Population Dynamics and Land Use in the Yarsha Khola Watershed

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Abstract

The increasing population is putting pressure on local natural resources leading to rapid changes in land use that seriously affect the long term sustainability of the food, feed, and fuelwood production systems. Aerial photographs were used together with intensive field verification and GIS overlay techniques to quantify the population and land use dynamics in the Yarsha Khola watershed between 1961 and 1996.

The population in the Yarsha Khola watershed more than doubled between 1961 and 1996. This represents an average annual growth rate of 2.6 per cent, higher than the national average. The changes in land use as derived from the GIS analysis showed that the forest area increased between 1981 and 1996 at the expense of rain fed agricultural land and shrub land. The forests were dominated by mixed broadleaf forest (43%), followed by pine (31%), and *Alnus Nepalensis* (22%). However, the forest quality was relatively poor with 70 per cent of all forest having less than 30 per cent crown cover; and 72 per cent of the forest being immature.

Introduction

The Yarsha Khola Watershed covers an area of 5338 ha and is situated between 27° 33' 45" and 27° 40' 00" N, and 86° 05' 00" and 86° 11' 15" E in the middle mountains of Nepal. It is located about 190 km east of Kathmandu along the Lamo Sangu Jiri road (Figure 12).

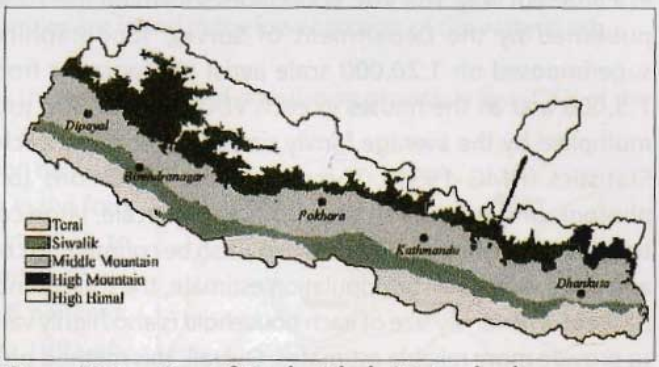

Figure 12: **Locaiton of Yarsha Khola Watershed**

The elevation ranges from 930 to 3030 masl. As a result of the large topographic variability, the watershed contains many areas with distinct micro-climatic conditions that influence the land use systems and composition of the resident ethnic groups. Land use is dominated by agriculture with two annual crops in those areas where irrigation water is available, one to two annual crops in rainfed areas, and three crops grown over a two-year period at higher elevations.

The Lamo Sangu Jiri road, which connects Kathmandu to Jiri, runs through the northern part of the watershed, making it easily accessible.

Objectives

The increasing population is putting pressure on the local natural resources, and this is leading to rapid changes in land use that seriously affect the long term sustainability of the food, feed, and fuelwood production systems. The aim of this study was first to document processes and trends in the Yarsha Khola Watershed (YKW) from 1961 to 1996 through a study of past and present population dynamics, land use changes, and population-land use interactions; and second to analyse the forest situation using a geographic information system (GIS) as an integrating tool.

Methodology

Population

Population information is available once every ten years for each village development committee (VDC) area. The population information for 1971, 1981, and 1991 published by the Central Bureau of Statistics (HMG 1991) was used to show the past trends of population dynamics in the watershed. There are some problems with this information, however, because: a) the VDC boundaries change frequently; b) the data is not clearly geo-referenced; and c) the VDC boundaries do not coincide with the sub-catchment and watershed boundaries.

As no census data were available for 1996, the population data for 1996 were estimated in a different way. The VDC boundaries shown on the 1:25,000 scale topographical maps published by the Department of Survey, Topographical Survey Branch, 1996 were superimposed on 1:20,000 scale aerial photographs from 1996 enlarged to a scale of 1:5,000 and all the houses in each VDC counted. The total number of houses was then multiplied by the average family size determined for each VDC by the Central Bureau of Statistics (HMG 1991). There are some limitations to counting houses from aerial photographs. Because of the photographic scale, large cowsheds, schools, health posts, temples, post offices, and offices may also be counted. To compensate for such errors and to arrive at a more realistic population estimate, the total number of houses was reduced by 10 per cent. The family size of each household is also highly variable so average data were used to provide more reliable estimates. Overall, this method proved to be the most reliable way of collecting population data for 1996.

Land use

Land use data for 1996 were determined from 1:25,000 scale aerial photographs and field surveys. Detailed qualitative and quantitative information about the land surface in

terms of land use, landforms, topography, soils, and the drainage network was obtained using three-dimensional stereo images. General land use categories such as irrigated land, rainfed terraces, forestry, grassland, shrubland, and others were delineated on each photograph and additional details were collected during intensive fieldwork.

Land use information for 1961 and 1981 was obtained from the 1961 Survey of India data and from the topographic and land use maps produced by the Land Resource Mapping Project (LRMP 1981). The 1961 Survey of India only defined two classes of land use—agriculture and forest—whereas the 1981 LRMP survey used more detailed land use classes. As a result of the different land use classifications and scales used by the three sources, the land use in 1961, 1981, and 1996 could not be compared directly—but an attempt was made to record the general trends.

Geographic Information System Analysis

All the land use information was digitised into the GIS database and each temporal set of land use information recorded. The total areas and units under the various types of land use were determined from the digital database, and the land use changes over time examined quantitatively using GIS overlay techniques.

Population Dynamics in the YKW between 1971and 1996

There are four VDCs in the Yarsha Khola watershed. More than half of the total area of Namdu VDC is situated outside the watershed, but the majority of Kabre (and all of its population), and almost all of Gairimudi and Mrige, lie within the watershed (Figure 13). The three dominant ethnic communities in Yarsha Khola are Tamang (27%), Brahmin (25%), and Chetri (25%). In general, the higher parts of the watershed are dominated by Sherpas and Tamangs, whereas other communities are found in the lower section of the watershed.

Figure 13 and Table 16 show the population and population growth in the VDCs of the watershed in 1971, 1981, 1991, and 1996, and Table 17 shows the population densities in 1996. The overall population in the four VDCs increased from 10,885 in 1971 to 20,620 in 1996. This is equivalent to an average annual growth rate of 2.6 per cent, which is slightly higher than the 1991 annual national average of 2.1 per cent. The population increased mainly on the south facing slopes in Namdu and Kabre VDCs. There was a lower increase or reduction in the population of the north facing slopes in Mrige and Gairimudi VDCs.

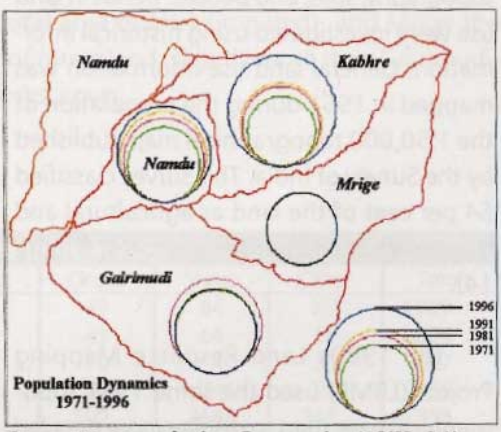

Figure 13: **Population Dynamics (1971-96)**

Table 16: **Total Population of Yarsha Khola by VDC, 1971 to 1996**					
VDC	1971	1981	1991	1996	Population Growth Rate 1971-1996 (%)
Gairimudi	4,423	5,584	4,299	4,375	-0.04
Mrige*	-	-	3,216	3,276	0.2 (1991-6)
Namdu	3,431	4,259	4,938	5,357	1.8
Kabre	3,031	3,894	4,235	7,612	3.8
Watershed Total	10,885	13,737	16,688	20,620	2.6
District Total	130,022	150,576	173,236	NA	

Note: The values shown are for the whole of each VDC.
* Mrige VDC did not exist in 1971 and 1981.
Sources: 1971, 1981, and 1991 data from Central Bureau Statistics, HMG, Nepal; 1996 data are estimates from enlarged 1:5,000 aerial photographs

Table 17: **Population Density in 1996 (persons per square kilometre)**			
VDC	Total Population	Total Area (ha)	Population Density
Gairimudi	4375	1989	220
Mrige	3276	1324	247
Namdu	1981	667	297
Kabre	7612	1358	560
Watershed Total	17244	5338	331

Note: Except for Namdu, values are for the whole of each VDC. Values for Namdu relate to the part of the VDC within the watershed.

The construction of the Lamo Sangu Jiri Road has had a significant impact on the watershed. The road, which was constructed in the 1980s, passes through the Namdu and Kabre VDCs. The expansion of population in Namdu and Kabre most likely resulted from the road construction, which provided access to markets in Jiri, Naya Pool, Maina Pokhari, and Charikot. There was a significant movement of people from Gairimudi to the other areas following the construction of the road. The largest expansion of population occurred in Kabre VDC, with a 3.8 per cent growth rate between 1971 and 1996.

Land Use

Land use is determined by the climate, topography, soils, and people. Trends in land use were investigated using historical information. General land use information was mapped in 1961 during the preparation of the 1:50,000 topographical map published by the Survey of India. This survey classified 64 per cent of the land as agricultural and the remaining 36 per cent as forest (Figure 14).

The 1980s Land Resource Mapping Project (LRMP) used the same 1961 topographical base map to display more detailed

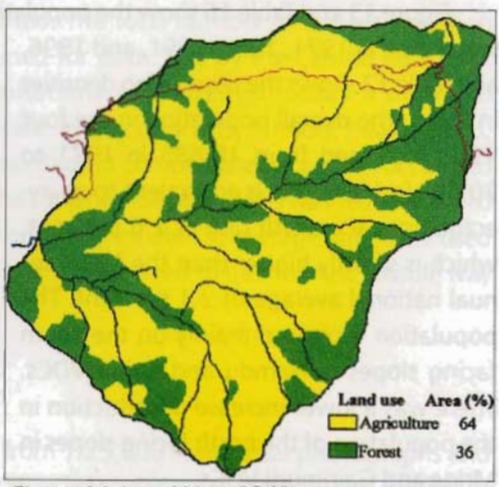

Figure 14: **Land Use, 1961**

land use data derived from 1:50,000 scale aerial photographs flown in 1979-80. The results are shown in Figure 15. Although the 1961 and 1981 maps were prepared at the same scale, it is difficult to compare the data sets because of the different classifications used. The total amount of *khet* (irrigated agricultural land) and *bari* (rain fed agricultural land) shown in the 1981 map is 65 per cent, suggesting that there was effectively no overall change in land use between 1961 and 1981, and that the category 'forest' used in the 1961 map included the categories 'grass', 'shrub', and 'other land' shown in the 1981 map.

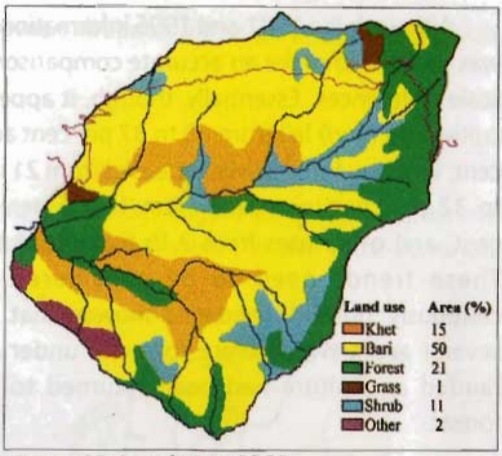

Figure 15: **Land Use, 1981**

A detailed land use survey was conducted by PARDYP using the 1:20,000 aerial photographs from1996. Intensive field verification was carried out to understand the patterns of land use within the watershed. The data were analysed by GIS techniques. The final map is shown in Figure 16. Thirty-two per cent of the watershed was under forest cover, 37 per cent under rainfed cultivation (*bari*), 14 per cent irrigated agricultural land (*khet*), 6 per cent grassland, 5 per cent shrubland and the remaining 7 per cent 'other land cover' (landslides, rills, gullies, settlements, rocks and boulders). Table 18 shows the land use distribution by VDC as generated by the GIS. Gairimudi had the largest total area of khet (irrigated), and Mrige the smallest. Mrige had the largest total amount of forest land, slightly more than Gairimudi, Kabre much less, and Namdu relatively little forest cover.

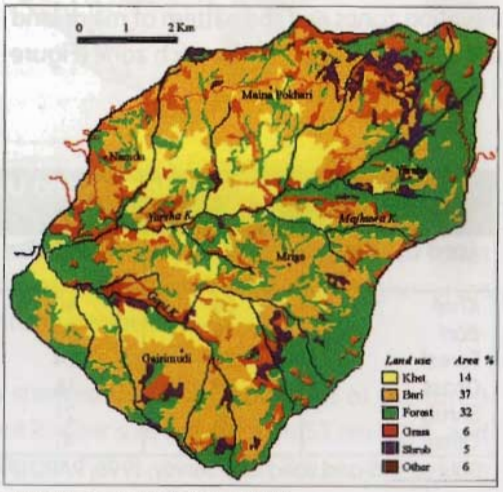

Figure 16: **Land Use, 1996**

Table 18: **Land Use Distribution by VDC, 1996 (area in ha)**

VDC	*Khet*	*Bari*	Forest	Grass	Shrub	Other	Total
Gairimudi	290	768	651	79	84	117	1,989
Mrige	66	417	677	42	66	56	1,324
Namdu	171	240	127	70	4	55	667
Kabre	217	573	226	111	114	117	1,358
Watershed Total	744	1,998	1681	302	268	345	5,338

Although the 1981 and 1996 information sets used the same classification categories, it was difficult to make an accurate comparison of land use at these dates as a result of the scale differences. Essentially, though, it appeared that the amount of land under rainfed cultivation (*bari*) fell from 50 to 37 per cent and the amount of shrubland from 11to 5 per cent; whereas forest cover increased from 21 to 32 per cent, grassland from 1 to 6 per cent, and other uses from 2 to 6 per cent. These trends need to be considered cautiously, but field evidence showed that several areas which were formerly under rainfed agriculture had been returned to forests.

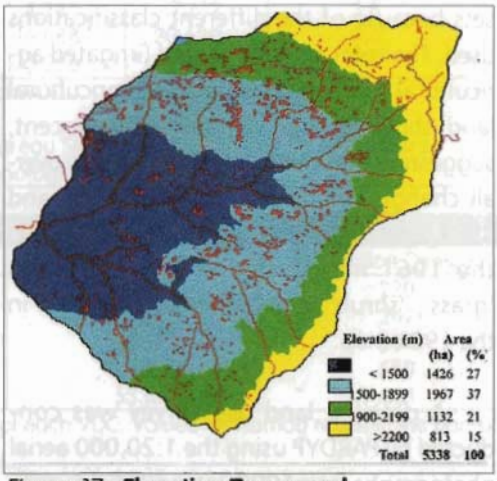

Figure 17: **Elevation Zones and Distribution of Houses**

Land Use by Elevation Zone

The watershed was divided into four elevation zones and the pattern of major land use classes determined for each zone (Figure 17 and Table 19).

Table 19: **Percentage of Different Land Use Classes within the Different Elevation Zones**

Land Use Class	<1500m	1500-1899m	1900-2199m	>2200m	Watershed Total
Khet	59	40	1	0	14
Bari	19	50	26	5	37
Forest	23	24	22	31	32
Grass	48	18	12	22	6
Shrub	8	21	43	28	5
Other	20	41	23	16	6

Source: GIS and Land Use Survey, 1996, PARDYP-MNR/ICIMOD

The largest section of the watershed (37%) lies between 1,500 and 1,900m. Most of the settlements are located in this zone, which also shows the greatest ethnic diversity, very few people live above 2,200m.

The majority of irrigated (*khet*) land (59%) was located at elevations below 1,500m, whereas half of the rainfed agricultural land (*bari*) (50% or about 1,000 ha) lay between 1,500 and1,899m (Figure 16 and 18).

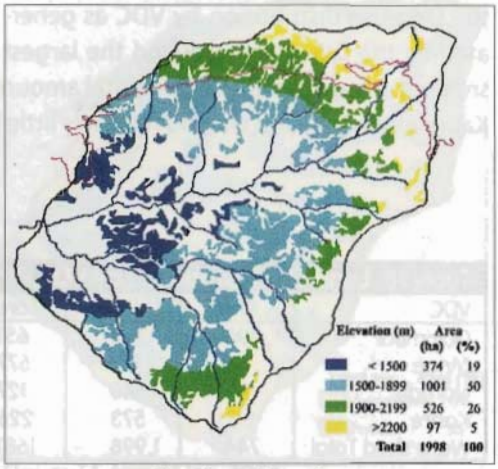

Figure 18: ***Bari* by Elevation Classes**

Forest was almost equally distributed between all zones, although the largest portion was found above 2200m (31%) (Figure 19).

Forest Types and Distribution

The forest was classified in terms of dominant species (Figure 20). *Alnus nepalensis* (31% of the forest area) and pine (23% of the forest area) were the two most common dominant tree species in the watershed.

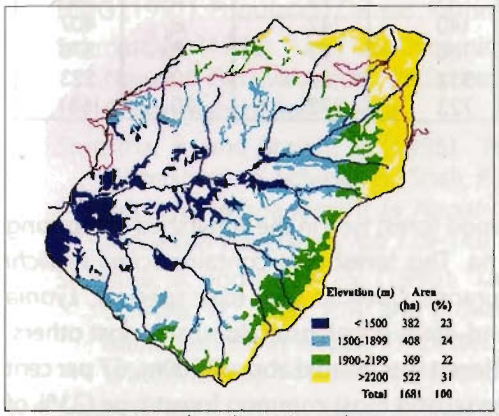

Figure 19: **Forest by Elevation Classes, 1996**

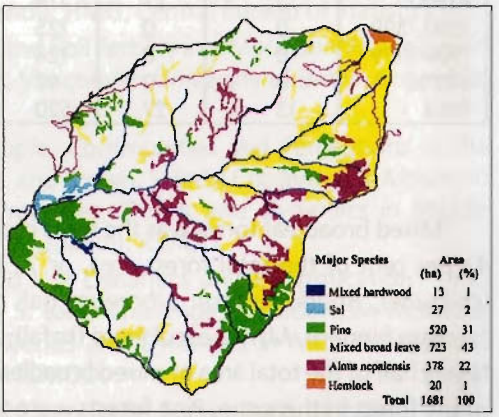

Figure 20: **Major Forest Species, 1996**

The forest was also classified in terms of forest type (Figure 21). Hardwood forest was the most widely distributed and comprised 42 per cent of the total forest area. Mixed forest comprised 24 per cent of the forest cover and was mostly distributed in the higher areas (>2200m) in the north-east and south-east of the watershed.

Classification according to maturity class showed that only 8 per cent of the forest within the watershed was mature to over-mature (timber size greater than 53 cm DBH), and 72 per cent was immature (28-53 cm DBH) (Figure 22). Furthermore, 70 per cent of the forest had a crown cover of less than 30 per cent.

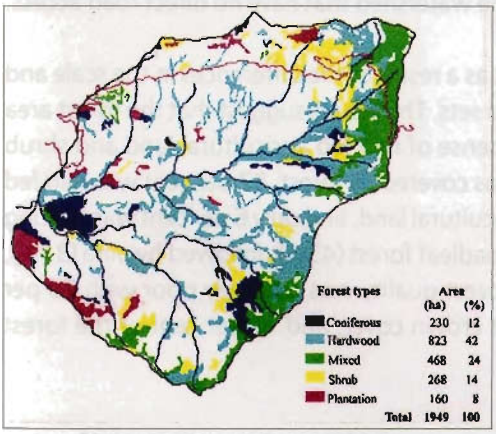

Figure 21: **Major Forest Cover, 1996**

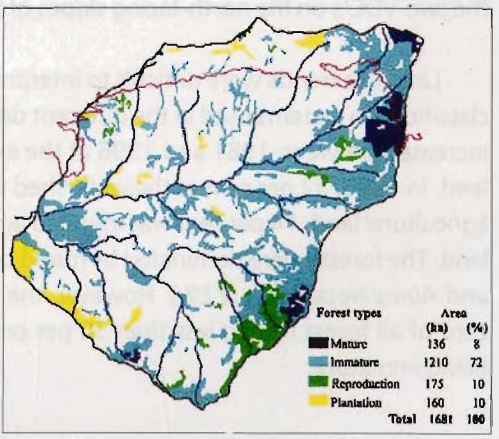

Figure 22: **Forest Maturity Classes, 1996**

Forest Species Distribution by Elevation Zone

The major forest species were overlaid on the elevation zones, and the distribution in relation to elevation examined. The results are shown in Table 20.

Table 20: **Forest Species Distribution by Elevation Zone (ha)**

Elevation	Mixed Hardwood	Sal	Pine	Mixed Broadleaf	*Alnus Nepalensis*	Hemlock	Total
<1500	13	27	174	71	95	0	381
1500-1899	0	0	125	140	142	0	407
1900-2199	0	0	124	160	87	0	370
>2200	0	0	97	352	54	20	523
Total	13	27	520	723	378	20	1681

Mixed broadleaf forest was the most common forest type in the watershed comprising 43 per cent of the total forest area, or 723 ha. This forest type contains *Scima wallichi* (chilaune), *Rhododendron arboreum* (lali gurans), *Quercus spp.* (oak species), *Lyonia formosa* (angeri), *Myrica esculenta* (kafal), and *Alnus nepalensis* (alder) amongst others. Nearly half of the total area of mixed broadleaf forest was located above 2200m, 67 per cent of the forest in this zone. Pine forests were the second most common forest type (31% of total forest). This was the most common forest type at altitudes below 1,500m. *Alnus nepalensis* was the third most common forest type, 38 per cent of *Alnus* forest was found at elevations between 1,500 and 1,900m.

Conclusion

The population in the Yarsha Khola watershed more than doubled between 1961 and 1996. This represents an average annual growth rate of 2.6 per cent, which is higher than the national average. There were large differences in the distribution of population growth within the watershed. There was a small drop in the population in Gairimudi and possibly in Mrige, the two VDC's on the north-facing slopes of the watershed that have no direct road access.

Land use trends were difficult to interpret as a result of the differences in the scale and classification systems used in the different data sets. The results suggest that the forest area increased between 1981 and 1996 at the expense of rain fed agricultural land and shrub land. In 1996, 32 per cent of the watershed was covered by forest, 37 per cent was rain fed agricultural land, 14 per cent was irrigated agricultural land, and only 6 per cent was grazing land. The forests were dominated by mixed broadleaf forest (43%), followed by pine (31%), and *Alnus Nepalensis* (22%). However, the forest quality was relatively poor with 70 per cent of all forest having less than 30 per cent crown cover; and 72 per cent of the forest being immature.

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