

GIS for Sustainable Development at Local Scales: Applications in the Rural Hillsides, Savannas and Forest Margins of Latin America

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I. Introduction

During a recent users group meeting of a popular geographic information systems (GIS) software developer, thousands of GIS professionals appeared stunned by the keynote speaker's comments. After congratulating his audience on their technical wizardry, their impressive graphics and computer simulations, the speaker announced that all the elaborate and sophisticated methods in the world would not solve the principal problem facing successful application of these new technologies. How decision-makers

and citizens resolve competing interests will ultimately determine the success or failure of sustainable development efforts. Better decision-making in the developed countries is one clear result of new digital mapping and analysis technologies. But can these relatively new technologies do the same in the underdeveloped world? Resource-poor regions in less developed countries have yet to take full advantage of the geographic information revolution and new tools for analyzing development problems. Our paper reviews results of recent work at the International Center for Tropical Agriculture (CIAT) to evaluate the potential of geographic information systems (GIS) for natural resources management in the Central American hillsides, the Colombian savannas and the Peruvian forest margins. The work presented here focuses on GIS applications and the challenges and opportunities of applying the technology at local scales in three reference sites in the developing-world tropics. Although we can only speak of our own experiences in applying geographic information technology to development problems, we believe the same considerations are relevant for other locales in less developed countries where sustainable development is a priority.

Using an extensive GIS database of Honduras we designed the sampling for participatory research on agriculture and natural resources in hillside environments. We analyzed information obtained at local scales using a well-being ranking methodology to orient development of specific strategies applicable nationwide (Ravnborg 1999). We are helping farmers in five villages to elaborate sustainable agricultural development plans using participatory methods and low-cost GIS in the Colombian savannas. This village-level work updates the Puerto Lopez land use plan developed by the local government and CIAT in 1999. The local Ministry of Agriculture in the Amazonian department of Ucayali, Peru, together with CIAT is developing GIS for decision making in the agricultural hinterland of Pucallpa, a forest margins site with high deforestation rates. Applications include accessibility analysis, land cover mapping with satellite imagery, and analysis of farming systems.

Our experience suggests that successful application of GIS in resource-poor regions of Latin American hillsides, savannas and forest margins will lead to more

sustainable development. However, data limitations, the lack of a GIS “presence” in these regions, and technical and human resources barriers to successful GIS implementation will likely continue to impede progress towards full utilization of spatial information technology at local scales for some time to come. Achieving consensus among stakeholders in the community remains a major challenge to GIS applications for sustainable development. GIS technology is increasingly playing a facilitating role for improved decision-making. Whether these challenges can be overcome will depend largely on capacity-building for GIS professionals in developing countries, increased North-South collaboration and scientific exchange, information policies oriented towards maximum use of geographic information and political leadership to promote the technology.

The greatest challenge for sustainable development in the less developed world is to bring the scientific advances of the information technology and geographic information revolutions to bear on problems of severe environmental degradation while at the same time improving livelihoods. Although evaluating impact of information technology is complicated and difficult to carry out, we speculate on the impact or potential impact of geographic information technology on sustainable development in our three reference sites. We conclude with some recommendations about using GIS at local scales in future work. Our recommendations include suggestions for addressing the so-called north-south digital divide in the use of information technology.

II. Methods

Our research strategy grew out of recent thinking about rural development based on the *ecoregional* concept. Natural resources problems affecting rural livelihoods and environmental quality are tied to the ecological context of local places. Thus the solutions are likely to come from research that focuses on the particular problems of each agroecosystem. The strategy has the advantage that research at a site can potentially be “scaled up” or “extrapolated” to larger areas, thus achieving greater impact.

Our recent work has focused on three sites that are representative of typical tropical ecosystems. Vast numbers of developing world people inhabit the tropical hillsides of Latin America, Africa and Asia. Their challenge is to improve well-being while preserving the resource base by controlling soil erosion, managing water for a more efficient agriculture, and integrating their farming system into markets of nearby urban centers. The tropical savannas represent one of the largest tropical ecosystems spanning large areas of Brazil, Venezuela and Colombia in Latin America, and a large part of sub-saharan Africa. Farmers face problems of native grassland and introduced pasture management, as well as nutrient availability for crop production. Despite the agricultural potential of the savannas noted by many observers, broad-scale progress toward sustainable development of these regions has yet to take hold. Researchers and policy-makers have debated the potential for sustainable development in the lowland humid tropical agroecosystems for several decades. Some observers have argued that the humid-lowland forest margins represent huge opportunities for future development if managed wisely (Sanchez and Salinas 1981). Others believe that the carrying capacity of these lands is low and they should be managed in a more traditional style that emphasizes conservation (Fearnside 1987). Sustainable development problems are clearly evident in the three regions. Can Geographic Information Science be brought to bear for sustainable development in these areas? Over the last decade, CIAT has used methodologies towards this end.

Across the three environments, our activities focus on three broad categories of GIS applications -- participatory mapping, land use planning and geographic analysis of development problems. Basic geographic information and remote sensing science supports our work in these activities. We use all these methods at the different sites to differing degrees. In all cases, our work involves collaboration with local decision-makers, governmental and non-governmental organizations, and farmers and other citizens. The level of technical capacity needed to do the work varies from analogue mapping at the farm plot level to highly technical remote sensing and spatial analysis over broad areas.

Participatory mapping methods are now becoming popular throughout the world. GIS technology has stimulated much of this interest because of its potential for analyzing different land use scenarios. Our methods range from simple sketch mapping with paper and pencil to projecting computer-generated maps onto a presentation screen. We ask participants to share their knowledge of their local area to help fill in maps or to create different scenarios of what they want their community to be like. The mapping exercises take place in a community meeting or in a household interview setting. A facilitator guides the discussion around a development-related objective (Vernoy et al. 1999, Beaulieu et al. 2000). Base maps are created from air photos, satellite imagery or paper maps, and produced on wall-size posters or papier-mache models, or projected from a computer. Participants then fill in these maps with their knowledge of environmental problems and opportunities. In separate exercises, we develop scenarios of what a landscape might look like given a set of land use decisions. We are experimenting with virtual reality computer models and “fly-by” techniques to simulate the probable consequences of land use decisions (Leclerc et al. 2000).

We are giving emphasis to land management because many of the communities we work with need better planning and have either a legal or political obligation to develop a land use plan. In Spanish the term for this activity is *ordenamiento territorial* and refers to the development of guidelines for wise use of land resources. Traditionally, this exercise consists in comparing actual land use maps to land use potential maps developed in a rather top-down way by government experts. Where the two maps disagree it is often considered a land use conflict. Another approach used at local scales is termed ecological and economic zoning. The local area is divided into homogenous units based on the biophysical potential of the land and current socioeconomic conditions. Given these conditions, a plan is developed providing guidelines for making land use decisions. In contrast with these approaches, the strategy we adopt and promote for “ordenamiento territorial” is very much akin to the participatory mapping approach. As described in Beaulieu and others (2000), the desired conditions for the municipality and/or village are discussed collectively in workshops with the community. The actual

conditions are then discussed, and a diagnosis on the causes of the gap between actual and desired conditions is made. A preliminary list of actions and requests is collectively drawn. Geographic data is then gathered to verify the validity of locally perceived conditions and trends and is also used to make the goals of planned actions more precise. The geographic information database is later used as the basis for monitoring the progress of the actions towards the goal. This approach facilitates the diagnosis, a stage in which many planners get stuck if they gather large quantities of information without knowing – even roughly - what they want to demonstrate with it. With this approach, land use is planned in function of opportunities and activities desired by the stakeholders, not in function of available data. The geographic data – only that necessary for the task - is used to determine if the land can sustain these activities, and how desirable uses and activities can be optimally located within the territory. Land evaluation becomes an intermediate step in the process rather than forming the basis of it, and this addressed one of the landmines of GIS use: the continuous gathering of new data and endless correction of existing data.

A third broad category of our efforts at applying GIS to sustainable development is traditional database development to produce analyses aimed at better decision-making. This work is based on the hypothesis, now being tested worldwide, that greater access to information, better data and better tools to analyze data will result in better decision-making. A decade ago government offices at local levels rarely had computers, limiting the possibility to analyze digital information. Today, local governments in developing countries are just beginning to employ geographic information technology. Most of the work to date has been development of basic digital map layers. For example, agricultural extension agents are locating villages with GPS units. Then, data collected for each village is linked to the location on a map. Database and spatial analysis is then employed, permitting a more thorough analysis of information.

Some observers have argued that much of the digital mapping revolution over the last two decades is overrated. Traditional mapping and analysis methods can often be less expensive and give better results than new digital technologies. In fact, it is still to be

proven that a digital map leads to better decisions than one obtained by overlaying transparencies manually. Have more information and better tools resulted in better applications of GIS and remote sensing for sustainable development? Are the human resources, hardware, software, data and technical capacities found in developing-world contexts sufficient for advancing sustainable development goals? We attempt to answer these questions in the following case studies.

III. Case Studies

We spent a part of the last several years applying our capacities in GIS and remote sensing to research and development problems in three reference sites in Latin America. In hindsight, we insufficiently planned monitoring and evaluation activities for these sites. All three sites are the object of on-going efforts. Generally the impact of the application of GIS in these sites is not yet fully known. However, we can draw some general conclusions about the successes and failures of these efforts. The evaluation presented here is preliminary. Being involved in the efforts, the evaluation is subjective. In the case studies below, we reflect on how well we have applied the technology at local scales.

Participatory mapping work in Honduras ranges from simple sketch mapping on transparent paper to “fly-by” simulations with sophisticated software. Grenier (2000) recently demonstrated one of the earliest and best known applications of GIS to land use analysis in a study of farm-level land planning in northern Honduras (Figure 1). Instead of using digital technology, which the local community did not possess, local farmers and extension agents used transparent paper and felt tip pens to map out their farms. They mapped current land use, potential land use, and finally made an overlay analysis to map the differences between the two. For many GIS professionals in natural resources management, this mapping exercise takes us back to our early GIS education. It now seems unsophisticated to many of us, yet is simple enough to non-professionals for exploring and understanding the possibility of new land use options. This type of exercise could be the proper entry point for the adoption of GIS by communities.

A second exercise in participatory mapping in Honduras were CIAT's efforts to map poverty based on local perceptions (Ravnborg 1999). Poverty indicators developed at national scales or for cross-country comparison are often unsuitable for local scale analysis. The United Nations promotes the "basic needs unsatisfied" method to be able to compare different countries in Latin America. The method rarely works at local scales because invariably some of the indicators are irrelevant for small areas (Hyman and Leclerc 2000). Ravnborg (1999) developed a method that ranks households in a community using local perceptions of poverty. A large number of contrasting communities were selected to give us a sample that represents the range of community types throughout the country. Informants consider the conditions of their neighbors and rank them according to how well they are perceived to live. The responses of many informants in a community are then compared. Households are generally categorized into the well off, not-so-poor and poor. These characterizations are then analyzed to extract poverty indicators. We used neural networks to link these indicators to proxy indicators found in the population and agricultural census. The indicators are then mapped. Figure 2 shows the result of the mapping for the Tascalapa watershed in Honduras. For the first time, local perceptions of poverty have been represented in a format that policy-makers can understand – country level maps aggregated at municipal or department levels. The well-being ranking method proved to be most helpful to our researchers and local extension agents in prioritizing research and development activities. Yet, the pathway to translate our new knowledge about local communities into actions that result in sustainable development remains unclear.

At the other end of the technical spectrum is work at the Honduras reference site to simulate the changes that occur given a set of land use decisions (Leclerc et al. 2000). The work was inspired by a recent development in urban planning – the use of ray tracing software to generate realistic "virtual" representations. Only GIS professionals can develop this model as it requires sophisticated software and experienced users. We used a low-cost software (VistaPro 4.0) to simulate the consequences of land management incentives in a hillside watershed in Honduras. The analyst needs a digital elevation

model and a land cover map. We developed these data sets using softcopy photogrammetric methods to create orthophotos of the Yoro watershed in Honduras. We made the land cover map from visual interpretation of the orthophotos. An optimization model that treats the watershed as a large farm, reassigns land units according to various scenarios, for example a sustainable forest option, or an environmental payments option. VistaPro allows the user to input this data and simulate a “fly-by” of the watershed in the form of a animated graphic presentation on a desktop computer. The result is a visually impressive aerial tour over the simulated landscape (Figure 3). Although it is difficult to gauge the effect of demonstrating the simulation to local community leaders, their reaction indicated heightened awareness of the consequences of land use decisions. This visualization exercise needs to be refined. We need to set up simulations for alternative land use scenarios and then come up with a more objective way of evaluating the effect of the simulations on future land use decisions. This is a direction that GIS will take in the coming years and could be a key to greater adoption of geographic information technology.

Our work in the Colombia savannas reference site is being carried out in the context of land use planning at the municipality level. Recent legal requirements in Colombia require each municipality to develop land use plans for the next decade (Ministerio del Medio Ambiente de Colombia, 1997). Land use planning is relatively new to most of these political entities to whom digital geographic information technology is usually entirely new. Aiming to develop and/or demonstrate simple tools and approaches and make them available to all municipalities in Colombia, we accompanied the personnel of the city hall of the Municipality of Puerto López in the elaboration of their Basic Land Use Plan (Jaramillo et al., 2000, Alcaldía de Puerto López, 2000).

We quickly realized that local stakeholders lack the capacity to use full-fledged GIS and remote sensing software packages. They would need some pre-processed data and software that could be widely distributed at little or no cost. We needed a Spanish language software that could handle vector digital maps and imagery. We are aware of only one software package that fit these criteria – ArcExplorer in Spanish

<http://www.aeroterra.com/ae/spnarcexplorer.htm>). The disadvantage of ArcExplorer is the inability to digitize on screen and its poor handling of imagery. We had some experience with MapMaker software (Dudley 1999), but it was not available in Spanish. Project leaders decided to work with the software developer to make a Spanish language version of MapMaker, called MapMaker Popular. As soon as we had developed our new version of MapMaker, we built a geographic information database for the municipality (Figure 4). MapMaker has several advantages for broad-scale use in developing countries. Anyone can download the basic software from the Internet for free. The software handles image formats that permit on-screen digitizing and overlay of vector graphics on top of imagery. Another advantage of the software for local scale studies is the tools it offers for field level mapping with a rudimentary plane table and compass. The feature is especially useful for agricultural extension agents to help farmers map their fields and farm when GPS technology is not available.

Using a participatory approach, local authorities and CIAT staff used the GIS database of Puerto Lopez to develop the federally mandated land use plan. The integrating nature of GIS is evident in these efforts. Professionals of different backgrounds participated in the mapping process and reviewed the integrated data with a broad range of stakeholders. For the municipal-level general land use planning, we find it suitable to make land use restriction recommendations in function of geomorphological landscape types (Rubiano et al., 1999). To support the specific land use planning, we developed spreadsheet programs that run parallel to the GIS to help the municipal agricultural extension service assess agricultural restrictions for different types of land units (Rodriguez et al., 1999). In community planning meetings, participants can locate their present or planned crops on printed land evaluation maps, as shown on Figure 5 (Cardona, 2000). They can consult the digital maps on the computers of the city hall or of the agriculture extension service, with the help of an extension agent.

The use of GIS in participatory mapping and planning only addresses some of the issues at stake in the Puerto Lopez community. We found that the mapping exercise stimulated discussions of other issues that are much more difficult to resolve. During one of the meetings the forces operating at regional, national and global levels quickly became apparent. Farmers raised the issue of Colombian national trade liberalization policies that are forcing them to compete against often heavily subsidized foreign producers for urban markets in Colombia. They feel that they cannot manage their businesses in a sustainable manner as long as they lack protection from foreign competition. Strategies to help them become more competitive include the formation of associations, agro-enterprise and the elaboration of value-added products, which do not necessarily require the elaboration of maps in their planning.

Our approach in applying GIS for sustainable development in our Peruvian Amazon reference site is less participatory and more focused on working with the local agencies to develop information technologies that provide a base for improved decision-making. We are working with partners at the Peruvian Amazon Research Institute (IIAP) and the local ministry of agriculture to develop and use agricultural and population census data, remote sensing imagery and biophysical and economic surveys (IIAP 1998). Several elements of GIS are lacking in the study area's local institutions. The data needed for improved decision-making exists and is in a usable format. Local agencies lack software, hardware and the human resources to take full advantage of GIS technology. The applications described below were developed with local agencies, but the information technology was implemented far from the local site.

We used GIS technology to development poverty maps for targeting research and development activities in the Peruvian forest margins. Targeting efforts require that we know the location of our clients and their living conditions with respect to natural resources, access to markets and socioeconomic setting. We began to develop a profile of the study area by collecting available information. Poverty information from the census institute is only available at district level, much too coarse for local scale analysis. Detailed data in Peru and many developing countries is usually difficult to acquire. We

had to make a special contract with the census institute to acquire local level data. But once local level data was acquired, we found that it was inappropriate at the local scale. As in Honduras, Peru uses the “basic needs unsatisfied” method. An indicator like house type assumes that modern home construction materials imply greater well-being. But in the lowland Amazon thatch roofs and walls are usually the best construction material for the hot and humid environment. Another useless poverty indicator is whether households have plumbing facilities or not. On the seasonally inundated floodplains of the Amazon and its tributaries, it makes no sense to construct plumbing facilities. We had to develop our own poverty indicators from the agricultural and population censuses of the region. Figure 6 shows an index of agricultural resources that ranks communities according to their possession of natural and economic resources for agricultural development. We developed the indices from multivariable statistical analysis of census data. The methodology provides a solution to the difficulty matching data derived from national scale programs to local scale problems.

A second application of GIS to sustainable development in our forest margins site is an analysis of land cover change and the factors underlying current deforestation rates. Figure 7 shows land cover change at our Peruvian Amazon research site. The research project is part of an ongoing effort to monitor deforestation rates by CIAT and partners (IIAP 1996). The map is based on air photos and satellite imagery for 5 dates since 1955. We separated the map into deforested areas for each of the dates for which we had data. Using common presentation software and scrolling through each date, the viewer can see the march of deforestation over the last half century. Presenting the data in this visual manner clearly communicates the deforestation problem in the study area. Since local officials are well aware of the importance of the forest for economic growth in the timber industry, among cattle ranchers and for slash and burn farmers, the visualization exercises emphasize the coming crisis. The lack of forest resources will soon begin to be felt by the entire community. People will have to move elsewhere or accept a lower standard of living derived from a depleted resource base.

Assessing the impact of our deforestation studies in the Peruvian Amazon is difficult. We believe presentation of the maps and studies to local officials has had a positive impact on decision-making. Policies have changed over the last decade. Deforestation rates have decreased. As with most natural resources management studies, assessing impact is frustrating. How do we know what effect specific local decisions have had when contrasted with national policies that might affect deforestation. Local officials in Pucallpa changed the rules for timber development in the early 1990's. But how much of the reduction in the deforestation rate is due to forces in the global wood products market? Recently in Peru, a new law reduced gasoline taxes in the Amazon, lowering the costs of wood transport. How will this affect deforestation? More in-depth studies will be needed to analyze these impacts. Our work here shows that we cannot ignore forces acting on regional, national and global scales as we apply GIS technology for decision-making at the local scale.

IV. Discussion and Conclusions

Some common issues are apparent in our application of GIS technology to our reference sites in Latin America. These issues can be broadly categorized as visualization as a means of communicating the results of applied spatial information science, scale issues in decision-making at the local level, and local capacity to implement geographic information technology.

The improved use of visualization in applying geographic information technology to local scale problems will benefit from future research and development. Although it is difficult to measure the impact of visualization exercises, we found these techniques to increase awareness, giving decision-makers new knowledge about the likely outcomes of their decisions. In Honduras, farmers could see the likely effects of environment-friendly incentives. Puerto Lopez decision-makers developed a vision of what they wanted the municipality to be like and they could modify it using participatory mapping techniques. Decision-makers in the Peruvian Amazon clearly saw that past land use decisions were

unsustainable and changes are needed. Research in visualization as a means of communicating is a high-priority need among the remote sensing and geographic information professional community. Participatory mapping, computer simulation and standard cartographic presentation techniques hold out promise for more effective communication with decision-makers and the public.

In all three local scale case studies, we could not escape the influences of cross-scale effects on environmental and economic processes. We often collect data to address national, regional or global issues, making it difficult to study the particular circumstances of issues like poverty at local scales. We need to develop new techniques for applying GIS to particular problems at local scales. Local decisions affecting agricultural policy or deforestation are often overwhelmed by broad-scale processes like regional trade liberalization or global population growth. Our recent work in Latin America suggests that cross-scale issues affecting local places is a timely topic deserving greater attention.

Much of the success or failure in applying GIS to sustainable development in less-developed countries will depend on technology and data access. The so-called “digital divide” -- where less-developed countries lack Internet access, technology training, and generally have weak capacities in the use of information technology – must be overcome. Developing countries will need to develop spatial data infrastructures that address the problems of data quality, access, intellectual property rights and metadata. The access to low-cost or to free GIS software can greatly help the development of GIS skills and culture.

However, access to data and software does not guarantee more efficient or “better” decision-making and can even make the process more cumbersome if planning goals are not clear. This is why we have joined GIS methods with participatory methods that help people determine how they want their local environment to be and how they can progressively transform it through better management of their natural resources.

V. References

- Alcaldía de Puerto López. 2000. Plan Básico de Ordenamiento Territorial. Puerto López, Colombia. 3 Vol. y planos generales. [Mayorality of Puerto López. 2000. Basic Land Use Plan. . Puerto López, Colombia. 3 Vol. and general maps.]
- Beaulieu, N., Rubiano, Y., Vrieling, A, Rodriguez, M., Jaramillo, J.E., Muñoz, O.J., and Zakhia, N. Patricia Cardona and Luis Marino Santana (1999). Use of GIS in land resource management in the Colombian Orinoco Region. Presented at the 6th JIRCAS International Symposium "GIS Applications for Agro-environmental issues in Developing Regions", Japan International Research Center for Agricultural Sciences, Tsukuba, Japan, 7-9 September 1999.
- Beaulieu, N., Imbach, P., Muñoz, O y Jaramillo, J. 2000. Guía de aprendizaje del programa MapMaker. CIAT, Cali, Colombia, 96p. Distributed on MapMaker Popular CD-ROM. [MapMaker Program Training Guide]
- Beaulieu, N., Jaramillo, J., Leclerc, G. 2000. Propuesta metodológica para el componente participativo del ordenamiento territorial, basada en el desarrollo de una visión común. CIAT, Cali, Colombia, 12p., distributed on MapMaker Popular CD-ROM [Methodological proposal for the participatory component of land use planning, based in the development of a common vision].
- Cardona Londoño, P. 2000. Perfil Socioeconómico de cinco comunidades del municipio de Puerto López (Meta). Informe interno, CIAT, Cali, Colombia, 56 p. [Socioeconomic profile of five communities of the Puerto López municipality, Meta. Internal report].
- Dudley, E. (2000). MapMaker, Demystifying GIS - Map Processing for Windows. Software and documentation available at <http://www.mapmaker.com>. Spanish version, MapMaker Popular, available at <ftp://ftp.ciat.cgiar.org/MapMaker-Popular>
- Fearnside, P.M. 1987. Rethinking Continuous Cultivation in Amazonia. BioScience **37**, 209-214.
- Grenier, Gaston. 2000. Watershed scales and levels: experiences with projects in Central America. Paper presented at the Scale Effects in Decision-making workshop, San Jose, Costa Rica. July 4 – 7.
- Hyman, Glenn and Gregoire Leclerc. 2000. Alternative poverty mapping strategies to address needs at national and sub-national scales. Paper presented at “Scale Effects in Decision Making for Ecoregional Development” workshop. July 4 – 6. San Jose, Costa Rica.
- Instituto de Investigaciones de la Amazonia Peruana (IIAP). 1996. Deforestación en el Area de Influencia de la Carretera Federico Basadre – Pucallpa. Iquitos: IIAP. [Deforestation in the area of influence of the Federico Basadre road, Pucallpa].

Instituto de Investigaciones de la Amazonia Peruana (IIAP). 1998. Zonificación Ecológica Económica de la Cuenca del Río Aguaytia [Ecological-economic zoning of the Aguaytia River watershed]. Pucallpa: IIAP.

Instituto Nacional de Estadística e Informática. 1995. IX Censo Nacional de Población y IV de Vivienda [National Census of Population and Households]. Lima: INEI.

Instituto Nacional de Estadística e Informática. 1996. III Censo Nacional Agropecuario [3rd National Agricultural Census]. Lima: INEI.

Jaramillo, J.E., Castro J., Pabón S., Gómez, D., Beaulieu, N., Rubiano, Y., Rodríguez, M., Muñoz O., 2000, El plan de ordenamiento territorial de Puerto López, una experiencia exitosa de cooperación interinstitucional. Informe interno, CIAT, 7 p. [The land use plan of Puerto López: a successful experience in inter-institutional cooperation].

Leclerc, Gregoire, Hernandez, Alexander, and Barbier, Bruno 2000. Communicating a vision of the future with optimization models and virtual landscapes: An application to community management of the Jalapa watershed in Honduras. Paper to be presented at the XXIVth International Conference of Agricultural Economists, Berlin, August 12-18.

Ministerio del Medio Ambiente de Colombia (1997). Bases ambientales para el ordenamiento territorial. Ley 388 de julio 17 de 1997. [Environmental base for land use planning. Law 388 of July 17th, 1997].

Ravnborg, Helle Munk. 1999. Developing regional poverty profiles based on local perceptions. CIAT publication No. 291. Cali: International Center for Tropical Agriculture.

Rodríguez, M, Rubiano, Y, Beaulieu, N. y Muñoz, O. 1999. Guía para la evaluación de la capacidad de uso de los suelos y su aptitud para cultivos específicos usando el sistema de información geográfica MapMaker Popular y la hoja de cálculo Excel y. Informe interno, CIAT, Cali, Colombia, 46p, [Guide for the evaluation of land use capacity and potential for specific crops MapMaker Popular GIS y Excel spreadsheets. also distributed on CD-ROM with MapMaker Popular].

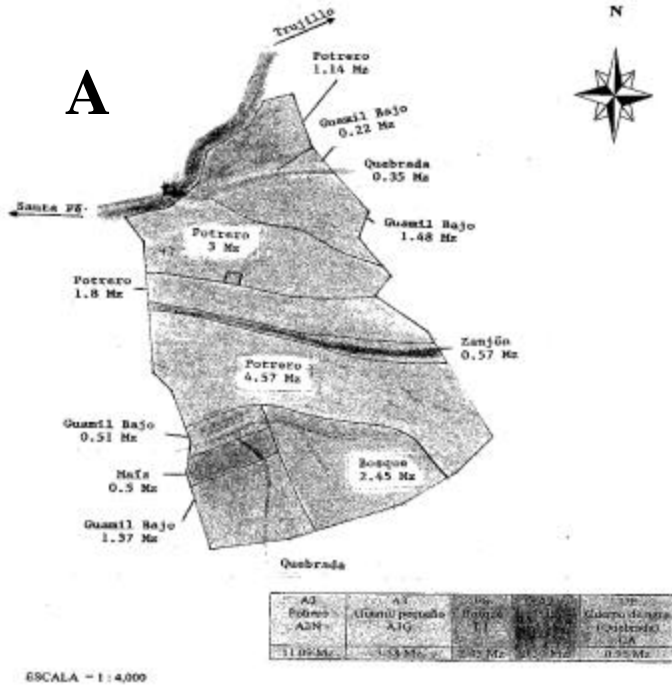
Rubiano, Y, Santana, L.M. y Beaulieu, N. 1997. Criterios para la planificación del uso de la tierra basada en unidades de paisajes, aplicación al municipio de Puerto López. Informe interno, CIAT, Cali, Colombia, 27 p. [Criterias for land use planning based on landscape units, application to Puerto López municipality].

Sanchez, P.A. and Salinas, J.G. (1981) Low Input Technology For Managing Oxisols And Ultisols In Tropical America, Academic Press.

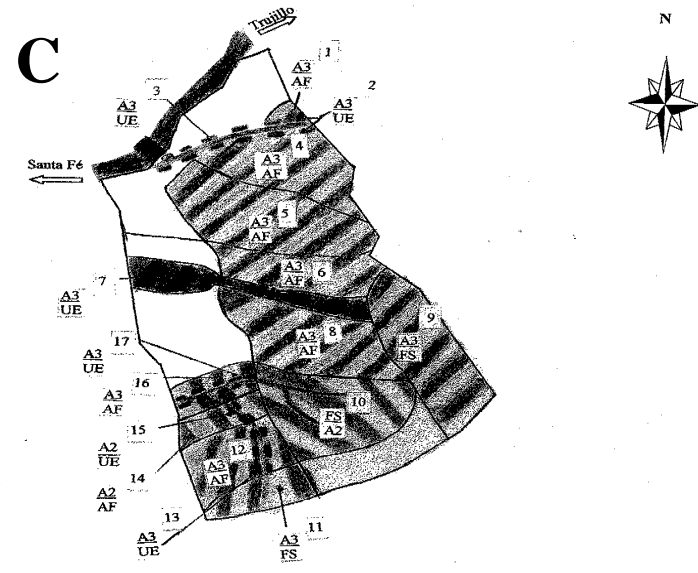
Ucayali Consortium for Sustainable Development (CODESU). 1998. Characterization of Amazon Products, Market Opportunities for Amazonian Products. Pucallpa. Perú.

Vernoy, Ronnie, Nohemi Espinoza y France Lamy. 1999. Mapeo, Análisis y Monitoreo Participativos de los Recursos Naturales en una Microcuenca. de la Serie Instrumentos Metodológicos para la Toma de Decisiones en el Manejo de los Recursos Naturales. CIAT: Cali, Colombia.

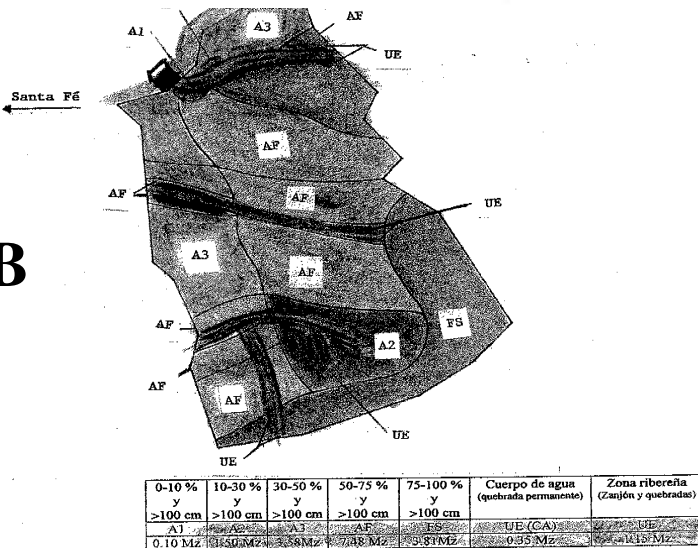
MAPA DE USO ACTUAL



MAPA DE CONFLICTO DE USO



B



Nº	Uso Actual	Área (Mz)	Capacidad de Uso	Tipo de conflicto
1	Guamil pequeño (A3-A3G)	0.22	Sistema agroforestal (AF)	Sobretutiliza
2	Guamil pequeño (A3-A3G)	0.15	Uso especial (Zona ribereña-UE)	Sobretutiliza
3	Potrero (A3-A3N)	0.20	Uso especial (Zona ribereña-UE)	Sobretutiliza
4	Guamil pequeño (A3-A3G)	1.48	Sistema agroforestal (AF)	Sobretutiliza
5	Potrero (A3-A3N)	1.50	Sistema agroforestal (AF)	Sobretutiliza
6	Potrero (A3-A3N)	1.00	Sistema agroforestal (AF)	Sobretutiliza
7	Potrero (A3-A3N)	0.64	Uso especial (Zona ribereña de zanjón-UE)	Sobretutiliza
8	Potrero (A3-A3N)	1.80	Sistema agroforestal (AF)	Sobretutiliza
9	Potrero (A3-A3N)	1.34	Forestal artesanal (FS)	Sobretutiliza
10	Bosque (FS-1)	1.71	Cultivo anual semi-irrigado (A2)	Sobretutiliza
11	Guamil pequeño (A3G)	0.4	Forestal artesanal (FS)	Sobretutiliza
12	Guamil pequeño (A3G)	1.17	Sistema Agroforestal (AF)	Sobretutiliza
13	Guamil pequeño (A3G)	0.2	Uso especial (Zona ribereña de quebrada-UE)	Sobretutiliza
14	Maíz (A2)	0.1	Uso especial (Zona ribereña de quebrada-UE)	Sobretutiliza
15	Maíz (A2)	0.4	Sistema agroforestal (AF)	Sobretutiliza

A - Actual Land Use
B - Potential Land Use
C - Conflicting Land Use

Figure 1. Sketch maps on transparent paper

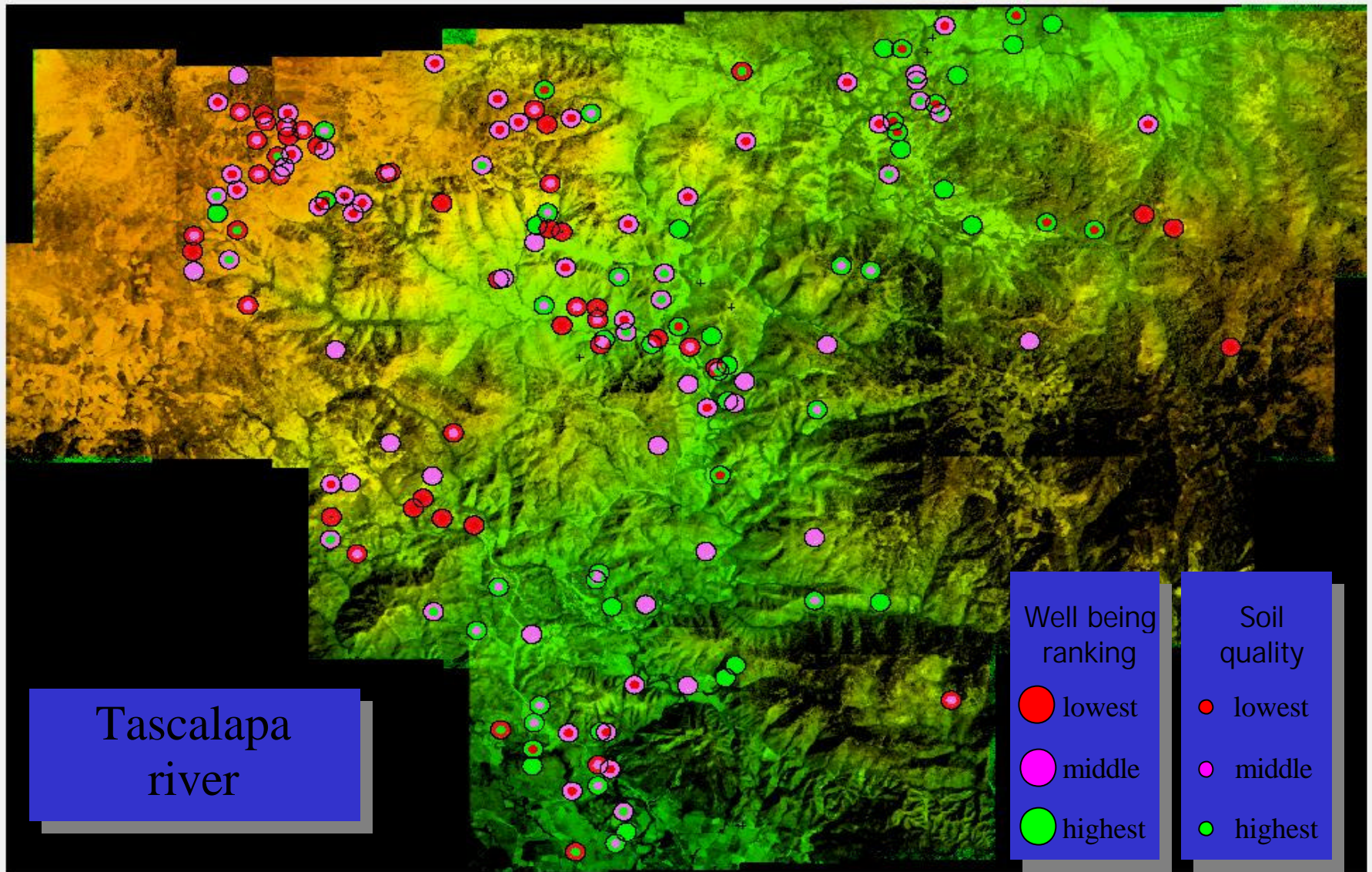


Figure 2. Community-level well being rankings in Honduras



Figure 3. Simulated land cover change in a Honduran watershed.

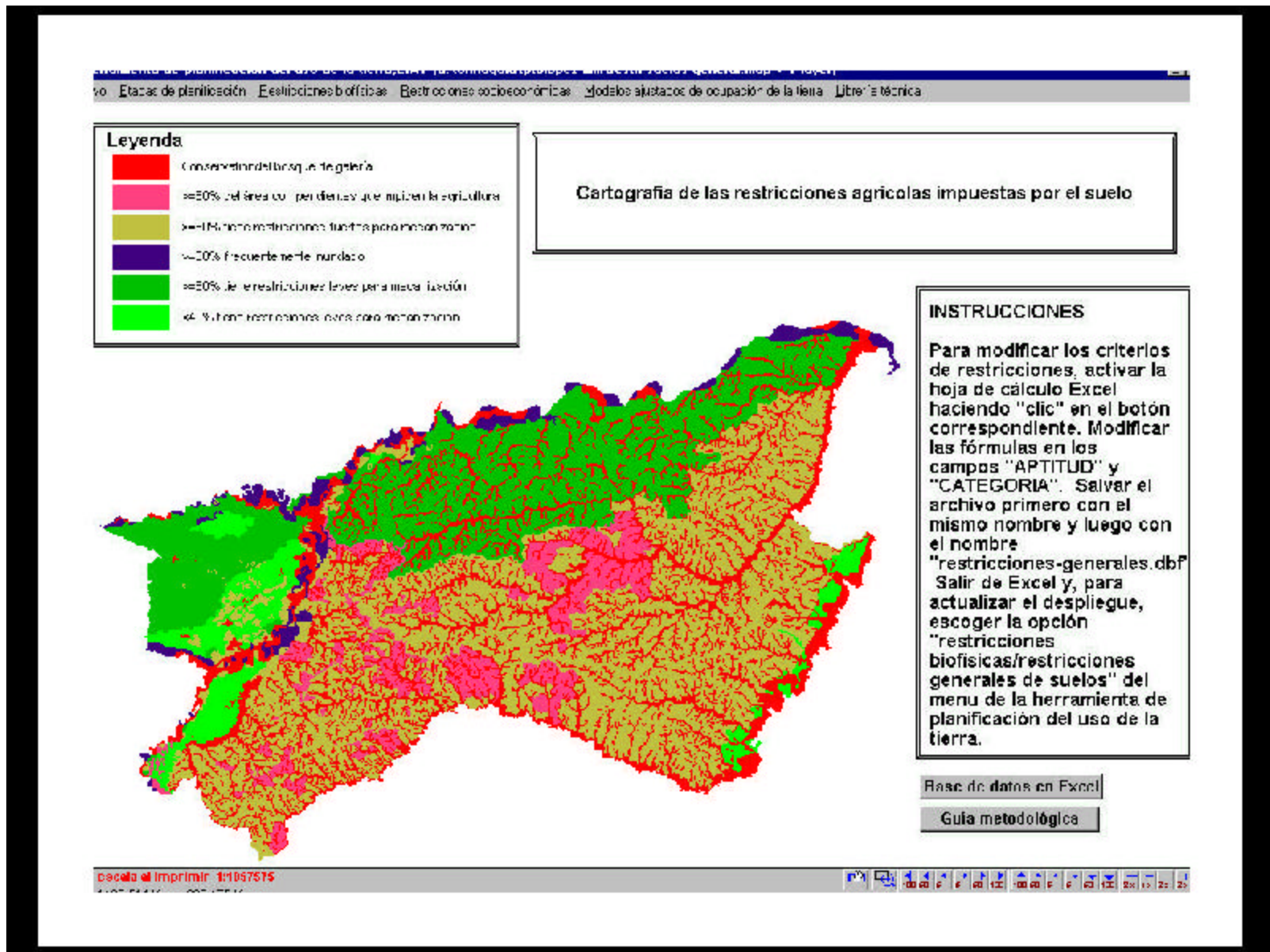


Figure 4. Spanish language version of MapMaker software with Puerto Lopez GIS database

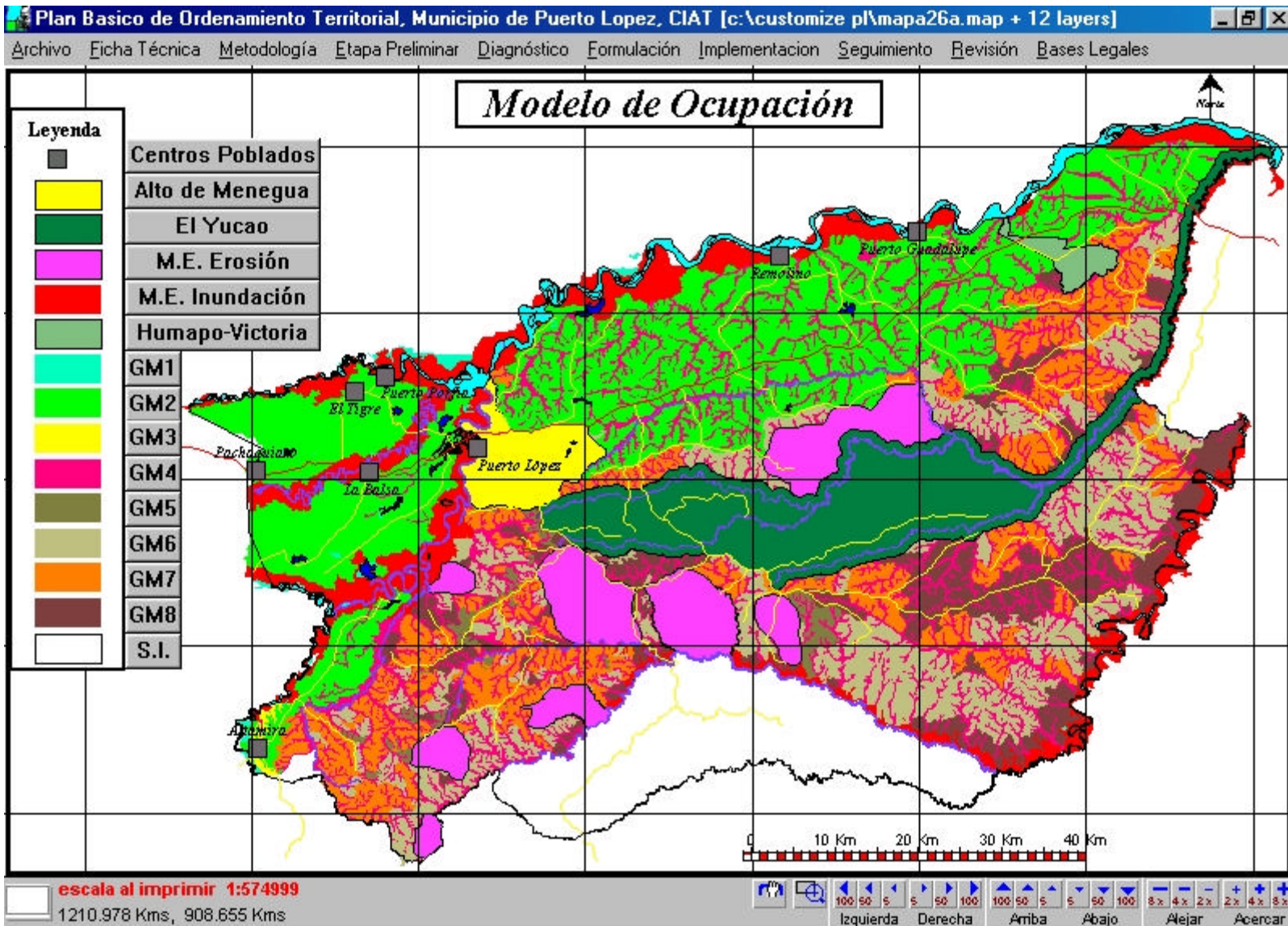


Figure 5. Using MapMaker software for land use planning in Puerto Lopez municipality, Meta Department, Colombia

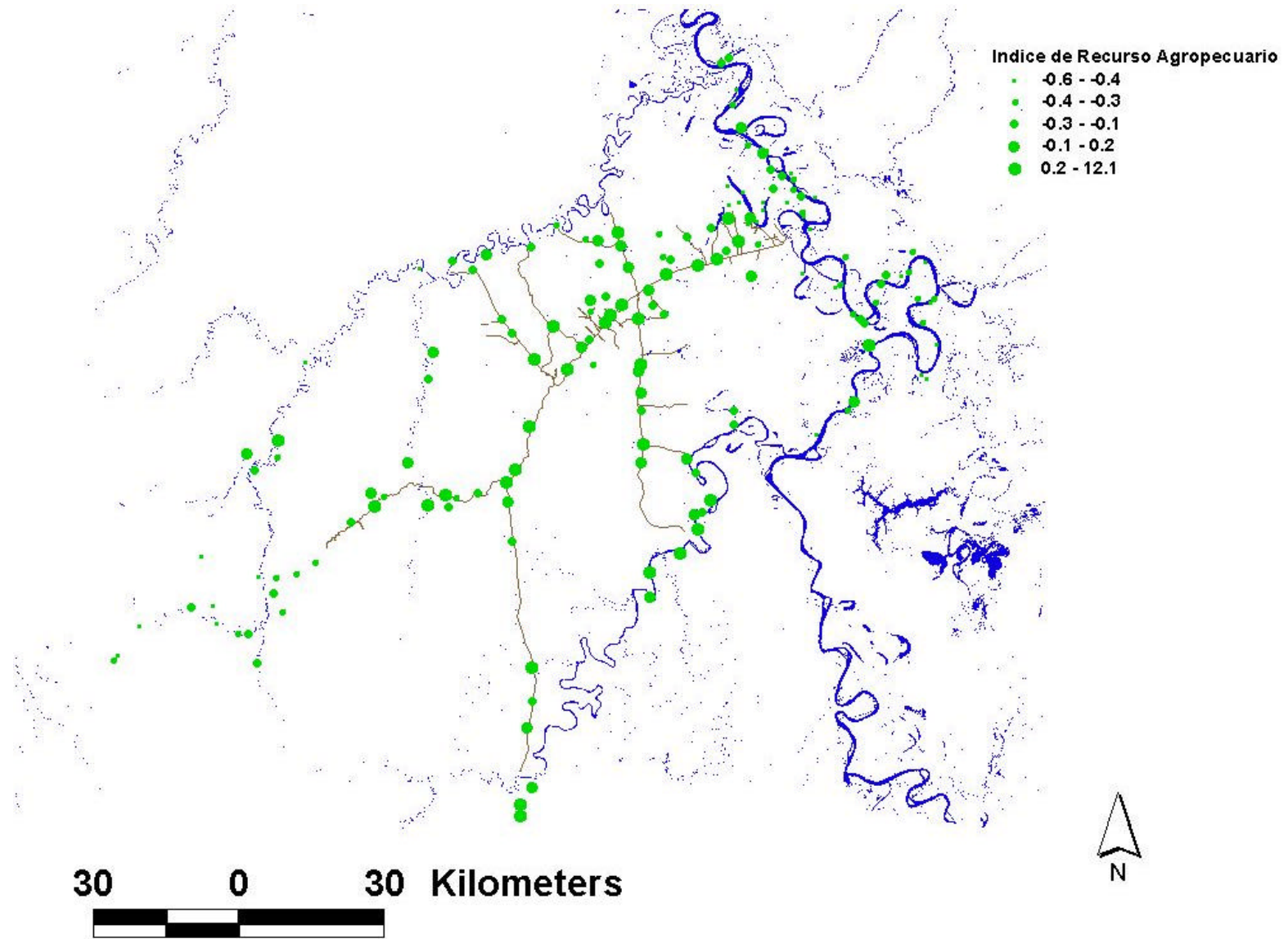
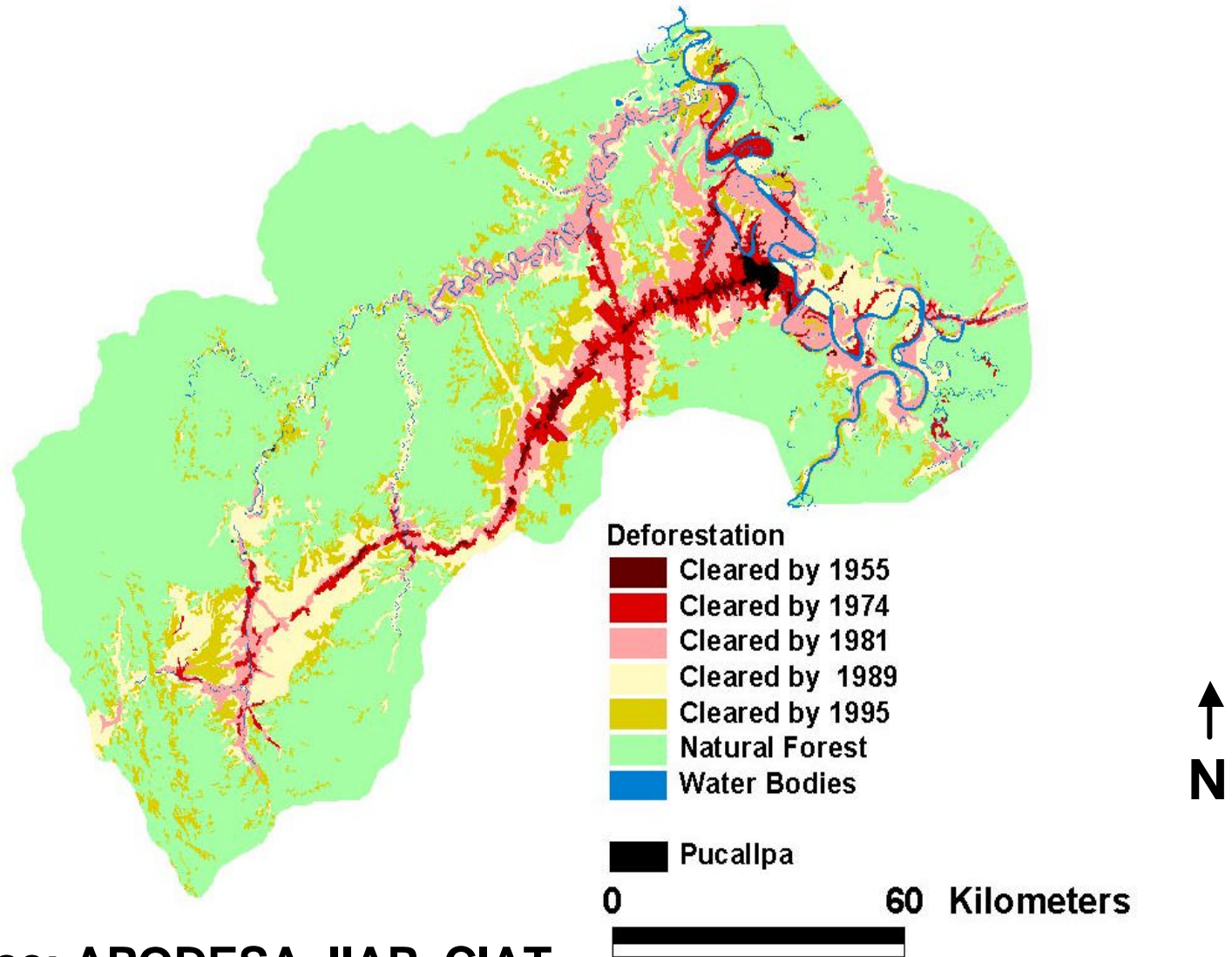


Figure 6. Poverty Indices developed from the agricultural census. The area surrounds the city of Pucallpa in the Peruvian Amazon.



Source: APODESA, IIAP, CIAT

Figure 7. Deforestation Map of Forest Margins reference site near Pucallpa, Peru