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Integrating Geomatics and Participatory Techniques for Community Forest Management

Case Studies from the Yarsha *Khola* Watershed, Dolakha District, Nepal

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Preface

The work described in this publication has been conducted as part of the People and Resource Dynamics' Project (PARDYP), implemented by ICIMOD. PARDYP is a three-year watershed management research and development project in the fields of:

- cooperative rural participation,
- hydrology and meteorology research,
- soil erosion and fertility studies,
- conservation activities,
- rehabilitation of degraded areas, and
- agronomic and horticultural initiatives

PARDYP operates in five watersheds in four of ICIMOD's partner countries - Pakistan, India, Nepal, and China. It approaches watershed dynamics and research in a holistic, interdisciplinary, and participatory manner.

The goal of PARDYP is to improve the understanding of environmental and socioeconomic processes associated with degradation and rehabilitation of mountain ecosystems and to generate wider adoption and adaptation of proposed solutions by stakeholders in the Hindu Kush-Himalayas (HKH).

By providing a basic understanding of the processes concerned with natural resource degradation, it seeks to recommend proven strategies and programmes for community and farm-based rehabilitation of the natural resources in the HKH region.

PARDYP is funded by the Swiss Agency for Development and Cooperation (SDC), the International Development Research Centre (IDRC - Canada), and ICIMOD. It is actively supported by institutions in both the collaborating regional countries and further afield, notably the University of British Columbia, The University of Bern, and the Swiss National Hydrological and Geological Survey.

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Abstract

There is a growing need for forest resource information in community forestry to provide baseline data enabling changes in the resource to be assessed. Traditional methods of forest resource assessment are not appropriate for community forestry owing to the time and expense involved and their focus on timber production.

This paper shows how recent geomatics' technology can be used in conjunction with participatory techniques to provide a framework for low cost, appropriate technology forest resource assessment. The role and value of a variety of different approaches are evaluated by using case studies as examples.

The use of geomatics in a participatory context has great potential for community forest resource assessment in providing basic spatial data for management purposes rapidly and effectively, and by acting as a facilitation tool.

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Part One
Setting and Methodology

1.1 INTRODUCTION

Rapid population growth and changing resource dynamics are of great concern in the Hindu Kush-Himalayan (HKH) region. Increasing population exacerbates pressure on a limited land base and can result in natural resource transformations, including the degradation of forest resources. This has the potential to affect the sustainable use of natural resources in the mountains of the HKH region.

One potential mechanism for preventing forest degradation is to increase community involvement in the management and ownership of forest resources. This is often termed social or community forestry (the term community forestry is used in this paper for the generic approach). The HKH region has a long association with community forestry, with Nepal and India in particular being instrumental in the development of state of the art approaches. The central theme of community forestry is returning forest resources to the local community, allowing them to manage the resource and directly benefit from it. During the early stages of the handing over process (from state-controlled management to community management), it is essential that participatory work is carried out by the Forest Department and villagers to ensure that resource use is equitable at village level and to identify and resolve conflicts. The Nepalese approach is to establish a village-level Forest User Group (FUG), in close liaison with the District Forest Office, through the local forest range post (for background information on community forestry see, for example, Jackson et al. 1996; Hobley 1996; Gilmour and Fisher 1991). Traditionally, the majority of forestry work has examined social issues, ensuring that all ethnic groups and minorities are adequately represented. Whilst this work is undoubtedly of paramount importance, it is thought increasingly that the collection of forest resource information is inadequate. There is usually little baseline resource information available prior to handing over the forest; and little is obtained during the handing over process itself on the extent of the resource, the type of resource, the quality of the resource, and how it can be managed. This is partly because of its secondary importance compared to social information, and also because collecting resource information is seen as time consuming and costly.

There are a number of reasons why there is a need to collect forest resource information for community forests. These include the following.

- FUGs have become established and are functioning fully and want more information about the management potential of their forests.
- Some FUGs are producing timber commercially.
- There is a growing interest in the concept of sustainable forest management.
- The requirements of international interests in Biodiversity
- The potential of Non Timber Forest Products (NTFPs)
- For strategic planning in the forest/forest product sectors

All of these require information about the forest resource before any meaningful observations or management suggestions can be made.

Traditional approaches to resource assessment tend to collect detailed information through forest inventories, which are not felt to be appropriate for community forestry because of the great cost, time consumption, and focus on timber production (Branney 1994; Jackson et. *al*. 1996). The approaches currently used for community forestry assessment are usually based on Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) approaches which, by themselves, do not provide accurate quantitative or spatial information. The need for an intermediate level of information between these two extremes has been identified.

This paper outlines a number of new approaches aimed at providing practical methods for collecting forest resource information to allow for improved community forest management. These approaches have a strong basis in participatory resource assessment techniques, but combine them with other tools from the geomatics' field. They involve using aerial photographs in a participatory context, using Global Positioning Systems (GPS) for mapping and georeferencing, and using Geographical Information Systems (GIS) for information management and dissemination purposes. The use of these techniques is examined critically, not just to determine their technical performance, but to evaluate their practical roles within the current community forestry framework. The main issues dealt with in this paper are technical approaches, a companion paper (Jordan, in Press) to be published by the NACFP deals with the participatory and institutional issues.

The paper is divided into two parts: the first part provides the background and explains the quite complex tools and methodologies employed, and the second part examines the use and evaluation of these methodologies through a number of case studies. The case studies involved the intensive participation of local FUGs in the Yarsha Khola watershed in the Dolkha District of Nepal. Much of the work has been subject to comparative studies in different watersheds of Nepal. This work is part of the People and Resource Dynamics Project (PARDYP) of ICIMOD.

1.2 AIMS AND OBJECTIVES

The rationale for the work described in this paper is the acknowledged need to provide more quantitative information for community forest management. As discussed in the introduction, there are a number of reasons why quantitative baseline resource information is required for improved forest management. However, traditional 'information heavy' approaches to obtaining quantitative information are not appropriate for community forestry, because of the time and expense involved. A number of relatively recent tools and approaches has been tried and evaluated to determine how they could be used to obtain information to improve community forest management. Some of the approaches are based on methods and ideas developed by the Nepal Australia Community Forestry Project (NACFP), the Swiss Agency for Development and Cooperation (SDC), and the Nepal UK Community Forestry Project (NUKCFP), although they have been modified substantially.

The key objectives of this work are to show how recent tools for community forestry management can best be used, and how they can be incorporated into a framework for community forest resource assessment.

Within the overall objectives of this work, the specific aims are to:

- increase the participation of FUG members,
- improve the accuracy of information obtained,
- explore the potential for integrating qualitative and quantitative techniques,
- simplify the current approach, and
- provide a mechanism for disseminating the 'inventory' information to maximise its use.

The extent to which these aims have been met is detailed in the discussion section of this paper.

The term inventory is used throughout this paper. It should be stressed that this does not refer to a conventional forest inventory (except where specified), but refers instead to a process of collecting information about the forest resource involving participatory and simple inventory techniques. The range of information collected is greater than with a traditional forest inventory.

1.3 AN OUTLINE OF THE METHODOLOGY

Overview

This section deals with some of the quite discrete methods that have been used to obtain quantitative information for improved community forest management. The unifying thread for these techniques is that they all obtain spatial information about the resource, and they all involve community or stakeholder participation (to a greater or lesser extent). These methodologies are examined by looking at a number of case studies in part two of this paper.

The methods used in a new way for resource assessment for community forestry discussed in this report are:

- the use of aerial photos for increasing participation and planning a forest inventory,
- the use of GPS for georeferencing and surveying purposes,
- using GIS to manage and display the information, and
- using GIS and other Information Technology (IT) tools to disseminate the information.

All these techniques fall under the banner of 'Geomatics', which refers to the integration of means used to acquire and manage spatial data (McDonnell and Kemp 1995). There are three main technologies involved in geomatics: remote sensing, GPS, and

GIS. These technologies have been widely applied to conventional forestry (McKendry and Eastman 1992). To date, there has been only a limited application of geomatics to community forestry. Applications are listed in Table 1 below.

Table 1: Matching Applications with Geomatics' Technology

Application	Data Needed	Geomatic Technology
Land use and occupancy	Maps based upon local knowledge and practice	Sketch mapping , GPS for more accuracy*
Demarcation	Positional base/images if available	GPS*
Gathering and protecting traditional knowledge	Traditional environmental/management knowledge	Sketch mapping, GPS for more accuracy*
Boundary monitoring	Sequential visual data	GPS and aerial photo, satellite imagery, radarsat imagery
Resource mapping	Local data upon base maps	Aerial video/photo,* GPS*, GIS for map-making*
Ecological recuperation	High resolution imagery	Aerial photography
Impact monitoring	Aerial imagery	Aerial video/photo, GPS
Resource management	Comprehensive cultural and ecological	Aerial video/photo*, GPS*, satellite imagery, GIS for analysis*
Local communication	Local views and landscape data	Sketch maps, aerial photo

Modified from Carter 1996, Appendix A.
Note: * denotes addressed in this study.

Two other areas of the work, which are not discussed in great detail in this paper, are the development of a participatory inventory methodology to collect baseline data and returning the information to the range post and FUG. These will be dealt with elsewhere (Jordan, in press).

The description of the methodology deals with each key technique in turn, with explanations as appropriate. Prior to examining each method in detail, it is important to understand the framework and approach to obtaining community forest resource information that have been employed.

The Framework for Resource Assessment

The framework and methods described here aim to meet several requirements for obtaining resource information. They are based on combining and modifying a number of approaches to forest resource assessment, some of which are commonly used in Nepal, and some of which are new. The approach uses the ideas of the Canadian Standards' Authority and the International Standards' Organization to form a 'Systems' based approach' to resource assessment (CSA, 1996a,b). This means that rather than having a rigid prescriptive approach (such as always measuring information for timber production), the systems' based approach provides a framework for how the assessment will be carried out. The key stages are identified in Table 2 below.

Table 2: A Framework for a Systems' Based Approach to Participatory Community Forest Resource Assessment

Stage	Tools	Comments
1. Identify stakeholder groups	Desk research, semi-structured interviews (SSI) with key informants	Stakeholders may include FUGs, DFO, forest rangers, donor agencies, national and international policy agencies
2. Identify stakeholder information needs and indicators	RRA tools (SSI, transect walks, focus groups, participatory mapping) and standard interviews	RRA work with local community, interviews, discussions and reading literature for agencies etc
3. Determine what can be collected within the constraints of time/money etc	Project planning and budgetary analysis	A controlling aspect of assessment planning. Low cost, time effective methodology more important than statistical reliability
4. Decide on what information will be collected	Analysis of stakeholder needs, ranking of importance, budgetary analysis	Critical if the resource assessment is going to be of value to stakeholders, particularly FUGs
5. Develop outline inventory method	Project planning, technical forestry expertise	Methodology must be feasible, practicable, and produce desired information
6. Carry out participatory aerial photo mapping session	Participatory aerial photograph session, based around sketch mapping approaches. Use of GPS to geo-reference	Further RRA work with FUG members to obtain spatial and qualitative information for the community forest resource
7. Determine rough size of each 'compartment', and probable sampling intensity	Analysis of participatory aerial photo maps, use of survey maps, use of GPS	Standard techniques for developing sampling design, time availability being a limiting factor on sampling intensity
8. Carry out inventory	Participatory inventory, working with, and training, FUG members	Combine training and information collection, with FUG members being trained in inventory skills
9. Analyse information	Database for inventory information, GIS for spatial information, and link them together	Information analysis should be geared to the needs of stakeholders
10. Feedback to FUG and disseminate information	Prepare management information, maps and resource information	Information needs and dissemination methods are different for each stakeholder group

Stakeholders will always include the FUG, forest ranger, and DFO. They may also include line agencies, private companies, other projects, and national/international interests (such as biodiversity monitoring). Information needs are determined through participatory work with the FUG and meetings/interviews with other stakeholders. These will also vary depending on whether the FUG is in the early stages of establishment, or has been established for some time. The inventory method should address the information needs and reflect them. This is where the importance of having a systems' based approach rather than rigid methodology is apparent. The inventory should be simple, so that the FUG members can understand why operations are carried out, what information is being obtained, and why it is being obtained. They should be able to perform the tasks themselves after training. If large-scale aerial photographs are available for the forest, they are useful in the early stages of the inventory for both planning and obtaining information (see below).

The inventory methodology that has been used with FUGs so far is loosely based on the NACFP simple forest/shrubland inventory methods (see Jackson *et al.* 1996).

It is hoped that the approach briefly detailed in the framework will provide an 'intermediate' level of information between that of 'rapid appraisal' of forests (ocular estimates of the resource) and the more complex forest inventory methodology (which has proved to be too complex and time consuming for many forest rangers). It is hoped that nearly as much information can be obtained using the framework outlined here, that the information will be faster and simpler to analyse, and that it will be easier for the FUG to understand.

From the framework outlined above, it should be apparent how the new methods discussed here fit into the overall resource assessment process. Aerial photographs are used as a participatory tool fairly early on in the resource assessment procedure. They also have a more conventional role of allowing sampling strategies to be planned and of acting as a navigational aid. GPS is used as a part of the inventory procedure for boundary mapping or georeferencing. GIS is used at stages 9 and 10 for analysing, displaying, and disseminating the information.

Initial Participatory Session

The initial participatory session with FUG members is part of the process of identifying stakeholders and stakeholder needs. It is the first detailed contact with the FUG concerning the forest resource assessment procedure. It should be noted that this participatory session is part of the resource assessment procedure and not a key part of the user-group formation process, which focuses on building users' confidence and involving them in decision-making (Hobley et al. 1996). The specific format for the initial participatory session is semi-structured rather than being entirely rigid, as the information needs, proximity to the hand-over date, and main issues of concern will vary with each situation. The sessions were based around topical RRA, concentrating on the FUG and the forest resource. The key tools used were focus group discussions, semi-structured interviews, group walks through the community forest, and time charts.

The initial participatory meeting and examination of the resource with representatives of the FUGs had a number of purposes.

- To establish rapport with the FUG members
- To set them at ease regarding the nature and aims of the work
- To explain the work to them
- To identify the key ways in which they interact with the resource
- To identify key problems associated with the resource
- To determine the level of interest for the work
- To identify key features of the resource
- To initiate the mapping process
- To identify the potential problems with the rapid appraisal approach

The main tasks carried out during the initial session are outlined below.

Establishing Rapport

Meetings were arranged with representatives of the FUG, through the forest ranger. Three or four days advance notice were given to allow news of the meeting to be spread. It was specifically asked if representatives of all ethnic groups and both genders could be present. Usually, the Chairperson of the FUG would be one of the first to arrive at the designated meeting place, with some other Committee members. An initial conversation would take place, establishing how many members were in the FUG, how many Committee members there were, caste composition of the village, and of the FUG Committee.

As FUG members arrived, the Chairperson or forest ranger would begin the meeting. The meetings involved all participants, seated on the floor, with no-one excluded from the circle. Women usually sat together, and the facilitator had to ensure that they were a part of the main circle. It was easy for them to be partially excluded at this stage, which made it harder for them to participate fully later on.

It was explained that the aim of the work was to assist FUGs with forest management by providing them with information about the resource and knowledge about how to obtain that information. To be able do this, information was required concerning what their key issues were regarding the forest resource and what their needs were from the forest. It was explained that information could be provided for the FUG, such as accurate maps, and information about the resource that could help them to manage it to meet their needs. The use of GPS and aerial photographs was discussed, and the potential role of these in providing the community with information was also mentioned. It was also explained that part of the work would involve using simple methods to obtain baseline data about the forest resource, and that participants in this work would receive training to allow them to repeat the work themselves.

The time scale for the work was explained, along with the time commitment required from the FUG. The FUG representatives were then asked if they were interested in the proposed work and willing to commit themselves.

Invariably the above involved a two-way flow of information, with questions being asked and key problems and issues being raised.

Focus Group Semi-structured Interviews

The major difference between a semi-structured interview and a formal survey is the use of a list of topics rather than a questionnaire (Fox 1989). The topics may take the form of open-ended questions and directed enquiry. Semi-structured interviewing can be described as a guided conversation in which only the topics and key questions are predetermined. New questions or insights arise as a result of the discussion (Subedi and Sharma 1997). This provides a greater degree of flexibility and allows salient areas to be probed in greater depth. It is important to avoid the use of leading questions and best to avoid questions requiring a yes/no answer, as a greater depth of understanding is required. For example, the question 'Do you use fuelwood?' would be better replaced with 'What do you use for fuel?' or 'Where do you get your fuel?', with further questioning to follow. Focus group interviews were used as a means of rapidly obtaining a basic understanding of relevant information. They have also been identified as being a particularly useful tool for learning about natural resource use patterns and the spatial distribution of land-use practices (Fox 1989).

The focus group interviewing commenced by repeating some of the key information given earlier and explaining the main areas that the interview/discussion would cover. The two main areas were examining existing management systems and problems with the forest resource. The key topics covered were as follow.

- The main products obtained from the forest
- Uses of the forest products
- Gender divisions in the collection of forest products
- Seasonal break down of time spent collecting forest products (labour and activity sequence calendars)
- Changes in time taken to collect forest products
- Which areas of the community forest were used for what products, and when
- Restrictions on where users can go
- Restrictions on quantities of forest products households can use
- Systems for allocating quantities of forest products to households
- Cash crops obtained from the forest
- Key problems and issues with the forest resource and use of the forest resource
- Problems with the size of the resource
- Changes of the resource (size and quality)
- Conflicts over the use of the resource (within user group/between user group)

- Area of the resource
- How yields in the operational plan were determined

Group Walk through the Forest (Direct Observation)

Direct observation is important for validating information gained from interviews and in generating additional questions that may not be apparent until the resource and usage patterns are examined (Chambers 1985). The following activities were undertaken during the group walk.

- Identification of key features (forest blocks, species, rangeland, grazing land, topographical features)
- Identification of internal boundaries
- Noting features for future geo-referencing (ridge tops, large boulders, isolated trees, and so on)
- Examining what products were obtained from various locations
- Discussion with FUG participants about the resource and how it was used

It should be noted that the information obtained was brief, just giving a degree of familiarisation with the resource. Usually 10-20ha of resource were examined in a couple of hours.

Aerial Photographs

Aerial photography has been an important tool for forest resource assessment for many decades. Until the advent of satellite imagery, it was the main method for remote sensing, and in the mid-hills of the HKH region it remains the most important remote-sensing tool. This is due to the extremes in topography rendering image processing of satellite imagery very difficult. Aerial photographs are now relatively inexpensive and, used in conjunction with field sampling, can be used to produce maps showing land use, topography, and infrastructure. Aerial photographs suffer from image displacements due to aircraft tilt, topographic relief, and varying distance from the camera. These drawbacks can be overcome by using orthophotographs in which the displacements have been corrected, or by using digital orthoimages in which image analysis software is used to manipulate the digital image to rectify displacements (Dykstra 1997). These have not been used in this study due to the significantly higher costs of these images over others, making them inappropriate at present as a participatory tool for general community forestry work.

Aerial photographs have been used for resource assessment purposes in the HKH region for many years, for example for the Land Resource Mapping Project in Nepal (Carson 1985). Until recently, in Nepal, there have been problems about access to aerial photographs, and the costs have usually been high (Jackson et al. 1994). The situation has recently changed in Nepal, with the HMG Department of Survey having a series of high quality dia-positive images for most of the country that are available for use by Government Departments, projects, and so on.

The methodology involving the use of aerial photographs for this study is a departure from the traditional role of aerial photography in which the photographs are used as a remote-sensing survey tool. They are used here primarily as a participatory tool to facilitate the procurement of spatial and resource information from FUG members. This approach has been used previously in a limited way (Fox 1986), and is being examined by other researchers in Nepal (Mather 1998). These techniques are still in the developmental phase.

Aerial photographs can fulfill two distinct roles as a participatory tool. They can be used to facilitate participatory sessions, and they can be used as a source of quantitative information from participatory discussions. In this study, these two roles were combined, with the emphasis being on obtaining quantitative information. It was noted that they have a number of advantages as a facilitation tool over traditional techniques, particularly in animating discussions, encouraging the participation of women, and in allowing non-literate members of the FUG to participate fully. It should be apparent that their potential to encourage the participation of women is of significance. Women are the main forest users and make the day-to-day management decisions (from where to gather fodder, fuelwood, and other forest products). But it is often difficult to obtain their full participation as men tend to dominate proceedings, and any tool that can be used to increase their vocalisation is of value. The role of aerial photographs as a participatory tool is discussed by Mather (1998) in more detail.

As well as being used as a facilitation tool and a means of obtaining information from a wide cross-section of villagers, aerial photographs can be used to obtain quantitative information about the forest resource, regarding sizes of compartments, for example. This information is necessary before carrying out a forest inventory, so that a sampling strategy can be developed and sufficient time allocated for the inventory work. If an FUG is recently established and the process of handing over the forest not complete, there may be no survey map (there may not be one anyway). Cadastral survey information varies in accuracy depending on the survey methods employed, but it is often of questionable reliability, and in many cases it is very difficult to locate any mapped features on the ground (Keeling 1996). Participatory sketch maps are not spatially accurate. In many cases, aerial photographs can be an important tool in determining the spatial characteristics of the community forest.

For participatory sessions, aerial photographs enlarged to a scale of 1:5 000 from 1:20 000 were used. The scale appeared to be adequate for picking out all relevant features. This is a much larger scale than the one commonly used for aerial photographs (usually 1:20 000 to 1:50 000).

The methodology employed in this study was based around a participatory session in which the external boundary was defined and then internal boundaries added. The boundaries were drawn on acetate overlays taped to the aerial photographs. Water-based coloured acetate pens were used, and this enabled us to rub out boundaries during FUG discussions and re-draw them once consensus was reached. Information was obtained regarding the use of each compartment and the condition of each compartment (as a ranking exercise). Other information, such as where medicinal plants are obtained, water sources, and areas of conflict, can also be obtained. See Photograph 1.

Photo 1: Participatory Plots' Map Session - Defining the Forest Boundaries

A map, the 'participatory photo map' (also known as an 'aerial photo map' - see Mather, 1998), is produced of the forest, with external and internal boundaries marked, and other features obtained from the participatory process. This map has been found to be far more planimetrically accurate than traditional participatory sketch maps, and work is currently being carried out to assess the geographical accuracy of these maps in relation to survey maps. It is anticipated that this method will allow a reasonably accurate map of the resource to be drawn up as a result of the participatory approach. Additionally, more traditional RRA information is obtained during the participatory process such as usage patterns, the importance of various parts of the resource, key products obtained from different compartments, and how the FUG manage different parts of the resource.

Global Positioning Systems (GPS)

Global Positioning Systems' technology makes it possible to determine very accurate geographical positioning from a lightweight hand-held receiver. GPS is a network of 24 satellites installed by the US military (there is also a similar Russian network). The GPS receiver picks up signals from a selection of these satellites and, using this information, calculates the current position, or georeference. For the GPS to operate effectively, there must be an unobstructed view of four satellites for a three-dimensional positional fix. This factor can limit the usefulness of this technology in mountainous or densely-forested terrain, particularly those situated towards the polar regions (Jordan and Carlisle 1998). When using a GPS in the field, the operator enters a rough position (accurate to within approximately 100km), and the GPS receiver computes the exact location. During this initial process, obtaining a fix may take several minutes. Once you have determined the position, moving several kilometres and determining a new position takes less than one minute. For background information on GPS see Hurn (1989) or Carter (1996, Appendix A).

GPS technology can be used to obtain accurate spatial locations rapidly and cost-effectively, so features can be identified by their geographical coordinates (known as georefencing or geocoding). Key forestry applications for this technology include: mapping forest boundaries; obtaining 'control points', which are georeferenced points for entering aerial photos into a GIS or geocorrecting aerial photographs (an operation known as 'rubbersheeting'); and locating sample and demonstration plots.

Magellan Pro Mark 10CP GPS receivers were used for this study. These are capable of tracking up to ten satellites at a time and of producing sub-metre accuracy under ideal conditions. The information below refers to these receivers, and may vary with other models or makes.

GPS receivers can be used in stand-alone or differential mode. Stand-alone means using one receiver which is taken into the field and used to collect information as described above. The advantages of using a stand-alone receiver are speed, cost-effectiveness, and the fact that no post-processing work is needed. The disadvantage is an unquantified variability of spatial accuracy. Using stand-alone GPS, an accuracy of +/- 100m should be assumed. Accuracy can be increased by averaging a number of fixes (several hundred) for each position. This takes five to ten minutes per point. This method still only allows an accuracy of +/- ca. 50m, owing to a variety of errors, such as 'selective availability', a deliberate degradation of the satellite signals by the American military. Differential mode involves having one GPS at a known location (for example a range post or project site) and another GPS in the field recording positions. By using post-processing software, much of the error can be removed and an accuracy of +/- 10m can be obtained quite quickly and easily, although not in the field (using 'carrier phase' differential GPS, sub-metre accuracy is obtainable). However, the costs, post processing time, and organizational difficulties are much greater. For most applications, differential GPS is necessary, for example for boundary mapping. Real time differential GPS facilitates very accurate georeferencing whilst in the field, but the expense is much greater than using standard differential GPS. This is more applicable to utility surveying than natural resource management.

GPS has been used and evaluated for two separate roles in this study, boundary mapping and georeferencing control points.

Boundary mapping uses GPS as a survey instrument. The receiver is manually taken around the forest boundary and records the geographical location at predetermined intervals (usually one second). This information is stored in the GPS receiver and later downloaded on to a computer and post-processed, using the technique of differential processing outlined above. See Photograph 2.

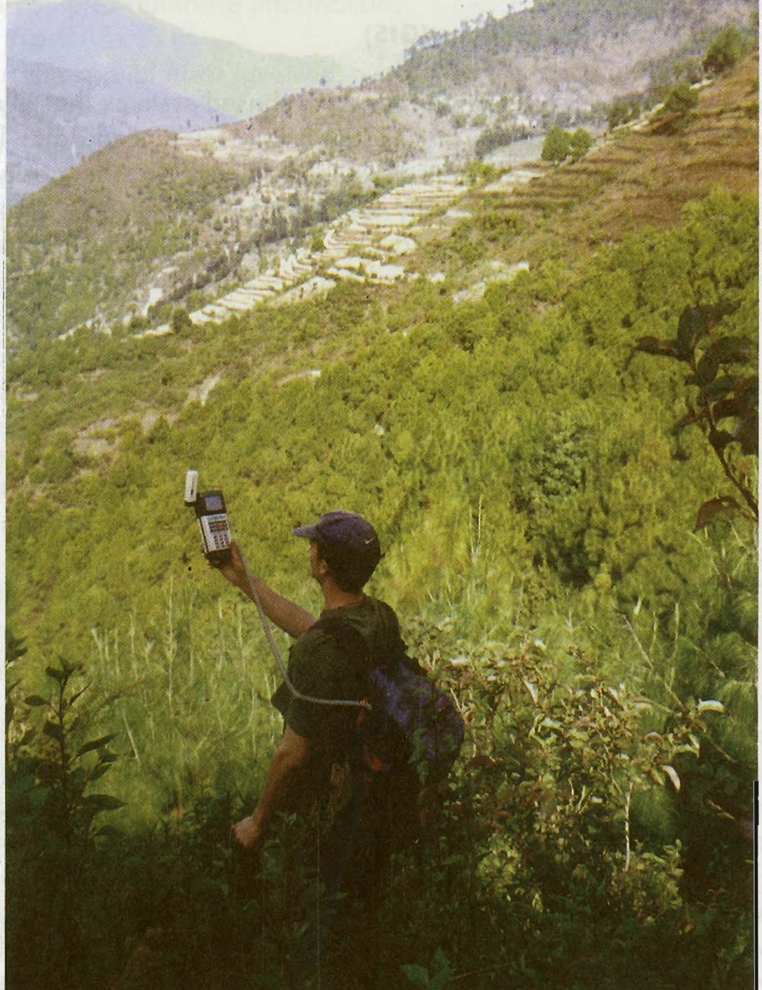


Photo 2: Bob Edmonds Using GPS to Map *Chulletto Panchi* Boundari

Georeferencing control points refers to obtaining an accurate geographical location for an identifiable feature (bend in road, house, temple, hilltop, etc) which can then be used as a control point for entering boundary information from an aerial photo or survey map of a forest. Having control points that are georeferenced facilitates the entry of spatial information into a GIS. For example, 'participatory photo' maps that are georeferenced using control points and then entered into a GIS, feature prominently in the case studies in part two of this paper. Obtaining georeferenced control points can be facilitated in two ways. A stand-alone GPS receiver can be used for collecting fifteen to thirty minutes of readings (at one per second). The average of these readings is then calculated. A more accurate method, and the one used for this study, is to use two GPS receivers for carrier phase differential GPS. For this, five minutes of readings are required for an accuracy of ca. +/- 5m. Control points must be easily recognised from aerial photographs and in positions in which there is little obstruction for satellites.

Geographical Information Systems (GIS)

Geographical Information Systems are computer-based systems that allow the input, management, analysis, and output of geographically referenced data. They facilitate thematic mapping, inventory work, multidisciplinary surveys, and the production of maps for a specific purpose. GIS is particularly useful for natural resource management, for which much of the information required and obtained is spatial (Heit and Shortreid 1992). They can be used to organize and analyse this information in quantities and ways that were previously prohibitive.

GIS for Information Analysis and Management

Spatial data were obtained during this study from participatory photo map sessions and by using GPS. For this information to be analysed and integrated with other data sources, it needed to be entered into a GIS. This was done in two ways. Information from participatory photo maps was digitized and entered into a GIS (both Terrasoft and IDRISI GIS's were used, vector and raster-based respectively). The work carried out using GIS for information analysis and management involved the following.

- Converting participatory photo maps into GIS maps. The external and internal boundaries of community forests that had been determined by FUGs during mapping sessions were entered into a GIS. Basic topographical features were added if appropriate. Attribute information was added, entering basic information on species, condition, and products obtained for each compartment.

- Georeferencing participatory photo maps. In order to georeference the maps, control points were needed (accurate coordinates of a known, identifiable feature). These points were marked on the large-scale aerial photographs and on the acetate sheets on which the boundaries were marked. These points were digitized, and the coordinates manually entered into the GIS.

- Determining basic spatial statistics. Once the participatory maps were converted into GIS images, spatial statistics such as the percentage of natural, plantation, and degraded forest could be determined.

- Entering GPS data (control points, forest boundaries, roads). Control point information was obtained by differentially correcting GPS control point information and manually entering the coordinates into the GIS. Forest boundaries and roads were directly entered into the GIS from GPS post-processing software as desktop publishing format data.

- Linking GIS maps of community forests with information obtained from RRA sessions and participatory inventories. A database containing analysed inventory information and qualitative information from RRA sessions was linked with the images, so that the GIS images could be used as a front end for accessing the data. This facilitates access to complex database information.

- Estimating the spatial error involved in using uncorrected aerial photographs in a participatory context for boundary mapping. As mentioned previously, uncorrected aerial photographs have various types of inherent spatial inaccuracy. Boundaries were compared that had been obtained from aerial photographs and from GPS surveying. This facilitated the estimation of aerial photograph error estimated for the study area.

GIS for Information Dissemination

As well as being useful for analysis and management of information, GIS can also be used to assist with information dissemination and understanding. The methodology involved preparing information for three levels of dissemination: the FUG, range post and other DFO staff, and national (policy) level.

- GIS was used to produce maps of their community forests, which had management information associated with the images for FUGs. This proved to be popular with FUGs and helped them understand spatial relationships between written information and where specified management regimes should be implemented. Information was designed to be non-technical, providing practical management advice.

- Similar information was prepared for information dissemination for Forest Department personnel. The GIS images contained the same information, but the accompanying database information was more detailed, and the technical aspects of yield calculations, suggested silvicultural regimes, and so on were given in full. This will help DFO staff to carry out further analysis of the information and evaluate the management suggestions in detail.

- GIS is known as an ideal tool for information dissemination at a national level, providing information in a form that is easily interpreted and understood (ICIMOD 1997). The potential for developing a district- or national-level database of community forests, with specific local-level information, was examined. This part of the work is currently in the early stages of exploring the potential of using GIS and other technologies for this role. This is examined in more detail in part two of this paper.

1.4 THE STUDY AREA

This section presents background information on the Yarsha *Khola* watershed. Unless otherwise referenced, the information has been produced by PARDYP/ICIMOD.

Location

The Yarsha *Khola* Watershed is situated between approximately 27⁰ 33′ to 27⁰ 40′ latitude and 86⁰ 05′ to 86⁰ 11′ longitude in the higher part of the middle hills of Nepal, covering a total area of 5,400 ha. It is located about 190 km east of Kathmandu, along the Lamosangu Jiri road (Plate 1). The proximity to this road makes the watershed unusual and may have important development implications. The watershed ranges from 930 to 3,030 masl. Due to the wide variation in topography, it has a highly heterogeneous climate (covering subtropical to temperate), natural vegetation, land use, and ethnic group composition (Plate 1).

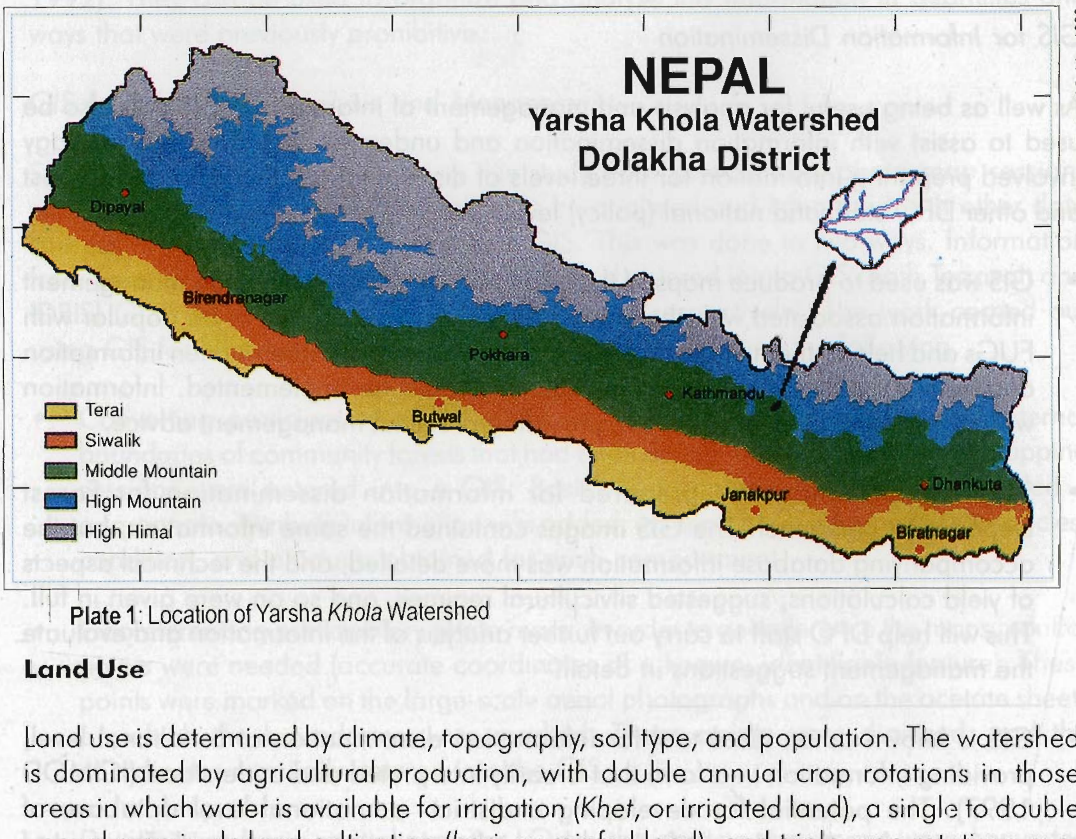


Plate 1: Location of Yarsha *Khola* Watershed

Land Use

Land use is determined by climate, topography, soil type, and population. The watershed is dominated by agricultural production, with double annual crop rotations in those areas in which water is available for irrigation (*Khet*, or irrigated land), a single to double annual crop in dryland cultivation (*bari*, or rainfed land), and triple crop rotations over a two-year period at higher elevations (*bari*).

A detailed land use survey was carried out using 1:20 000 aerial photographs and intensive field verification to understand the patterns of land use within the watersheds. GIS analysis determined the percentage land cover for each main land use. These are illustrated in Plate 2. The 'other' uses category covers landslides, rills, gullies, settlements, rock, quarries, and boulders (Plate 2).

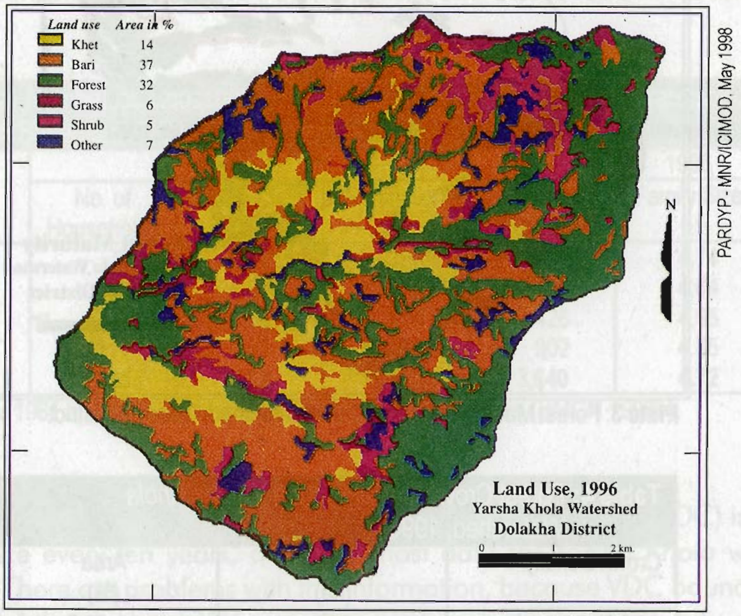


Plate 2: Land Use, 1996 - Yarsha *Khola* Watershed, Dolakha District

The area under forest cover within the watershed (32%) appears extensive, but the forest condition in terms of crown cover, maturity, and species' composition is generally poor. GIS evaluation shows that only eight per cent of the total forest within the watershed area has mature trees of logging size timber (with an average diameter at breast height (dbh) greater than 53 cm), and most of the forest resources are immature forest or in a fairly early stage of regeneration (See Table 3 and Plate 3).

Table 3: Forest Maturity Classes in Yarsha *Khola* Watershed, 1996

Forest Type	Area (ha.)	Area (%)
Mature (>53 cm dbh)	136	8.1
Immature (28-53cm dbh)	1,210	72.0
Regenerating (13-28cm dbh)	175	10.4
Plantation	160	9.5
Total	**1,861**	**100.0**

Very little (1.3%) of the forest has a crown density greater than 50 per cent, and a large portion of the forest (about 72%) has a crown density of less than 30 per cent (Table 4). Generally, this relates to the maturity status of the forest resource.

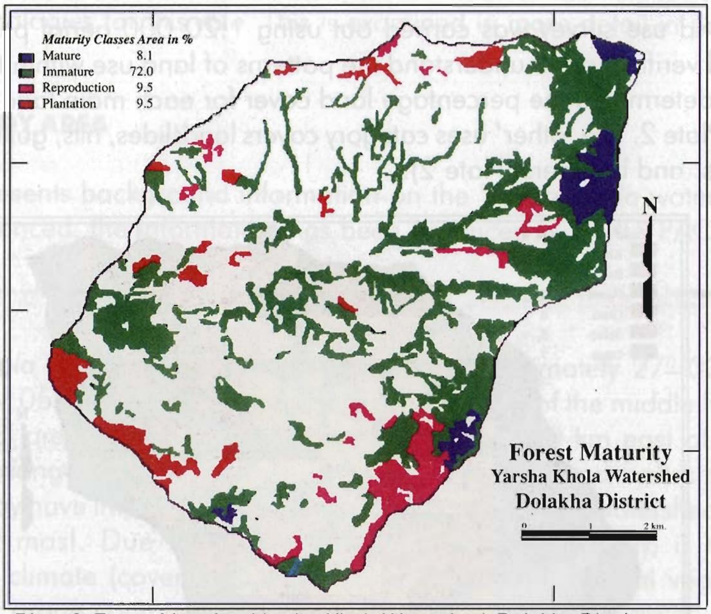


Plate 3: Forest Maturity - Yarsha *Khola* Watershed, Dolakha District

Table 4: Forest Crown Density in the Yarsha *Khola* Watershed, 1996

Crown Density	Area (ha)	Area (%)
< 10 %	278	16.5
10-30%	926	55.1
30-50%	456	27.1
>50%	21	1.3
Total	**1,681**	**100.0**

Aerial photographs and field investigation, coupled with a GIS for information analysis and output, were used to evaluate species' composition for the watershed. This work determined that *Alnus nepalensis* is the most dominant species (comprising about 23% of the forest cover), and varieties of *Pinus* species make up about 31 per cent of the forest cover. The rest of the cover is composed of a range of principally broad-leaved species, with *Shorea robusta* being important at the lower altitudes and *Rhododendron* species becoming prominent at higher altitudes.

Much of the forest resource, particularly at lower to middle altitudes, appears very degraded due to excessive and uncontrolled harvesting of fuelwood, fodder, litter collection, and overgrazing in the past. The present community forestry policy in Nepal might improve bio-diversity and lead to better management of the forest resource. RRA work indicates that this appears to be happening already in the forest areas returned to local community management, with FUGs reporting a greater abundance of fodder and fuelwood and less time required to collect these products.

Population

Population growth with only limited land space is seriously affecting the sustainable use of natural resources. One of the main problems in the Yarsha *Khola* watershed is the apparently rapid population growth since 1961 (see Table 5), leading to increased pressure on agricultural land, land fragmentation, and cultivation of increasingly marginal land.

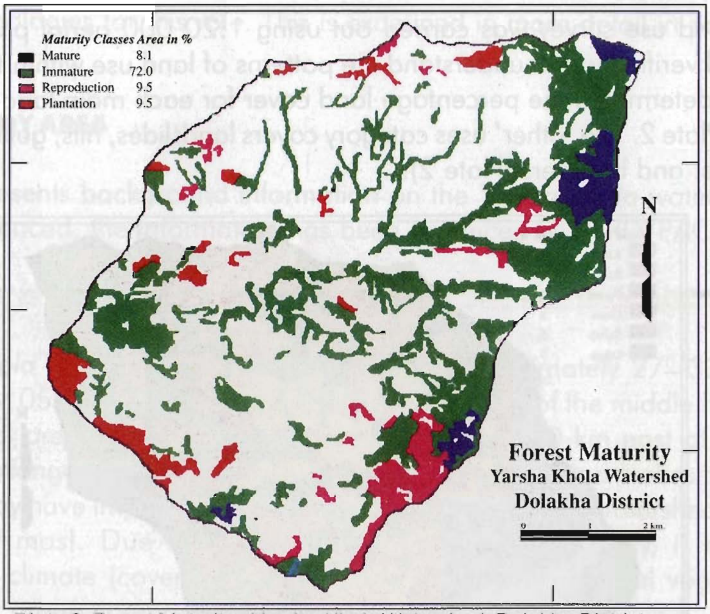
Table 5: Total Number of Households and Population of Yarsha *Khola* Watershed from 1961 to 1996 Based on VDC Census Data

VDC	1961			1996		
	No. of Households	Family Size	Population	No. of Households	Family Size	Population
Kabhre	84	4.74	398	1606	4.74	7,612
Mrige	38	4.64	176	706	4.64	3,276
Namdu	46	4.65	214	426	4.65	1,981
Gairimudi	117	4.85	567	902	4.85	4,375
Total	**285**	**4.72**	**1,355**	**3,640**	**4.72**	**17,244**

Family sizes for 1961 and 1996 are based on HMG/ Nepal census data (HMGN 1996b).

Population information for each Village Development Committee (VDC) is theoretically available once every ten years, although most data for Yarsha *Khola* watershed are unavailable. There are problems with this information, because VDC boundaries change frequently and the data are not georeferenced, so only summary data are available. Also, VDC boundaries do not coincide with watershed boundaries. To document the population dynamics within the watershed, VDC boundaries were overlaid with topographical maps on a scale of 1:25 000 (HMGN 1996a). Aerial photo interpretation and data on family size from the VDC census (HMGN 1996b) formed the basis for analysis . A series of 1:20 000 scale aerial photographs of the watershed were enlarged to 1:5 000, enabling all houses to be counted. The number of houses was then multiplied by the average family size determined for each VDC.

This methodology proved to be the most reliable means for collecting population data for 1996. As no historical census data were available, the 1961 numbers were obtained from 1:50,000 scale topographical maps (Government of India 1965) in which cartographers marked all houses present in the watershed. Again, the number of houses was multiplied by the average size of family. This information is summarised in Table 5 below. According to this data, on average the population has grown by approximately 7.3 per cent per annum. This figure appears to be very high, and it should be noted that the 1961 figures, and any subsequent population change estimates, are reliant on the correct identification and labelling of all houses present in the Yarsha *Khola* watershed by the 1961 cartographers. These types of assumption, which are hard to justify, have to be made when working with historic datasets in the HKH region (Thompson and Warburton 1985).



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There are limitations to counting houses from aerial photographs. Due to photographic scale, large cowsheds, schools, health posts, temples, post offices and offices are also counted. To compensate for such errors, the total number of houses was reduced by 10 per cent to arrive at a more realistic population estimate for that time in history.

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Part Two
Case Studies from the Yarsha *Khola* Watershed

2.1 INTRODUCTION TO THE CASE STUDIES

Results from the application of the methodologies described in part one of this paper are presented below as a number of case studies. All the case studies are based on work carried out with four FUGs in the Yarsha *Khola* watershed. Case studies are presented from specific FUGs because they are of particular interest or reflect the potential of the methodology. The discussion details how applicable these approaches might be generally. It should be noted that the topic of the first case study (the initial participatory session) has not been covered in detail in the methodology, owing to the employment of standard RRA techniques, that are thoroughly documented elsewhere (Chambers 1983; Davis-Case 1990; Bartlett and Nurse 1991; Messerschmidt 1995)

Background on the FUGs and Their Forests

The FUGs span a range of altitudes, forest types, and terrain. They were chosen for this heterogeneity rather than to be representative of the watershed, as the key task was an evaluation of the methodology presented here. Summary information is presented in Table 6 below.

Table 6: Summary information for FUGs/Forests Used as Case Studies, Yarsha *Khola* Watershed

Name of FUG/ Forest	Handover Date	Forest Type	Condition	Terrain	Altitude (metres)	Area, ha (from DFO)
Baishakeswori	In process	Natural	Good	Very steep	2200-2500	Not known
Dhungeswori	1994	Nat/ Plantation	Fire Damage	Gentle/ Moderate	1800-2100	71
Ningure	1993	Nat/ Plantation	Over grazed Degraded	Gentle/ Steep	1000 -1400	95
Chuletro Pakha	1995	Plantation	Good	Moderate	1600-1750	14

2.2 AN EXAMPLE OF A PARTICIPATORY SESSION

The methodology behind the initial participatory session was explained in detail in Part One of this paper. Below is an example of how this methodology performed when used with members of Dhungeswori community forest. Overall, the methodology appeared to provide a reasonable overview of the forest resource and the FUG's relationship with it. It provided enough information to plan the next stages of the resource assessment procedure.

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Aerial photograph sessions were used with each FUG involved in this study. The main purpose of these sessions was to obtain spatial information about the resource and to

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The Initial Participatory Session with Dhungeswori FUG

The RRA team for this meeting consisted of the forest ranger, the forest guard, both authors, and a gender specialist.

Mostly men were present for this meeting, and the women who were present didn't take a very active part. The gender specialist tried to overcome this by encouraging them to voice their views, making sure questions were directed at them that concerned the use of forest resources and talking to them as a separate focus group. We met in the usual village meeting place, a flat, shaded area. Initially we had an informal chat with the FUG chairman & secretary - they told us about the village cooperative committee for future development. Each family puts in 50-200 rupees each, and the money is used as loans for micro-industries, farming, etc. As often happens, the RRA process was creating as many questions as answers received. Who can have access to this? Who can afford to put in that much money? "Everybody", said the Chairman, a wealthy *Brahmin*.

Background Information

The FUG used to have 206 households, but now there are 197 due to deaths and outmigration. The average household size is 5, so there are approximately 1,000 people in the FUG. It has been established for 5 years. There are 15 committee members, 6 are women. The village castes are *Brahmin*, *Chettri* and *Sarkhi* (shoemaker). All present at the meeting were *Brahmin* and most appeared well educated and powerful within the village.

Problems with the Community Forest Resource

The main problem with the community forest used to be animal grazing. Now animals are stall fed, with fodder and bedding collected from the forest. Also, the trees are still small, so villagers cannot use them for constructional timber. They buy timber from people with private woodlands within the village. There is not enough fuelwood. The fuel used is mainly maize residues/grasses. Richer people use some kerosene.

Use of the Forest Resource

Key products obtained from the forest include: leaf litter, green grasses, and a little small dimension timber. A fire (about 7 years ago) damaged medicinal plants and the Non-Timber Forest Products (NTFPs). The FUG want to plant bamboo and hardwood species. NTFPs currently obtained include *Phyllanthus emblica* (*Amala*, a gooseberry like berry containing Vitamin C), and approximately 2,000kg are collected and sold every year. They also collect *Rubus ellipticus* (*Ainselu*). Anyone in the FUG can collect NTFPs, in any quantity. Every year 140ft^3 of timber for construction can be harvested. This is divided between seven 'needy' households, chosen by the FUG committee. The school may also receive some timber. The key species for this is *Pinus roxburghii* (*Khote salla*, or Chir pine). They also get litter, which is used for composting.

Women collect grasses, fuelwood and litter from the forest. Each household can collect 60 *bhari* (1 *bhari* = approximately 40kg for this FUG) in total. The forest is opened twice a year for the collection of grass and fuelwood. Each household is allowed to collect 1 *doko* of fuelwood per year (a *doko* is a carrying basket which holds 25-40kg of fuelwood). Only households near to the forest collect leaf litter, 2-4 *bhari* per household per year. This all took a lot of discussion, and it was obvious that there was a lot of disagreement and debate. Men collect timber (although women are also involved in carrying the timber), and they also dig up roots. FUG male members said tasks are not always gender dependent, it depends on who is available. The women just laughed at this.

A seasonal time diagram was drawn up after the discussion.

Seasonal Time Diagram of Activities within the Community Forest					
January	**February**	**March**	**April**	**May**	**June**
Grass collection (all day)	Fuelwood collection, firebreak digging (1-2 hours per day)	Fuelwood collection, firebreak digging (1-2 hours per day)	Timber harvesting (7 households only, all day)	Planting (each household averages 1-2 days per season)	Planting
July	**August**	**September**	**October**	**November**	**December**
Planting. Forest open 6-9 a.m. for grass & litter collection	Planting	Fuelwood collection (1 hour per day)	Fuelwood collection(1 hour per day)	Fuelwood collection(1 hour per day)	Fuelwood collection(1 hour per day)

The above diagram was based on a lot of discussion and should be regarded as a rough indicator only, particularly regarding time commitments.

Changes in the forest resource

The time taken to collect grasses and litter has been getting shorter, due to no grazing and a controlled utilisation of the resource, and improvements since the fire. For other products the forest is still young, and has not reached the age for production. Generally, the resource is improving, largely due to stopping grazing. If people illegally graze their livestock in the community forest area there is a penalty system of fines.

Usage Patterns

Any member of the FUG can go and collect products (up to their limit) in any part of the forest.

Cash Crops from the Forest

At present there is only *Amala*. The FUG is hoping to plant *Thysanolaena maxima* (*Amrisho*, or broom grass) in the future.

Problems with the Community Forest Resource

There is a conflict over the forest boundary. Fifteen years ago the Forest Department surveyed and mapped the forest. The cadastral survey 6 years ago mapped part of the forest as private agricultural land, and it is being used as this. The disputed land is 7 *ropani* in area (approximately 0.4ha).

The forest resource is too small, they are trying to manage it to increase productivity by enrichment planting on degraded sites. There is a nearby area of state-owned forest that could be converted into community forest, but there are disputes between existing FUGs over who should have it.

The FUG has very little information on how to manage the resource. They do not know how much of the various products can be removed sustainably, and they estimate how much can be removed based on their experience and knowledge.

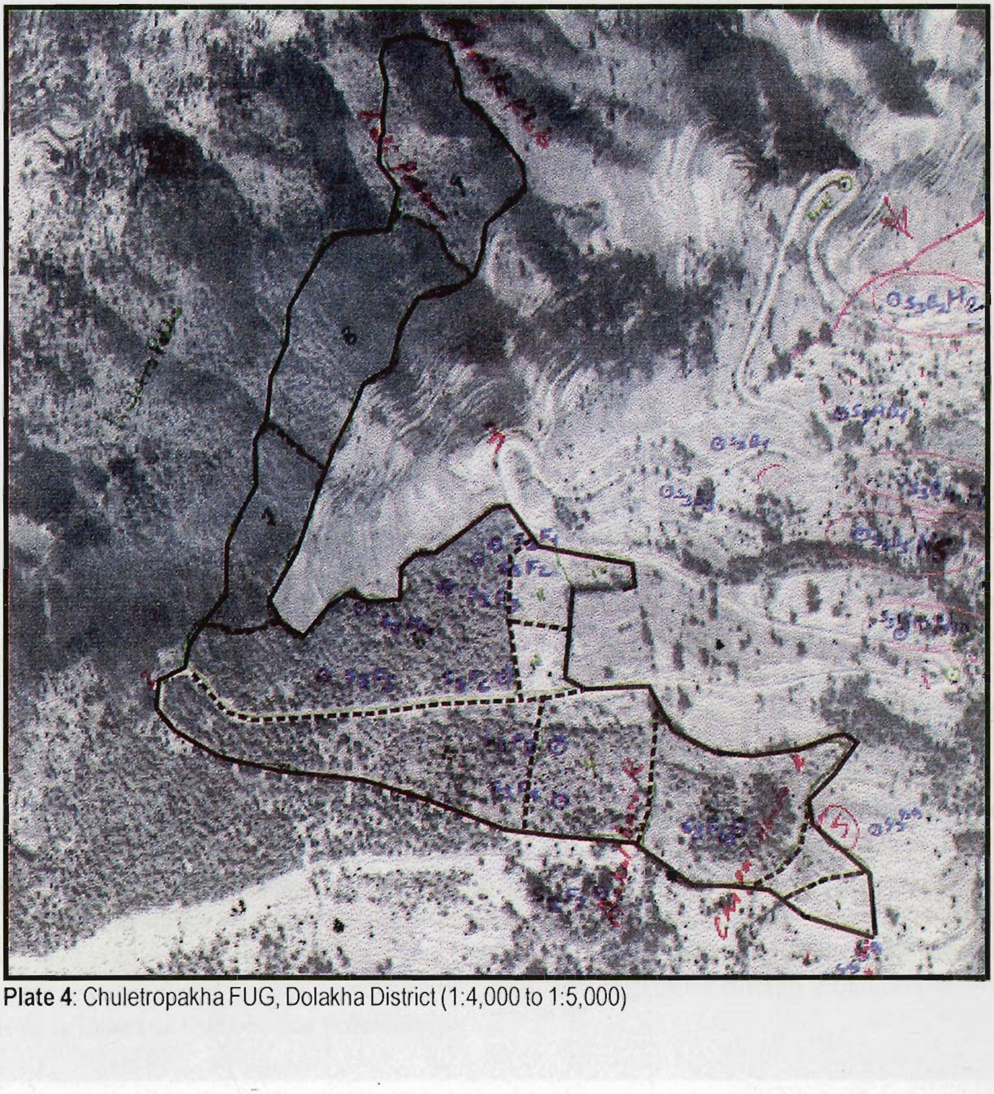
Group Walk

We walked across part of the resource, and examined the extent of fire damage. Eight participants, 5 men and 3 women, accompanied us. Most of the trees are quite young, the far side of the resource near a ridge used to be important for collecting fodder and fuelwood, but since the fire it has been used only for grass collection (there is now no dead wood, and the trees are too young to lop). Whilst walking, we identified a number of NTFPs which had not been mentioned during the discussions. This illustrated the importance of actually getting into the forest resource as soon as possible. It also became apparent that there are a number of internal boundaries within the forest - there are 8-9 individually named areas. For example, the area lowest in the Yarsha *Khola* watershed is called 'big rock to ridge'.

produce a participatory photo map of the community forest, although it was found that aerial photographs were also an excellent tool for facilitating traditional RRA work. Therefore, other information was collected during this process such as ranking the quality of each area of the forest and the criteria the FUG used for this ranking process. Usage patterns were also recorded. Two scales of aerial photographs were used, 1:20 000 and 1:5 000 enlargements from these. The smaller-scale photographs were used to identify general features (nearby roads, main rivers, local villages or towns), and the larger-scale photographs were used to identify local features (houses, temples, trails, fire breaks, forest boundaries).

The general procedure for aerial photo sessions involved an introduction explaining that a map of the forest resource would be produced and explaining what it would be used for and how the information would be returned to the FUG. The aerial photographs were introduced into this participatory discussion; often by the participants who would notice them and grab them! One of the key aspects of this approach was its animation and excitement. It is important to have good facilitation. As villagers start to identify features, they need to be informed about what has been identified correctly and have some of the key features pointed out to them. Generally, villagers can identify features very rapidly. This is probably due to them living in mountainous terrain and being familiar with viewing fields, houses, rivers, and forests from an 'aerial' perspective.

Once the villagers are able to interpret the image correctly and are confident in their abilities at interpretation, the mapping procedure can begin. It has been found that the best approach is to commence with border areas that are clearly delineated (next to a road, track or agricultural land) and, once the group has marked these, to move on to the less clearly defined areas. Usually the group will nominate one or two people to draw on the boundary, but the final boundary is definitely drawn by the consensus of all who are present (see Photograph 1). The mapping of the external boundary was found to take from twenty minutes to an hour and a half. Internal boundaries were harder to define in many cases, as the distinctions were often not so apparent on the photograph. As mentioned in the methodology section of this paper, the best approach was found to be to separate men and women into two mapping groups after the initial discussion. This was in practice quite difficult, and the facilitator had to be firm in preventing the groups from coalescing back into one. A useful technique was to have two activities occurring simultaneously, for example, the forest ranger would talk to the men about management issues whilst the women were mapping the boundary. It was also useful to have the women map the forest first, otherwise they tended to leave the meeting prematurely. When both the men and women had mapped the resource, the group was merged into one again and differences between the maps compared. Usually a consensus was quickly reached. There is an example of a section of a participatory photo map overlaid on to the aerial photograph in Plate 4.



PARDYP - MNR/ICIMOD, 1998

Plate 4: Chuletropakha FUG, Dolakha District (1:4,000 to 1:5,000)

Once the resource was mapped, questions were asked regarding usage patterns, access, areas where there are conflicts, and other questions about the FUG. It was found that this provided the facilitators with a much greater level of spatial awareness of these issues than a standard participatory session would have provided.

A Participatory Aerial Photo Session, Baishakeswori FUG

After arriving and drinking tea with the Chairman of the FUG, the FUG members for the session slowly arrived. The aims of the mornings work were explained, and the FUG members seemed happy and enthusiastic about the work. Initially 1:20 000 aerial photographs were used by the group to get their bearings, identify key features, etc. Facilitation at this stage is very important, aiding correct identification. If this is not done, either the group may identify features wrongly, which leads to great confusion when mapping starts, or they may lose confidence in their abilities and become very hesitant. The session was very participatory and vocal, with men and women freely joining in, gesticulating wildly, and influencing proceedings. All the participants were highly enthusiastic, and it was impossible for the facilitator to split the group by gender. Once the group had established where main features were (which took about ten minutes), they concentrated more on the 1:5 000 aerial photograph to identify features in more detail and determine where the forest boundary was. This switch of photograph scales occurred spontaneously with no influence from the facilitators. Some participants voiced the opinion that it would be better if the session moved to the forest (meaning to view the forest), but the majority wanted to stay in the village. The boundary was drawn on by 2 men with the assistance of the rest of the group (a number of women wandered off after about an hour, but they had contributed considerable inputs. This is a *Sherpa* village with a high level of equality). Once the external boundaries were drawn, internal boundaries were established. There was some unwillingness to do this without viewing the forest, and the internal boundaries looked as though they were drawn in a fairly arbitrary manner. It became clear at this point which part of the forest was scheduled for handing over almost immediately, and which part would be handed over in a year or so, owing to conflicts over private/community land. It had been impossible to determine this accurately from traditional participatory sketch maps.

After the first map was drawn, we moved to a location from where the forest was visible, on top of a small hill, and another map was drawn (again, all this was voluntary, with no suggestions from the facilitators). The two maps were broadly similar, although it is interesting to note that most of the boundary and divisions were slightly different.

It was hoped to have the men and women produce maps separately, but this was not possible. Owing to the high level of participation, it was not important from the perspective of obtaining accurate boundaries, but an added advantage of having two maps is to identify why the different gender groups have mapped different boundaries. This was not possible in this case.

Overall, the participants said that the process was quite simple to understand and easier to do than participatory mapping sessions they had performed with DFO staff. They also said that they had had an excellent and entertaining morning!

2.4 USING GPS

As discussed in Part One of this paper, GPS was used for two main purposes in this study: for directly mapping forest boundaries and to obtain control points for georeferencing participatory photo maps.

Much of the information collected during the participatory sessions was spatial, and its usefulness was dependent on accurate forest boundaries. Additionally, in order to enter information into a GIS, it needed to be accurately georeferenced. GPS was identified as the most cost-effective means of doing this.

Boundary mapping used GPS as a survey instrument. The receiver was manually taken around the forest boundary and recorded the geographical location every second. This information was stored in the GPS receiver and later downloaded on to a computer, post-processed, and put into a GIS. In many cases GPS could be used to map forest boundaries rapidly and accurately. The feasibility (in terms of speed and accuracy) of this largely depended on terrain: forests that had very steep slopes and no clear delineation between community forest and other land were difficult to map. This was due partly to the physical difficulties and dangers of using GPS on this terrain. In this region of the mid-hills of Nepal 70 per cent of the land has a slope angle greater than 30 degrees, and slope angles in excess of fifty degrees are common (ICIMOD 1997). It was also due to the obstruction of satellites by the hillsides.

It was found that to get useful results, differential GPS, used in mobile mode, was necessary. This mode does not allow carrier phase differential correction (which can obtain sub-metre accuracy), and accuracies of +/- 5-20 metres were obtained. For resource mapping in Nepal, this is more than adequate (and far more accurate than the other spatial information available). Stand-alone GPS did not provide a sufficient level of accuracy, with positional fixes at any one point being highly variable. This was partially overcome by recording fixes for 15-20 minutes at each point and averaging the fixes, but this is prohibitively slow (and still susceptible to greater spatial error than differential GPS).

Georeferencing control points in the context of this study refers to obtaining an accurate geographical location for an identifiable feature (bend in the road, house, temple, hilltop etc), which can then be used as a control point. Having control points that are georeferenced facilitates the entry of spatial information from participatory photo maps into a GIS. This technique provided a means for rapidly mapping approximate forest boundaries (they are only approximate due to the spatial distortion inherent in standard aerial photographs). Differential GPS was used to survey control points. As the receiver is stationary, the more accurate carrier phase differential correction can be applied. For this, five minutes of readings are required for an accuracy of *ca.* +/- 1-5m. Control points must be easily recognised from aerial photographs and in positions in which there is little obstruction for satellites.

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One problem that faces GPS users in most of the HKH region is the lack of georeferenced base stations in convenient and secure positions; and these are necessary for differential GPS. This was overcome by locating the GPS base station in a project building in the same watershed as the mapping and resource assessment work. The location was determined by averaging over 30,000 individual readings. Analysis of the data determined that the location was accurate to within approximately +/- 5m, more than adequate for this type of work.

For GPS to work effectively in Nepal, it appears that ten channel receivers are required (each channel monitors one satellite), otherwise too much time is wasted by the receivers losing satellites and locating new ones. This has proved to be a common problem in mountainous regions or where a dense forest canopy partially obscures the sky (Jordan and Carslisle 1998). Overall, this case study found GPS to be an appropriate technology for this kind of research and very effective for mapping control points and some boundary mapping applications. This is looked at in more detail in the discussion section of this paper.

Using GPS for Mapping Chulettro Pakha Community Forest

Instead of coming as 'outsiders' with our strange pieces of unexplained equipment, we attempted to inform the FUG of the work we were doing. We described the operation of the GPS in fairly simplistic terms prior to demonstrating it, as the sight of the GPS caused much excitement. A detailed technical understanding of how it worked was felt to be inappropriate (do you have to know how a fax machine works to understand what it does?). We told the participants that the GPS collected information from satellites above us, in the same way as satellite television works and similar to how their radios work. We said the information received from the satellites allows us to know exactly where we are, and by putting the information into a computer we can draw a map of the forest area, or get the location of schools, meeting places (*chautara*) etc. The Magellan ProMark 10 used allows one to view the status of each satellite and the satellite configuration, which were of interest to the participants. We explained that we wanted to map the forest boundary, and the forest guard and six members of the FUG accompanied us.

At first things went very well. The forest boundary was a distinct boundary between *Bari* and *Pinus patula* plantation, and the trees were quite small (<8m). It was quite easy to obtain readings with an acceptable PDOP value rapidly, although we had to be 2 - 3 m from the actual boundary (A PDOP value is a measure of the spatial reliability of a positional fix). However, we soon encountered difficult terrain, with the slope angle increasing greatly, and dense scrub and woodland with no physical boundary between community and private land. The going was both difficult and dangerous, steep gullies with slope angles *ca.* 45^0, wet mud, and loose vegetation, particularly whilst trying to hold a GPS upright. Most of the participants (and team!) stayed above on a trail. With the steep slopes, denser vegetation, and a less favourable aspect, PDOP values were poor, and there were gaps in the data collection. Once we got back on to a trail, PDOP values improved again. The whole forest boundary was surveyed in approximately two hours (the area was approximately 14ha) (See Plate 2).

From the above, it can be seen that GPS has a role to play in boundary surveying for most terrains, particularly where there is a distinct boundary to the forest. It also makes the forest walk more interesting, and it takes the team and participants to areas of the forest that they may not otherwise visit. It became quite apparent that most users did not know exactly where the boundary was, the forest guard was the most knowledgeable. Additionally, as the whole forest boundary is traversed, a feeling for the surrounding land uses and terrain can be got that is difficult to obtain from aerial photographs. If the boundary survey is carried out with a group of participants, information that is similar to that from a 'traditional' group forest walk can be obtained.

2.5 INFORMATION ANALYSIS AND DISSEMINATION: THE ROLE OF GIS

GIS has been used in this study as the principal tool for organizing, analysing, and providing a mechanism for disseminating spatial information. This section uses a number of brief case studies to illustrate these roles.

GIS was used to convert hand-drawn participatory aerial 'photo maps' into images suitable for publication and dissemination. This process also facilitated basic spatial analysis and georeferencing of the maps, so that they could be assimilated into a larger spatial database. Control points were generated for this purpose.

GIS Case Study 1
The Process of Converting the Dhungeswori Participatory Photo Map into a GIS Image

Once the participatory photo map had been generated from participatory sessions, control points were collected. Features that could be identified from the aerial photographs were located, and the GPS was used to obtain spatial coordinates. The most convenient features were sharp bends in the road that goes around the forest and the site of an old Buddhist *Chorten* on a ridge top. This process is quite rapid, and three control points were logged in about one and a half hours. The main problem is the interest generated by this procedure: if the control points are near a village, it is so difficult to prevent too many people crowding round that satellites are completely obscured!

When all the data were collected, they were transferred to the GIS. The control point coordinates were manually entered into the GIS and digitized. The participatory photo map was then digitized and assigned topography. The individual compartments were given different colour fills to aid visualisation. Once this procedure was conducted, it was possible to obtain spatial statistics such as area. For Dhungeswori Community Forest, there were nine individual compartments identified by the FUG. The areas of these are given on the map in Plate 5. The whole procedure takes two to three hours. At this stage, and without further evaluation, the spatial accuracy cannot be determined due to the unknown error in the aerial photograph used as the basis for mapping. However, the spatial accuracy is considerably greater than that generated by participatory sketch mapping.

From the GIS Case Study One above, it can be seen that it is a relatively straightforward and rapid process to convert a hand-drawn participatory photo map (by digitizing) into a GIS image which allows basic spatial analysis to be carried out. However, it is not possible to determine the error in the image due to the distortion inherent in the aerial photograph. There are two approaches to assessing this error.

- Compare the participatory aerial photo map boundary of the community forest with the one obtained from transferring the boundary on to a geo-corrected aerial photograph. Unfortunately, at present, these are difficult and costly to obtain in Nepal.
- Compare the boundary obtained from digitizing the aerial photo map with a boundary obtained by using GPS as a survey instrument. GPS boundary surveying

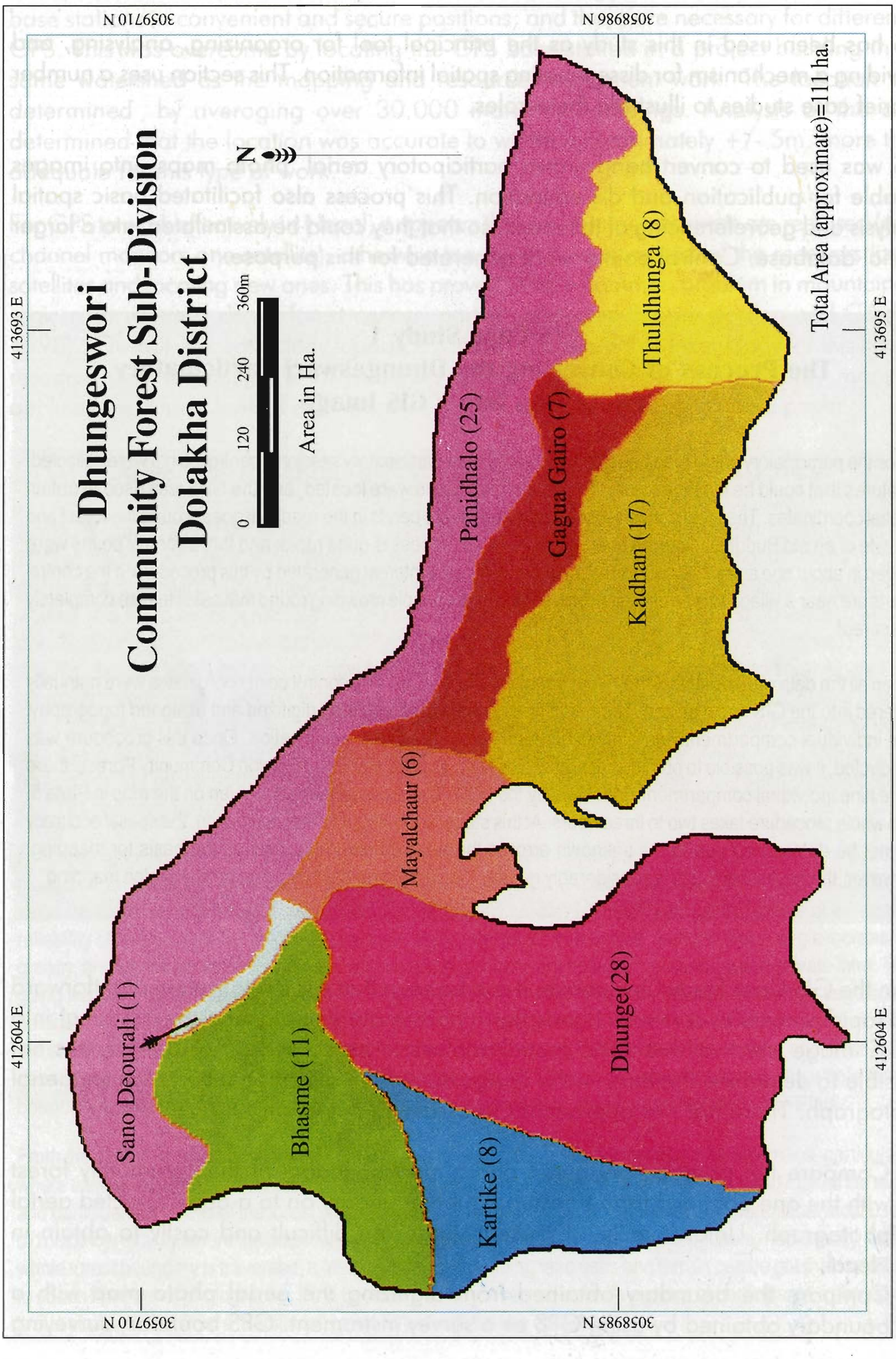


Plate 5: Dhungeswori Community Forest Sub-Division, Dolakha District

is the most accurate means of boundary surveying in the mid-hills of Nepal, due to the difficulties of traditional survey methods on steep terrain and with a limited line of sight.

The second of these two methods was used to evaluate the spatial accuracy of the participatory survey maps. This is detailed in GIS Case Study Two below.

GIS Case Study 2
Comparison of Methods Used to Evaluate the Boundary of Chulettro Pakha Community Forest

Chulettro Pakha was one of three community forests used as study areas for evaluating the accuracy of participatory photo maps, stand-alone GPS, and Forest Department Surveys. The Baseline data used for the evaluation were differentially corrected GPS data, which are accurate to +/- 1-5 metres (Magellan 1996, p143). This information was collected by walking the forest boundary with a 'rover' GPS (the term used for the GPS receiver used for field surveying), accompanied by members of the FUG, the forest guard, and forest ranger. This ensured that the boundary was followed as closely as possible. The information collected and stored in the rover GPS was downloaded on to a PC at the PARDYP field office and differentially corrected using information collected by the GPS 'base station'. The base station is a GPS receiver at a geographically known location, in this case the field office.

Back in Kathmandu, the participatory photo map and Forest Department survey map for Chuletro Pakha were digitized and entered into a GIS. The GPS data (both uncorrected [stand-alone] and differentially processed) were exported from the GPS post processing software as DXF files, and imported into the GIS. This facilitated carrying out a spatial comparison in terms of area and geographical accuracy. This information is shown in Plate 6. It can be seen that the participatory photo map border closely follows the differentially corrected GPS border (the 'real', or baseline, border). It can also be seen that the uncorrected GPS data are inaccurate. The Forest Department survey map also has a high level of spatial inaccuracy. The areas represented by these various borders are given below.

Method Used for Obtaining the Border	Total Area (Ha)
Differential GPS (Baseline data)	14.82
Participatory Photo map	17.0
Stand-alone (uncorrected) GPS	20.63
Forest Department Chain and Compass Survey	15.51

From this, it can be seen that the chain and compass most closely approximate the actual area, followed by the participatory photo map. So what are we to make of this information? In the other study areas there was a greater difference between the chain and compass survey and the baseline data. As Plate 6 shows, the chain and compass survey does not reflect the border very accurately, and it is 'lucky' that the area corresponds so closely. It can be seen that stand-alone GPS, without differential correction, has a high degree of error. Although projects use this method in Nepal, it should be used with caution. So why the error between the participatory photo map and the baseline data? There are two sources of error. Firstly, the distortion in the aerial photograph. The photograph used for participatory mapping had not been corrected. Secondly, the boundary drawn by the FUG and the boundary surveyed on the ground will differ slightly, maybe substantially where the boundary is poorly delineated. At the moment it is not possible to quantify how much error is due to each source. Work in this area is currently being carried out by the authors.

From the above (and the other studies), it can be surmised that, if a potential error of +/-15% is acceptable, participatory photo maps from uncorrected aerial photographs are a rapid, simple and cost-effective means of obtaining spatial information. Plus or minus 15% may sound like a lot of error, but from our work it appears that chain and compass surveys have a similar error budget, and participatory sketch maps have an error of up to 300%! If a higher degree of accuracy is required, use GPS. But it should be remembered that, even though GPS is very accurate, there is a potential for human 'error'. There may be vested interests on the part of participants, to include or exclude certain areas of which an outside surveyor is unaware. Where the GPS is taken depends on where the participants say the boundary is. Therefore the boundaries should be regarded as 'fuzzy', something that researchers with a western scientific training are often inclined to forget.

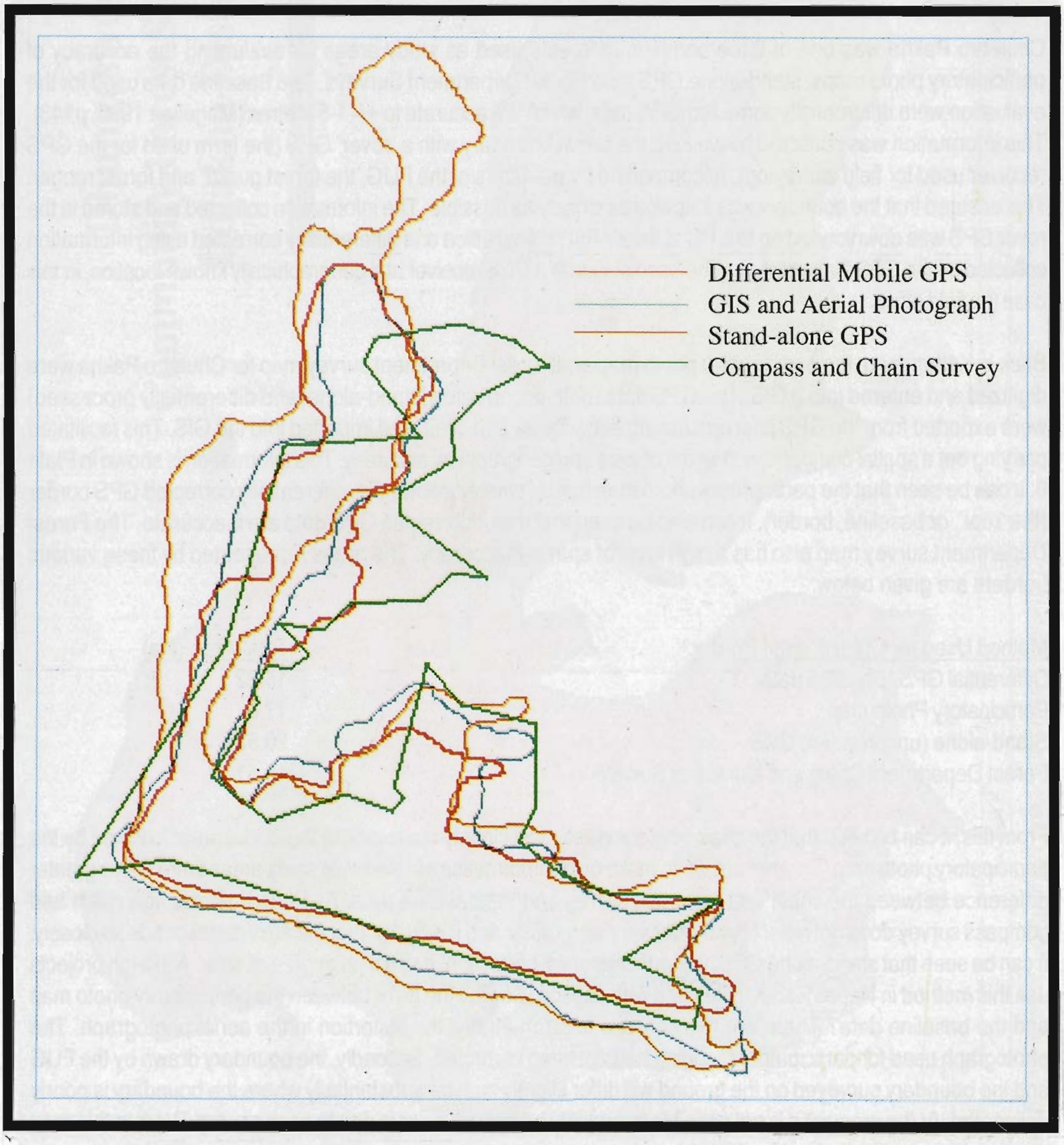


Plate 6: Comparison of Boundaries of Chuletropakha FUG

From Case Study Two above, and other evaluations we have conducted, it appears that participatory photo maps have an accuracy of +/-10-15 per cent compared to boundaries surveyed using differential GPS. It should be noted that insufficient studies have been conducted to date to support this statement statistically.

GIS can be used for information dissemination to FUGs, Forest Departments, and for decision- and policy-making purposes. The type of information required for these purposes is different. GIS Case Study Three below gives an example of information dissemination for Forest Department purposes; information of use to forest guards, rangers, and District Forest Office staff. Information for FUGs is portrayed in a similar way, but the information has less technical content and a greater emphasis on practical management issues. Information for decision- and policy-making requires more detail. The raw and analysed data from the geomatics' work and forest resource assessment need to be made available, along with summaries of the key issues (condition, changes in the resource, and biodiversity information). GIS, combined with relational database information, is a good means of presenting this information. It is anticipated that the Internet will be a good vehicle for the dissemination of this information, particularly as there is substantial potential for pop-up menus for access to various parts of the database and results. There are already good examples of this available (see PARDYP Project 1997). This part of the work in connection with this study is still being carried out.

GIS Case Study 3

An Example of the Information Returned to the Forest Range Post for Part of Ningure Community Forest

Participatory sessions with Ningure FUG and DFO records determined that Ningure had 11 individual compartments recognised by the FUG and Forest Department. During the course of this work, they were mapped, and a number of them had participatory resource assessments conducted. The data from the resource assessments were analysed and resource management information obtained. In order to make this easily accessible to forest range post staff, a summary of this information was overlaid on to a GIS image of the forest compartments. An example of the type of information is given in Plate 7 for one compartment of the forest. An explanation of how the management information was obtained from the data is outside the scope of this paper, but is explained elsewhere (Jordan, in press). This is not the only information that is presented to range post staff. Additionally, there is a more traditional report detailing:

- background information,
- FUG information, including concerns and interests of the FUG,
- general forest management information,
- detailed compartment by compartment information with raw and analysed data, and
- a copy of the information given to the FUG.

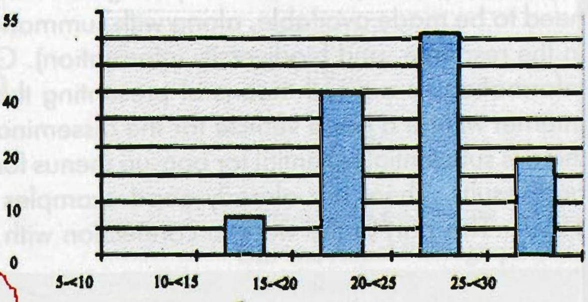
Feedback from range post staff has been very favourable. Forest guards have said that this information provides them with the first resource management data that they have had on a compartment by compartment basis.

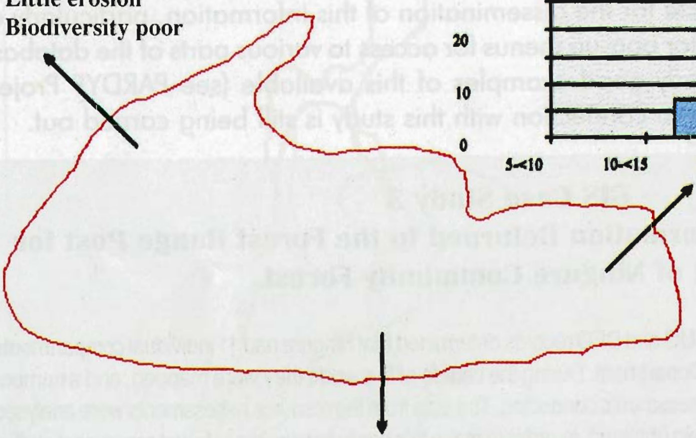
The analysis and presentation of the data are quite time consuming. The whole process of entering the resource assessment information, generating the GIS images, analysing the information, and preparing reports takes three to four days per community forest, longer if there are more than ten compartments. This has human resource implications.

Salleri Cherdung Forest Sub-Division of Nigure FUG, Dolakha District

Resource Information
Chir pine (Khote Salla) plantation
Tree condition good
Moderate south facing slope
Natural regeneration of pine & broadleaf species
Pruned, no excessive lopping
Little erosion
Biodiversity poor

Size class distribution for Chirpine (cm)





Management Information
Approximate area of compartment: 7ha
Average dbh = 21.5cm
Number of stems per ha (>5cm dbh) = 600
Basal area = 14m^2/ha
Standing volume timber = 14m^3
Sustaibable utilisation volumes:
Fuelwood, 3825 bari, once every 3 years
Fodder, 600 bari per year
Protect from grazing (current problem)

Plate 7: Forest Resource Information for Salleri-Cherdung, Ningure Community Forestry

2.6 DISCUSSION

Although this paper has focussed on the technical aspects of using geomatics in combination with participatory approaches, it should be remembered that these techniques are just tools to obtain information to enable the FUG members, in consultation with the Forest Department, to improve their forest management and to disseminate this information to a wider audience. Therefore, the aim is to simplify and improve resource assessment procedures and help with the analysis and dissemination of this information. The techniques appear to be appropriate for this role. Either participatory photo maps or the use of GPS provide enough spatial data to plan a participatory inventory. GIS is a good tool for presenting the results of this work, and FUGs and Forest Rangers are very happy with the maps and information produced.

The use of geomatics is integral to the forest resource assessment framework outlined in the methodology section. The minimal employment of geomatics to apply the framework successfully is by using aerial photographs to plan the participatory resource assessment. It has been found that participatory photo maps are far superior as a planning tool than participatory sketch maps. Additionally, owing to their excellence as a participatory tool in their own right, they are far superior to survey maps as a means of obtaining resource information from participatory sessions. This 'incidental' benefit is of great importance. GPS is also required if the spatial information (boundaries, resource quality, management practices, etc) is to be georeferenced, and this is necessary for compiling a GIS database. If information on a number of FUGs is to be combined at a watershed, district- or national-level, these data are required. GPS is also useful for obtaining very accurate boundaries which are useful for research work, and it may have a role to play in boundary conflict resolution. There are also traditional roles for GPS, such as georeferencing Permanent Sample Plots and erosion plots.

Key Issues

GPS is regarded with some suspicion amongst resource management researchers and practitioners in Nepal. This may be due to the use of inappropriate equipment, or not using it in the optimal way. The work carried out in this study (and other supporting research, Jordan 1997) indicates that GPS is entirely practicable for use in the mid-hills of Nepal. It is simple to use for obtaining control points and, as long as the terrain is not excessively steep or vegetated, it is easy to use for boundary mapping. As long as its operation and limitations are fully understood and appreciated, the authors have no hesitation in recommending its use for resource assessment in the HKH region.

Are geomatics' tools appropriate technology for community forestry in Nepal? There is no way that, in the near future, District-level Forest Departments in Nepal and in much of the HKH region will be able to afford this type of equipment. Two GPS receivers, a cheap GIS, a PC, and printing capability still costs in excess of $10 000. It is felt that an appropriate method of employing the technology would be through an NGO or a

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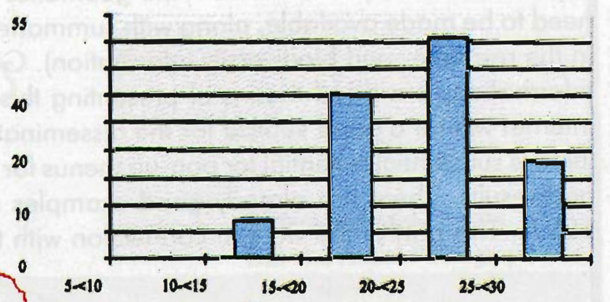

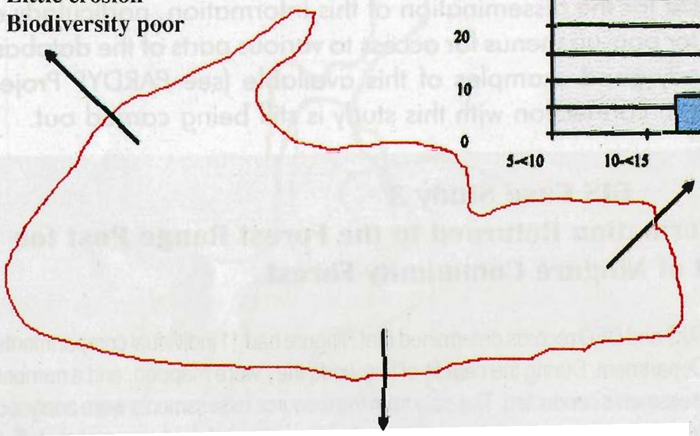

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Central Forest Department who would undertake the surveying and resource assessment of FUGs at their request. This could be an income-generating activity for the NGO. FUGs would pay for the service which would provide them with a management plan indicating a sustainable level of use. This could be used by the FUGs in consultation with DFOs to discuss income-generating activities such as timber sales. It could become a pre-requisite for the commercial production of forest resources by an FUG that the resource has been monitored and a management plan developed by a DFO-approved organization.

Can the work be replicated satisfactorily, and is it applicable elsewhere? Much of the work discussed in this study has been replicated elsewhere in Nepal. There appears to be no difficulty in the technical performance of the geomatics' technology in other areas, and the participatory techniques are quite standard and have been used successfully world-wide. There are some practical problems that need to be considered before this methodology is adopted.

- Aerial photographs of 1:5 000 are required for optimal participatory work. Can these be obtained? Good quality small-scale aerial photograph dia-positives will be required. Attempts to make copies not using the dia-positives have proved unsuccessful. They need to be fairly recent (last 10 years). In Nepal, the situation is good, with most of the country being covered by 1992 or 1996 aerial photographs which are available. The situation may not be so positive for other HKH regions.

- Are aerial photographs appropriate participatory tools? They are easily interpreted by FUG members in the mid-hills of Nepal, but they may not work so well in flatter areas where people are not used to 'aerial perspectives' from ridges.

- Is there access to a digitizer and GIS? This is required if the information is going to be organized into a spatial dataset. As this equipment becomes more widespread, this limitation is becoming less important.

- Is the area in a restricted or sensitive region? Military authorities may not appreciate the use of large-scale aerial photographs or GPS in border areas.

Apart from the above practical limitations, this work appears to be widely applicable.

Addressing the Aims

In Section 1.2, six main aims were listed for this study. These are examined below to see whether they have been addressed successfully.

- Increase the participation of FUG members - the forest resource assessment framework allows FUG members to be decision-makers regarding what information is collected and how the inventory is performed, although the overall structure is already in place. Additionally, they play the principal role in the inventory process, and hopefully have a greater feeling of ownership of the information as a result. Although FUG members do not operate the GPS themselves, they get an understanding of why the information is being collected and how it will be analysed.

- Improve the accuracy of information obtained - participatory photo maps are far more accurate than traditional participatory sketch maps and provide an ideal basis for resource assessment. If orthophotographs or digital orthoimagery were available (corrected aerial photographs), participatory photo maps would be even more accurate spatially. Using GPS in differential mode is probably the most accurate means currently available in the HKH region for mapping community forest boundaries, although there are limitations on steep terrain ($> 45^0$) or in dense vegetation.

- Explore the potential for integrating qualitative and quantitative techniques - it appears that the use of aerial photographs to obtain information through participatory sessions has great potential and is regarded as a key area to be developed. Aerial photographs can be used themselves in an integrated manner to produce qualitative information from RRA methods and as a source of quantitative spatial information.

  The forest resource framework presented in the methodology section appears to integrate these techniques in a beneficial way. Background information is obtained from participatory sessions, and more detailed spatial information gathering, analysis, and organizing are performed using quantitative tools and techniques

- Simplify the approach - it is felt that some approaches to simple forest inventories that have been advocated are complex and could be very daunting to forest rangers. The approach described here simplifies the work by only using one approach to forest and shrub assessment, always keeping the plot the same size, simplifying plot location, and performing the analysis for the ranger. If the bare minimum of geomatics is used - aerial photographs, the approach is very simplistic, and using the photographs reduces the complexity and time involved in boundary mapping or surveying.

- Provide a mechanism for disseminating the 'inventory' information to maximise its use - for national-level dissemination this involves using GIS technology. This appears to have good potential. Feeding information back to the FUG is of fundamental importance, the ethos of the participatory inventory is forming an agreement with the FUG that involves the return of information to them. The high visual impact of GIS imagery appears to be of benefit in this respect.

Overall, this approach to participatory forest resource assessment appears to be very effective for allowing improved community forestry management, both as a training exercise and as a means of obtaining information about the forest resource.

2.7 CONCLUSIONS

The work described in this paper and illustrated by the case studies indicates that there is a great potential for combining geomatics and participatory techniques for community forestry management. This area has seen a rise in interest over the last few years, as the need for resource management information has become apparent. Certainly, in Nepal, more practitioners are starting to look at appropriate means of obtaining forest resource information to facilitate implementation of better and more demanding forest management. Geomatics is one area that can provide some of this information, and its use ties in with cost effective, rapid, and participatory means of assessing forests.

A number of different approaches has been discussed in this paper. If readers are still unconvinced by the value of 'hi-tech' GPS/GIS approaches, it is still recommended that they explore the role of aerial photos as a participatory tool and as a cost-effective, fairly simple means of obtaining information on the extent and distribution of a community forest resource. The spatial information obtained is accurate enough for basic forest resource assessment, and aerial photographs are an excellent participatory tool.

GPS is a worthwhile and appropriate tool for obtaining information and for research purposes. It can also be used as a participatory tool if FUG members accompany the survey team, and it is treated as a group walk. If accurate maps are required, GPS is cost-effective and rapid.

The use of GIS for information management and dissemination for the purposes discussed here appears promising. This is a good way of organizing both quantitative and qualitative information about individual forest compartments, and there is great potential for using GIS to display local-level information in a district, national or regional database. This is a GIS facility that has been largely overlooked.

Limitations

Practical limitations are discussed in Section 2.6. A limitation that has not been addressed is the inability to use the more technical geomatics' tools in a truly participatory manner. Although the framework of forest resource assessment integrates these areas, the use of GPS and GIS is still the domain of trained professionals. This is likely to remain the case. However, FUG members can be given a basic understanding of how the technology works, what it can do, and what information will be provided to them. If they are made aware of its potentials, they can ask for specific information about their resource, which effectively empowers them.

Access to Information Technology is still a problem once you move away from the cities and large towns of the HKH region. This means that this type of work has to be centralized, removing the information from the area it was collected into a centralized location before returning it. This slows down the process, and it means the FUG members (or forest rangers) do not take part in the information analysis.

The case studies described in this paper are taken from a pilot study, using four FUGs in the Yarsha *Khola* watershed, and one outside for comparative purposes. This work should be evaluated in a larger study. Although the approaches have been successful in this study, and have been easily replicated in the limited comparative studies conducted, much of the work presented in the case studies is not statistically supportable at present.

Further Work

The use of geomatics for community forestry in Nepal is in the early stages. The methods and techniques described in this paper are not meant to be taken as definitive ways of carrying out this work but as an important step in developing an understanding of how these techniques can best be used. Further work is required if this understanding is to deepen. The key areas that have been identified as needing further work are as follow.

- The evaluation of spatial error in uncorrected aerial photographs
- The replication of this, or similar, work in other watersheds. Although this has been partly performed, a full comparative study is required
- Researchers trying and testing the techniques presented in this paper, and developing and modifying them
- Using the Internet for information dissemination, and as a potential means of directly linking FUG members and their ideas with policy-makers

It is hoped that this paper will encourage other researchers, practitioners, and community members to explore the great potential of using geomatics' technology in a participatory context.

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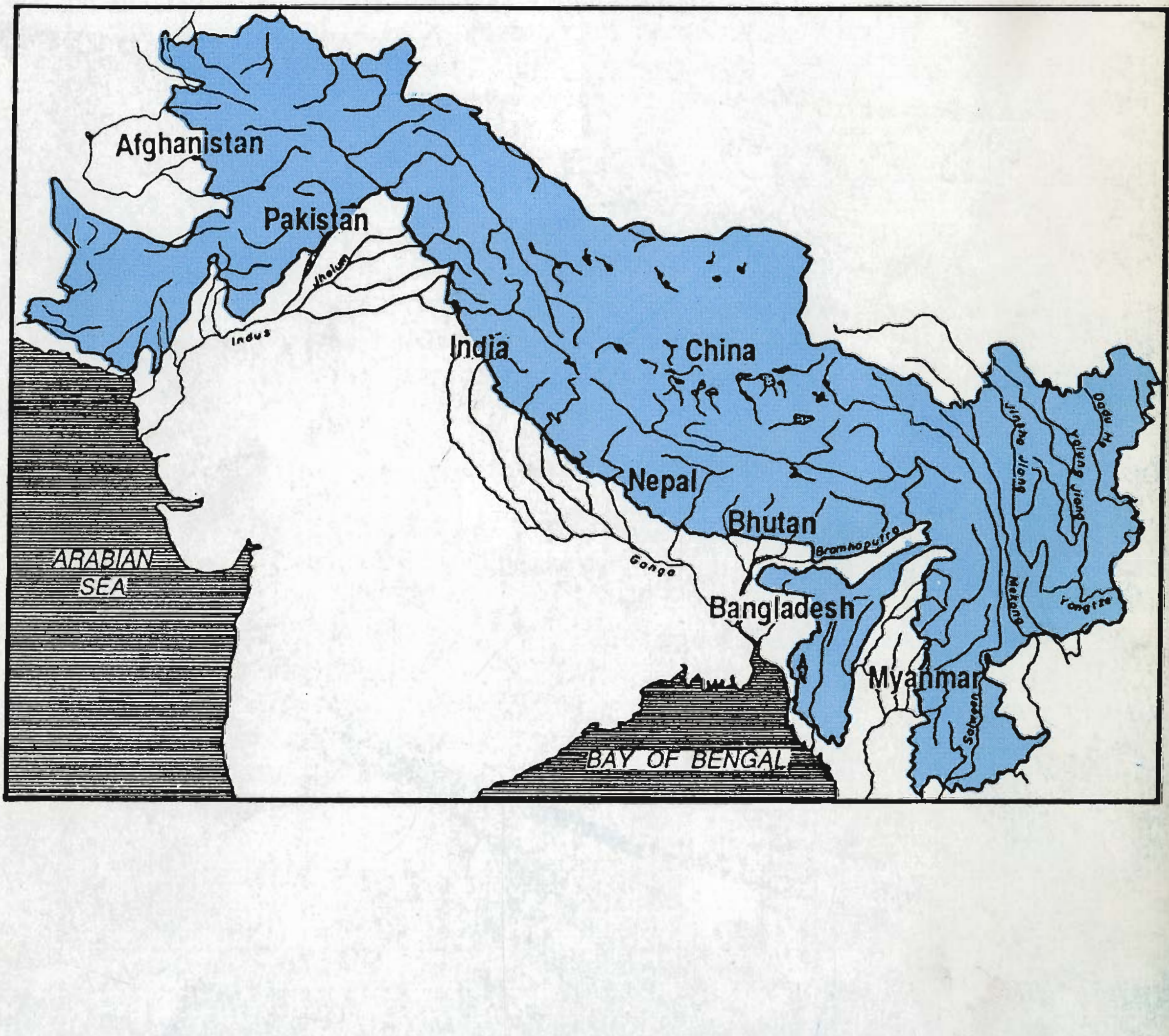
Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bhutan
- India
- Nepal
- Bangladesh
- China
- Myanmar
- Pakistan



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