RESEARCH INTO THE LONG TERM IMPACT OF DEVELOPMENT INTERVENTIONS IN THE KOSHI HILLS OF NEPAL

GIS ANALYSIS REPORT

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Acronyms and Abbreviations

ADB	Asian Development Bank	KII	Key Informant Interviews
APP	Agriculture Perspective Plan	KIS	KHARDEP Impact Studies
BNMT	Britain-Nepal Medical Trust	KOSEVEG	Koshi Seed and Vegetable
CBO	Community Based Organisation	LFP	Livelihoods & Forestry Project
CBS	Central Bureau of Statistics	MLD	Ministry of Local Development
CEDA	Centre for Economic Development and Administration	NDHS	Nepal Demographic and Health Survey
CEPREAD	Vegetable Production through Centre for Environment and Agricultural Policy Research Extension and Development (CEPREAD), Seed Sector Support Project (SSSP)	NGIIP	National Geographic Information Infrastructure Programme
CFUG	Community Forest User Groups	NGO	Non-Government Organisation
CPS	Community Support Programme	NLSS	Nepal Living Standard Survey
DANIDA	Danish International Development Agency	NPC	National Planning Commission
DFID	Department for International Development	NSCA	National Sample Census of Agriculture
DHO	District Health Office	NUKCFP	Nepal-UK Community Forestry Project
DHS	Nepal Demographic and Health Survey	PAC	Pakhribas Agriculture Centre
DNPWC	Department of National Park and Wildlife Conservation	PAF	Poverty Alleviation Fund
DoE	Department of Education	PCRW	Production Credit for Rural Women
DoHS	Department of Health Services	PHCC	Primary Health Care Centre
EDG	Effective Development Group	PGRS	Pakhribas Gurkha Reintegration Service
EDR	Eastern Development Region	PRA	Participatory Rural Appraisal
EMIS	Education Management Information System	PSC	Project Steering Committee
FCHV	Female Community Health Volunteer	RAP	Rural Access Programme
FGD	Focus Group Discussions	RCA	Reality Check Approach
FHH	Focal Households	SHP	Sub-Health Post
GIS	Geographic Information Systems	SMIP	Safe Motherhood Innovative Project
GIZ	German International Assistance	SNV	Netherlands Agency for Development
GoN	Government of Nepal	SSSP	Seed Sector Support Project
HHH	Host Households	TBAs	Traditional Birth Attendants
HMGN	His Majesty's Government of Nepal	TMI	The Mountain Institute
HMIS	Health Management Information System	TOR	Terms of Reference
HP	Health Post	UNDP	United Nations Development Programme
ICIMOD	International Centre for Integrated Mountain Development	UNICEF	United Nations International Children's Emergency Fund
IT	Information Technology	UNIFEM	United Nations Development Fund For Women
KHARDEP	Koshi Hill Area Development Project	VDC	Village Development Committee
KHDP	Koshi Hills Development Programme	WB	World Bank
KHST	Koshi Hills Study Team	WUG	Water User Groups

Acknowledgements

This study deals with the use of Geographical Information Systems (GIS) to investigate and chart land use and land use change, as a component of the research project: '*Research into the Long Term Impact of Development Interventions in the Koshi Hills (KH) of Nepal'.* This report focuses on GIS based analysis of spatial patterns in the use of land-based environmental resources and cultural landscapes, with particular reference to the impacts of development interventions over the past 40 years in the Koshi Hills region of Eastern Nepal. GIS technology has long been an important tool for spatial and integrated analysis of environmental resources and when combined with several other non-spatial factors helps in judicial planning of development activities and policy decision making.

The GIS database and mapping work for this research has been carried out by the Central Department of Geography (CDG), Tribhuvan University in Kathmandu, on a service contract basis with the GRM International and the CDG's Ms Puspa Sharma has carried out this work. On behalf of the KH study team, I would like to extend my sincere gratitude to CDG's GIS study coordinator, Ms Puspa Sharma for her untiring efforts to make the GIS work both successful and satisfactory.

The field verification surveys for the GIS work were carried out on two occasions, each for a period of two weeks during April-May and June 2012 in the Koshi Hills by Ms Puspa Sharma and Mr Chhabi L Chidi. During the course of the field surveys, the team conducted consultation meetings with several key personnel from line agencies, different community organizations and local people from the KH districts — Bhojpur, Dhankuta, Sankhuwasabha and Terhathum, on the change in land use and issues and problems related to development impacts. The author extends his gratitude to them for supporting the study by making available valuable data, information, and publications. The GIS study has benefited largely from the LANDSAT imagery data that was provided by MENRIS/ICIMOD under the joint-collaboration programme of the CDG, as well as the precipitation data of 1956-2011 across the Koshi Hills by the CDG. The Team is delighted to recognise their contribution and generosity.

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Executive Summary

Introduction and Objectives

The GIS work for the Koshi Hills, comprising four districts of Bhojpur, Dhankuta, Sankhuwasabha, and Terhathum, has three objectives: to establish a geographical digital data base to map land use; to assist in the selection of village areas for the Reality Check Approach field research in terms of differential changes in land use, and to interpret land use types, changes over time, possible factors behind land use change and their impacts on cultural landscapes, as well as setting up attribute data sets for facility locations, such as road and health.

Data and methods

The GIS mapping work for the Koshi Hills has drawn analogue and digital data from three different sources: LRMP (1986), toposheet (1996), and Landsat imagery (2010). The 1986 map data has been considered as the baseline year for the construction of a spatial database on land use and land use change. As these different sources have different map scales from 50,000 to 25,000 and 15 m resolution, the scale of 25,000 has been set as the baseline scale for this study and in so doing, all map scales have been converted to this scale. Five broad categories of land uses: arable land, forest, scrubland, grassland, and others (water bodies, snow land, bare land, rock and ice, settlement built-ups, and roads) have been determined, based on the land use types of the 1996 toposheets as defined by the Survey Department, the Government of Nepal. All relevant GIS mapping data transformation processes were followed. The map layouts of land use category for the three years: 1986, 1996, and 2010 have been prepared following the standard colours, and other GIS functions such as buffer and overlay were employed wherever feasible and suitable.

The GIS mapping work has been confined to the Koshi Hills only. The map scale available was not large enough for detailed analysis of land use change versus roads, and other facilities. The verification of land use and land use change and associated factors in the field was carried out across the Koshi hills, but this field verification was limited only to the areas accessible by roads. The attribute data available over time from the record or base data at the district level were limited and inconsistent. However it should be considered that this study has begun the process to set up GIS mapping work for the Koshi Hills.

Results and discussions

Based on the available data, the map layouts for land use, roads and trails, healthcentres, and population have been constructed for the entire study period, while those for schools, hāt bazaars, religious monuments, and major public services have been made only for the year 2011 due to lack of data for all four districts in the earlier years. The map layouts have been prepared at two levels: (i) the Koshi Hills region, comprising a total of 21 thematic map layouts and (ii) the individual four districts — each district comprising 16 map layouts, thus a total of 64 map layouts. By adding these two levels, altogether 85 map layouts are being produced. Each map has been given a map index number and letters to distinguish the Koshi Hills from the districts, as well as the districts from each other.

After creating land use maps for each district, the land use change by four major categories: arable land, forest, grassland, and scrubland have been built, as well as one single map showing the combined land use change map for all four categories, to determine the changes in these categories. These were used to assist in the selection of villages for RCA field research.

The analysis of the results on land use indicates dynamic change in land use by spatial location and over time in the Koshi Hills. Significant changes have occurred in overall land use:

For instance, forested land has increased by 18.4% over the past 24 years, while there was a decline in population at an average of 38% in the Koshi Hills from 1991-2011. The inter-culture growth of amreso and cardamom in the shrub lands and private forests shows an increase in practice by farmers in areas linked by roads. Use of land for agricultural purposes increased by 10% from 1986-1996, but decreased from 1996 onwards. Traditional subsistence cereals crops have been replaced in places with commercial vegetables particularly seen in substantial increases in their cultivated areas along the sides of roads.

On the other hand, increasing areas of abandoned agricultural land across the Koshi Hills have been observed. From 1986-2010, there has been a decrease in scrubland and grassland by a substantial amount at 81 and 39% respectively, while forest land has increasingly taken over scrubland, grassland and arable land. Overall a significant fluidity of land use has been demonstrated across the Koshi Hills.

The patterns of change in arable land and forest coverage have shown consistency over time among the individual districts. For instance, arable land in Terhathum has continually declined, while forest has consistently increased. In 1996, arable land coverage was highest and forest coverage was lowest in Dhankuta and Sankhuwasabha but the reverse was the case in both districts at the previous recorded time (1986) and the subsequent recorded time (2010) respectively. Furthermore, arable land, scrubland, and other land uses have decreased, while forest and grassland have increased but at differential ratios in all four districts from 1996 to 2010.

Of several factors, government initiatives focussing on the adoption of policies and programmes appear to have been closely correlated to land use change. In the Koshi Hills there were two specific activities to maintain and conserve forest coverage. First, the Makalu-Barun National Park and its buffer zone, set up in 1992, which is being managed by forest user groups. Second, the Community Forestry Programme, which was initiated in the late 1980s, would seem to have contributed to the increase in forest coverage after 1996. The Community forestry activities seem to have had a beneficial effect on the balance of land use as part of a broader process of agrarian change, as well as contributing in part to a significant improvement in availability of fodder, fuel wood, and fruit tree resources. Scrublands and grasslands are being converted into more productive categories of forest land, reflecting the care of communities in managing and conserving their own forest resources. An increase in the arable land during 1986-1996 could be attributed to the building of Dharan-Dhankuta road in 1985 and the introduction of improved agriculture development programmes through CEPREAD and KOSEVEG that initiated the growth of off-season vegetables, seeds, cardamom, ginger, fruits and livestock rearing in the early 1980s. Recent evidence suggests that reliance on subsistence farming is declining as opportunities increase for off-farm income.

The distribution of population appears to be closely associated available arable land in the Koshi Hills. Over 90% of population clusters are concentrated in two elevation zones: 1000-2000m and over 1000m, where over 90% of the total arable land is also found. Moreover, there was no significant change in the distribution of population clusters by elevation zones between 1991 and 2001. Two reasons to explain it areas follows: (i) limited population increase at 8.8% between 1991 and 2001 across the entire Koshi region and (ii) an internal movement of people within the same zone, among areas that have facilities such as roads and other basic services - schools, health centres, and markets. Overall, no significant change has taken place to the long standing,

traditional pattern of scattered settlements over the hills that suffer from poor access to these facilities.

Large proportions of the population are found within the 3 km buffer zone health facility locations in the years of 1996 and 2010, which are either due to movement of people closer to facility locations or improvements in the numbers of health facilities, or both. This is very significant, since roads connect only a few places across the region. With regards to road accessibility, the largest proportions of the population still lives within 'above 5 km' buffer zone, indicating that significant travelling time is required to reach the road-head point, though there was a decline in the proportion of the population living in this buffer zone in 2010 compared to 1986.

The spatial digital database being established provides an illumination of the spatial development conditions for the three map point-years: 1986, 1996 and 2010. It has been possible to exhibit and analyse the spatial relationships within the GIS framework between land use change and development interventions such as roads and other facilities. GIS mapping can provide a useful tool to investigate further spatial changes in land use, social and economic impacts on land use, facility accessibility, flows of goods and people between places over time and so on. As such, the spatial database requires updating on a regular basis in the future to see the impacts of development activities on changing land uses vis-à-vis cultural landscape change.

1. Introduction

Land use is dynamic and frequently changes, often because of human interventions. Current land use patterns are the result of centuries of human activities in specific areas and are strongly influenced by natural conditions. Today's heterogeneous landscapes with their mosaic of arable land, patches of natural vegetation, grassland, agro-biodiversity, built-up areas and others reflect the diverse land use in an area. Studies have shown that external factors such as agricultural policy and forest conservation policy are frequently the driving forces behind changes in the use of land in rural areas (Lourenco et al 1997). Similarly, social, economic, and demographic changes affect land use patterns over time (Axinn and Ghimire 2011).

Land use represents an insightful reflection of human interaction with its environment in an area (Gautam et al 2002; Virgo and Subba 1994; Thapa 1996; Jackson et al 1998). Their study can provide useful insights into changes to local and external pressures of various kinds and how these translate into changes in land use patterns over time. Development interventions in the form of, for example, infrastructure, the introduction of new technologies, or changes to policies are likely to translate into changes in land use and socio-economic development in response to these drivers of change.

Land use studies are generally concerned with the spatial and temporal patterns of land conversion at different geographic scales through human activities and with understanding the causes and consequences of these changes. They also deal with explaining the economic process, vis-à-vis human behaviour that underlie land use change, i.e. causal relationships between individual choices and land use change outcomes (Axinn and Ghimire 2011). As human systems of production change, be they shifting cultivation, subsistence agriculture, or commercial production, patterns of consumption from the land change and these changes alter the use of the land and the nature of the resulting land cover. Provisions of schools, health services, markets, and transportation services may all change social life and patterns of land use. These changes in patterns of consuming land are likely to have important consequences for local land use and land cover.

Land use is a fundamental measure of how the environment is organized in a setting. Changes in land use are reflected in the relative magnitude of the land area devoted to agricultural and non-agricultural activities. Over time, as the population changes, as the economy grows, and as government infrastructure spreads, land use is likely to be transformed in many ways, for instance, in the conversion of agricultural land to land for housing and other non-agricultural enterprises, the reduction of public forest and grazing lands, and the intensification of farm land.

Studies on land use change require maps from different years, complemented by household survey data to comprehensively capture the complex relationships between change in land use due to development interventions and the resulting change in social and economic conditions. But in the case of the Koshi Hill districts – namely Bhojpur, Dhankuta, Sankhuwasabha and Terhathum – there was absence of reliable baseline household data and therefore this study has used GIS mapping to record changes in land use through different years. GIS mapping allows spatial data to be assembled on land use changes over time. It also supports the identification of locations with major changes to land use categories.

1.1 Objectives

The GIS report of the Koshi Hills study has three objectives:

i. To establish a spatial database to map land use change

ii. To assist in the selection of village areas (Village Development Committees, or VDCs) for the field research conducted using the Reality Check Approach (RCA), based on differential changes in land use
iii. To determine land use categories and their interpretation, as well as to identify factors responsible for land use change

1.3 Sources of GIS Datasets

The GIS datasets for this study are drawn from three different map sources:

i. First the analogue data of 1986, known as LRMP– Land Resources Mapping Project (KESL 1986), which is the only available map data for the entire country.[1] This analogue map sheets prepared at the scale of 1: 50,000 contain three datasets, *viz*. land utilization, land capability, and land suitability. Here, land utilization has been used.
ii. The second map source available for the entire country is the Toposheet of 1996 (SD 1996). The 1996 data sets prepared at two scales: 1: 25,000 and 1: 50,000[2] include *nine* layers, *viz.* land use and land cover, administrative boundary (VDC, municipality and district), hydrography, contour, transportation, building foot-prints, utilities/facilities, national parks and protected areas, and place names, which are available in the digital form.
iii. The third source is the Landsat imagery of 2010[3], which was acquired covering the entire Koshi hill districts. Thus, the land use study of the Koshi Hills has been based on these three data point years: 1986, 1996 and 2010. As no analogue data before the year 1986 was available at the district level in Nepal, the 1986 has been considered as the baseline year for spatial database and land use change.

1.3 GIS Mapping Methods

Land use is defined as the of proportion of total land area of the study region shared by the folling activities: *arable land* (land cultivated for cereal crops like rice, wheat, maize, and millet, tea, fruits trees), *forest land* for permanent forests and woodlands, *grazing land* for meadows and pastures, and *other land* for built-up areas, roads, and barren land, which is usually computed into percentage. This definition is designed to broadly include the social and economic purposes and contexts for and within which lands are managed (or left unmanaged). Change in land use type refers to those that occurred in three different year-points, as stated above. The driving forces on

[1]KESL– the Kenting Earth Science Limited– had prepared the LRMP map sheets to support the Survey Department (SD), the only government authorised agency to deal with both analogue and digital data for the country, as well as to make them available for use to the public. The SD has for the first time published analogue map sheets, known as '***1:1 mile colour toposheet***' in 1954, but these map sheets are restricted to public use. This then was followed by two series of analogue map sheets at the national level such as LRMP and toposheets; the latter has also been converted to digital form. In addition, there are several agencies that deal with the GIS based digital data such as the National Planning Commission, Central Department of Geography (CDG)/Tribhuvan University, ICIMOD –International Centre for Integrated Mountain Development, Department of Roads, Department of Forest, Department of Water Supply and Sewerage, Department of National Parks and Wildlife Conservation, Department of Health Services, Higher Secondary Education Board, Janajati Empowerment Project/Nepal Federation of Indigenous Nationalities (NEFIN), and so on. However, the data available from these agencies are project and topic specific, but their source maps are also the LRMP, the toposheets and satellite imageries.

[2]The 1:25,000 scale map sheets are prepared for the districts of Tarai and urbanised Hills, whereas the 1:50,000 scale map sheets for the mountain and rural hill districts. There are altogether 675 toposheets covering entire country and a total of 64 data sheets cover the entire Koshi zone (6 districts).

[3]Previously, it was proposed to use the RapidEye MSS (Multi Spectrum Satellite) imagery (at 5m resolution) of 2010 (March/April) for our purpose. But due to some practical reason, it has to be replaced by Landsat imagery (15m resolution). The imagery data were acquired from the generous support of the joint collaboration between CDG and ICIMOD, Kathmandu, Nepal.

land use include those factors that influence human activity of the Koshi Hills, including local culture, economics, environmental conditions, and land policy and development.

Change in land use is being considered as a proxy indicator for the development impacts and drivers. The GIS approach to change in land use consists of its four broad components: preparation of spatial digital data, processing of data, outputs, and interpretation. Here, map units refer to land mapping units or spatial units (polygon, line, and point) and each map unit refers to an area that possesses a degree of homogeneity in physical characteristics. In regard to the GIS mapping, the following activities were adopted.

2. GIS Mapping Methods

2.1 GIS Mapping Process

The GIS mapping data transformation process for the Koshi Hills[4] included the following steps (Figure 1):

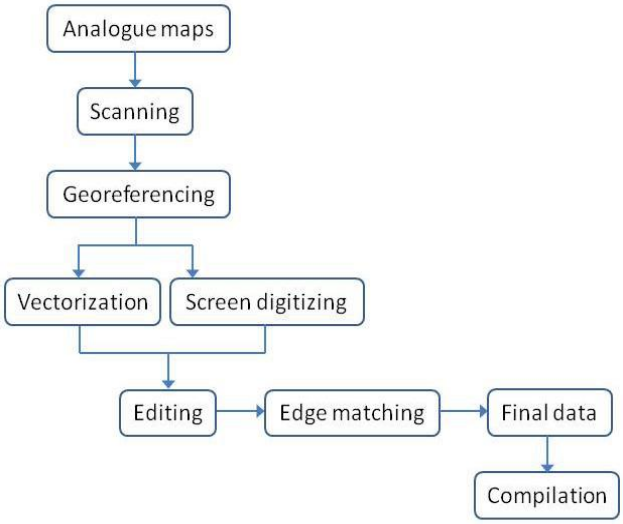


***Figure 1*: GIS digital data processing steps**

- As the LRMP datasets were available only in analogue form, the data sheets were scanned and processed into the compatible data form by adopting all basic steps, viz. geo-referencing, digitizing (missing features), topology building, editing, edge matching, appending, and map layouts at the ArcGIS format.
- The acquired digital datasets based on the 1996 toposheet were in semi-refined form and therefore the features such as river levels, road types, and contours were defined and edited.
- The processing of the ortho-corrected Landsat imagery 2010 followed all the steps from re-projecting to the modified UTM –Universal Transverse Mercator coordinate system (adopted by the Survey Department of Nepal) through re-sampling of ≤0.5 pixel (equivalent to approximately 10-15 m), training sites selection (based on in-situ assessment provided by ground truthing work), multiple signatures creation, identification and classification of land use and land cover (LULC) by maximum likelihood classifier, post reclassification assessment (based on existing land use, digital elevation model and field data), and refinement of classification by filtering. The classification accuracy as explained by the Kappa statistics was at 85.3% (above the minimum level of classification accuracy).
- The base map has been set at the scale of 1:25,000 and all the map data with different scales such as the LRMP data at 1: 50,000 and the Landsat with 15m resolution were adjusted to the scale of 1:25,000. The mappable unit at this base scale is approximately 5 hectare. So the area of mapping units below this threshold polygon could not be detected for computation.

[4]The GIS mapping work included only four districts of the Koshi Hills, due to the cost and volume of data to be processed and analysed within the given time duration. Thus this work excluded two associated regions such as the Koshi Tarai Districts (Morang and Sunsari) and the Neighbouring Districts (Ilam and Khotang).

However, careful calculation of these mapping units was made by using the appropriate GIS function.

- Following the development of draft map outputs, the team conducted a number of field visits in the Koshi Hills[5] to verify and update the land use types. In the field, consultation was first undertaken with different district office personnel of each of the four districts: district development committee, agriculture, health, irrigation, and development projects in order to determine the change of [any] land use types on the current (2010) enlarged land use draft colour maps generated by GIS. Meanwhile, publications such as district profiles and reports of the districts offices wherever available were also acquired. As suggested, the verification included particularly updating the location of additional feeder roads, the growing areas of commercial vegetables, cardamom and *Amriso* (broom grass), health services, abandoned arable land patches, hāt bazaars, and place names. The verification work was assisted by using GPS equipment with 3m resolution, as well as by asking people of the local areas where visited and feasible. The colour toposheets and service centre maps were also carried as reference maps to assist in the verification work. Updates of changed land use features on the land use layouts were made using a computer.

2.2 Attribute Data

- The data on population, production of the major crops, such as vegetables, cardamom, ginger, and non-timber forest products (e.g. herbs), and woods were gathered as attribute data for GIS mapping. They were acquired from the district consultation workshop, profile publications, reports and digital data available from the district headquarters offices, municipalities, and non-government offices of each of the four Koshi Hill districts.
- Integration of the attribute data related to land use, as well as to the district, municipality and Village Development Committee (VDC) has been based on standard coding system of the Central Bureau of Statistics (CBS).

2.3 Methods of GIS Mapping

The methods of GIS mapping for interpretation and analysis being adopted comprise the following. Two levels of maps – namely district and Koshi Hills (KH) – have been prepared, depending on the importance. Further, these GIS mapping exercises are assumed to depict an exemplary work, as well.

2.3.1 Definitions and classifications

First, classification of the land use of the KH into different categories has been made, based on the land use types of the 1996 toposheet, defined by the Survey Department, which was also consistent with the 1986 land use classification. This classification method also provided the basis for the 2010 satellite imagery data. Thus the land use types being considered are arable land, forest, scrub, grassland (grazing land), and others. Arable land refers to the cultivated land including both lowland and sloping terraces. Forest refers to all lands having trees with more than 10% crown cover (DFRS 1999). Scrub refers to bush, or degraded forest or secondary growth forest, where there are scattered trees standing or less than 10% crown cover. Others include water bodies, snow, bare land, rock and ice, settlements, and roads. The map layouts of land use types have been made for the district level, as well as for the KH region (combining all four districts).

[5]The field survey team consisting of a GIS specialist + an assistant visited each of the four district headquarters and the places en routes for three weeks during January–February and June 2012.

The rationale behind considering those broad land use types is that each of them has a significant role in development and natural conservation in Nepal. For instance, forest contributes to rural development by providing forest products such as firewood, fodder, timber and herbs to rural communities, and by regulating atmospheric conditions. Besides, forests are also essential to sustain agriculture and livestock (buffaloes, cows and goats) rearing in the low and mid mountains. Arable land is a fundamental resource to support the livelihoods of the majority of rural people in the area. There is a close link between agriculture and forest resources. The former derives products from the latter such as fodder, leaf-litter, etc to maintain the nutrient levels and soil structure. Grassland has an immense role to contribute not only to raising livestock, such as cows, sheep, and yaks in the high mountains, but also to maintain the watershed.

Secondly, contours have been set at 1000m interval, showing different altitudinal zones at the KH level.

Thirdly, the distribution of population has been depicted by the dot method at the KH level, with one dot representing 50 persons. Location of dots has been carefully placed on the map, with respect to the population and area of VDCs and municipalities, but avoiding water bodies, forest, rocky, sloppy, and snow area.

2.3.2 Buffer function

Based on the available data and considering the practicability for mapping, access to location of two facilities – namely, road (infrastructure) and health (basic service) – has been performed at three categories of buffer distance: (i) <3 km, (ii) 3–5 km, and (iii) >5 km. The reference of 3 km buffer distance[6] has been taken according to the study carried out by Pradhan and Pradhan (1994) in the hills of Nepal.

2.3.3 Overlay function

Like in the buffer function, the GIS overlay function has also been used to determine change and relationships for the selected features provided it was practicable to map, such as land use, population versus altitude and facilities versus distance.

Change in the land use categories has been computed by the overlay function between a pair of two consecutive years, such as: (i) 1986 and 1996 and (ii) 1996 and 2010. Magnitude of change in the land use categories has been determined at four levels (in percentage), such as: (i) ≤25, (ii) 26–50, (iii) 51–75, and (iv) >75, based on the mapable polygon size. This exercise has been performed both at the KH region and the district levels.

Relationship between altitudes and population concentrations has been obtained by defining the altitudes at 1000m contour intervals and the population distribution by representative dots for two years: 1986 and 2010 at the KH region level. Change in the population concentrations by altitude has also been depicted. Populations from the 1981 and 2001 censuses were used accordingly.

Two separate overlay mapping computations in terms of three buffer zones for two year points: 1986 and 2010 were constructed for those two facilities: (i) access of people to roads and (ii) access of people to health service have been performed at the KH region level.

[6]The study on GIS use in Lalitpur district, Nepal (Pradhan and Pradhan 1994) has set 20 minutes for average walking distance per kilometre (3 kms = 1 hour), based on GIS computation of impedance factors such as ups and downs (slope) and curvature and length of trails for access to the locations of given facilities.

3. GIS Map Outputs (Layouts)

The map layouts generated by the GIS tool are at two levels: KH and its district and are depicted in Tables 1a and 1b respectively. All maps (layouts) are given in Annex A and B accordingly. These maps together with the associated tables comprise the 'spatial data sets' of the KH study.

Based on available analogue data, the map layouts for land use, roads and trails, health, and population are made over time and by type wherever applicable, while those for schools, hāt bazaars, religious monuments, and major public services are made only for the year – 2011, since no such data were available for all four districts for the previous year.

The maps on arable land, forest change, grass land change, scrub land change, and combined of all land uses, showing magnitude of changes in percentage at four levels: ≤25, 26-50, 51-75, and >75 between 1986 and 1996 (numbers: 09 – 12) for each of the four districts were made for the purpose of selection of areas for RCA field research (referring to objective # 2). Therefore, the results are not used for interpretation of land use changes, as sought for objective 3.

Table 1a: Map layouts (Code No and titles) at the KH level

MI	Titles	MI	Titles
KH 01	Location of Koshi hills	KH 12	Type of roads and major trails, 2005
KH02	Drainage systems	KH 13	Type of roads and major trails, 2010
KH 03	Relief (contours)	KH 14	Type of roads and major trails, 2011
KH 04	Terrain three dimension view 2010	KH 15	Location of schools by level, 2011
KH 05	Land use 1986	KH 16	Location of health service, 1996
KH 06	Land use 1996	KH 17	Location of health service, 2011
KH 07	Land use 2010	KH 18	Location of hāt bazaars, 2011
KH 08	Patches of commercial agriculture	KH 19	Population distribution, 1991
KH 09	Location of abandoned arable sites	KH 20	Population distribution, 2001
KH 10	Type of roads and major trails, 1986	KH 21	Grid and toposheet index, Koshi hills
KH 11	Type of roads and major trails,, 1996		

Table 1b: Map layouts (Code No and titles) at district level, the Koshi Hills

MI	Titles	MI	Titles
BD 01	VDCs & municipalities location, 2011	DD 01	VDCs & municipalities location, 2011
BD 02	Drainage systems	DD 02	Drainage systems
BD 03	Land use 1986	DD 03	Land use 1986
BD 04	Land use 1996	DD 04	Land use 1996
BD 05	Land use 2010	DD 05	Land use 2010
BD 06	Roads & trails and hāt bazaars, 2011	DD 06	Roads & trails and hāt bazaars, 2011
BD 07	Location of schools by level, 2011	DD 07	Location of schools by level, 2011
BD 08	Location of health service, 1996	DD 08	Location of health service, 1996
BD 09	Location of health service, 2011	DD 09	Location of health service, 2011
BD 10	Religious monuments, 2011	DD 10	Religious monuments, 2011
BD 11	Major public facilities, 2011	DD 11	Major public facilities, 2011
BD 12	Arable land change, 1986-96	DD 12	Arable land change, 1986-96
BD 13	Forest change, 1986-96	DD 13	Forest change, 1986-96
BD 14	Grassland change, 1986-96	DD 14	Grassland change, 1986-96
BD 15	Scrubland change, 1986-96	DD 15	Scrubland change, 1986-96
BD 16	Combine land use change, 1986-96	DD 16	Combine land use change, 1986-96

MI	Titles	MI	Titles
SD 01	VDCs & municipalities location, 2011	TD 01	VDCs & municipalities location, 2011
SD 02	Drainage systems	TD 02	Drainage systems
SD 03	Land use 1986	TD 03	Land use 1986
SD 04	Land use 1996	TD 04	Land use 1996
SD 05	Land use 2010	TD 05	Land use 2010
SD 06	Roads & trails and hāt bazaars, 2011	TD 06	Roads & trails and hāt bazaars, 2011
SD 07	Location of schools by level, 2011	TD 07	Location of schools by level, 2011
SD 08	Location of health service, 1996	TD 08	Location of health service, 1996
SD 09	Location of health service, 2011	TD 09	Location of health service, 2011
SD 10	Religious monuments, 2011	TD 10	Religious monuments, 2011
SD 11	Major public facilities, 2011	TD 11	Major public facilities, 2011
SD 12	Arable land change, 1986-96	TD 12	Arable land change, 1986-96
SD 13	Forest change, 1986-96	TD 13	Forest change, 1986-96
SD 14	Grassland change, 1986-96	TD 14	Grassland change, 1986-96
SD 15	Scrubland change, 1986-96	TD 15	Scrubland change, 1986-96
SD 16	Combine land use change, 1986-96	TD 16	Combine land use change, 1986-96

Notes: *MI = Map Index Number; DB = Bhojpur District, DD = Dhankuta District, SD = Sankhuwasabha District, and TD = Terhathum District.*

4. Analysis of Land Use and Land Use Change and Its Impacts

4.1 Land use and land use change in the Koshi Hills

The Koshi Hills have two predominant land use categories – forest and arable land between 1986 and 2010 (Figure 2). In 1986, they covered 39.5 and 30% respectively of the Koshi Hill area – a total area of 656,115 km². By 1996, forest coverage decreased to 37.5% while arable land increased slightly to 33.5%. By 2010, forest coverage had sharply increased to 46.8% while arable land coverage was reduced to 29.9%. The coverage of scrub remained at around 9% in the years 1986 and 1996 but it declined sharply to 1.8% in 2010. Grassland experienced a decrease from 9% in 1986 to 5.5% in 2010. Others comprising water bodies, snow land, bare land, rock and ice, built-ups, and roads comprised 11.8% in 1986 and rose to around 16% in the following two survey point years. Table 2 depicts the coverage status of the major land use categories both in terms of area and percentage, whereas map index numbers: KH05, KH06 and KH07 are land uses of the Koshi Hills for 1986, 1996, and 2010 respectively (*Annex A*) .

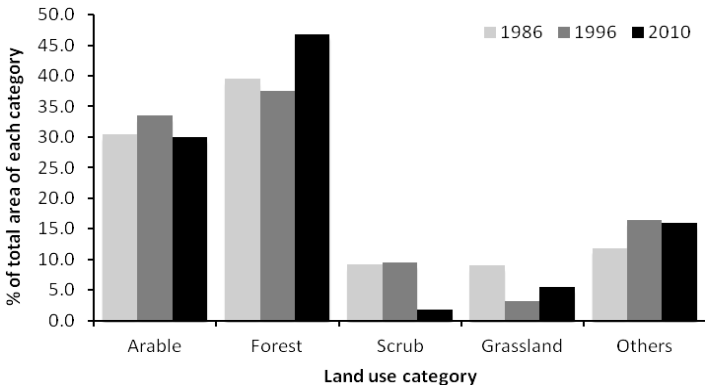


Figure 2: Coverage of land use categories by year,

Changes have occurred in arable land and forest coverage. There was an increase of 10.2% in arable land between 1986 and 1996, while a decrease of 5.2% in forest between the same two years (Table 3). Contrary to these changes, arable land decreased by 10.6% (23,288 ha), while forest saw an increase of 25% (61,236 ha) in 2010 compared to 1996.

Table 2: Coverage status of land use categories by year, Koshi Hills

Land use categories	1986		1996		2010	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Arable	199,404	30.4	219,688	33.5	196,400	29.9
Forest	259,366	39.5	245,918	37.5	307,154	46.8
Scrub	60,541	9.2	61,946	9.4	11,544	1.8
Grassland	59,254	9.0	20,718	3.2	36,216	5.5
Others	77,551	11.8	107,846	16.4	104,802	16.0

Sources: LRMP 1986, Toposheet 1996, and Landsat imagery 2010.

Table 3: Magnitude in change (%) in land use categories by year, Koshi Hills

Land use categories	1986-96		1996-2010		1986-2010	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Arable	20,284	10.2	23,288	-10.6	3,004	-1.5
Forest	13,449	-5.2	61,236	24.9	47,788	18.4
Scrub	1,405	2.3	50,402	-81.4	48,997	-80.9
Grassland	38,536	-65.0	15,498	74.8	23,038	-38.9
Others	30,295	39.1	3,044	2.8	27,251	35.1

Sources: LRMP 1986, Toposheet 1996, and Landsat imagery 2010.

Over the past 24 years, the area of arable land decreased 1.5% while that of forest increased 18.4%. But a remarkable change has occurred in scrubland and grassland over the past years. Table 3 depicts that the grassland declined by an area of 38,536 ha, or by 65% during 1986-96, while the scrubland declined by 81.4% (50,402 ha) during 1996-2010, but that grassland increased by 15,498 ha (75%) during the same years (1996-2010). Thus over the past 24 years (1986-2010), the scrubland and the grassland declined by 81 and 39 % respectively.

4.2 Land Use and Land Use Change in the Districts of the Koshi Hills

Arable land is the largest natural resource of Dhankuta and Terhathum, among the four Koshi Hill districts. Both districts had over 52% arable coverage of their total land area in 1986 (Table 4). Arable land decreased in Dhankuta to 48.4% in 2010, and similarly it has continuously decreased in Terhathum over the past 24 years. Changes have occurred in arable land coverage in Bhojpur and Sankhuwasabha with similar pattern: first increased and then decreased. For instance, in 1996 both districts had shared the largest arable land with 49% and 17% respectively, while this share was smaller in 1986 and further declined in 2010.

Forest remains to be the largest natural resource in terms of coverage in Bhojpur and Sankhuwasabha. There appears to be the same pattern in change of the forest area in both districts: first decreased and then increased (Table 4). In 1996, forest had the lowest coverage at 42.5% and 36.8% in Bhojpur and Sankhuwasabha respectively. By 2010, it rose substantially to around 51% in the latter district and 46% in the former. Terhathum has shown continually increased in the forest coverage in all three survey point years. On the whole, there was increased in the forest coverage in all three districts except in Bhojpur in the past 24 years.

Table 4: Magnitude in change (%) in land use category of each district of the Koshi Hills by year

Land use category	Map year	Relative % of total area of district by land use type				Relative share %
		Bhojpur	Dhankuta	Sankhuwasabha	Terhathum	
Arable	1986	42.7	52.0	14.5	55.7	30.4
	1996	49.0	52.6	17.0	53.0	33.5
	2010	44.5	48.4	15.6	46.3	29.9
Forest	1986	46.0	33.9	39.6	31.8	39.5
	1996	42.5	30.6	36.8	36.2	37.5
	2010	45.8	38.6	50.8	39.5	46.8
Scrub	1986	5.3	7.0	12.4	4.9	9.2
	1996	3.9	4.9	13.9	4.9	9.4
	2010	1.6	2.2	1.5	3.0	1.8
Grassland	1986	4.8	4.4	12.7	5.7	9.0
	1996	2.3	3.0	3.2	4.7	3.2
	2010	6.7	8.7	3.3	10.1	5.5
Others	1986	1.1	2.6	20.8	1.9	11.8
	1996	2.3	2.6	29.1	1.2	16.4
	2010	1.4	2.2	28.8	1.1	16.0
Total area (ha)		**152,325**	**89,854**	**346,896**	**67,040**	**656,115**

Note:

- *The values were derived from land use GIS map as depicted in **Annex B**: map index numbers: 03, 04 and 05 of each district.*
- *The summation of the values of the five land use categories along the column of each district of a single year gives 100 %, e.g. (42.7+46.0+5.3+4.8+1.1 = 100).*

It is interesting to note that the patterns of change in both arable and forest coverage have shown consistency over time. For instance in Terhathum, arable land has continually declined, while forest land has shown a reverse trend, i.e. continually increased. Likewise in Bhojpur, the arable land had the highest coverage in 1996, while the forest coverage had the least in the same year. In the case of Dhankuta and Sankhuwasabha, again the 1996 appears to be critical year – in that year arable land coverage was the highest and then declined in both years – before (1986) and after (2010) and conversely, forest was the lowest coverage in 1996 and then rose in those both years (Table 4). Further, arable land, scrubland, and "others" have shown a decreasing trend, while forest and grassland have shown an increasing trend at differential ratios in all four districts from 1996 to 2010.

Change in the two land use categories – arable and forest of the Koshi Hills's can be compared with that of its associated districts; the Koshi Tarai districts –Morang and Sunsari and neighbouring hill districts –Ilam and Khotang. Though GIS mapping has not been done for these two regions, available sources indicate that average arable land coverage of the Koshi Tarai districts was 65% in 1986 (LRMP 1986) and continued to increase to 74% in 2000 (JFTA 2001). But the average forest coverage of the Koshi Tarai districts was only 24% in 1986 and it further declined to 17% in 2000. Over the past 14 years (1986-2000), there was virtually no change in arable land coverage of the Koshi neighbouring districts, but the forest coverage declined from 53% in 1986 to 40% in 2000. In the Koshi Hills too, the forest coverage declined from 39.5 in 1986 to 37.5% in 1996, but the arable land increased from 30.4 to 33.5% during the same two years. These patterns of change in the two land use categories of the Koshi Hills are comparable with those of the Koshi Tarai districts, though the magnitude was comparably minor in the former region.

In regard to scrubland, the coverage has decreased in all four districts of the Koshi Hills' during the past 24 years; with the largest decrease in Sankhuwasabha from 12.4% in 1986 to 1.5% in 2010 and likewise in Dhankuta from 7.0 to 2.2 % between the same two years. There was minimal difference in the decrease percentile in scrubland coverage in the other two districts during the two years.

The grassland coverage, unlike scrubland, has increased in all three districts except for in Sankhuwasabha during the last 24 years. In Sankhuwasabha, it declined, like scrubland, from 12.7 to 3.3% between 1986 and 2010. The decreased in these two land uses – scrubland and grassland – could be linked to the increase in the forest coverage in Sankhuwasabha. However the differential percentile increases in grassland coverage in the rest three districts were minimal, between the same two years.

In terms of percentage coverage of "others" land use category, there appears to be minimal change in all three districts except in Sankhuwasabha, where it rose from 21% to 29% between 1986 and 2010. This increase could be linked to the decreased in arable land, scrubland, and grassland.

4.3 Matrix of Change in Land Use Categories

Table 5 exhibits the relative proportions of different land use categories in order to demonstrate change in the particular land use category over time in matrix form. For instance, an indicated increase of the arable land by 10.2% between 1986 and 1996 (refer to Table 3), appears to be largely caused by encroaching upon the forest land (7.8%) and very small proportions on other three land use categories (Table 5a). An increas in the scrubland during the decade of 1986-96 was assumed to be mostly due to consuming relatively greater proportion of forest land. The Table 5a also shows that the arable land and scrubland were two major land coverages to consume most of the forest land during 1986-1996.

Table 5b exhibits that a decrease in the arable land from 1996-2010 was due to the conversion of this land to grassland (7.2%) and to forest and scrubland. During that decade, increases in forest land appear to be caused largely by decreases in scrubland, followed by grassland and arable land. Because all the latter three land use categories found to be declined largely.

Thus, during the past two and half decades (1986-2010), forest land appears to have increased at the cost of encroaching upon scrubland, grassland, and arable land. Increase in "others" land use, mainly encroaching upon the forest, arable and grassland might be due to the construction of roads, expansion of settlement clusters and institution buildings, and others (Table 5c).

That arable land has increased at the cost of decreased forest land during 1986-1996 might be due to the expansion of cultivated land over the forest area through the practice of the slash and burn farming by the local tribal communities, the expansion of commercial farming on land pockets lying along road sides, and the establishment of tea estates. Studies (Sugden 2004; CEAPRED 2001) indicate that the coming of the roads together with the intervention of agricultural innovations has encouraged local farmers to commercialise vegetables cultivation particularly along the road sides as shown in map index (MI) KH08 (Annex A).

Table 5: Matrix of relative changes (in %) of land use categories, Koshi Hills

(d) 1986 - 1996

Land use Categories	Change (%) in LU categories					Total	
	Arable	Forest	Scrub	Grassland	Others	area (ha)	%
Arable	0.0	-2.7	0.5	-11.2	7.1	20,276	10.2
Forest	7.8	0.0	1.0	-11.9	8.2	-13,439	-5.2
Scrub	1.4	-1.6	0.0	-16.4	21.0	1,403	2.3
Grassland	0.7	-0.3	0.3	0.0	2.8	-38,536	-65.0
Others	0.3	-0.6	0.4	-25.4	0.0	30,295	39.1

(e) 1996 - 2010

Land use Categories	Change (%) in LU categories					Total	
	Arable	Forest	Scrub	Grassland	Others	area (ha)	%
Arable	0.0	20.5	-7.6	13.4	-0.2	-23,288	-10.6
Forest	-1.6	0.0	-53.1	41.0	-1.9	61,236	24.9
Scrub	-1.8	1.6	0.0	4.8	-0.1	-50,402	-81.4
Grassland	-7.2	1.8	-4.5	0.0	-0.7	15,498	74.8
Others	0.0	1.0	16.2	15.6	0.0	-3,044	-2.8

(f) 1986 - 2010

Land use Categories	Change (%) in LU categories					Total	
	Arable	Forest	Scrub	Grassland	Others	area (ha)	%
Arable	0.0	13.2	14.7	6.8	6.4	-3,004	-1.5
Forest	0.9	0.0	51.2	16.7	18.3	47,788	18.4
Scrub	0.1	1.0	0.0	1.0	1.0	-48,997	-80.9
Grassland	0.5	2.0	3.9	0.0	9.3	-23,038	-38.9
Others	0.0	2.3	11.1	14.5	0.0	27,251	35.1

The conservation of forests and the expansion of forests by the initiation of community forestry, leasehold forestry and private forestry programmes, as well as the conversion of some of the scrublands into the mature forest trees may be assumed to be plausible reasons for the increase in forest land from 1996-2010.

That patches of arable land have turned into scrubland and grassland, might be due to abandonment of cultivation. The GIS map being built based on field observation [7] shows

[7] Due to scattered patches of abandoned farmland, their locations are shown by points on land use map.

abandoned arable land sites across the Koshi Hills, plausibly due to increased out migration among the labour force. This is evidenced by the fact that absent population was at 8.4% of the total population in the Koshi Hills in 2011 (CBS 2012).

Thus, during the one and half decades, only forest land has increased relatively, while the three major land use categories –arable land, scrubland and grassland– have decreased at different rates (Table 5c). It is evident from Table 5c that the increase in forest land came mostly at the expense of scrubland, grassland and arable land. Studies indicate that community forestry, leasehold forestry and private forestry programmes have been expanded over barren lands, conversion of scrubland to mature tree canopies, plantation of trees such as uttis, chiraito, lokta, salla, bamboo, and growing of amreso and large cardamom within the forest lands.

4.4 Factors of land use change

Significant changes have occurred in overall land use, indicating the dynamic, changing nature of land use. For instance, forest land has increased by 18.4% in the past 24 years. Many factors can be identified in this story. For example, there was a decline in population at an average of 38.3% in the Koshi Hills from 1991-2011 due mainly to out-migration (absent population). A decrease of 5% in the population between 2001 and 2011 in the Koshi Hills was also due to migration plausibly caused by the Maoist Insurgency. Further, considerable internal interchange appears to have occurred between land use categories, especially between "forest" and "scrub" or "grassland," demonstrating a fluidity of land use. Scrublands and grasslands are being converted to more productive categories of forest land, reflecting the care of communities in managing and conserving their own forest resources. The private forest areas and scrublands are also being used for growing *Uttis* cum *Amreso* (broom grass) and large cardamom.

Use of land for agricultural purposes appears to have slightly decreased during the last decades (1996-2010). But during the period from 1986-1996, there was an increase in arable land, i.e., land being used for cultivation, which coincided with a decrease in the forest coverage. Meanwhile, the commercial production or intensification of agriculture system such as the vegetable farming has been associated in particular with areas along the roads. Moreover, intensification in the form of inter-culture growth practice of two or more crops, for instance, maize with beans and/or potato, and double cropping of staple crops such as rice and wheat, or maize is associated with areas where such farming systems are feasible due to irrigation systems, roads and market access, and other associated facilities. On GIS maps, the growing areas of commercial vegetables are being confined in areas around the motorable roads and patches of abandoned cultivated land are scattered across the Koshi Hills.

Government initiatives applied through the adoption of policies and programmes appear to be crucial in impacting on land use change in the Koshi Hills. For instance, there were two specific activities to maintain and conserve the forest coverage (ref: KHST: Documentary Review, 2012). First, the Makalu-Barun National Park and its buffer zone set up in 1992, which together cover 2,330 km², are being managed by forest user groups. Second, the Community Forestry Programme, which was initiated in the late 1980s under the Koshi Hill Development Programme, the Nepal-UK Community Forestry and the Livelihoods and Forestry Programme have contributed to increase in forest coverage after 1996. By 2011, over 115,000 ha of forests were handed over to 1,449 Community Forests User Group in the KH. The Community forestry activities have had a significant effect on the balance of land use as part of a broader process of agrarian change and have correlated with a significant improvement in fodder, fuelwood, and fruit tree resources. Furthermore, a number of enterprises based on the non-timber forest products appear to have

existed to produce essential oils, handmade paper, fruit squash, briquettes, herbs and Chiraito, and *Allo* based handicraft production (Kunwar et al 2009).

The increase in arable land during the 1986-1996 decade could be attributed to the building of Dharan-Dhankuta road and the introduction of improved agriculture development programmes through CEPREAD (Centre for Environmental and Agricultural Policy Research, Extension and Development) and KOSEVEG (Koshi Seeds and Vegetables) that initiated the growth of off season vegetables, seeds, large cardamom, ginger, fruits and livestock rearing in the early 1980s (CEAPRED 2001). Modern transport service began in the Koshi Hills after building of 66 km roads in 1985, which increased to a total of 934 km roads by 2010. The import of dung (chicken and goats) loaded in trucks has been observed in the KH and in turn exports of high value crops to the Tarai towns. Recent evidence suggests that reliance on subsistence farming is declining as opportunities are increasing for off-farm income, but whether this has allowed population pressure on land resources to be contained is debatable (Virgo and Subba 1994). Studies show that the traditional subsistence cereals crops have been replaced not only with commercial vegetables, but their cultivated areas have also increased substantially (Pant 2002; Sugden 2004; Shrestha 2006).[8]

4.5 Land use and settlements versus elevation zones

Land use types that depend on environmental conditions (temperature, precipitation, moisture, vegetation, terrain, wind, etc), vary according to elevation in the mountain region of Nepal. Change in land use occurs due to human activities that map to these elevations over time. These processes combine to determine the location of settlements. Considering the dynamics of land use change and changes in population (increased during 1991-2001 and decreased during 2001-2011) in the Koshi Hills, land use and spatial distribution of settlements is assumed to be changing according to elevation over time.

Table 6: Share of total land by land use categories according to elevation zones, Koshi Hills

Elevation Class (m)	%ile share of total land by land use category by year														
	Arable			Forest			Scrubland			Grassland			Others		
	'86	'96	'10	'86	'96	'10	'86	'96	'10	'86	'96	'10	'86	'96	'10
< 1000	30	30	31	28	25	23	15	19	13	4	10	34	7	6	4
1000-2000	65	63	61	28	31	30	36	27	70	20	29	41	1	1	1
2000-3000	5	7	7	32	35	33	20	19	8	31	44	11	1	1	2
3000-4000	0	0	0	11	9	13	25	27	8	18	15	6	4	15	15
> 4000	0	0	0	1	0	1	4	7	1	27	3	8	87	76	77

While arable land is distributed across the elevation zones, it is mainly below 3,000 m, while all other four land use categories are distributed across all elevation zones at varying magnitudes (Table 6). A large proportion of arable land (over three-fifths) is concentrated in the elevation zone between 1,000-2,000 m, and this together with the proportion of the arable land lying in the sub 1,000 m zone represents over 92% of the total arable land area. Only a small proportion of arable land is located between 2,000-3000 m zone and above this zone no arable land exists due to the unsuitable climate. Forest is found in relatively greater proportions in the 2000-3000 m zone; scrubland in the 1000-2000m; grassland within the range of 1000-3000m, and 'others' in the zone above 4000 m. In the latter case, snow land, bare land, and rock and ice are dominant sub-land

[8] For instance, the large cardamom area in the KH grew from 1,564 ha in 1991 to 3,224 ha in 2008 and ginger area rose by 3 folds and fruits area by 28% in holdings during 1971-2007.

use units under 'Others' rather than its other sub-land use units such as settlement built-ups, and roads.

Land use categories by elevation zones show minimal change over time. This is true in both the case of arable land and forest coverage. For instance arable land has decreased at a differential percent of 4 points in the zone of 1000-2000m between 1986 and 2010, while forest has decreased at 5 points in the sub 1000m zone over the same period. There has been a substantial increase in scrubland in the 1000-2000m zone, with 70% in 2010 up from 36% in 1986, but a large decrease in two zones: 2000-3000 and 3000-4000 during the same years. A pronounced change has occurred in the grassland in all elevation zones; its sharing increased in 2010 compared to that in 1986 in two zones: <1000m and 1000-2000m, while its share decreased in 2010 compared to that in 1986 in all remaining three zones above 3000 m. There has been decrease in area of 'Others' in 2010 compared to 1986 in the zone >4000m, as opposed to the area in the zone from 3000-4000m, where it increased between the two years.

The distribution of population clusters by elevations in the Koshi Hills has been assessed by means of GIS overlay functions, showing the location of population dots in the elevation zones.[9] The exercise exhibits that the elevation zone between 1000-2000m is most favourable, where over 70% of the total population[10] are found to be living (Table 7). Next is the elevation zone of sub 1000m, where there is about 23% of population. Only in Sankhuwasabha, some settlements are found in the zones above 3000m, while in other three districts all settlements are within the elevation zones below 3000m.

Table 7: Distribution of settlements (values in %) by elevation zone and by year

Elevation class	Bhojpur		Dhankuta		S_sabha		Terhathum		Total	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
< 1000	20.6	21.2	32.6	32.3	31.1	31.0	8.4	8.2	24.0	24.2
1000 - 2000	73.7	73.1	65.3	65.2	59.6	59.7	83.6	83.7	69.9	69.6
2000 - 3000	5.7	5.6	2.2	2.5	9.1	9.0	7.9	8.1	6.0	6.1
3000 - 4000	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
> 4000	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0

When comparing the distribution of population clusters between 2001 and 1991 over elevation zones, there was no significant variation (Table 7). Two reasons to explain it are: one, there was limited population increase at 8.8% (51,868 people) between 1991 and 2001 across the 6,557 km^2 of the Koshi region and secondly, there has been an internal movement of settlements/population within the same zones.

The distribution of population appears to be closely associated with the distribution of arable land in the Koshi Hills. Over 90% of the population clusters are concentrated in two elevation zones:

[9]Population dots were put on each of the district maps, based on the 2001 census, which were derived dividing the total population of VDC/municipality by 50 persons per each dot. Dots were carefully put on the map avoiding drainage, gorges, land uses, steep slopes, rock, snow land, and pasture land. No population data was available at VDC/municipality level in 2011 preliminary population census result.

[10] The populations in 1991 and 2001 respectively of four districts and Koshi Hill as a whole were: Bhojpur (198,784 and 202,576), Dhankuta (146,386 and 165,069), Sankhuwasabha (141,903 and 159,008), Terhathum (102,870 and 113,061), and the Koshi Hills (589,943 and 639,714).

1000-2000m and <1000m, where over 90% of the total arable land is found. About 6% of population clusters on average are found in the elevation zone of 2000-3000m, due to dominance of grassland where the major occupations of the population is animal husbandry and tourism. Administrative headquarters, major market towns, road alignments, basic facilities such as schools and health, religious monuments and other amenities generally have major population clusters close by. It appears that people tend to have moved to places for permanent settlement where there are roads and other facilities, while those still living in the remote areas are devoid of basic facilities. This process of development and migration of people has created disparity in the level of development, as well as differentials in the impacts of development interventions. Scattered settlements over the Koshi hills appear to be a crucial problem for the provision of basic facilities to the people living in such settlements, as it involves significant cost for the provision of basic facilities, which are beyond the capacity of the local communities. There is an urgent need to reduce such disparity. Agglomeration of settlement development as a policy is potentially an essential measure[11] for cost effective deployment of infrastructure and facilities, which would have reasonably a fair impact of development interventions over the places and people throughout the Koshi Hills.

4.6 Outflows of Local Products

The outflows of local products being traded through the towns and the district headquarters of the Koshi Hills include vegetables such as cabbage, cauliflower, tomato, radish, etc and other high value products (*Akabare*, cardamom, ginger), fruits (orange, lemons), potato, and tea (Table 8a). Vegetables comprise the largest share, with about 56% of the total volume of outflows, followed by potato and orange. However, the volume and type of exported products, particularly vegetables, differ in among the Koshi Hills districts. Overall, Dhankuta being the largest district, accounts for about 41% of the total traded volume of the Koshi Hills, while Sankhuwasabha being the smallest accounts for 10%. The other two districts share about one-fourth each.

Table 8: Outflows of local products from the Koshi Hills districts

(c) Quantity (mtons) of outflows of local products

Export goods	Bhojpur	Dhankuta	Solukhumbu	Terhathum	Total	%
Akabare	70	122	-	-	192	0.1
Cardamom	222	177	959	3,000	4,358	2.9
Ginger	4,010	2,261	572	2,000	8,843	5.8
Lemons	665	-	-	-	665	0.4
Orange	4,701	2,688	1,672	2,000	11,061	7.3
Potato	21,335	2,860	6,051	12,050	42,296	27.8
Tea	-	-	6	-	6	0.0
Vegetables	6,460	53,485	5,505	19290	84,740	55.7
Total	37,463	61,593	14,765	38,340	152,161	100

***Source**: District Consultation Workshops and Record files of the Koshi Hill districts, June 2012.*

[11]This policy measure has also been suggested by one of the steering committee members, representing the association of the district development committees during the NPC workshop.

(d) Relative distribution of outflows by destination places

Destination places	Volume in % shared by destination centres				Total	%
	Bhojpur	Dhankuta	Sankhuwasabha	Terhathum		
Biratnagar	-	30	25	25	80	19.8
Birtamod	10	15	20	20	65	16.0
Dharan	15	35	30	35	115	28.4
Hile	35	-	-	-	35	8.6
Itahari	10	-	-	10	20	4.9
Kakarvita	-	15	20	-	35	8.6
Khandbari	25	-	-	-	25	6.2
Kathmandu	10	-	5	-	15	3.7
India	-	5	-	10	15	3.7
Total (mtons)	37,463	61,593	14,765	38,340	152,161	100
%	24.6	40.5	9.7	25.2	100	

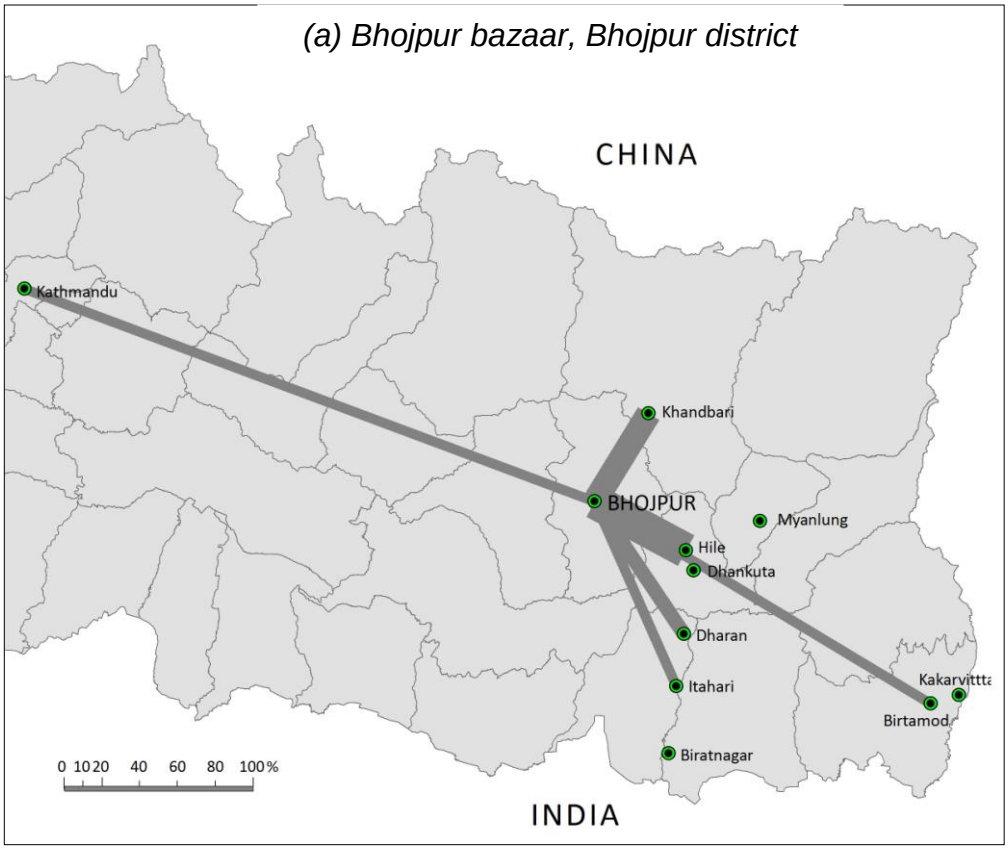
***Note**: Values (percentage) are computed from each of the district's total and then added up by places. Relative sharing of volume of goods outflows for each place is computed from the sum (total) value.*

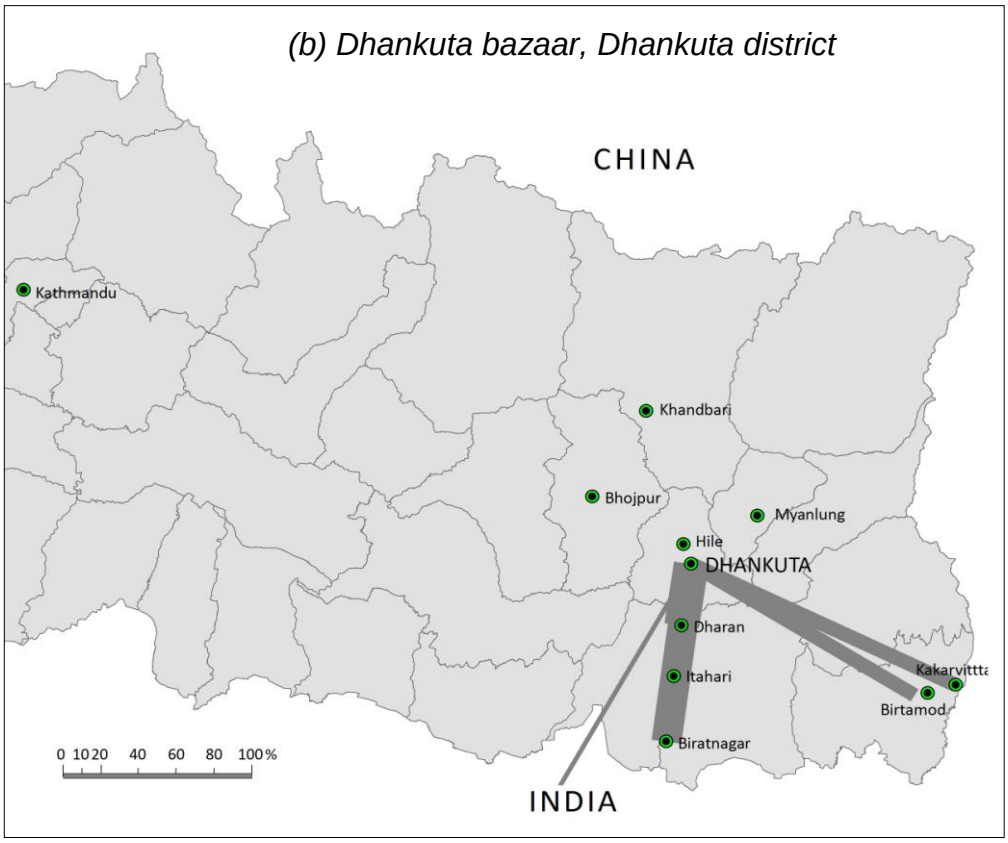
Two types of flows of local products are discernible. First, flows of local products take place through already existing network of market centres, including the hāt bazaars across each district, and second through major trading centres of other districts where there are road links. Figure 3 built on GIS frame depicts that the outflow of the local traded goods from Bhojpur takes place with Khandbari of Sankhuwasabha and Hile of Dhankuta and then through these latter two centres to other places outside of the Koshi Hills (Figure 3a), while the outflow from the other three districts occurs directly to external destinations (Figure 3b, c, and d) within the country, as well as of India.

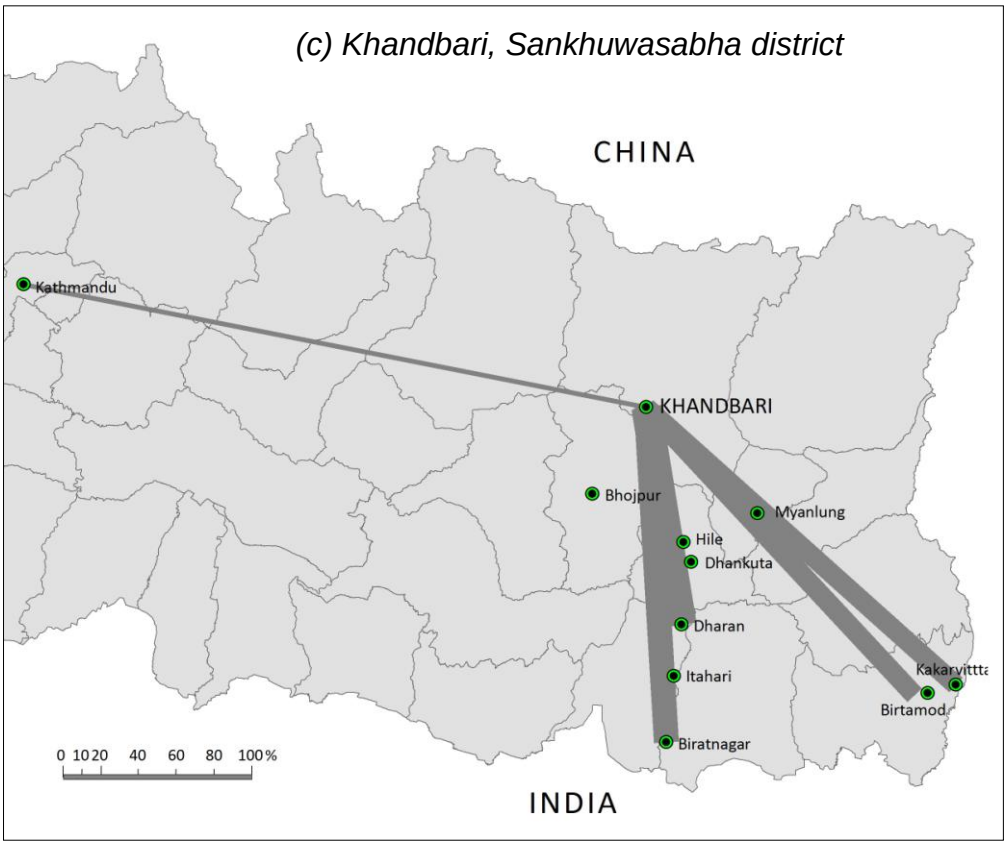
The following observations can be derived from the patterns of outflow of local products. Roads have played crucial role in dictating the direction and size of flows of goods within the Koshi Hills, as well as to other places outside the Koshi Hills. All three districts except Bhojpur had previously had road links among themselves, where flows of goods take place throughout the year, while there was seasonal flow of goods between Bhojpur and other three districts, due to a fair weather road link. Major flows took place between Bhojpur and locations in the Koshi Hill's other districts during the fair weather season, indicating that Bhojpur had not yet developed centres that create direct trade links external locations. The other three districts have the benefit out of outflows of traded goods directly with external centres through the all-weather road links. Further research has shown that the flows of goods with external locations, particularly Itahari, Birtamod and Kakarvita are primarily for export to the Indian cities, while that with Dharan and Biratnagar are for both internal consumption and export to Indian cities. Only Bhojpur and Sankhuwasabha have the benefit out of outflows of traded goods with Kathmandu due to their direct air transportation links with the latter centre, the capital city of Nepal.

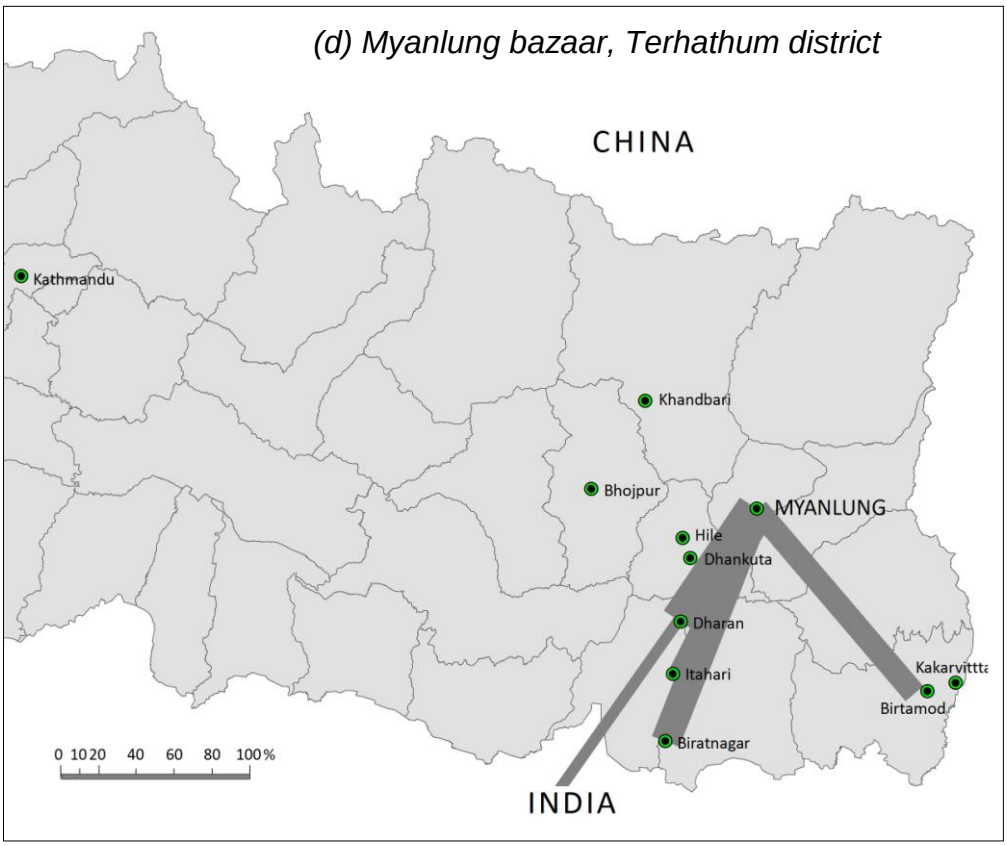
Further, the existing patterns of flows of goods provide the following development implications. The flows of traded goods that take place between the local markets or hāt bazaars (lower level) and market towns or intermediary centres of higher level located outside the districts tend to lead to specialise in the production systems. Intensification of vegetable production and other high value crops is of best example. On the other hand, the flows of local products that take place between the same lower order places within the districts indicate that the production systems are towards subsistence-oriented and that no specialisation can be expected through such marketing link of flows of local products.

Figure 3: Outflow of local products through the Koshi Hill districts






(c) Khandbari, Sankhuwasabha district
CHINA
Kathmandu
KHANDBARI
Bhojpur
Myanlung
Hile
Dhankuta
Dharan
Itahari
Kakarvittta
Birtamod
Biratnagar
0 10 20 40 60 80 100%
INDIA


(d) Myanlung bazaar, Terhathum district
CHINA
Kathmandu
Khandbari
Bhojpur
MYANLUNG
Hile
Dhankuta
Dharan
Itahari
Kakarvittta
Birtamod
Biratnagar
0 10 20 40 60 80 100%
INDIA

5. GIS in Measuring Accessibility of Facilities

A number of GIS maps have been constructed to establish baseline data, showing the location of schools, hāt bazaars, religious monuments, police posts, and post offices at the Koshi Hills' district level.

It has been stated above in the methodology section that some GIS functions have been applied for spatial analysis of the facilities, wherever feasible in terms of data on location and by year, given the map scales. It suggests further exploration of use of GIS in a wide range of problems of spatial analysis. However, below is the description of how GIS being used to compute potential populations with access to given roads and health facilities

5.1 Access to roads

The first road came into being in the KH in Dhankuta in 1982 and in Bhojpur only in 2007. In the KH, the total length of roads increased from 66km in 1986 to 934km in 2010 and the road accessibility by person improved from 7,624 per km road to 652 per km between the same two years (Table 9). The current road density is 11 km per 100 km^2.

Before the construction of the Dharan-Dhankuta road in 1982, the KH people had to walk over a day along the traditional trail routes from Dhankuta to Dharan, the gateway town to the Tarai. Marsh's study carried out in 1984 found that the daily foot traffic was 3,000 persons per day and the number of daily porter traffic was estimated to be over 800. There was zero foot traffic along the roads after opening of vehicular traffic, displacing all traditional modes of transports in 1984.

The situation of the roads is that, those linking locations within Bhojpur and Sankhuwasabha are only fair-weather roads. In other words, no public vehicles are passable along the earth roads during the rainy monsoon season in these two districts. So, access to roads means only the movements of people by vehicles during the fair-weather season.

Table 9: Access of people (potential) to roads and health facility locations, KH

Buffer Class (km)	*Roads*		*Health*	
	1986	2010	1996	2010
Below 3	9.86	38.86	74.66	84.37
3 – 5	4.74	17.02	21.67	13.37
Above 5	85.40	44.11	3.67	2.26

Access figures for people to roads (both all-weather and fair-weather) have been derived from counting the number of settlement locations within the buffer zones from the road alignment or road head points. The population counted or their per cent is the potential number. The buffer zones have been defined for three classes and access to roads has been made at two points-years: 1986 and 2010 as shown in Table 9.

The GIS buffer analysis reveals that there was a majority of 85.04% of the population living further than 5 km from the roads in 1986; this is the broad zone which also includes remote areas of the districts from where people have to travel several hours to reach the nearest road head. This was also the year in which construction of roads had just begun in some areas of the Koshi Hills, particularly Dhankuta district. So considering the whole Koshi Hills, only a small proportion of the population was living in other two buffer classes with the opportunity to easily access to roads in 1986. By 2010, several hundred kilometres of roads had been built penetrating into several places

of the Koshi Hills and therefore access to roads has been substantially improved. For instance, half of the proportion of the potential people living further than 5 km distance from roads across the Koshi Hills appears to be reduced in 2010. As a consequence, the proportions of people living in other buffer classes also increased tremendously (Table 9). Moreover as the length of road being constructed in Dhankuta and Terhathum that was all-weather was greater than in Bhojpur and Sankhuwasabha, the population of the former two districts has had better access to roads (Annex D).

Patches of commercial vegetable farming mostly located along the road sides are considered to be an impact of roads on land use patterns (Annex A: KH 08). However, this GIS mapping exercise can be further elaborated, provided that the data on traffic flows or road users over time, impact on agricultural land use patterns (large map scale), socio-economic development and access of people to schools and health facilities were available.

5.2 Access of People to Health Facility Location

Unlike the roads, health is a basic facility and they health centres are located at regular locations across the district. Based on the available data, when computing the population living in three different buffer classes or access zones away from the location of health facilities (hospital, health centres and health posts) as shown in Table 9, only a very minimal proportion (3.7%) were living in the greater than 5 km zone in 1996[12]. This declined to 2.3% of the total population living in that zone in 2010. Some improvements then have occurred in the access of people to the health facilities locations between 1996 and 2010 but the baseline indicates a good starting point.

In general, access provided for people to health services depends on the number and location of these established across the districts. A larger proportion of people living within the closer buffer zones signify better health facility.

Within the 3 km buffer zone, access for people to health facilities has improved considerably in Bhojpur compared to the other three districts between 1996 and 2010 (Annex E). This result is quite in contrast to the roads access indicator in Bhojpur, where road lengths were less than in other districts. This implies that if the road network is incorporated into the analyse of the accessibility for people living in different buffer zones from health services, a more accurate measure of health service would be achieved.

Moreover, this analysis is limited to a consideration of the population of potential health service users, irrespective of the quality of health facilities and the number of actual users. To achieve this data on different types of health facilities and the number of health users would need to be fed up to the GIS tool to undertake a more accurate analysis of health service accessibility.

5.3 Comparison of Access between Roads and Health Service

The term ‘accessibility’ applies to the distance and time required to reach a service location, as well as to the method of dispensing the service. Service accessibility is a measure of the ease with which a community can overcome the distances between the living places and service locations. The facility location in a rural and hilly region like the Koshi Hills should be designed to achieve community welfare objectives with a minimum of travel distance or cost to its users. As such the facility location should also seek to maximising demand and equity of services for its users. These are all necessary to achieve efficiency and effectiveness in service delivery (Pradhan 1998;

[12] No data on health service location was available for 1986.

Pradhan, Shrestha and Sharma 1999). On the other hand, the effectiveness of service delivery also depends upon quality, adequacy, and behaviour of working staff, service delivery mechanism, organisation structure, and so on (Wanmali 1992).

Interestingly, a majority of the population lived within the 3km buffer of health facility locations in both record years: 1996 and 2010, presumably either due to the movement of people closer to facility locations or an improvement in the numbers of health facilities, or both. This is very significant, since roads are available connecting only few locations across the region. This supports evidence for the achievement of the health service policy of the government of Nepal to attain health facility locations (as basic service) within half an hour walking distance for people living in rural regions. Less than 15% of the population live beyond 3 and 5 km distance (1-2 hours) from health facility location, which may also be reduced if the roads facility is considered for health location accessibility. In the case of road accessibility, there are still largest proportions of population living in the 'above 5 km' buffer distance or about over 2 hours walking distance, though there was a significant decline in the population living in this buffer zone from 1986 to 2010.

Improved access to health services implies an increase in the utilisation of health services among the communities with attendant improvements in the provision of immunisation, family planning services, and the availability of curative treatments and so on. Improved road accessibility also means an increase in access to health, schools[13] and other facilities such as market locations, reducing transportation cost for traded goods, and by implication contributing to the increase in the volume of local products for export, increasing social interactions among the communities, etc. For instance, there has been increased in the volume of local products in the KH with centres outside, such as Dharan, Biratnagar and even Siliguri in India.[14]

[13] Due to crowded of the school locations on the map, accessibility of schools could not be accomplished.

[14] For instance, export of vegetables including cabbage, cauliflower, carrot, radish, beans and squash and potato through Sidhuwa along the Hile-Basantapur road corridor to the Tarai cities and India increased from mere 25 metric tons in 1990 to 17,000 metric tons in 2004.

6. Conclusions and Recommendations

The intent of using GIS in the Koshi Hills was to achieve three objectives: (i) to establish a geographical digital data base to map physical, social, economic, and development facilities and infrastructure, as related to land use change, (ii) to assist in the selection of village areas in terms of differential changes in land use for the RCA field research, and (iii) to analyse land use types and identify possible factors responsible for land use change in three years: 1986, 1996 and 2010, as well as to set up attribute data for facility locations such as road (basic infrastructure) and health (basic service).

The GIS work has been confined to the Koshi Hills and its four districts only — Bhojpur, Dhankuta, Sankhuwasabha and Terhathum. The verification of land use and land use change and associated factors in the field was carried out across the Koshi hills, but this field verification was limited only to the areas accessible by road. The attribute data available as a baseline at the district level was limited and inconsistent. However it should be considered that this study has just begun to set up GIS mapping work for the Koshi Hills.

The results of the GIS mapping exercise are as follows:

(i) GIS map datasets have been prepared covering 21 different themes for the Koshi Hills as a whole, and 16 thematic maps for each of four districts, thus totalling 85 map layouts. These maps are a benchmark for spatial development conditions over the three record years: 1986, 1996 and 2010 and in so doing, offer opportunities for comparison against each other and with development activities insofar as they may have contributed to or caused these changes.

(ii) The RCA field research was carried out in all nine VDCs, the selection of which was assisted by the GIS generated land use maps; and

(iii) Understanding has been increased on land use change and the inter-relation with such of various development interventions and socio-economic development.

Forest and arable land has been the predominant land use in the Koshi Hills over the past 24 years, comprising over three-quarters of its total area, and a similar proportion in each of the four districts. In terms of change in magnitude, scrubland, grassland and other categories have been the most important. During the past 24 years, the area of scrubland and grassland decreased by 81% and 39% respectively and that of ‘others’ land use type increased by 35%. Meanwhile forest area increased by 18.4% encroaching mostly over scrubland and grassland, but arable land decreased by 1.5%. On the whole, the forest coverage increased in all three districts except in Bhojpur. From 1996 to 2010, arable land, scrubland, and ‘others’ have shown a decreasing trend, while forest and grassland have shown an increasing trend at differential ratios in all four districts.

Government policies and programmes, including the Makalu-Barun National Park and buffer zone, the Community Forestry Programme, building of roads, introduction of improved agriculture development programmes through CEPREAD and KOSEVEG initiated since the 1980s together with the initiatives of local communities appear to be the most important factors contributing to land use change and their differential impacts on improving social and economic conditions of the people and in areas across the Koshi Hills. The cultivation of commercial vegetables, intensification of cropping patterns, and inter-culture of different crops, fruits, trees, broom grass, ginger and cardamom particularly in areas where there are roads and other facilities and their export to outside places of the Koshi Hills and even to neighbouring cities of India are examples of impacts of the contributory impact of development interventions.

There has also been improved in the access of people to the health facility and roads, but yet the largest proportions of rural population living particularly in the scattered settlements have to travel enormous distance to reach the nearest road-heads and health facilities locations. Meanwhile, patches of abandoned cultivated land are plausibly due to a scarcity of labour force.

It has been possible to exhibit and analyse spatial relationships through a GIS framework investigating the inter-relationship between change in land use and development intervention. Further GIS mapping could be utilised to look into further spatial analyses such as social and economic impacts, schools accessibility by location and time, flows of goods, people, information and money between places over time.

As such, the spatial digital database would benefit from regular updates over time to chart and analyse the impacts of development activities on changing land uses vis-à-vis cultural landscape change in the Koshi Hills.

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Annexes

Available on Request (please contact sean.kirwan@edgroup.com.au)