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.

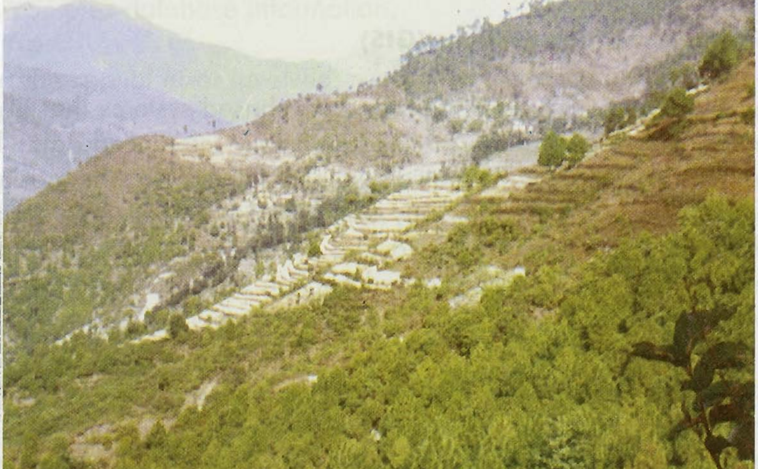


Photo 2: Bob Edmonds Using GPS to Map *Chulletto Panchi* Boundari

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 27° 33′ to 27° 40′ latitude and 86° 05′ to 86° 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).

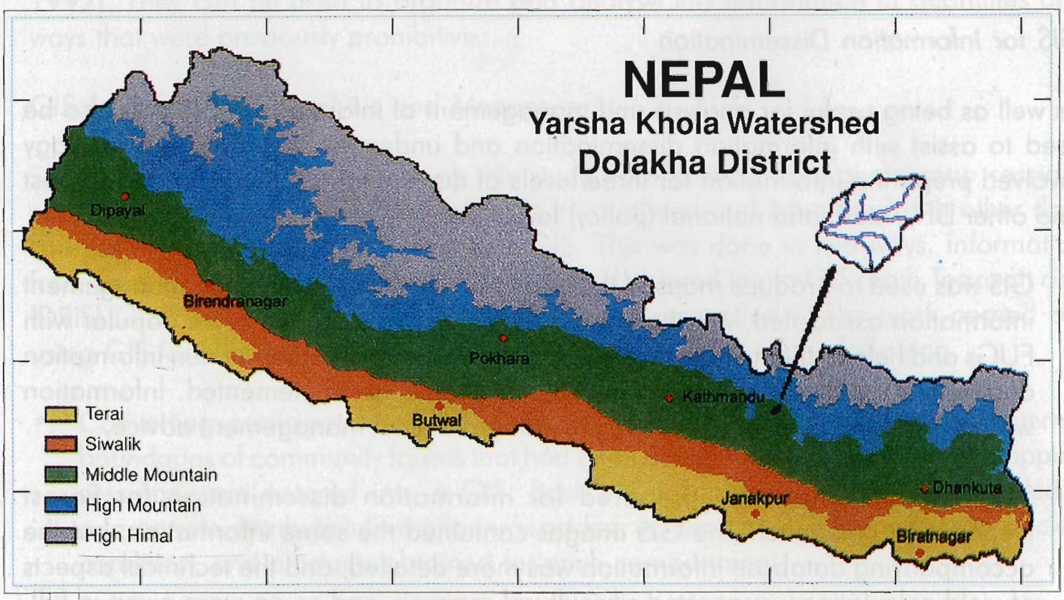


Plate 1: Location of Yarsha *Khola* Watershed

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).

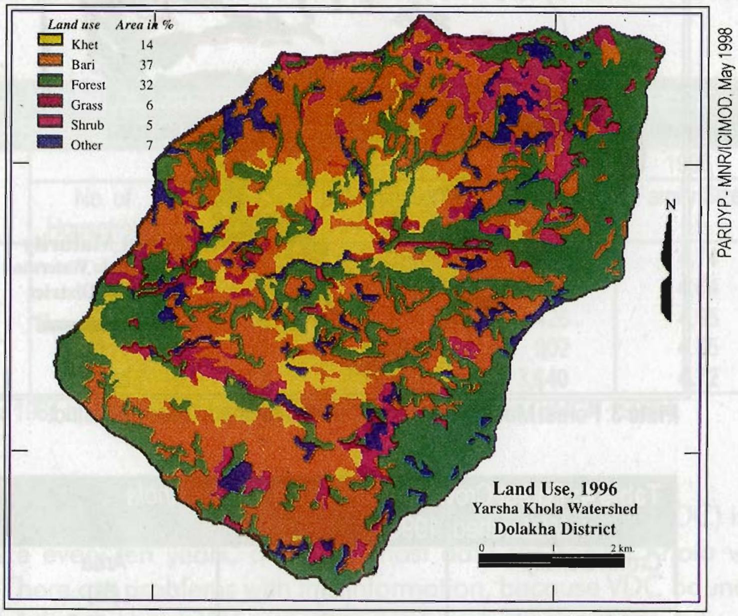


Plate 2: Land Use, 1996 - Yarsha *Khola* Watershed, Dolakha District

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.

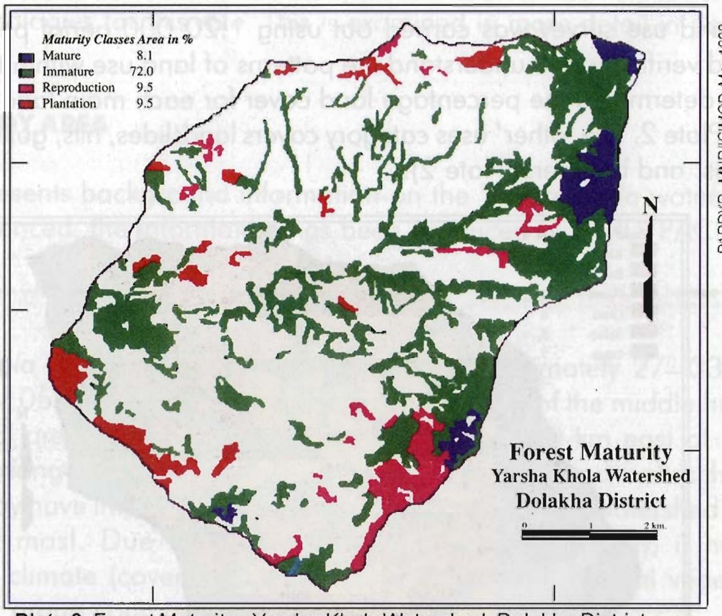


Plate 3: Forest Maturity - Yarsha *Khola* Watershed, Dolakha District

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.

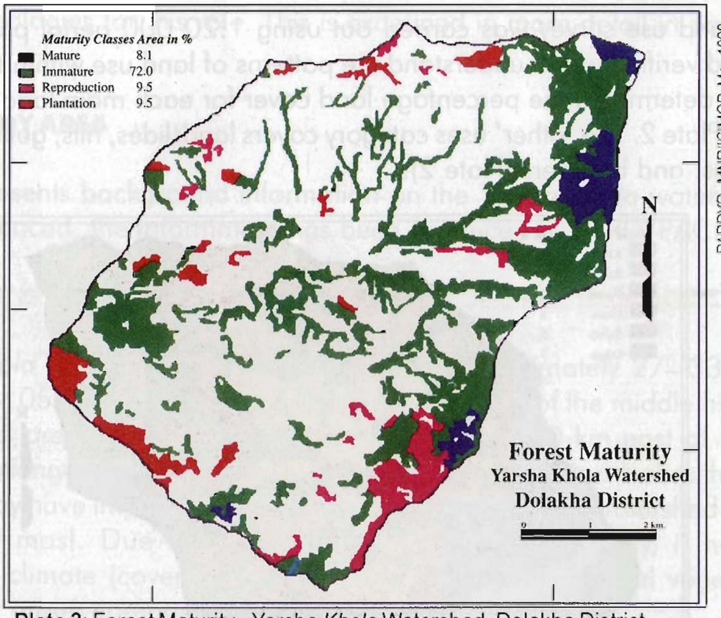
Table 5: Total Number of Households and Population of Yarsha *Khola* Watershed from 1961 to 1996 Based on VDC Census Data

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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