9 REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS FOR COMMUNITY-BASED FORESTS – Resources Mapping in the Jhikhu Khola Watershed

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Abstract

There is a growing need for large-scale maps and data in developing countries for the quantification, management, and planning of forest resources at community level to address emerging needs and the demands of a rapidly growing population.

This paper demonstrates how remote sensing, global positioning systems (GPS), and digital elevation models (DEMs) can be used to produce large-scale geometrically correct orthophotos. Furthermore it describes the potential for the application of advanced geographical information systems (GIS) technology in participatory community-based forest resource inventories in the middle mountains of Nepal .

Geometrically corrected orthophotos were used to conduct a detailed community forestry inventory in a middle mountain watershed in order to provide better management and planning of the forest resources by the local communities. An intensive field survey was conducted in 36 community forests in the watershed, with the participation of forest user groups.

Introduction

A key problem in developing countries is the absence of large-scale accurate maps and datasets. Large-scale spatial information is very important for proper planning and development at different administrative levels, for example, communities, watershed, district and regional levels. Due to poor data availability, many plans and development programmes are designed without this basic information and thus the ability to document and plan at a large-scale spatial level. This is particularly problematic at community and watershed level. For example, His Majesty's Government of Nepal has handed over the forests to forest user groups (FUGs), but has not set any clear boundaries. Hence many cases of conflict over the community forest boundaries occurred between the different FUGs and surrounding land users.

The People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas project (PARDYP) in Nepal has paid particular attention to large-scale information use. The production of orthophotos to document, map, and quantify natural

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resources is an illustrative example. This large-scale information helps towards understanding processes, trends, and interactions of present as well as future benchmark studies.

An orthographic photograph image, also called an orthophoto, is a geo-referenced image produced out of normal remote sensing images or normal aerial photographs. It has the geometric properties of a map but at the same time the quality of photographs, representing detailed and accurate terrain features at a specific moment in time. Normal aerial photographs or remote sensing images are distorted. This distortion is caused by a combination of camera angles and undulating topographic landscapes. The amount of distortion depends on the distance to the image centre and the morphology of the landscape.

The digital orthophoto is created by scanning an aerial photograph with a precision image scanner. The scanned image file is digitally rectified to an orthographic projection using image-processing software. This process requires ground control points (GCP), parameters on the camera position, and an accurate digital elevation model (DEM).

Orthophotos contribute significantly to the production of accurate maps and the images generated can be used to create comprehensive spatial databases in many different thematic areas. Using the orthophoto a community-based natural resource survey was conducted in the Jhikhu Khola watershed, Nepal. The orthophoto was used to delineate village development committee (VDC) boundaries, to map the forest resources, to locate existing services, and to record soil data.

The objectives of this study were
- to produce orthophoto images for the entire 111 km^2 Jhikhu Khola watershed;
- to delineate community forest boundaries and quantify forest types on a detailed level;
- to link the derived forestry information to a geographic information system (GIS) in order to address queries and perform scenario analysis.

Study Area

The Jhikhu Khola study area was selected within the Kabhrepalanchok District. The watershed is located in the middle mountains about 45 km east of Kathmandu along the Arniko Highway and covers a total area of 11,141 ha. The altitude of the watershed ranges from 800 to 2100m above sea level. Due to its wide variation in topography, the climate, composition of natural vegetation, land use, and ethnic groups are very diversified. Land cover comprises 55% agriculture, 30% forest, 6% grass, 7% shrub, and 6% others (Shrestha 1998).

Methodology

The quality of the final orthophoto depends on several major factors such as the accuracy of the DEM, the clarity of the aerial photos, the scanning resolution and quality, the GCP accuracy, the camera model, and the mosaicing. Therefore, it is important to be precise with all of these factors. Scanner distortions should be taken into account when using the orthophoto for more accurate mapping purposes. However, if digital aerial photos are available, scanners are not required. When mosaicing photos together it is sometimes difficult to entirely remove the tonal differences. This is more apparent when using photos taken in different weather conditions or at different times of day.

GCP

The processing of the orthophoto with complete coverage of the Jhikhu Khola watershed started with the identification of a minimum of six GCP on each of the 23 aerial photographs acquired in December 1996. These points were visited with a global positioning system (GPS) receiver and their locations were determined. The GPS locations were re-projected to the national map coordinate system, which rendered the locations of the control in the appropriate coordinate system with a relative accuracy of about 2m.

Scanning aerial photos

The aerial photographs (scale of 1:20,000) from 1996 were scanned on a normal desktop scanner with a resolution of 600 dpi (dots per inch). This corresponds with a ground resolution of about 0.85m at nominal scale. It is important that the fiducial marks of all four corners appear clearly in each scanned image.

DEM

A 25m interval contour map produced at 1:20,000 and a topographical map of the Jhikhu Khola watershed were used as the source for the DEM. The triangulated irregular network (TIN) module of ArcInfo GIS software was used to interpolate the digitised contour lines into a continuous raster surface.

Orthophoto generation

The imagery was ortho-rectified using the DEM, the GCP, and the scanned imagery with state-of-the art image processing software. The absolute accuracy of the final products was about 10m in the lower parts and 20m in the steep upper parts of the watershed. The main source of error was inaccuracies in the DEM, which was produced from a 1:20,000 contour map based on limited ground control. Finally, the images were assembled into a seamless orthophoto mosaic of 1m resolution. This resulting image can be used as background in any GIS application. The orthophoto image has the obvious advantage that any section of it can be printed on a normal black-and-white printer and taken to the field to map the forests and discuss management issues with the FUGs.

Field survey

An intensive field survey was conducted in 36 community forests in the watershed, with the participation of FUGs. The community forest boundaries were drawn on transparent overlays on top of the enlarged 1:5,000 scale aerial photographs. Water-based coloured pens were used and this enabled the rubbing out of boundaries during the FUG discussion and re-drawing once consensus was reached (see Figure 9.1).

PARDYP Nepal

Figure 9.1: **Community members drawing boundaries on the aerial photographs**

Once the teams had identified the community forest boundaries, additional surveys were conducted on forest species composition, forest crown cover, forest maturity classes, and forest types.

GIS

All collected field information, which was based on the rectified orthophoto, was digitised and geo-referenced in a GIS for detailed analysis and for addressing queries. Thematic maps on forest species composition, forest types, forest crown cover, and maturity types including the forest boundaries of each community forest were prepared, to be used for better management of the existing forests.

Results and Accuracy

Forest covers about 30% (3358 ha) of land in the Jhikhu Khola watershed (Shrestha and Brown 1995). There are 36 formal user groups identified in the watershed, with a total forest area of about 1,500 ha, nearly half of the watershed forest area (Figure 9.2). The total area of community forest coverage involves 20,000 people of approximately 5,200 households. The individual community forest areas range from 2 to 173 ha. The number of participants in community forest management has been increasing and people are highly motivated to become more involved in the protection, management, and utilisation of community forests.

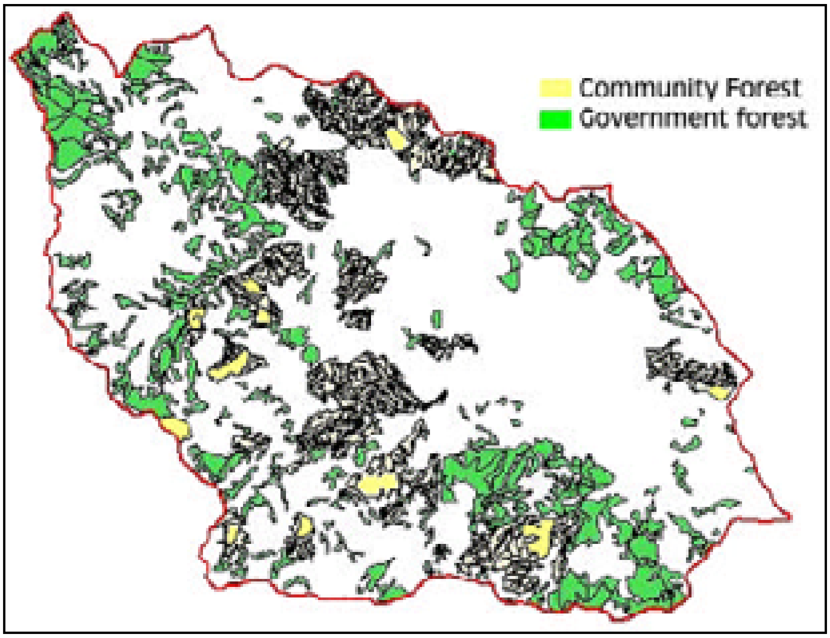

Figure 9.2: **Areas of government and community forests**

The accuracy of the orthophoto product was checked within the Dhaireni community forest using three commonly used land survey methodologies: chain survey, plane table survey, and GPS/GIS/Orthophoto. The district forest office of Dhulikel performed a chain survey of the community forest boundary and the plane table survey was based on a detailed topographical survey at 1:50,000. Using the GPS methodology, the total area of the Dhareni forest was found to be 17.6 ha, the plane table approach resulted in a total area of 17.1 ha, and the chain survey resulted in an area of 9.8 ha. This shows that the GPS and tacheometry methodology have quite similar results, whilst the chain survey showed an unacceptable deviation.

In a different study the conclusion was drawn that chain survey methods have an accuracy of ± 43%, whereas the orthophoto along with GPS/GIS/Orthophoto have ± 3% differences with the plane table survey.

The chain survey method has been widely used in boundary delineation in the Forest Department. It is a method of surveying in which only linear measurements are made on the ground. It is only suitable for small areas of open ground with simple details. The chain survey method may prove tedious when applied to the survey of a dense forest, pond, or other areas (Clark 1967), whereas the plane table survey is a method for surveying peculiar features with a high accuracy at a detailed level in any kind of survey. Differential correction and projection to the national map coordinate system provided a relatively high accuracy of about 2m, but due to the unavailability of large-scale digital terrain models, it was not possible to produce the desired accuracies. The main source of error was inaccuracies in the DEM topographical map, which was produced at a scale of 1:20,000 with limited ground control. The absolute accuracy of the orthophoto is about 10m in the lower parts and 20m in the steep upper parts of the watershed (Bitter and Shrestha 2000). Although there are some limitations, it has a consistent error throughout the whole study area and all research was conducted in the same way, which increased accuracy substantially.

Community Forest Mapping

Increasingly there has been a need for obtaining more quantitative information for forest management purposes. PARDYP, in collaboration with the Department of Forest, the District Forest Office, Dhulikhel, Kabhrepalanchok district, and the FUGs conducted a detailed community forest inventory, using GPS, GIS along with aerial photography, and orthophotos. The purpose was to identify and quantify the forest resources, spatial forest resource status, forest crown coverage, maturity classes, dominant species composition, and major forest types along with the socioeconomic characteristics of FUGs for the entire watershed. Participatory techniques have been the primary tool for obtaining community forest and resources information.

The aerial photographs (scale 1:5,000) were successfully transferred into rectified orthophoto images for GIS analysis following discussion with users and rectification of the images (Figure 9.3).

People's perceptions on community forestry were linked to orthophoto images along with GIS in order to examine perception of the boundaries and the socioeconomic characteristics of the watershed. A socioeconomic survey was conducted together with

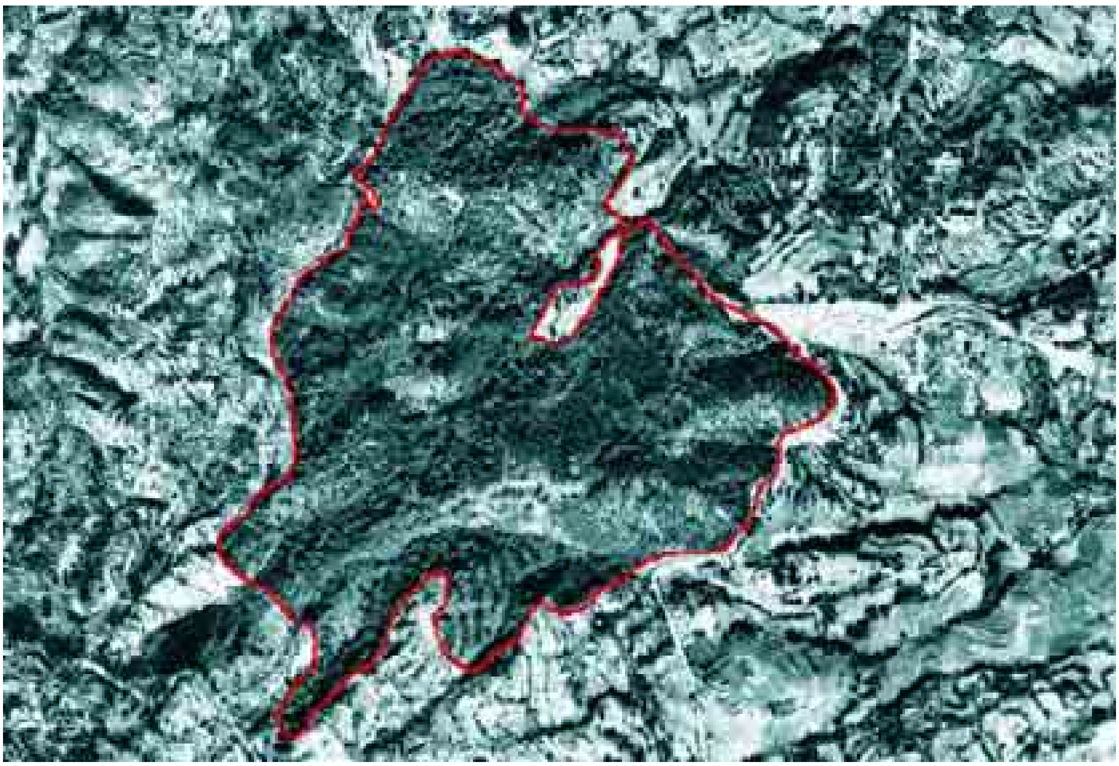

Figure 9.3: **Orthophoto image of Jhikhu Khola watershed (scale 1:12,500).**
Thuliban community forest in ward numbers 3, 4 and 7 of Panchkhal VDC covers a total area of 61 ha and serves five major villages totalling about 422 households with a total population of 2,448. The average population density of the community forest is 40 people/ha^2. Brahmin and Chhetri are the dominant ethnic groups, comprising about 80% of the population Community forest boundaries were delineated with the active participation of FUGs and field verification.

a detailed forestry inventory to gain understanding of the social characteristics of community forests. With the participation of FUGs, 36 community forest socioeconomic surveys were conducted in 8 VDCs, within the Jhikhu Khola watershed.

Conclusions

Because of their favourable potential and characteristics, orthophotos can be applied in a wide variety of thematic areas. In other words, orthophotos provide valuable high-resolution information for resource planners, researchers, and local communities and can therefore play a more important role in land surveys than conventional maps.

Orthophoto images are very versatile and were used for all kinds of community-based natural resources surveys, including demarcation of VDC boundaries, location of existing service centres, soil surveys, spring surveys, socioeconomic surveys, and dug well surveys. The method was found very useful for identifying the true geographical location during the socioeconomic survey, and the use of GIS helped in understanding of people's spatial perceptions and problems.

GIS is a useful tool for enabling the participation and empowerment of FUGs by providing them with improved information for informed decision-making. The use of GIS enhanced the participatory process in this work. It allowed quantitative and qualitative information to be combined to provide resource management information that was both relevant to the communities' needs and detailed enough to determine sustainable forest management.

Specifically, the information collected provides a framework for the FUGs to come up with operational plans and to select silvicultural practices that best suit the management units. The FUGs can identify areas for plantation activities, select appropriate species according to soil types, and estimate the quantity of timber, fuelwood, grasses, and shrubs that can be harvested on an annual basis. Boundary conflicts between FUGs can be solved easily using the information collected.

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