

Mapping What Matters: Participatory GIS as a Method for Water Governance in Data-Poor Mountain Regions

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Abstract

Sound water governance depends on knowing where water is, how it moves, and who depends on it, yet in the mountain regions of the Global South this spatial knowledge is largely missing, and the dispersed springs and small sources that communities rely on lie beyond the reach of formal mapping. This paper argues that participatory geographic information systems offer a rigorous and practical method for generating that missing spatial knowledge, and that they should be treated not as a consultative add-on but as a core methodology for water governance where conventional data are absent. It sets out why mountain water governance is data-poor, what participatory GIS and volunteered geographic information contribute, and how their outputs can be made analytically robust and consequential rather than merely illustrative. The paper develops a methodological framework in which communities and analysts co-produce a spatial knowledge base of local water systems, that base is integrated with formal geospatial layers and multi-criteria analysis, and the resulting maps are routed into governance decisions with the community retaining authority over its own knowledge. The framework is illustrated through the mapping of springs and traditional water structures in the Kumaon Himalaya. Its contribution is to convert the local, often undocumented knowledge that mountain communities hold about their own water into a governable spatial resource, transferable to data-poor regions across the Global South.

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INTRODUCTION

To govern water is, in large part, to act on spatial knowledge: to know where sources are, how catchments drain, which settlements depend on which supplies, and where the resource is under stress. In the data-rich settings for which most water-management tools were built, that knowledge is supplied by gauging networks, cadastral records, and official maps. In the mountain regions of the Global South, it is largely absent. The springs, naulas, and small sources on which hill communities depend are typically unmapped, their catchments undelineated, and their condition unrecorded, so that the authorities charged with managing mountain water must act on a resource they cannot fully see (NITI Aayog, 2018; Scott et al., 2019). This data poverty is among the deepest obstacles to mountain water security.

Yet the knowledge is not truly absent; it is undocumented. The communities that live with these sources hold detailed, place-specific knowledge of where springs emerge, how their flow changes with the season, and how the local water system behaves, knowledge accumulated over generations of dependence. The methodological question is how to convert this dispersed, informal knowledge into a spatial resource robust enough to guide governance. This paper argues that participatory geographic information systems, understood within the wider field of volunteered geographic information in which citizens act as generators of geographic knowledge (Goodchild, 2007; Haklay, 2013), are the method suited to that task, and that in data-poor mountain regions they deserve to be treated as a core governance methodology rather than a token of consultation.

The paper sets out the data-poverty problem in mountain water governance, reviews what participatory GIS and volunteered geographic information offer and the concerns they raise, and then develops a methodological framework in three parts: the co-production of a spatial knowledge base, its integration with formal geospatial analysis, and its routing into governance with community authority preserved. It illustrates the framework through spring and traditional-structure mapping in the Kumaon Himalaya. The contribution is methodological and conceptual, and the illustration is an application of the method to a documented setting rather than a report of fieldwork.

2. The data-poverty problem in mountain water governance

Mountain water governance is data-poor in a specific and consequential way. Conventional hydrological monitoring is sparse in mountains because the terrain is difficult, the population dispersed, and the sources numerous and small, so that official networks that adequately gauge a large lowland river leave the individual springs of the hills unobserved (Buytaert et al., 2014; Njue et al., 2019). The resources that matter most to hill communities are therefore precisely the ones least represented in the data available to those who govern them. The consequence is governance that proceeds on inference: interventions are planned without knowing which sources are failing, protection is not targeted because recharge areas are undelineated, and communities cannot substantiate the claims they make about their own water. Filling this gap with conventional methods is prohibitively slow and costly, which is what makes an alternative, community-based route to spatial knowledge not merely attractive but necessary.

3. Participatory GIS and volunteered geographic information

Participatory GIS refers to the use of geographic information tools and methods in ways that engage communities directly in producing, analysing, and using spatial information about their own environments. It belongs to the broader phenomenon of volunteered geographic information, in which non-professionals generate geographic data, a phenomenon that has reframed citizens from consumers of maps into producers of them (Goodchild, 2007). The participation involved can range from communities supplying local knowledge that experts map, to communities themselves collecting and using spatial data, a spectrum of engagement that has been carefully typologised (Haklay, 2013). For water governance in data-poor regions the appeal is direct: participatory methods can generate, quickly and at low cost, exactly the fine-grained spatial knowledge of local sources that formal networks lack, and they do so by mobilising the detailed local knowledge that communities already hold. The evidence from citizen science more broadly is that such community-generated data, when the process is well designed, can meet high standards of reliability (Kosmala et al., 2016), so the method's outputs need not be treated as merely anecdotal. The recurring concern, that community-generated information is under-used by formal institutions, is a matter of governance design rather than of the data's quality (Carlson & Cohen, 2018).

4. APPROACH

The paper treats participatory GIS as a methodology to be specified rather than a principle to be endorsed, and it develops that specification in three linked parts that answer three questions: how to produce a robust spatial knowledge base with communities, how to make that base analytically powerful by joining it to formal geospatial data, and how to ensure it changes decisions while remaining under community authority. The specification is guided by two commitments. The first is rigour, so that the participatory origin of the data is a source of richness rather than an excuse for looseness, with protocols, validation, and documentation applied throughout (Kosmala et al., 2016). The second is authority, so that communities retain ownership of and a decisive voice over the knowledge they generate, which is both an equity requirement and a practical condition of the method's durability (Haklay, 2013; Goodchild, 2007).

5. A METHODOLOGICAL FRAMEWORK

5.1 Co-producing the spatial knowledge base

The first part assembles, with the community, a spatial knowledge base of the local water system. Community members locate and characterise their springs and traditional structures, describe seasonal behaviour and use, and delineate, from lived knowledge, the areas they associate with recharge, while analysts provide the geospatial tools and the protocols that make the resulting data consistent and verifiable. The output is a documented, georeferenced account of the local

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water system that did not previously exist in any formal record. Because the knowledge originates with those who depend on the sources, it captures detail, such as which springs fail first in a dry year, that no external survey would readily obtain, and applying a consistent protocol and validation to its collection is what raises it from anecdote to data (Kosmala et al., 2016; Buytaert et al., 2014).

5.2 Integrating with formal geospatial analysis

The second part joins the co-produced base to formal geospatial layers and analytical methods, so that local knowledge and scientific data strengthen one another. Community-mapped spring locations become ground truth against which terrain, drainage, and land-cover data are interpreted; community-delineated recharge areas become hypotheses that a formal catchment analysis can test and refine; and where interventions or protections must be prioritised, the combined information can feed a transparent multi-criteria analysis of the kind widely used in spatial water planning (Malczewski, 2006; Saaty, 1980). This integration is the step that gives participatory GIS its analytical power: it neither romanticises local knowledge as sufficient on its own nor dismisses it in favour of remote data, but combines the two into a spatial picture more complete than either could produce alone.

5.3 Routing knowledge into governance

The third part ensures the resulting knowledge changes decisions. This requires defined channels through which the co-produced maps enter the planning of source protection, the prioritisation of revival, and the allocation of water, and it requires that the community retain authority over its knowledge as those maps travel. Absent such channels, participatory mapping produces attractive outputs that sit unused, the same failure that leaves so much community-generated data inert in the wider field (Carlson & Cohen, 2018). Designing the pathway from map to decision, and safeguarding community ownership along it, is therefore integral to the method rather than a subsequent concern, and it is what distinguishes participatory GIS as a governance methodology from participatory GIS as an exercise.

6. Illustrative application: the Kumaon Himalaya

The framework can be read through the Kumaon Himalaya, where spring-dependent communities possess deep knowledge of local water systems that exists in no formal record. Applying the method, communities would co-produce a georeferenced base of their springs, naulas, and dharas, recording seasonality, use, and the recharge areas they recognise from experience. That base would be integrated with terrain, drainage, and land-cover data to delineate and test spring catchments and to prioritise, through transparent multi-criteria analysis, the sources whose protection or revival offers the greatest benefit (Malczewski, 2006; Saaty, 1980). The resulting maps would then feed the governance of the belt's water, informing catchment protection and the targeting of spring-shed interventions of the kind demonstrated in the region (Tambe et al., 2012; NITI Aayog, 2018), with the communities retaining authority over the knowledge they created. The product would be a spatial knowledge base for water governance where none existed, built from the community's own knowledge of its own water. As elsewhere in this paper, the application illustrates the method rather than reporting mapped results, which implementation would yield.

7. DISCUSSION

The framework's claim is that in data-poor mountain regions the spatial knowledge on which water governance depends is not absent but undocumented, and that participatory GIS is the method for converting it into a governable resource. Three points follow. First, the approach reframes participatory mapping from consultation to methodology: with protocols, validation, and integration into formal analysis, its outputs are robust enough to guide decisions, not merely to illustrate them (Kosmala et al., 2016; Goodchild, 2007). Second, it addresses the binding constraint directly, generating the fine-grained spatial data that mountain water governance lacks and that conventional methods cannot supply affordably (Buytaert et al., 2014; Njue et al., 2019). Third, it embeds equity in method, placing the production of and authority over spatial knowledge with the communities whose water is at stake (Haklay, 2013), an arrangement consistent with the nexus insistence that resources be governed with, not merely for, those who depend on them (Hoff, 2011; Grey & Sadoff, 2007). The limitations are real. Participation is not automatically equitable, and the design must guard against local power imbalances shaping whose knowledge is recorded. Sustaining the process and the currency of its data requires institutional support. And the routing of community knowledge into official decisions depends on institutional willingness to accept it (Carlson & Cohen, 2018). These define the agenda for a pilot through which the protocols, the integration, and the governance channels could be established and tested.

8. CONCLUSION

Water governance in the data-poor mountains of the Global South is hampered less by an absence of knowledge than by the fact that the knowledge which exists, held by the communities that depend on the sources, is undocumented and so ungovernable. This paper has argued that participatory GIS is the method for closing that gap, and that it deserves to be treated as a core governance methodology rather than a consultative gesture. The framework it proposes co-produces a spatial knowledge base with the community, gives it analytical power by integrating it with formal geospatial data, and makes it consequential by routing it into decisions while preserving community authority. Illustrated through spring mapping in the Kumaon Himalaya and transferable across data-poor regions, the approach turns what mountain communities know about their own water into a resource their governance can use. Its promise now rests on implementation, and on the institutional willingness to let communities map what matters to them and to act on the result.

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