GEOMATICS IN PARTICIPATORY COMMUNITY -BASED FOREST RESOURCES INVENTORY IN THE MIDDLE MOUNTAINS OF NEPAL

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ABSTRACT:

An Orthophoto is a geo-referenced image produced from normal remote sensing images. It has geometric features of a map and in the mean time qualities of photographs representing all terrain features. Due to its unlimited capability it can be use in the management, planning and development of any specific micro level program by illiterate or literate people, planners to decision makers, development agencies to researchers, natural resource scientists to social scientists. In order words Orthophotos provide invaluable and unlimited high resolutions information to all kinds of peoples for management, plans and program of communities, watersheds, district and regional level.

Recent developments in digital photogrammetric techniques can be used to develop precisely Orthorectified air photos quickly, cheaply and easily. Available contour maps were used to develop a DEM for the study area using the Triangulated Irregular Network module. Vertical air photos at a nominal scale of 1:20,000 were scanned using a flatbed scanner at a resolution of 600 dpi. For these air photos Ground Control Points (GCP) were collected using a GPS receiver.

There is a growing need of large scales maps and data for the quantification, management and planning and sustainable development of natural resources and socio-economic characteristics forest resources at the community level to address the emergent needs and demand of rapid population

The geometrically correct Orthophoto image applied to assess the detailed community forestry inventory in the middle mountain watershed of Nepal for the better management and plan of the forest resources by the local communties. An intensive field survey was conducted to 36 communities forest in the watershed with the participation of Forest User Groups.

This paper demonstrates how Remote sensing, GPS, Digital Elevation Model (DEM) can be used to produce Orthophoto images and describe their accuracy and wide application for documentation, integration and assessment of participatory community-based forest resources inventory in the middle mountains of Nepal using GIS.

INTRODUCTION:

Large scales spatial information is very important for the sustainable proper planning and development at all levels from communities to watersheds and districts to regional. But due its unavailability most of the development plans, projects and planning are running without having these information. PARDYP Nepal has given much more emphasis of these kinds of large scale information producing Orthophotos to document and quantification of natural resources and socioeconomic characteristics for synthesizing the vast amount of datasets to understand, the process and trends and its interaction of present as well as future bench mark studies.

An Orthophoto is a geo-referenced image produced from normal remote sensing images. It has geometric features of a map and in the mean time qualities of photographs representing true detail terrain features of specific time periods. It produced from normal aerial photographs or other remotely-sense images. Orthographic photograph image is also called Orthophotos.

Normal aerial photographs or remotely-sense images are distorted as a result of the combination of camera and undulating topographic landscape. The amount of distortion depends on the distance from the image center and the difference in elevation. The digital Orthophoto is created by scanning an aerial photographs with a precision image scanner. The scanned image file is digitally rectified to an Orthographic projection by processing each image pixel. This process requires ground control points, camera orientation parameters, digital elevation model, aerial photographs and scanning.

Orthophoto has unlimited capability it can be use in the management, planning and development of any specific micro level program by the illiterate to literate people, planners to decision makers, development agencies to researchers, natural resource scientists to social scientist. In order words it provides invaluable and unlimited high resolutions information to all kinds of peoples in documentation, management, plans and program of communities, watersheds, district and regional level.

The objectives of this study is to:

1. produced Orthophoto images for entire Jhikhu Khola watershed
2. delineation of community forest boundaries and quantify detailed forest types
3. geo-referenced to forestry information into Orthophotos and link to GIS for its multiple query and scenarios on community forestry in the Jhikhu Khola watershed.
4. conduct the socioeconomic characteristics of community forest user groups

GEOMATIC AS A METHODOLOGY:

MAPPING PROBLEM:

One of the key problems in developing countries is availability of larges scale accurate maps and datasets, which is especially very critical in community and watershed levels. Many plans, development programs and activities are running without having these basic information and not able to document in the large scale or in the community level.

Government of Nepal has handed forest to FUGs and does not have any clear exact boundaries and whatever the existing have always mislead among the user groups due to lack of planimetric details. Hence many cases there has been conflicts between community forest boundaries among the FUG's.

The introduction of Orthophoto minimized greatly to solve existing mapping problem, which will able to apply on detailed community-based natural resource management at community to watershed levels. The images generated were applied in comprehensive spatial as well as socioeconomic database on many different topics on community-based natural resource survey was conducted in the Jhikhu Khola watershed, where many different scientist used the information to delineated VDC boundaries, detailed community forest mapping, located existing service, soil survey, spring survey, socioeconomic survey, dug well survey and etc.

METHODOLOGY:

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

Ground Control Points (GCP)

A complete Orthophoto coverage of the Jhikhu Khola watershed started with the identification of minimum of six ground control points on each of the 23 aerial photographs flown in December 1996. These points were then visited with a Global Positioning System (GPS) receiver and their locations were measured. Differential correction and projection to the national map coordinate system rendered the locations of the control points in map Northing and Easting with a relative accuracy of about 2 meters.

Scanning air photos

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

Digital Elevation Model (DEM)

25 meters interval contour map produced at 1:20,000 topographical map of Jhikhu Khola watershed were used as source for the DEM. The Triangulated Irregular Network (TIN) module of Arc Info GIS software was used for the development of the DEM.

Orthophoto Generation

After importing the digital images into the ERDAS remote sensing software, the ground control points have been identified and the individual images have been Ortho-rectified. The absolute accuracy of the final products is about 10 meters in the lower parts, 20 meters in the steep upper parts of the watershed. The main source of errors are inaccuracies in the Digital Elevation Model which was produced from a 1:20,000 contour map based on limited ground control.

Finally, the images have been assembled into a seamless Ortho-photo-mosaic of 1meter resolution. This dataset can be used as background in any GIS application for deskwork. More importantly, any sections 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 Forest User Groups.

Field survey

An intensive field survey also was conducted to 36 communities forest in the watershed with the participation of Forest User Groups. The community forest boundaries were drawn on acetate overlays to the enlarged 1:5000 scale aerial photographs. Water-based coloured acetate pens were used, and this enabled to rub out boundaries during the FUG discussion and re-draw them once consensus was reached.

Once the teams get the clear community forest boundaries then additional survey on were conducted on forest species composition, forest crown cover, forest maturity classes and forest types.

GIS

All field information collected were carefully transferred into rectified Orthophoto images of each community forest along with its forest boundaries, details forest units and types, which were latter geo-referenced to GIS for detailed analysis and queries. Thematic maps on forest species composition, forest types, forest crown cover, maturity types along with forest boundaries of each community forest were prepared to use for better management and plan of existing forest.

ACCURACY:

Forest covers about thirty percent (3358 ha.) of land in the Jhikhu Khola Watershed (Shrestha & Brown 1995). Thirty six formal user groups were identified in the watershed covering about 1500 ha., which is 49 percent of the total forest area within the watershed, total forest involving of twenty thousand people with an average households of 5201 in the Watershed. Community forest in the watershed ranges from 2 to 173 ha. (table 1). The number of participants in community forest management has been increasing and more and more involved in the protection, management and utilization of community forests.

Table 1: Comparison of areas of Community forest between Orthophoto/ GIS, Chain survey and Plane table by VDCs (ha.)

S.#	Name of Community forest	VDC	GIS Area	Chain Area	Differences GIS/ Chain	Planetable Area
1	Ratmate Thapako Gairo	Phoolbari	1.75	2.62	1.00	
2	Batasedanda	Dhulikhel	2.83	2.40	0.00	
3	Mandalidevi	Dhulikhel	4.64	2.40	2.00	
4	Mudule Thumka	Kabhre	7.74	NA		
5	Thumki	Panchkhal	8.60	NA		
6	Dhanchare	Dhulikhel	9.05	NA		
7	Chayaldevi	Dhulikhel	10.74	16.40	6.00	
8	Bhasemepakha	Baluwa	12.43	9.32	3.00	
9	Shantipur Rohini	Patlekhet	12.93	12.80	0.00	
10	Bhasmepakha	Panchkhal	14.98	13.25	2.00	
11	Dhaireni	Panchkhal	17.62	9.75	8.00	17.14
12	Gaukhureswor	Dhulikhel	18.49	21.50	3.00	
13	Kalidaha	Anaikot	18.65	NA		
14	Jurethumka	Kabhre	19.96	22.25	3.00	
15	Tanke	Anaikot	20.31	21.50	1.00	
16	Pakuchadovan	Dhulikhel	20.53	46.50	26.00	
17	Bhimchula	Kabhre	20.87	NA		
18	Swargehuman danda	Dhulikhel	22.41	NA		
19	Kanthesote	Anaikot	25.37	NA		
20	Makleban	Anaikot	26.52	NA		
21	Thuloban	Patlekhet	28.05	NA		
22	Jaumonbote	Anaikot	28.86	75.75	47.00	
23	Amprungti Bigne	Anaikot	31.21	NA		
24	Chautarapakha	Patlekhet	33.47	27.58	6.00	
25	Kapileswor	Patlekhet	33.91	32.00	2.00	
26	Karkikhop	Anaikot	50.71	41.75	9.00	
27	Bokse	Panchkhal	52.24	43.17	9.00	
28	Thuliban	Panchkhal	61.27	63.30	2.00	
29	Bhainse Khola	Panchkhal	63.54	138.00	74.00	

30	Katuwapakha	Kabhre	64.83	68.60	4.00
31	Karnail ko Ban	Patlekhet	88.00	99.54	12.00
32	Namdi Khola	Sathighar/Kharelthok	90.64	45.25	45.00
33	Laukine Gyangle	Anaikot	111.89	179.00	67.00
34	Ratmate Khawa	Panchkhal	120.01	121.75	2.00
35	Bela Kholepakha	Baluwa/Phoolbari	168.88	141.30	28.00
36	Kazi ko Ban	Panchkhal	172.89	181.75	9.00
		Total	***1496.82***		

The accuracy of Orthophoto product is independently checked with traditional and latest land survey methods using Chain survey, Tacheometry survey and Orthophoto and GIS.

The area calculated using the chain survey for community forest boundaries, surveyed by District Forest Office, Dhulikhel were used to check the accuracy with Tacheomtry and Orthophoto along with GIS.

Secondly detailed survey was conducted using the Tacheometry survey in the same forest called "Dhaireni Samudayik Ban", which was based on base line survey without known geodetic control and ground control points from topographical survey at 1:50,000.

The third survey based on GPS, Orthophoto and GIS. The total area within the Dhaireni Community Forest was recorded 9.8 ha from Chain survey, 17.1 ha in Tacheometry and 17.6 ha from Orthophoto and GIS. It was found that there is big differences in term of total area between Chain and Orthophoto of 7.8 ha, where as very little of 0.5 ha between Tacheometer and Orthophoto.

From case study and its evaluation it was found that Chain survey method have an accuracy of +/- 43%, where as Orthophoto along with GIS has +/- 3% differences with Tacheometry survey.

LIMITATION

Differential correction and projection to the national map coordinate system provide the locations of the control points in a relative accuracy of about 2 meters. But due to unavailable of large scales digital terrain model could not able to produce the desired accuracies. The main sources of errors are inaccuracies in the digital elevation model topographical map produced at 1:20,000 with limited ground control. The absolute accuracy of the Orthophoto is about 10 meters in the lower parts and 20 meters in the steep upper parts of the watershed Bitter, P and Shrestha, B). Although there are some limitation but has consistence error through out the whole study area and in the mean time all research were conducted in the same base, which increased substantially accuracy.

APPLICATION OF GEOMATICS:

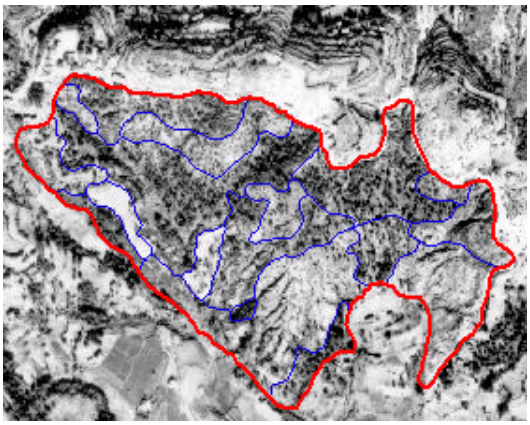
Orthophoto and enlarged aerial photographs has invaluable base information, which were applied in the Jhikhu Khola watershed for detailed documentation of participatory surveys of forests and other resarch and monitoring aspect of the PARDYP project in Nepal. A comprehensive spatial as well as socioeconomic database on many different topics on community-based natural resource survey was conducted in the Jhikhu Khola watershed, where many different scientist used the information to delineated VDC boundaries, detailed community forest mapping, located existing service, soil survey, spring survey, socioeconomic survey, dug well survey and etc. The maps derived from these Orthophotos are planimetrically accurate and results are useful for community level to watersheds planning and management.

STUDY AREA:

The study area is selected within the Kabhrepalanchok district in the Jhikhu Khola Watershed situated between 27^0 33' 45" to 27^0 42' 30" latitude to 85^0 31' 15" to 85^0 42' 30" longitude. The watershed in located in the Middle Mountain covering the total area of 11,141 ha, about 45 km east of Kathmandu along the Araniko Highway. The watershed ranges from 800 to 2100 meters above mean sea level. Due to its wide variation in topography it comprises very distinct climate, natural vegetation, land use and ethnic group compositions covering 55% agriculture, 30% forest, 6% grass, 7% Shrub and 6% others (Shrestha, 1999).

COMMUNITY FOREST:

Detailed community forestry mapping were conducted for the entire watershed in the Jhikhu Khola using GPS, GIS along with aerial photography and Orthophotos. The watershed comprises of 39 forest user groups and survey had been conducted for 36 of these with the participation with local community using the aerial photographs scale 1:5,000, which were latter transferred into rectified Orthophoto images for GIS analysis. An example were given for one of the community forest and similar mapping were conducted for all forest within the Jhikhu Khola watershed. A detailed forestry survey was conducted in terms of forest species composition, maturity class, crown cover and types along with its actual forest boundaries for each community forest were mapped in the whole watershed.

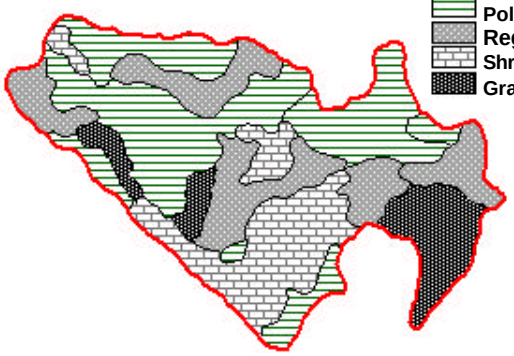


Dhaireni Community Forest
Orthophoto image
Jhikhu Khola Watershed
Scale 1:10,000

Dhaireni community forests covers the total of 18 ha., which is located in the lower elevation near the Tinpipale at about 975 metres from mean sea level.

Community forest boundaries were delineated with the active participation of FUGs and field verification.

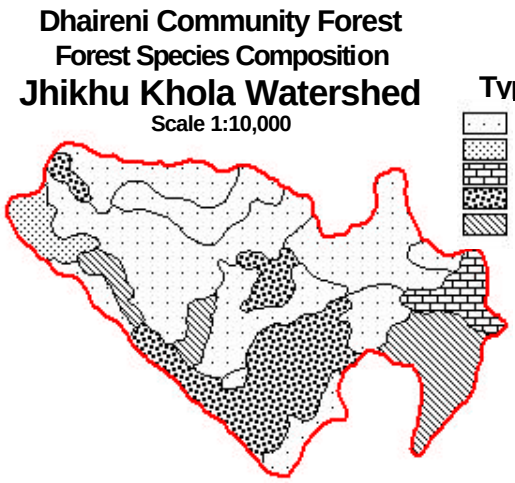
Dhaireni Community Forest
Forest Maturity Classes
Jhikhu Khola Watershed
Scale 1:10,000

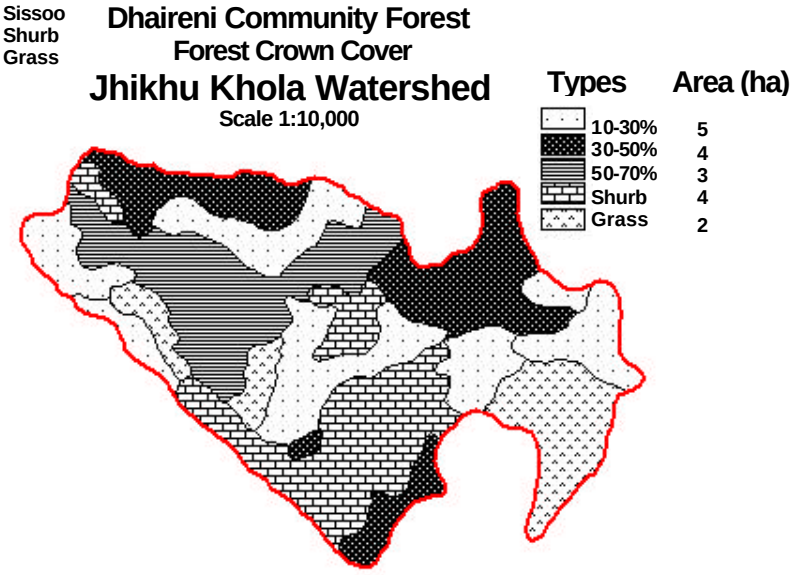


39% (7 ha) of Dhaireni Community Forest areas are under pole size between 13-28 cm diameter breast height (DBH) and 28% (5 ha) under regenerating forest below 13 cm DBH. Most of the northern section of the community forest are under pole size and regenerating forest are distributed evenly, where as shrub land are mostly dominated in southern section comprising the area of 22 % (4 ha).

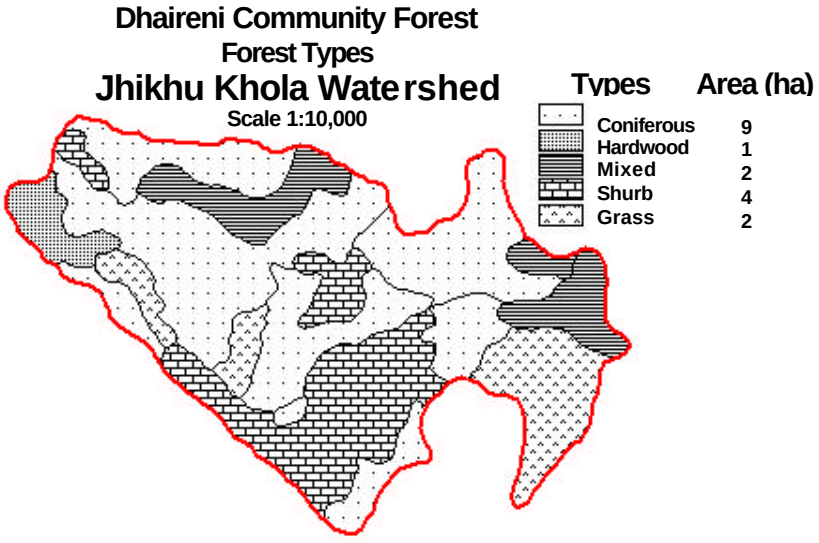
Pinus roxburghii (Pine) is the most dominating species covering more than 50 of its total area (10 ha), where as shrub land covers 22% (4). Pine trees are nainly distributed to the north, where as *Shorea robusta* (Sal) in west and Dalbergia sissoo in the east.

10
1
1
4
2





Only 17% of its total land are under good forest between 50-70 (3 ha), which is located in north west where as large areas under very sparse crown covers.



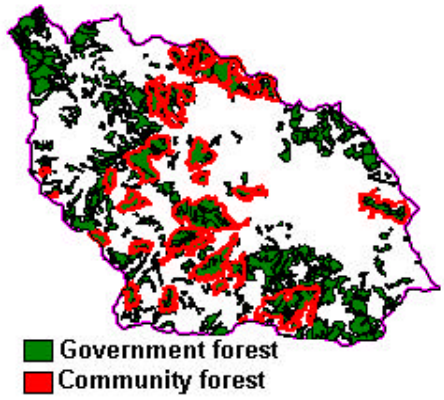
Large section of forest are under the coniferous dominated by coniferous cover 9 ha especially dominated with pines trees. It has very limited hardwood species covering only I ha of land.

SOCIOECONOMIC SETTINGS:

Participatory techniques have been the primary tool for obtaining community forest and resources information.

Increasingly there has been a need for obtaining more quantitative information for forest management purposes. People perceptions on community forestry were linked to Orthophoto images along with GIS to examine the location variation and socioeconomic characteristics in the watershed. A socioeconomic survey was conducted along with a detailed forestry inventory to understand the social characteristics of community forests. Thirty-six community forest socioeconomic survey were also in eight Village Development Committee (VDCs) within the Jhikhu Khola watershed with the participation of forest user groups.

The whole watershed consists of 8002 households in 1996 (Shrestha 1998). Thirty-six forest user groups consist 5201 households, which comprises 65% of the total household of watershed were recorded during the intensive community forest inventory.
Forest in the watershed is under great pressure due to increasing demand of the growing population and limited access to community forest. Forest covers 30% (3319 ha) of the watershed in 1996 (Shrestha, 1998).



PARDYP in collaboration with Department of Forest and District Forest Office, Dhulikhel, Kabhrepalanchok district and the Forest User Groups conducted detailed community forest inventory to identify and quantify the forest resources along with spatial forest resource status, forest crown coverage, maturity classes, dominant species composition and major forest types along socio-economic characteristics of FUGs for the entire watershed. Thirty six formal forest user group's community forest were identified and found that the Department of Forest, Dhulikhel has handover 1497 ha, of land to the forest user groups, which is about 45% of the Jhikhu Khola watershed total forest involving of twenty thousand people with an average households of 5201 in the Watershed. Community forest in the watershed ranges from smallest of 2 ha to largest of 173. The number of participants in community forest management has been increasing and more and more involved in the protection, management and utilization of community forests.

CONCLUSION:

Orthophoto image contain terrain features in fine detail with maps information. It has geometric features of a map and in the mean time qualities of photographs. Due to its unlimited capability it can be use in the management, planning and development of any specific micro level program by the illiterate to literate people, planners to programmers, development program to researchers. In order words orthophotos provide invaluable high resolution information for resource planners, researchers and local communities for regional to community planning and management. Therefore, orthophotos can play a more important role than conventional maps in land surveys.

Orthophoto images are a very versatile and were used for any kind of community based natural resources survey in demarcation of Village Development Committee boundaries, located existing service centers, soil survey, spring survey, socioeconomic survey, dug well survey and etc.

GIS is a useful tool for enabling the participation and empowerment of FUG's through providing them with increased information for 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.

The outcomes of this exercise will be useful for the sustainable development, management, planning and utilization of forest resources. It will generate scientific information for the better understanding of social and natural resources to provide a basis for adopting sound

development strategies for the policy makers, District Forest Office, FUGs and guidelines for the other watersheds and districts of Nepal.

Specifically, the information collected provides a framework to the forest user groups to come up with operational plans and to select silvi-cultural 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.

Orthophoto and GIS is a worthwhile and appropriate tool for obtaining information for research purposes as well as to disseminate research results to the community. This is a good way of organizing and accessing both quantitative as well as qualitative information.

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