GIS, GPS, AND REMOTE SENSING

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The role of information and communication technology (ICT) in accelerating development is drawing increasing attention. ICT promises to help isolated and disenfranchised communities transform themselves into development participants who are better informed and integrated. However, this promise is tempered by concerns that the control and application of ICT could reinforce—or simply reconfigure—existing forms of inequity and marginalization and might be unsustainable in more remote rural areas.

Information and Communication Technology Tools

Low-income rural residents have adopted some information technologies with considerable success. The best known is the mobile phone, which, for example, helps reduce the information gap between farmers and traders. Mobile phones are inexpensive, require no special training, and serve social functions beyond their use in rural trade. They are also easily shared or rented out, providing non-farm income opportunities for enterprising rural households.

Another group of more specialized ICT tools 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 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).

While obstacles exist—particularly in developing countries—geographically referenced data is providing new insights into global issues such as the patterns and processes of human settlement, natural resource use and degradation, agricultural performance, disease, and conflict. Agriculture, unlike most other forms of economic activity that benefit from geographic concentration, is tied to a natural resource base that is spatially dispersed and highly variable. Physical, social, and economic geography thus play a crucial role in determining the scale and scope of agriculture at a given location.

GIS technology provides tools for visualizing, integrating, and analyzing spatial data and a unique capacity to merge information from many sources. By using a common spatial framework, GIS enables users to analyze how physical, social, and economic factors interact. Constraints to widespread use of GIS have been its high cost and complexity and the difficulty of obtaining geographically referenced (georeferenced) data. However, as the technology has become cheaper and less complex, it has become more accessible to non-specialists.

GPS and remote-sensing techniques have also reduced the problem of obtaining georeferenced information. For instance, most field surveys now use GPS to capture the

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location of sample points, such as plots or households, enabling easy visualization of survey results and integration with other geographic data. GPS receivers range from the handheld models that are inexpensive, easy to use, and provide coordinate accuracy of about 10 meters to differential receivers that yield accuracy in centimeters.

Great advances have also been made in remote sensing and aerial photography. Image-processing techniques generate digital maps from aerial photos or satellite data that combine the accuracy of a topographic map with the rich contextual information of a photograph. Despite these advances and the falling prices of some satellite data, however, their direct use is likely to remain the domain of specialized users.

How Spatial Technologies Benefit the Poor

Spatial technologies have benefited the rural poor mostly indirectly, by generating improved information for research, policy analysis, planning, and monitoring. Precision farming techniques are used in high-intensity commercial agriculture, where detailed location information determines, for example, the level of fertilizer applied to each portion of a field. However, the capital, maintenance, and training requirements are well beyond the means of most farmers in developing countries, particularly smallholders whose small field sizes make these technologies uneconomic.

One of the most direct applications of GIS in developing countries is participatory mapping, where, for example, specialists interact with farming communities 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 to local levels of government.

GIS is increasingly being used widely in parcel mapping. Without proper land registration, formal land markets are less efficient and the incentives to invest in land conservation might be limited. Also, without land titles, farmers often have difficulty accessing credit. In many instances, however, land ownership, access, and use rights may be complex—especially where resources are communal. Land-titling systems tend to assume that a given piece of land is uniquely assigned to an owner, while in reality it may be subject to a complex web of overlapping, shared uses based on informal, mutually beneficial agreements. Formalizing and administering such complex patterns in the fairly rigid language of digital cartography is difficult and in some cases impossible.

Public Participation GIS

Questions do arise about the political economy and sustainability of GIS approaches applied at the community level, and research on those issues has given rise to a literature on Public Participation GIS, or PPGIS. PPGIS research primarily addresses concerns about GIS as an invasive technology that benefits some people and institutions while marginalizing others. While this work has often focused on developed-country experiences, its concerns are even more pertinent to poor communities in developing countries. PPGIS issues include

- Changes in local politics and power relationships resulting from the use of GIS in spatial decision making;
- The effects of differential access to GIS hardware, software, data, and expertise;

- The educational, social, political, and economic reasons for lack of access and exemplary ways in which communities have overcome these barriers;
- The ways in which socially differentiated communities and their local knowledge might best be represented within GIS;
- GIS as local surveillance; and
- Identifying public data policies that positively or negatively influence small-scale local businesses.

Two important PPGIS research thrusts have emerged. The first focuses on the design of truly participatory GIS-based processes for conflict resolution and decisionmaking with regard to community resources. The second aims at advancing the ability of nongovernmental organizations, agents, and other representatives of indigenous and local communities to use GIS to advocate for inclusion, participation, and recognition.

Successful Pro-Poor Applications of Spatial Technologies

Many successful pro-poor applications of spatial technologies exist at the more aggregate levels of agricultural planning and research. Detailed information about agroecological and socioeconomic conditions, for instance, enables better targeting of agricultural technology. Geographic information also assists in planning rural infrastructure, such as prioritizing national investments in rural roads, electricity, health, and education. The preparation of welfare or poverty maps can greatly improve targeting interventions to the poorest communities. Geographic targeting at the level of small communities reduces the chance that the intended recipients are missed or that resources leak to the nonpoor. Other successful GIS applications in rural areas include emergency planning and response.

The key to successful GIS applications is the availability of detailed spatial data. While remotely sensed information and GPS-based field surveys help plug some data gaps, much information is still difficult to obtain at a geographic scale that is relevant for operational impact. This is particularly true for socioeconomic data, which cannot be captured remotely or interpolated from sparse observational information. The main sources of such information—censuses and surveys—do not address all information needs. The former are carried out infrequently and provide only the most basic information, while the latter can provide detailed information but usually not at aggregation levels that are suitable for operational work. Strengthening of formal and informal capabilities for spatial-data collection at local levels is thus one of the priority needs.

Future Benefits of Spatial Technologies

Geographic information technologies will continue to provide considerable indirect benefits through better-informed policymaking, research, planning, and development support by both government and non-government agents. As national spatial-data infrastructures continue to develop, baseline geographic data should be easier to obtain. This improvement will enable more practitioners to make use of digital mapping and analysis, particularly if parallel enhancements are taking place in Internet accessibility. Through an Internet map server, geographic information can be made accessible to non-specialized users through standard browsing tools. Combined with other initiatives to bridge the digital divide, such as wireless technologies, Internet mapping could help disseminate critical geographic information to local cooperatives or farming communities.

Examples are weather maps based on up-to-date satellite images or regional commodity-price information.

The future might also bring cheaper and easier-to-use tools that enable farming 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 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.

For further reading see Committee on the Human Dimensions of Global Change, *People and Pixels: Linking Remote Sensing and Social Science* (Washington, D.C.: National Research Council, 1998); Nancy J. Obermeyer, "PPGIS: The Evolution of Public Participation GIS," www.ucgis.org/oregon/ppgis.pdf; and John O'Looney, *Beyond Maps: GIS and Decision Making in Local Government* (Redlands, Calif.: ESRI Press, 2000).
