MIGIS

Using GIS to Produce Community-Based Maps to Promote Collaborative Natural Resource Management

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INTRODUCTION

Deforestation caused by the felling of trees for firewood is a major cause of environmental degradation. This is of particular concern in the headwaters of major catchments such as the Black River where increased runoff, erosion, and sediment yield impact on the Hoa Binh Dam and those living down stream, north of Vietnam. While the links between forest clearance, lost biodiversity and the ability of farmers to sustain production are understood, the pressures on farmers to survive from year to year are less well appreciated. The real challenge for these communities is to recognise their situation and work out their own solution rather than suffer the imposition of well meaning, but too often inappropriate, top-down intervention. It is essential therefore that the changes which have taken place are documented and their future impact illustrated. This information must be portrayed in a manner that makes it accessible and comprehensible to all, including preliterate farmers. For this reason, the use of graphics offers considerable merit over textual and numerical analyses.

This paper explores the use of MIGIS (an acronym for community based planning which integrates the techniques of Participatory Learning Action or PLA and Mobile Interactive GIS) to facilitate a negotiated, bottom up approach to deforestation with the Hani farmers of Luchun County, Yunnan in southwest China.

China's forest resources are small relative to its area and population. Population growth in traditional forest regions, and rising demand for forest products and services continue to put tremendous pressure on both biodiversity and forest resources. While plantation forestry has increased total forest area and stock to meet this growing demand, significant areas of mature and often natural forest have been destroyed (**Figure 1**).

Figure 1. Although it is against government policy, destruction of natural forest areas is occurring rapidly. This has a wide range of impacts on water resources, environmental sustainability, and biodiversity.

Therefore although forest areas may have expanded, forest quality has declined. Provinces in the southwest (Sichuan, Guizhou, Yunnan, and Tibet) and northeast (Liaoning, Jilin, and Heilongjiang), traditionally natural forest regions, suffer the most serious deforestation. They consequently face increasingly severe soil erosion, loss of biodiversity, and increased flooding (Peili Shi and Jintao Xu, 2000).

During the last two decades, there has been a wide acceptance by members of the academe and policy-makers that public involvement is a critical component of effective environmental decision-making. It has been advocated that if local people are engaged in the process of knowledge production, then development projects are more likely to be sustainable over the long term (Chambers, 1997). It has been further argued that this involvement is both desirable and necessary for attaining more sustainable forms of development and resource management (Goodwin, 1998). In response, a range of techniques had been developed that attempt to elucidate, assess, and integrate the views of stakeholders in environmental planning situations (Engle, 2000).

Participatory Research Methods (PRM) and Geographic Information Systems (GIS) have been recognised independently over the past 20 years for their contributions to planning more sustainable forms of development. In spite of the increasing popularity of PRM and GIS, it has only been within the last decade that researchers have considered integrating the two as a way of enhancing public participation in environmental planning (Engle, 2000). This has been made possible by improvements and increased flexibility in computer hardware and software rather than any change in attitudes or concepts. The key to PRM methodologies is to place people at the centre of their own development - a goal that is achieved by generating information at the community level directly with members of the community (Mosse, 1994). By linking information important to communities with geographical data conventionally found in a GIS, the hybrid methodology would strengthen the capacity of local knowledge within mainstream multi-participant planning processes (Weiner and Harris, 1999). However, while the capability of GIS for gathering and disseminating information has been hailed as democratising and empowering, it has simultaneously been criticised as inherently authoritarian, complex, and even dangerous (Kyem, 2000).

In the context of participatory development, the power of maps can be utilised to the potential benefit of marginalised peoples. As McKinnon *et al.* (2000) argue, it would be a mistake to underestimate the visual impact of community-based maps. This is true in situations where regional authorities under-rate and under-value the capacity of local people to make their own decisions and determine their own priorities. Often getting "onto the map" is the first step in groups gaining public acknowledgement of their condition. GIS provides an especially powerful mechanism for community groups *"to participate in the traditional power structure .... and to inspire others to appreciate their situation and proposed solutions"* (Craig and Elwood, 1998).

These beliefs motivated the development of the MIGIS (Mobile Interactive GIS) approach to problem articulation and negotiated action plan formulation (McKinnon *et al.*, 2000).

WHAT IS MIGIS?

MIGIS is the acronym for community based planning that uses a Mobile Interactive Geographic Information System in conjunction with, and fully informed by PLA. MIGIS brings the best of indigenous knowledge and scientific information together to provide common ground on which farmers, government administrators, and planners can optimise 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.

The advantages of using the 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;
- Are easily updated;
- Provide baseline information against which development interventions can be evaluated;
- Allows the physical, social, and economic constraints impacting on the communities to be quantified and assessed;
- Assist in monitoring the situation, or any actions and interventions;
- Stored within the GIS are accessible to all;
- Can be used to answer an infinite number of questions, with the power of the GIS being limited only by our ability to ask "the right questions"; and
- Can be used to test scenarios and help address potential conflicts.

This paper presents a set of techniques used in China to empower a negotiated, bottom up approach to developing an understanding and mitigation strategy that limits the continued clearance of native and regenerating forest for firewood thereby further diminishing biodiversity.

STUDY AREA

Luchun County (**Figure 2**) is one of the 50 poorest counties in the whole of China. The county has nine townships, the major one being Dashun, and 82 administrative villages. It has a total area of 3,300 km^2 with a population in 1998 of 198,000 of which 87% are Hani. Almost half the population live below the poverty line. The villages of Shapu (Xiashapu - lower Shapu and Shangshapu - Upper Shapu) are approximately 18 km from the town of Dashun. These villages are located in the headwater catchment of the Black River (the Da River in Vietnamese).

The Shapu villages are typical of the six villages in this 9 km^2 headwater catchment. This land is also typical of the region and characterised by steep slopes and rugged relief. Within a distance of about 2 km from the divide to the major stream, the elevation drops over 800 m. The steep slopes, relatively high elevations (approximately 2,000 m), deeply incised "V-shaped" valleys combined with the heavily jointed bedrock and presence of jasperite suggest that the landscape has been strongly influenced by tectonic activity. Small earthquakes are still reasonably common.

Erosion is a major problem. Over

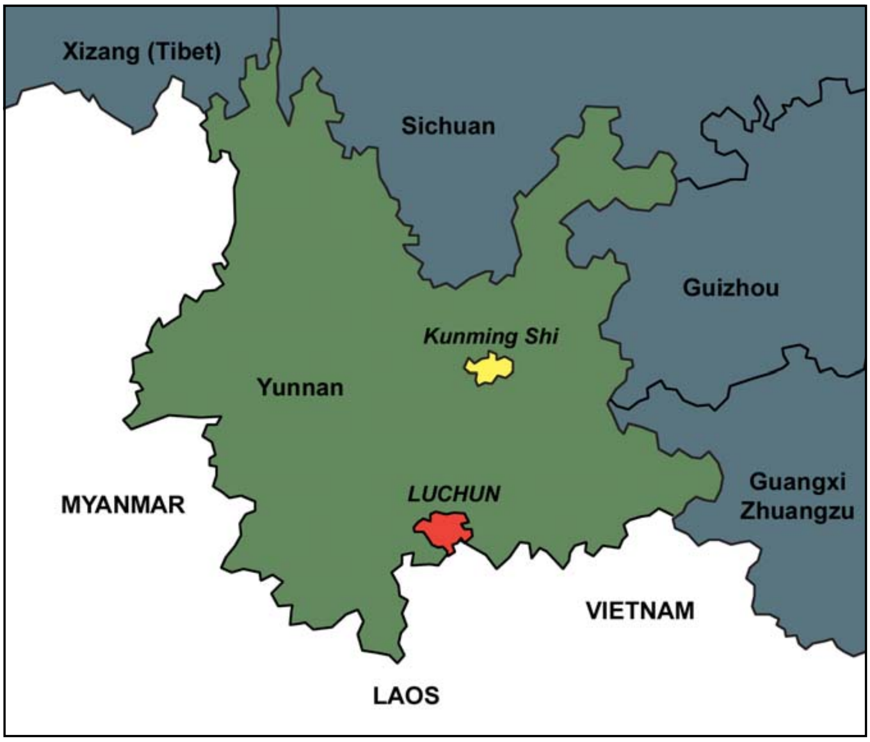

Figure 2. Land management practices in the headwater catchments of Luchun County in southern Yunnan Province have a potential impact for all communities downstream.

30% of the ground is partially exposed. The relatively low cohesion of the material results in instability during both the dry months and the rainy season. Irrigation canals, paddy fields, and so forth therefore require careful management.

Under a continuous forest cover, it is likely that extreme runoff events were rare and limited to the occasional severe or intense rainstorm. Runoff in the wet season was therefore delayed and stored on the slopes, providing a relatively reliable water supply for the remainder of the year. The removal of much of the forest cover, particularly over the past ten years, has led to a number of environmental consequences.

- Normal precipitation is no longer stored on the slope but runs off much more rapidly.
- The increased volume of runoff, and the reduction in vegetation cover, exacerbate the impact of erosion.
- The formation of gullies is increasing rapidly and has reached a point where they are now self-generating.
- Major gullies actively erode back into the headwaters, including areas under mature forest.
- The increase in storm runoff reduces the availability of water during the rest of the year.

Farmers from both communities commented on the reduction in irrigation water over recent years and linked this to the removal of forest. They are the first to be affected and the researchers located a number of dry and abandoned irrigation canals. In some places, aggradation of the streambed as a result of severe gullying upstream exceeds 10 m (**Figure 3**). This impacts not only on other potential water users downstream but also more dramatically on the aquatic ecosystem. On higher ground, increased runoff has led to rapid down cutting and incision in areas that were then stable deposits. On lower ground, a number of paddy fields have been buried and lost under coarse debris.

If the communities of Shapu are to survive, they should adopt some form of sustainable agriculture and forestry. In this manner, they will be able to extend productivity for a longer period by stopping severe or permanent degradation of land resources and destruction of the ecosystem. Making the correct land use and management decisions to ensure this is a huge challenge. It will require what Bocco and Toledo (1997) have called an *integration of knowledge (scientists) with wisdom (farmers)*. From our experience, it is clear that the decision-making process can be greatly enhanced if farmers and planners share an understanding of the processes at work, and can agree on what needs to be done.

The aim of this project was therefore to take a GIS into a remote field area in southwest China. Data collected from two communities, via a range of PLA activities, would be encoded, manipulated, and analysed. The results would be presented immediately back to the villagers, who would then check the data, validate any translations, provide credibility to the database, and review and critique 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 produce a significant amount of "village focused" primary data, the MIGIS allows these data to be triangulated, extrapolated, and explored within a wider context through the use of secondary data sources. The main sources of these secondary data are maps, aerial photographs, satellite imagery, and National Census data.In most cases, these secondary data sources can be prepared prior to the fieldwork. Analysis also provides considerable insights to the environment and potential development issues that may arise.

IMAGES

Topographic and land use maps were made available to the project at a scale of 1:25,000. Although

Figure 3. The removal of natural forests has led to severe gullying. Debris from these gullies causes dramatic aggradation of riverbeds that threatens productive paddy lands.

there were 1:10,000 scale maps for the area, these were not made available to us because of the politically sensitive nature of the study site (close to Vietnam). Maps made available to us provided 10-m contour information but the relatively small scale and very steep topography, hence close contours, made digitising difficult. It was easier for our GIS counterpart to digitise only every second contour. This had no detrimental impact on the analysis, or the credibility of our findings. These data, together with other information, were used to produce:

- **Terrain Model.** A digital elevation model (DEM) was computed using a 20-m grid size. This DEM was then used to produce a hillshade model to improve the quality of the team's presentation graphics. It also allowed the very rapid quantification and analysis of some of the physical constraints imposed by the landscape such as slope and aspect. These maps could in turn be used in models to calculate temperature and evapotranspiration regimes.
- **Land use map**. A land use map compiled in 1990 (**Figure 4**) was updated at a scale of 1:25,000 with information collected during a fieldwork in1999 (**Figure 5**). Comparing and contrasting the two maps led to considerable discussion regarding deforestation that, initially, the villagers did not want to talk about.
- **Resource Maps** are a critical element of most PLA exercises, and in Shapu the generation of such maps was one of the first exercises undertaken. To make sure these maps could

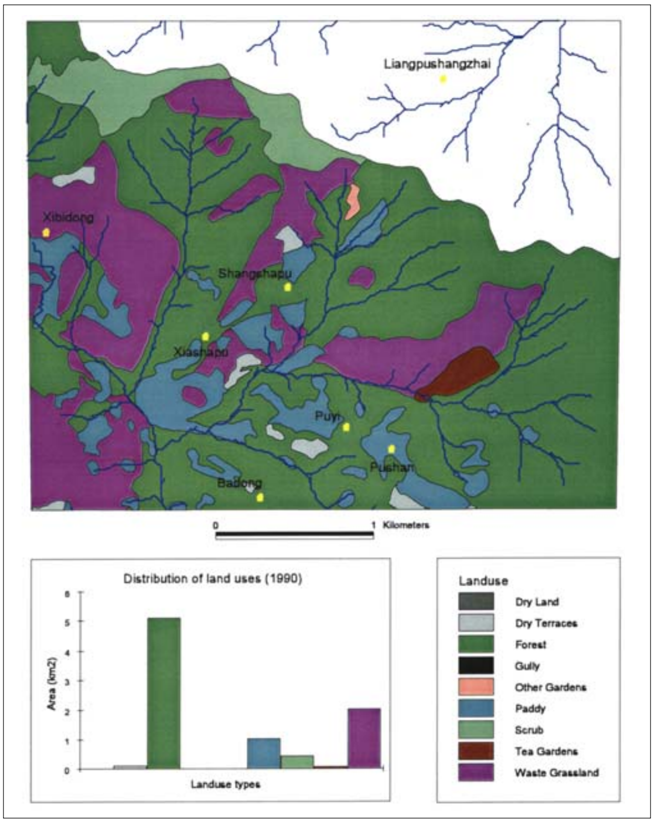

Figure 4. Land use in the study area was surveyed from aerial photographs in 1990.

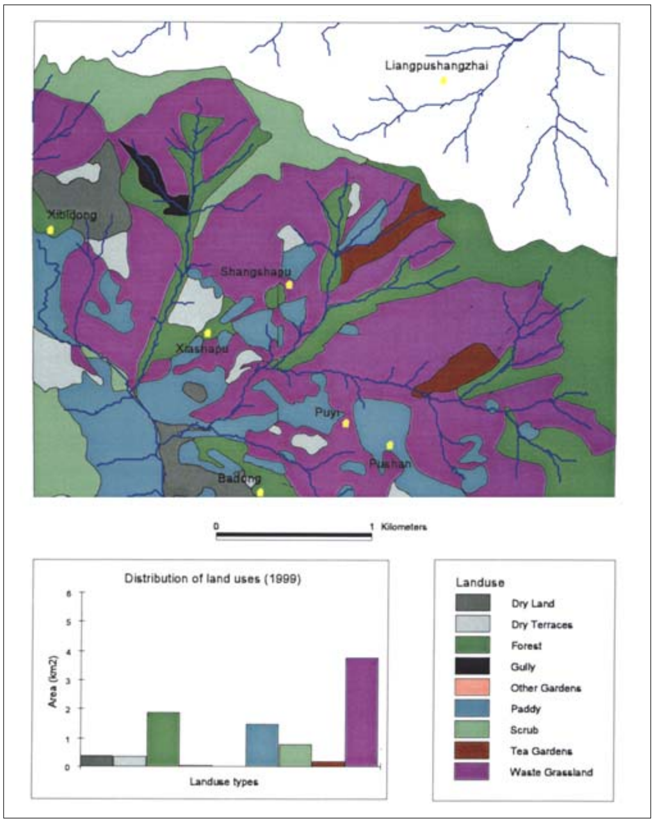

Figure 5. Land use was remapped during fieldwork and through PLA exercises during 1999.

be georeferenced, and that the data could be quantified, an outline of each village estate was drawn. This showed the main paths, rivers, streams etc. at a scale of approximately 1:1,000. Once the villagers had located and marked in their various resources, these maps were digitised into the database. In all cases, the error associated with this process was less than 70 m, thus suggesting a high degree of reliability in the results.

Although we have met many people who believe that villagers with little or no formal education could not recognise their environment on plan views, be they maps or aerial photographs, our experience with the following farmers completely contradicts this position:

- Khmer farmers of Kampong Spueu, Cambodia;
- Hani of Luchun County, Yunnan, P.R.China; and
- Karen of Mae Wang, North Thailand.

None of these farmers, including men, women, and children, had experienced problems identifying the various elements of the landscape. They could locate themselves, and subsequently their various resources accurately. Wherever possible, the resource maps constructed by these mostly preliterate farmers were checked in the field and found to be remarkably accurate and reliable.

The resource maps generated considerable discussion at evening sessions attended by nearly every able-bodied person in the community. Having resource maps in digital and visual form also readily resolved any confusion and disputes. This was achieved by the rapid feedback and presentation of all data sets, often obtained through small focus groups, to the entire village during evening session on the days these were collected. Corrections, adjustments, and clarifications were made on-screen until the entire village was happy with the information. In this manner, consensus was reached on the accuracy and interpretation of the data.

RESULTS

Riparian Buffers

The availability of high quality georeferenced digital data allowed the testing of various future management scenarios. For example, it was obvious that the establishment and protection of riparian forest zones along streams is critical to sustainable environmental management and ecosystem security. Slope erosion processes are supplying large amounts of debris to the stream channels that are rapidly aggrading and covering the most productive paddy with coarse gravel. The thick deposits of gravel in the stream channels also mean that a large volume of water now flows beneath the surface, reducing the availability of water for irrigation. These impacts are posing a major threat to land use productivity.

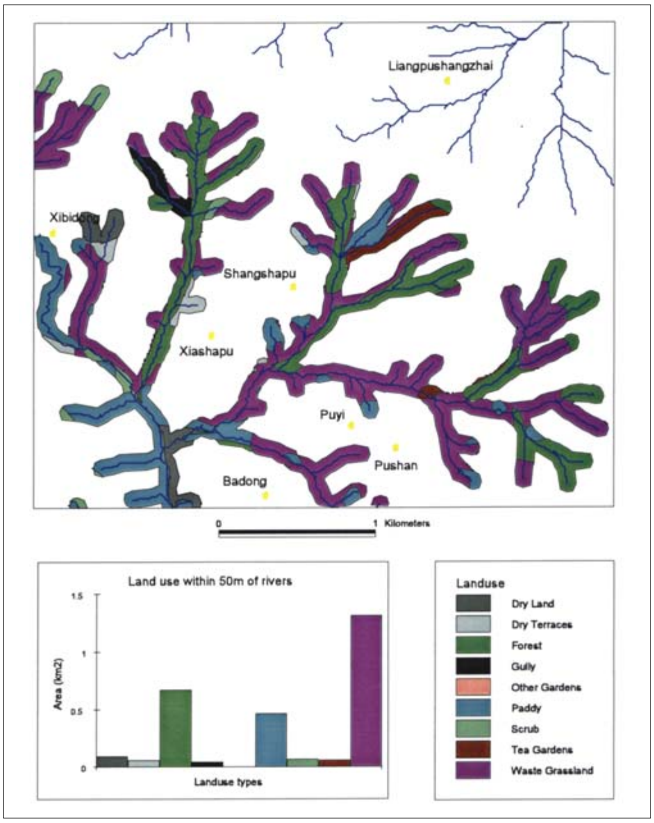

Figure 6. The establishment of riparian forest reserves offers considerable potential to maintain biodiversity and enhance environmental quality and production. Being able to quantify the potential loss of production, and present the results visually facilitated the acceptance of such a proposal by the village communities.

Maintaining and improving the management of the riparian forests therefore appeared to be a relatively simple strategy for improving environmental sustainability and biodiversity. Initially however, the farmers saw this proposal as restricting their options and potential production. Thus the villagers had to be convinced that the benefits from improved channel stability and water supply, and safeguarding paddy lands, were worth any loss in production. This was essential because of the marginal existence of the majority of households.

Using the 1999 land use map, buffers of 50 m and 100 m were created around all the streams. The area of each land use within the buffer was then quantified. It was immediately obvious that, for example, a 50-m buffer, while leading to significant improvement in environmental quality would not reduce productivity (**Figure 6**). Most of the land that would be affected is currently wasteland and unproductive. Areas of paddy, or already under forest, would not be affected since these are sustainable land uses.

Being able to quantify the impact, and present visually the "cost" of protecting riparian buffers have facilitated the acceptance and adoption of this strategy by the entire community.

Scenario Testing

A major issue facing the Shapu villages is the rapid destruction of forest cover (**Figure 7**). As a result, it was decided that the rate of forest clearance be quantified and modelled in the near future to show what will happen if nothing is done to reverse the trend. Estimates of firewood usage were obtained through the PLA process during discussion with the local villagers. The major uses of firewood are for domestic consumption, and for the distilling of lemon grass oil, a practice since about 1995.

Each household in the villages was surveyed to determine the amount of firewood burned during both the summer and winter periods (**Figure 8**). The standard basket for firewood gathering was used as the unit of measurement (**Figure 9**). The survey showed that each year approximately 36,700 baskets of firewood are used for domestic purposes, and an estimated 50 baskets of firewood to distil the oil from 1 mu of lemon grass (*a mu is the standard unit of land measurement equivalent to 660m^2*) (**Figure 10**).

Figure 7. Clearance of natural forest areas has increased runoff and accelerated erosion and the formation of gullying. Despite these adverse consequences harvesting of firewood from these areas continues.

The land use and village resource maps identified 0.95 km^2 of land used for lemon grass production. Therefore each year, just over 71,000 baskets of firewood are used to process lemon grass. This survey therefore showed that the villages burn about 108,000 baskets of firewood each year.

The surrounding forests were then surveyed to determine how much firewood was available. A number of village women, who are responsible for gathering firewood, were asked to estimate the number of baskets of firewood available in a random sample of one *mu* plot. The

Figure 8. Firewood is essential to these communities for heating and cooking while the smoke from fires acts as an important preservative for both food and timber. No alternatives exist which meet the many demands of firewood.

Figure 9. The gathering of fuelwood is a major commitment of both time and labour for the women of the village. The firewood basket was used as the standard unit of measurement for the survey of firewood usage and forest productivity.

average of these estimates was that each *mu* of forest yields approximately 86 baskets of firewood. Based on the estimates of consumption and forest productivity, the annual rate of forest destruction attributed to firewood gathering was calculated to be approximately 1,250 *mu* (0.83 km^2).

To provide a check on this estimate, the loss of forest identified on the land use maps between 1990 and 1999 was calculated. This yielded a value of 0.81 km^2 per year. Since the two methods gave values within 2%, a high degree of confidence can be placed in the estimate of the current rate of forest clearance.

This estimate was then used to model how much forest will remain after the next 1, 2, and 5 years. Using the existing area of forest as the starting point, a model was developed to predict which forest areas will be cleared in the near future at the rate of 0.83 km^2 per year. It was hypothesised that the areas most at risk were those closest to the villages and near access paths. While these assumptions may not be entirely valid, e.g., the *dragon forest* is likely to be protected, they appear reasonable for a first approximation. Each 10-m grid in the study area was therefore ranked on the basis of its distance from the villages and all access tracks. Areas most at risk (those nearest the tracks entering the villages) were ranked with low values, while more remote areas received higher ranks. The "grids" were then removed at the appropriate rate of forest clearance in rank order. This model shows that all remaining forest will be gone within three years unless some intervention is implemented (**Figure 11**).

Such a model is a very powerful tool to quantify the magnitude of the problem and generate discussion within the community regarding the identification of issues and what needs to be done. The results of any intervention can also be modeled in the scenario to check their potential effectiveness.

OUTCOME

During the MIGIS exercise, GIS was used at four levels to:

- Construct a database to store information relating to each household. Both visual and statistical records of the villages were created;
- Identify and quantify the constraints on development options imposed by the physical environment e.g., slope, aspect, and land use;
- Compile baseline information as to the conditions present at the start of the project. The results of any development initiative or intervention can be assessed against this situation; and
- Test various scenarios such as the impact of setting up riparian forest buffers, and to model what would happen to the remaining forest if no action

Figure 10. From the early 1990s lemon grass oil became an important cash crop for the village communities. This has had a dramatic impact on forest clearance both in terms of land conversion to lemon grass and the consumption of firewood to distil the oil.

is taken. These scenarios provided valuable information that stimulated discussion and helped farmers to focus attention on issues, problems, and possible solutions.

The information and motivation provided through this MIGIS exercise stimulated a number of development initiatives. The Shangshapu village headman and 14 other villagers formed a watershed protection committee. They reclaimed land that belonged to the collective, and which they considered unsuitable for cultivation and placed it under their protection. All remaining forest was declared part of a village reserve. A forest reserve agreement was negotiated, and the head of each household placed his fingerprint on the document as a commitment to abide by its principles.

Ten *mu* of this land was planted to Chinese fir as a symbolic act, with the Department of Forestry providing the seedlings. The project was seen as a simple "first act" and was carried out *"for this generation and the next"* to mark the Half Year Ceremony. This occasion was followed four days later by household ceremonies at which a chicken was killed to ensure good fortune. Initially, 3,000 seedlings were planted, and this was followed by an additional 5,000. Each household had to give a levy of 2 yuan to pay the annual honorarium of the appointed forest guard.

MIGIS therefore added significantly to the standard PLA approach. It proved to be a very powerful set of tools that assists in defining, and refining development initiatives that are appropriate, accepted and adopted by the local people, and have a high probability of success.■

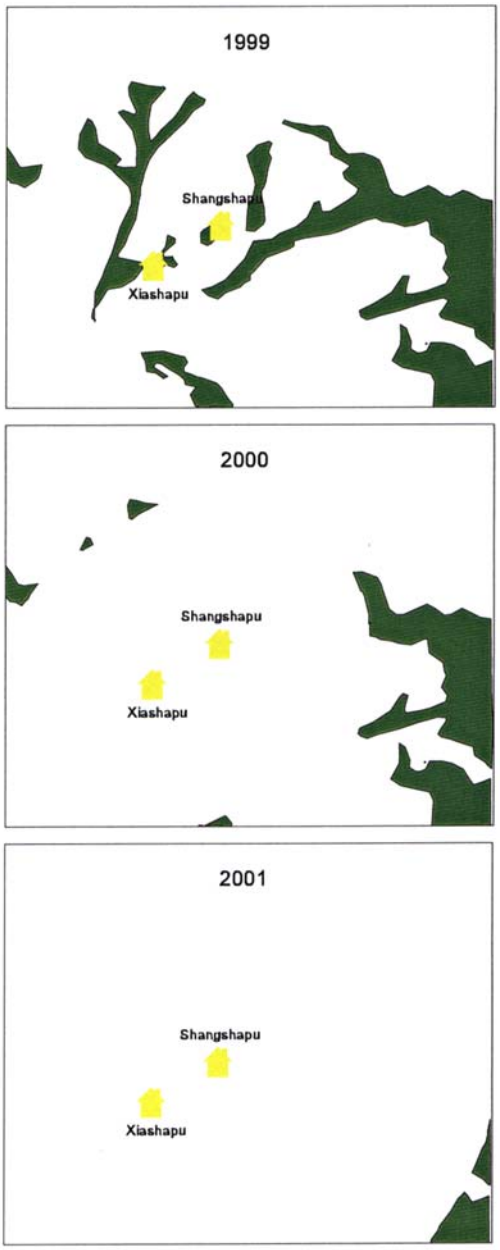

Figure 11. Based on the current rate of clearance, all natural forests will be gone from this headwater catchment within approximately 3 years.

Jack McConchie *and* **John McKinnon** *have a long association with the Institute of Geography, School of Earth Sciences, Victoria University, in Wellington, New Zealand.*

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