8. POTENTIAL GIS APPLICATIONS

8.1 Potential GIS Application I: Cost Distance Modelling

8.1.1 Background

The spatial complexity of the mountain environment requires particular attention in order to assess the cost of travelling in different directions through an area of high relief. The cost distance analysis is a standard function of GIS and involves calculation of a distance surface from a given location. The source location is generally a feature or a point on a raster grid.

8.1.2 Objective

The main objective of this application is to demonstrate the potential of GIS for cost distance modelling, i.e., proposing an environmentally least costly path in a mountain area.

8.1.3 Pilot Area

The Nagarjun forest, located north west of the Kathmandu Valley, has been selected as the pilot area for this application. The altitude of the area varies from 1,386 m, near the base, to 2,097m at the top (Jamachowk). The area is covered for the most part with hardwood forest, mixed forest, deciduous or coniferous forest, shrub land, and grassland. At present, there is a road to the top, but it is in a poor condition. So, this study looked at other alternatives, i.e., to construct a road at least cost to the environment.

Data Used

The following data on the pilot area were used for this study:

- Land-use data on a scale of 1:50,000 (Figure 8)
- Digital Elevation Model (DEM) at a resolution of 10 metres (Figure 9)
- Location of top and base

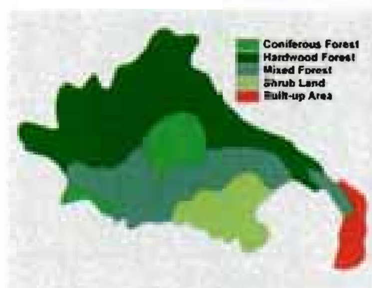


Figure 8: **Existing Land Cover Map of the Study Area**

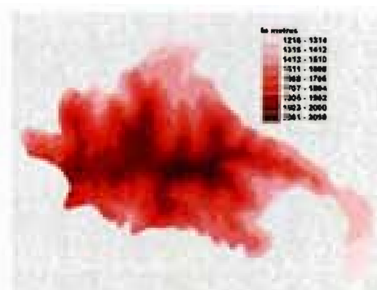


Figure 9: **Digital Elevation Model (DEM) of the Study Area**

Methodology

First of all, the vector data, i.e., land-use data, base point, and top point were entered in raster format in the same resolution as that of the DEM. From the available data sets, the following spatial criteria have been established for the analysis:

- If the land-cover type is grass or shrub, the environmental cost will be less than it would be for an area of forest.
- The higher the slope, the higher the environmental cost.
- The southern aspect is preferable because other aspects incur higher costs.

Based on the above criteria, the qualitative cost for land cover, qualitative cost for slope, and qualitative cost for aspects have been calculated using a GIS linear combination model. Different types of land cover offer varying degrees of friction. It is evident that, from the point of view of the environment and the cost, forested areas are more difficult to traverse than agricultural areas or grassland. So, different values (1 – 100) were assigned for each type of land-cover class depending upon the preference, as given in Table 5.

Table 5 : **Weight Score Values for Land-cover Classes**

Land Cover Type	Value	Score
Hardwood Forest	1	40
Coniferous Forest	2	20
Mixed Forest	3	30
Shrub Land	4	5
Urban	5	0

A slope map (Figure 10) of the pilot area was derived from DEM and reclassified into 10 different slope classes. The weightages of score value were assigned to different slope classes ranging from 1 to 100, reflecting the actual human energy required to cross each slope pixel; i.e., the steeper the slope, the higher the weightage (Table 6). An aspect map (Figure 11) was also derived from the DEM and reclassified into 9 different classes. Low score value was assigned to the preferable aspects (Table 7). Generally, the southern aspect is

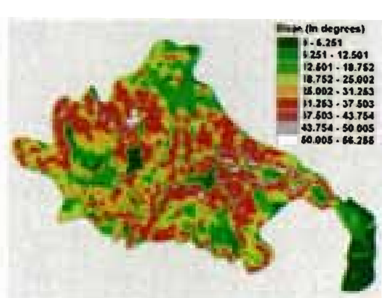


Figure 10: **Slope Map**

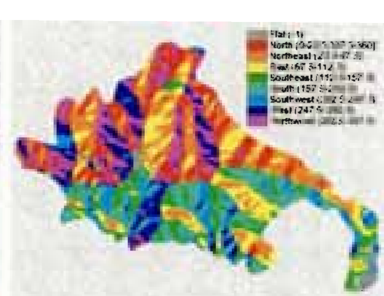


Figure 11: **Aspect Map**

Table 6: **Weight Score Values for Slope Classes**

Slope Classes	Old Value	Score
0 – 5	1	1
5 – 10	2	10
10 – 20	3	20
20 – 30	4	30
30 – 40	5	40
40 – 50	6	50
50 – 60	7	60
60 – 70	8	70
70 – 80	9	80
80 – 90	10	90

Table 7: **Weight Score Values for Aspect Classes**

Aspects	Old Value	Score Value
Flat	-1	0
North	0-22.5, 337.5-360	20
North East	22.5-67.5	30
East	67.5-112.5	40
South East	112.5- 157.5	15
South	157.5-202.5	10
South West	202.5-247.5	15
West	247.5-292.5	50
North West	292.5-337.5	60

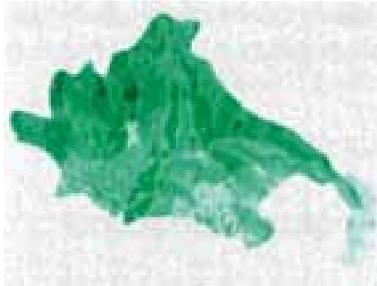


Figure 12: **Cost Surface**

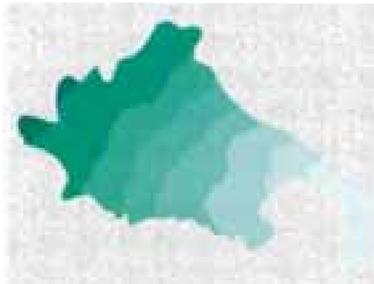


Figure 13: **Accumulated Cost Distance**

preferred for this kind of analysis, because the soils of other aspects normally contain moisture leading to a high risk of failure.

The qualitative costs for land cover, slope, and aspects were combined to produce cost surface (Figure 12). A grid of the base point and cost surface was used to calculate the accumulated cost distance (Figure 13), representing the cost for each cell to traverse from the source cell (base point). It spreads from a cell into the neighbouring cell of lowest cost, adding up the distance of weighted costs as it traverses along. The accumulated cost distance and the top (destination) point were used to calculate the least cost path to move from the source to the destination point. Figure 14 below shows the proposed road using this cost distance modelling method. This application illustrates the cost distance modelling function of GIS. However, in mountain areas, many other parameters, including socioeconomic parameters, need to be considered. Such complex analyses are possible using GIS.

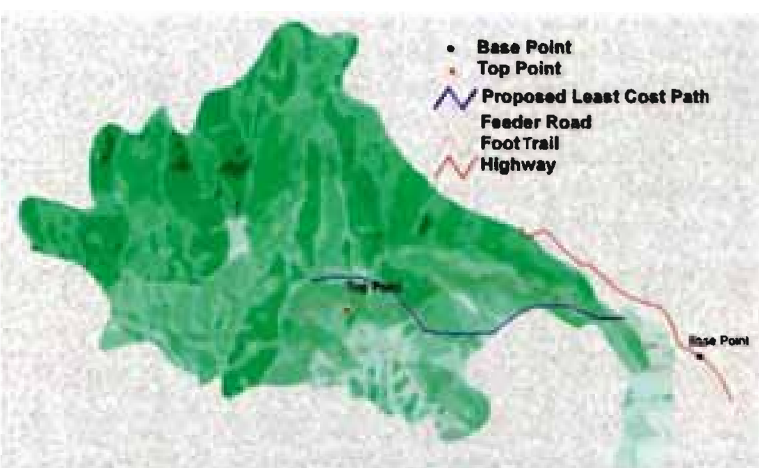


Figure 14: **Proposed Environmentally Least Cost Path**

8.2 Potential GIS Application II: Land-cover Change Analysis and Urban Growth Detection

8.2.1 Background

The rapid growth of population generates increasing competition for the land and the use of its resources. This situation makes the study of land cover and land use an important subject in the development planning process. Information on changes in land cover is of particular importance when such changes could lead to continual degradation of the land in the long run. Derivation of land cover through classical methods is costly, time-consuming, and subject to a variety of errors of different types and sources. Recent developments in GIS and related technologies have led to the establishment of accurate and up-to-date information on the status and pattern of land-cover dynamics.

8.2.2 Objective

The main objective of this application is to demonstrate the potential of GIS and remote-sensing technology for generating land-cover maps in a temporal series from various sources, enabling us to detect land-cover changes over time. This application also evaluates the effectiveness of satellite images of various resolutions (including very high resolution) taken at different times in the production of land-cover maps. It also evaluates the effectiveness of such images in detecting change.

8.2.3 Land-cover Changes between 1978 and 1995

Study Area, Data Description, Methodology, and the Result

The study area was considered to be all three districts of Kathmandu Valley: Kathmandu, Lalitpur, and Bhaktapur. The total area is about 927 sq. km. A land-use/-cover map on a scale of 1:50,000 (LRMP1978), published by the Land Resource Mapping Project, (LRMP) and a topographic map on a scale of 1:25,000 (HMG/FINNIDA1995), published by the Survey Department in cooperation with the Finnish International Development Agency, (FINNIDA) were used for analysis. These maps were digitised using PC Arc/Info and transformed into UTM coordinates. The digital data thus generated were generalised into the same standard major land-cover classes, and depicted in rasters at resolutions of 10 metres. The analysis was carried out using UNIX-based Arc/Info. It was customised using Arc Macro Language (AML) programming, and output maps were produced using ArcView GIS software. The major land-cover changes taking place between 1978 and 1995 are given in Table 8, and shown in Map 48.

Table 8 : **Matrix of Land-cover Change between 1978-1995 (area in sq. km.)**

1978 ↓ / 1995 → Value	Built-up	Forest	Grass	Shrub	Agricu-lture
10	20.167	0.109	1.215	0.000	7.593
20	0.053	205.741	0.000	20.143	42.587
30	0.053	47.489	0.000	5.253	51.809
40	0.000	40.596	0.000	27.113	25.662
50	8.746	28.736	0.149	4.40.	374.765

The result shows that grassland, shrub land, and agricultural land have been converted into forest, and some agricultural land has been converted into built-up area. However, the results show no significant land-cover conversion. The result also shows mistaken classifications of land-cover classes, e.g., conversion of built-up to other classes, and it is apparent that different scales of maps are not suitable for this kind of analysis. This scale is too small to capture urban land-cover changes. In the following sections, attempts have been made to use different satellite images to complement spatial data sets through time series' data and to validate these data to analyse land-cover change.

8.2.4 Land-cover Changes between 1988 and 1997

Study Area, Data Description, Methodology, and the Result

The study area was the three districts of Kathmandu Valley: Kathmandu, Lalitpur, and Bhaktapur. The total area is about 927 sq. km. A Landsat TM image (30m) dated 11th October, 1988, and an ADEOS-AVNIR M image (16m), dated 11th January, 1997, were used for the analysis.

Both images were rectified and geometrically corrected using the geodetic control points, and the digitised road and drainage networks were used from a topographic map on a scale of 1:25,000. The images are geo-referenced to the UTM coordinate system and re-sampled into 10 metre resolution. Supervised classification of both images was carried out to produce a land-cover map of 1988 and 1997, respectively. Difficulty was encountered in discriminating the features, e.g., urban and sand/gravel were encountered along the river side during digital image processing due to their similar spectral characterisations. Digital image classification had to be improved and this was done through extensive field visits, by defining and applying certain knowledge-based rules, neighbourhood classification, and by masking operations. Knowledge-based rules pertained to pixel classification: *if the pixels are classified as built-up area in 1988, but the same pixels are classified as agriculture in 1995, then classify them as agriculture for 1988.* The masking operations were mainly carried out for river and water body features. Digital image processing was carried out on ERDAS Imagine 8.3.1 and change analysis on UNIX based Arc/Info. The customisation was done using Arc Macro Language (AML) programming, and output maps were produced with ArcView GIS software. The main land-cover changes derived from the analysis are given in Table 9, and shown in Map 49.

Table 9:Matrix of Land-cover Change between 1988-1997 (area in sq. km.)

1988 ↓ / 1997 → Classes	Built-up	Forest	Grass	Shrub	Agriculture	Others
Built-up	12.012	0.383	0.219	0.000	0.000	0.000
Forest	1.184	203.335	19.378	9.252	48.393	4.146
Grass	1.052	5.857	7.275	0.337	11.98	0.636
Shrub	0.448	79.598	56.881	19.409	34.953	1.798
Agriculture	7.650	99.223	78.894	5.148	143.49	7.795
Fallow Land	0.517	34.221	2.181	0.446	5.259	4.953

The result shows that the agricultural area has been subject to significant conversion into built-up area, forest, grass, and shrub land; and forest has been converted to agricultural area to a significant degree.

8.2.5 Land-cover Changes between 1986 and 1997

Study Area, Data Description, Methodology, and the Result

The increasing use of high-resolution satellite images prompted attempts to evaluate the usefulness of high-resolution satellite images to detect urban land-cover changes. The SPIN-2 KVR 1000 satellite image (with 2-metre resolution), dated 5th February 1991, was used for this purpose. The acquired SPIN-2 image covers only the core urban areas of Kathmandu and Lalitpur districts and their surroundings. The coverage of the SPIN-2 image used in this application is given below.

LLX: 729233 LLY: 3057748 (UTM)
URX: 742623 URY: 3070685 (UTM)

The SPIN-2 image was merged with SPOT-XS (20-metre resolution), dated 12th March 1986, and ADEOS-AVNIR (with 16-metre resolution), dated 11th January 1997.

Supervised classification of both the merged images produced land-cover maps of 1986 and 1997. Based on these images, analysis of urban land-cover changes from 1986 to 1997 took place. The main land-cover changes derived from the analysis are given in Table 10, and shown in Map 50.

Table 10: Matrix of Land-cover Change between 1986-1997 (area in sq. km.)

1986 ↓ / 1997 → Classes	Built-up	Forest	Grass	Shrub	Crop Land	Fallow Land
Built-up	17.449	0.000	0.000	0.000	0.000	0.000
Forest	1.152	41.079	0.847	3.306	8.094	0.549
Grass	1.051	5.789	2.822	3.225	5.653	4.191
Shrub	2.343	0.250	9.009	3.223	2.677	9.048
Crop Land	2.753	1.960	12.386	7.278	8.729	6.932
Fallow Land	0.258	0.033	1.863	2.065	1.460	2.520

8.2.6 Limitations

Remote sensing images are interesting in themselves, but the value of the data increases substantially if the discernible patterns in the image can be related to recognisable objects or patterns observed on the ground or portrayed on topographical and thematic maps. Data extracted from remote sensing may yield very important information about the earth, but, its value can only be realised if it is integrated with other spatial data.

Many issues need to be considered in processing satellite images for land-cover mapping and in analysing land-cover change. In the present study, different types of satellite imagery taken on different dates have been used for this kind of analysis and problems have been encountered with them. Based on this experience, some important issues are summarised below.

- **Mis-classification of pixels**: One of the main disadvantages of remote-sensing technology is that mis-classification of pixel values occurs due to similarities in spectral characterisation. Improvement by extensive field verification and integration with GIS is needed. Improvement of the classification for urban features and sand/gravel mainly was carried out by this study.

- **Different resolutions**: Analysis was carried out using Landsat-TM and ADEOS-AVNIR images, with resolutions of 30 and 16 m, respectively, and both images were re-sampled to 10 m resolutions. Firstly, the use of images of different resolutions does not produce accurate results, and, secondly, some information will be lost during the re-sampling process. Hence it is preferable to use images of the same resolution.

- **Different seasons**: Satellite images used in this study were taken on different dates and in different seasons. Natural and spatial phenomena obviously differ, e.g., different agricultural commodities in different seasons, different types of or high/low densities of vegetation, and so on. So, using satellite images from different dates and different seasons can lead to inaccuracies.

- **Definition of land-cover classes**: Classification also varies depending upon the definition of land-cover classes. For instance, on topographic maps, grasslands, such as the stadium or Tundikhel(parade ground), are generalised into the 'built-up' classification, whereas in remote-sensing images, they are discernible as grassland.

8.3 Urban Growth Detection

Over the years, satellite-based remote sensing data have been used successfully for mapping, monitoring, planning, and development of urban sprawl, urban land use, and urban environment. With high spatial resolution satellite images, it is now possible to explore, either singly or in combination, the different urban land uses, survey, and planning; for example urban housing, urban utilities, urban land-use change detection, and so on. The Urban growth detection between 1978-1995 and 1988-1997 is shown in Maps 51 and 52 respectively

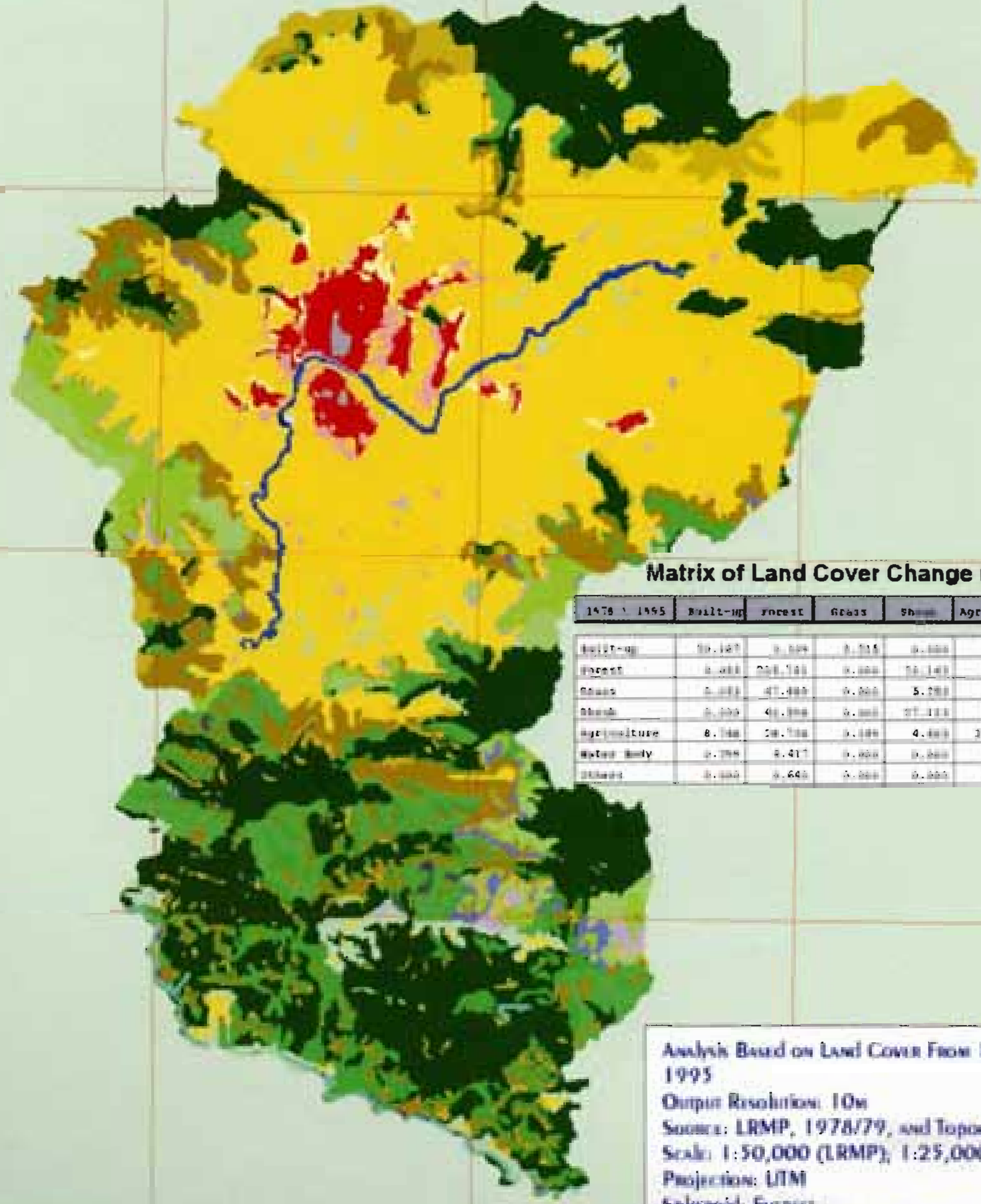
Table 11: Urban Growth in Kathmandu Valley Derived from Various Data Sources

Dates	Source of Analysis	Growth (sq. km.)
1978 – 1995	LRMP and topographic map 1:25K (*Whole of Kathmandu, Lalitpur, and Bhaktapur districts*)	9
1988 – 1997	Landsat TM '88, and ADEOS AVNIR, 1997 (*Whole of Kathmandu, Lalitpur, and Bhaktapur districts*)	10.86
1986 – 1997	Merged SPIN-2 and SPOT-XS, and Merged SPIN-2 and ADEOS-AVNIR (*Only core urban area*)	7.6

The present application demonstrates the potential of GIS and remote-sensing techniques to provide regular assessments of urban expansion between various dates using topographic maps and satellite images. Based on the outcome of the analysis, as described in

Sections 1, 2, and 3, respectively, an analysis of spatial and temporal urban growth expansion was carried out. Again, considering the slopes as the main factor, some areas unsuitable for urban development, particularly on higher slopes, were identified (see Map 53).

List of Maps Prepared from Land Cover Change Analysis and Urban Growth Detection



Matrix of Land Cover Change (Area in Sq.Km.)

1978 \ 1995	Built-up	Forest	Grass	Shrub	Agriculture	Water Body	Others
Built-up	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Forest	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Grass	[illegible]	[illegible]	[illegible]	5.[illegible]	51.[illegible]	[illegible]	[illegible]
Shrub	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Agriculture	8.[illegible]	[illegible]	[illegible]	4.[illegible]	[illegible]	[illegible]	[illegible]
Water Body	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Analysis Based on Land Cover From 1978/79 and 1995
Output Resolution: 10m
Source: LRMP, 1978/79, and Topographic Map, 1995
Scale: 1:50,000 (LRMP); 1:25,000 (Topographic map)
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

Kathmandu Valley

Map 48
Land Cover Change between 1978-1995

Legend

- Agriculture to Agriculture
- Agriculture to Built-up
- Agriculture to Forest
- Agriculture to Grass
- Agriculture to Others
- Agriculture to Shrub
- Agriculture to Water Body
- Built-up to Agriculture
- Built-up to Built-up
- Built-up to Forest
- Built-up to Grass
- Built-up to Water Body
- Forest to Agriculture
- Forest to Built-up
- Forest to Forest
- Forest to Others
- Forest to Shrub
- Grass to Agriculture
- Grass to Built-up
- Grass to Forest
- Grass to Others
- Grass to Shrub
- Others to Agriculture
- Others to Forest
- Shrub to Agriculture
- Shrub to Forest
- Shrub to Others
- Shrub to Shrub
- Water Body to Agriculture
- Water Body to Built-up
- Water Body to Forest
- Water Body to Water Body

5 0 5 Kilometres

Scale 1:300,000

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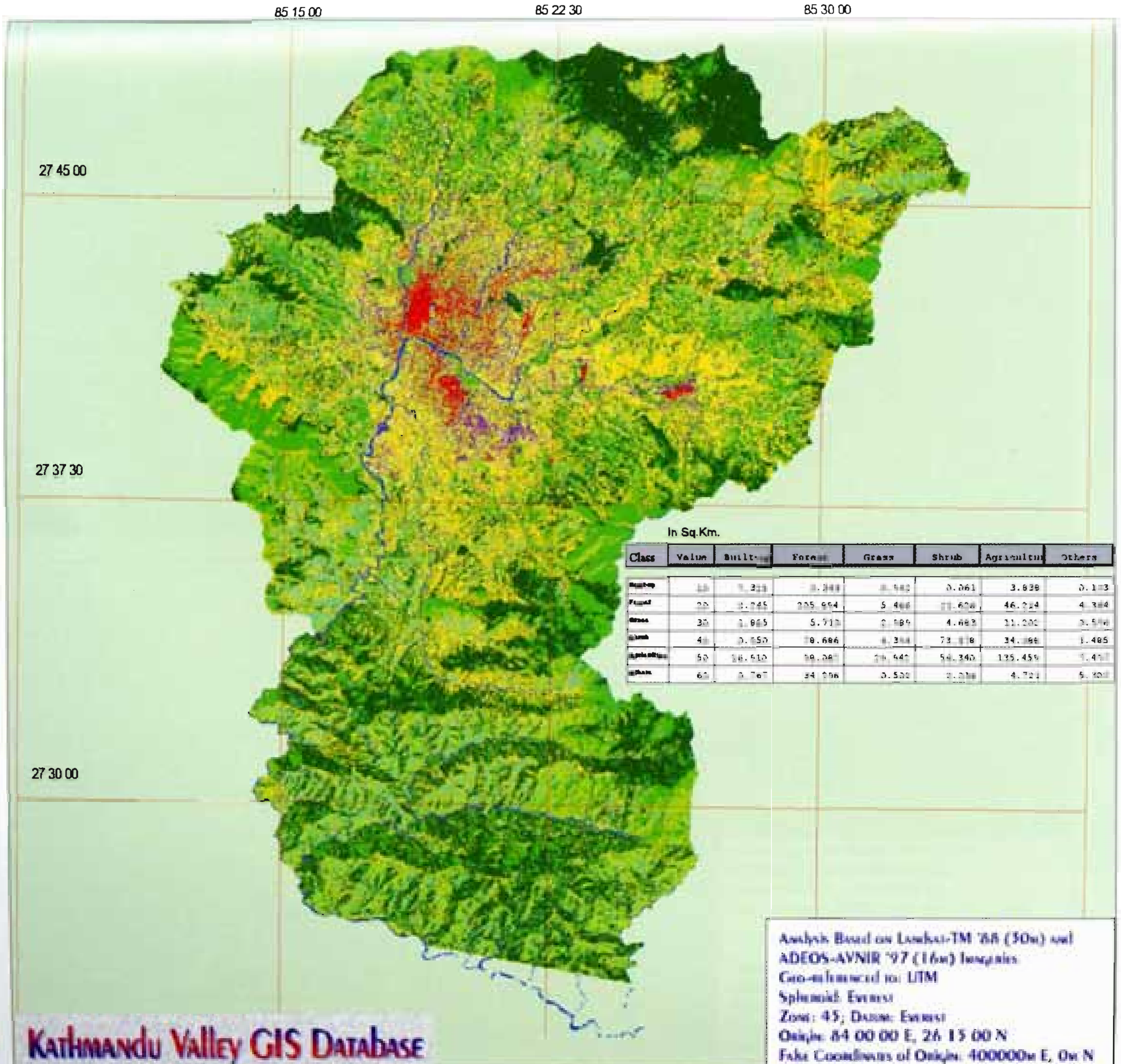
Kathmandu Valley

Map 49

Land Cover Change between 1988-1997



In Sq.Km.

Class	Value	Built-up	Forest	Grass	Shrub	Agriculture	Others
Built-up	10	[illegible]	[illegible]	[illegible]	0.061	3.838	[illegible]
Forest	20	[illegible]	205.994	5.466	[illegible]	46.224	4.384
Grass	30	1.865	5.713	[illegible]	4.683	11.202	[illegible]
Shrub	40	0.550	78.686	[illegible]	[illegible]	34.066	1.485
Agriculture	50	18.510	[illegible]	[illegible]	54.340	135.459	[illegible]
Others	60	[illegible]	[illegible]	0.502	[illegible]	4.721	[illegible]

Analysis Based on Landsat-TM '88 (30m) and ADEOS-AVNIR '97 (16m) Imageries
Geo-referenced to: UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

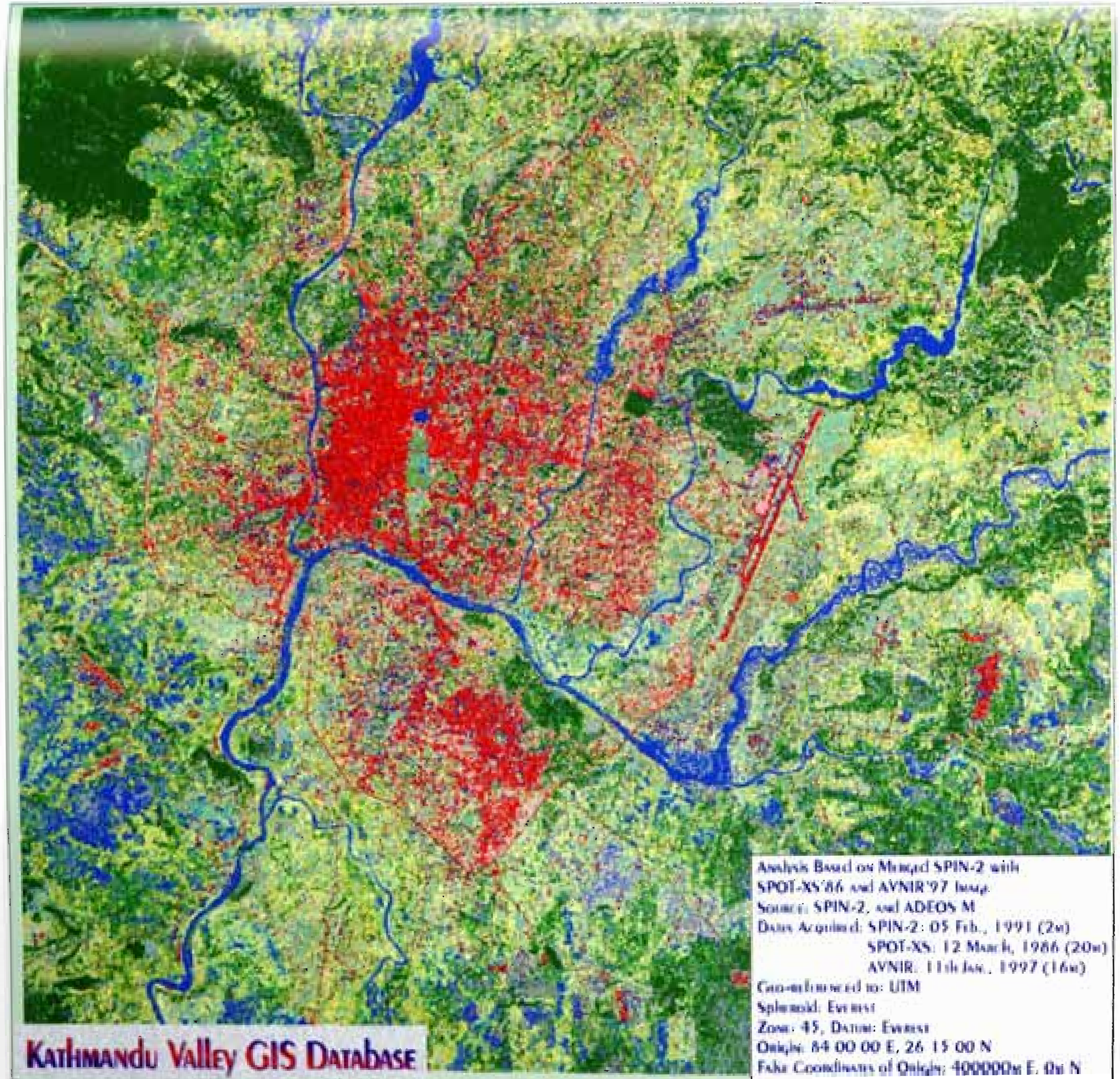
Legend

- Built-up to Built-up
- Others to Built-up
- Forest to Forest
- Others to Forest
- Grass to Grass
- Others to Grass
- Shrub to Shrub
- Others to Shrub
- Agriculture to Agriculture
- Others to Agriculture
- Others

5 0 5 Kilometres

Scale: 1:275,000

ICIMOD
MENRIS '99



Kathmandu Valley

Map 50

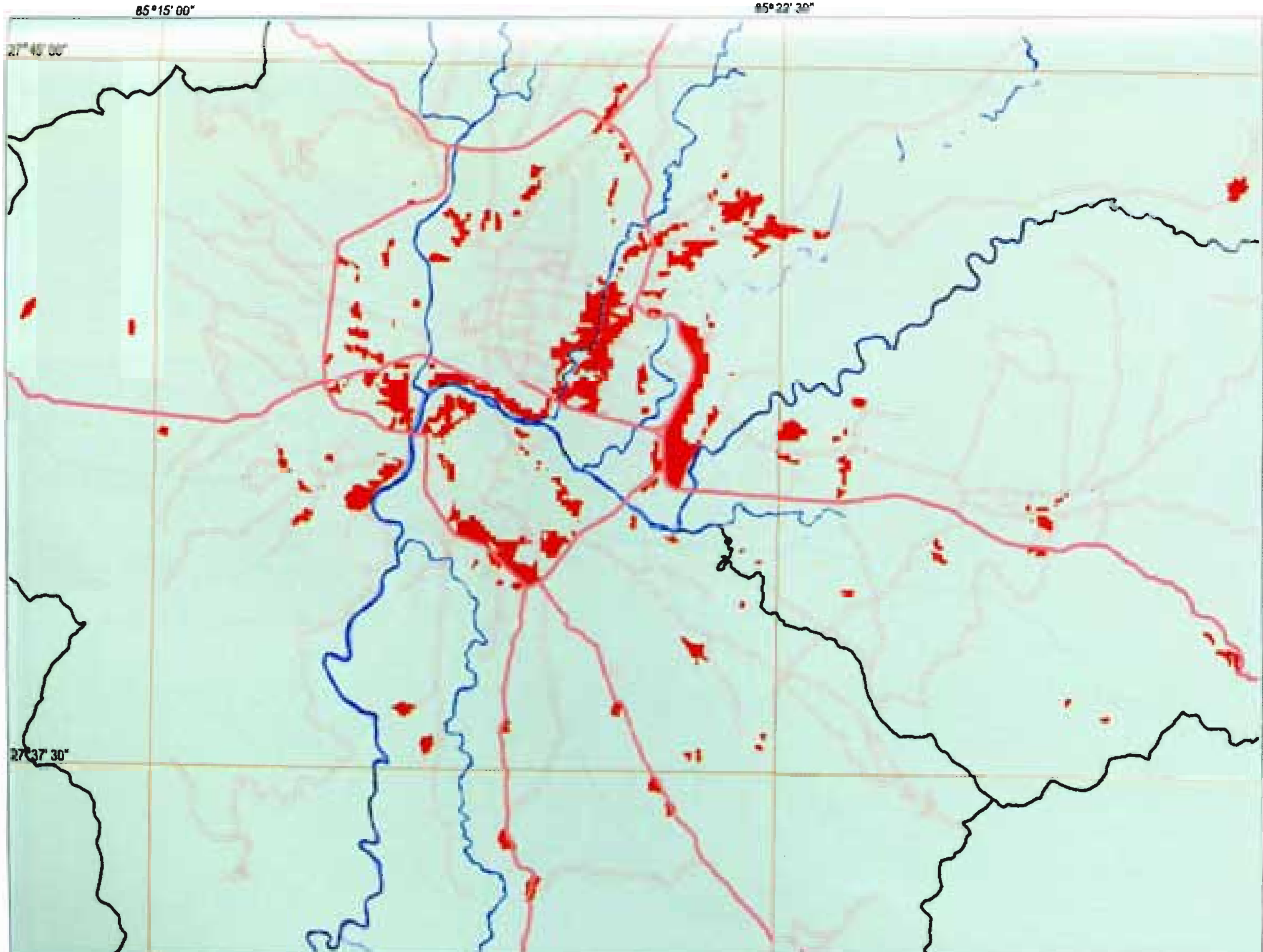
Land Cover Changed on Merged SPIN-2 with SPOT XS, 1986 and AVNIR, 1997 Image

Legend

- Built-up to Built-up
- Others to Built-up
- Forest to Others
- Forest to Forest
- Grass to Others
- Grass to Grass
- Shrub to Others
- Shrub to Shrub
- Agriculture to Others
- Agriculture to Agriculture
- Others

2 0 2 Kilometres

ICIMOD
MENRIS '99



Kathmandu Valley

Map 51
Urban Growth between 1978-1995

Legend

- Urban Growth
- Sandy Area
- Water Body
- Highway
- Major Road
- District Boundary

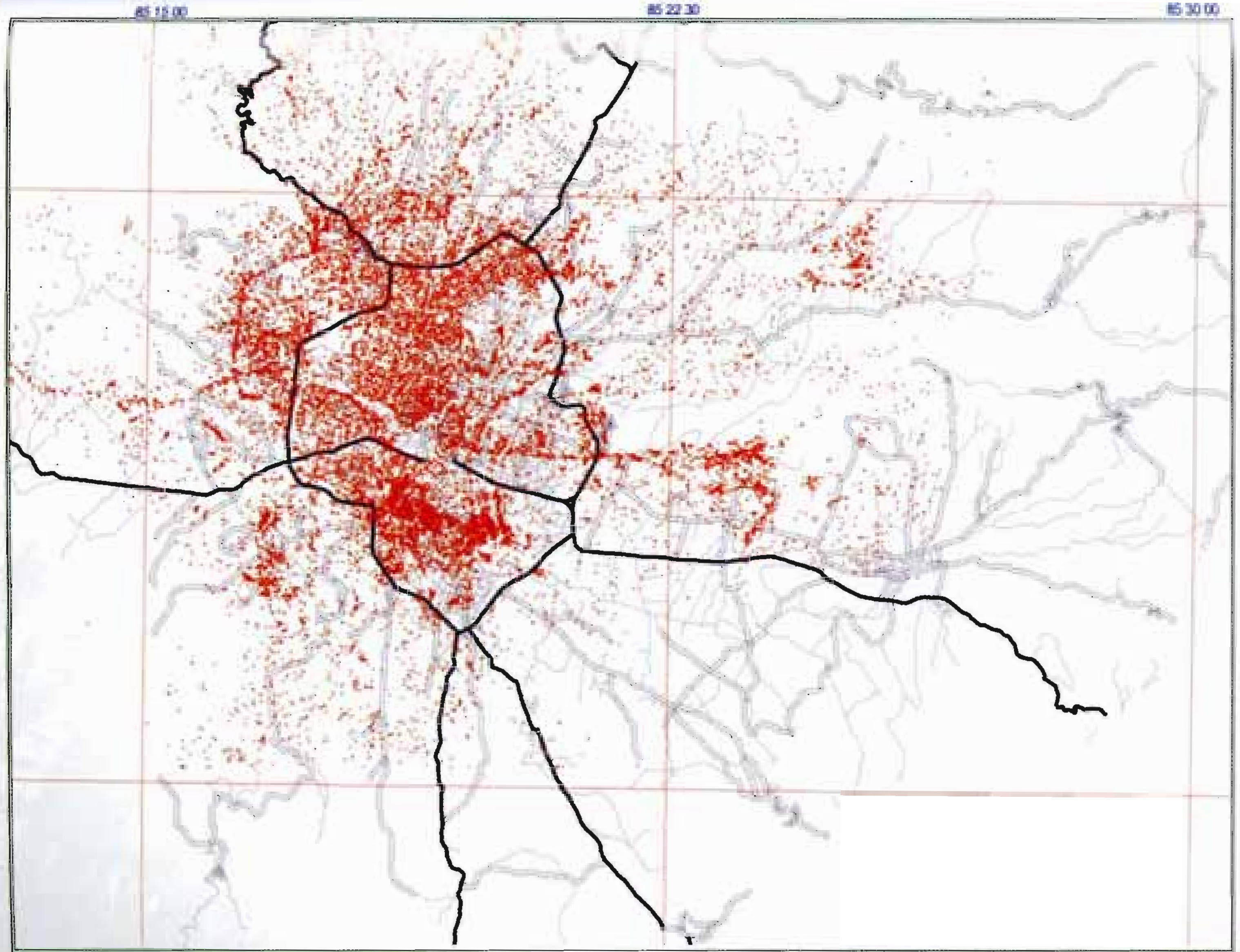
Value	Count	Area_Sq.Km.
1	91499	9.15

2 0 2 Kilometres
Scale 1:100,000

Analysis Based on Land Cover From 1978/79 and 1995
Output Resolution: 10m
Source: LRMP, 1978/79, and Topographic Map, 1995
Scale: 1:50,000 (LRMP); 1:25,000 (Topographic map)
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

ICIMOD
MENRIS '99

Kathmandu Valley GIS Database



Kathmandu Valley

Map 52

Urban Growth between 1988 - 1997

Legend

- Urban Growth
- Highway
- Major Road

Value	Count	Area in Sq.Km.
1	25266	22.8

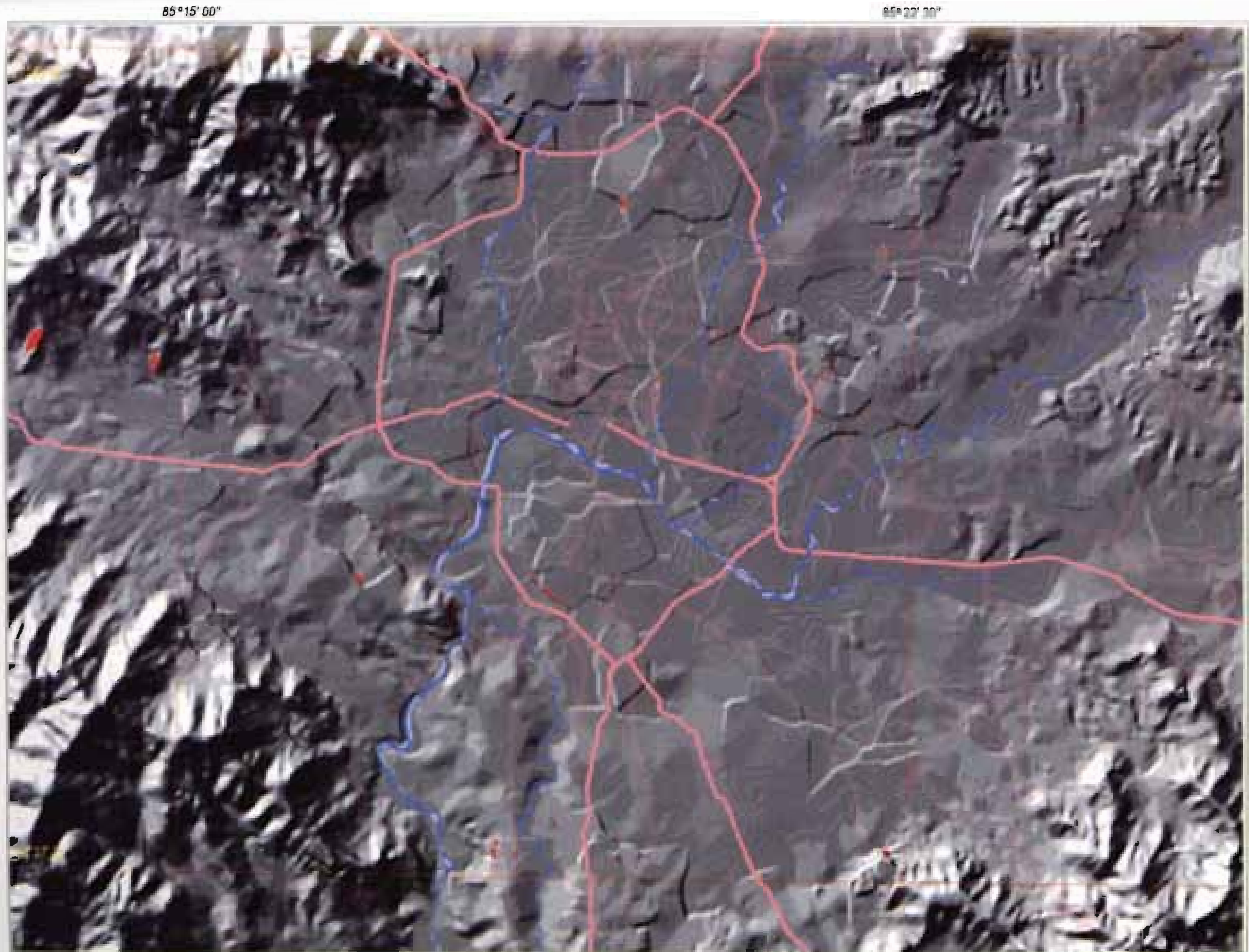
2 0 2 Kilometres

Scale: 1:125,000

Analysis Based on Landsat-TM '88 (30m) and ADEOS-AVNIR '97 (16m) Image
Geo-referenced to: UTM
Spheroid: Everest
Zone: 45, Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

ICIMOD
MENRIS '99



Kathmandu Valley

Map 53
Hazard-prone Urban Growth between 1978-1995

Legend

- Hazard-prone Urban Growth
- Sandy Area
- Water Body
- Highway
- Major Road

Value	Count	Area_Sq.M.
1	2174	217400

2 0 2 Kilometres

Scale 1:90,000

Analysis Based on Land Cover Data From 1995 and DEM
Output Resolution: 10m
Source: Topographic Map, 1995
Scale: 1:25,000 (Topographic map)
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

ICIMOD
MENRIS '99

8.4 Potential of GIS Application III: Suitability Analysis

GIS tools and techniques can be used to perform the complex spatial analyses that provide qualitative as well as quantitative assessments of current situations and trends. For instance, identifying suitable areas for locating new schools; identifying suitable areas for different types of agricultural commodities and vegetable farming; identifying suitable areas for locating carpet industries; identifying areas that should be encouraged for future urban expansion or which are not suitable for urban expansion, and so on.

The suitability analyses have been carried out on the basis of the Kathmandu Valley GIS database to demonstrate the potential of GIS applications in real life situations; and these have been categorised below. It is to be noted that the criterion for each suitability analysis varies depending upon experts' knowledge and their preferences and the status of the area. However, standard criteria have been defined for each analysis for demonstration purposes, and these may or may not be suitable for the whole of the Kathmandu Valley.

- **Agricultural land under the most unsuitable farming systems** (Maps 54 and 55) - This analysis identifies agricultural areas on high slopes that are normally not suitable for agricultural farming systems, but which could be useful for other purposes, e.g., forestation. In this study, the existing agricultural areas that have slopes of more than 30 degrees are considered under this class.

- **Land suitable for forestry and fruit framing** (Map 56) - This analysis identifies areas suitable for forestry and fruit farming – considering that these lands are not easily accessible to main roads and are not suitable for agriculture. In the study, the agricultural areas that are not irrigated, having slopes of more than five degrees and three kilometres away from the main road, are considered.

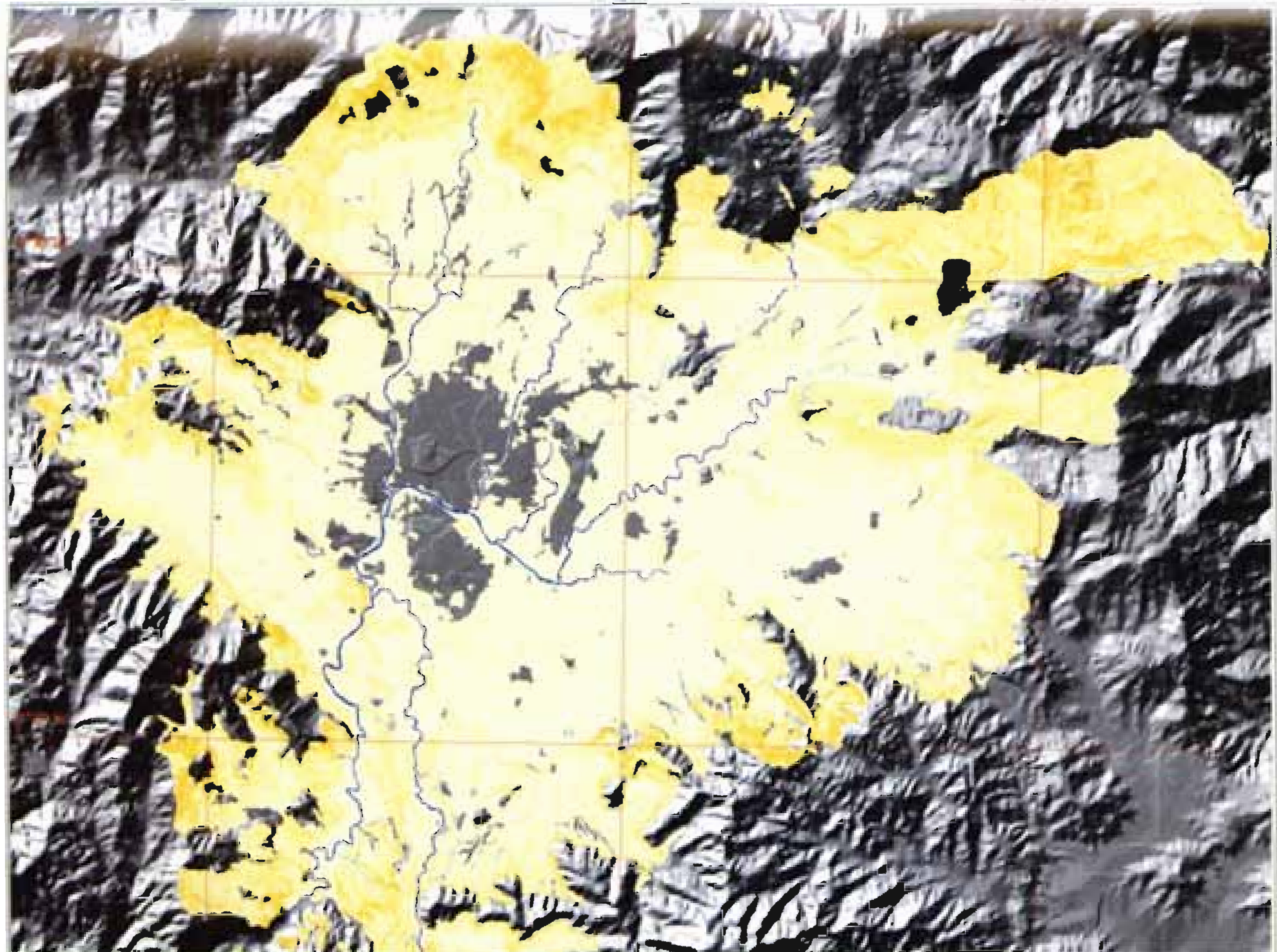
- **Land suitable for cereal and cash crops** (Map 57) - This analysis identifies areas that are suitable for cereal and cash crops – considering that these are prime agricultural areas close to main roads. In this study, such land is identified based on agricultural areas with slopes less than five degrees as prime land within two kilometres from the main roads.

- **Land suitable for non-arable crops** (Map 58) - This analysis identifies agricultural areas that are suitable for non-arable crops. Such land is available unirrigated agricultural areas with moderately sloping (> 5 degree) land not easily accessible from the main roads (4 km away from the main roads).

- **Areas suitable for carpet industries** (Map 59) - This analysis identifies areas that are suitable for locating carpet industries, considering that it is strictly prohibited to locate carpet industries within the core urban area (for instance, within the ring road area in this study). This analysis also considers other factors such as preference for low elevations (below 1,500 m), closeness to the riverside (within 100 to 500 metres) , and closeness to main roads (within one km from the main road). Field verification was carried out using a GPS to identify the existing carpet industries in the valley. This verification was overlaid with the area identified as suitable and the present existing carpet industries; thus showing present areas vs suitable areas for carpet industries.

- **Endangered Forest** (Map 60) - This analysis identifies the forests, except projected forests that are very close to existing settlments considering that these forests could be lost into some other land use types by the expansion of settlments. In this analysis, the existing forests within three kilometres from the settlements are identified as endangered forest.

List of Maps Prepared from Suitability Analysis



Kathmandu Valley GIS Database

Analysis Based on Land Cover Data From 1995 and DEM
Output Resolution: 10m
Source: Topographic Map, 1995
Scale: 1:25,000 (Topographic map)
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley

Map 54

Agricultural Lands by Slope Category, 1995

Legend

Agricultural Land by Slope Category (In Degrees)

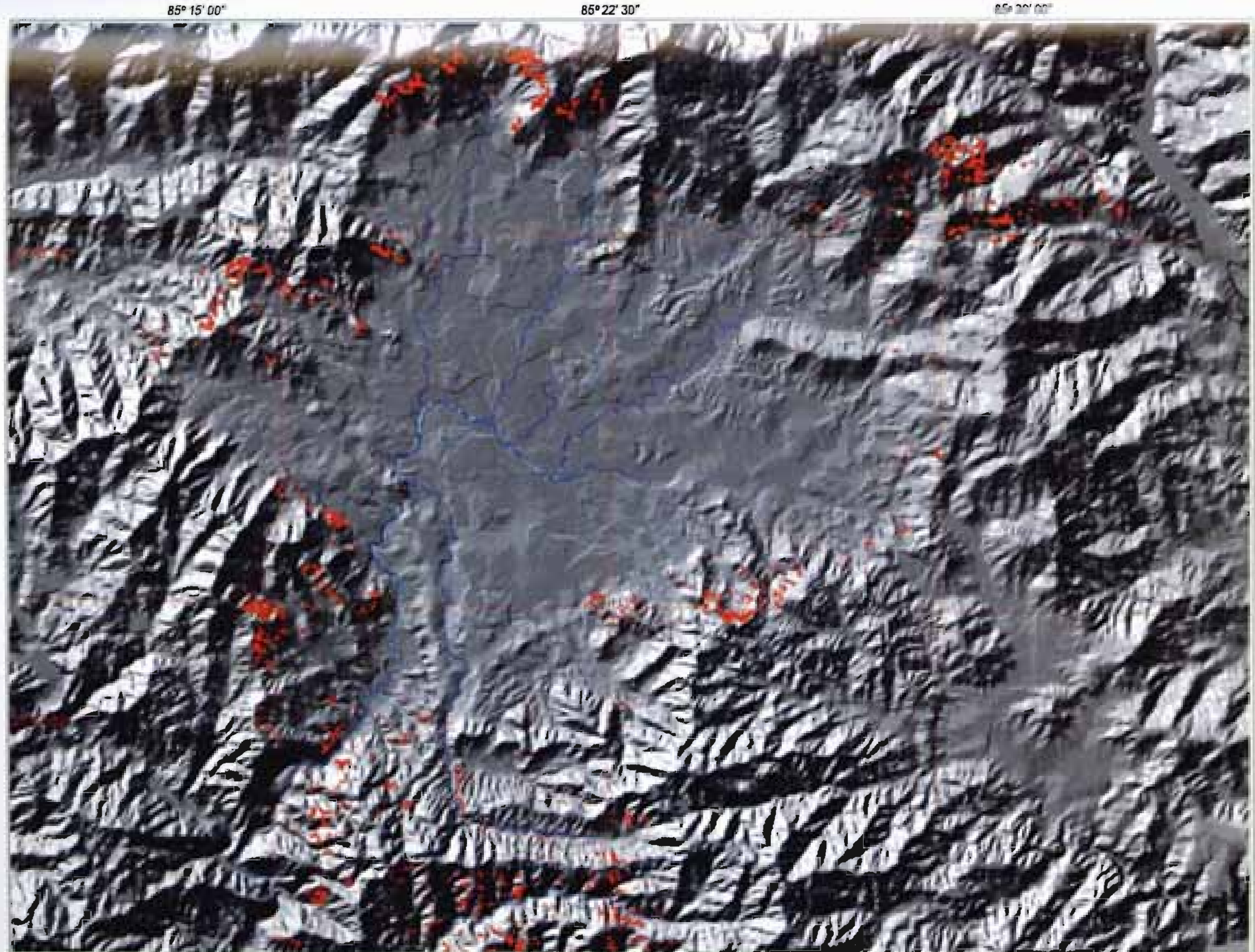
- Below 5
- 5 - 15
- 15 - 25
- 25 - 30
- 30 - 40
- 40 - 50
- 50 - 55
- 55 - 60
- Above 60
- Sandy Area
- Water Body

Value	Class	Area_Sq_Km
1	Below 5 deg	[illegible]
2	5 - 15 deg	[illegible]
3	15 - 25 deg	[illegible]
4	25 - 30 deg	[illegible]
5	30 - 40 deg	[illegible]
6	40 - 50 deg	[illegible]
7	50 - 55 deg	[illegible]
8	55 - 60 deg	[illegible]

2 0 2 Kilometers

Scale 1:160,000

ICIMOD
MENRIS '98



Kathmandu Valley

Map 55
Agricultural Lands under Most Unsuitable Farming Systems, 1995

Legend

- Unsuitable Farming Systems
- Sandy Area
- Water Body

Value	Count	Area Sq.Km
1	198640	20

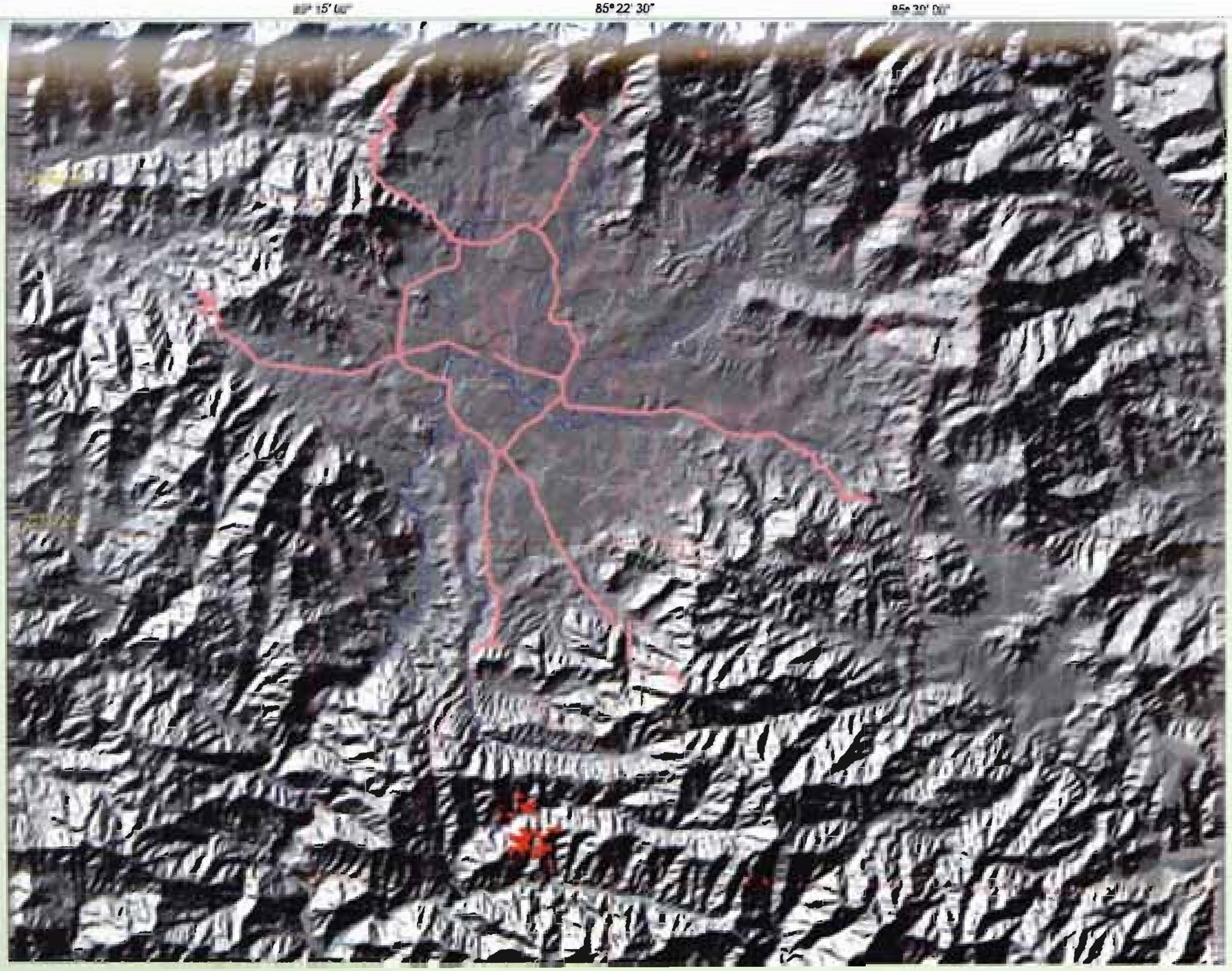
5 0 5 Kilometres

Scale 1:200,000

Analysis Based on Land Cover Data From 1995 and DEM
Output Resolution: 10m
Source: Topographic Map, 1995
Scale: 1:25,000 (Topographic map)
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

ICIMOD MENRIS '99



Analysis Based on Land Cover Data From 1995 and DEM
Output Resolution: 10m
Source: Topographic Map, 1995
Scale: 1:25,000 (Topographic map)
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

KATHMANDU VALLEY GIS DATABASE

KATHMANDU VALLEY

Map 56
Lands Suitable for Forestry and Fruit Farming, 1995

Legend

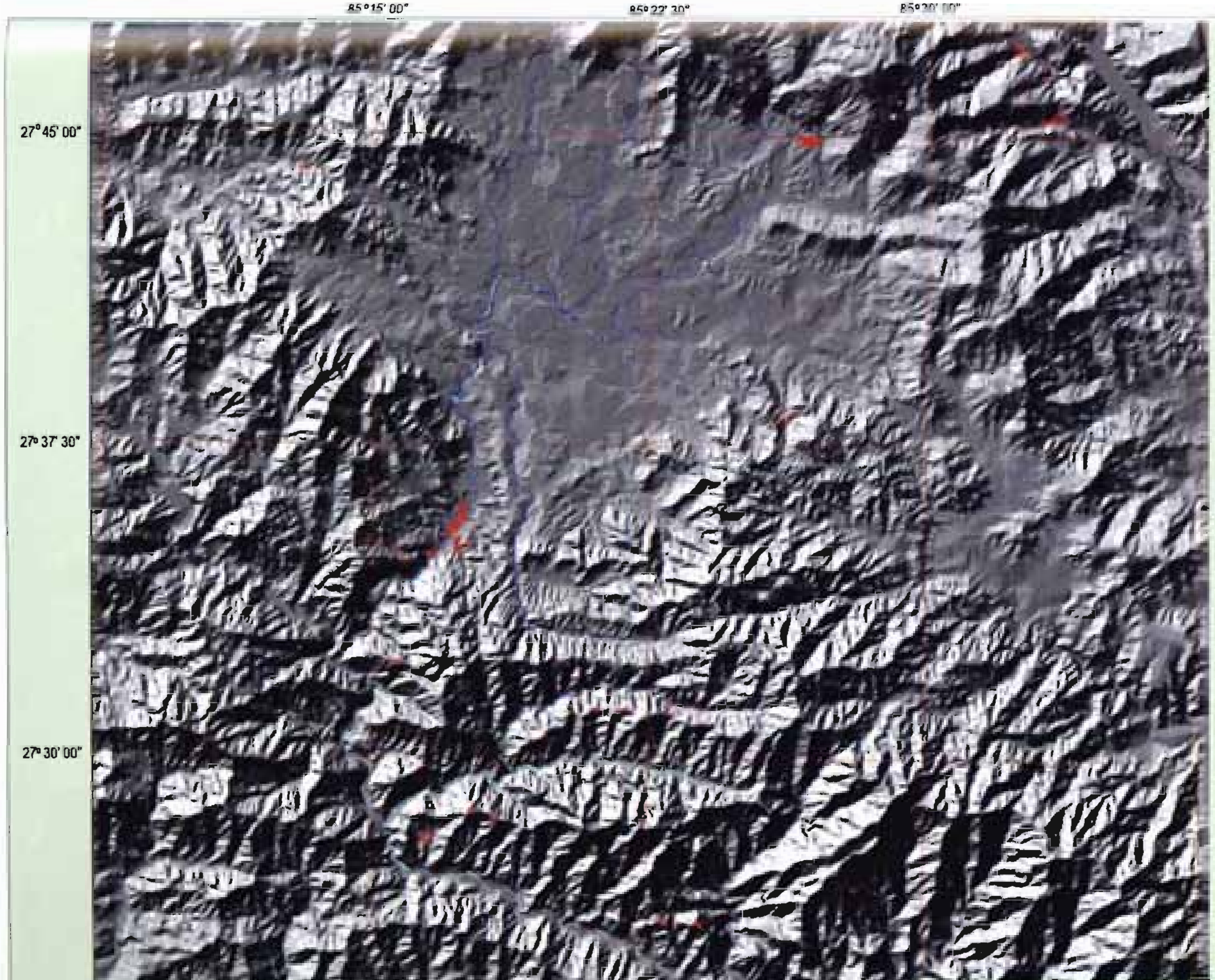
- Lands Suitable for Forest and Fruit Farmings
- Sandy Area
- Water Body
- Highway
- Major Road

Value	Count	Area_Sq.Km.
1	17354	1.7

4 0 4 Kilometres

Scale 1:225,000

ICIMOD
MENRIS 98



Analysis Based on Topographic Data From 1995 and DEM
Output Resolution: 10m
Source: Topographic Map, 1995
Scale: 1:25,000
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

Kathmandu Valley

Map 57
Land Suitable for Cereal and Cash Crops, 1995

Legend

- Land Suitable for Cereal & Cash Crops
- Sandy Area
- Water Body

Value	Count	Area in Sq.m.
1	26300	2630000

5 0 5 Kilometres

Scale 1:250,000

ICIMOD
MENRIS '99

KATHMANDU VALLEY

Map 58

Land Suitable for Non-arable Crops

Legend

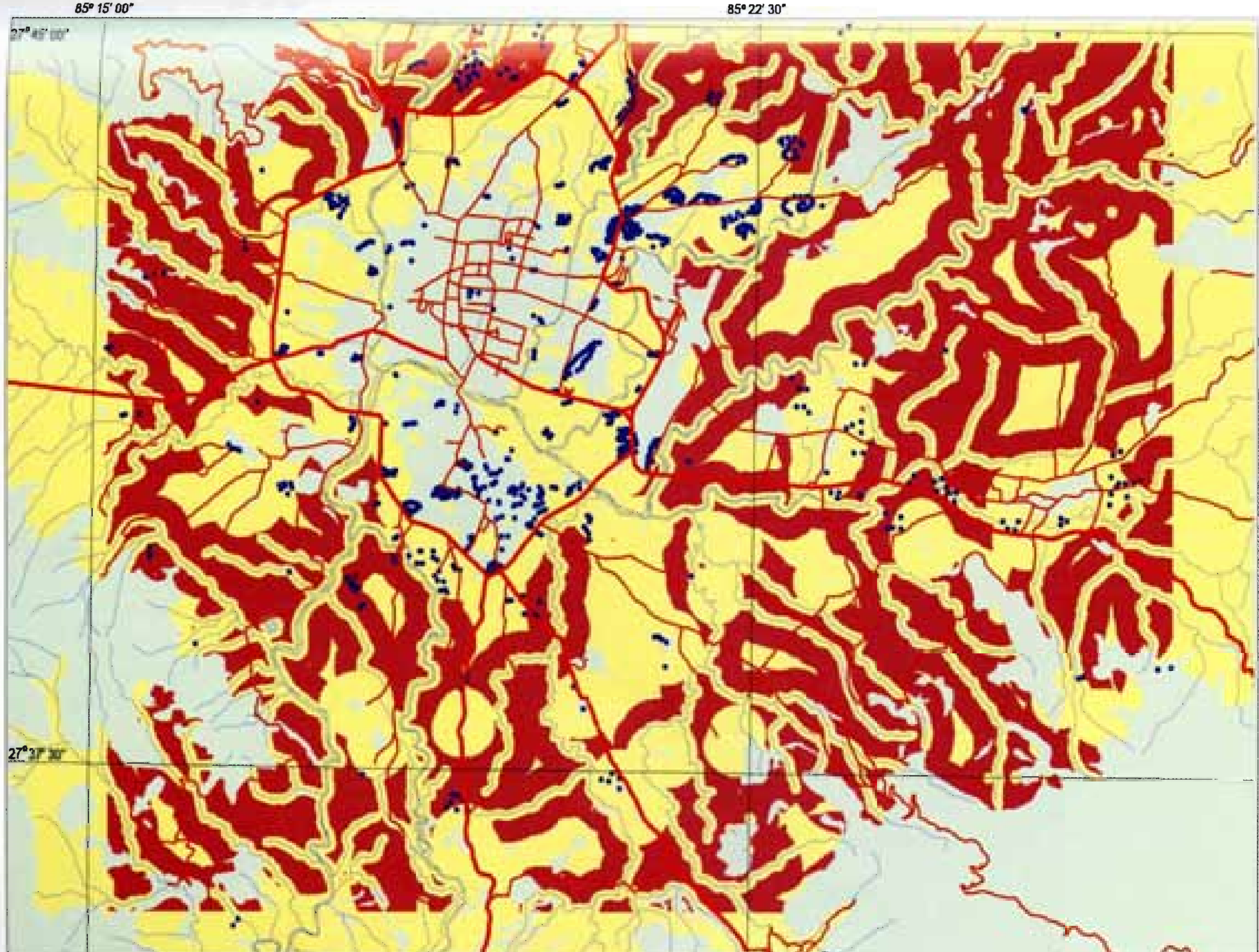
- Lands Suitable for Non-arable Crops
- Sandy Area
- Water Body
- Highway
- Major Road
- Feeder Road
- Foot Trails
- Minor Foot Trails

3 0 3 Kilometres

Analysis Based on Land Cover, 1995, and DEM
Output Resolution = 10m
Source: Topographic Map, 1995
Scale: 1:25,000
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

ICIMOD
MENRIS '99

KATHMANDU VALLEY GIS DATABASE



Kathmandu Valley

Map 59

Areas Suitable vs Existing Carpet Industries

Legend

- Highway
- Major Roads
- Rivers
- Existing Carpet Industries
- Area Suitable for Locating Carpet Industries
- Agricultural Area

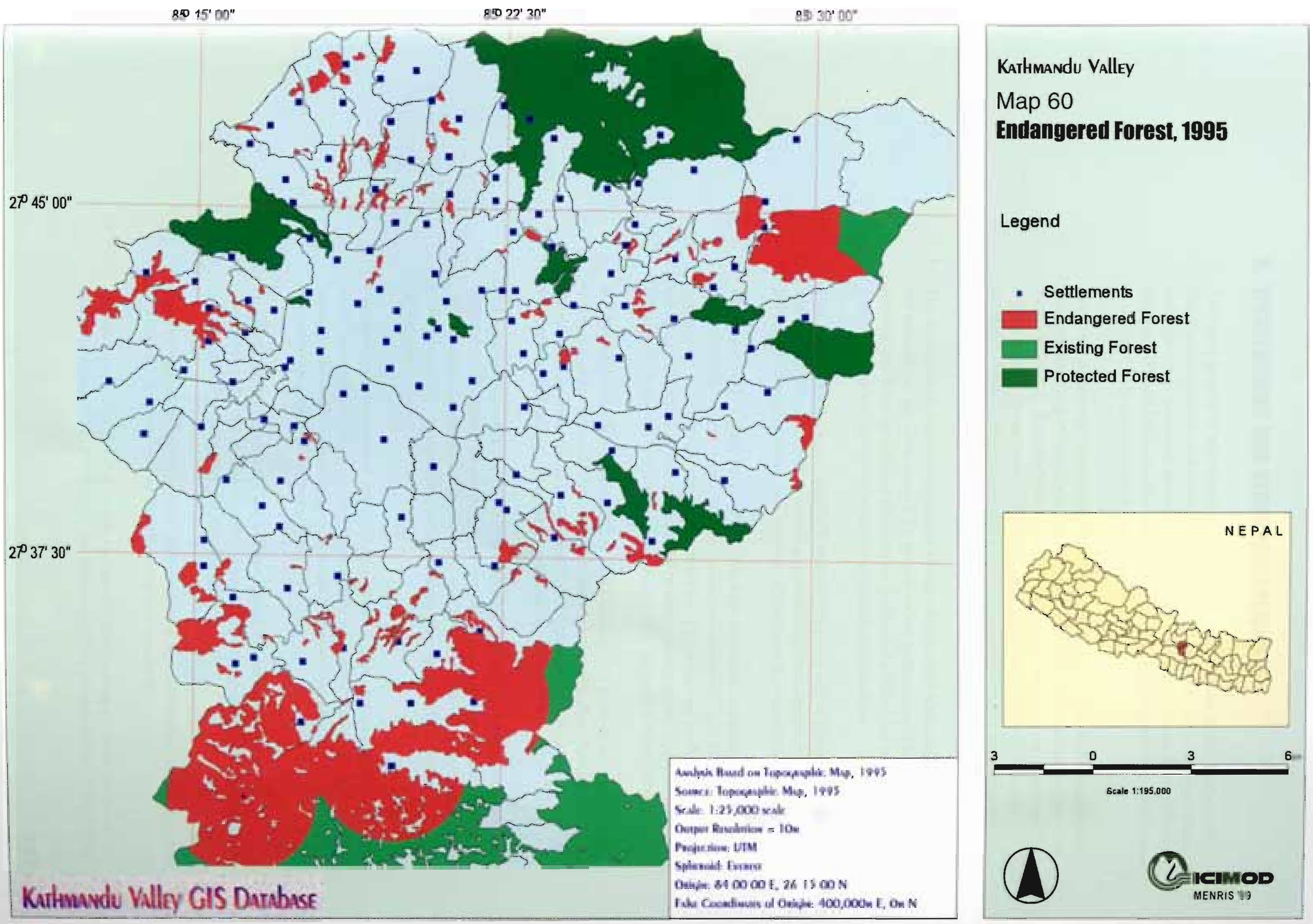
2 0 2 Kilometres

Scale 1:100,000

Analysis Based on Field Data and Land Cover Data, 1995
Source: Topographic Map, 1995
Scale: 1:25,000
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

ICIMOD
MENRIS '99


85° 15' 00"
85° 22' 30"
85° 30' 00"
27° 45' 00"
27° 37' 30"
Kathmandu Valley
Map 60
Endangered Forest, 1995
Legend
Settlements
Endangered Forest
Existing Forest
Protected Forest
NEPAL
3 0 3 6
Scale 1:195,000
ICIMOD
MENRIS '99
Analysis Based on Topographic Map, 1995
Source: Topographic Map, 1995
Scale: 1:25,000 scale
Output Resolution = 10m
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400,000m E, 0m N
Kathmandu Valley GIS Database