Bridging the Gap: The Role of Spatial Information Technologies in the Integration of Traditional Environmental Knowledge and Western Science

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Abstract
Agenda 21 dedicates a whole chapter to the role and importance of information for sustainable development. Among the provisions on harnessing the potential of information and communication technologies (ICT) one paragraph addresses the need for a *strengthening of the capacity for traditional information.* Local communities and resource users should benefit from mechanisms that provide them with the know-how they need to manage their environment and resources sustainably, applying traditional and indigenous knowledge and approaches.

This paper will examine how this objective is being implemented through the use of spatial information systems (including GPS and Remote Sensing), which collect, manipulate and distribute data on a variety of environmental factors, in order to inform and encourage sustainable resource management practices. Some initiatives have adopted grassroots and participatory approaches, whereby local communities map their territories and resources with the help of information technologies. This paper will review a sample of these projects and analyze how they can generate synergies between traditional knowledge and modern science.

1. Introduction

Accurate and reliable information is a key ingredient, if not precondition for sustainable development. With the growing importance of knowledge-intensive production modes, developing countries are hard pressed to jump on the bandwagon and to harness the potential of new technologies and networks.

One area where the revolutionary changes in the acquisition, processing and dissemination of information have become particularly significant is that of environmental management. The challenge to understand the complexities of ecosystems and to mitigate the negative impacts of man-made interventions have spurned a flurry of research programs, networking efforts and scientific co-operation. A veritable glut of data is now at the disposal of policy-makers and planners.

In this quest for more and better information, researchers and decision-makers have recently turned to a long ignored body of knowledge about the environment, that of local people and communities. Particularly those, whose livelihoods depend on the subtleties of ecological cycles and patterns, have accumulated a body of wisdom, commonly referred to as "traditional environmental knowledge." (TEK)[1]

Western scientists and "experts" have tended to regard TEK as methodologically questionable, anecdotal, or – at best – of localized importance. At the same time, the adoption of science-based innovations and technologies by local people has often been stifled by their perceived incompatibility with traditional value systems and cultural practices.

This tension between two epistemologies, which has plagued many development projects, is the central subject of this paper. We examine how new information and communication technologies (ICT) have shaped and altered this relationship. We have chosen to illustrate this question by looking at spatial information technologies (GPS, GIS, Remote Sensing) and their use by local communities in Asia and elsewhere. Our analysis seeks to assess whether these technologies can bridge the gap between Western science and local knowledge and thus contribute to more equitable and sustainable development.

To frame this question, the paper reviews the intrinsic qualities and use of spatial information, both in scientific analysis and traditional environmental knowledge. We then offer a brief synthesis of the main features of spatial information technologies, to be followed by the core of the paper, in which we examine the technologies' advantages and disadvantages for community-based natural resource management.

2. Two Ways of Knowing

The above mentioned dichotomy between science and folk wisdom applies also to a particular subset of information: spatial or geographic data. These are data that include a reference to a location on the surface of the earth. In the Western scientific tradition, coordinate systems such as altitude/longitude are the most common geo-reference. We typically represent spatial data through points, lines or polygons and visualize them in maps. On the other end of the spectrum, local knowledge about the environment is represented in a variety of forms often involving non-linear notions of space, references to stories, myths and different taxonomies. Maps often exist "only" in the minds of the people.[2]

2.1. Space Matters

Accurate and comprehensive spatial data play a critical role in all areas of environmental management and sustainable development. Apart from the various branches of geography, whose disciplinary nerve center evolves around spatial relations, almost all other "environmental sciences" rely on geographical information. Be it as an input for pollution models of environmental chemists, the gap analysis of population ecologists or the formulas of spatial econometrics, data are acquired and processed at all levels of aggregation.

While in the past most spatial information was the prerogative of governments and government-sponsored research institutions, these days new players – particularly from the private sector - have entered the market. The epitome of old-style spatial analysis, the bound atlas, is quickly being superseded by digital maps and networked databases.

In most developing countries, reliable spatial data are often a scarce resource. This can be attributed not only to the remoteness of many areas but also to the lack of technical capacities and competing priorities in the fledgling economies. Therefore, in many countries, maps and other geographical products from the colonial era often serve as the baseline.

In addition, a number of institutional factors have hampered the use of comprehensive spatial data in environmental planning and management. Fox (1991) notes, for example, that among the most common obstacles to be found in Asia are official restrictions for security reasons as well as the rigidity and compartmentalization of government bureaucracies, which consider certain types of information as their property. Furthermore, in some countries bottlenecks in terms of financial and human resources have hindered the establishment of efficient and effective spatial information systems.

Another feature in the acquisition and use of geographical information has been the dominance of the Western science paradigm, which led to a large-scale dismissal of local environmental knowledge and wisdom. Or, as Chambers (1980) put it: “The most difficult thing for an educated expert to accept is that poor farmers may often understand their situations better than he does. Modern scientific knowledge and the indigenous technical knowledge of rural people are grotesquely unequal in leverage. It is difficult for some professions to accept that they have anything to learn from rural people, or to recognize that there is a parallel system of knowledge to their own which is complementary, that is usually valid and in some aspects superior.”

2.2. Traditional Environmental Knowledge

It is only in the recent past, that decision-makers and members of the scientific community have “discovered” that local people are experts of their environment, particularly where they have maintained their traditional livelihoods and subsistence economies (Freeman n.d., Johnson 1992). Ironically, certain advocates of TEK tried to throw the baby out with the bathwater and conjured up the image of the noble savage, whose wise stewardship over the world’s resources contains all the answers for a sustainable planet (Myer 1998).

In the more balanced setting of global policy-making, traditional environmental knowledge has received a belated acknowledgment as a legitimate source of information and guidance. Chapter 26 of Agenda 21, for example, calls for the “recognition of [indigenous peoples’] values, traditional knowledge and resource management practices with a view to promoting environmentally sound and sustainable development.” [3] (Quarrie 1992)

What are the specific features of TEK and how does it differ from the Western scientific epistemology? Johnson (1992) defines it as “a body of knowledge built up by a group of people through generations of living in close contact with nature. It includes a system of classification, a set of empirical observations about the environment and a system of self-management that governs resource use.” This definition emphasizes a number of structural properties:

- TEK is in essence a geographical information system derived from and embedded in the close relationship of local people with their land and natural resources.

- This knowledge system functions like a distributed database, with members of the community serving as repositories for different types and categories of data, according to their experience and social status.
- TEK is a "scientific" system in that it consists of taxonomic structures, employs particular methodologies and relies on its own "experts".

Box 1: Two Examples of Traditional Environmental Knowledge

- The Akha are a group of mountain peoples spread over southern China, eastern Myanmar, Laos, northern Vietnam and northern Thailand. They have been traditionally governed by a body of customary law called *zang*. These rules and regulations include detailed knowledge about the rich local flora and fauna, which informs the management of the village forests. In order to protect their settlements and to have a source of food and medicine, the Akha commonly maintain a forest belt around their villages, even in heavily deforested areas.

- The Marovo people occupy a group of islets and lagoons in one of the seven provinces of the Solomon Islands of the South Pacific. They are fishermen, and their livelihoods depend on the sustainable exploitation of the marine resources. To this end, they have developed approximately 60 different fishing methods. In a documented conversation between a Marovo fisherman and an internationally renowned marine biologist, the local expert was able to teach the Western scientist various subtleties of courtship and spawning among a group of small coral reef fish.

Source: Johnson 1992

Like any other knowledge system, TEK is not static. On the contrary, its information base is constantly renewed and revised. Unfortunately, in many cases the dynamics of globalization, industrialization and urbanization have favored the assimilation and loss of much of this knowledge. This trend has been facilitated by the fact that a significant amount of this information is oral history (Johannes 1989, Johnson 1992).

2.3. The Challenge of Reconciliation

The Brundtland Report, *Our Common Future*, and other key documents of the sustainable development debate have stressed the importance of harmonizing these two "ways of knowing". Agenda 21, for example, notes that governments should "provide local communities and resource users with the information and know-how they need to manage their environment and resources sustainably, applying traditional and indigenous knowledge and approaches when appropriate." [4] (Quarrie 1992) But how can such an integration be achieved? After all, the differences between these two epistemologies seem considerable. Table 1 gives a generalized overview of the two systems.

Table 1: Comparing TEK and Western Science	
Traditional Ecological Knowledge	**Western Science**
• Oral tradition	• Written tradition
• Learned through observation and hands-on experience	• Taught and learned abstracted from the applied context
• Holistic approach	• Reductionist
• Intuitive mode of thinking	• Analytic and abstract reasoning
• Mainly qualitative	• Mainly quantitative
• Data generated by resource users (inclusive)	• Data collected by specialists and experts (exclusive)
• Diachronic data (long time-series on one location)	• Synchronic data (short time-series over a large area)
• Environment as part of social and spiritual relations	• Hierarchical and compartmentalized organization
• Based on cumulative, collective experience	• Based on general laws and theories
Adapted from Johnson 1992	

Given this state of affairs, what role can spatial information technologies play in reconciling TEK and Western science? Like other tools of the information revolution, GIS, GPS and Remote Sensing have seen a rapid proliferation, both in the developed and the developing world. While many observers argue that these technologies contribute to an empowerment of local-level actors and their knowledge systems, others are more skeptical and consider them as part and parcel of the Western scientific hegemony. Before taking up these views in more detail later, we need to review briefly these technologies and their key features.

3. Digital Space – A Technology Overview

Spatial information technologies include three major types:

a) Global Positioning System (GPS)
b) Geographical Information Systems (GIS)
c) Remote Sensing (Airborne and Satellite)

These three categories are related and often employed in an integrated fashion; remote sensing images and GPS data serve as input into GIS, and aerial and satellite images are often verified or ”ground-truthed” with GPS co-ordinates. Furthermore, many spatial data are now available in distributed and Web-based databases.[5] Thus, the developments in spatial information technologies can not be separated from the general trends in ICT.

3.1. GPS

The Global Positioning System is a satellite-based navigation system consisting of a network of 24 satellites, which send out continuous signals. On earth, a GPS receiver compares the time a signal was transmitted with the time it was received. This time difference gives the distance of the satellite. By adding distance measurements from two more satellites, the position of the receiver’s latitude/longitude can be triangulated. A fourth satellite allows to determine a three-dimensional "fix", which includes altitude (Larijani 1998, Poole 1995a).

The accuracy of a GPS position depends on a number of variables. Originally developed for the U.S. military and still managed by it, the GPS system can be subject to "selective availability", the deliberate degradation of the signal for civilian purposes. In recent years, less and less use has been made of this policy, partly because a technique called differential GPS has made significant improvements in accuracy possible.[6] All signals are subject to errors due to atmospheric effects, the constellation of the satellites and terrain features such as mountainous or urban areas.

GPS has been used for quite some time in aerial and maritime navigation, and like many other electronic technologies, a gradual miniaturization of components has allowed GPS receivers to become very small and affordable.[7] As a result, uses of the technology have proliferated and include now various forms of civilian and military navigation, mapping and surveying, habitat inventories and wildlife tracking, etc. (Larijani 1998).

3.2. GIS

A Geographical Information System is generally defined as a computer-based system used to capture, store, edit, analyze and display geographically referenced data (Poole 1995a). In other words, location information is linked to non-spatial data, commonly referred to as attributes. While "digital maps" can be generated by other software types such as Computer-Aided Design (CAD) programs, GIS is a distinct and more powerful tool. Its main strength is the integration of spatial and attribute data and the layering of information in a number of different themes, which can be superimposed upon each other, revealing complex spatial relationships between variables.

One can distinguish five general functions in a GIS: input, manipulation, management, query and analysis, and visualization (Johnson 1997).

- Input: Spatial and non-spatial data must be translated into a compatible format, which, in the case of geographical data, often involves the digitization of analog information such as traditional paper maps.
- Manipulation: Often necessary prior to analysis, in order to make different data compatible.
- Management: Typically based on relational database concepts and internal reference structures.
- Queries and analysis: The key function and strength of GIS; includes the creation of new geographical structures through topological overlays and the identification of variables within a given distance of an object or area.
- Visualization: GIS enables the display of maps that can be tailored to specific needs, and be rapidly and dynamically updated.

Geographical Information Systems have become an integral tool in a number of applications, including environmental management and conservation.[8] GIS programs now cover a wide spectrum of complexity and cost, and many universities and private companies offer degrees and training programs in the use of this technology. Big software firms also offer a range of services, and GIS has developed its own industry with trade fairs, specialist journals and a flourishing consultancy circuit.

This is partly true also in developing countries, and tends to be a function of the general penetration of information technologies. While the functionality of GIS should favor widespread adoption, there are, however, a number of obstacles (Yapa 1991, Yeh 1991):

- Cost: Despite the drastic decrease in prices of computer hard- and software, for many institutions in the developing world the acquisition and operation of suitable GIS equipment is beyond reach.
- Complexity: While many GIS packages have become very user-friendly, some of them have exploited the advances in processing power by adding ever new functionalities. This may require significant investment in training and capacity-building, yet another scarce resource for many developing countries.
- Data: A GIS is only as good as the data available. While the GPS has helped to improve the accuracy of many data, the availability of useful digital data is often limited, and, where given, might entail significant cost. While more and more geographical data are available for free on the Internet, they often do not meet the specific needs of users.

3.3. Remote Sensing

A third set of technologies that has had a profound impact on environmental management, is Remote Sensing. Aerial photo- and videography have been used for a number of applications for a long time. In recent years, two trends have shaped the evolution of these technologies: a) Digital cameras are rapidly replacing analog models, facilitating the ease of data manipulation; [9] b) Advanced sensors and optics are breaking new grounds in the resolution and quality of images. These advances have made significant contributions in many applications such as tropical forest conservation (Freeman and Fox 1994). For example, TREE (Tropical Forest Ecology Experiment), a NASA-sponsored project, successfully tested a series of new sensors. One of them, AVIRIS (Airborne Visible and Infrared Imaging Spectrometer), separates sunlight reflected from the surface into up to 224 wavelengths across the electromagnetic spectrum and can thus depict such properties as vegetation densities, plant chemistry and water contents of leaves (O'Neill 1993).

Even more significant advances have been brought about by the evolution of satellite technology. Like airborne sensing, the benchmark of development is the image resolution. Landsat 1, the first earth observation satellite, launched by the US in 1972, had a resolution of roughly 80m. In the second half of the 1980s, a major breakthrough occurred with the first French SPOT satellites. SPOT not only brought the resolution down to 10m but also initiated an ambitious program for the commercial distribution of its images. Currently, the highest resolution images come from former Russian military satellites [10]. 1999 will represent another landmark in the development of Remote Sensing: At least three new satellites with 1m resolution sensors are scheduled for launch this year. While most remote sensing satellites operate in the visible and infrared electromagnetic spectrum, there are also radar satellites[11], which can penetrate obstacles such as forest and cloud cover. They have been particularly useful in the monitoring of land use, crop conditions and deforestation.

It is evident from the above survey that spatial information technologies have taken a firm place in a science-based approach to environmental management and sustainable development. While a number of obstacles to their widespread adoption and use still exist in many developing countries – cost, human resources - they have become familiar tools for planning agencies and environment ministries. But what about local communities and their traditional environmental knowledge? Are these technologies widening the gap between the haves and have-nots and reinforcing the prevalence of one development epistemology at the cost of the other? Or are they helping to subvert existing power relations and information monopolies and to empower weaker groups? Table 2 lists a number of applications, where spatial technologies have been used for or by rural communities in various land and resource management projects.

Table 2: Matching Applications with Technologies

Application	***Data Requirements***	***Technology***
Demarcation	Base Maps, Images	GPS
Land use and occupancy	Maps based upon local knowledge and practice	Sketch mapping, GPS
Ecosystem monitoring	Sequential visual data	GPS and aerial video, satellite images
Resource inventories	Local data upon base maps	Aerial video/photo, GPS, GIS
Resource management	Comprehensive ecological and socio-economic data	Aerial video/photo, GPS, satellite images, GIS

Source: Poole 1995

4. Bridging the Gap ?!

It is only recently that researchers and development practitioners have started to explore how spatial information technologies can assist in the integration of traditional environmental knowledge and Western science-based paradigms of environmental management and sustainable development (Aldenderfer and Maschner 1996, Poole 1995b, Tabor and Hutchinson 1994). This debate is often shaped by the growing trend towards bottom-up and participatory models of environmental planning and development (Hutchinson and Toledano 1993, Kyem 1998). Furthermore, the proliferation of information technologies in general has resulted in a more reflexive approach vis-à-vis their utilization and impacts on society. We can distinguish at least three levels of discourse on the role of spatial information technologies. While many of the following arguments and considerations apply equally to the use of GPS and Remote Sensing, our analysis focuses on GIS, as it has attracted the brunt of the pertinent literature and illustrates best the critical issues.[12]

4.1. Empowerment vs. Marginalization

This dichotomy reflects the most “abstract” perspective on the relationship between GIS and society. Many representatives in the GIS community consider “their” technologies as inherently democratic and empowering, as they allow an ever increasing number of users to participate in a process of information collection, processing and dissemination (Harris and Weiner 1998b, Pickles 1995). Old prerogatives of the state and governments have been eroded by the proliferation, accessibility and commodification of spatial data. Similarly, prices for hardware, software and data are in a downward spiral, making the technology available to a large number of users.

While this view dominated the early stages of GIS use and dissemination, the past years saw a growing number of more skeptical voices (Fox 1998, Rundstrom 1995). Many observers have started to question the positivism and hegemonic power relations embedded in GIS. They emphasize, above all, the differential access to GIS data and equipment. Rather than being a “technology of freedom” (Pool 1983), GIS and related tools reinforce, they argue, the prevalent technocratic paradigm. As a result, those groups in society that are already disadvantaged are further marginalized as they can not participate fully in the benefits of the spatial information revolution.

A third school of thought seeks a middle ground by noting that GIS and related technologies are a double-edged sword and often contradictory. According to them, impacts on social objectives such as equity largely depend on the political, social and economic context, the technologies are embedded in (Harris and Weiner 1998b).

4.2. Participatory and Community GIS

On a more concrete and pragmatic level, the debate about the benefits of GIS has given birth to the concepts of Public Participatory (PPGIS) and Community-Integrated GIS (CIGIS) (Harris and Weiner 1998a, Kyem 1998). Both notions can be linked to the broader discussion on participatory development and community-based resource management. It is most probably fair to say that, at this point in time, PPGIS and CIGIS are efforts to capture these trends in a process rather than distinct methodologies or approaches.

Harris and Weiner (1998b) see the following criteria as constitutive of a community-integrated GIS:

- Likely agency-driven, but not top-down nor privileged toward conventional expert knowledge;
- Assumes that local knowledge is valuable and expert;
- Broadens the access base to digital spatial information technology and data;
- Incorporates socially differentiated multiple realities of landscape;
- Integrates GIS and multimedia;
- Explores the potential for more democratic spatial decision making through greater community participation;
- Assumes that spatial decision making is conflict ridden and embedded in local politics.

Box 2: Community Mapping in Kalimantan

In many parts of South-East Asia, forestry is shaped by the tension between state-controlled forest regimes and traditional management practices by local people. In recent years, there has been a growing acceptance of indigenous knowledge and practices, and countries like the Philippines or Indonesia, have recognized customary tenure regimes.

While this represents an important step towards more equitable resource management, in most cases this recognition remained a hollow shell, as land and resource rights were not demarcated. Governments often lack the political will and resources to carry out these processes. In a few projects, however, local communities, with the support of NGOs and researchers, started autonomous mapping exercises, making use of a variety of spatial information technologies.

One example of such a community mapping project is the demarcation of customary lands in the village of Long Uli in East Kalimantan. The village territory borders with a nature reserve, and in the past, a number of land use conflicts between the villagers and the forest department occurred.

The project's objectives were to:

- Map the customary lands using oral history, traditional knowledge, sketch maps and a global positioning system;
- Use a geographic information system (GIS) to overlay this information with official land use maps in order to clarify land-boundary conflicts; and
- Identify management alternatives taking into account TEK.

The project demonstrated that spatial information technologies can assist in the assessment of indigenous ways of organizing and allocating space, in the reconciliation of local resource management systems and government-instituted science-based regimes, and in the formal recognition and protection of customary forest tenure arrangements.

Source: Sirait et al. n.d.

While the project in Kalimantan fulfilled most of the criteria enunciated by Harris and Weiner, Sirait et al. noted a number of constraints, which include the political will of the parties involved to recognize different forms of land rights, and the ability of social scientists and mapmakers to accurately reflect the complex relationships of traditional resource management regimes on maps.

4.3. Culturally-appropriate GIS

It is this last point, the cultural appropriateness or sensitivity of GIS, that informs a third perspective on the use of spatial information technologies by local communities. Many GIS practitioners, including indigenous experts, argue that GIS and related technologies can help demonstrate the close relationship between local people and their land by illustrating the multiple dimensions of human-land relations such as folk taxonomies of flora and fauna, place names, myths and legends (Johnson 1997, Poole 1995b). The overlay feature and linkages to attribute databases, including multimedia (recordings, photographs, animations, etc.), represent a step away from the classic cartographic metaphors and spatial precepts established by Western science. The easy manipulation of data also makes it possible to integrate and revise input from a large and diverse group of informants.

On a pragmatic level, advocates of spatial information technologies argue that these tools are well suited to preserve, revitalize and disseminate knowledge and practices that are on the brink of extinction (Harmsworth 1999). Even if not all facets of this knowledge can be captured by a GIS, through a combination with other methodologies such as participant observation, a fair representation of local cultures can be attained. Furthermore, in order to deal effectively with government authorities and other stakeholders, a common language must be found (Sirait et al. n.d.)[13]

Box 3: Conservation and dissemination of Maori traditional knowledge

Like most indigenous peoples, the Maori of New Zealand have a comprehensive body of traditional knowledge and values, most of which closely associated with their lands and natural resources. According to present legal requirements, this knowledge must be taken into account in land-use planning. In recent years, there has been a growing interest on the part of the Maori in recording their traditional knowledge, particularly at the local and community levels. With the increased access to computers, these efforts used database management systems to store and organize the information.

Many of these databases have been integrated into geographical information systems and organized according to specific tribal areas. The main challenge of these geo-referenced TEK systems, was to combine Maori cultural values with biophysical information for the benefit of environmental management planning, while at the same time protecting the confidentiality and intellectual property of certain types of information. The latter goal was accomplished by linking information that is too sensitive to store in the GIS via a database directory to an individual person.

These projects in New Zealand address the critical question to what degree GIS and related technologies can be utilized in a culturally-sensitive and appropriate way and actually help to conserve and disseminate the rapidly vanishing traditional knowledge of local people.

Source: Laituri 1998 and Harmsworth 1999

This pragmatism stands at the core of many criticisms of GIS for local communities. Certain purists consider GIS technology as “a tool for epistemological assimilation, and as such, as the newest link in a long chain of attempts by Western societies to subsume or destroy indigenous cultures.” (Rundstrom 1995) Spatial information technologies can not capture the “ethnological content of spatial patterns” (Fox 1998), i.e. the cultural patterns imbued in landscapes and natural resources.

Most traditional resource management practices are characterized by a high degree of fluidity and flexibility. Boundaries that exist in cognitive/mental maps are continuously redefined. Once a map establishes clear borders, claims and entitlements are “out in the open”, often rendering the management of conflicts more difficult (Fox 1998, Sirait et al. n.d.). Furthermore, spatial information is often restricted or secret.

The knowledge of sacred sites or certain practices is often limited to a small group of people and can not be disclosed. While the example of the Maori shows that mechanisms can be developed to take privacy considerations into account, spatial information technologies could contribute to violations of this "space".

5. Conclusions

Are spatial information systems appropriate technologies (Yapa 1991)? In other words, can they help local communities to manage their environment more effectively and efficiently, while at the same time respect and enhance traditional cultures? We are tempted to conclude with Krantzberg's First Law : "Technology is neither good nor bad, nor is it neutral" (Castells 1996), which points to the importance of the social, political and economic context of technologies. This is the short and easy answer.

We hope, however, that the preceding analysis has highlighted another point: The gap to bridge might not be very far and, hence, much of the debate about the social impacts of spatial information technologies rather redundant. It seems that, in many ways, traditional environmental knowledge is much closer to the technologies' structural features and functionalities than some of our Western methodologies.

Another word of caution: While spatial technologies are an important step towards integrating data at various levels of analysis and from different epistemologies, they can not relieve the researcher and policy-maker from the task to determine which social, economic, and political factors impact human-environment relations and lead to sustainable development.

Whatever the exact repercussions of GIS, GPS and Remote Sensing might be in the individual case, one thing seems to be sure: Even in the age of the Internet, cyber-space and virtual reality, there is room for space.

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Notes

[1] Other terms in use are “indigenous knowledge” and “traditional ecological knowledge” (Lawas and Luning 1996).

[2] For an example of cognitive/mental mapping see Brody 1981.

[3] Similarly, Article 8j of the Convention on Biological Diversity calls on the Contracting Parties to “… respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices.” (Glowka et al. 1994)

[4] In a similar vein, the Recommendations of the Inuit Circumpolar Conference (1996) on Traditional Indigenous Knowledge and Science call for “collaborative efforts between researchers and communities” and “an atmosphere of cooperation, and not of competition”.

[5] See for example the GIS Data Depot at www.gisdatadepot.com.

[6] 15 feet or better.

[7] Handheld GPS receivers sell for as little as $75.

[8] A good impression of the variety of applications can be gained by looking at the agenda of ESRI’s – a major GIS software company – annual user conference at: http://andes.esri.com/uc98/UCAgenda/view_papers.cfm.

[9] See for example the new DAIS-1 sensor from Space Imaging (http://www.spaceimage.com/newsroom/releases/1999/aerial.htm.

[10] Distributed as SPIN-2 (http://www.spin-2.com), 2m resolution images can be purchased for 25$ per 100 km2.

[11] The European Space Agency (ESA) operates ERS-1 and ERS-2, and Canada RADARSAT.

[12] Moreover, GPS data and aerial/satellite images are increasingly used as input for GIS.

[13] This argument has been most persuasively made in a number of land right claims by native groups in Canada and the United States.

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Dr. Gernot Brodnig is currently a Research Associate at Harvard University's Weatherhead Center for International Affairs, where he is engaged in research and advisory services on natural resource management and biodiversity conservation issues. His projects include a study on the use of Geographical Information Systems and related technologies in community-based natural resource management. Before coming to Harvard, Dr. Brodnig worked for UNESCO and UNDP on various environment and social development projects. Dr. Brodnig has been trained in law, international affairs and geography in Austria, England, and the United States.

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