# Participatory Geographic Information Systems (GIS): The future of environmental GIS?

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## 1 Introduction

The past decade's use of geographic information systems (GIS) for environmental research has largely been viewed as a critical success both by GIS practitioners and their scientific peers (Maguire *et al.*). The spatial representation of information gives GIS unique analytical abilities and gives the results it generates added power and perceived authority (Wood). A recent criticism of this success is that it has been achieved by tackling the 'easy questions' (Harris *et al.*). Social and cultural information has largely been excluded from environmental investigations. GIS technology has been used to reinforce top-down, 'expert' analysis of development issues. The power of GIS has been accused of supporting the status quo in society by limiting information access to select groups. The GIS community is making attempts to answer these criticisms through the development of new approaches involving increased 'local' participation and the representation of multiple realities for single issues.

This paper intends to examine the traditional uses of GIS in environmental analysis and the criticisms targeted at such approaches. The new techniques being developed to address these failings will be described and the potential future applications for these participatory GIS discussed.

## 2 Traditional Environmental GIS

For the purposes of these discussions a GIS has been defined as; a means of integrating spatial and non-spatial information into a single computer system for analysis and graphical display. The system is housed and maintained within an organisation and as such reflects its mandate.

This last organisational aspect is of crucial importance and often overlooked in assessments. Value judgements must be made in the initial selection of data and its future use and management. The basis for these judgements is often related to the ideology of the organisation in which the GIS is housed. The idea of objective GIS is therefore a flawed concept (Harris *et al.*).

The methodology employed within traditional environmental GIS can be characterised as 'top down'. Outside 'experts' set the agenda of what the goals are and the information relevant to realising them. The viewpoint of the analyst to this process is crucial as there is generally no one solution and the choices to be made on data collection and analysis techniques are vital to the outcome. Part of the historical justification for this exclusive

process has been the high costs related to GIS analysis. This has made the systems available only to wealthy institutions rather than a wider community. This elitism has led to the calls that GIS is undemocratic as it accumulates information into the ownership of a select few (Harris *et al.*, Dunn *et al.*). Without equity of access to the information and technology of GIS small, or less wealthy groups, (both financially and technologically), have been disadvantaged in their ability to fully engage in the process by which decisions utilising spatial analysis have been made (Harris *et al.*).

Despite these concerns traditional GIS has been employed increasingly widely over the past decade to investigate environmental issues. The perception of 'expert' reviewers is that, in general, these applications have been a success (Maguire *et al.*).

It may be supposed that these successes have generally been in areas where physical environmental processes are the primary factors. However, even here problems can be identified. Weiner provides a specific example of how 'top down' environmental GIS approaches can be exclusive, undemocratic and only present one answer to a problem with multiple solutions. During the former apartheid era in South Africa's Soil and Irrigation Research Institute a maximum 12 percent slope angle for ploughable land was set. This was based on the requirements of mechanised cultivation and GIS land suitability analyses was carried out accordingly. This slope angle reflected the Institute's viewpoint and constituency as hand hoeing and animal ploughing, as practised by the majority of black farmers, allows cultivation on much steeper slopes. The information created by this analysis was therefore undemocratic as the data on which it was based excluded a large percentage of the local user base without explicitly stating that this solution represented only one of many possible answers.

This example illustrates the concerns raised over the traditional application of GIS technology to environment and development issues. That is, these issues cannot be addressed without reference to the users of the resource being investigated and the constraints, both social and physical, within which they operate. In order to address some of these concerns new approaches are currently being developed to integrate local expertise and perception into a GIS framework.

## 3 Participatory GIS

Traditional GIS has been accused of not fully addressing and incorporating social issues although this deficiency has been blamed on society's priorities rather than inherent limits in the technology itself (Weiner *et al.*). GIS practitioners have created digital representations of social and natural phenomena that best reflect their (singular) expert viewpoint (Weiner *et al.*). Recently, attempts have been made by a number of independent studies to address these concerns and build what have been described as participatory GIS (P-GIS).

Three particular studies have been identified (and will be referred to here) that have explicitly attempted to include participatory techniques in the GIS process. These are:

The Kiepersol GIS (Eastern Transvaal, South Africa) (Weiner *et al.*); the Namibian Wildlife GIS (Tagg *et al.*) and the Namaqualand GIS (Northern Cape, South Africa) (Cinderby *et al.*).

All three have been developed in the Southern African region to engage local interest groups in the policy formulation process on a more even footing with government management organisations. The grouping of all three projects in this geographic region may be a reflection of the rapid political and social changes occurring in the area. These changes are allowing the possibility for new ways of communication to be fostered and have led to increasing emphasis being placed on the democratisation of the development process.

Participatory techniques have been developed as a way of enhancing local peoples abilities to share and analyse their knowledge of lifestyles and conditions thereby better enabling them to plan (Chambers). Empowering people to act has been considered part of this process. Truly participatory studies have not been intended for outsiders to learn about local conditions but instead to facilitate local people to conduct their own analysis and develop their own agendas (Chambers).

Within these overall ideals, the three studies have developed to enhance local communities' abilities to engage in the policy development process. A number of similarities become apparent when investigating the techniques utilised by the three projects.

Firstly (and obviously), the P-GIS attempt to promote 'bottom up' policy development by incorporating local concerns and knowledge within a spatial database. A technique common to all three studies has been the utilisation of perceptual maps of the local conditions produced by different sectors of the communities being engaged. Such 'mental' maps are a common technique in traditional participatory analysis (Chambers). The new dimension here is the incorporation of these perceptions of the environment within a GIS database. The production of such perceptual maps typically involves members of the local community drawing features of interest in a workshop. The features selected for inclusion are dependent on the community group with or without guidance from an outside facilitator. Once produced the meaning of the features represented on the maps can be interrogated during interviews and the maps subsequently enhanced to illustrate any greater understanding thus generated.

The use of spatially referenced base data, such as paper thematic maps or air photography, has allowed these mental maps to be integrated into a GIS. The incorporation of mental maps into a digital database allows the use of traditional GIS techniques to analyse these unique data sets. By overlaying numerous individuals, or groups, mental maps of the local conditions, differing perceptions of the importance or varying access rights to resources and potential areas of conflict can become all the more explicit. This combination of different perceptions allows for the investigation of the multiple realities of a single issue. For example, in the production of the Namaqualand GIS community groups from four different neighbouring villages independently produced maps detailing their use and access to communal grazing land (see figure 1 and 2). By overlaying these four maps within the GIS it was possible to highlight areas of conflict on resource use, where the perceived villages boundaries overlapped (see figure 3). This process enhanced the local people's information of how they utilised the local resource base. It also presented it in a form more useable and understandable by outside government agencies empowering the community as they engaged in the land reform process.

Figure 1. During interviews and workshops farmers produced maps detailing their perceptions and use of the resources in the communal area of Namaqualand, South Africa.

Figure 2. An example of the type of information indicated on the perceptual maps drawn by the Namaqualand farmers.

Figure 3. The 'boundaries' indicated on the perceptual maps of four neighbouring communal villages were overlaid.

The second common technique utilised by the three studies has been the incorporation of traditional 'top down' agency produced information. In the Kiepersol GIS, a land types map was integrated with the community's perceptual information. The perceptual maps indicated soil conditions as well as access rights to land for the black farmers of the area. The integration of the two types of data was useful as it highlighted disagreements in the government agency assessment of land potential in the area and the local farmers' perceptions of the same issue. The comparison showed broad agreement between the state assessment of soil conditions and that of the higher resolution knowledge of the local communities. The integration, however, highlighted the importance of land and water access as the true limiting factors to farming potential in the area, rather than soil capability. Access to land within the bantustans is partly controlled by the chief who allocates fields to specific farmers. The perceptual maps revealed this, indicating how social mechanisms also affect farming practise.

In the Namaqualand GIS, information on water quality produced by a hydrological surveyor was combined with perceptual maps indicating water resource types and their typical use, such as a household water bore hole (see figure 4). The combination of the different data sets enhanced the understanding of both the local community and the surveyor. The perceptual maps indicated far more water points than had been identified by the outside agency. The maps also indicated what use the water was being put to which was largely unknown to the surveyor before the comparison was made. The data on water quality was useful to the local communities as various contaminants exist in the local water bodies. By highlighting where water quality is highest the use of wells for human consumption could be reassessed and the case for better water supplies made more powerfully to the provincial authorities.

Figure 4. The combination of the local knowledge of water supplies with hydrological surveys of water quality gives a unique insight of potential health problems in the Namaqualand communities.

This combination of perceptual and traditional spatial data allows for increased communication both internally within communities and externally with outside groups. Maps can be seen to represent a more universal visual language. The P-GIS information helps to facilitate greater shared understanding and can enhance local groups' positions when negotiating with outside agencies (Tagg *et al.*).

## 4 Advantages & Criticisms

The potential of incorporating participatory approaches within a GIS appears to offer a solution to the criticisms levelled at traditional 'top down' spatial analysis. These include the undemocratic nature of GIS analysis and the representation of single solutions to multiple reality issues.

The development of P-GIS allows these multiple viewpoints to be accommodated within a single frame of reference. Perceptual maps can help to describe communities' knowledge of their local environment in a form intelligible both to members of the group and also outsiders. Evidence from the three studies investigated indicates that local environmental knowledge is of high quality when compared to data compiled by outside experts (Weiner *et al.*, Cinderby *et al.*). It also holds numerous advantages when compared to traditional spatial data sets. Perceptual maps contain information unobtainable from other environmental data on the social settings for resource use. This can provide insight into the varying perceptions of, and access right to, a resource by different sectors in a community.

For example, as part of the Namaqualand GIS, Landsat satellite imagery was classified to show the levels of green biomass and the types of land cover present across the four villages being investigated. When these data sets were compared to the village assessments of grazing quality the same patterns were broadly differentiated (Cinderby *et al.*). The village assessments however contained additional differentiation based on social factors. For example, an area of average grazing land was found to have physical conditions that should have classified it as the good grazing according to the satellite assessment. However, the mental maps showed the area to be perceived as prone to jackal attacks on livestock. This factor had reduced its attractiveness to the herders. This type of information is unavailable on traditional spatial data sets.

The combination of existing environmental information with that obtained from the users of the resource allows greater insight into the limitations and possibilities for its local development. By combining these multiple viewpoints visually increased clarity of communication can result. This allows the potential for local groups to engage on a more level footing with outside agencies.

Potential problems do exist with the integration of GIS within participatory studies. In order to facilitate the use of mental maps in a GIS some kind of geographically referenced base map has to be utilised. Whilst this technique has been used in traditional participatory surveys it is unclear whether the imposition of a base map forces a certain view of the world on the surveyed group. Constraining people in this way may reduce or restrict what they would discuss if they had been given a blank sheet to draw on. The extent to which this is a factor and how it varies amongst different groups (spatially, culturally and with age and gender) is unclear and requires further investigation (Wood).

Techniques exist within GIS that allow for the representation of indistinct (fuzzy) classes for handling qualitative data rather than forcing it into restrictive quantitative classes (Maguire *et al.*). The perceived accuracy of fuzzy results generated on a computer in this way may represent a problem. If results are presented without building the capacity of the participating groups to understand the limitations of any analysis, then conflicts within a community could be exacerbated by the use of P-GIS. If the boundaries drawn on maps are perceived as distinct, as opposed to fuzzy, by participating communities they could polarise any conflict into arguments over lines on the map. The P-GIS should be used to drive discussions rather than be an end in itself.

Chadwick and Seeley indicate a potential problem with the utilisation of perceptual information. They investigated local farmers soil classifications in Nepal and their use in

quantifying soil properties across regions. They point out that little is known about whether the limits to soil criteria as expressed by the local farmers are absolute or relative. This problem of scale is particularly pertinent to P-GIS where multiple perceptual maps over a wide geographic area could be combined. The extent to which an individual's or group's perception of conditions in a location is comparable with an assessment by a different group in another (although physically similar) region is unknown. For example, does good grazing land mean the same to villagers from one location as it does to those from another adjacent location or is it dependent on the range of conditions to which they are accustomed? Further investigation will be required to address this complex issue and it is likely that the results will be case specific. Care must therefore be taken when combining perceptual information over a wide geographic extent.

As with all forms of participation it must also be considered who is participating. Communities are not homogenous groups. When engaging with them it is possible (even probable) that powerful individuals will dominate the communication. Care must be taken that the viewpoints of different groups are given equal weight, where possible.

The final criticism of P-GIS is the extent to which it really is participatory. Participatory studies are intended to enable local people to conduct their own analysis, develop plans and take action (Chambers). The extent to which it is possible to achieve these ideals utilising GIS techniques is a matter for debate. Kumar *et al.* complained that GIS is a 'social process which imposes a quantitative rather than a qualitative view of space and can lead to the worst form of positivism'. The nature of GIS technology at present still requires the extraction of data and its analysis by people skilled in their operation. However, as the case studies show if carried out in collaboration with the communities this analysis can assist in empowering them with information unavailable by other means. The use of fuzzy logic for analysing qualitative classes removes the need to force this type of data into a quantitative framework for analysis. The complaints levelled at GIS seem, therefore, to be aimed not at the technology but its use. The key to the successful implementation of P-GIS activities rests with the process of partnership between spatial analysts and local groups. The local groups set the agenda and the outside experts facilitate the analysis. In this respect the techniques described should more accurately be called GIS for participation rather than truly participatory GIS (Harris *et al.*). In this way the use of GIS for local planning becomes a tool to help communities in their communication internally, between groups, and externally rather than a rod used by outside experts to beat them into agreement with the 'expert' viewpoint.

## 5 Conclusions

As with the development of participatory techniques in other disciplines the development of P-GIS within the spatial analysis and environmental planning community is liable to be a slow, possibly painful, process. The techniques described here represent some of the first steps in this evolution. The techniques appear to offer a new and powerful way of engaging local groups in the planning and decision-making process on a more equal footing with outside technologically endowed agencies and organisations. The spatial representation of issues allows unique communication of viewpoints on a range of issues by different sectors of society.

Traditional environmental GIS has been described as a success. This may be because it presented single 'definitive' solutions to complex problems. When multiple viewpoints on environmental issues are included in the analysis it remains to be seen whether GIS will offer the same attractiveness to the decision making process. There is a risk that it will lead to information overload. However this democratisation of spatial analysis will at least make more explicit some of the choices that have been made in achieving a decision. In this respect participatory GIS offers some unique insights and challenges to the planning and policy process.


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