7. GIS DATABASE DESIGN AND DEVELOPMENT

Kathmandu Valley GIS Database integrated map data, satellite data, and secondary sources of data. The study attempted to integrate these divergent sources of data. To do so, it was essential to collect and compile spatial and non-spatial information from disparate sources and merge this information by using GIS. The study made extensive use of satellite imagery and specifically explored the use of high-resolution satellite imagery for urban environmental management. Thus, the study was able demonstrate the applicability of GIS and RS technologies to planning and management of the Valley. The advancement of space technology made it possible to look at the possibilities for using different satellite imagery to complement spatial data. Efforts were made to integrate attribute information from the Population Census 1991, e.g., aspects of demography and socioeconomic data.

Data for the topographic map (vector format) were organized into the database by digitising topographical maps; remote sensing data (raster format), i.e., satellite images and aerial photos, were organized into the database by means of image processing; and the non-spatial data (attribute information) were organized into a Relational Database Management System (RDBMS). The overall methodology employed is given in Figure 3.

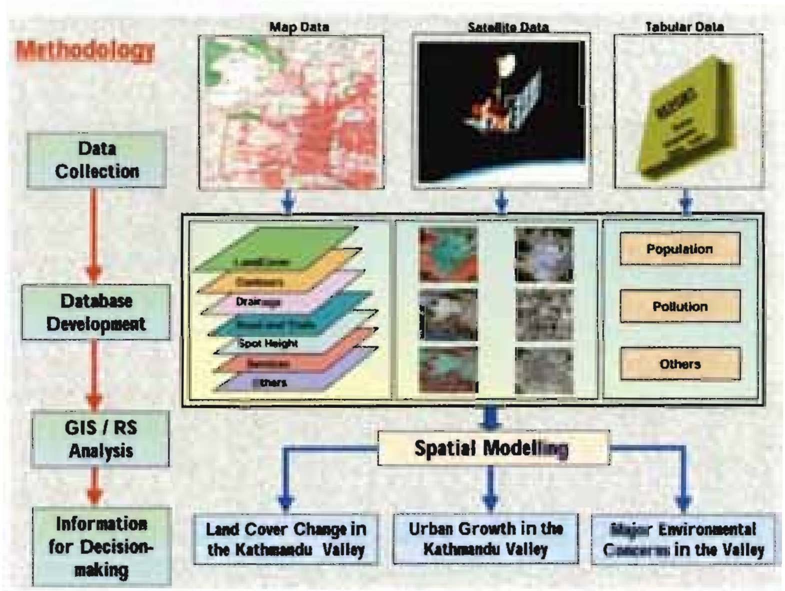


Figure 3: **Overall Methodology of GIS Database Development**

7.1 Topographic Database

For development of a GIS database of Kathmandu Valley, the following secondary sources of information were used.

- Topographic maps published by the Topographical Survey Branch, Department of Survey of Nepal on a scale of 1:25,000, 1992

- Maps published by the Land Resource Mapping Project (LRMP) on a scale of 1:50,000, 1978/79
- Socioeconomic data published by the Central Bureau of Statistics of Nepal, 1991

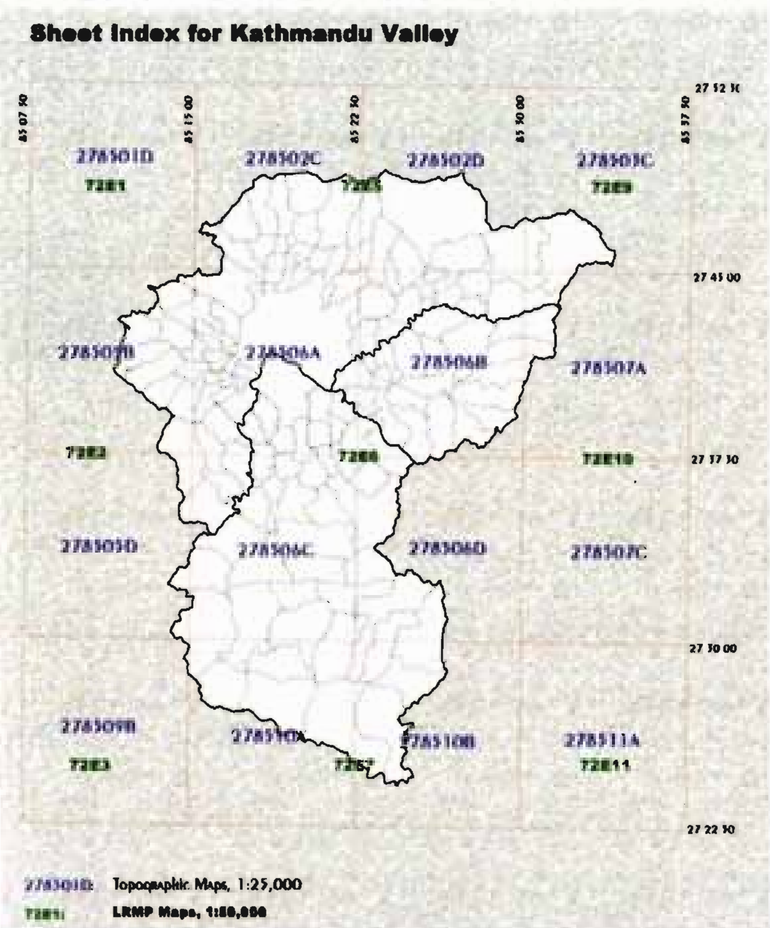


Figure 4: **Reference System for Topographic and LRMP Map Sheets**

Information from existing maps was extracted by manual digitisation using PC Arc/Info software Version 3.5. These maps were digitised sheet by sheet and joined on an IBM Workstation Computer using Arc/Info version 7.0.3 software. The reference system for the 1:25,000 scale maps produced by FINNMAP is shown in Figure 4 and, on the basis of this reference, all other thematic layers were extracted.

Information on land use, road and trails, drainage network, contours, settlements, spot heights, services, and administrative boundary was extracted from 1:25,000 scale topographic maps (1991); land use, land systems, and land capability were based on a 1:50,000 scale map published by LRMP (1978/79). Although the maps produced by LRMP were published in 1986, the aerial photographs used for the project were from 1978 and the field verification was carried out in 1982. Table 1 indicates the various themes of the topographic database of the Kathmandu Valley.

The methodology used for preparation of the topographic database of Kathmandu Valley is depicted in Figure 5.

Table 1: **List of the Topographic Database of the Kathmandu Valley**

Layers	Source	Scale	Date
Road Network	Topographic Map	1:25,000	1995
Drainage Network	Topographic Map	1:25,000	1995
Contours	Topographic Map	1:25,000	1995
Land Use/Cover	Topographic Map	1:25,000	1995
Services	Topographic Map	1:25,000	1995
Spot Heights	Topographic Map	1:25,000	1995
Land Use/Cover	Topographic Map	1:25,000	1995
Land Use/Cover	LRMP Map	1:50,000	1978/79
Land Capability	LRMP Map	1:50,000	1978/79
Land Systems	LRMP Map	1:50,000	1978/79

The details of these data layers, i.e., the data dictionary, are presented in Annex 2. The database thus developed was then applied to attain more knowledge by creating secondary layers, e.g., Elevation Zone, DEM (Digital Elevation Model), Slope, and Aspect, were derived from contours. The main topographic features and the derived data layers are briefly discussed below.

7.1.1 Contour/Spot Height

The digitised index contours at 20-metre intervals and supplementary contours at 10-metre intervals were interpolated using the TIN (Triangulated Irregular Network) module of Arc/Info 7.0.3 version software to derive a DEM of the Kathmandu Valley on a resolution of 10 metres. The derived DEM was, again, used to generate DTMs (Digital Terrain Models), e.g., Slope, Aspect, and Hillshade. The database included spot heights representing elevation (in metres) of particular locations, and these can be used as an alternative approach to interpolating surface to derive a DEM.

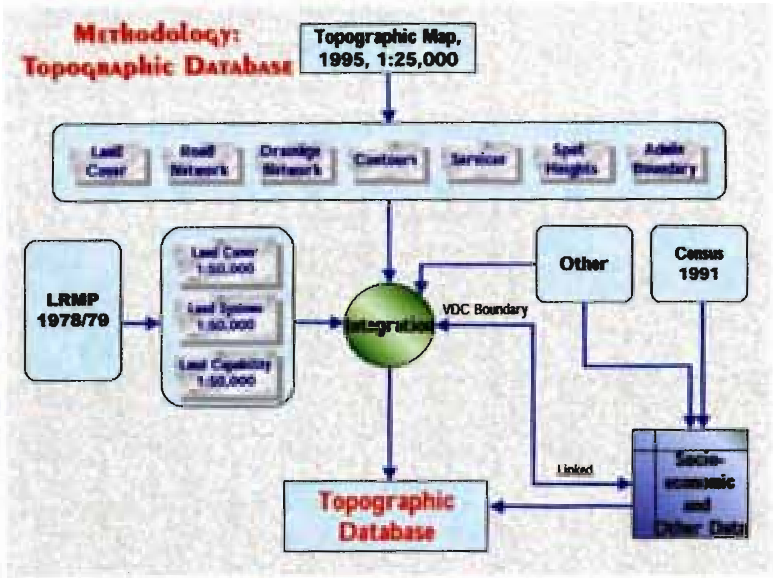


Figure 5: **Methodology Applied for the Preparation of a Topographic Database**

7.1.2 Road Network

The road network database contains the different types of roads in the Kathmandu Valley, and these have been entered in five categories.

Highway	Roads used mainly for travelling long distances.
Major Roads	Motorable paved roads mainly within urban areas.
Feeder Roads	Motorable unpaved roads
Foot Trails	Foot trails along which only light vehicles such as motor-cycles, cycles, etc. can pass.
Minor Foot Trails	Trails that are only for walking.

7.1.3 Drainage Network

The drainage database includes different types of rivers, such as river embankments, main rivers, seasonal rivers, sandy areas, and so on. Sample pictures of sources showing types of rivers in terms of water pollution were also integrated into the database. This was to show the potential integration of multimedia into the GIS database, giving the pictorial situation of each location.

7.1.4 Land Use and Land Cover (1:25K)

The database on land use and land cover was generated from a topographic map (1:25K) with the same categories of classification and some of the classes were generalised into standard classes for the purpose of analysis. So, the database includes both detailed and generalised classifications.

7.1.5 Location of Services

The database includes the location of 11 different types of service taken from a 1:25K topographic map, for example, hospitals, bus terminals, schools, and so on. This information can be used for planning infrastructure for basic services and network analysis.

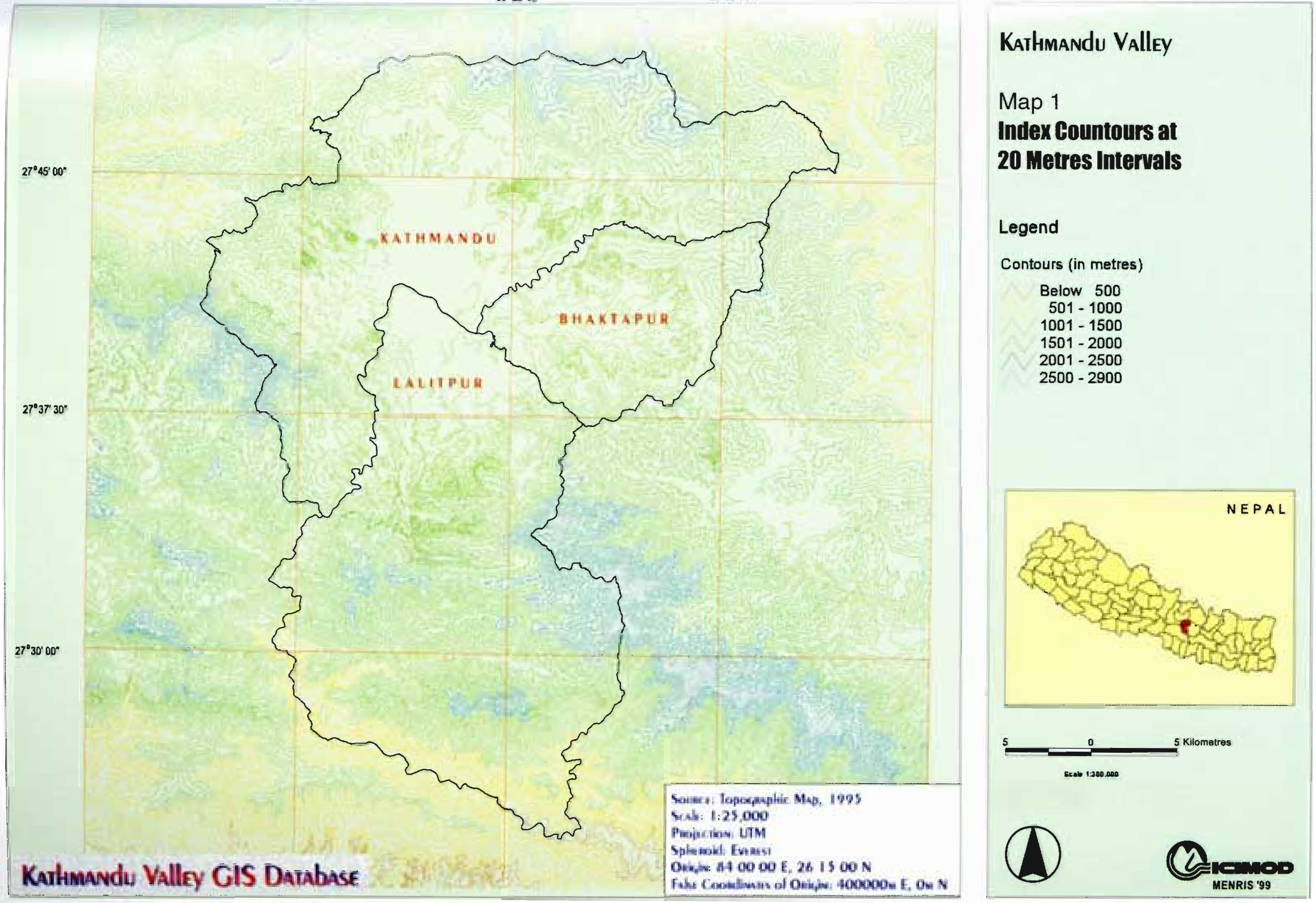
7.1.6 Land Use, Land Capability, and Land Systems (1:50K)

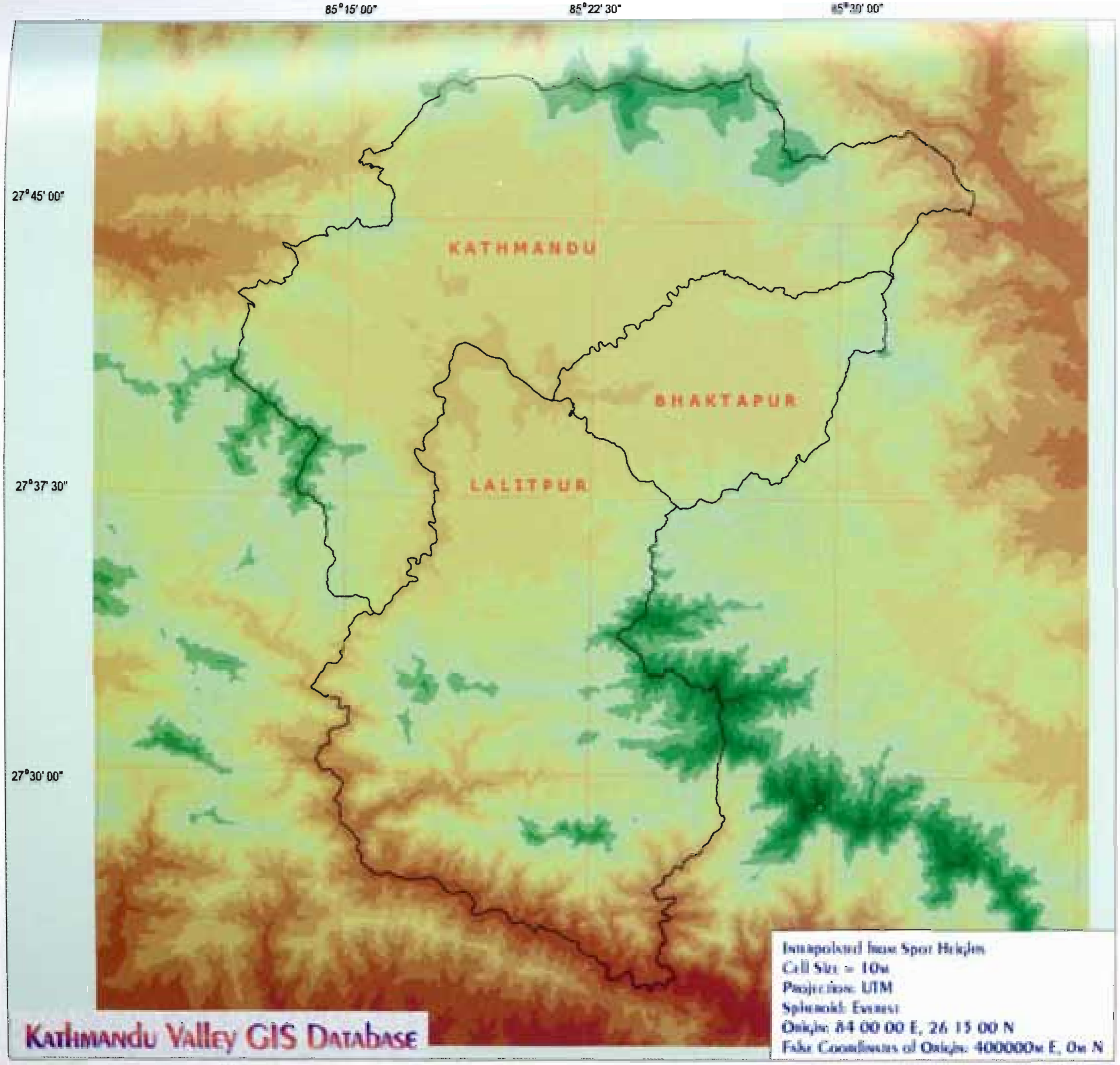
The database also includes information on land use/cover, land capability, and land systems. Maps published by the Land Resource Mapping Project (LRMP) on a scale of 1:50K were digitised for this purpose. For details, users may refer to the LRMP report published in 1986.

It is our observation that a database on this scale might suffice for natural resources and many environmental management applications, but such a database may not provide the right answers for application to specific urban or municipal environments. Maps on higher scales of 1:5,000 or above are not available for the entire valley. This is one of the reasons why we used high-resolution satellite imagery. However, efforts have been made to produce maps of the urban area of the Kathmandu Valley on higher scales of 1:2,000 through collaborative projects, e.g., Nepal Telecommunications (NTC) and Department of Water Supply and Sanitation (DWSS) and metropolitan area mapping by the Department of Survey (DoS). A list of other maps available (with potential new projects in the near future) of the valley from different sources is provided in Annex 3. We have no specific information about digital versions of these.

The following maps (Maps 1 - 14) were prepared from the spatially referenced database for spatial visualisation purposes.

List of Maps Prepared from Spatially Referenced Topographic Database


85° 15' 00"
85°22' 30"
85°30' 00"
27°45' 00"
27°37' 30"
27°30' 00"
KATHMANDU
BHAKTAPUR
LALITPUR
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 1
Index Countours at
20 Metres Intervals
Legend
Contours (in metres)
Below 500
501 - 1000
1001 - 1500
1501 - 2000
2001 - 2500
2500 - 2900
NEPAL
5
0
5 Kilometres
Scale 1:300,000
ICIMOD
MENRIS '99



Kathmandu Valley

Map 2
Elevation Zones

Legend

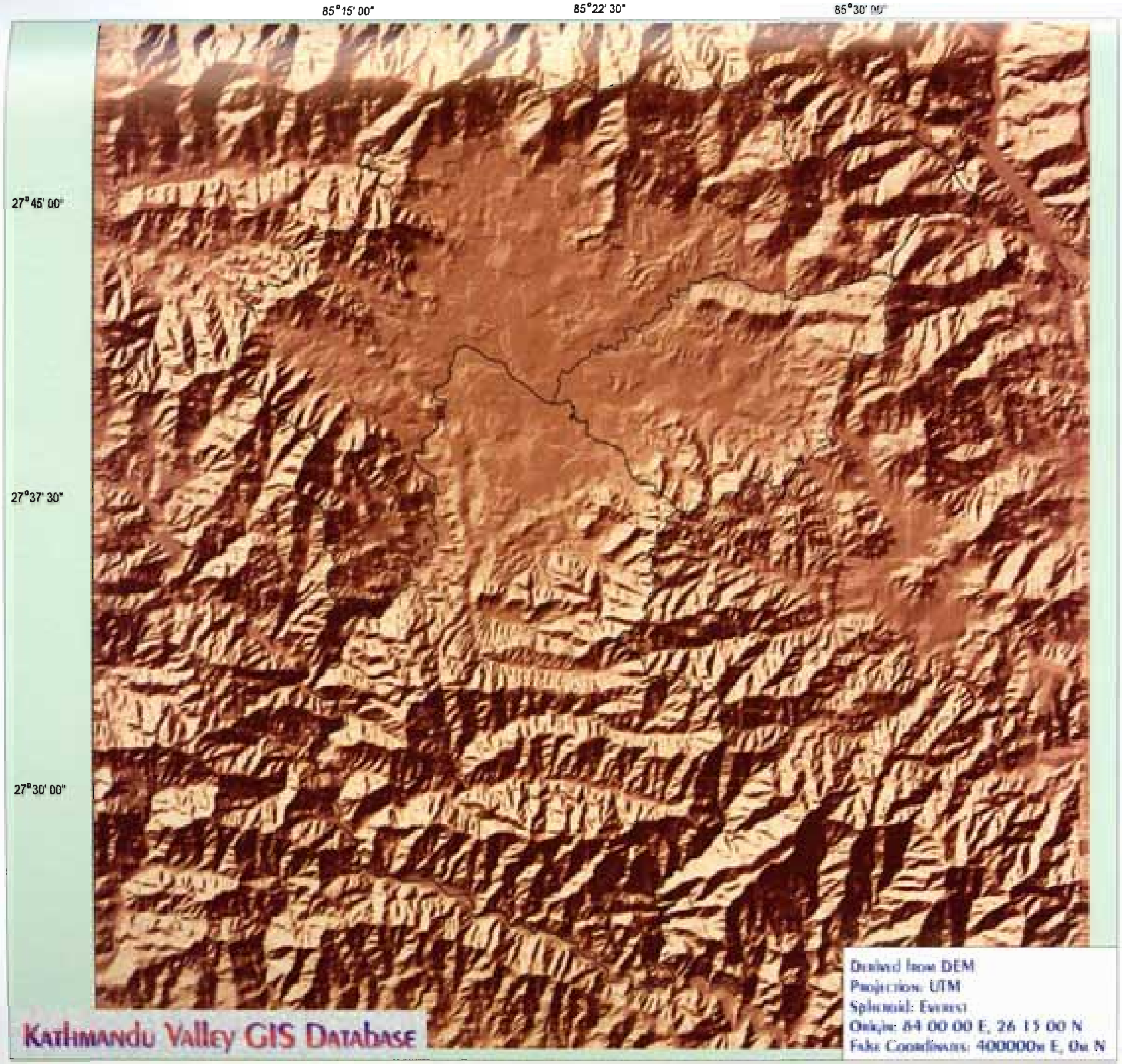
Elevation Zones (in metres)

300 - 500m
501 - 700m
701 - 900m
901 - 1100m
1101 - 1300m
1301 - 1500m
1501 - 1700m
1701 - 1900m
1901 - 2100m
2101 - 2300m
2301 - 2500m
2501 - 2700m
2701 - 2900m

5 0 5 Kilometres

Scale 1:300,000

ICIMOD
MENRIS '99



Kathmandu Valley

Map 3
Hill Shade of Digital Elevation Model (DEM)

Legend

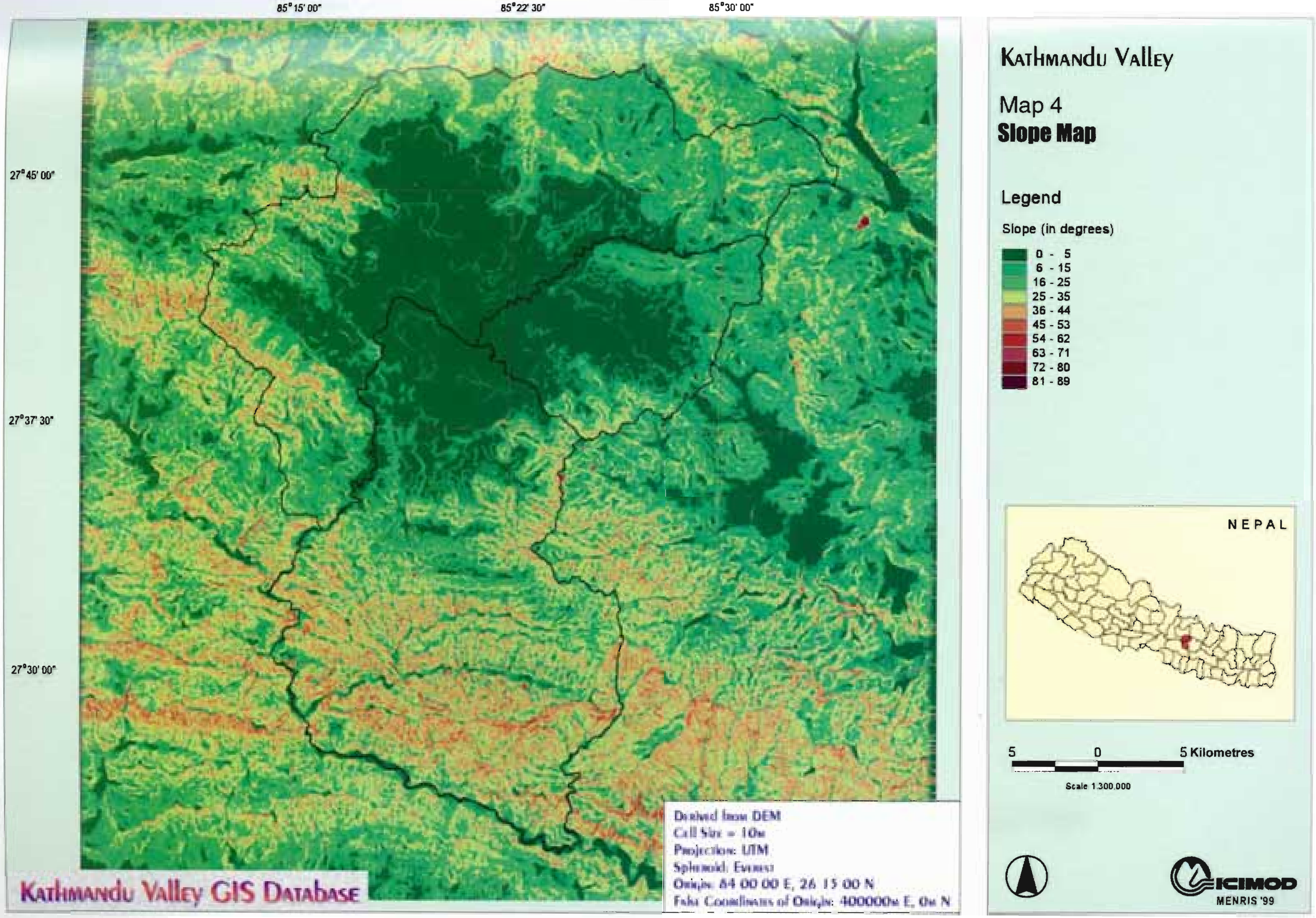
- Sandy area (4)
- Water body (5)

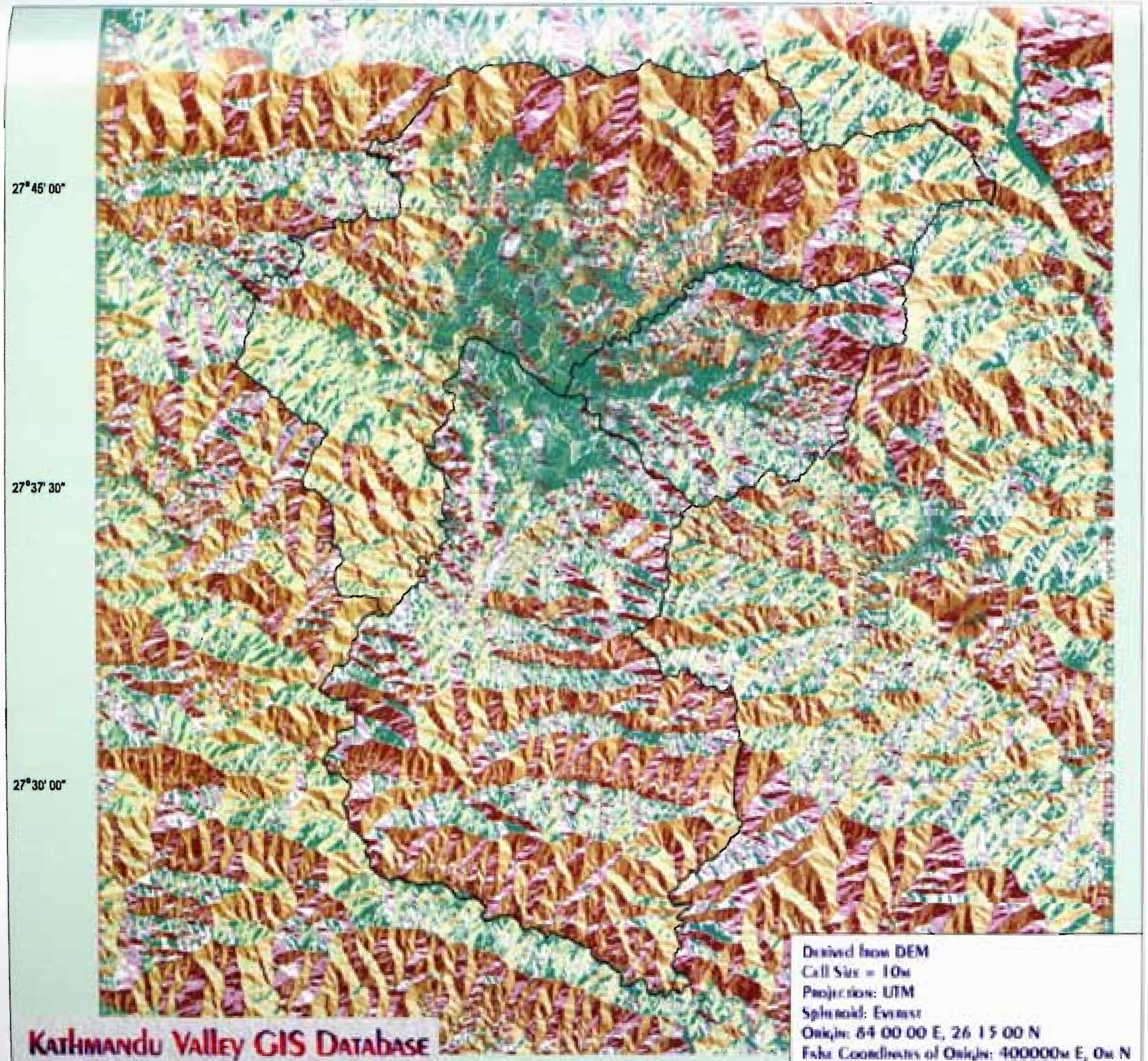
Azimuth = 315 deg.
Altitude = 45 deg.

5 0 5 Kilometres

Scale 1:300,000

ICIMOD
MENRIS '99


85°15' 00"
85°22' 30"
85°30' 00"
27°45' 00"
27°37' 30"
27°30' 00"
Kathmandu Valley GIS Database
Derived from DEM
Cell Size = 10m
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N
Kathmandu Valley
Map 4
Slope Map
Legend
Slope (in degrees)
0 - 5
6 - 15
16 - 25
25 - 35
36 - 44
45 - 53
54 - 62
63 - 71
72 - 80
81 - 89
NEPAL
5
0
5 Kilometres
Scale 1:300,000
ICIMOD
MENRIS '99



Kathmandu Valley

Map 5

Aspect Map

Legend

Aspects (in degrees)

- North 0 - 22.5, 337.5 - 361
- Northeast 22.5 - 67.5
- East 67.5 - 112.5
- Southeast 112.5 - 157.5
- South 157.5 - 202.5
- Southwest 202.5 - 247.5
- West 247.5 - 292.5
- Nortwest 292.5 - 337.5

5 0 5 Kilometres

Scale 1:300,000

ICIMOD

MENRIS '99

Kathmandu Valley

Map 6
Road Network

Legend

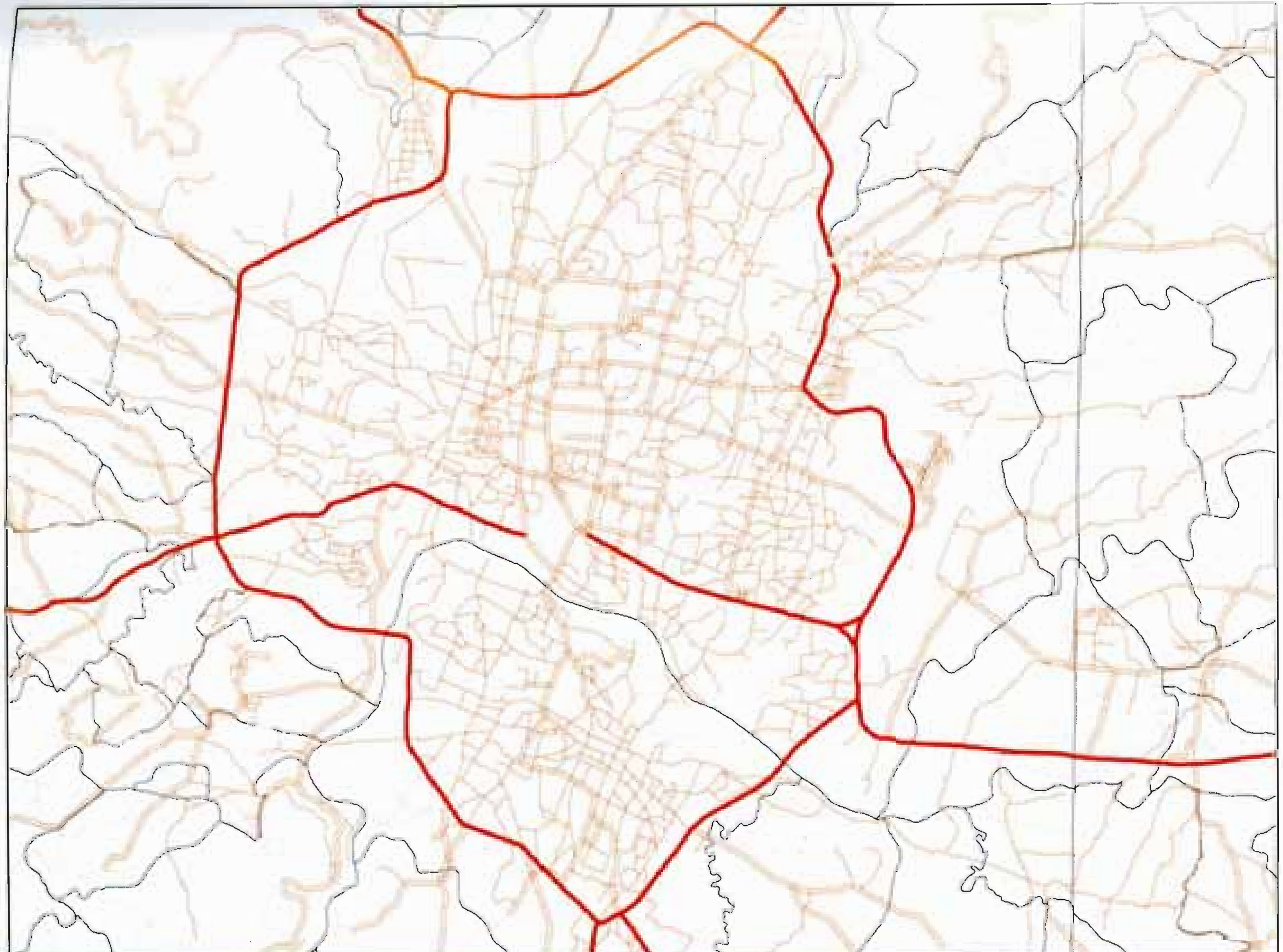
Road Types
- Highway
- Major Road
- Feeder Road
- Foot Trails
- Minor Foot Trails
- VDC Boundary

Road Type	Length (Km)
Highway	98.7
Major Road	435.7
Feeder Road	640.7
Foot Trails	304.3
Minor Foot Trails	2273.2

5 0 5 Kilometres

Scale 1:300,000

ICIMOD
MENRIS '99



Kathmandu Valley

Map 7
Road Network: Core Urban Area

Legend

Road Types
- Highway
- Major Road
- Feeder Road
- Foot Trails
- Minor Foot Trails
- VDC Boundary

Road Type	Length (Km)
Highway	98.7
Major Road	435.7
Feeder Road	640.7
Foot Trails	304.3
Minor Foot Trails	2273.

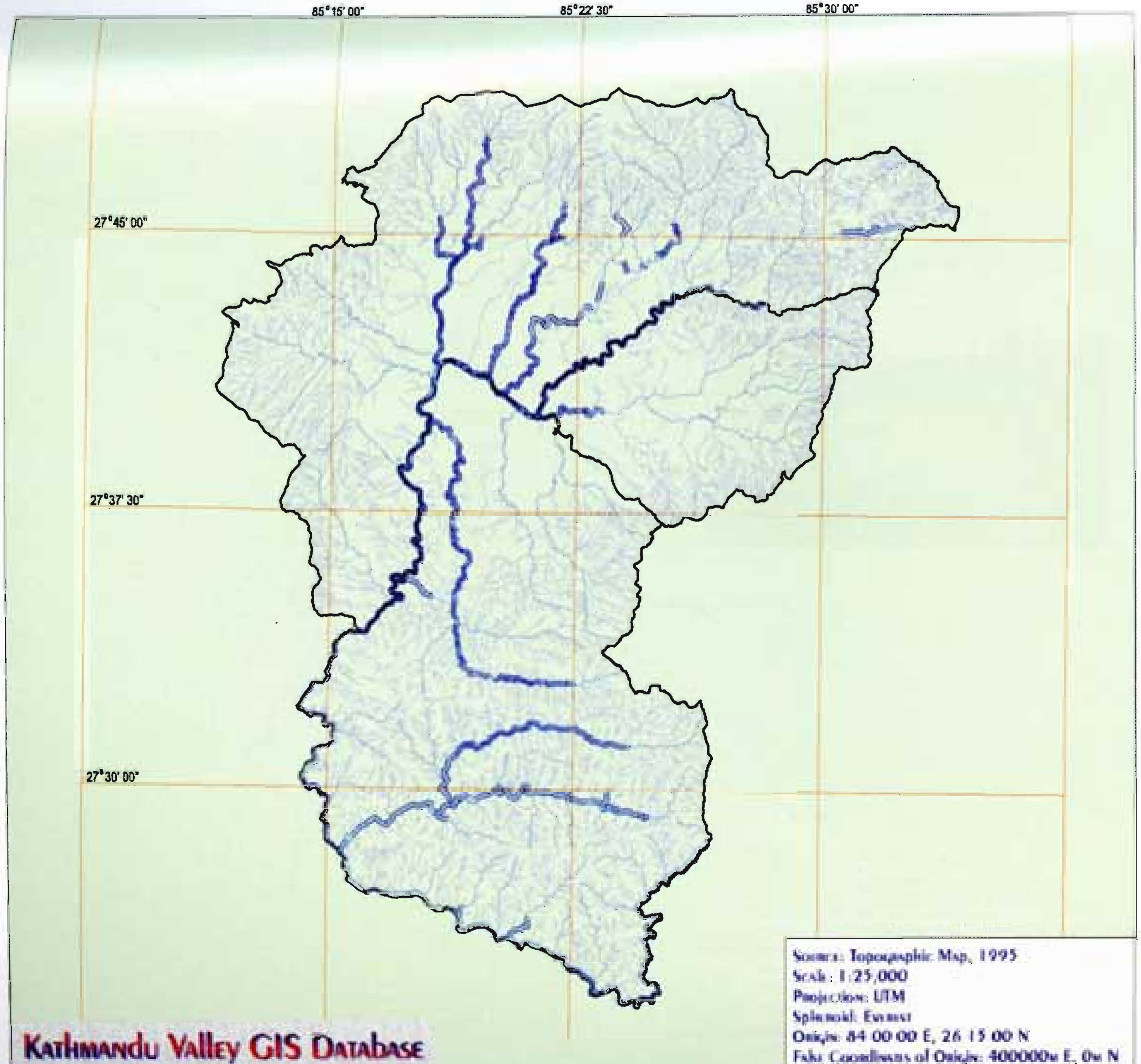
5 0 5Kilometres

Scale 1:300,000

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



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 8
Drainage Network

Legend

- River Banks
- Main Rivers
- Minor Rivers
- District Boundary
- Sandy Area
- Water Body

5 0 5Kilometres

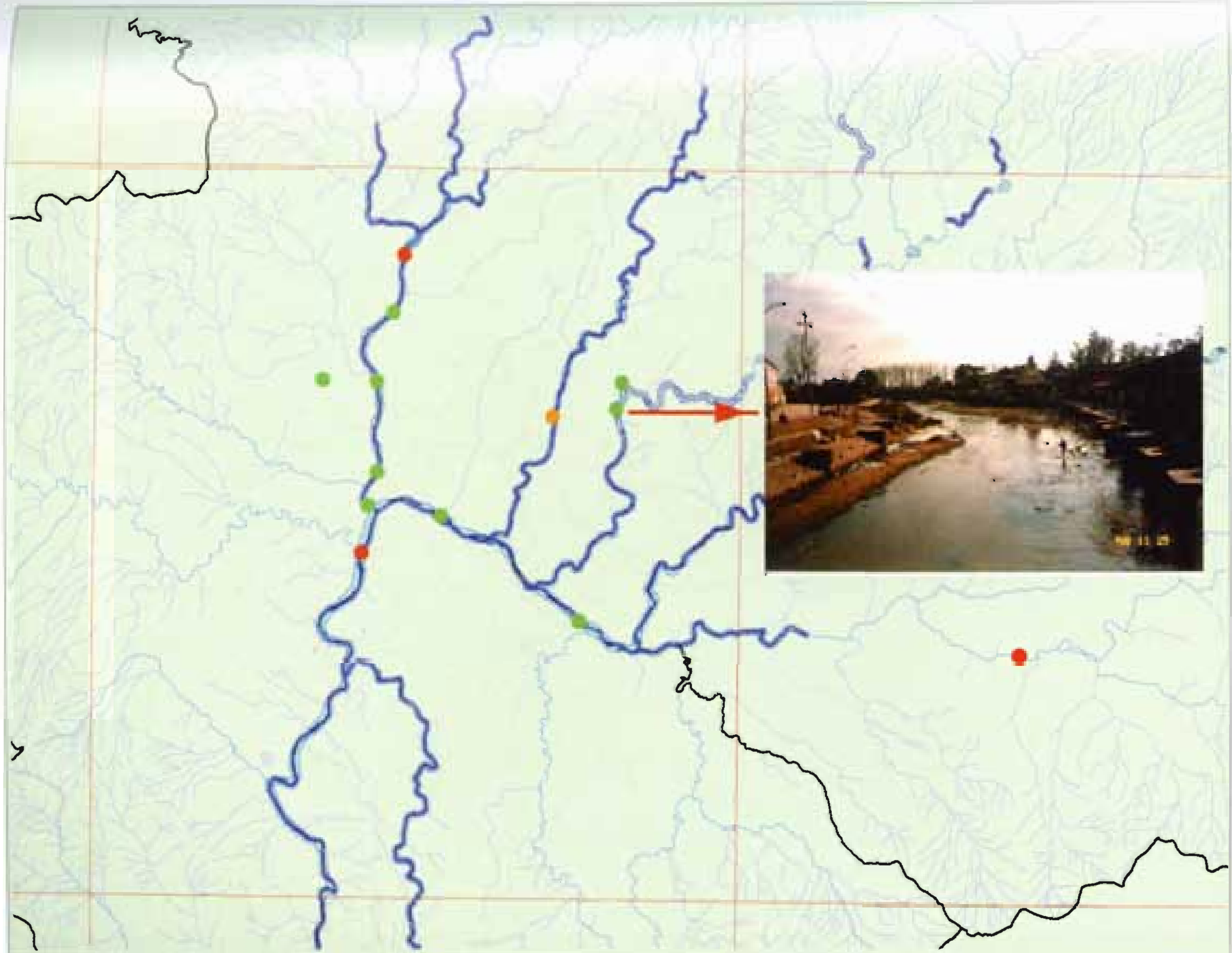
Scale 1:300,000

ICIMOD
MENRIS 99

Kathmandu Valley

Map 9

Sources and Types of River Water Pollution



Legend

- Industrial Water Pollution
- Sanitary Sewer Outfill
- Storm Sewer Outfill
- River Banks
- Main Rivers
- Minor Rivers
- District Boundary
- Sandy Area
- Water Body

2 0 2 Kilometres

1:100,000 scale

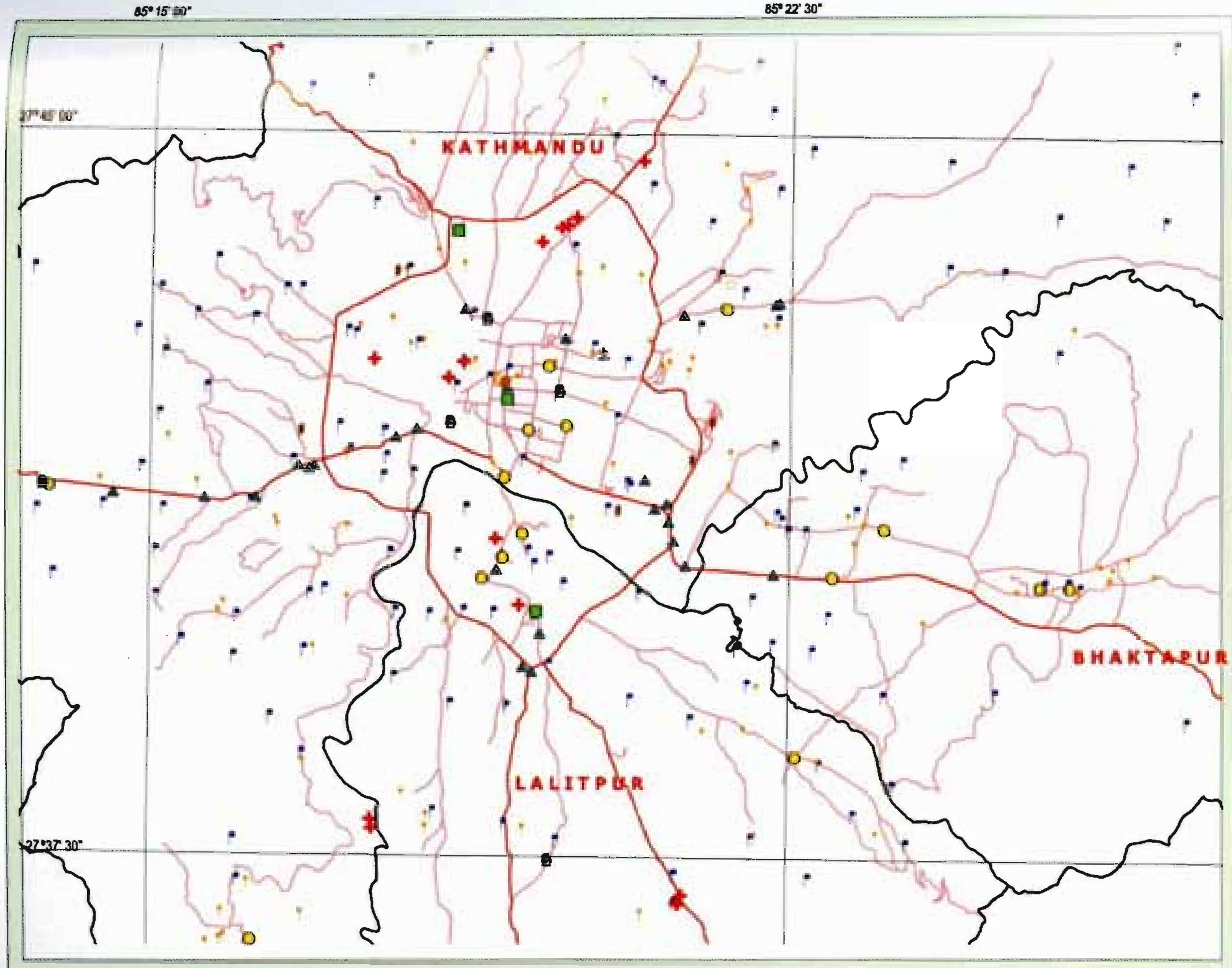
Source: Field Verification and Topographic Map, 1995
Scale: 1:25,000
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N
Field visit done by - Mr. T. M. Tamrakar, NPC
Photograph by - Mr. Anirudha M. Shrestha, ICIMOD

ICIMOD MENRIS '99

Kathmandu Valley GIS Database

Kathmandu Valley

Map 10
Location of Services



Legend

Services
- Bus Terminal
- Church
- Hospital
- Mani
- Mosque
- Others
- Petrol Pump
- Post Office
- School
- Temple/Stupa
- Transformer Station

Roads
- Highway
- Major Roads
- District Boundary

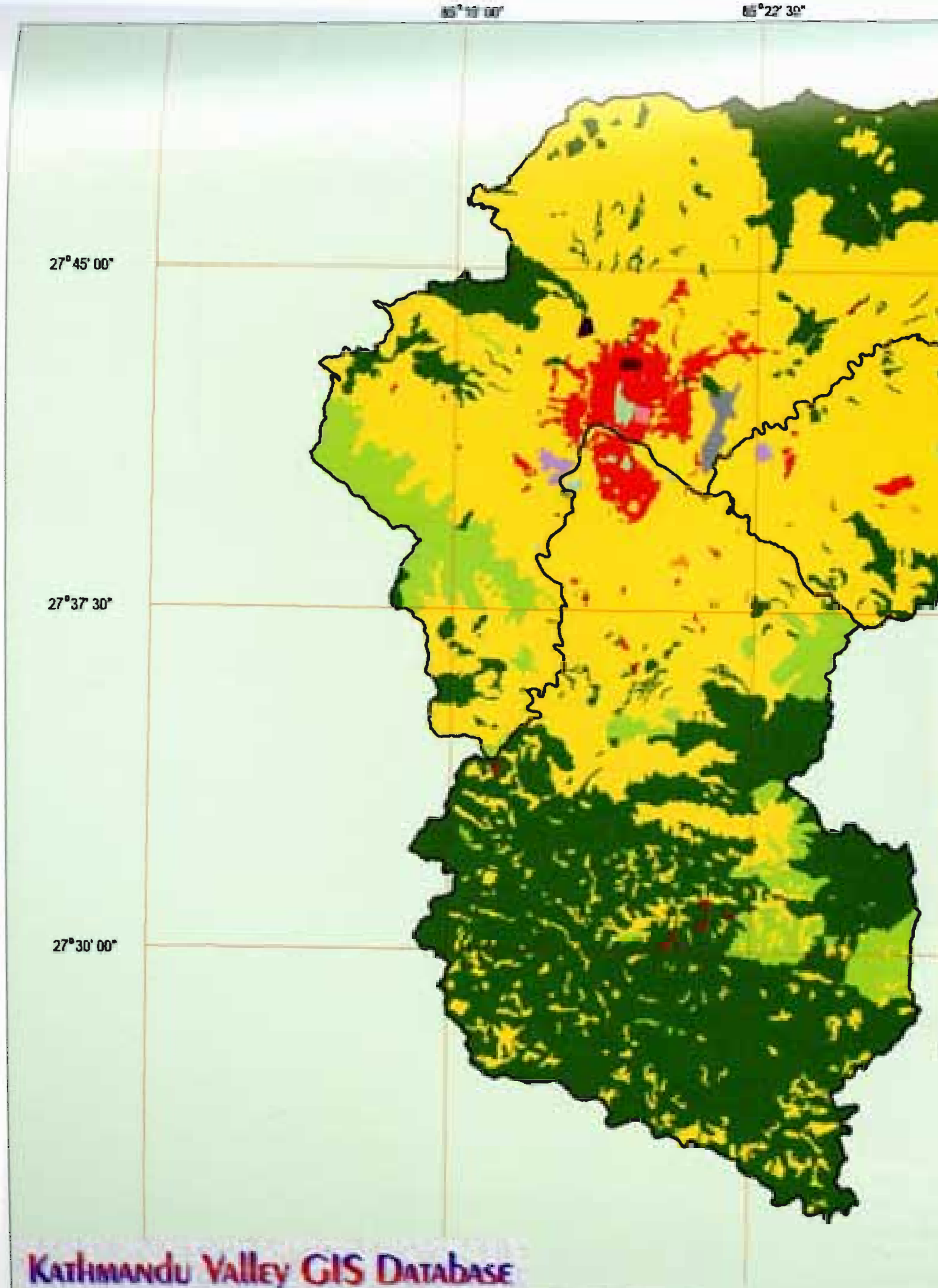
2 0 2 Kilometres

Scale 1:100,000

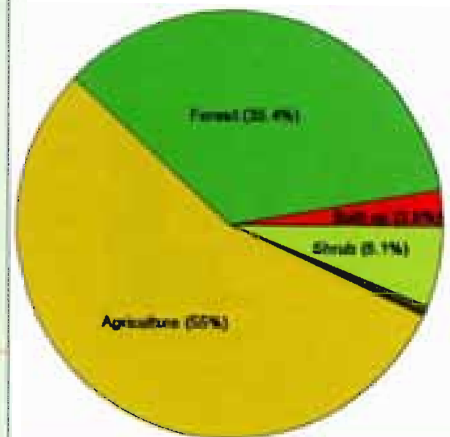
ICIMOD
MENRIS '99

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



Land Cover Chart of Kathmandu Valley, 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

Kathmandu Valley

Map 11
Land Cover Map, 1995

Legend

Land cover classes

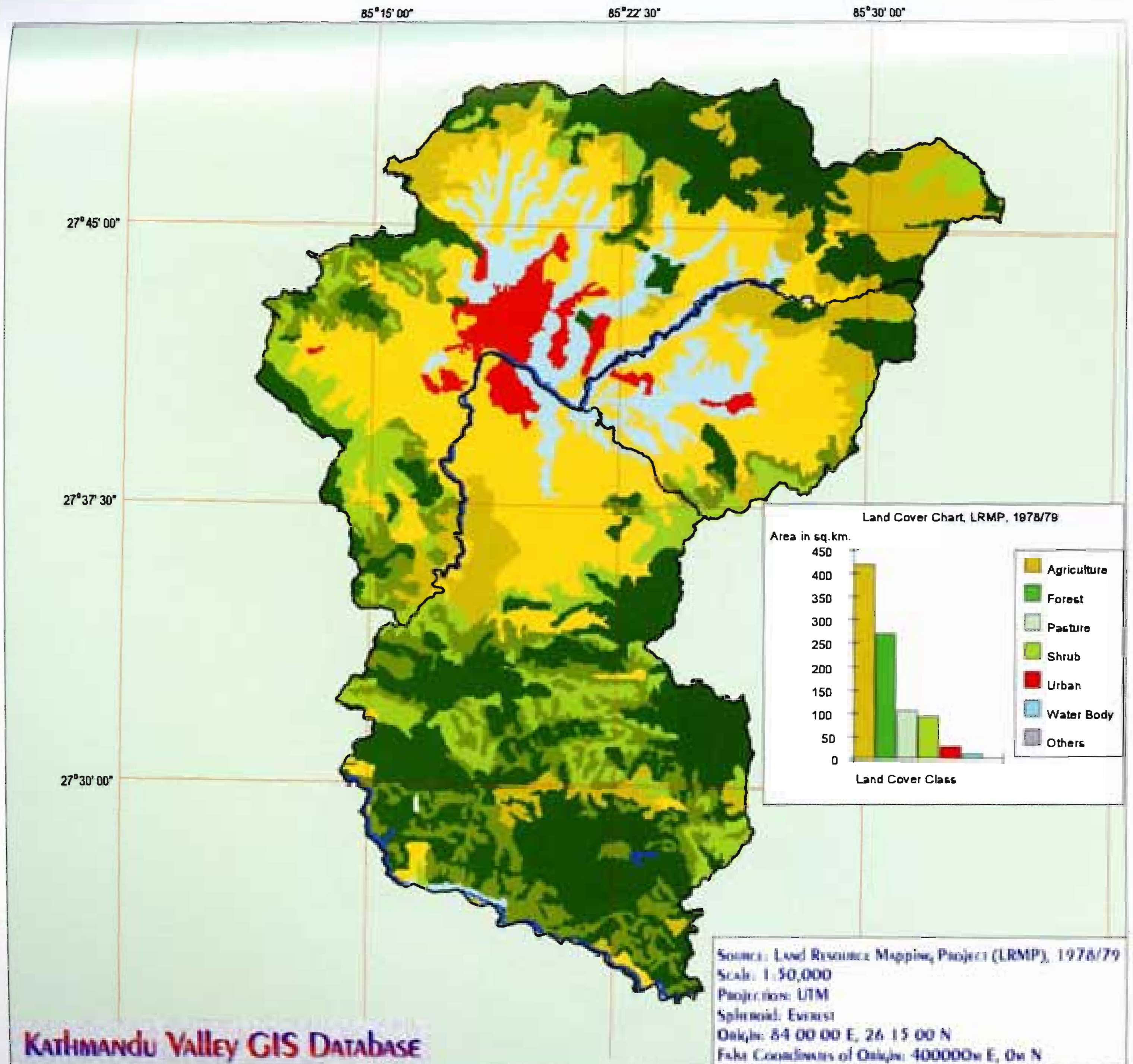
- Agriculture
- Airport
- Brick Factory
- Built-up
- Forest
- HMG Secretariat
- Industrial Area
- Institutional Area
- Open field
- Royal Palace
- Shrub Land
- Soil Cliff
- Water Body

Class	Area_SqKm	Percent
Built-up	24.4	[illegible]
Forest	[illegible]	35.4
Agriculture	[illegible]	55.[illegible]
Open Field	[illegible]	[illegible]
HMG Secretariat	0.4	[illegible]
Royal Palace	0.4	0.[illegible]
Water body	0.[illegible]	[illegible]
Institutional Area	1.[illegible]	[illegible]
Airport	[illegible]	[illegible]
Brick Factory	[illegible]	[illegible]
Industrial Area	0.4	[illegible]
Shrub Land	56.[illegible]	6.1
Soil Cliff	1.1	[illegible]

5 0 5 Kilometres

Scale 1:300,000

ICIMOD
MENRIS '99



Kathmandu Valley

Map 12
Land Cover, 1978/79

Legend

Land Use/Cover Class

- Forest
- Hillslope Level
- Pasture
- Water Body
- Shrub
- Tars, Alluvial Fans
- Urban
- Valley Floors

Class	Land Cover Class
Agriculture	4[illegible].6[illegible]08
Forest	268.5029
Pasture	105.1[illegible]1
Shrub	93.6138
Urban	[illegible]4.1439
Water Body	12.2368
Others	[illegible].6652

5 0 5Kilometres

Scale 1:300,000

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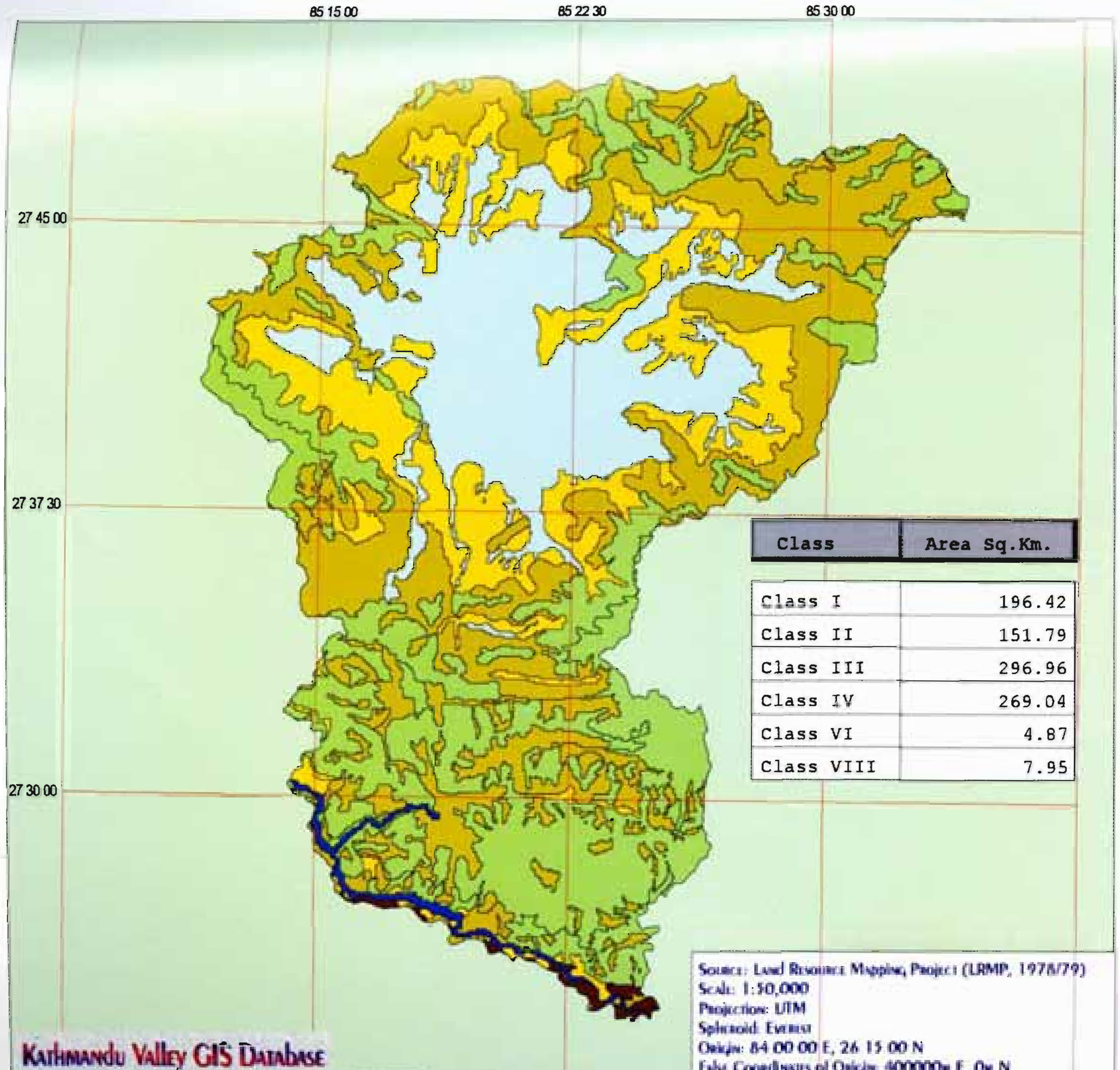
Kathmandu Valley

Map 13
Land Capability



Class	Area Sq.Km.
Class I	196.42
Class II	151.79
Class III	296.96
Class IV	269.04
Class VI	4.87
Class VIII	7.95

Source: Land Resource Mapping Project (LRMP, 1978/79)
Scale: 1:50,000
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Legend

- Class I: Slope nearly level (<1 deg.)
- Class II: Slope gentle (1-5 deg.) Soils: deep and well drained
- Class III: Slope: moderate to steep (5-30 deg.) Soils: 50-100cm deep, well drained
- Class IV: Slope: too steep for terracing (> 30 deg.) Soils: more tham 20cm deep, well to iperfectly drained
- Class VI: Slope: very steep (40-50 deg.) or varied slope (< 40 deg.) Soils: varried depth and drainage or < 20cm deep
- Class VIII: Riverbeds

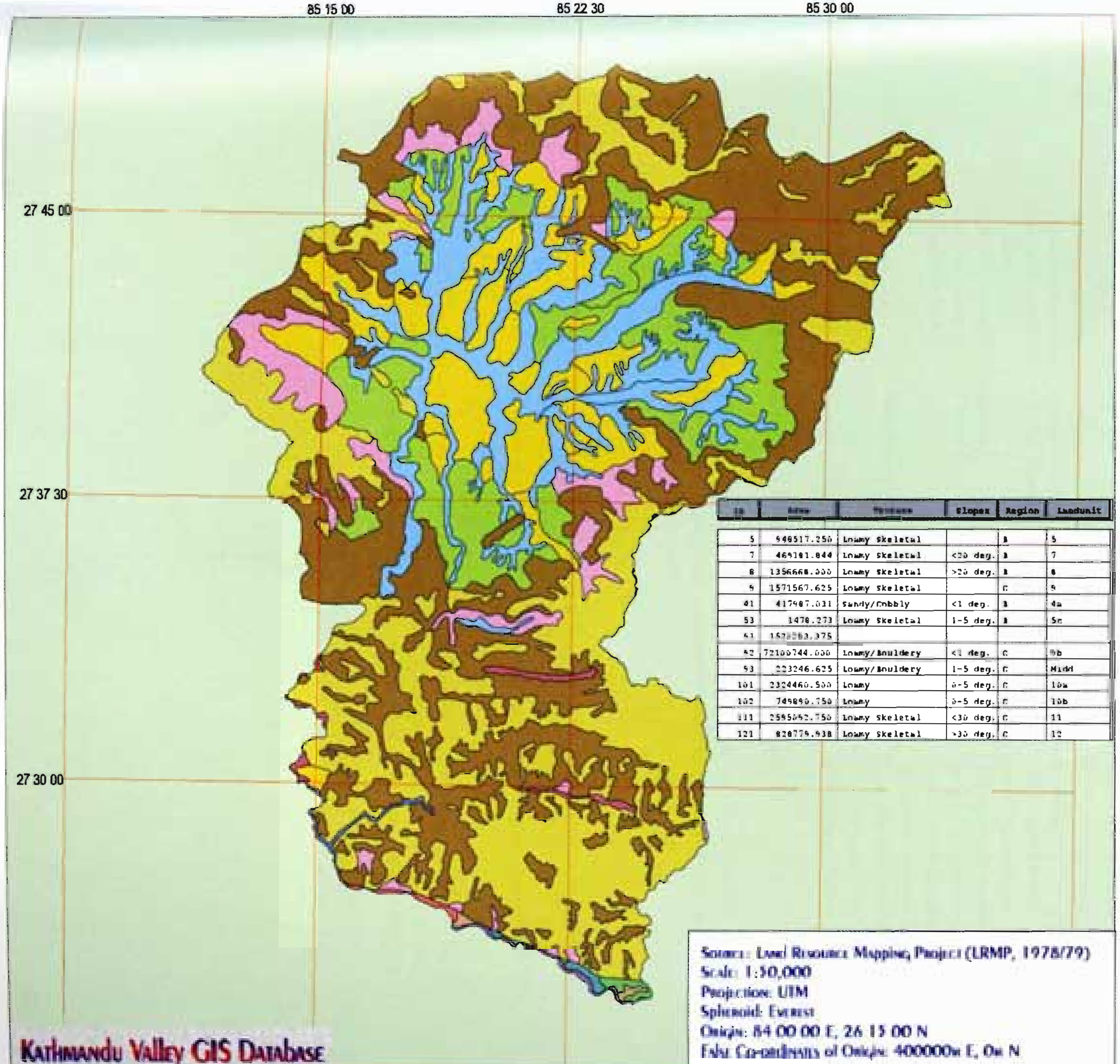
5 0 5 Kilometres

Scale 1:300,000

ICIMOD
MENRIS '99

Kathmandu Valley

Map 14
Land Systems



[illegible]	[illegible]	[illegible]	Slopes	Region	Landunit
5	948517.250	Loamy Skeletal		B	5
7	469181.844	Loamy Skeletal	<20 deg.	B	7
8	1356668.000	Loamy Skeletal	>20 deg.	B	8
9	1571567.625	Loamy Skeletal		C	9
41	417987.031	Sandy/Cobbly	<1 deg.	B	4a
53	1470.273	Loamy Skeletal	1-5 deg.	B	5c
61	[illegible]				
92	72100744.000	Loamy/Bouldery	<1 deg.	C	9b
93	223246.625	Loamy/Bouldery	1-5 deg.	C	Midd
101	2324460.500	Loamy	0-5 deg.	C	10a
102	749890.750	Loamy	0-5 deg.	C	10b
111	2595092.750	Loamy Skeletal	<30 deg.	C	11
121	828779.938	Loamy Skeletal	>30 deg.	C	12

Source: Land Resource Mapping Project (LRMP, 1978/79)
Scale: 1:50,000
Projection: UTM
Spheroid: Everest
Origin: 84 00 00 E, 26 15 00 N
False Co-ordinates of Origin: 400000m E, 0m N

Legend

- Loamy Skeletal
- Loamy Skeletal, Slope < 20 deg.
- Loamy Skeletal, Slope > 20 deg.
- Loamy Skeletal
- Sandy/cobby, Slope < 1 deg.
- Loamy Skeletal, Slope 1-5 deg.
- Fragmented Sandy, Slope < 1 deg.
- Loamy/Bouldery, Slope < 1 deg.
- Loamy/ Bouldery, Slope 1-5 deg.
- Loamy, Slope 0-5 deg.
- Loamy, Slope 0-5 deg.
- Loamy Skeletal, Slope < 30 deg.
- Loamy Skeletal, Slope > 30 deg.

4 0 4 Kilometres

Scale 1:300,000

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Kathmandu Valley GIS Database

7.2 Integration of Socioeconomic Information

As depicted in Figure 5, the topographic database also includes socioeconomic or non-spatial information. The socioeconomic information, e.g., information on population, household distribution, and so on at Village Development Committee (VDC) level is available from the Census 1991 statistical report published by the Central Bureau of Statistics (CBS). This information has been linked to the spatial information about the administrative unit, i.e., the VDC, by digitising the VDC boundaries. The information was organized in a GIS relational database management system that can be used to portray various socioeconomic indicators in the form of maps (Table 2). The details of attribute data can be found in the Data Dictionary (Annex 2).

Table 2: Integration of Socioeconomic Information at the VDC Level

Themes	Layers	Source	Scale	Date
Administration	District boundary	Topographic map	1:25,000	1995
	VDC boundary	Topographic map	1:25,000	1995
	Metropolitan and sub-metropolitan boundaries	Topographic map	1:25,000	1995
Social Information	Total population at VDC level	Census report		1995
	Male population	Census report		1995
	Female population	Census report		1995
	No. of households at VDC level	Census report		
	Population density	Derived		
	Ratio of males to females at VDC level	Derived		
Others	Sources of environmental concern	Various sources		

7.2.1 Administrative Boundary (District / VDC boundary)

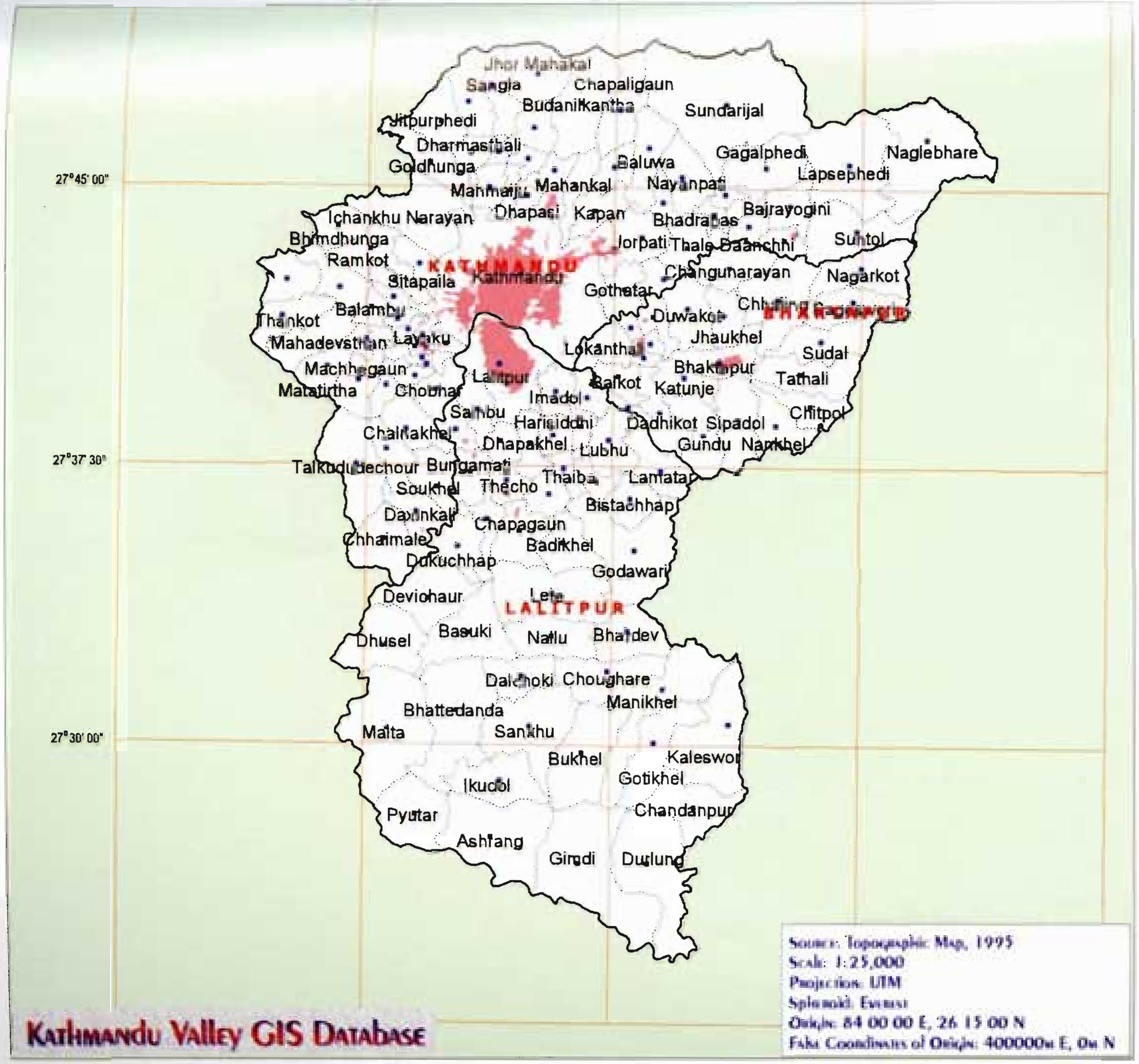
The Administrative Unit layer is at district-level with Village Development Committee (VDC) boundaries and metropolitan and sub-metropolitan boundaries. These were compiled from 1:25K topographic maps.

7.2.2 Census 1991 Data

Using the Census report of 1991, population and household data at the VDC level were integrated with the administrative layer and different layers were generated through GIS. This was done to illustrate the integration of non-spatial data with a GIS Database.

The database thus developed was used to produce the following maps (Maps 15-22). These maps are merely for the demonstration of integration of socioeconomic data into a GIS. Many such maps can be produced once integration of the census database has taken place.

List of Maps Prepared from Integrated Socioeconomic Information



KATHMANDU VALLEY

Map 15

Administrative Map

Legend

- District Boundary
- VDC Boundary
- Built-up Area

5 0 5Kilometres

Scale 1:300,000

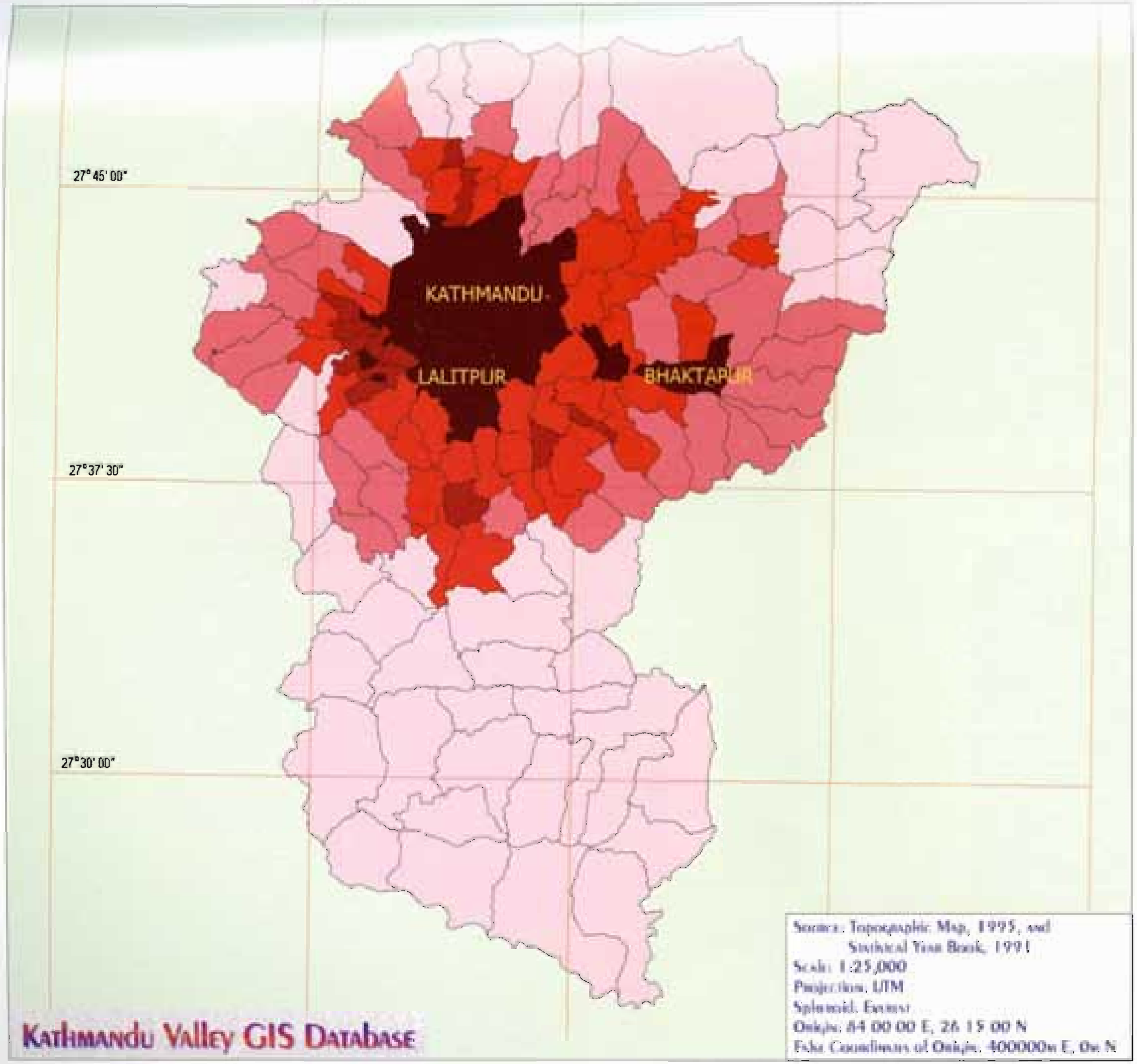
ICIMOD

MENRIS '99

Kathmandu Valley

Map 16

Population Density by VDC, 1991



Legend

Population Density per Sq.Km.

- 0 - 500
- 501 - 1000
- 1001 - 2000
- 2001 - 4000
- 4001 - 12848

5 0 5 Kilometres

Scale 1:300,000

ICIMOD MENRIS '99

Kathmandu Valley

Map 17
Household Distribution by VDC, 1991

Legend

Household Distribution (In Numbers)

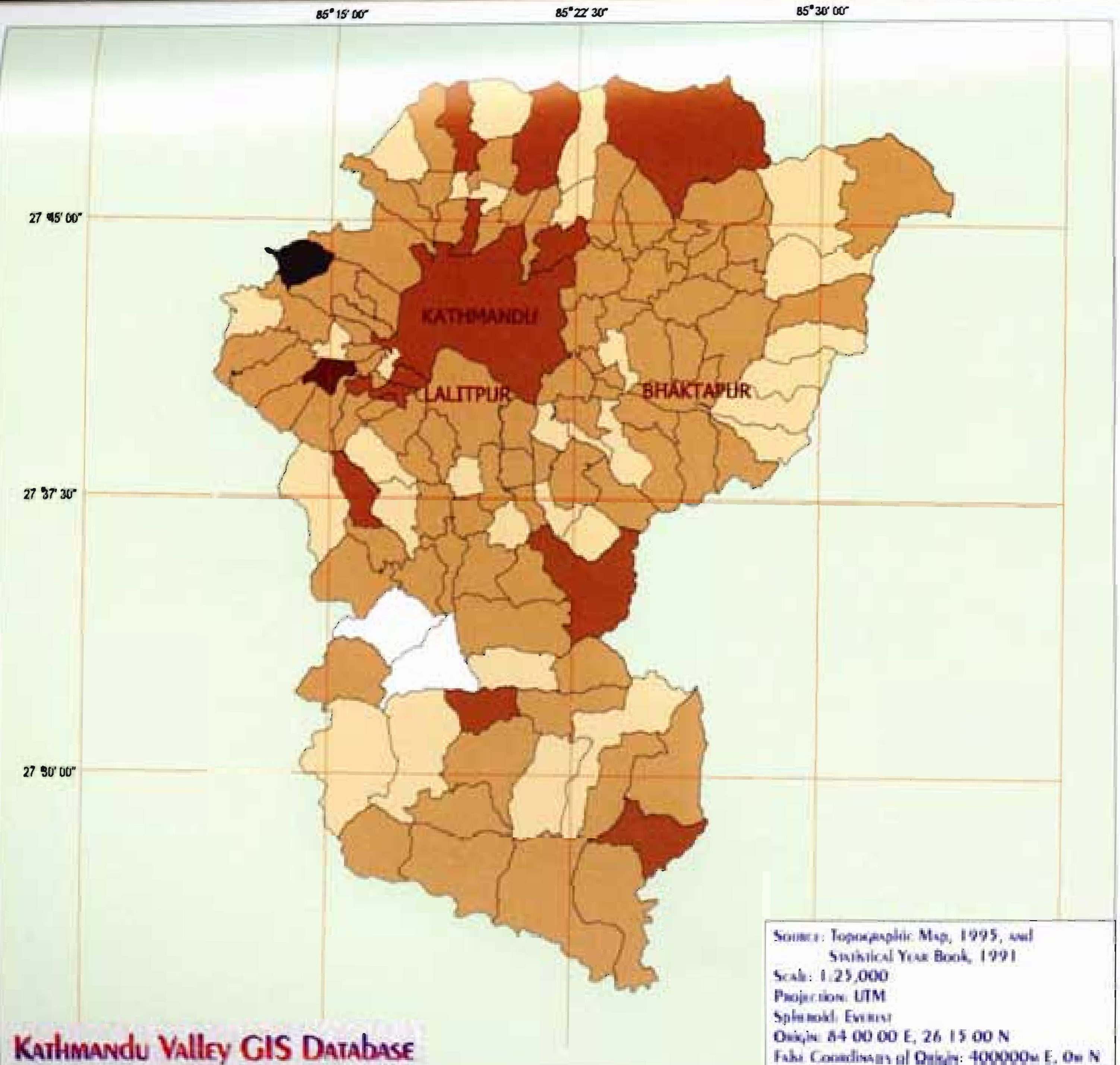
- Below 600
- 601 - 2000
- 2001 - 10000
- 1001 - 20000
- Above 20000

5 0 5 Kilometres

Scale 1:300,000

ICIMOD

MENRIS '99



Source: Topographic Map, 1995, and Statistical Year Book, 1991
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 18
Percentage of Males by VDC, 1991

Legend

Male Population (in percentage)

- 47 - 49
- 50 - 51
- 52 - 56
- 57 - 61
- 62 - 80
- No Data

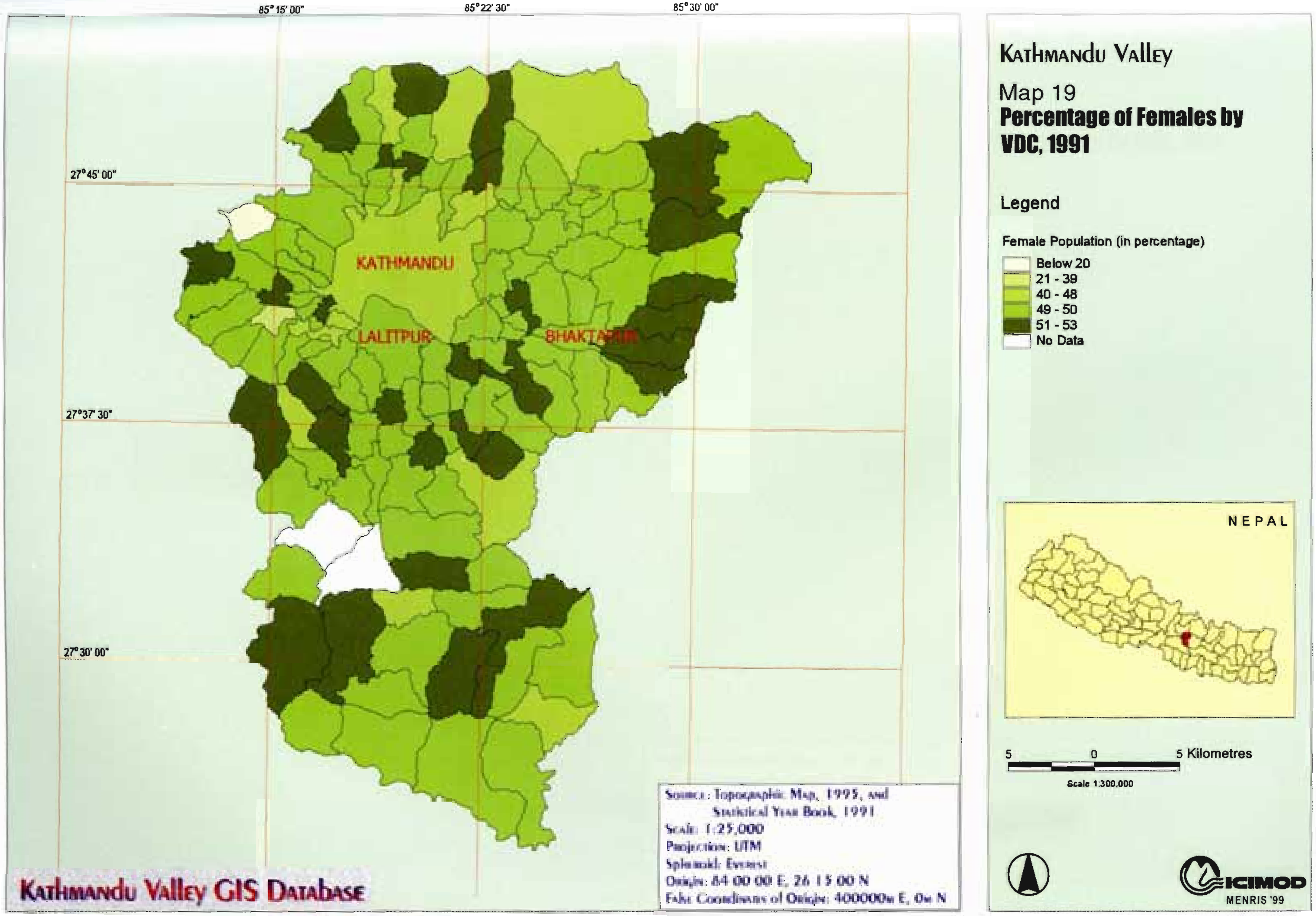
5 0 5 Kilometres

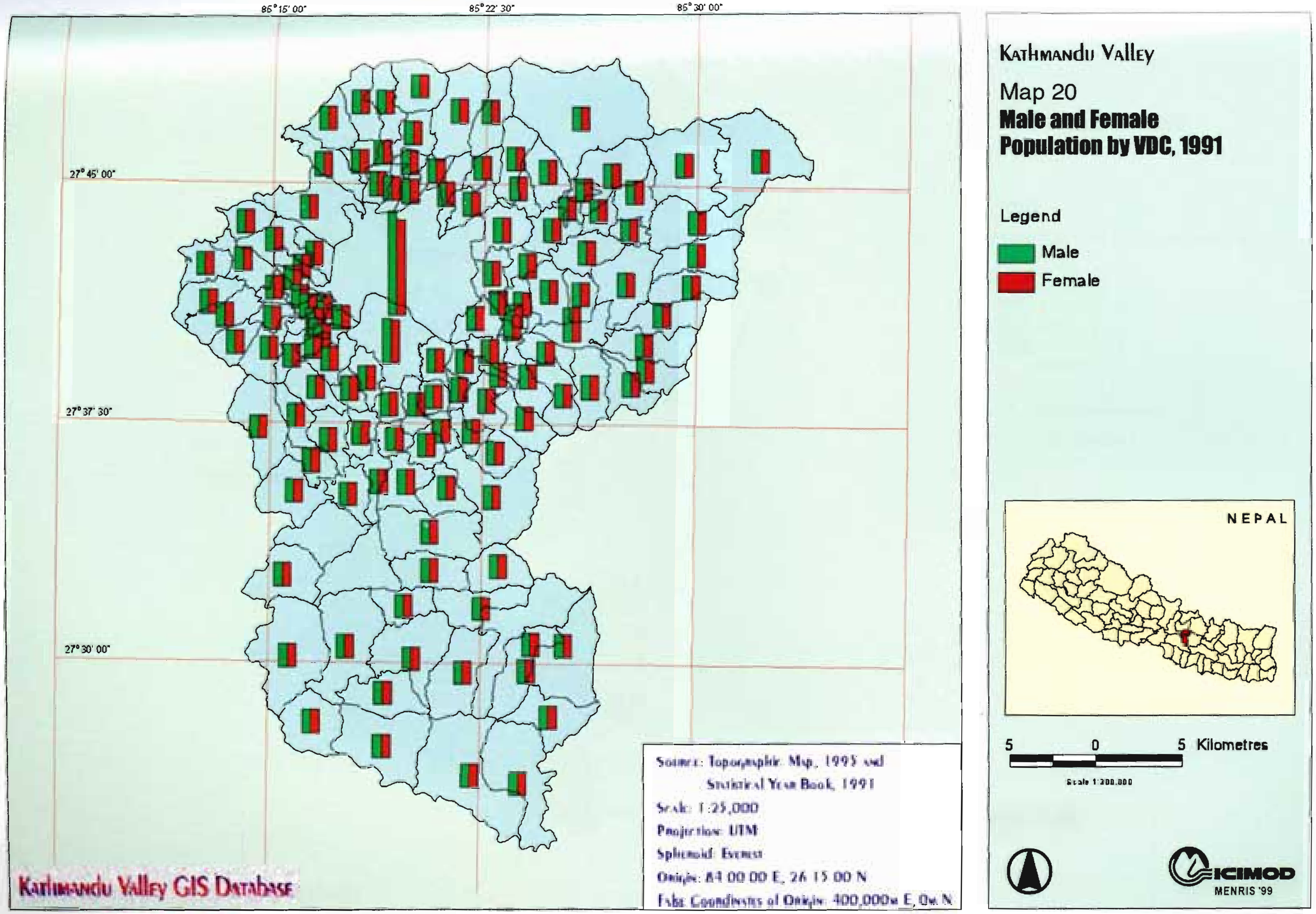
Scale 1:300,000

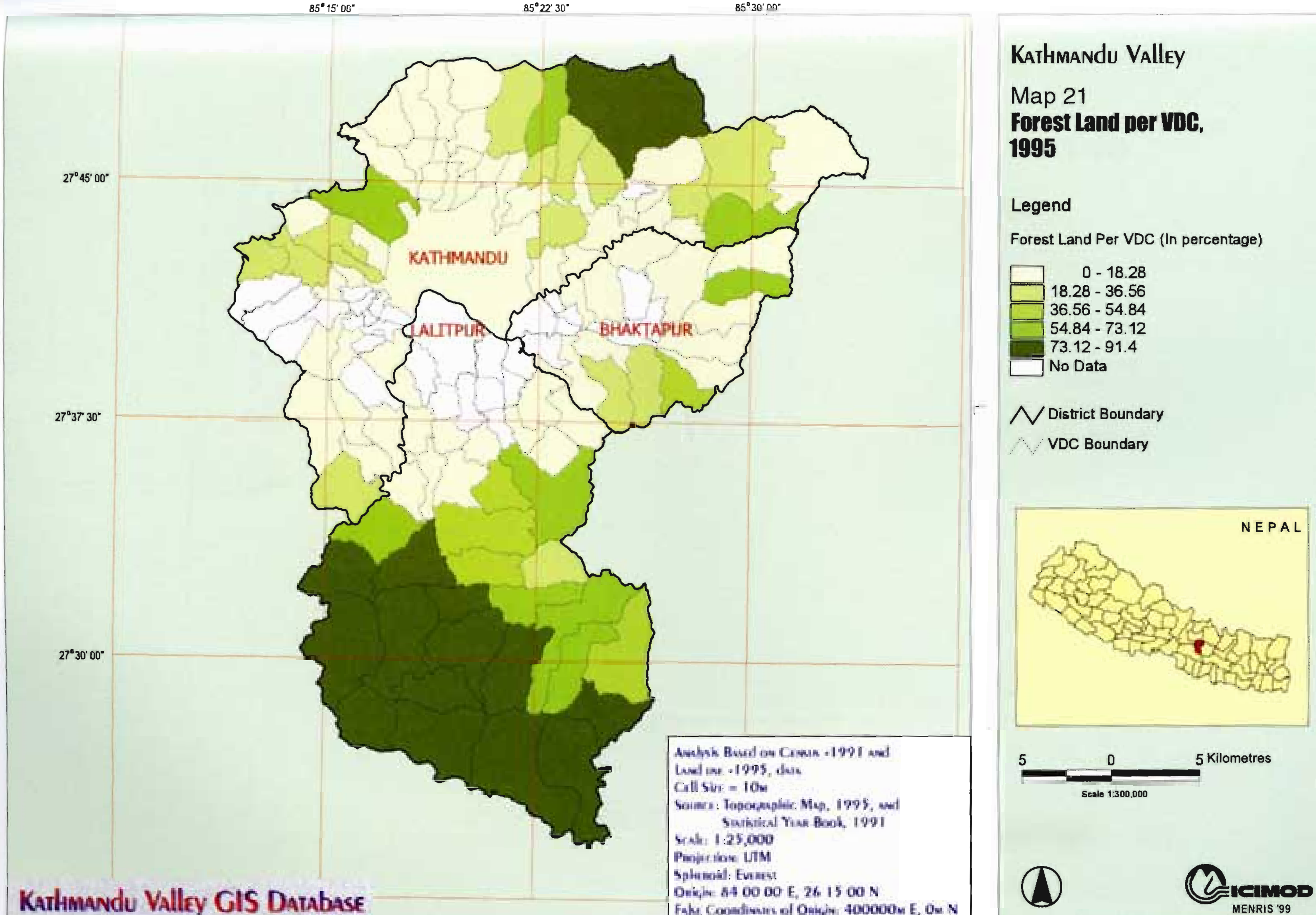
ICIMOD
MENRIS '9

Kathmandu Valley

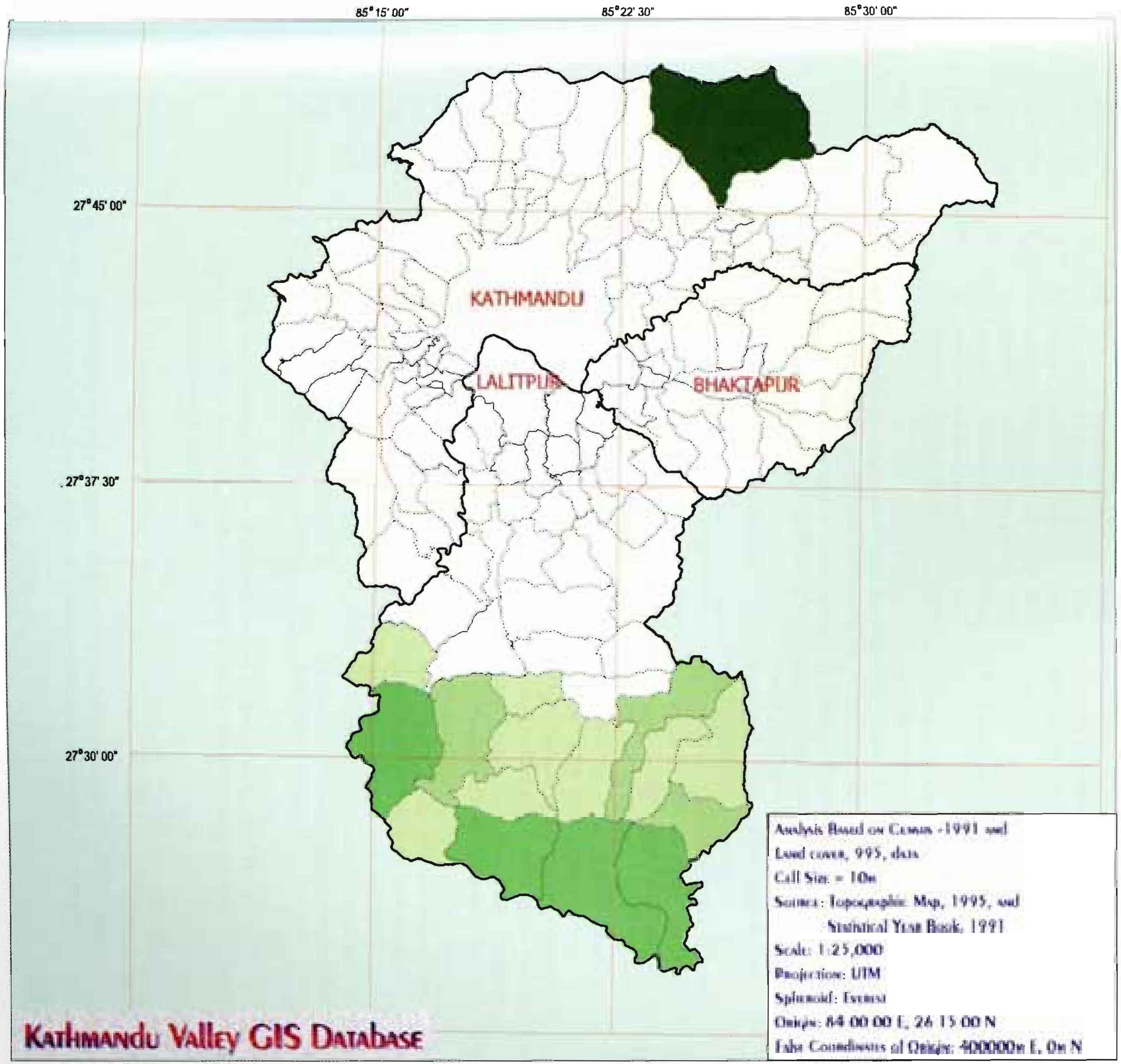
Map 19
Percentage of Females by VDC, 1991




Kathmandu Valley
Map 20
Male and Female Population by VDC, 1991
Legend
Male
Female
NEPAL
5 0 5 Kilometres
Scale 1:300,000
ICIMOD
MENRIS '99
85° 15' 00"
85° 22' 30"
85° 30' 00"
27° 45' 00"
27° 37' 30"
27° 30' 00"
Source: Topographic Map, 1995 and Statistical Year Book, 1991
Scale: 1:25,000
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



85°15' 00"
85°22' 30"
85°30' 00"
27°45' 00"
27°37' 30"
27°30' 00"
KATHMANDU
LALITPUR
BHAKTAPUR
Kathmandu Valley GIS Database
Analysis Based on Census -1991 and
Land use -1995, data
Cell Size = 10m
Source: Topographic Map, 1995, and
Statistical Year Book, 1991
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
Map 21
Forest Land per VDC, 1995
Legend
Forest Land Per VDC (In percentage)
0 - 18.28
18.28 - 36.56
36.56 - 54.84
54.84 - 73.12
73.12 - 91.4
No Data
District Boundary
VDC Boundary
NEPAL
5 0 5 Kilometres
Scale 1:300,000
ICIMOD
MENRIS '99



Kathmandu Valley

Map 22
Forest Land Per Person by VDC, 1995

Legend

Forest per Population per VDC (In sq.m.)

- 1 - 3000
- 3000 - 6500
- 6500 - 9500
- 9500 - 13000
- Above 13000
- No Data

District Boundary
VDC Boundary

5 0 5 Kilometres
Scale 1:300,000

ICIMOD
MENRIS '99

7.3 Satellite Image Database

The emergence of high-resolution satellite imagery (1 to 3 metres) has brought about revolutionary changes in comprehending our real world situations. The applications of high-resolution satellite imagery are proving to be useful in urban applications. This study aims to use satellite imagery for the Kathmandu Valley and especially high-resolution satellite imagery for urban applications in particular, hence this study has used high-resolution satellite data (two metres) for the first time in Nepal to validate data for urban and environmental management applications.

Table 3: **List of the Satellite Imageries Included in the Kathmandu Valley GIS Datbase**

Name of the Satellite	Spatial Resolution	Type	Date
Landsat TM	30 metres	Multi-spectral	1988
SPOT-XS	20 metres	Multi-spectral	1994
SPOT-XS	20 metres	Multi-spectral	1992
SPOT-XS	20 metres	Multi-spectral	1986
SPOT-PAN	10 metres	DEM (Stereo Pair)	1992
IRS-1C	5.6 metres	Panchromatic	1996
ADEOS-AVNIR	16 metres	Multi-spectral	1997
SPIN-2	2 metres	Panchromatic	1991

The database includes various satellite images of Kathmandu Valley acquired from different satellite sensors on different dates (Table 3).

The important characteristics of each of these satellites can be found in Annex 4.

7.3.1 Processing of Satellite Data

Raw satellite images received directly from the distributors have their own format and can not be used directly for analysis. To make use of these raw satellite images, pre-processing needs to be carried out, i.e., rectification and geometric correction to the standard coordinate system of the country. To establish the satellite image database, all the satellite images were rectified and geometrically corrected using the Ground Control Points (GCPs) of the Geodetic Survey Branch of the Ministry of Land Reform and Management - Department of Survey. All the GCPs were verified in the field (Table 4) with the aerial photographs, topographic maps, and SPIN-2 satellite images. The GCPs were then registered on the SPIN-2 image by identifying the same location on the images, features of the topographic map, i.e., digitised road and drainage networks, and geo-corrected using ERDAS Imagine 8.3.1 image processing software. The geo-corrected SPIN-2 image was then used to rectify other satellite images. The training samples were selected through visual interpretation and supervised classification of all satellite images was carried out for mapping land cover of the Kathmandu Valley.

Table 4: **List of GCPs Used for the Geo-correction of Satellite Images**

Grid Sheet No.Align-ment No.	ID No.	UTM Coordinates Easting	UTM Coordinates Northing	Height above mean sea level
102	7	628633.79	3069584.06	1317.29
102	6	632479.08	3069423.39	1353.84
102	8	629248.02	3068335.66	1329.11
102	9	627440.20	3066912.23	1407.11
102	10	626572.01	3064882.02	1328.06
102	11	627507.35	3064088.09	1297.88
102	13	628436.17	3061733.76	1304.19
102	12	627969.86	3062701.79	1278.74
102	14	627915.80	3061023.77	1355.72
102	15	626291.25	3062667.17	1414.83
102	3	635081.60	3066372.31	1339.08
102	4	636492.53	3067786.07	1319.31
102	5	636916.20	3069600.81	1338.03
102	2	633310.55	3062518.81	1247.31
102	1	629600.05	3065364.84	N/A

The methodology used for the preparation of a satellite image database of Kathmandu Valley is depicted below (Figure 6) and the following maps (Maps 23-47) were prepared using the image database.

7.3.2 Visualisation of Satellite Images

Colour plays an important role in effective visual interpretation of satellite images. There are two colour display methods: colour composite and pseudo-colour display.

Colour composite is used to generate images with multi-band data and pseudo colour is used to assign different colours to grey scales on a single band image. Three selected single-band images are composed using three primary colours; for instance, RGB (Red, Green, Blue). Different colours can be generated depending upon selection of three band images and the assignment of the three primary colours. The assignment of image bands to primary colours can be in any combination, however, there are two standard methods, namely, True Colour Composite (TCC), and False Colour Composite (FCC).

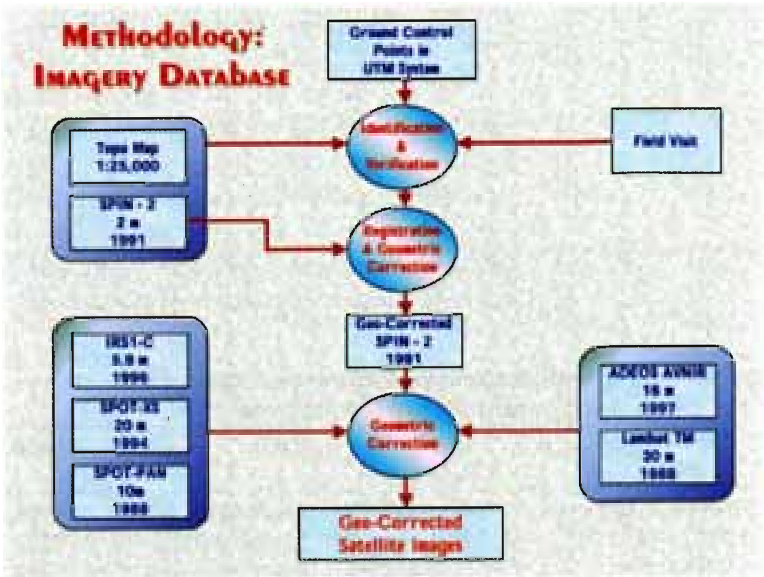


Figure 6: **Applied Methodology for Preparation of the Image Database**

True Colour Composite (TCC)

True Colour Composite was used to generate an image of natural composites that make it possible to see features as they would be seen by the human eye. It can be prepared by using Landsat TM bands 3 (red), 2 (green), and 1 (blue) for the primary colours. The advantage of this composition is that it is easier for a lay person to interpret the features.

False Colour Composite (FCC)

Multi-band images through remote sensing sensors are not always divided into the same spectral region as the three primary colours. In addition, invisible regions, such as infrared, are used to enhance spectral resolution. Within an infrared band, a colour composite is no longer a natural colour, hence false colour composite. In this composition, blue to green band, green to red band, and red to infrared band are assigned. The main advantage of this is that one can study different types of vegetation cover. In this composition, the vegetation is red.

Examples of these compositions are given in the maps (e.g. refer to Maps 23 and 27).

7.3.3 Data Fusion

Different types of satellites use different numbers of bands with varying resolutions. The characteristics of some of the most common satellite imagery are presented in Annex 4. Satellite images from different sensors can thus be used for different purposes. Different techniques in digital image processing help identify the features of the earth's surface as accurately as possible by using different types of satellite image. One popular technique is data fusion or resolution merge, combining information from different satellite images. Usually it entails enhancement of lower resolution, multi-band images by merging them with higher resolution, panchromatic (grey-single band) images. This technique has been used in the present study to enhance and recognize spatial patterns. In this study, the ADEOS-AVNIR (multi-band) image in 16m x 16m resolution and Landsat TM (multi-band) image in 30m x 30m resolution are merged with a SPIN-2 (panchromatic) image in 2m x 2m resolution. The result is a multi-spectral image with improved spatial resolution, i.e., 2m x 2m, which can be used for both visual interpretation and digital image processing in detail (Maps 33, 34, 42, and so on).

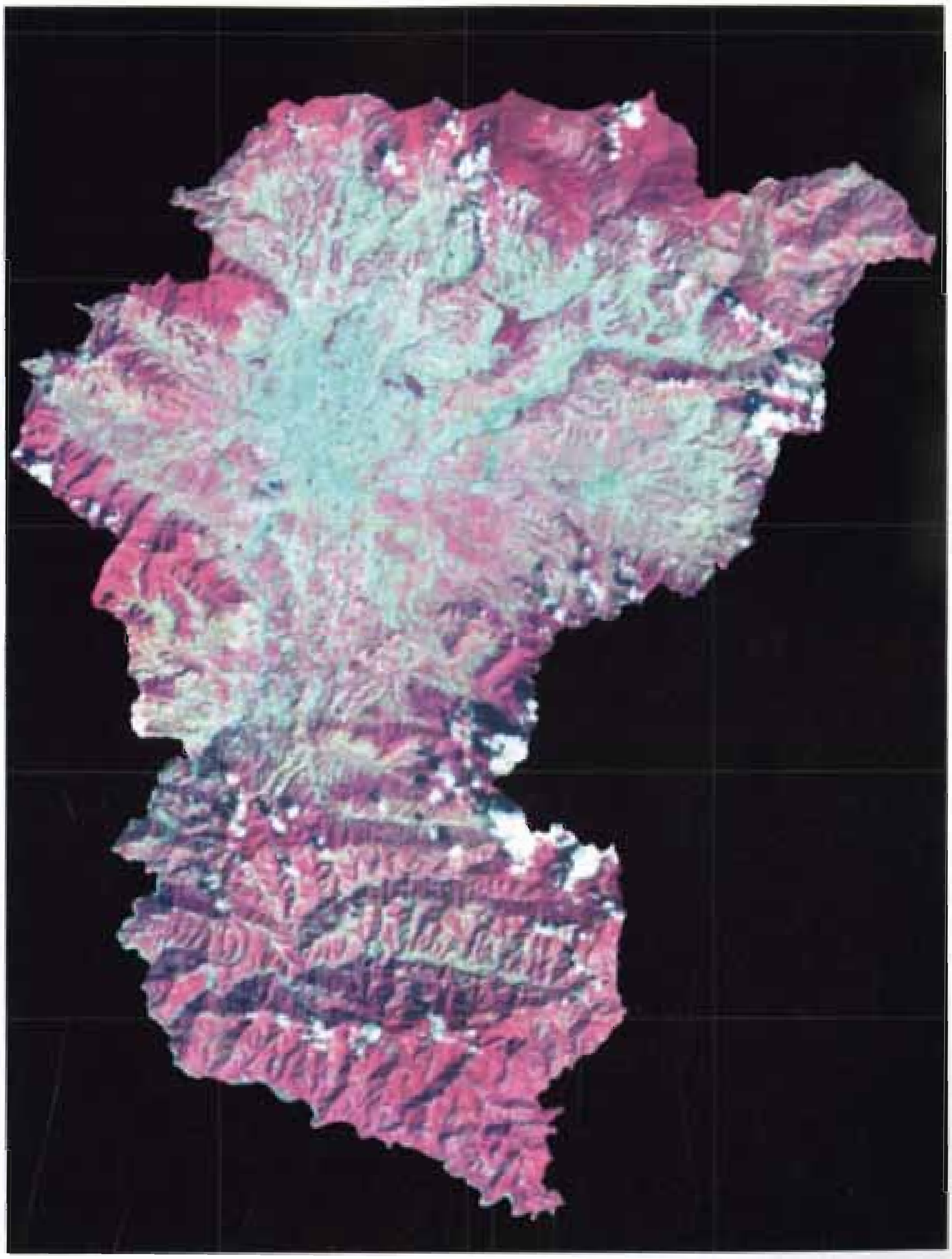
7.3.4 Image Draping

Image draping is another important function of digital image processing. This involves overlapping a satellite image or any raster-based GIS data over a DEM. This is useful for gaining a realistic perspective and carrying out analyses such as visibility analysis. Several maps were prepared by draping different satellite images and land-cover maps over a DEM to provide a visual impact of the landscape (e.g. Maps 24, 26, 28, 30, 33, 37, 39, 41, and so on).

List of Maps Prepared from Satellite Image Database

Map 23

The False Colour Composite (Red:4, Green:3, Blue:2) of Landsat-TM image, 1998 Kathmandu Valley, Nepal



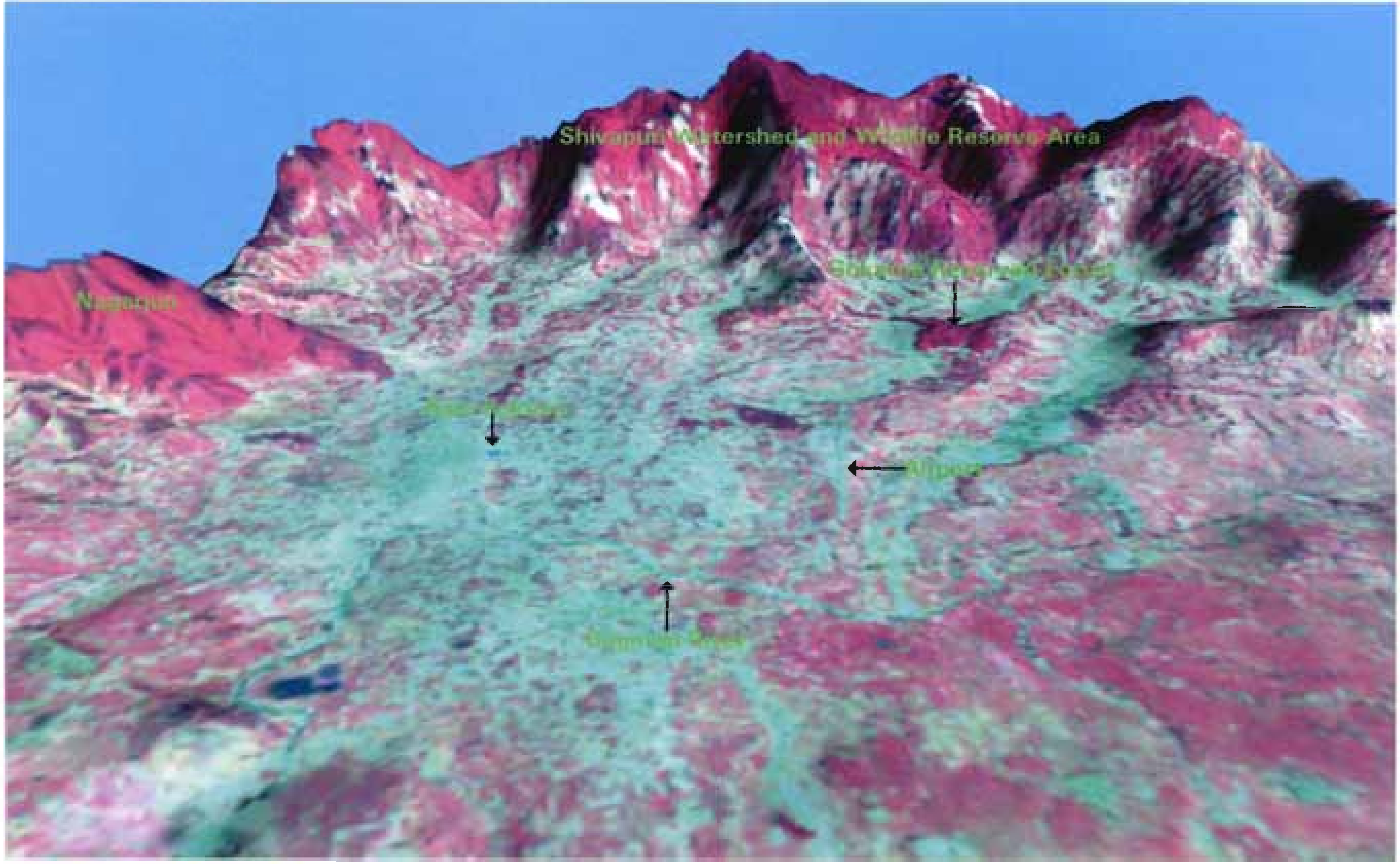
Spatial Resolution: 30m
Date Acquired: 11th October, 1988
Geo-referenced to: UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Co-ordinates of Origin: 400000m E, 0m N

Scale
5 0 5 Kilometres

ICIMOD
MENRIS '99

Map 24

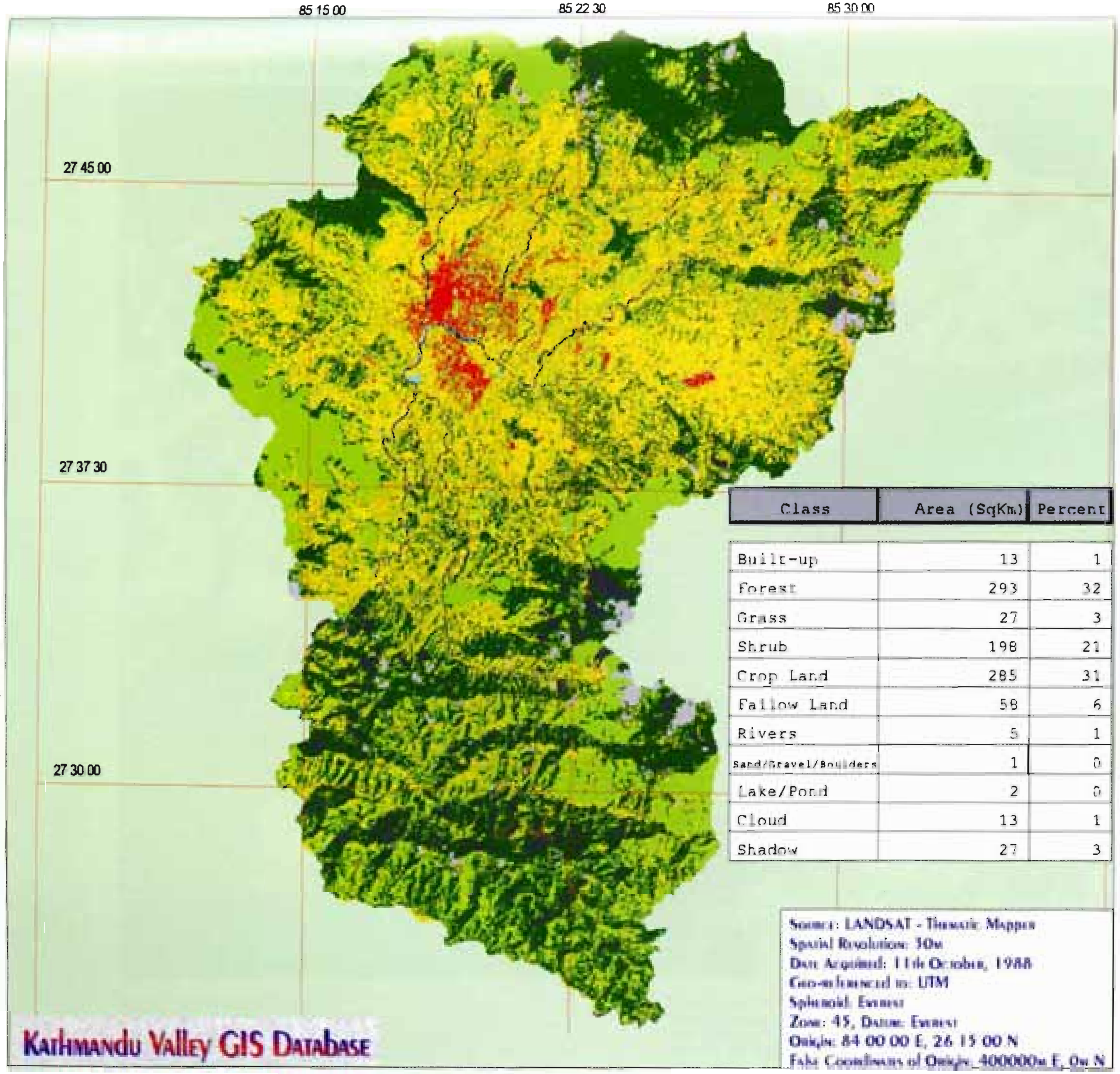
False Colour Composite (Red:4, Green: 3, Blue:2) of Landsat-TM Image Draped on DEM, 1988
Kathmandu Valley, Nepal



Spatial Resolution: 30 metres
Date Acquired: 11th October, 1988
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest

Above Ground Level (AGL): 1600 metres
Above Sea Level (ASL): 3000 metres
Field of View (FOV): 75 degrees
Azimuth: 375 degrees
Exaggeration: 4

ICIMOD
MENRIS '99



Class	Area (SqKm)	Percent
Built-up	13	1
Forest	293	32
Grass	27	3
Shrub	198	21
Crop Land	285	31
Fallow Land	58	6
Rivers	5	1
Sand/Gravel/Boulders	1	0
Lake/Pond	2	0
Cloud	13	1
Shadow	27	3

Source: LANDSAT - Thematic Mapper
Spatial Resolution: 30m
Date Acquired: 11th October, 1988
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

Map 25

Land Cover Based On Landsat-TM Image, 1988

Legend

- Built-up
- Forest
- Grass
- Shrub
- Crop Land
- Fallow Land
- Rivers
- Sand/Gravel/Boulder
- Lake/Pond
- Cloud
- Shadow

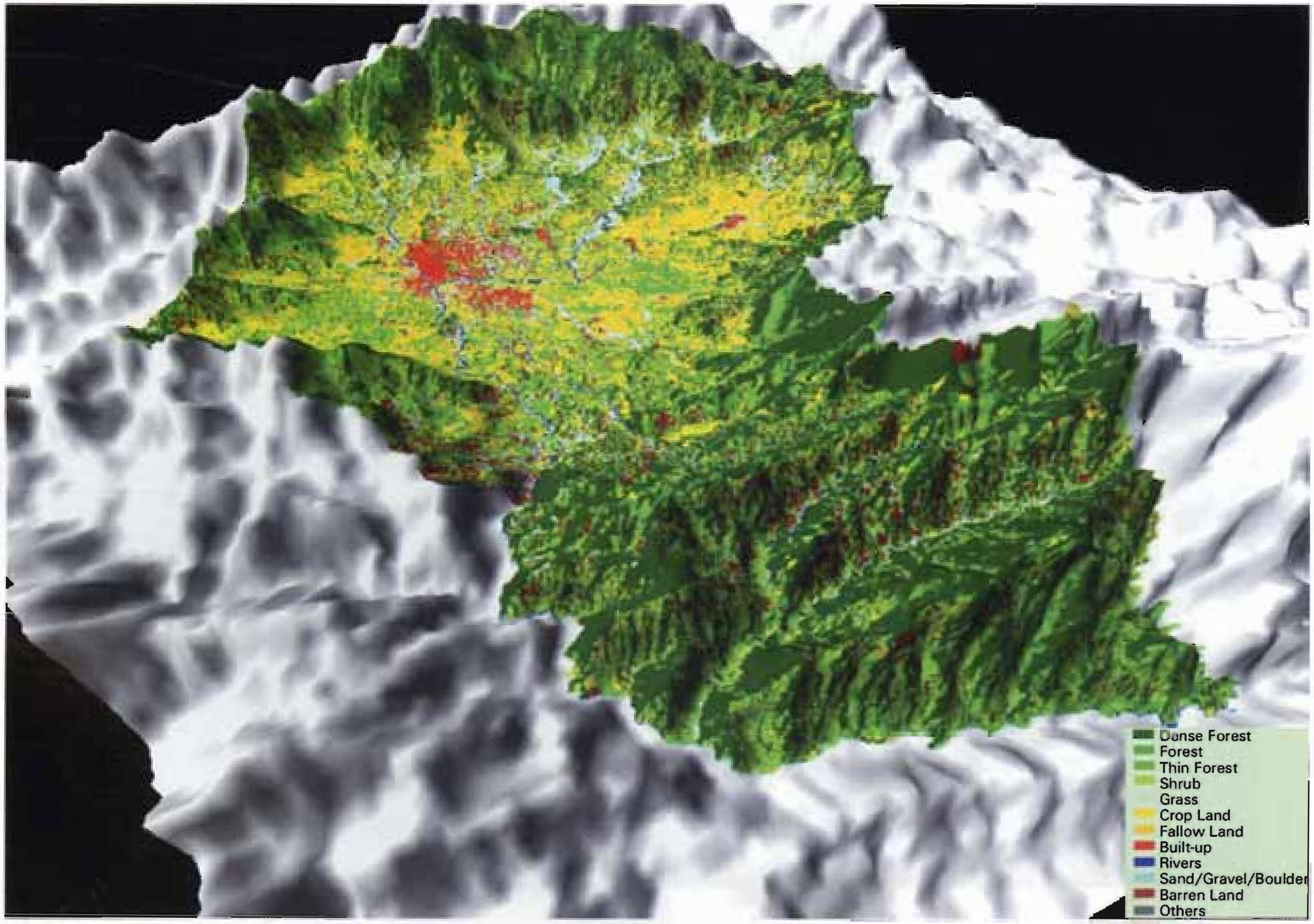
5 0 5 Kilometres

Scale: 1:275,000

ICIMOD
MENRIS '99

Map 26

Land Cover Based on Landsat-TM, 1988, Image Draped on DEM
Kathmandu Valley, Nepal



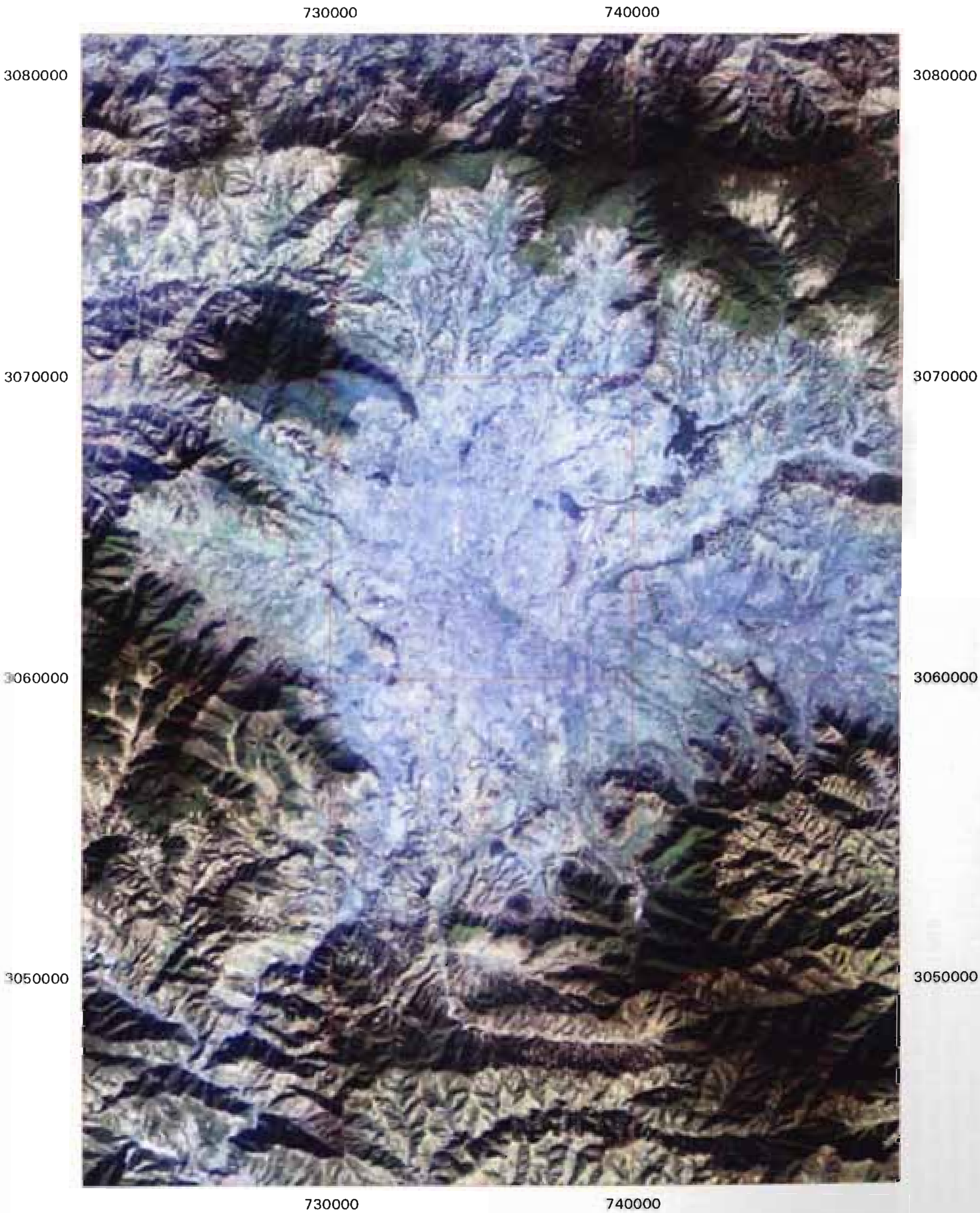
Spatial Resolution: 30 metres
Date Acquired: 11th October, 1988
Geo-referenced to UTM
Spheroid: Everest
Zone: 45, Datum: Everest

Above Ground Level (AGL): 6710 metres
Above Sea Level (ASL): 8000 metres
Field of View (FOV): 75 degrees
Azimuth: 33 degrees
Exaggeration: 6

ICIMOD
MENRIS '99

Map 27

True Colour Composite (Red:3, Green:2, Blue:1) of ADEOS-AVNIR Image, 1997
Kathmandu Valley, Nepal



Spatial Resolution: 16 metres
Date Acquired: 11th January, 1997
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

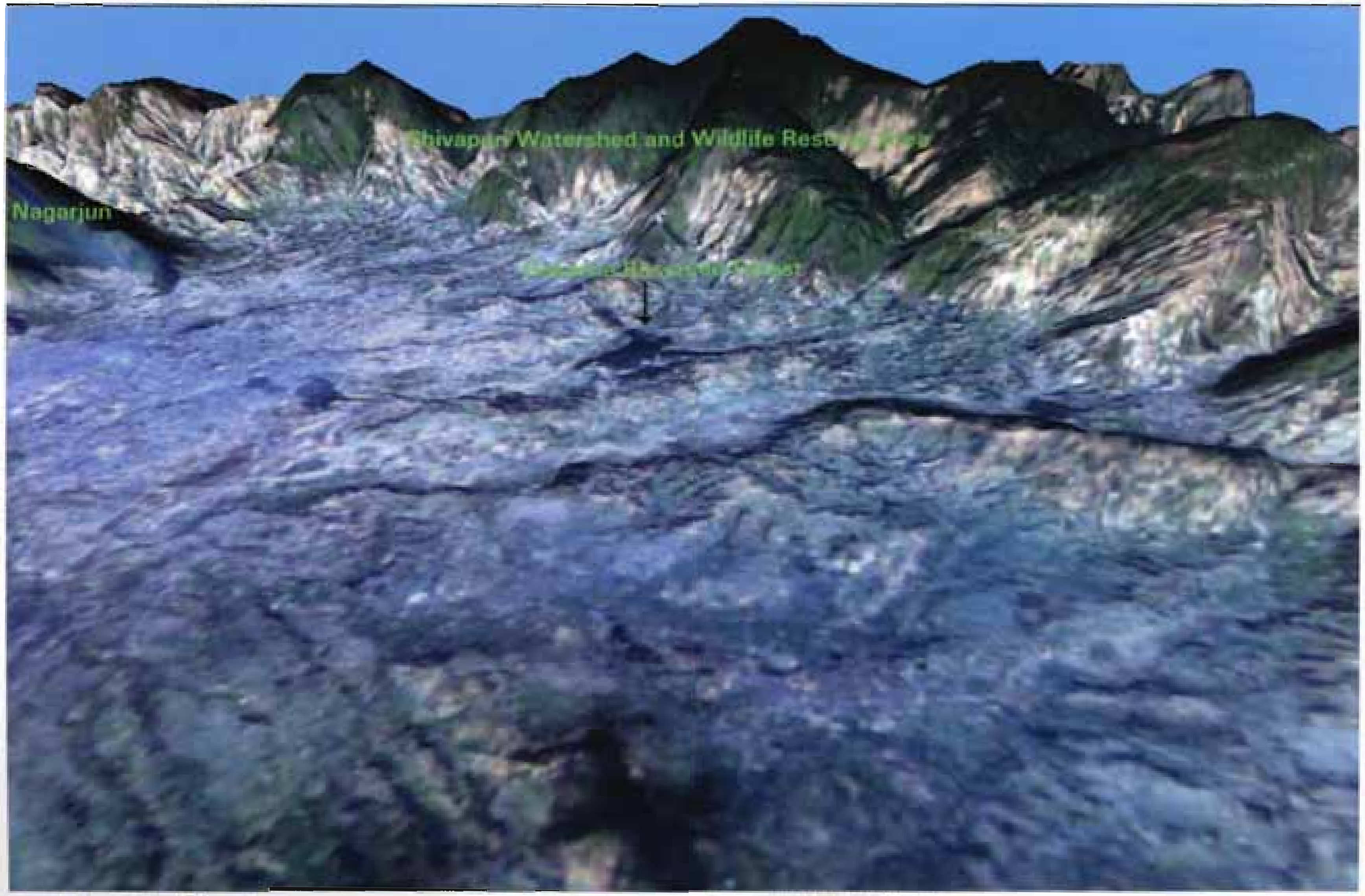
Scale

5 0 Kilometres

ICIMOD
MENRIS '99

Map 28

True Colour Composite of ADEOS-AVNIR Image Draped on DEM, 1997 Kathmandu Valley, Nepal
Kathmandu Valley, Nepal



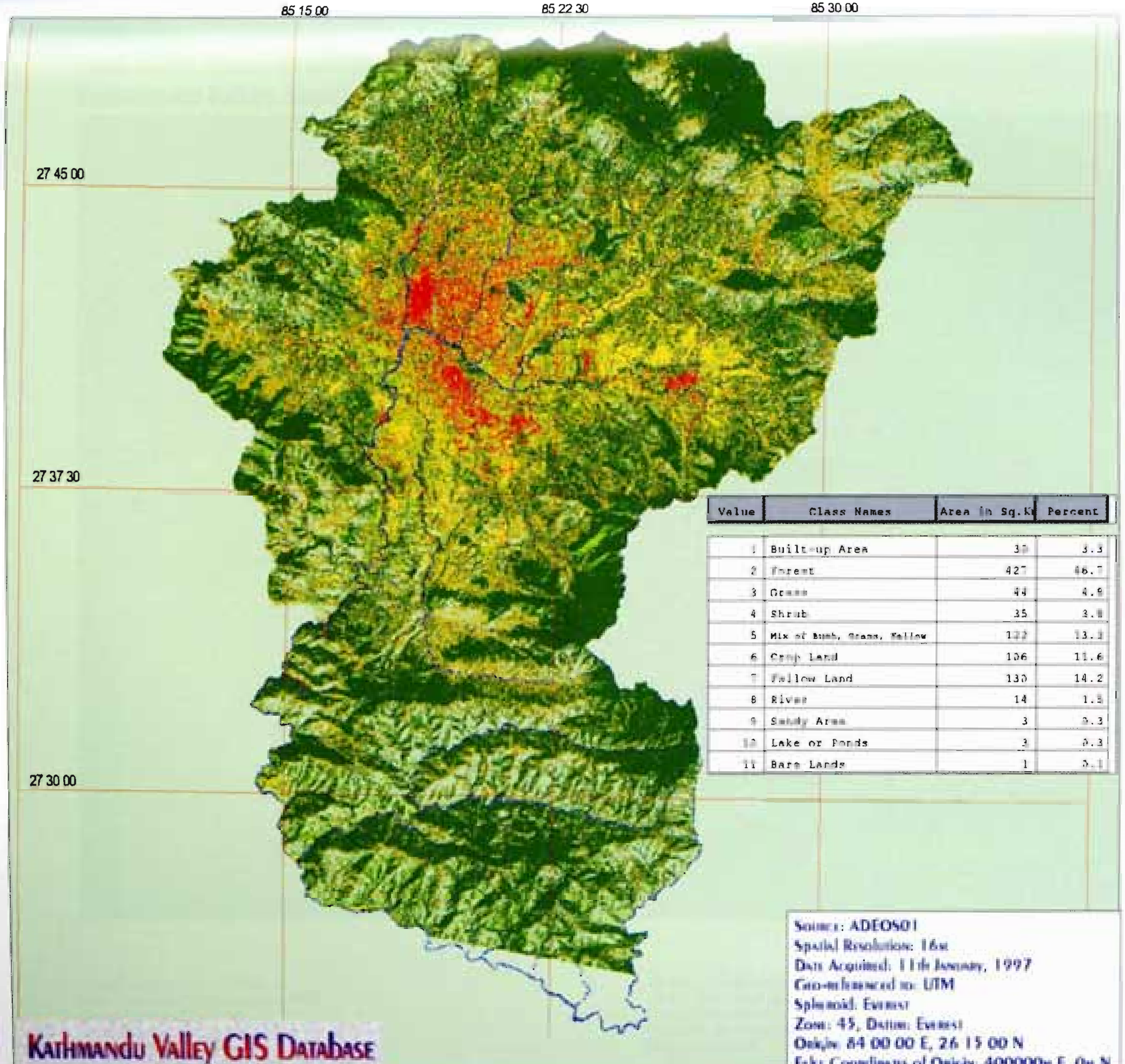
Spatial Resolution: 30 metres
Date Acquired: 11th October, 1988
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest

Above Ground Level (AGL): 1503metres
Above Sea Level (ASL): 3000 metres
Field of View (FOV): 85degrees
Azimuth: 345 degrees
Exaggeration: 4

ICIMOD
MENRIS '99

Kathmandu Valley

Map 29
Land Cover Based on ADEOS-AVNIR Image, 1997



Value	Class Names	Area in Sq.Km	Percent
1	Built-up Area	30	3.3
2	Forest	427	46.7
3	Grass	44	4.9
4	Shrub	35	3.8
5	Mix of Bush, Grass, Fallow	122	13.3
6	Crop Land	106	11.6
7	Fallow Land	130	14.2
8	River	14	1.5
9	Sandy Area	3	0.3
10	Lake or Ponds	3	0.3
11	Bare Lands	1	0.1

Source: ADEOS01
Spatial Resolution: 16m
Date Acquired: 11th January, 1997
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

Land Cover Class
- Built-up Area
- Forest
- Grass
- Shrub
- Mixed (bush, grass, fallow)
- Crop Land
- Fallow Land
- River
- Sandy Area
- Lake or Ponds
- Bare Lands
- No Data

5 0 5 Kilometres

Scale: 1:275,000

ICIMOD
MENRIS '99

Map 30

Land Cover Based on ADEOS-AVNIR Image, 1997, Draped on DEM
Kathmandu Valley, Nepal

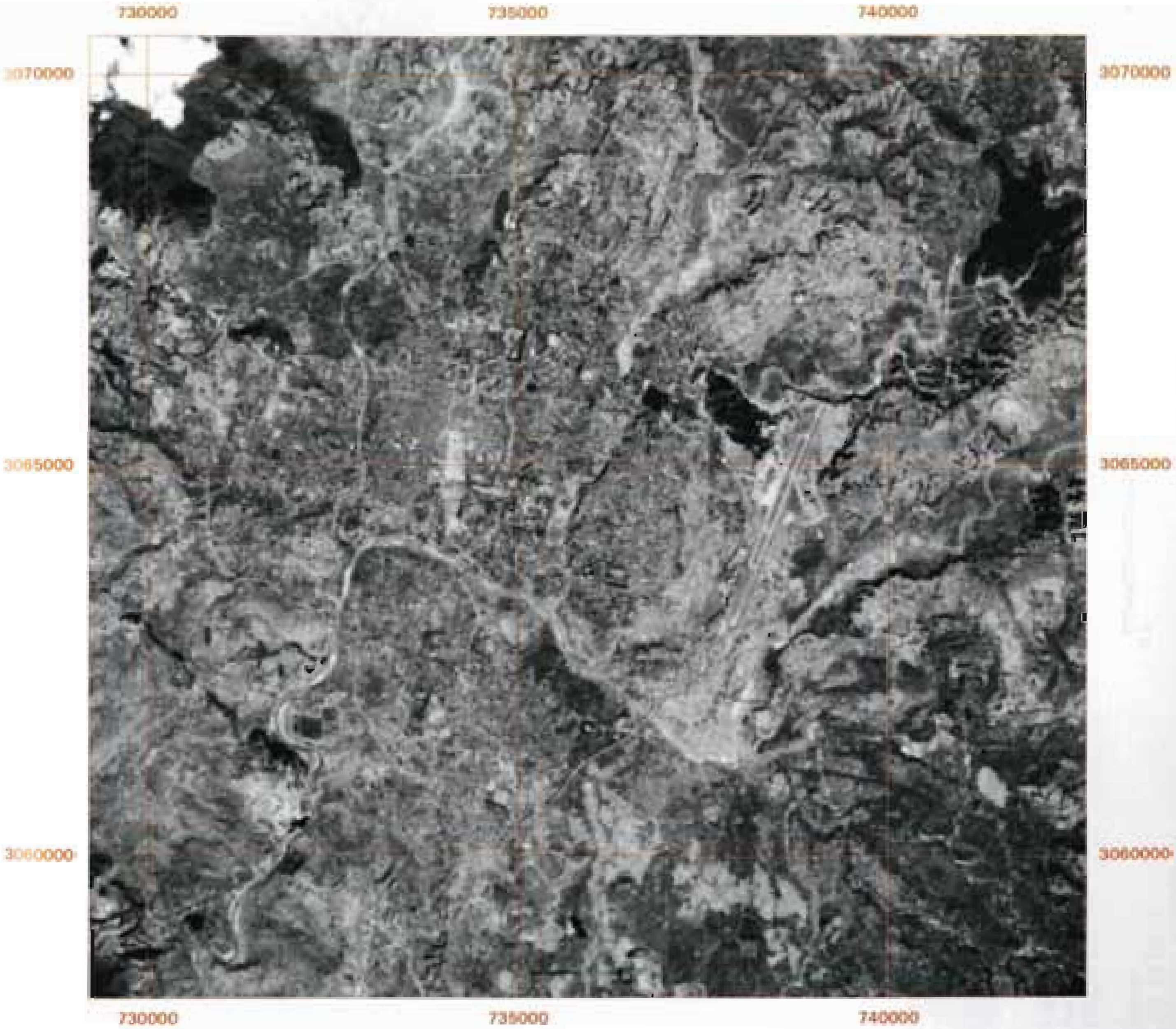
Spatial Resolution: 16 metres
Date Acquired: 11th January, 1997
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest

Above Ground Level (AGL): 6557 metres
Above Sea Level (ASL): 3776 metres
Field of View (FOV): 75 degrees
Azimuth: 38 degrees
Exaggeration: 4

ICIMOD MENRIS '99

Map 31

SPIN-2 Two Metre KVR-1000 Image, 1991
Kathmandu Valley, Nepal



Spatial Resolution: 1.99992 metres
Date Acquired: 5th February, 1991
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Co-ordinates of Origin: 400000m E, 0m N

ICIMOD
MENRIS '99

Map 32

SPIN-2 Two Metre KVR-1000 Image, 1991 (Core Urban Area)
Kathmandu Valley, Nepal

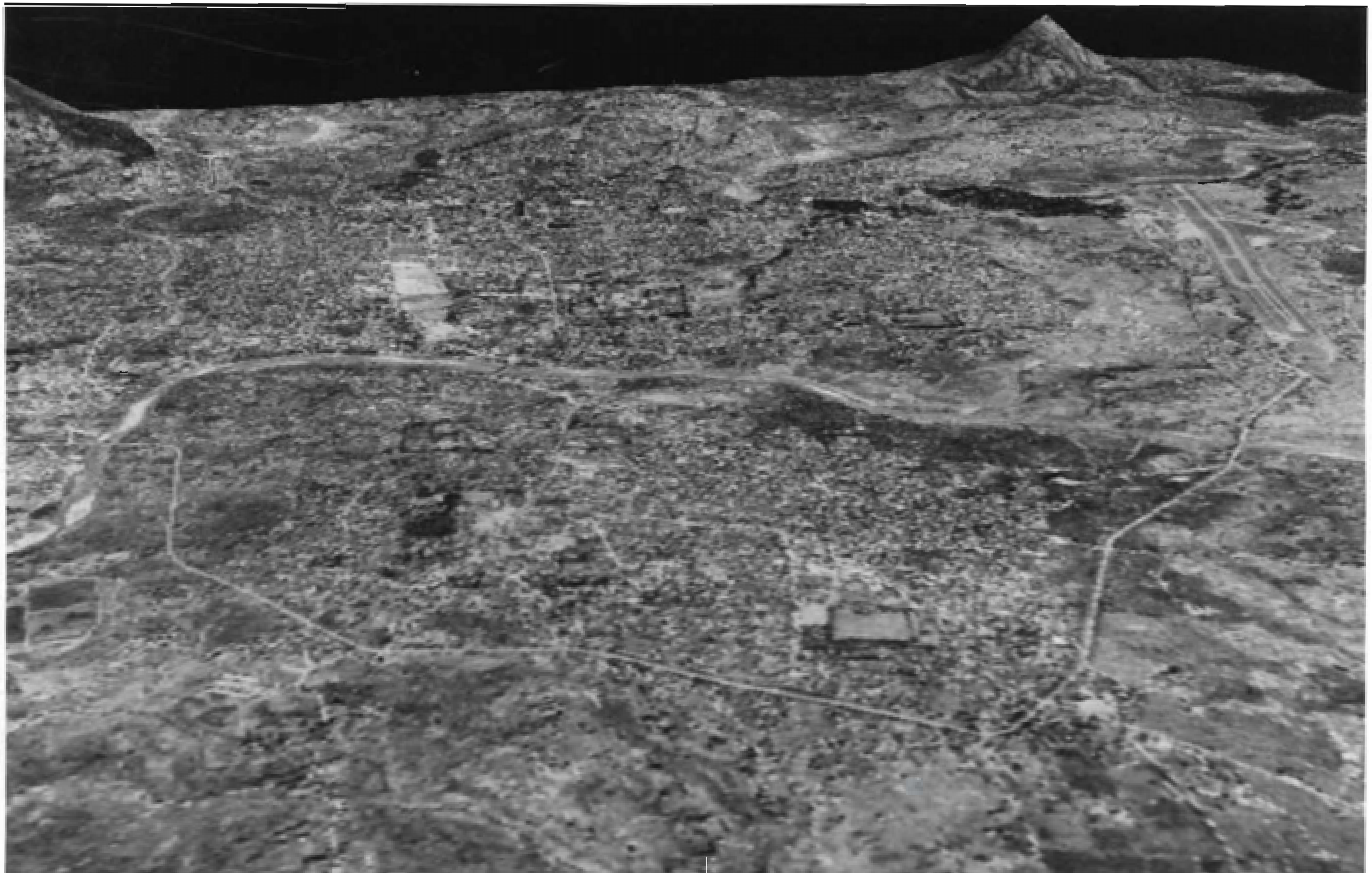
Spatial Resolution: 1.99992 metres
Date Acquired: 5th February, 1991
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Scale
0.5 0 Kilometres

ICIMOD
MENRIS '99

Map 33

SPIN-2 Two-metre KVR-1000 Image, 1991, Draped on DEM
Kathmandu Valley, Nepal



Spatial Resolution: 1.99992 metres
Date Acquired: 5th February, 1991
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest

Above Ground Level (AGL): 800 metres
Above Sea Level (ASL): 2000 metres
Field of View (FOV): 50 degrees
Azimuth: 2 degrees
Exaggeration: 4

ICIMOD
MENRIS '99

Map 34

SPIN-2 Two Metre KVR-1000 Image, 1991, Merged with ADEOS-AVNIR Image, 1997 (Part 1) Kathmandu Valley, Nepal

Spatial Resolution: 2 metres.
Dates Acquired:
SPIN-2: 5th Feb., 1991
AVNIR: 11th Jan., 1997
Geo-referenced to UTM
Spheroid: Everest.
Zone: 45, Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Co-ordinates of Origin: 400000m E, 0m N

Scale

0.5 0 Kilometres

ICIMOD

MENRIS '99

Map 35

SPIN-2 Two Metre KVR-1000 Image, 1991, Merged with ADEOS-AVNIR Image, 1997 [Part 2] Kathmandu Valley, Nepal

Spatial Resolution: 2 metres
Dates Acquired:
SPIN-2: 5th Feb., 1991
AVNIR: 11th Jan., 1997
Geo-referenced to UTM
Spheroid: Everest,
Zone: 45, Datum: Everest
Origin: 84 00 00 E, 26 15 C0 N
False Co-ordinates of Origin: 400000m E, 0m N

Scale

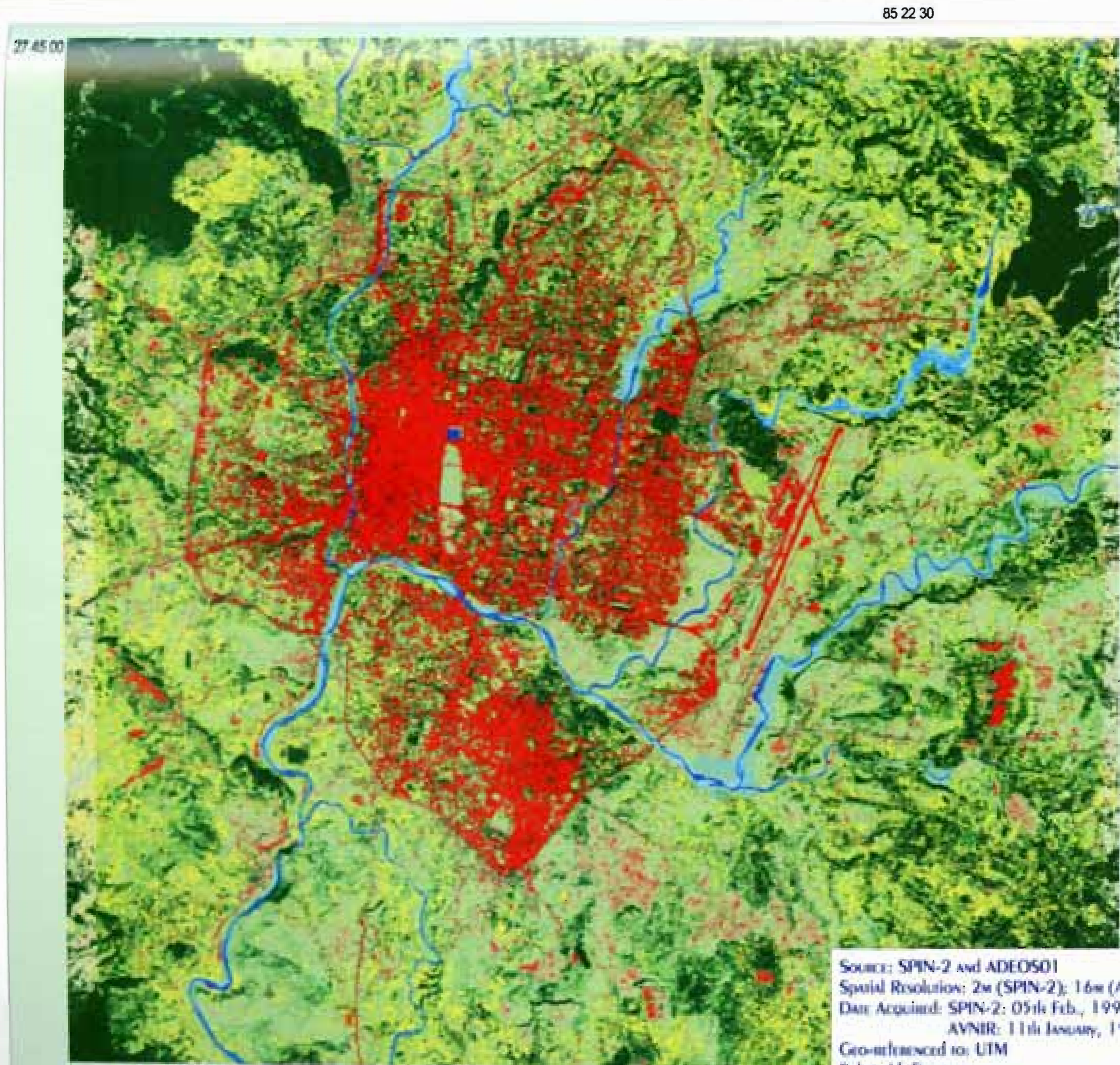
0.5 0 0.5 Kilometres

ICIMOD
MENRIS '99

Kathmandu Valley

Map 36

Land Cover Based On Merged SPIN-2 Image, 1991 and ADEOS-AVNIR Image, 1997



Legend

Land Cover Classes

- Built-up
- Forest
- Grass
- Shrub
- Crop Land
- Fallow Land
- Rivers
- Sandy Area

1 0 1 2 Kilometres

Scale: 1:80,000

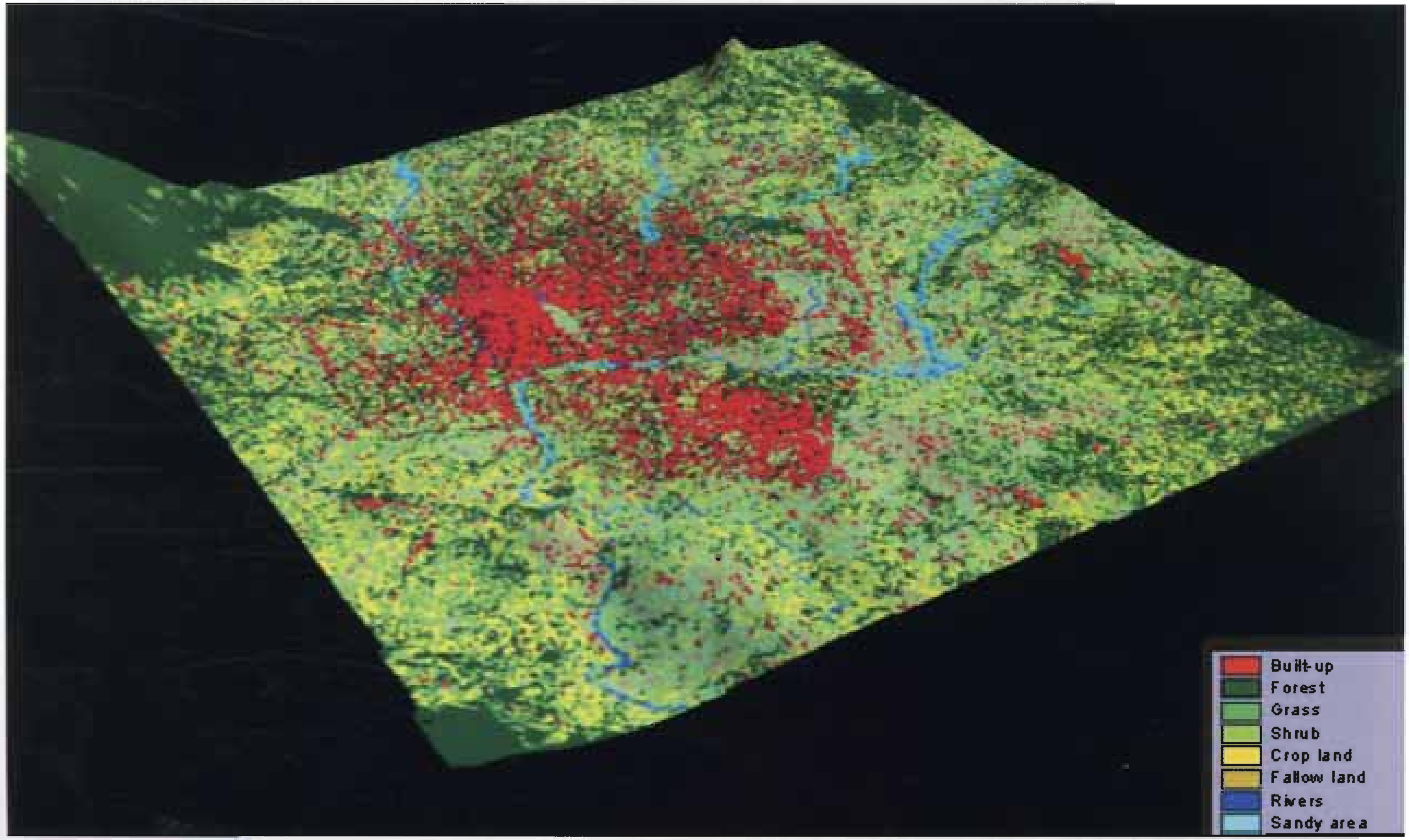
Source: SPIN-2 and ADEOS01
Spatial Resolution: 2m (SPIN-2); 16m (AVNIR)
Date Acquired: SPIN-2: 05th Feb., 1991
AVNIR: 11th January, 1997
Geo-referenced to: UTM
Spheroid: Everest
Zone: 45, Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

Kathmandu Valley GIS Database

ICIMOD MENRIS '99

Map 37

Land Cover Based on Merged SPIN-2 Image, 1991 and ADEOS-AVNIR Image, 1997, Draped on DEM Kathmandu Valley, Nepal



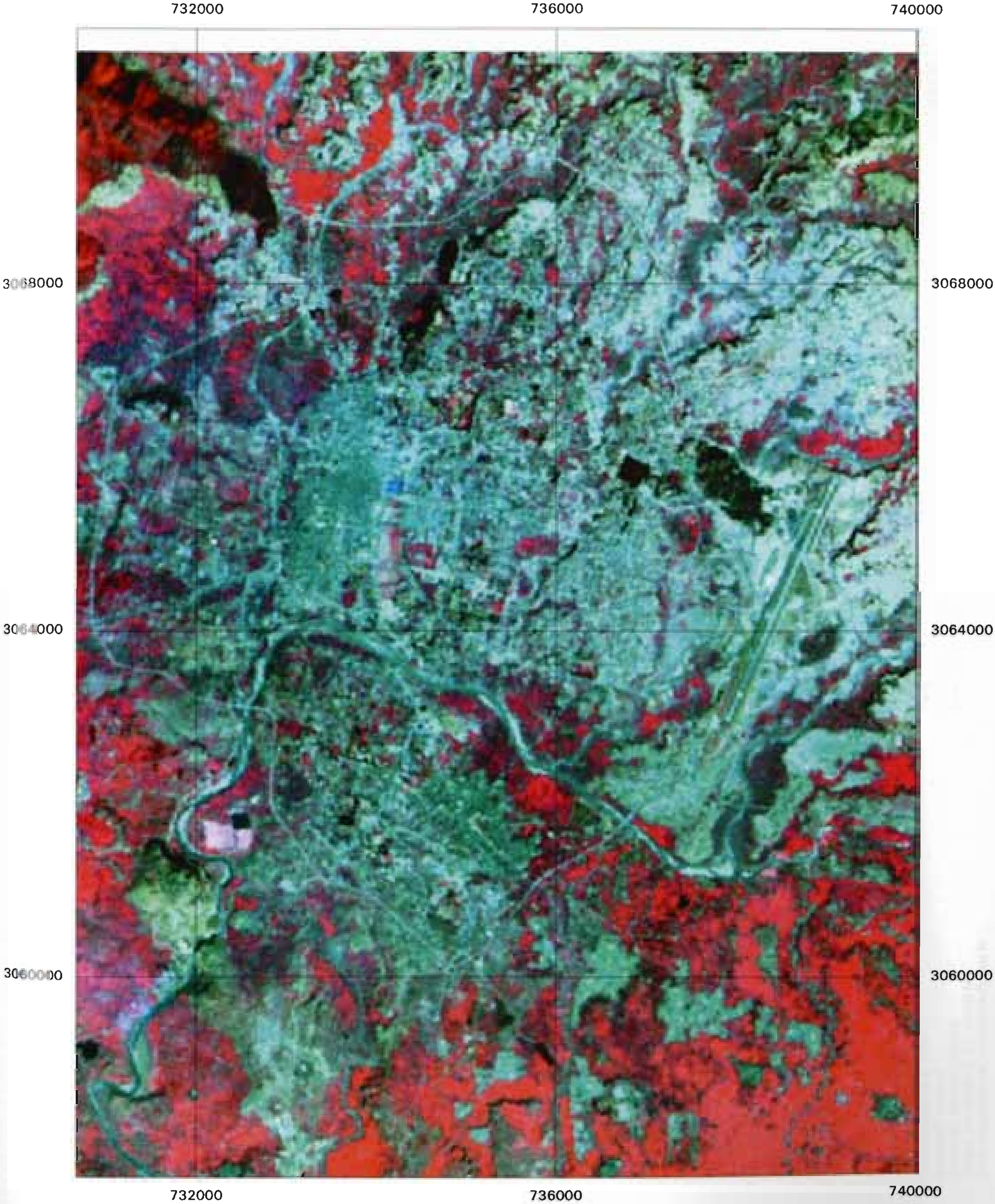
Output Spatial Resolution: 2 metres
Dates Acquired:
SPIN-2: 5th Feb., 1991
AVNIR: 11th Jan., 1997
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest

Above Ground Level (AGL): 2652 metres
Above Sea Level (ASL): 4122 metres
Field of View: 65 degrees
Azimuth: 33 degrees
Exaggeration: 4

ICIMOD
MENRIS '99

Map 38

False Colour Composite (R3 G2 B1) of SPOT-XS HRV1 Image, 1986
Kathmandu Valley, Nepal



Spatial Resolution: 20 metres
Date Acquired: 12th March, 1986
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Co-ordinates of Origin: 400000m E, 0m N

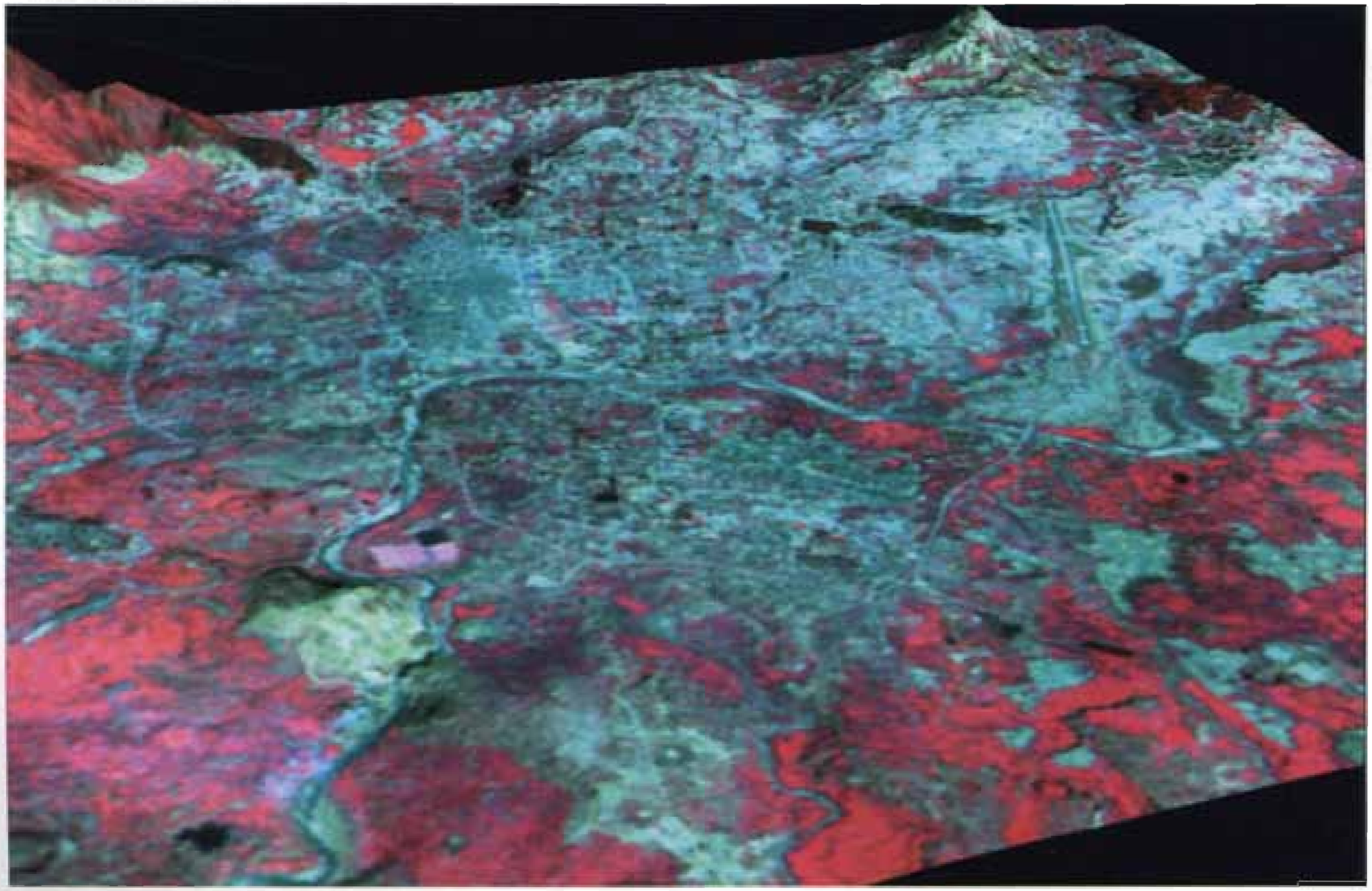
Scale

2 — 0 Kilometres

ICIMOD
MENRIS '99

Map 39

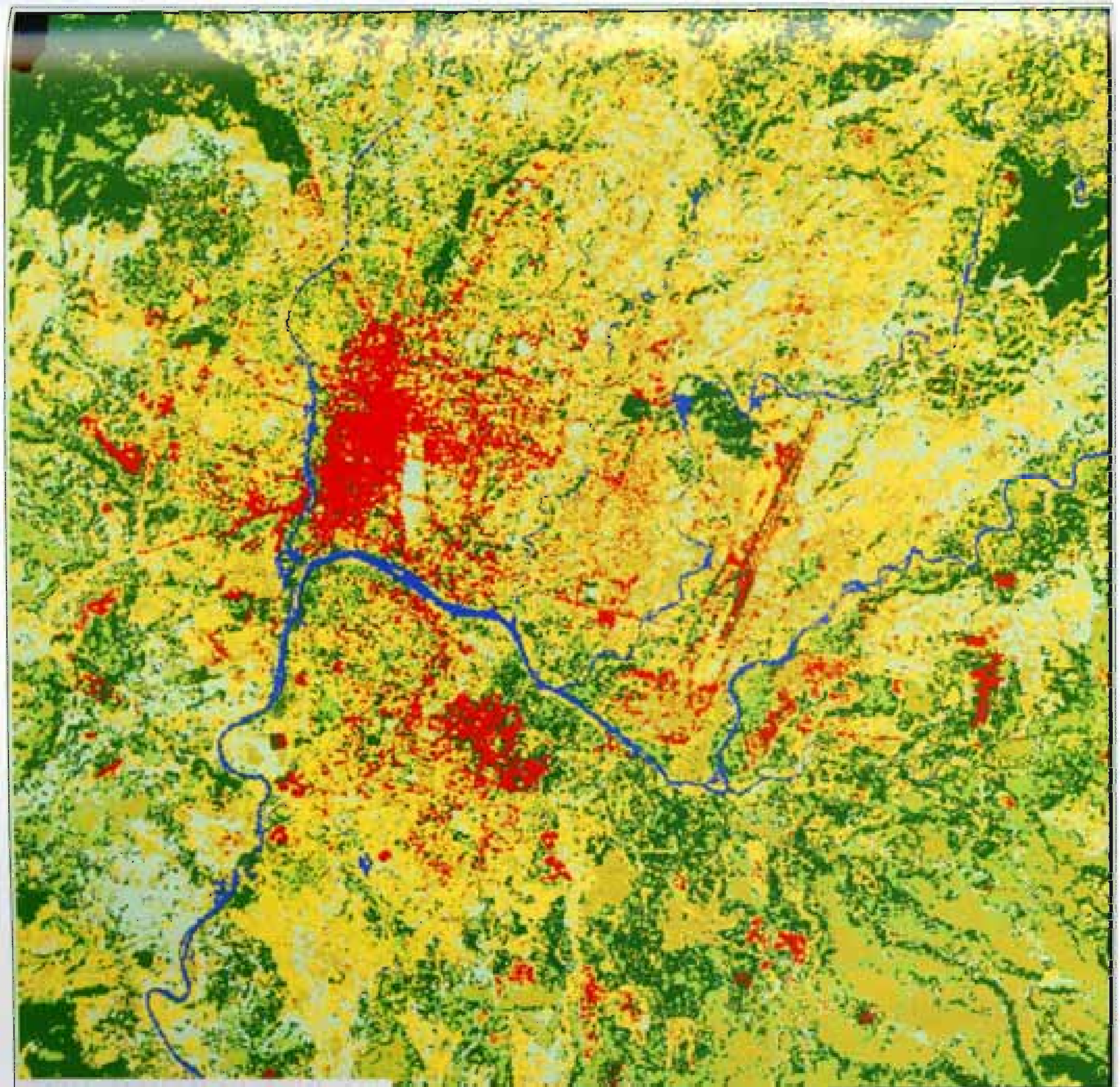
False Colour Composite (FCC) of SPOT-XS HRV1 Image, 1986, Draped on DEM Kathmandu Valley, Nepal



Spatial Resolution: 20 metres
Date Acquired: 12th March, 1986
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 85 00 00 E; 26 15 00 N
False Coordinates: 400000m E, 0m N

Above Ground Level (AGL): 1800 metres
Above Sea Level (ASL): 2678 metres
Field of View (FOV): 50 degrees
Azimuth: 39 degrees
Exaggeration: 4

ICIMOD
MENRIS '99



Kathmandu Valley GIS Database

Kathmandu Valley

Map 40

Land Cover Based on SPOT XS HRV1 Image, 1986

Legend

	Count	Area_sq.km.	Percent
Built-up Area	24487	10	5.65
Forest	96652	39	22.03
Grass	51806	21	11.86
Shrub	53987	22	12.43
Crop Land	103167	41	23.16
Fallow Land	101879	41	23.16
Water Body	6595	3	1.69

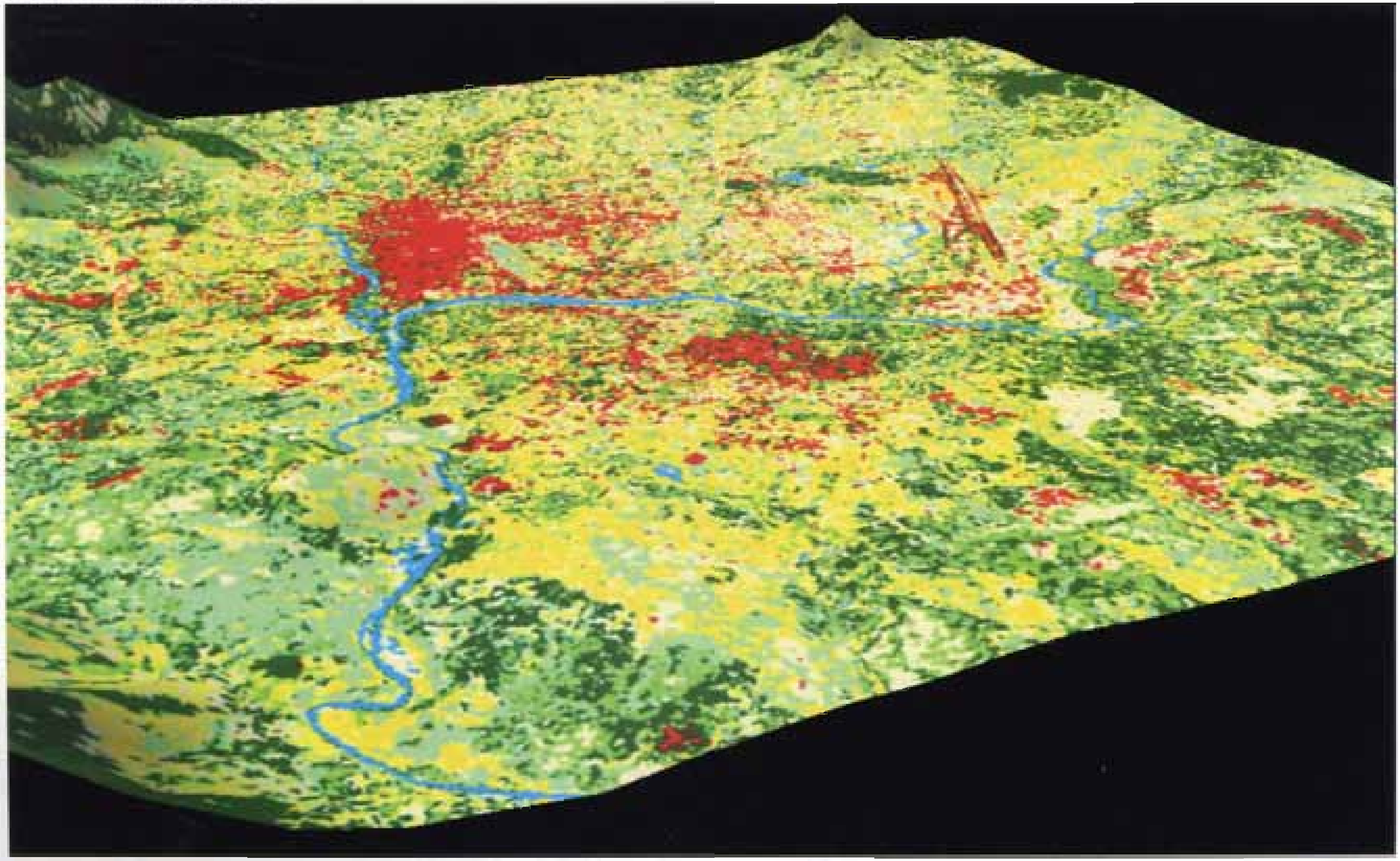
1 0 1 Kilometres

Image Extent: LLX: 729233 LLY: 3057748
URX: 742623 URY: 307068537
Source: SPOT-XS HRV1 Satellite Image
Date Acquired: 12th March, 1986 (20m)
Geo-referenced to: UTM; Output Cell size: 20m
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

ICIMOD
MENRIS '99

Map 41

Land Cover Based on SPOT-XS HRV1 Image, 1986, Draped on DEM
Kathmandu Valley, Nepal



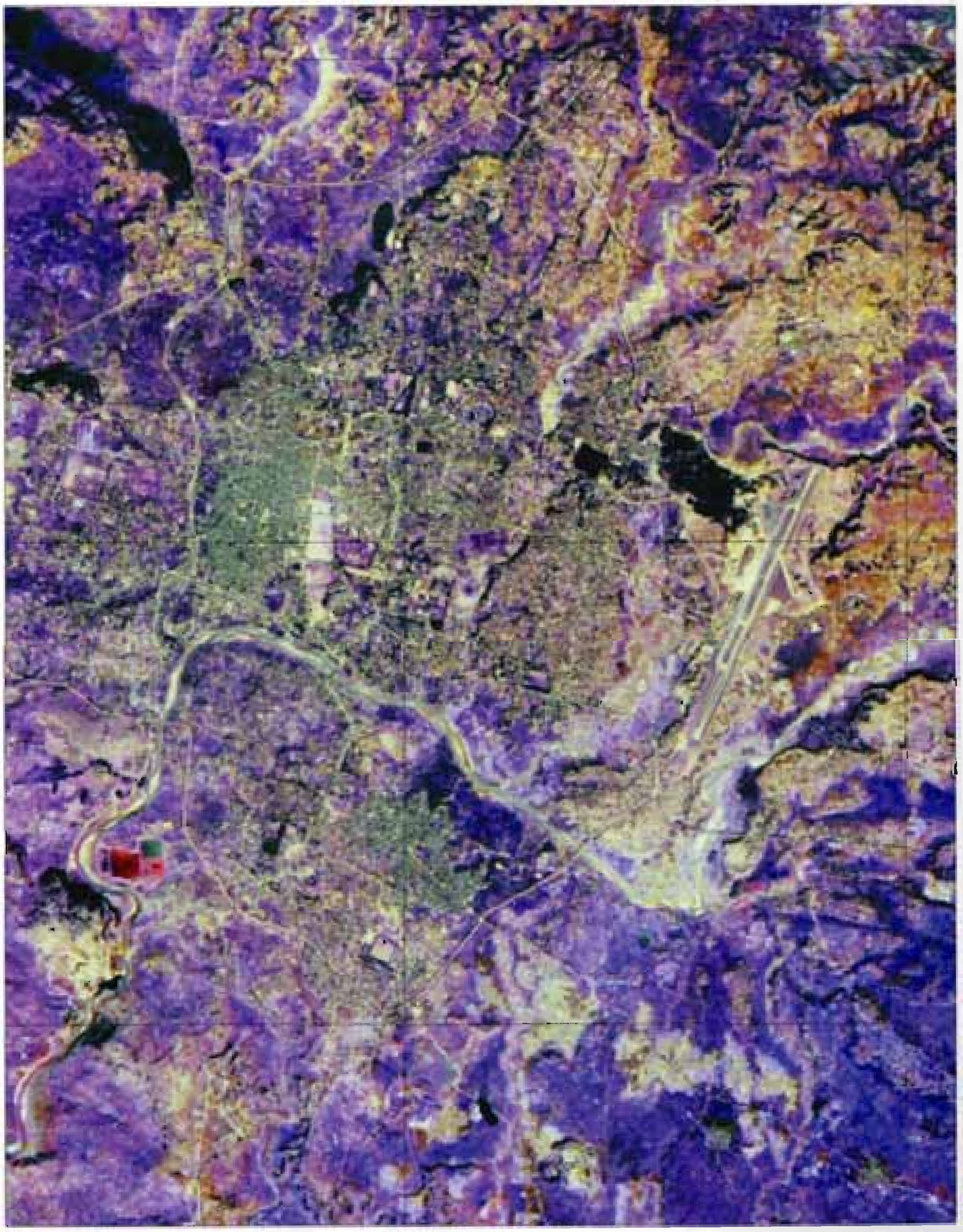
Spatial Resolution: 20 metres
Date Acquired: 12th March, 1986
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Co-ordinates of Origin: 400000m E, 0m N

Above Ground Level (AGL): 1435 metres
Above Sea Level (ASL): 2806 metres
Field of View (FOV): 50 degrees
Azimuth: 25 degrees
Exaggeration: 4

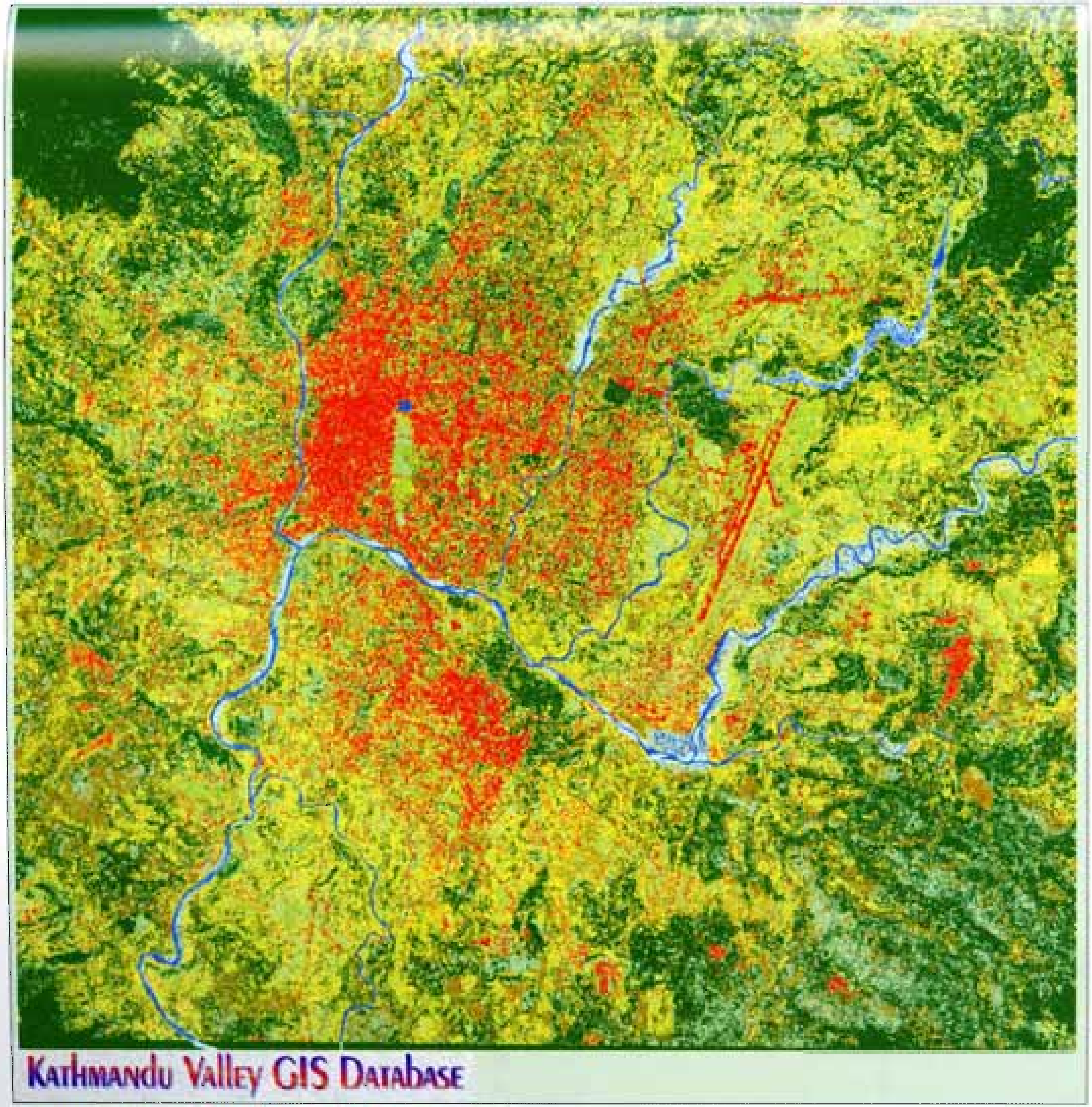
ICIMOD
MENRIS '99

Map 42

Merged (SPIN-2, 1991, and SPOT-XS, 1986) Image
Kathmandu Valley, Nepal



Output Resolution: 2 metres
Dates Acquired: SPIN-2: 5th February, 1991
SPOT-XS: 12th March, 1986
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

Map 43

Land Cover Based on Merged SPIN-2 Image, 1991 and SPOT-XS HRV1 Image, 1986

Legend

- Built-up Area
- Forest
- Grass
- Shrub
- Crop Land
- Fallow Land
- River
- Sand/Gravel/Boulder

2 0 2 Kilometres

Image Extent: LLX: 729233 LLY: 3057748
URX: 742623 URY: 307068537
Source: SPIN-2 and SPOT-XS HRV1 Satellite Image
Dates Acquired: SPIN-2: 05th Feb., 1991 (2m)
SPOT-XS: 12th March, 1986 (20m)
Geo-referenced to: UTM; Output Cell size: 2m
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400000m E, 0m N

ICIMOD
MENRIS '99

Map 44

IRS-C Satellite Image, 1996
Kathmandu Valley, Nepal

Spatial Resolution: 5.6 metres
Date Acquired: 23rd November, 1996
Geo-referenced to UTM
Spheroid: Everest
Zone: 45; Datum: Everest
Origin: 84 00 00 E, 26 15 00 N
False Coordinates of Origin: 400,000m E, 0m N

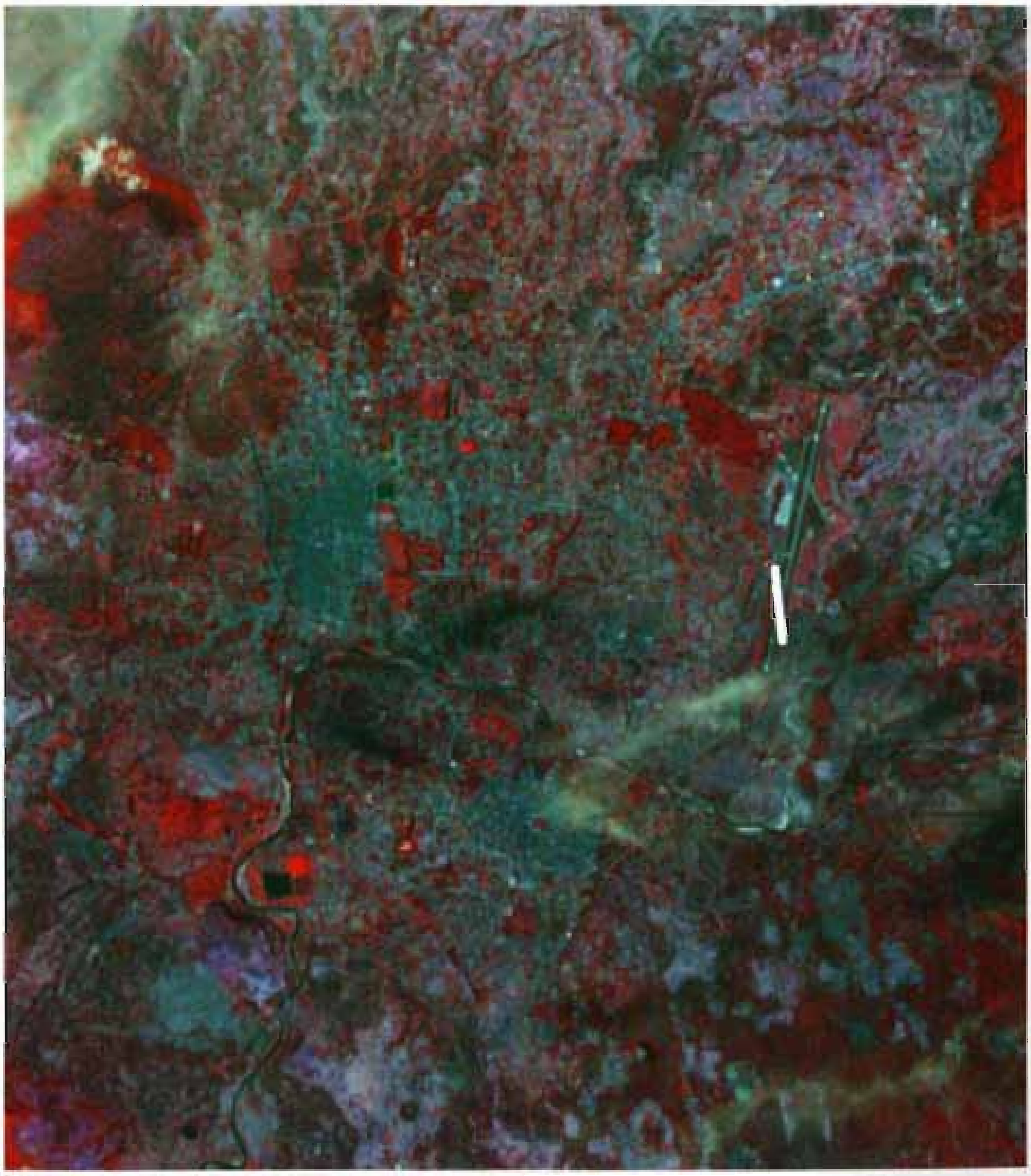
Scale

2 0 Kilometres

ICIMOD
MENRIS '99

Map 45

False Colour Composite (R3 G2 B1) of SPOT-XS HRV1 Image, 1991
Kathmandu Valley, Nepal

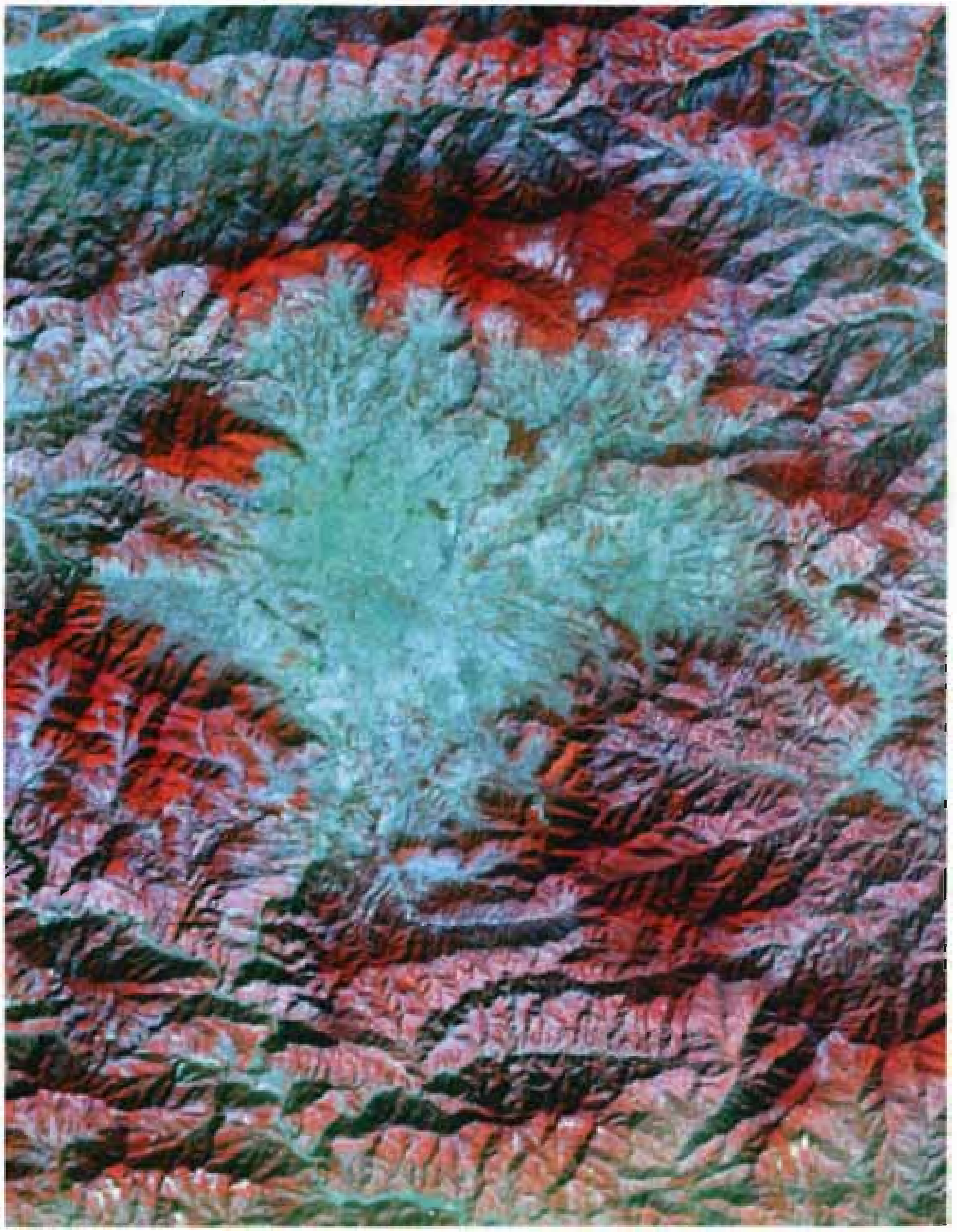


Spatial Resolution: 20 metres
Date Acquired: 05th May, 1991
Geo-referenced to: None

ICIMOD
MENRIS '99

Map 46

False Colour Composite (R3 G2 B1) of SPOT-XS HRV1 Image, 1994
Kathmandu Valley, Nepal

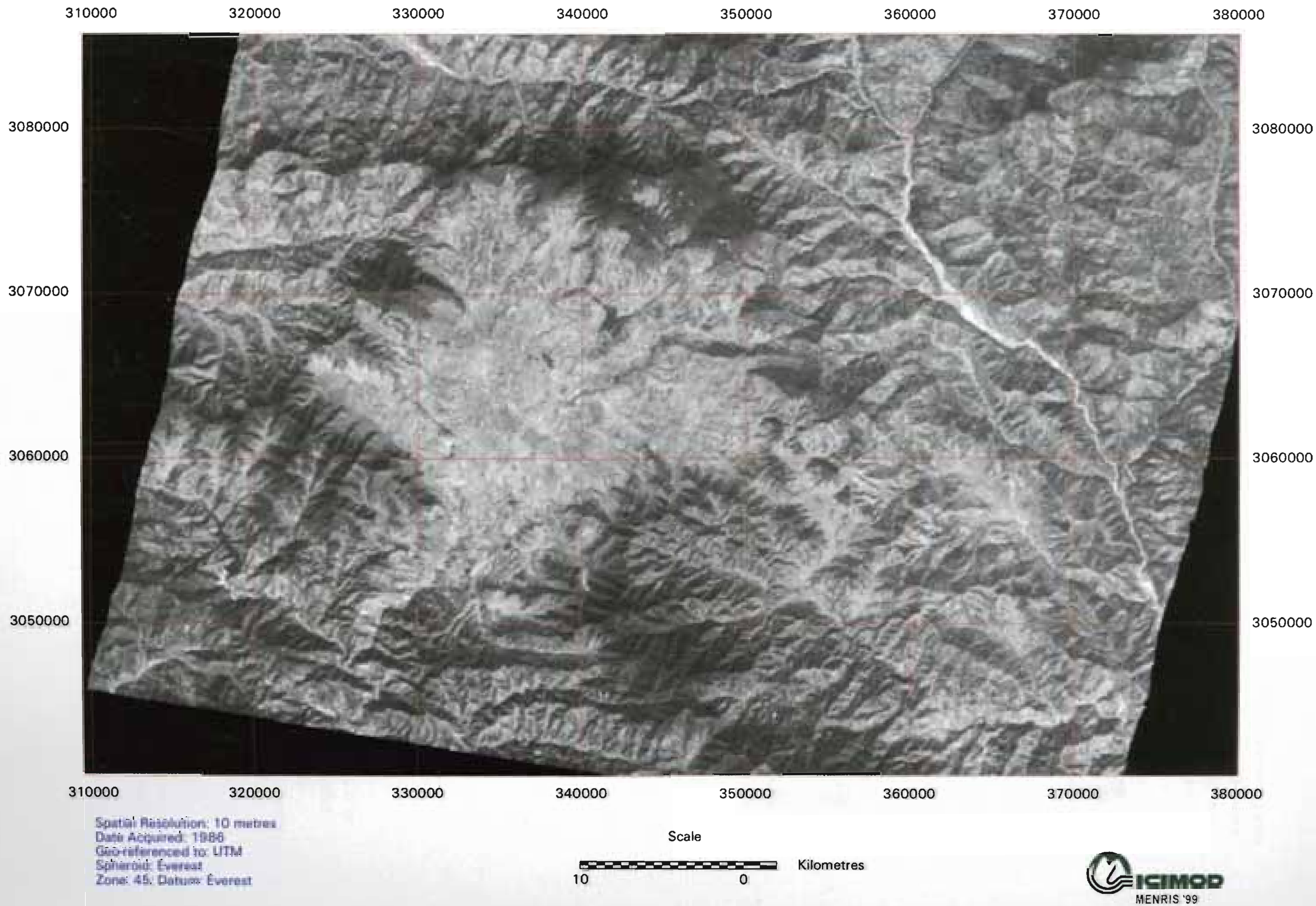


Spatial Resolution: 20m
Date Acquired: 12th December, 1994
Geo-referenced to: None

ICIMOD
MENRIS '99

Map 47

SPOT-PAN Ortho Image, 1986
Kathmandu Valley, Nepal



7.4 Integrated GIS Database

Each of the various GIS data layers mentioned in the above sections is converted into a raster-based structure using 10-metre cell sizes. All layers are registered into the Universal Transverse Mercator (UTM) geographic coordinate system. All spatial data, including digitised thematic maps and satellite images and tabular data have been integrated into a single information system, and spatial indices have been created to link different data sets using their spatial locations. The overall methodology employed to create an integrated GIS Database is depicted in Figure 7. Based on this, an integrated spatial database has been established using workstation-based Arc/Info 7.0.3 and Arcview 3.1 software. Satellite images were processed in workstation-based ERDAS Imagine 8.3.1 software.

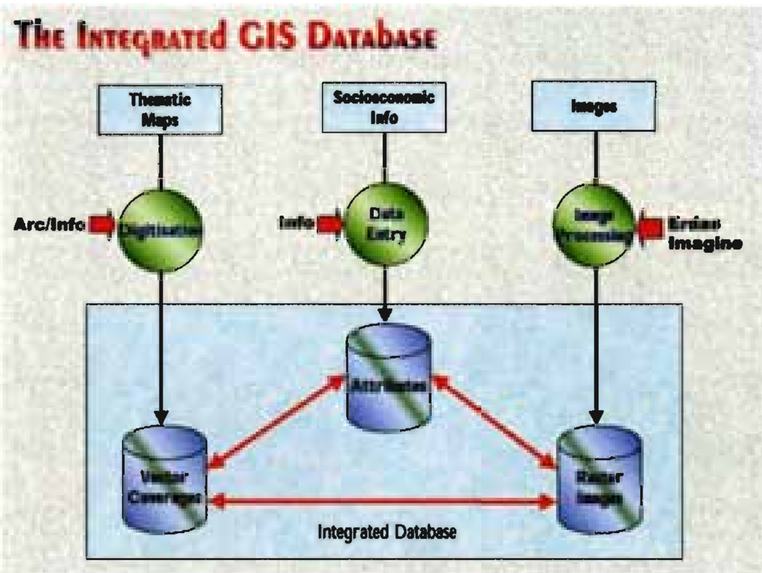


Figure 7: **The Integrated Database**

Developing databases takes a lot of time and resources, normally production cost is 70 per cent or more for most GIS projects. The integrated database developed can be used by many organizations for different applications such as natural resource management, environmental and urban applications, and so on. However, the database may be far from complete depending upon the particular application, but it encourages a building block approach to database development, management, and revision. In the next section, some of the potential applications using GIS and related technologies are shown, but merely for demonstration purposes rather than as comprehensive applications. Many applications can be developed once a comprehensive database is in place.