EJISDC (2004) 17, 3, 1-13

Integrating Indigenous Knowledge and GIS for Participatory Natural Resource Management: *State-of-the-Practice*

Nitesh Tripathi
School of Natural Resources and Environment
University of Florida
Nitesh_t@hotmail.com

Shefali Bhattarya
Department of Urban and Regional Planning
University of Florida
Shefalibhattarya@hotmail.com

Abstract

Experience has shown that development efforts that ignore indigenous knowledge (IK), local systems of knowledge, and the local environment generally fail to achieve their desired objectives. IK systems are becoming extinct because of rapidly changing natural and social environments. A Geographic Information System provides a framework to document and store indigenous knowledge meaningfully. Participation by the local community in development initiatives is critical for achieving sound natural resource management to utilize the full potential of IK systems. The main premise of this paper is to review the literature available on the approach of integrating indigenous knowledge with Geographic Information Systems as a way of promoting participatory natural resource management and giving opportunity to the local community to participate in development programs and decision-making both as contributors and as users of knowledge.

Keywords : Indigenous Knowledge, Participatory Natural Resource Management, and Geographical Information Systems

1. INTRODUCTION

The complex nature of sustainable natural resource management demands research that uses a systems approach; i.e. research that is interdisciplinary - combining bio-physical and socio-economic dimensions, and attempts to understand the interrelatedness of system components (Barr and Dixon, 1998). Community based participatory natural resource management is being adopted widely as a possible solution to address such complex problems. Also, participation and knowledge of local groups (e.g. farmers, peasants) is understood to be a valuable resource in community level natural resource management, decision making and policy planning processes.

It is generally recognized that indigenous knowledge (IK) plays an important role in the sustainable management of natural resources and can also have an impact on issues of global concern. This recognition is directly related to the growing realization that scientific knowledge has contributed very little to the development of communities and societies; in fact it has commonly hastened the depletion of their social and natural resources (Murdoch and Clark, 1994; Norgaard, 1992; FAO, 1990; Ulluwishewa, 1993). The potential disappearance of indigenous practices could have a negative effect primarily on those who have developed them and who make a living through them. A greater awareness of the important role that IK can play in the development process is likely to help preserve valuable skills, technologies, artifacts and problem solving strategies among local communities. It is a belief that indigenous knowledge and scientific technical knowledge can complement their strengths and weaknesses (Ogunbameru and Muller, 1996).

The documentation and mapping of indigenous knowledge and traditional knowledge is intended to preserve and honor knowledge held by local indigenous people, people whose ancestors have long inhabited a region, or people who are new to a region and bring their own traditions to a new community. However, the collection of information from diverse indigenous sources is often a laborious, time-consuming and costly process. Proper storage and management must be ensured if the information is to be made available and accessible for quick analysis and manipulation to all those who need it, e.g., planners and decision makers involved in the management of land resources.

GIS is capable of performing these functions and is widely used in the management of information for planning and decision making purposes. GIS also makes it possible to create, analyze and process different scenarios, using the information stored in the computer (Jordan and Shrestha, 1999). Programs involving the integration of GIS and IK have for the most part been used within natural resource management projects where increased food or income source choices for local communities and effective participation in benefits sharing are the main goals (Mbile et al., 2003).

GIS is a tool that combines ordinary statistics with geographic location to create meaningful, clear and attractive maps that can be applied to development needs (USAID, 2002). Due to the spatial nature of Indigenous Knowledge Systems (IKS), Geographic Information Systems technology can facilitate the inclusion of IKS in local decision-making processes. However, up until now the possible application of GIS in IK management has been inadequately explored (Lawas and Luning, 1996). There is an increasing interest in the use of GIS in a participatory context, with this development either causing alarm or being seen as providing a potentially valuable tool (Jordan and Shrestha, 1999). The present paper reviews work carried out to date by various researchers who have integrated IK with GIS, and demonstrates this through examples that show how such systems can facilitate the management of indigenous information. Examples also show how such systems can enhance its usefulness for natural resource management of local communities through participatory processes.

2. NATURAL RESOURCE MANAGEMENT

Information describing the natural resources of any region forms the base upon which sustainable development must be built (Tabor and Hutchinson, 1994). Integrated Natural Resource Management (NRM) is a research approach that aims at improving livelihoods, agro-ecosystem resilience, agricultural productivity and environmental services. In other words, it aims to augment social, physical, human, natural and financial capital. It does this by helping solve complex real-world problems affecting natural resources in agro-ecosystems (CGIAR, 2002).

To manage our natural resources in a sound manner, we need to manage information and knowledge resources effectively. Information is data that has been given meaning whereas knowledge is the appropriate collection of information; such that it intends to be useful in decision-making.

"Knowledge management" focuses on the processes and the people involved in creating, sharing and leveraging knowledge among scientists, communities, resource managers and policy makers. Information management, in contrast, is more concerned with establishing processes and systems to gather, organize, summarize and package information, including its timely delivery to the right decision makers for the situation involved.

There is widespread recognition, that participatory development is critical for achieving sound resource management. However, this kind of development requires a more flexible and evolving process of planning for change, and poses new challenges for decision-makers and evaluators alike. In particular, this requires responsiveness at the local level to

empower and enable communities. Because these programs are designed to be responsive to changing community needs, one of the most pressing challenges is to develop participatory and systems-based processes based on the communities' local knowledge.

3. INDIGENOUS KNOWLEDGE

Indigenous knowledge is local knowledge unique to a culture or society. It is the basis for local level decision making in agriculture, health care, food preparation, education, natural resource management and a host of other activities in communities (World Bank, 1998). There is general agreement that the concepts 'indigenous knowledge' (IK), 'traditional knowledge', 'local knowledge', 'community knowledge' and 'rural peoples' knowledge' are all terms for knowledge belonging to local people. While certain distinctions can be made, these terms often refer to the same thing (Mathias, 1994; Warren, 1992; Reijntjes et al., 1992; Howes and Chambers, 1979; Roach, 1994). The term 'indigenous knowledge' denotes a type of knowledge that has evolved within the community and has been passed on from one generation to another.

Many authors (e.g. Mathias, 1994; Labatut and Akhtar, 1992; Warren, 1992) have stressed the value of IK for development. But IK has its limitations (Bebbington, 1993; Bonds, 1991; Reijntjes et al., 1992; Leach and Mearns, 1988), and is not in itself capable of addressing all the issues related to sustainable development (Murdoch and Clark, 1994). Sustainable development may well be better served by a system that incorporates both indigenous and scientific knowledge systems (Icamina, 1993). Organizations like the IUCN[1] (IUCN, 1980) and the WCDE[2] (WCDE, 1987) also stress that the sustainable management of natural resources can only be achieved by developing a science based on the priorities of local people, and creating a technological base that includes both traditional and modern approaches to problem-solving (Johnson, 1992).

Incorporating indigenous and scientific knowledge means integrating information collected from farmers with scientific information and technology. This means that we must find a way to process indigenous information in the same way as scientific information (Lawas and Luning, 1996).

The resource assessment information needs do not replace the need for social information, but extend the range of information that has to be collected, analyzed, and collated. Much of this information has a spatial component, and GIS has been increasingly used for data management and analysis (Jordan and Shrestha, 1999).

4. GEOGRAPHIC INFORMATION SYSTEMS

GIS is being recognized as an important decision-making tool for natural resource management. GIS technology is used to address the problems associated with the storage, analysis and processing of indigenous information. It is also employed in the integration of the two types of information. Such a process is useful in planning and decision making for the sustainable management of resources (Lawas and Luning, 1996). A GIS is mapping software that links information about where things are with information about what things are like. Unlike a paper map, where "what you see is what you get", a GIS map can combine many layers of information (ESRI, 2003). GIS is a specialized set of information and communication technology (ICT) that helps manage and interpret data about an area's resources and infrastructure, such as digital maps or images of a village, watershed, or entire country. Researchers, planners, and other technical specialists are making greater and greater use of this information. The tools include systems to store, manage, and analyze

[1] International Union for Conservation of Nature and Natural Resources
[2] World Commission on Environment and Development

geographically referenced data (geographic information systems, or GIS); devices that measure geographic location (global positioning system, or GPS, receivers); and airborne data collection systems that provide periodic land use, land cover, and other thematic information (aerial photos and satellite remote sensing) (Deichmann and Wood, 2001).

While obstacles exist - particularly in developing countries - geographically referenced data are providing new insights into global issues such as the patterns and processes of human settlement, natural resource use and degradation, agricultural performance, disease, and potential conflict. GIS is a tool that combines ordinary statistics with geographic location to create meaningful, clear and attractive maps that can be applied to development needs. The impact of a map is related to the fact that data are visualized in their environment, letting the user take into account not only the data themselves, but also all the surrounding factors that make up those data like topological information such as adjacency, etc. It has been used for natural resource management for visualization, communication, data management, as development tool and for developing knowledge base systems.

One of the most direct applications of GIS in developing countries is participatory mapping, where, for example, specialists interact with local communities (e.g. farmers) to create spatial inventories of natural resources, property status, land-use rights, and perceived problems. Such inventories feed into a consultative process aimed at building consensus on more equitable and sustainable resource-management arrangements. Experience has shown that villagers can quickly relate to geographic representations of their surroundings. Community mapping can also help foster the process of transferring greater decision-making power and fiscal responsibility from central to local levels of government.

4.1 Indigenous Knowledge and GIS

There are important spatial aspects to IK. However, until now the possible application of GIS in indigenous knowledge management has been under explored. Such a system can facilitate the management of indigenous information and enhance its usefulness (Lawas and Luning, 1996). According to Marozas, 1991, due to the spatial nature of traditional knowledge, GIS can assist in the inclusion of indigenous knowledge in the local decision making process.

Tabor and Hutchinson (1994) and Gonzalez (1995) have described the advantages of using GIS and knowledge-based systems (KBS) to document indigenous knowledge. Lawas and Luning (1996) have documented GIS applications at the local level in Northern Luzon, the Philippines, while Marozas (1991) has examined how GIS are being used in American Indian land and water rights litigation. Madsen (1994) has provided interesting examples of the potential power of GIS and remote sensing for the exploitation of indigenous peoples, particularly by non-indigenous groups. Examples from New Zealand (Harmsworth, 1995, 1997a, 1997b) demonstrate that where indigenous people develop and employ GIS tools, they are able to add their own cultural imprint to existing applications. Moreover, such tools complement the indigenous knowledge systems traditionally used to store and transfer knowledge and information, whereby an important role is reserved for the relationship with individuals, places, cultural activities, experience and the spoken word (Harmsworth, 1998).

4.2 Approaches for IK Management using GIS

Researchers, by overlooking the role of IK, have not sufficiently understood the human-environment relationship in less developed regions (Nazarea-Sandoval 1995: 72). While some have argued for the distinction between scientific knowledge and indigenous knowledge (Agrawal, 1995), according to Waldron and Sui (1999), IK should be recognized as important as other types of information (e.g. in discussing agricultural suitability, factors could include soil, climate, hydrology, IK, etc.) that are factored into the scientific decision-

making process. If used in this way, it would be important to understand clearly what IK is, where it comes from, how to collect it, store it, and process it in order to aid the decision-making process in ecosystem management (Waldron and Sui, 1999). As there are important spatial aspects to IK, GIS is capable of storage, processing and management of this IK for planning and decision making purposes (Lawas and Luning, 1996). Figure 2 illustrates some of the spatial aspects of IK and how the natural resource base of a community can be stored in a GIS.

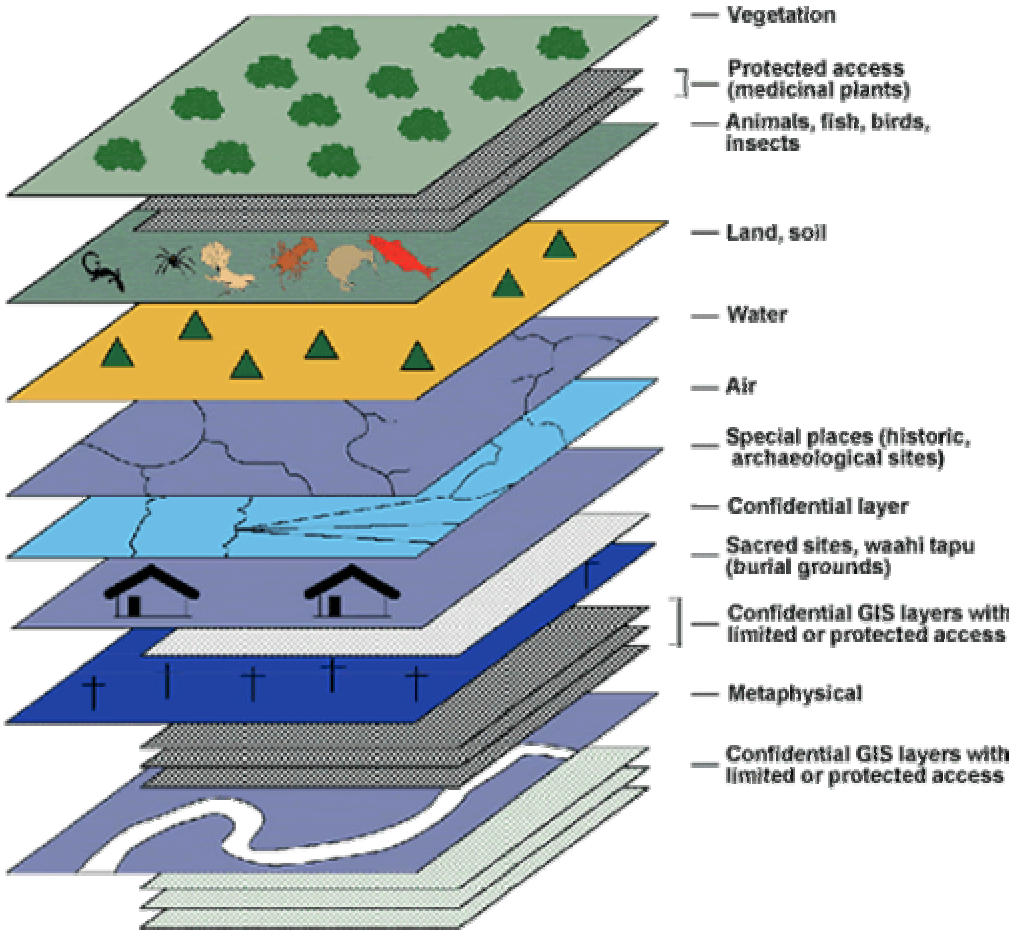

Figure 2: (Source: Harmsworth, 1998[3])

Many researchers have integrated indigenous knowledge into GIS for various purposes. Though almost all approaches are participatory in nature, the application has differed according to the need and objectives of the project or the community where such an approach is used. Waldron and Sui (1999) have described the use of GIS for integrating indigenous knowledge for land suitability analysis. Gonzalez (1995) used participatory approaches for integrating IK into GIS for natural resource management. In her approach she used aerial photographs and satellite images for mapping community situations and aspirations in the Philippines. Mather et al. (1998) used aerial photographs and 'photo-maps' for participatory mapping of community forests in Nepal. Jordan and Shrestha (1999) have also used GIS in participatory context for community forestry user groups (FUGs) in Nepal. Puginier (2001) used local knowledge in GIS as a communication tool for community level land use planning in northern Thailand. Mari and Bitter (1996) have used GIS and Rapid Rural Appraisal (RRA) in local level land use planning in Sri Lanka. Harmsworth (1998) has

[3] With permission from the author.

outlined a methodology for storing indigenous values of Maori culture of New Zealand in GIS. All the approaches adopted by these researchers for integrating GIS and Indigenous Knowledge for natural resource management have been participatory in nature involving local inhabitants. This approach is called Participatory GIS. Participatory GIS is widely used for community mapping or for participatory resource mapping with little variation in techniques and participatory tools used by different researchers.

While Participatory GIS exists, there is a new technique called Mobile Interactive Geographic Information System (MIGIS), developed by McConchie and McKinnon (2002) for integrating indigenous knowledge for community based planning. McConchie and McKinnon (2002) have pioneered this methodology for integrating IK into GIS to produce community-based maps for collaborative natural resource management. The method has been successfully tested in Thailand, China and Cambodia, is presently being used in Bangladesh and will soon be tested in India (McConchie, 2003). Both Participatory GIS and MIGIS methodologies are briefly described below.

4.2.1 Participatory GIS

There is an increasing interest in using GIS in a participatory context. However this application can either cause alarm, through fears such as misinterpretation, exploitation of knowledge and intellectual mining, or be seen as providing a potentially valuable tool that empowers communities (Jordan and Shrestha, 1999). In many projects the effective participation of a local community is of paramount importance and will affect the outcome. This could be quite negative if the participatory decision-making process is not tailored to local needs and non-participation often results in distancing the local community from the decision-making process. There is also increased potential for the information to be misused or wrongly interpreted, or not being used at all - if it is not decentralized. If poorly designed, the project can disempower underprivileged groups by not involving them in the participatory process, effectively excluding them from their own resource mapping and knowledge systems. On the other hand, if the GIS participatory process is well designed it can lead to the empowerment of local communities and has the potential of being a valuable tool for scaling up local knowledge and concerns to the regional level, so that community information can be incorporated into regional and national policy.

Participatory GIS is a spatial decision-making tool designed to utilize GIS technology in the context of the needs and capabilities of communities that are involved with, and affected by development projects and programs (Abbot et al., 1998) For the collection of primary data, a number of different data acquisition techniques are used, such as Rapid Rural Appraisal (RRA), village immersion, the farmer-based interview schedule, field visits and observations, the use of a checklist of questions, analog maps and aerial photographs. Such integrated techniques of data retrieval have proved efficient in obtaining reliable information from the farmers. Each technique is selected for a particular purpose. For example, aerial photographs used in Northern Luzon in the Philippines, enabled farmers to identify their own fields and to explain the previous use of specific areas of land for land resource management (Lawas and Luning, 1996). The following five points need to be concentrated on when developing a participatory GIS (Jordan and Shrestha, 1999):

1. GIS should be used if there is a need and only if it adds to the participatory process.
2. Collection and dissemination of information that are an integral part of a participatory process should be a priority rather than technical issues related to use of GIS in the process.

3. Like any other participatory process, decision-making should be the focus of a participatory GIS activity. The information collected and put into a GIS should be useful to aid the decision making process in the community.
4. Ownership of information, how it is stored and who has access to the information are also important issues to keep in mind when engaging in a participatory GIS activity.
5. Infrastructural and institutional support to obtain participatory information, input it into a GIS, analyze it, and return it to the participants in a way they can use it, should be in place.

The major advantages and disadvantages of Participatory GIS, as described by Jordan and Shrestha (1999), are listed below in Table 1.

Participatory GIS: Advantages and Disadvantages	
Advantages	**Disadvantages**
Viewed as a participatory process it can empower the community by involving them in the decision-making process	If the participatory process is not well structured the community does not feel to be a part of the decision-making process
It can be used to effectively combine quantitative and qualitative approaches to community development	There is a potential risk of the focus getting shifted mainly towards extractive data collection
Spatial data in the form of maps and other resource information can be utilized by the community in their decision making process rather than having access to GIS	There is a likelihood of sensitive spatial information like cadastral maps being subject to unintended misuse if held centrally
Natural resource information can be easily put together, analyzed and returned to the community for use	Excluding disadvantaged groups from the 'mapping' process can have a disempowering effect on them
Useful information can be returned to stakeholders for informed decision making	Availability and knowledge of the technology itself encourages a centralized approach

Table 1. Advantages and Disadvantages of Participatory GIS: (adapted from Jordan and Shrestha, 1999).

4.2.2 Mobile Interactive Geographic Information System (MIGIS)

MIGIS is the acronym for community based planning that uses a Mobile Interactive Geographic Information System in conjunction with, and fully informed by Participatory Learning and Action (PLA). MIGIS brings the best of indigenous knowledge and scientific information together to provide common ground on which farmers, government administrators, and planners can optimize their understanding of their environment and each other, and work as a team to plan for a better future. This approach adds a new dimension to existing PLA tools and can lead to a significant increase in our ability to define the environment and constraints on any development initiative or intervention.

According to McConchie and McKinnon (2002), the advantages of using GIS as a major component of the PLA activities undertaken for MIGIS are that it is highly visual and a powerful tool for storing knowledge. Besides these, the data are credible and quantifiable. It is easy to update and provides baseline information against which development initiatives can be evaluated. Within a GIS, it is possible to quantify and assess the physical and socio-economic constraints impacting the communities. The data can also assist in monitoring the situation, or any actions and interventions and is accessible to all. Most importantly GIS can be used to test scenarios and help address potential conflicts.

4.3 Common Problems with the Use of GIS for IK Management

According to Jordan and Shrestha (1999), the main problem associated with using GIS for 'participatory' work is the way that the technology has been used. GIS has not been viewed as a tool in a participatory process, but as a technology in its own right, looking for an application. This illustrates one of the key principles of participatory GIS: to evaluate at an early stage what GIS adds to the participatory process. As with any good participatory methodology, the focus has to be on the people, the participants. This has been the key problem with using GIS; the focus has usually been on the technology. The most charitable way of looking at this lack of participation associated with the traditional use of GIS in development work is to view GIS as enabling decision makers to correctly evaluate the required development input. But this is 'putting the technology before the people' (Jordan and Shrestha, 1999). There is little or no consultative process with communities. Their needs have not been identified, and the information gathered does not reflect their requirements. The 'old top-down development paradigm is being actively encouraged' (Hobley 1996; Jordan and Shrestha, 1999). While working in sub-Saharan Africa Jordan and Shrestha (1999) observed that most GIS applications for development work were used to demonstrate technological capability of GIS rather than for problem solving at local level. GIS is being often used at both local and national levels for demographic and socio-economic studies where there is little participation of local people in the implementation phase. This makes GIS a tool for the researchers, planners and policy makers rather than a tool for local people. Therefore the 'developmental' role of GIS is often one of disempowerment of local people (Jordan and Shrestha, 1999). It encourages the separation of the planning process from the people affected. There is little or no discussion with villagers regarding what information would be useful to them, and what information a GIS could provide (Jordan and Shrestha, 1999).

4.4 Achievements and Benefits of Integrating IK and GIS for NRM

All programs in which the approach involving the integration of GIS and IK have been used are within natural resources management projects where increased food/income source choices for local communities and effective participation in benefit sharing are the main goals (Mbile et al., 2003). The realization of these objectives regarding community benefits may only be attained and verified if project tactics and activities take into consideration community expectations and perceptions, knowledge and fears in an iterative way that clearly state potential benefits to communities through application of this methodology. Intentions and plans do not benefit communities by themselves; their effective implementations do. The application of this methodology will ensure that, unlike examples where Participatory Rural Appraisal (PRA) acquired data are stored in huge socio-economic reports - not often read by decision makers - or where a large quantity of socio-economic information remains unanalyzed, the data generated using this method will make PRA acquired data more readily available to decision-makers. Secondly, this method will allow each sample household to be monitored directly and intimately, thereby minimizing drawbacks of often misleading generalizations in decision-making derived from consolidated report-bound socio-economic studies. Finally, such household level interaction using participatory resource mapping methodology allows effective participation of local people in project implementation and evaluation. This is because the community is at the center of the data on which the implementation of community development project is based.

In planning and decision making exercises directed towards the sustainable management of natural resources, it is essential that the various types of information relating to a particular area of concern are available. As indigenous information is acknowledged to

be a valuable input in those exercises, it must be available and accessible at all times. GIS technology makes this possible. It can provide spatial and non-spatial information, which facilitates both planning, and decision-making aimed at the sustainable management of natural resources. Another benefit of GIS is the fact that it can narrow the information gap between professionals and resource users by making indigenous information more transparent, understandable, and accessible to a wider audience. This is essential for achieving any development goal (Lawas and Luning, 1996).

In a MIGIS project, a GIS was taken into a remote field area in southwest China. Data collected from two communities, via a range of PLA activities, were encoded, manipulated, and analyzed. The results were presented immediately back to the villagers, who then checked the data, validated any translations, provided credibility to the database, and reviewed and critiqued the findings. The GIS and PLA were regarded as two interacting, inter-dependent tools used within an iterative process, continually controlled, guided, and validated by the local people. While the PLA exercises produced a significant amount of "village focused" primary data, the MIGIS allowed these data to be geo-referenced, extrapolated, and explored within a wider context through the use of secondary data sources. Analyses also provided considerable insights into the natural and social environment and identified potential development issues that might have arisen (McConchie and McKinnon, 2002).

5. CONCLUSION

Today more and more people are recognizing and promoting the importance of indigenous knowledge for purposes of sustainable development. Such knowledge is a valuable resource and requires proper management. This approach of using GIS in a participatory context maximizes the utility of indigenous information for development, as it has the potential for empowerment of local groups and communities, but at the same time provides a platform that can be shared by many users. These users include natural resource managers, project or development planners, decision makers, people with a particular interest in indigenous knowledge functions, and communities themselves. There is a greater likelihood that information stored in a GIS environment will actually be shared, since it is in a central spatial repository and can be easily accessed and analyzed. Moreover, comparisons can be made and scenarios created on the basis of the information stored in the system. While the use of a GIS may initially be costly, it is important to consider the accessibility to data, which it offers, and the many other advantages to be gained from indigenous information. It is viewed by some as an exciting development as it allows spatial relationships for social, economic and natural resource issues to be examined, which were previously difficult to incorporate.

The future might also bring cheaper and easier-to-use tools that enable local communities to generate or access information about individual and shared resources without external facilitators. With better information about land management status and options and the effectiveness of farming technologies and resource-management practices, communities may avoid resource-related conflicts as they build consensus on uses, management, and rights. However, the cost-effectiveness of introducing GIS technologies into poor communities and the potentially harmful social consequences will continue to require close scrutiny by researchers and policymakers alike (Deichmann and Wood, 2001). An important challenge in using GIS in a participatory context is that the technology should not override the participatory process rather it should complement it; else it can result in the disempowerment of the local community. Thus there is a need for the researchers and policy makers to work with the communities to make GIS an effective participatory tool.

It can be concluded from the above account that GIS is an effective tool for managing the communities' IK and natural resources. The participatory approach to resource mapping

and management of natural resources can lead to sound decision-making regarding the communities' resource allocation. Participatory GIS as a tool also improves the participation of local groups (e.g. farmers, peasants) as well as empowers them and makes them feel important in the decision making process of their own resources.

6. RECOMMENDATIONS

To further the approach of integrating local knowledge into GIS, the practice should be applied to natural resource management to encourage a state of democracy of information by promoting dialogue and partnership building among local community, researchers, resource managers and policy makers, and other stakeholders. The process should be based on mutual support between various groups and levels of planning, using a bottom-up approach in conjunction with the spatial generalization method. Spatial generalization could be achieved through merging the various spatial levels in a holistic framework using GIS.

7. REFERENCES

Abbot, J., Chambers R., Dunn C., Harris T., Merode E., Porter G., Townsend J. and Weiner D. (1998) Participatory GIS: Opportunity or Oxymoron? *PLA Notes* 33, International Institute for Environment and Development (IIED), London, 27-34.

Agrawal, A. (1995) Dismantling the Divide Between Indigenous and Scientific Knowledge, *Development and Change,* 26, 3, 413-39.

Barr, J.J.F. and Dixon, P.-J. (1998) *Incorporating Farmers' and Fishers' Knowledge into Natural Resources Systems Research on the Bangladesh Floodplains,* http://www.taa.org.uk/barrdone.htm

Bebbington, A.J. (1993) Modernization from Below: An Alternative Indigenous Development, *Economic Geography*, 69, 3, 274-292.

Bonds R. (1991) *A Review of Communication Problems Between Indigenous and Professional Knowledge Systems in Rural Development, and Options for their Solutions*, Unpublished MA Thesis, Development Administration and Management, University of Manchester, UK.

CGIAR (2002) Integrated Natural Resource Management http://www.inrm.cgiar.org/

Deichmann, U. and Wood, S. (2001) GIS, GPS and Remote Sensing, 2020 Focus 7 (Appropriate Technology for Sustainable Food), Brief 7 of 9, August 2001 http://www.ifpri.org/2020/focus/focus07/focus07_07.htm.

Environmental Systems Research Institute Inc. (ESRI), (2003) http://www.gis.com/whatisgis/whatisgis.html

FAO/Netherlands International Conference on Agriculture and the Environment (1990) Social and Institutional Aspects of Sustainable Agriculture and Rural Development. Draft working document for discussion. Rome: FAO.

Gonzalez, R.M. (1995) KBS, GIS and Documenting Indigenous Knowledge, *Indigenous Knowledge and Development Monitor,* **3**, 1, 5-7. .

Harmsworth, G.R. (1995) Mäori Values for Land-Use Planning: Discussion Document, *Manaaki Whenua-Landcare Research,* unpublished report.

Harmsworth, G.R. (1997a) Mäori Values for Land-Use Planning, *Broadsheet Newsletter of the New Zealand Association of Resource Management*, February, 37-52.

Harmsworth, G.R. (1997b) Mäori Values and GIS: The New Zealand Experience, *GIS Asia Pacific,* April, 40-43.

Harmsworth, G.R. (1998) Indigenous Values and GIS: A Method and a Framework, *Indigenous Knowledge and Development Monitor*, 6, 3, http://www.landcareresearch.co.nz/research/social/ikdmpap.asp

Hobley, M. (1996) Why Participatory Forestry? In: Hobley, M. (Ed) *Participatory Forestry: The Process of Change in India and Nepal*. Rural Development Forestry Guide Three, ODI, London.

Howes, M. and Chambers, R. (1979) Indigenous Technical Knowledge: Analysis, Implications and Issues, *IDS Bulletin*, 10, 2, 5-11.

Icamina, P. (1993) Threads of Common Knowledge, IDRC Reports, **21**, 1, 14-16.

IUCN. (1980) *World Conservation Strategy: Living Resource Conservation for Sustainable Development*, Gland, Switzerland,

Johnson, M. (Ed.) (1992) *Lore: Capturing Traditional Environmental Knowledge*. Hay River, NWT: Dene Cultural Institute and International Development Research Centre.

Jordan, G. and Shrestha, B. (1999) A Participatory GIS for Community Forestry User Groups in Nepal: Putting People Before the Technology http://www.mtnforum.org/resources/library/jordx99a.htm

Labatut, G.M. and Akhtar, S. (1992) Traditional Environmental Knowledge: A Resource to Manage and Share, *Journal of the Society for International Development*, 4, 24-29.

Lawas, C.M. and Luning, H.A. (1996) Farmers' Knowledge and GIS, http://www.nuffic.nl/ciran/ikdm/4-1/articles/lawas.html

Leach, G. and Mearns, R. (1988) Trees for Rural People, in: Leach, G. and Mearns, R. (Eds.) *Beyond the Woodfuel Crisis: People, Land and Trees in Africa*, London: Earthscan Publications Ltd, 27-29.

Madsen, W. (1994) Protecting Indigenous Peoples Privacy from Eyes in the Sky, in: Onsrud, H.J. (Ed.), *Proceedings of the Conference on Law and Information Policy for Spatial Databases*. Tempe, Arizona: Centre for the Study of Law, Science, and Technology, Arizona State University College of Law.

Mathias, E. (1994) Indigenous Knowledge and Sustainable Development, *Working Paper No. 53,* Silang: International Institute of Rural Reconstruction.

Mari, M. and Bitter, P. (1996) GIS and RRA in Local Level Land Use Planning A Case Study in Sri Lanka, http://www.gisdevelopment.net/aars/acrs/1996/ts8/ts8006pf.htm.

Marozas, B.A. (1991) Enhancing Tribal Integrated Resource Management Plans by Integrating Traditional Knowledge with Geographic Information System Technology. http://www.nativemaps.org/abstracts/resource.html

Mather, R., Boer M., Gurung, M. and Roche, N. (1998) Arial Photography and 'Photo-Maps' for Community Forestry, http://www.mtnforum.org/resources/library/mathx98a.htm.

Mbile, P., DeGrande, A. and Okon, D (2003) Integrating Participatory Resource Mapping (PRM) and Geographic Information Systems (GIS) in Humid Lowland Sites of Cameroon, Central Africa: A Methodological Guide, *Electronic Journal on Information Systems in Developing Countries*, 14, 2, 1-11 http://www.is.cityu.edu.hk/research/ejisdc/vol14/v14r2.pdf

McConchie, J.A. and McKinnon, J.M. (2002) Using GIS to Produce Community Based Maps to Promote Collaborative Natural Resource Management, http://www.iapad.org/publications/ppgis/Using_GIS_to_produce_CB_maps.pdf

McConchie, J.A. (2003) Personal (email) communication.

Murdoch, J. and Clark, J. (1994) Sustainable Knowledge, *Geoforum*, 25, 2, 115-132.

Nazarea-Sandoval, V.D. (1995) *Local Knowledge and Agricultural Decision Making in the Philippines: ClassG gender, and Resistance*, Ithaca: Cornell University Press.

Norgaard, R. (1992) Coevolution of Economy, Society and Environment, in: Ekins, P. and Max-Neef, M. (eds) *Real-life Economics: Understanding Wealth Creation,* London: Routledge, 76-88.

Ogunbameru, B.O. and Muller, R.A.E. (1996) Integration of Indigenous and Scientific Knowledge Systems for Agricultural Development, Changing Agricultural Opportunities: The Role of Farming Systems Approaches, *Proceedings of the 14th International Symposium on Sustainable Farming Systems*, Colombo, Sri Lanka, 11-16 November.

Puginier, O. (2001) Can Participatory Land Use Plan at Community Level in the Highlands of Northern Thailand Use Geographic Information systems (GIS) as a Communication Tool?, in: Proceedings of *International Workshop on Participatory Technology Development and Local Knowledge for Sustainable Land Use in South East Asia*, Chiang Mai ,Thailand June 6-7, 2001. http://www.uni-hohenheim.de/i3ve/00068900/28534041.htm

Reijntjes, C., Haverkort, B. and Waters-Bayer, A.W. (1992) *Farming for the Future: An Introduction to Low-External-Input and Sustainable Agriculture*, London: Macmillan.

Roach, T. (1994) Ancient Ways Guide Modern Methods, *IDRC Reports*, 22, 2, 9-10.

Tabor J.A. and Hutchinson, C. (1994) Using Indigenous Knowledge, Remote Sensing and GIS for Sustainable Development, *Indigenous Knowledge and Development Monitor,* 2, 1, 2-6 http://www.nuffic.nl/ciran/ikdm/2-1/articles/tabor.html.

Ulluwishewa, R. (1993) National Knowledge, National IK Resource Centres and Sustainable Development, *Indigenous Knowledge and Development Monitor*, 1, 3, 11-13.

USAID Guinea (2002) Geographic Information Systems (GIS), http://www.usaid.gov/gn/infotechnology/gis/index.htm

Waldron, J.D. and Sui, D.Z. (1999) Integrating Indigenous Knowledge and GIS in Land Use Suitability Analysis, *Papers and proceedings of GISOC'99, an international conference on Geographic Information and Society*, Minneapolis, MN, June 20-22, http://www.socsci.umn.edu/~bongman/gisoc99/new/waldron.htm.

Warren, D.M. (1992) *Indigenous Knowledge, Biodiversity Conservation and Development*, Keynote address for the International Conference on 'Conservation of Biodiversity in Africa: Local Initiatives and Institutional Roles, Nairobi: National Museums of Kenya.

WCDE (1987) From One Earth to One World: An Overview, World Commission on Environment and Development. 1987. Oxford: Oxford University Press.

World Bank (1998) Indigenous Knowledge For Development - A Framework For Action, Knowledge and Learning Center Africa Region, World Bank http://www.worldbank.org/afr/ik/ikrept.pdf