolini and Gunther 2008; Empinotti and Jacobi 2013). In addition to natural resource deterioration, environmental services provided by the ecosystems (TEEB 2010), like those provided by regional water systems such as domestic water supply, hygiene and sanitation, climate and air humidity regulation and fisheries, also deteriorate.

Very large cities, especially those in developing countries, have been structuring themselves on the basis of a new form of spatializing the same old perverse, profoundly iniquitous social structures, establishing an abyssal cartography showing how social and environmental injustice are linked to glaring vulnerabilities (Santos 2007; Martinez-Allier 2007; Porto and Freitas 2003). Even so, the well-founded analyses of injustice still lack recognition of the fact that there can be no global social justice while an analogous cognitive exclusion is maintained. That statement is based on the recognition that hegemonic academic knowledge, the way it has historically been reproduced, marginalizes local, grassroots knowledge that can be just as valuable and legitimate and is endowed with great potential for application in local contexts (Santos et al. 2009). Indeed it can readily be acknowledged that it is the local practices and wisdom developed and reproduced in vulnerable urban communities that makes their subsistence feasible and establishes responses to their overall situation of precariousness and the glaring absence of the State (Magnani 2002; Nicolini 2012).

Added to that critical scenario of vulnerabilities is the question of climate change and its possible impacts, which tend to exacerbate all the above mentioned urban problems. Those impacts include climate events like prolonged droughts, torrential rains and floods and the landslides associated to these last. They are events that affect vulnerable locations more seriously and they may set up causal chains that can lead to profound systemic crises (Hales et al. 2004; IPCC 2013). According to Mayntz (2006), such socioenvironmental crises come under the heading of "persistent problems". A persistent problem is typified by the interdependence of the social actors involved, the outstanding need for action on various levels, a lack of

feedback that creates gaps in knowledge of the functioning of the urban system, and the very structure of the problems themselves which is in a state of total fragmentation. Such complexity calls for an entirely new governance model.

One way to transform that panorama would be to change the way in which the system is managed, that is to say, improve the governance structures. Governance can be considered to be a process in which new ways are proposed and adopted with a view to establishing an alternative relation between the government level and social demands thereby administering the different interests and existing conflicts, and with the participation of the social actors involved (Jacobi and Fracalanza 2005; Jacobi and Sinisgalli 2012). Taking into account the difficulties inherent to democratization and the extant situation of cognitive exclusion, to achieve any changes in governance there will need to be instruments available that incorporate society's demands such as the use of participatory approaches and social learning processes, which are inductors of collaborative arrangements and processes of co-accountability.

Different arrangements that foster the involvement of social actors, above all, of ordinary people subject to socioenvironmental vulnerability, can contribute towards improving governance structures. It must be taken into account that it is often necessary to overcome the inertia of the subjects in risk situations and make it possible to empower them through a process of getting them to reflect on their own living conditions, rights and possibilities for improvement. Sometimes reflexive processes of empowerment not only lead to a more intense protagonist role in the governance process but also create an interface with the decision-making process, resulting in positive interactions with the public policy agendas (Wallerstein and Duran 2010; Giatti et al. 2014b). The emergence of responses to contemporary problems from society itself, such as non-governmental organizations, Beck (1997) calls "subpolitics". They are legitimate responses and constitute an implicit criticism of the conventional governability paradigm. In that regard, the adoption of instruments capable of enhancing/supporting decision-making processes is an important initiative, particularly in the case of the spatial data management/processing techniques represented by Geographic Information Systems (GIS).

GIS are computer systems for managing geo-referenced, interrelated, spatial data with the functional capabilities of input, manipulation, visualization, analysis, modelling and output and designed to provide support for decision-making and planning (Bonham-Carter 1994). GIS also make it possible to visualize local knowledge. They can manipulate great quantities of data fast and at low cost and make it easier for citizens to fully understand the spatial consequences of proposals and actions. They also facilitate participation at any given moment. Participatory GIS (PGIS) refers to the combination of GIS technology with local knowledge stemming from whatever community is the object of study and it is an instrument that can greatly contribute to empowerment and improving governance (Technical Centre for Agricultural and Rural Development-CTA 2006; Mccall 2004).

The aim of this text is to explore ways in which PGIS can contribute towards expanding citizen participation in governance processes that are marked by social learning and perspectives of sustainability and the expansion of the urban systems' resilience.

## **2 Background Concepts**

### ***2.1 Sustainability and Resilience for a Healthy City***

The World Health Organization (WHO) defines the healthy city as one that is continually creating and improving the physical and social environments. Thus a healthy city would be one in which the municipal authorities prioritize the health of their citizens in the wider perspective of quality of life. According to WHO (1995), for a city to become healthy it must make every effort to provide:

- A safe, clean environment;
- A stable, sustainable environment;
- A high degree of social support without exploitation;
- A high degree of social participation;
- Satisfaction of basic needs;
- Access to experiences, resources, contacts, interactions and communication;
- Diversified and innovative local economies;
- Respect for and pride in the biological and cultural heritages;
- Universally accessible health services;
- High standards of health patterns.

The WHO Healthy Cities Project is a global movement responsible for engaging governments in promoting health in cities by means of political commitments, institutional changes, capacity building, partnership arrangements and innovative projects. To that end health must become a priority issue on government agendas and be addressed in the light of the inequality and poverty of vulnerable groups in risk situations and the need for participatory governance, and close attention must be paid to health indicators associated to social, environmental and economic factors. Thus the standard of health in a city is very closely bound to its governance model, that is to say, it must be founded on citizen participation, sustainability and resilience. To meet those governance criteria the focus must be primarily on citizen wellbeing, which means that all decisions must be taken bearing in mind the need to achieve equilibrium, based on an inclusive and participatory governance model.

In regard to sustainable use of resources in general, those that society depends on for its survival, especially water, energy and food, they are all interdependent and coupled with the environment. As an example, water and energy are needed to produce food; water, in turn, is needed to produce energy while, to gain access to

water, energy is needed. They are also dependent on the existence of solid infrastructure and their impacts whether positive or negative are also intimately interconnected (Cairns et al. 2017; Bazilian et al. 2011). That interdependence is termed the nexus on water, energy and food with respective trade-offs, and it needs to be profoundly investigated and taken into account in any kind of decision-making that seeks for sustainability, resilience and the reduction social inequalities (Karabulut et al. 2015; Dodds and Bartram 2014; Hoff 2011). According to Cairns et al. 2017, the nexus concept, in its aspect as an innovative and integrating approach, gives prominence to increasing the efficiency and safety of all processes involving resources and, furthermore, to observing the connection between the boundaries of the planet's major resources and human health and urban dynamics. Thus GIZ and ICLEI (2014) state that the urban nexus is an approach focused on: finding solutions for sustainable urban development; and orientating social actors in their efforts to identify possible synergies among sectors, organizations and even technical areas that might enhance performances, optimize resource use and efficiently manage the quality of the services and resources offers. However, for the sustainability perspective of the nexus to be incorporated to the urban governance model, new approaches and tools are needed to make the current, sector-based and compartmentalized, conventional administrative and management structures more transversal. Those new approaches must allow for the social, cognitive and environmental inclusion of society's varied bodies of knowledge, values and beliefs.

Whenever the governance model identifies the resource nexus and takes it into account, urban resilience tends to increase. The key to obtaining resilience lies in the fact that public administration can be called on to take action as soon as any kind of environmental disaster occurs, which means that the administration must be aligned with society's basic needs. As mentioned earlier, the interdependence of resources leads to impacts in series whenever any one of them, such as the availability of potable water, fails. Such impacts undermine urban resilience step by step. Resilience is an essential component that is crucial for achieving sustainable urban development; fostering resilience and enhancing it means adopting new governance models with a focus on equity, social learning and the adaptive capacity. Furthermore, resilience constitutes a bridge to different disciplines and stimulates dialogue among the various social actors for the construction of new policies (Chelleri et al. 2012).

## ***2.2 How Social Learning and the Ecology of Knowledge Can Contribute to Changing Governance***

The introduction stated how complex the concept of governance is and how it has gradually changed and evolved in the course of time. In short, governance is the institutionalization of decision-making processes (Levi Faur 2011). Current

governance is typified by the presence of a small group of specialists that holds all the knowledge, does the planning and makes decisions that have repercussions for the entire society (Jacobi et al. 2010). Again according to the Chelleri et al. (2012) urban governance is nothing other than the sum of the various ways in which citizens and public and private institutions plan and manage the city's ordinary affairs. It is an ongoing process whereby conflicting or divergent interests should be accommodated and a cooperative action can be decided on and it can include formal institutions just as well as informal arrangements and the social capital of the citizens. Finally Le Galès and Vitale (2012) consider that "governance is not a linear process, not always rational, incomplete and prone to discontinuities".

In recent years social inclusion practices have been developed that involve learning and dialogue, in keeping with the concepts of Social Learning and the Ecology of Knowledge, and they are aimed at changing the extant forms of governance. Social Learning embraces educational and socioenvironmental practices developed by facilitators together with civil society that are intended to contribute to decision-making processes. Social Learning fosters better collective decisions, builds trust among the social actors and constitutes a shared body of knowledge by means of participatory reflections and practices (Jacobi et al. 2005). The Ecology of Knowledge concept acknowledges the plurality of the knowledge held by various social actors and the need for such knowledge in order to undertake actions in society, among which are basic actions to ensure survival such as obtaining food, work, good health, infrastructure and even organizing social movements. It is important to note that those questions or practices are interdependent and some of them can even be highly innovative (Santos 2007; Stengers 2005).

It must also be borne in mind how, in parallel to the process that established positivist thinking, the hegemony of a certain form of academic thinking established itself which, without entering on a discussion of its merits or demerits, marginalized other forms of knowledge. Academic knowledge is, in fact, just one form of knowledge, not the only one. Based on the recognition of the importance and applicability of other forms of knowledge, such as the traditional forms of knowledge, and admitting the complexity of contemporary challenges, it is worth arguing in favour of promoting a hybridization of knowledge forms, conjugating, for example, traditional knowledge with academic knowledge and thereby leading the way to new learning and new solutions. That hybridization could be achieved by means of participatory interventions made in a more symmetrical perspective with the expectation of promoting an ecology of knowledge (Santos 2007; Giatti et al. 2014a), that is, promoting new forms of socially constituted learning capable of incorporating, among other things, greater robustness and social watchdog control over the relations among science, society and decision-making (Gibbons 1999).

Applying Social Learning and Ecology of Knowledge concepts and practices to address the mentioned persistent problems that Mayntz referred to, and adopting instruments such as participatory approaches could bring about changes in the governance models. It would mean that the society's opinions, knowledge and practices, as well as its demands, would be taken into account in decision-making

processes, thereby raising the level of sustainability of urban development. To that end the practices and concepts would have to be widely applied in society as a whole and not merely applied in isolated situations, as is usually the case. Technical support will be needed to make it feasible to broaden the outreach of practices and change the current panorama. PGIS could well provide support for enhancing that outreach and its potentiality is described in the following section.

### **3 Role of PGIS in Urban Sustainability: Boosting Social Learning and Ecology of Knowledge to Obtain a New Governance**

#### **3.1 *Method***

This section has been based on an unpublished, bibliographic review of the literature on PGIS and its applications that was undertaken and systematized by the authors. The review examined scientific articles found in two databases: Web of Science and Science Direct. The key phrase used in the search was “participatory geographic information systems”. The first screening of articles in the Web of Science portal yielded 282 results for the period covered by the database, which was 1900 to 2016, while the search of the Science Direct database yielded 4672 articles for the period 1972 to 2017. The articles were then filtered by reading all the abstracts and the refinement criterion adopted was that the research or review must make reference to the use of PGIS. After that process there remained 101 Science Direct articles and 118 from Web of Science. The next screening consisted of reading the full text of all the articles. As a result, 47 articles were selected from Web of Science and 43 from Science Direct.

PGIS first application is urban studies, in a range of 20 different topics founded in this review, with 18 articles. Second application is natural disasters in an urban context, intrinsically connected to urban resilience, with 11 articles. The cited bibliographic review revealed that the leading application for PGIS studies is in urban studies and that underscores its potentiality for improving governance and resilience of the cities and in consequence, the wellbeing and health of the citizens. Still referring to the review, the following urban planning-related themes were selected for study: tourism, accessibility, transport, parks, cycling pathways, urban green areas, spatial planning, urban aquatic environments, public spaces and studies on minority and marginalized groups. In addition, PGIS is also applied to questions related to natural disasters, more specifically, to floods and landslides. Most part of examined articles refers to research within marginalized groups, however, multi-level approach have been increasing through the last 10 years.

Finally, to build this chapter, some basic concepts that support the healthy and resilient cities building, were presented, such as governance model, ecology of

knowledge and social learning. Then, PGIS application comes to put together these concepts through its practices and tool facilities.

### 3.2 Discussion

Based on the review it was found that PGIS came into being due to the dissatisfaction of some researchers when they perceived that they were unable to respond to socioenvironmental demands using traditional GIS practices alone. Accordingly, some of them decided to input digital representations of the realities they were researching to databases and in that way obtain a new perception of reality in their pursuit of ways to help people to make their own analyses of the environment they lived in. At the Mapping for Change International Conference on Participatory Spatial Information Management and Communication held in Nairobi, Kenya in 2005, practical experiences with PGIS were widely discussed and the main conclusion was that it could have intense applications in marginalized groups, stimulating innovation, communication and dialogue and, accordingly, generating incentives for positive social changes (Ferreira 2012). That prospect could also be considered a kind of cognitive inclusion, overcoming the abyss separating hegemonic academic knowledge from grassroots forms of knowledge (Santos 2007).

Data gathering methods in participatory GIS practices range from the traditional mapping tools, such as hand drawn sketch maps, to embrace three dimensional models and the interpretation of aerial photographs and satellite images (Mccall 2004). A common step in PGIS, however, is participatory community mapping; a procedure that combines cartographic methods with participatory methods to represent a local community's spatial knowledge. It is firmly founded on the premise that local inhabitants possess a high degree of knowledge about the place where they live and that such knowledge can be expressed in the form of maps which, in turn, are susceptible to being understood by everybody. The maps materialize important elements for legitimizing the participation of social actors by enabling the latter to appropriate technical elements, to include information by their own perceptions, to view their environment in a different light and to think about possible solutions for their own community's problems (Mapping for Rights).

According to Astzmanstorfer et al. (2014), in the current context of metropolis formation PGIS makes it feasible for society to take an active part by denouncing socioenvironmental problems, making suggestions and new proposals or making complaints and even taking part in monitoring and the solutions of the problems; and to do so by means of a web app on cell phones. In addition citizens have an opportunity to connect with and boost social movements and initiatives. Some such initiatives already exist in Brazil like the new app of the city of São Paulo, *Cidade Linda*<sup>1</sup> (Beautiful City), which is intended to facilitate interaction and citizens'

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<sup>1</sup>(<http://cidadelindapp.com.br/>).



suggestions and complaints associated to specific themes: water/sewage, the quality of asphalt paving, street lighting, graffiti, signs and safety/security. There is also *Calçada Cilada*<sup>2</sup> (Treacherous Pavement), idealized by the *Corrida Amiga* (Friendly Run) program (a volunteer network that encourages people to move around the city on foot). *Calçada Cilada* endeavours to identify and report problems in São Paulo city's sidewalks. Such inputs mean that decisions can be made in a different way, taking the demands and opinions of society at large into account and gradually transforming the way governance is carried out. Other projects designed to interconnect citizens via internet and geo-referencing are underway all over the world. Some of them are much more than just apps; they are veritable platforms connecting stakeholders. An example is the Maptionnaire<sup>3</sup> software which provides mapping based on a questionnaire and facilitates analysis of the maps produced based on knowledge of the society. That platform is currently being applied in urban planning studies and even in research into city security.

The application of PGIS in disaster studies aims at promoting urban resilience through empowerment and by developing scenarios and action strategies to be unfolded in the event of the occurrence of a disaster. In addition, the products PGIS generates contribute to reducing the risks by inducing better reflection on the part of participants that are exposed to them, apart from the fact that it is an excellent instrument for extracting/obtaining local knowledge about flooding, landslides and all the other kinds of disaster. On the basis of that local knowledge, it is possible to elaborate public policies that are socially equitable and capable of incorporating the point of view that those at risk may have developed based on their insertion in given local contexts (Mccall 2004). Gaillard (2013) states that the unequal distribution of the power of decision is the major factor responsible for the vulnerability of populations when they are confronted with disaster events. In Asian countries it is quite common for the means of protection in episodes of disasters to only be available to the upper classes. The vulnerability of a society is profoundly connected to its governance structure. Lastly, in regard to the urban nexus and its connection with sustainability, there are many papers describing the application of PGIS to agriculture, water resources and renewable energy. Thus the PGIS tool could readily be applied to the study of the urban nexus thereby fostering a much-needed change in the governance model into more sophisticated structures and, consequently, an enhancement of urban resilience by addressing the way environmental disasters and issues like food and energy security are addressed.

According to Mccall (2003), the PGIS has all the features needed to meet the seven criteria of "good" governance (Chelleri et al. 2012), namely: sustainability, equity, efficiency, transparency, responsiveness, the social participation of all the actors present in a community, and security (providing support for citizens' basic rights). The PGIS stimulates social participation by developing maps together with its participants. The empowerment provided by the PGIS stems from the learning

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<sup>2</sup>(<http://corridaamiga.cidadera.com>).

<sup>3</sup>(<https://maptionnaire.com/>).

that is generated by the map and dialogue development processes and from the respect afforded and stimulus given to local knowledge. Enquiry is stimulated insofar as the participants in the PGIS process discover their own capacity to understand a socioenvironmental reality and give an opinion about it. Finally, the possession of information and use made of it and the products generated by the PGIS also imply in empowerment and power of decision over the use of the data. All of those elements boost the aforementioned Ecology of Knowledge and the Social Learning processes and they bring about changes in governance and social transformations in the direction of healthier and more sustainable urbanization.

As mentioned earlier, PGIS aims to represent local people's spatial knowledge by applying demand-driven geospatial technologies and spatial representation products (not only map products) that facilitate participatory decision-making processes and support communication and community advocacy. Therefore, it has great power to produce social change, especially through the practice of social learning (Mccall 2015).

The great potential of PGIS is evident in the diversity of situations in which its application has proved to be important and the prospect it offers of collaborating with social learning and improved governance structures by mapping aspects of interest within territories marked by profound inequities, for example, environmental racism (spatial correlation between environmental degradation and the distribution of ethnic groups, or the distribution of socioeconomic groups in cities) and environmental injustice and social inequities (for example, socioeconomic groups in disadvantage, mapping employment, ethnicity, language, gender, caste, age group and access to basic services) (Mccall 2003). Besides, a PGIS advantage is the possibility of using official data and citizen's data, which provide us a more complete background that allows qualitative and quantitative analysis, being therefore, a solid basis for any planning activity (Kahila and Kytta 2009). PGIS dynamics and the application of its results contribute to empowering marginalized groups and stimulating transparency in decision-making processes and applying them to the development of action plans for improvements in society (Drew 2002; Carver et al. 1999). In that way PGIS has an unquestionable role to play in improving governance, social inclusion, and social learning.

Although GIS is conventionally considered as a technical tool far from common sense, the PGIS shows the possibility to facilitate the organization of society and its interests, stimulating the collective aspect, which it achieves due to its high capacity for visualizing and demonstrating the urgent demands that the maps delineate. It is important to state that the product generated by the PGIS is the raw material for formulating and supporting new forms of public policies, that is to say, a tangible mechanism making it feasible to reinvent policies that incorporate a more reflexive role for society (Beck 1997). Indeed, the prospects opened up by PGIS use seem to be highly consistent with premises underlying the clamour for an Ecology of Knowledge (Santos 2007) given that, by its means, a technological digital platform moves out of the technical/academic domain to corroborate the inclusion of other kinds of knowledge, perceptions, and social representations, thereby materializing

Social Learning processes and identifying the best way forward towards sustainability and urban health and resilience.

## 4 Conclusions

This chapter explores how PGIS can be applied in urban studies towards sustainability, to improve participation and develop community awareness, which is a step towards empowering the citizens and providing a unique instrument to boost the actions unfolded by Social Learning practices based on Ecology of Knowledge. Furthermore, the bibliographic review of this seminal issue, shows that PGIS can enhance urban resilience by means of the innumerable possibilities it offers for analyses and generating products that can inform and support urban planning and decision-making. It also shows that PGIS as a participatory research and intervention tool has been applied in urban studies and also towards natural disaster research and prevention, which is the core for urban resilience and a healthy cities, considering threats due to climate change consequences. Besides, the potential of quantitative and qualitative data analysis is also an advantage of PGIS application for urban studies, overlapping the mainstream quantitative application of conventional GIS approaches.

It is recommended that PGIS should effectively be used in decision-making carried out together with the society involved and not only in providing informational support for urban planning but also in consultations of society at large, with varying degrees of social participation, thereby contributing to obtaining better governance structures. It should be noted that PGIS is a tangible method for promoting a fair cognitive inclusion and performing the role of engaging more citizens in decision-making processes, making it feasible to produce more critical, hybrid bodies of knowledge and taking society out of its traditional state of marginalization, powerlessness and its non-protagonist role in decision-making processes.

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