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Social use and consequences of PGIS in local communities: a structurationist analysis of Sierra Nevada Project

Natalia Aguilar Delgado
HEC Montréal, natalia.aguilar-delgado@hec.ca

Marlei Pozzebon
HEC Montréal, marlei.pozzebon@hec.ca

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Natalia Aguilar Delgado
HEC Montréal
natalia.aguilar-delgado@hec.ca

Marlei Pozzebon
HEC Montréal
marlei.pozzebon@hec.ca

ABSTRACT

The aim of this paper is to understand the social use and the consequences of PGIS in local communities, more specifically in Sierra Nevada, Mexico. In order to investigate the use of ICT by communities, we applied a multilevel and structurationist framework that articulates three dimensions: context, process and content. The results of our study draw attention to the implications of using PGIS not only as a technological tool in the strict sense, but as a process with the potential to achieve commitment across different social groups, even if they have distinct interests and skills. In addition, the consequences of its use for the communities are more likely to be related to the effectiveness of the underlying learning and emancipation processes.

KEYWORDS

Participatory GIS, local communities, structurationalism.

INTRODUCTION

During the last few decades, geographical information system (GIS) has been increasingly applied to different areas, such as spatial planning and natural resource management. According to Rambaldi, et al., (2005), the steadily decreasing cost of computer hardware and the availability of user-friendly software is allowing the diffusion of this modern spatial information technology to non-governmental and community based organizations, institutions that had previously been excluded from the spatial decision making process. In this type of application, we usually observe the use of inclusive methods for the mapping process, which is broadly termed participatory GIS (PGIS).

This is the case in a PGIS experiment in Sierra Nevada, Mexico. In this region, for the past 30 years, a series of environmental threats combined with unequal economic development, have been undermining the connection between the local population and their land. In 1997, after a metropolitan planning authority predicted an ecological crisis in the following decade, a community initiative called *"Proyecto Sierra Nevada"* was established to contain urban sprawl and ecological menaces through local and sustainable development projects. One of the challenges encountered was the need for re-appropriation of the territory by the community, which was addressed with the help of PGIS in an innovative implementation.

Using this case as background, our article aims to **analyze the social use and consequences of PGIS in a local community**. For this purpose, we first present a brief literature review, defining the most important concepts related to PGIS (definitions, opportunities and constraints), then introducing PGIS research over the past 10 years. Later on, we develop an

analytical framework to set up its application in an in-depth case study, presenting our methodological approach. Finally, we analyze the data and discuss the main implications for future theoretical and empirical work.

DEFINITIONS FOR GIS AND PARTICIPATORY GIS

While there have been many forms of mapping systems available since the 1960s, Madon and Sahay (1997) emphasize that Geographic Information System (GIS) technology has evolved since the early 1980s. GIS is a computer-based tool for mapping and analyzing spatially referenced data that can facilitate understanding of spatial aspects of social and economic development (Quan et al., 2001). Nevertheless, during the past decade, critical literature on GIS has emerged (e.g., Schuurman, 2000). This stream points to the importance of examining particular underlying processes of GIS development in social groups and the social implications of these GIS practices.

Mainly as a response to such critiques, a more socially aware type of GIS that gives greater legitimacy to indigenous knowledge has been growing. Variously labeled as Participatory GIS (PGIS) or Public Participation GIS (PPGIS), these newer approaches are context- and issue-driven rather than technology-led, and seek to emphasize community involvement in the production and/or use of geographical information (Dunn, 2007).

Opportunities and Constraints of PGIS

According to Rambaldi et al., (2005), PGIS practice generates community empowerment when embedded into long-lasting decision making processes. In this sense, effective participation is key to good PGIS practice, which can be ensured through good governance. For McCall (2003), it involves not just accountability per se but is a means of supporting legitimacy, respect, equity and competence. Based on Rambaldi et al., (2005), it is possible to infer that the main benefit of participatory GIS is making it available to less-favored groups to enhance their capacity to manage their own indigenous knowledge, with goals such as: managing conflicts among groups and collaborating in resource use planning.

Nevertheless, we were able to recognize several difficulties in real applications of PGIS. First of all, according to McCall (2003), there are critical divisions in communities related to gender, age, economic class, etc., which lead to an extensive range of needs, opinions and interests. In this regard, participatory approaches can become complex, time-consuming and often costly. Another aspect cited by Kyem (2001) is dependence on external assistance and costs of the technology and training, which can constitute a barrier to GIS projects in local communities. Finally, Carver (2003) argues that there will always be a significant proportion of the population who do not have the appropriate training or capabilities to use the information effectively and will thereby always be excluded from the decision making process.

In table 1 we summarize the opportunities and constraints of PGIS applications.

Opportunities	Constraints
Community empowerment in long-lasting decision making processes *Effective participation through good governance: legitimacy, respect, equity and competence* *Enhancement of community capability to generate, manage and use their own indigenous knowledge*	*High-cost, low accuracy and complexity of participatory approaches* *Lack of financial resources and expertise* *Exclusion of less skilled people from the decision making process.*

Table 1. PGIS Opportunities and Constraints

OVERVIEW OF PGIS RESEARCH STREAMS

When analyzing the literature on PGIS for the past 10 years, we identify three main axes: spatial planning, critical PGIS and natural resource management. We see some critical authors that discuss the ambiguities of the PGIS process (Elwood, 2006; Dunn, 2007) and its potential effect on community empowerment effect (Corbet and Keller, 2005; Kyem, 2001). On the other hand, various studies examine the use of PGIS for spatial planning issues, both in rural (Williams and Dunn, 2003; Bahuer, 2009) and urban (Elwood, 2002; Hoyt, et al., 2005) contexts. Finally, the third axis focused on is environmental collaborative policymaking (Puri, and Sahay, 2003; Owen et al., 2008) and the emerging participation of the community in natural resource management (Anderson et al., 2009; Jankowski; 2009). In table 2, we summarize papers published in the past ten years concerning PGIS.

Axes	Themes	Publications
Critical PGIS	Empowerment	Corbett & Keller (2005); Kyem. (2001).
	Ambiguities of PGIS	Dunn (2007);Elwood (2006);
Spatial planning	Urban planning	Elwood (2002); Hoyt et al (2005);
	Rural planning	Williams & Dunn (2003); Bahuer (2009);
Natural resource management	Strategies in local communities	Jankowski (2009);Anderson et al.(2009)
	Environmental collaborative policymaking	Puri & Sahay (2003); Owen et al. (2008)

Table 2. Papers published on PGIS

Even though empirical studies on implementation of PGIS are good for sharing experience, without systematic knowledge of its use, poorly designed PGIS is likely to be reproduced again and again, with negative social implications (Nyerges et al., 2002). Therefore, in the next section, we will present different frameworks used in the sense of consolidating PGIS research.

FRAMEWORKS OF ANALYSIS OF PGIS

We have identified two frameworks specifically addressing implementation of PGIS. The first one, developed by Corbett and Keller (2005), proposes to structure an analysis of empowerment resulting from PGIS implementation through a simple two-dimensional framework which incorporates two social scales (individual and community), and four catalysts of empowerment, (*information*, *process*, *skills* and *tools)*. The analysis of empowerment involves exploration of how different catalysts cause changes in capacity for empowerment at the individual and community levels.

The second framework, ,created by Sieber (2006), aims to provide guidelines for evaluating current PGIS activities based on four major themes found across the span of the PGIS literature: *place and people*, *technology and data, process* and *outcome and evaluation*.

In a sense, these frameworks are complementary and seek to encompass the complexity of PGIS in practice. However, we believe that the range of concepts presented by both authors is better framed in a recent paper written by Pozzebon et al., (2009) examining the use of information and communication technology (ICT) by communities. The framework is informed by a *structurationist view of technology, social shaping of technology and contextualism.* It combines three interconnected dimensions:

- **Context** - the identification of *relevant social groups* within a given community and the identification of the *technological frames* attached to them (shared and conflicting perceptions, assumptions, expectations and interests).

- **Process** - *negotiation* is the process corresponding to identification of occasions, spaces and mechanisms by which relevant social groups interact over time.

- **Content** – the result of the negotiation process (*technology-in-practice*), in order to recognize the nature of the *consequences*, both intended and unintended.

The Pozzebon's contextual dimension can be complemented by Sieber's conception of place (laws, culture, politics and history of the community) and Corbet and Keller's notion of skills and tools. Moreover, the process dimension as seen by Pozzebon et al., (2009) could be related to Sieber's and Corbet and Keller's views of decision-making structures. Finally, the content dimension, appears in Sieber (2006) as the pre-establishment of a set of outcomes expected and indicators. However we believe that many of the outcomes achieved are not deliberate and the use of indicators can sometimes be misleading, since some consequences of the technology in practice cannot easily be measured (i.e., growth in social capital).

Therefore, we suggest some adaptations of Pozzebon's framework (table 3), enclosing the concepts of place, as well as of skill and tools, in the contextual dimension. For better comprehension enfolding a multilevel perspective, we reorganized the contextual dimension, dividing it into two broader aspects, respectively, the institutional and interactional levels.

Dimension	Aspects
Context	*Institutional level* Laws, culture, politics and history of the community
	Interactional level Relevant social groups, technological frames, skills, tools
Process	Negotiation mechanisms
Content	Consequences of technology in practice

Table 3. Framework for PGIS analysis in communities (adapted from Pozzebon et al., 2009)

METHODOLOGICAL APPROACH

Our ontological assumption is that social reality is locally and specifically constructed (Guba and Lincoln, 1994). For purposes of this investigation, we applied an in-depth single case study (Stake, 2000) in Sierra Nevada project, Mexico. The rationale supporting this choice is that this case study represents a unique experience in terms of information technology's complex implications in communities. Since we will use the framework presented in the last section for the analysis, this research can be classified as an instrumental case study (Stake, 2000).

Data Collection

The main source of data is a series of interviews (table 4) carried out by one of the authors in August 2006 in Tlalmanalco (Mexico), during an immersion of approximately 1 week. The interviewees were selected according to the concept of relevant social groups, to their capacity to enlighten our investigation and, of course, to their availability.

Name / Group	Function	Number of Interviews
Pedro	Project coordinator	2
Elena	Project coordinator	1
Gisela	GIS coordinator	1
Delia	Projects design and communication	1
Rebeca	Field work coordinator	1
Guardianes de los volcanes	Students engaged in a project for environmental monitoring	1
Regidores	Municipal authorities	1
TOTAL		**8**

Table 4. Presentation of the interviewees

The interviews were semi-structured, in Spanish and English, and were tape- recorded and transcribed verbatim. It is important to note that a research protocol was built based on the research framework. In addition to the interviews, we had access to numerous documents, articles, doctoral dissertations, project material and PowerPoint presentations provided by the Sierra Nevada team. Finally, before and after the semi-structured interviews, a number of meetings with two of the founders of the Sierra Nevada Project occurred outside Mexico.

Data Analysis

The analysis of the empirical data comprised three phases, following Miles and Huberman (1994): data condensation, data presentation and elaboration, and verification of conclusions. We used NVivo® software to organize the set of data collected and assigned labels to the units of meaning according to the coding procedure, using the referential framework of Pozzebon et al., (2009) as guidelines. The use of inductive analysis enabled us to refine the framework through an iterative approach which never takes the initial frame for granted, leaving room for emergence of topics or dimensions which had not been initially considered (Berg, 2001).

CASE STUDY – SIERRA NEVADA PROJECT

In this section, we present the Sierra Nevada Project. We start by presenting the institutional and interactional contexts for creation of the project.

Institutional Context

The Sierra Nevada Project was officially created in 1997 in Tlalmanalco, a municipality of 45,000 people in Central Mexico between the Basin of Mexico and the Sierra Nevada Mountains (Figure 1). It is the result of a fruitful partnership between UAM and 12 municipalities, situated in the Sierra Nevada region.

Figure 1. Sierra Nevada logo and location

The entire region where Tlalmanalco is located is considered one of the world's most densely populated and critically threatened regions, primarily because it is situated directly in the ecological footprint of the Mexico City megalopolis. The external threats to the local environment started long ago but had reached their peak by the 1990s. The sense of localness was also disrupted, as uncontrolled sprawl from the metropolis threatens to transform Tlalmanalco from a predominantly rural area into a bedroom community.

Cruz and Freire (2001) argue that Mexican cities often lack the overall strategic vision and skills to tackle these problems in an integrated manner and that the upper levels of government often lack instruments to assist municipalities. One of the consequences of this institutional void is the growing number of non-profit organizations in such contexts.

In 1997, soil, water and atmospheric contamination, coupled with urban sprawl in the region, were leading it to an ecological crisis. That same year, with UAM professor Pedro Moctezuma as general coordinator, Sierra Nevada Project (figure 2) was established with the general objective of supporting local initiatives by applying academic research and inclusive techniques so as to transform the Sierra Nevada region into a green belt of micro-projects that would contain the encroaching city and halt environmental destruction of the region.

Interactional Context

In the interactional context we identified four main relevant social groups (figure 2): the Sierra Nevada team, the UAM researchers, governmental authorities and community organizations.

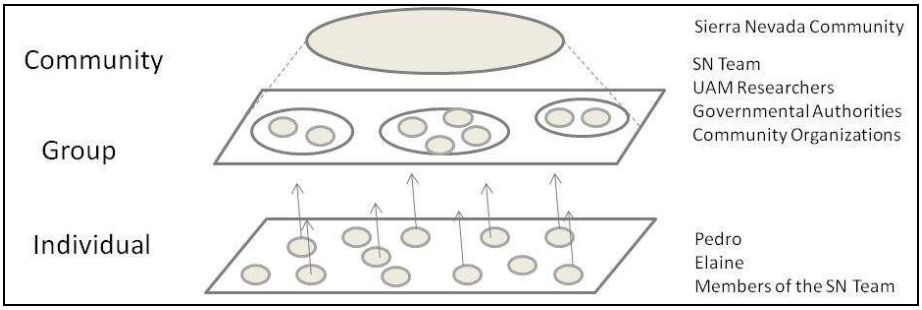

Figure 2. Relevant Social Groups in a Multilevel analysis

Rebeca, one of the members of the **Sierra Nevada Team,** highlights that although an external expert could provide good help in guiding the implementation of the technology, it was important to build competencies within the community since the aim is to develop competence through inclusive participatory methodologies. The PGIS is important to the project as a whole because it is seen as a means that can be put into practice with other sub-projects. "*Our whole project is able to survive in part because of the value of GIS products" (Elaine).*

What is particularly interesting at the individual level are the key roles of Pedro and Elaine in the creation and maintenance of the project. Through their social networks they established a partnership with the Universidad Autonoma de

Mexico (UAM). The group of **UAM researchers** are very relevant to the project in terms of legitimization. In turn, university professors have access to rich local knowledge and this contributes to their academic interests.

Another relevant social group is the **governmental authorities**, who use the PGIS Maps to help them with definition of territorial boundaries and natural resource planning for the region. The municipal authorities trust the maps generated by the SN Team but, at the same time, they see it as a kind of threat.

A number of formal and informal Sierra Nevada community groups have, in some way, been interacting with the PGIS technology as well. For instance, "**Guardianes de los Volcanes"** is group of 35 students participating in data gathering, monitoring of ecological sites and different types of training. Another example, are the **"Ejidatarios" and rural producers**, who participated actively in data gathering for the municipal atlases. In general terms, the community trusts the project and sees the technology as something genuinely relevant and advanced.

Table 6 summarizes the results of our analysis of relevant social groups based on the conceptual framework. For each group, we outline its technological frames and most relevant skills, as well as the tools it mobilizes.

Relevant social group	Technological frames	Skills	Tools
SN Team	✓ GIS supports the whole project financially	✓ Skills to operate GIS should be built internally	✓ Inclusive-participatory methodology
UAM Researchers	✓ Academic research is better done synthesizing local and technical knowledge	✓ Technical expertise	✓ Official resources (Aerial and satellite photos, existing official maps)
Governmental Authorities	✓ Maps are valuable when endorsed by the university	✓ Don't have skills to use the GIS, but participate in the data gathering and use the information	✓ Contracts
Community Organizations	✓ Maps are advanced and relevant ✓ A tool for ecological change	✓ Some of them have skills to use the GIS, many participate in the data gathering	✓ Inclusive-participatory methodology

Table 5. Interactional context of Sierra Nevada PGIS Project

For the analysis of the process and content dimensions that follow, we note that this understanding is derived mainly through the perspective of one of the relevant social groups, the Sierra Nevada Team.

Process

It is possible to identify the following processes concerning information generation, transformation and distribution:

a) **Local knowledge sharing** - the community shares indigenous knowledge with the non-profit organization, based on expectations of local development;

b) **Local information gathering** – the non-profit organization gathers information from the local community. This process is only possible with mutual trust and respect, which can be achieved over time through an inclusive-participatory methodology;

c) **Local and technical information synthesising** – with their technical expertise, the university's researchers synthesize the local information gathered, supported by resource-dependent data mobilized through the funding granted by governmental authorities.

d) **Global information providing** – through the synthesising process, the information is legitimized and turned into global information, used to support public policies.

e) **Global information sharing** – this global information finally comes back to the community and serves as a tool for capacity building and local development.

Pedro highlights that they have been able to survive and grow mainly due to their strategy of involving many different actors in the process. The principle of inclusiveness draws on the know-how of not only local people but of other participants, including university professors, regional experts, government representatives and the private sector. At the same time, he thinks it is important to build consensus in the group.

> *We always work with very inclusive group. (…) there is a peasant, and there is a teacher, and a local authority, we put everybody together to talk about things(…) always working with consensus building. (…) And so, when there is no-consensus on something we really don't find it useful to insist. (Pedro)*

Figure 3 aims to represent the social use of PGIS in Sierra Nevada, which results from the combination of technical and local knowledge, in a consensus-building approach.

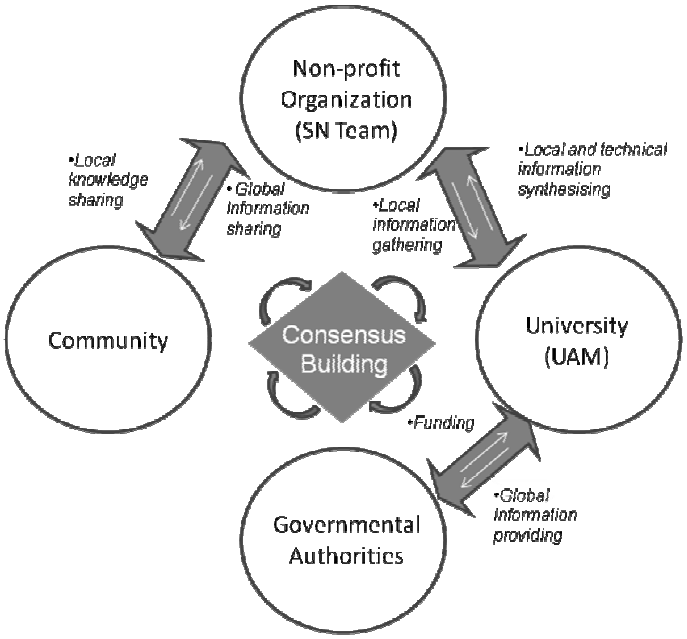

Figure 3. Sierra Nevada Process

One example of this interaction in our case is a project called "*Ordenamiento Ecologico*[1]". The government funded research enabling the university to create maps to support policy decision making. The community came together in participatory workshops and decided, along with the university experts and local authorities, which were the best uses for each part of the land. Finally, this enriched and legitimized map turned into an official government plan.

> *It is a strategic planning (…) linked to telling what you can and cannot do in the units of territory. And then our (maps) are very carefully made according to criteria in the communities that decided (…) What is the optimal use? And how do we make it happen? (…) I'm not saying here … that the university's legitimizing a little map that somebody draws on a piece of paper…I mean the university applies all the technical material. It uses the GPS; it uses soil analysis, it uses satellite images and all that the university has. But it combines and recognizes, and confirms, and synthesizes local knowledge which is incredibly rich… (Elaine)*

Content

The content consists of the results or consequences of the use of technology. What follows are some of the consequences identified by one of the relevant social groups, the Sierra Nevada Team.

a) Community awareness and empowerment

The community derives enormous benefit from the maps produced along with the SN Team and the university. The GIS used in participatory way can serve as a tool to promote awareness of the territory and empowerment of the community. Students, teachers, farmers, local producers, associations, eco-tourists and authorities have joined other academic and political bodies as users of SN maps. That is why the SN Team created a documentation center, a channel by which global information comes back to the community.

For instance, the community has access, at no cost, to a publication called *"Atlas municipal de recursos naturales" (Municipal atlases of natural resources)* for the six municipalities in the region, containing information on opportunities and challenges related to natural resource management. The maps also include information about the "ejidos[2]". This was a result of carefully gathering each small piece of information about land boundaries and can be seen as a way to reconnect people to their lands by recovering ancient traditions.

> *Rebeca trained (the ejidatarios to use the GPS)… Because in Mexico when the (...) "Comisariado ejidal", delivered the responsibility to the next committee, they would go around the boundaries of the "ejido" to recognize their own land. But this tradition was lost and some people didn't even know where the land started or where it finished… And also there were some conflicts in different communities because of the borders. And so, what Rebeca organized allows*

[1] « Ordenamiento ecologico", or, Ecological Ordering is a public initiative by the Mexican government since 1988 that establishes a planning process aiming to find the best uses for land. More information available on: http://www.semarnat.gob.mx/queessemarnat/politica_ambiental/ordenamientoecologico/Documents/documentos%20ordenamiento/manual_poe.pdf

[2] Up to 1970, much of Mexico's agriculture was self-sufficient and involved community-owned lands (*ejidos)*. The *ejidal* authorities built schools, water systems, chapels and sport areas. Currently, chaotic urbanization on *ejido* lands displaces agricultural uses and government policies have sought to dismantle the *ejido* in order to privatize it. (Moctezema, 2001).

> *the new authorities to go and walk the borders of the land with the GPS, and so to produce their own maps and to know exactly where the land was and where they have rights. (…) (The recovered this sense of belonging and empowerment to control their own communal plans. (Pedro)*

In this sense, *ejidatarios* now use the municipal atlases that were developed as if they were miniature bibles. *"With the information contained in these atlases they can now defend their lands" (Delia).*

b) Environmental and territory policies influencing

The increasing use of SN maps by municipalities and other governmental institutions is allowing the Sierra Nevada Project to exert a significant influence on environmental and territorial policies of the region, which, of course, is part of its mission. Their unique expertise on the use of the GIS in the region has had important consequences: *Having GIS technology has put us in the market, with a high value. And it's allowed us to have intervention in terms of government policy for this region.(Elaine).*

The development of the project "*Ordenamiento Ecologico*", presented in the last section, is one good example. The fact that SN maps exercise a strong influence on governmental plans and policy making is referred to as "bottom-up" law enforcement by the SN Team.

c) Financing for other sub-projects

GIS maps are often very expensive and the Sierra Nevada team, in partnership with UAM, is able to attract profitable governmental contracts. For municipal, regional and federal governments, each map or contract involves either a market-level price or an exchange for aerial and satellite photos which the Sierra Nevada team needs to enhance the precision of their maps.

Therefore, even though it was not planned that way, SN maps represent an important part of what the Sierra Nevada team can offer. The revenue it earns from such activity finances other Sierra Nevada sub-projects, some of which are unprofitable.

d) Spillover effects for new communitarian projects

For the local community, the maps are available for free and this leads to unintended spillover effects for other groups' projects on environmental management, such as "*Pueblos originales de la región de los volcanes*" (or *Native people from the volcanic region*), concerned with water improvement in the region:

> *I am a member of this social organization… and I have seen the impact of the technology outside the project. It is really motivating to be able to have access to this type of information… We are establishing a council for water management and this information is essential for us in our project. (Delia)*

The consequences of technology in practice are listed in the table 6, divided into intended and unintended outcomes, as follows:

Intended	Unintended
- Community awareness and empowerment	- Financing for other sub-projects
- Environmental and territory policies influencing	- Spillover effects for new communitarian projects

Table 6. Consequences of Sierra Nevada PGIS Project

CONCLUSIONS AND IMPLICATIONS

In this article we have tried to uncover the social use and consequences of PGIS in communities. To be able to achieve this purpose, we enriched a framework developed by Pozzebon (2009) and used it to analyze an application of this technology in a community in Sierra Nevada. The institutional and interactional contexts somehow stimulated establishment of the project. Given evidence of the real need for a response to growing social, economic and environmental problems in a context with problematic institutions, it is possible to understand why this project, committed to local beliefs and traditions, took hold.

Concerning the process, we believe that the mutual respect developed among the socially relevant groups - especially among the community, the Sierra Nevada team and the researchers - was key to the success of the project. With a process that aimed at effective participation by the different actors, the maps designed gained legitimacy.

In terms of consequences, the use of the maps generated through the PGIS tool allowed community members access to global information that they otherwise wouldn't have. More importantly, the GIS technology applied locally with a focus on competence building changed the community's perception of their own resources, enhancing their capacity to generate, manage and use local and global information. This ultimately resulted in community empowerment, since the maps offer a means to dialogue with governmental institutions in terms of spatial and natural resources management in the region.

The results of our study draw attention to the implications of using PGIS not only as a technological tool in the narrow sense, but as a methodology with the potential to engage people across different social groups, even if they have distinct interests and skills. Therefore, the consequences of its use for the communities are more likely to be related to the effectiveness of the underlying learning and emancipation processes.

In terms of a contribution for PGIS practitioners, we recommend special attention to the role of mechanisms that enhance the legitimacy and accuracy of indigenous knowledge. In our case, this was achieved through the partnership with the university. Furthermore, we believe that capacity building within the community is unquestionably essential to achieve a higher level of participation and empowerment.

From a theoretical perspective, the enriched framework used to guide our analysis of the case could be replicated for the analysis of other PGIS experiences. It is likely that, in future research, the application of this framework on in-depth cases would provide new elements for the better comprehension of social use and consequences of technologies in communities.

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