1. INTRODUCTION

1.1 Background

The planning on development strategies for agriculture in mountain areas depends upon the precise definition of the area and land use pattern. However, in conceiving a conceptual or operational approach for the development of hill areas, the key issue that should be taken into account is to first understand that the hills are characterised by a three dimensional spatiality unlike the plains that may have only a two dimensional spatiality. This additional dimension obstructs the applicability of development approaches of the plains to the hills. Because of this special factor i.e. undulating topography, precise estimates of actual areas can not be made by ordinary means like flatlands which are easy to measure. When hills are examined from the plains' perspective, the measured area is less and hence a huge discrepancy exists between actual area and the area for which planning/development measures must be taken.

Landscape area is almost always presented in terms of planimetric area hence square kilometer in a mountainous area represents the same amount of land area as a square kilometer in the plains. The multifaceted dimensions of hills can help in presenting an array of positive and negative attributes of hill situations. The focus of development interventions should be on protection and enhancement of positive attributes and maximisation of their role in development interventions. Even when describing mountains, the planning is generally based on only planimetric area although resources exist, distributed or limited spatially, the assessment of these using surface area is must. An understanding of these attributes can greatly help in determining developmental goals and priorities and in designing operational programmes.

For making strategies for sustainable development in hills, planners must take into account the amount of actual area available. Flatland estimates are unrealistic and vague in the mountain context. The multidimensionality of hill features calls for basic changes in developmental goals. The flat area of Himachal Pradesh in government records (which is commonly used for all planning purposes) is 55673 sq. km, however, due to extensive slopping valleys existing in most of the part, actual area may be much higher. As mostly, the development strategies for hill areas are resource-centred, the actual area calculation will act as constraints or indicators of resource base potentials of the state. The conventional planning approach of flat lands is thus highly ruled out and actual area calculation forms a compelling basis for an integrated approach to development interventions in hilly areas.

If the area estimates of a region are not precise then all the planning process is jeopardized. The time, effort and funds spent on the developmental process are either under or over utilized. Mountains are the places where area estimation is a tedious task by ordinary means; hence a geographical system based approach can be of help in such areas, where remote sensing data using satellite imagery sets can be utilized to estimate the precise area. Such approaches in Himachal Pradesh are very useful particularly in the tribal districts, which are mostly mountainous and are underdeveloped in many respects. For example, it has long been felt that there is a continuous increase in cultivable area in Himachal Pradesh, while the total area is remaining the same. The increase in area is not traceable, while it is always reported that the area under a particular crop has increased. Further, It is also essential that the development of a region depends upon the precise definition of the area and land use pattern.

Due consideration must be given to complexity of hill characteristics, their multiple dimensionality and their interrelationships to provide contextual perspective to decisions and actions in hilly areas. The additional area which may be locked up in five major classes of land cover i.e. agriculture, forests, settlements, snow fields or non-vegetation areas is certainly contributing and needs proper documentation, conservation and harnessing of mountain potentialities. The additional area would certainly alter development goals and needs in the state which should be described and defined in broader terms with an explicit focus on issues such as equity, environmental stability, and economic betterment. The present study is thus an attempt to calculate the surface area (district-wise) of entire Himachal Pradesh. Also, it is felt that this study will be most appropriate and desirable to help in the agricultural planning task as well as for farmer's development in Himachal Pradesh. An attempt has been made through this study to remove the anomalies in the precise estimate of the surface areas, by using a GIS platform.

1.2 Rationale

Area is a fundamental parameter derived from terrain analysis which is necessary for numerous decision-making processes. There is a need to obtain an accurate approximation of distance and area which are the fundamental terrain parameters associated with spatial data context since these have a bearing on cost (Navigation, cadastral applications). This problem has been addressed within the framework of a given data scale and a suitable projection. In most elementary GIS models, distance and area calculations are based on the vector data model which is a planar approximation of data layers. This does not approximate distance or area on an undulating surface in reality. Given the pre-conditions that the data layers are in the desired scale and projection, a novel way to integrate a raster elevation model to retrieve the near true area and distance (involving elevation data & slopes) is attempted in the present study.

1.3 Geographic Information of Himachal Pradesh

Himachal Pradesh is a mountain province in the Indian Himalayas, covering an area of over fifty thousand sq. km. Inhabited by five million people, of which over 92 percent rural population lives in over 16000 villages. It is located between 30"22' and 33"12' north latitude and between 75"45' and 79"04' east longitude. The mountainous state has altitudes ranging from 350 to 7000 meters (1050 ft. to 21000 ft.) above the sea level. As is common in the Himalayan region, human settlements are scattered but largely concentrated in the low and mid hill areas and highlands are sparsely populated. Himachal Pradesh can be considered special as development model in the entire Hindu Kush Himalayan region, as tremendous progress has taken place in the farm economy, food security with adequate institutional and infrastructure support and well being of its people (who enjoy reasonably better life styles than other mountainous states). The state provides a rare example of the success story in handling socio economic marginality of High Mountain communities, which are otherwise considered gifted with fragile, marginal and inaccessible conditions- leading to perpetual poverty.

In addition to the physical difficulties already encountered by mountain dwellers, various national policies adversely affect mountain areas. During recent year, the goal of macro-economic policies in the mountain areas has been directed towards the extraction of mountain resources, largely for use in the non-mountain hinterland (plains) or in urban areas within the mountains. The developmental policies for the investment or resource allocation pattern in Himachal Pradesh require additional specific information pertaining to area and resources. The area of Himachal Pradesh as per state revenue records is 55673 sq km. This area does not include the area locked up in slopes due to undulating topography of the state. Hence, a substantial amount of area is concealed and never been accounted for planning purpose before. The spatial distribution of land cover estimates for the state even through remote sensing has been made on government recorded area and may not be the exact surface area and may not be detailed.

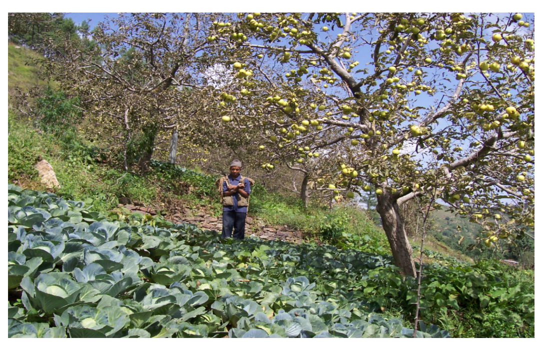
The state is dominated by mountains and associated rivers and valleys (Fig.1). The mountain peaks, hillsides and ridges in Himachal Pradesh are characterized by steep slopes. The slope varies from 0.5 to >70 per cent in the State. There is a drastic variation in the landform characters. Each landscape unit may be divided into several distinct areas (significant mountain and hillside terrain) with provision for accommodating different land use types. The slopes are being extensively cultivated in mountain areas and the undulating land is being used for infrastructure build up too and the area is in use which is the exact surface area (Fig. 2a and b).

Fig. 1. Mountains, river, valleys- view of river Beas at Manali, HP .


Sloppy Pasture lands in Himachal Pradesh


Settlements on slopes


Hill- Farming

Horticulture (Orchards)

Fig. 2a Different type of land use in Himachal Pradesh

Forest

Infrastructure/industries/mining

Water bodies-glaciers

Tea plantation on slopes

Fig. 2b Different type of land use in Himachal Pradesh

The land use in Himachal Pradesh is not limited to specific relatively plain areas. The areas with slopes too include agricultural/buildable lands, roadways, driveways, public structures, buffers etc. Up to 40 per cent of the slope area is being harnessed effectively in the state; however, in some parts with 60-70 percent slopes, agriculture is being made feasible.

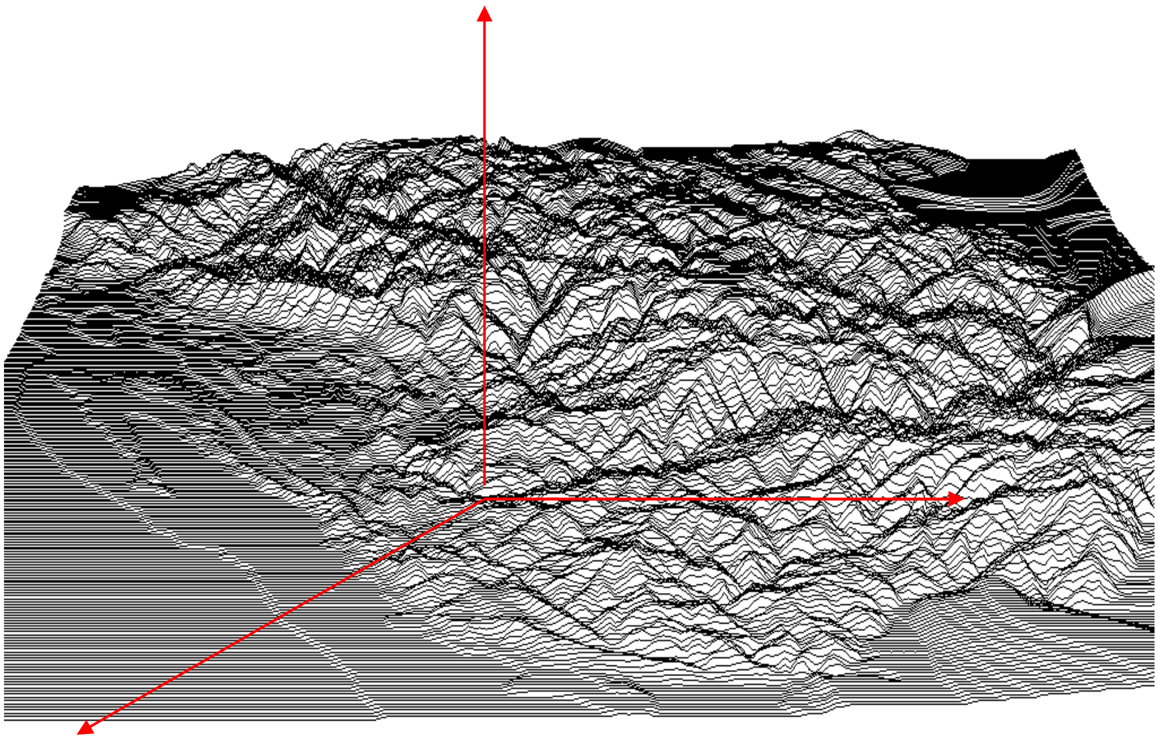


Fig. 3 XY ruled 3-D surface view of Himachal Pradesh.

Fig. 3 shows the XY ruled 3-D surface view of Himachal Pradesh. Area enclosed under a sloppy surface is bound be higher than the area of a plain surface (Fig. 4).

Fig. 4 Diagrammatic representation of plain versus slope area

This anticipated area is, however, currently unreported and as a result planning may be done for the less area. The present study is an attempt to calculate the surface area for Himachal Pradesh using modern Geo-IT tools viz., remote sensing and geographical information system.

1.4 Mountain areas and Remote Sensing/Geo-information Technology

Mountain areas present a great challenge for the application of Geo-Information technology due to their diversity, marginality, and strategic importance, as well as their different physical, biological, and societal systems. When compared with the plains in the lowlands, the physical characteristics of the mountain environment are more complex and need to be analysed using a three-dimensional approach/methodology to arrive at an approximate representation of the aspect, slope, and topography of the mountains (Heywood al. 1994). Digital Elevation Models (DEM) are used for different types of applications in mountain environments, e.g., regional resource inventory; planning and management, hazard assessment, modeling of the ecology, climate, or hydrology; and geomorphology (sources quoted in Stocks and Heywood 1994).

A Geographic Information System (GIS) is a computer-based system capable of holding and using data describing places on the earth's surface. The strength of Geo-Information technology is its ability to integrate data from various resource disciplines, using a common geographical boundaries as a reference. The system is characterised by two forms of data; i.e., attribute data, either statistical or textural, contained in tables, lists, catalogues, etc and geographic information, either spatial or locational, contained in various kinds of maps. Computer technology, for quite some time, has made it possible to manipulate and analyse statistical information. Recent development has facilitated the automation of maps into digital databases and allowed the manipulation to produce a combination of maps and tables that show 'where' and what', and to answer many questions that remained open. This computerized system, known as GIS, can store, manipulate, display, and produce geographic (spatial) information integrated with statistical and textual data; it is becoming one of the most useful and powerful analytical tools for resource planners and managers (Marble et al. 1984; Foote and Lynch 1996).

Application of remote sensing has a special place in Mountains as most of the areas are inaccessible and multi-stage approach using remotely sensed data increases the ability and accuracy of the work. Through remote sensing, new mechanisms for obtaining information on remote and inaccessible areas have become available. Visual and digital image analysis techniques have been very useful in studying mountain areas. Satellite imagery IRS1D LISS3 of Himachal Pradesh has been used in the present study.

1.5 Surface area calculations using GIS

Mountains are areas of high relief having distinct changes in terrain slope and thus require a three-dimensional representation for spatial modeling. Maps and GIS in general treat the world as flat (plain land); this two-dimensional view leads to incompatibility in appropriateness of GIS application between that for level land and mountains. Mountains have some very specific features that need heterogeneity. Unfortunately, it is not the practice, apart from few modifications made in GIS applications for mountain areas (Ghosh, 2001). Maps represent geographical area on the planar surface whereas due to slope differences in the mountains the actual surface area is greater, the discrepancy in area calculation leads to over or under estimation.

Decision making can be improved by utilizing the surface area calculation functionality with GIS. Such functionality does add a new dimension to the accuracy of the surface area value, although the dependency of accuracy also depends on the elevation model (TIN, DEM, DTED) in use, its information source (interpolated contours, stereo-imagery) and the resolution (Kundu and Pradhan, 2002). Three dimensional - 3D analysts in GIS software supports three primary data types for modeling features in three dimensions-grids, TIN and three dimensional shape files. The most accurate measure of the surface area within a polygon should include all the area within the polygon.

Surface area calculations have been attempted before (Strahler, 1952) and several algorithms were developed for the purpose, all of which are based on slope. Surface area, therefore is a second derivative of elevation data. Elghazali et al. (1986) described the areal parameter, which essentially is a global function that produces a ratio between the surface area and plan area. This parameter was used for terrain characterisation but also has usefulness as a measure to estimate surface area.

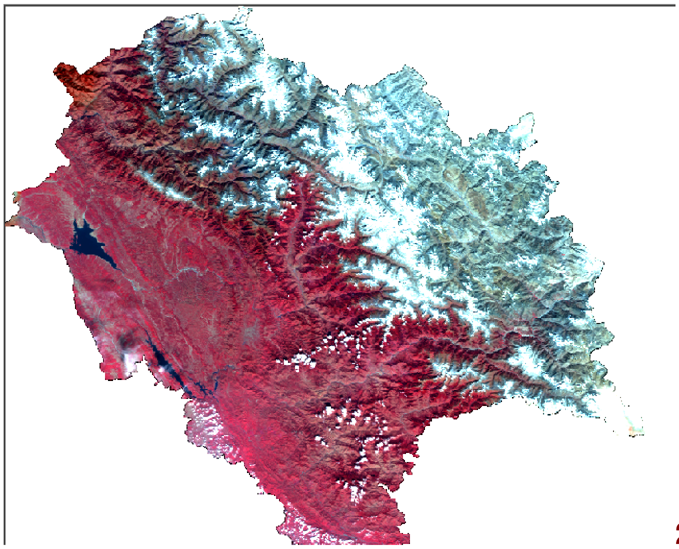
The triangulated irregular network (TIN) is a surface representation based on randomly or irregularly spaced data points that have x, y, and z coordinates. A typical example of this coordinate system is longitude (x), latitude (y), and an elevation or concentration (z). Non-overlapping, connecting triangles are drawn between all data points where the data points (or control points) are the vertices. In its basic form, tin elevations are calculated based on linear regression between control points; contours are then drawn across the sides of the connected, tilting triangular plates.

A DEM can be preferred to a TIN because the latter is based on slope inflection points and fail to capture the subtle difference in slope along a particular aspect. A DEM is essentially, "a regular gridded matrix representation of the continuous variation of relief over space" (Burrough & McDonnell, 1987). This in fact means that a DEM is a continuous grid containing the elevation at its spatial location in each grid cell. Before the 80s, topographic contour maps and aerial photographs were the primary sources of geomorphological information. The accuracy of these maps was highly questionable and there were also discrepancies in information content for two maps for the same region but from different sources. After the advent of DEM this discrepancy was reduced to a large extent. Nevertheless, a DEM is also subject to error depending on the method of its acquisition, as each method has its own advantages and limitations. Usually a DEM is interpolated from digitising spot heights as recorded on field or from an existing contour map. But a better DEM is extracted from stereo aerial photographs or stereo digital remote sensing imagery.

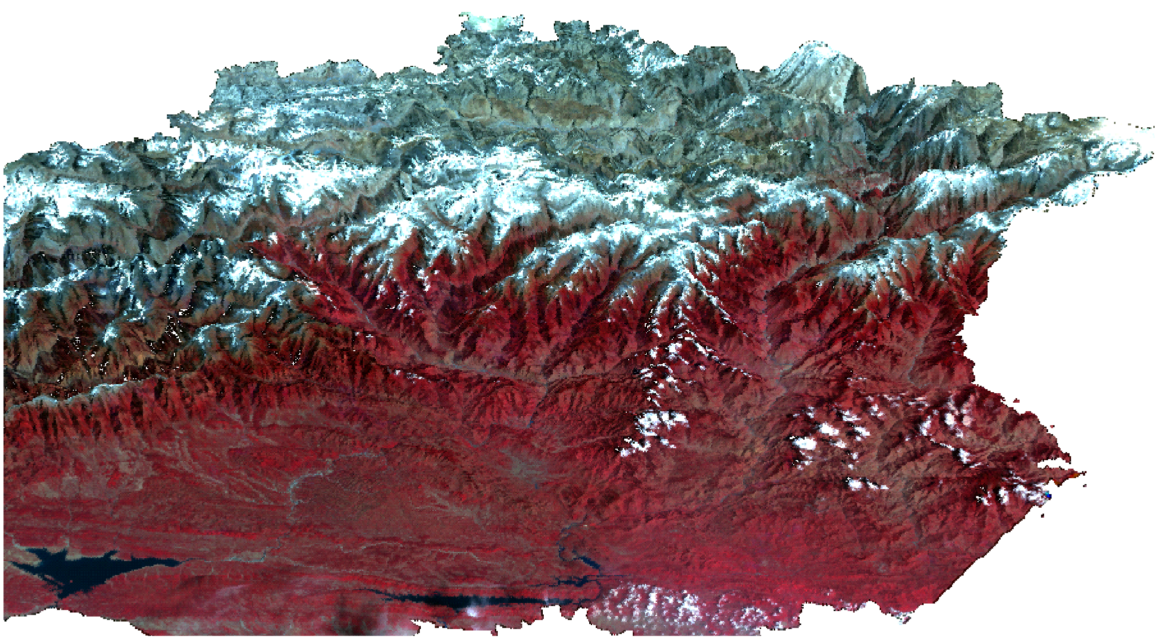
Three dimensional TIN elevation model can be created from contour lines. The contour produces results that range from smooth and relatively less accurate to less smooth and more accurate. For purposes of generating a series of structured contours, a single interpolation method is required that reflects semi-regional to regional geological trends, yet accurately reflect the control data. Triangulated Irregular Networks (TINS) approach to generate surface-area statistics is more accurate for calculating 3D area.

2. OBJECTIVE

- To develop district-wise surface area files for Himachal Pradesh



2 D Surface of HP



3 D Surface of HP

3. MATERIALS AND METHODS

3.1 The Study Area

The state of Himachal Pradesh is a mountain province in the Indian Himalayas covering an area of 55673 sq km where mountains and hills occupy most of the land. It extends from the Shiwalik hills in the South to the Great Himalayan range including a slice of Trans-Himalayas in the North. Geographically, the state of Himachal Pradesh is situated between 30^0 22’ 44” and 33^0 12’ 40” N latitude and 75^0 45’ 55” to 79^0 04’ 20” E longitude (Fig. 5).

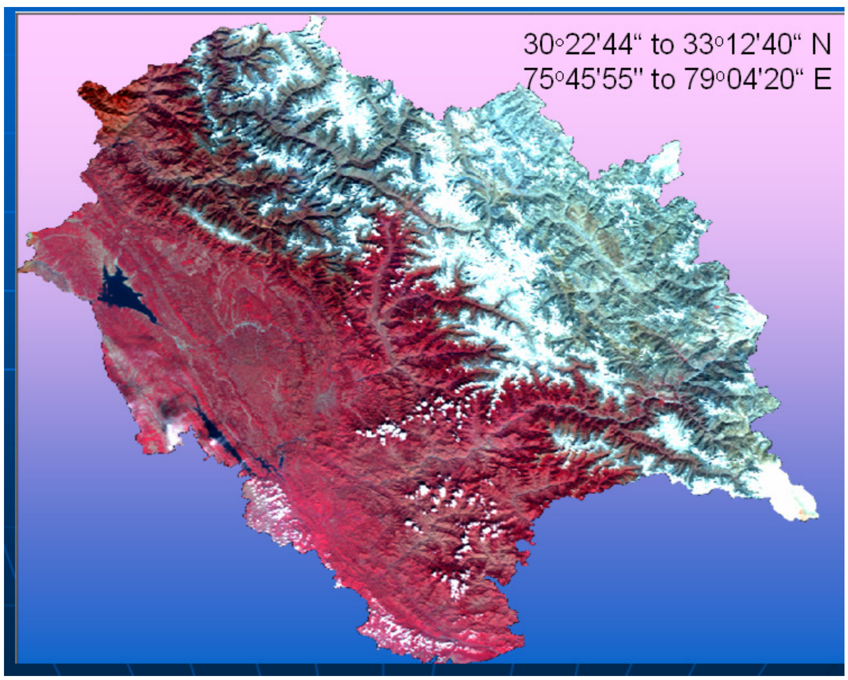


Fig. 5. Study area- A satellite image of Himachal Pradesh IRS1D LISS3.

The state of Himachal Pradesh comprises of 12 districts and 109 tehsils (Fig 6). The Tehsil and districts are the administrative units which are also repositories of all the data about the respective units. These are derived from Survey of India (SOI) toposheets (1:50,000 scale).

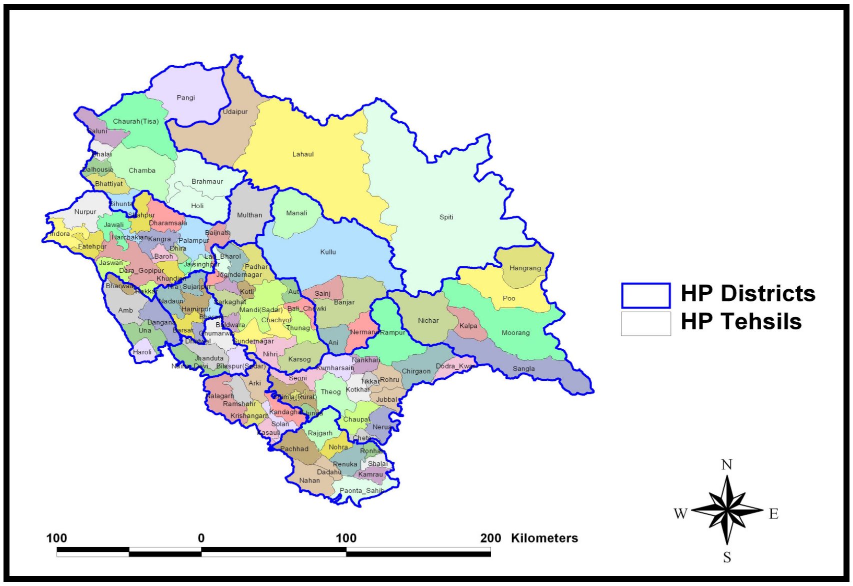


Fig. 6 Administrative map of Himachal Pradesh

The general land cover map of Himachal Pradesh is presented in Fig 7 which is generated by ISODATA clustering of GeoCover Landsat TM (bands 7, 4, 2) of Himachal Pradesh. The spatial distribution of land cover types indicates 14 % of the total area is under agriculture with 32 percent area as forests.

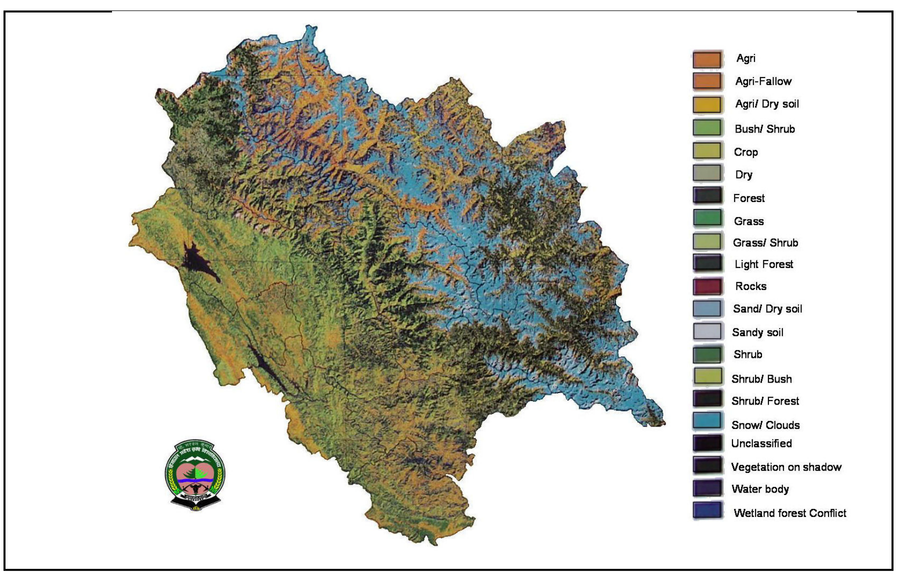


Fig. 7 Land cover of Himachal Pradesh

3.2 Inputs required for the calculation of 3-D surface area.

3.2.1 Topographic Maps

The topographic maps covering entire state of Himachal Pradesh, published by survey of India in the period from the 1960s-1970s on a scale of 1:50,000 have been acquired. Himachal Pradesh is situated between 30º 15' to 33º 15º 0' E longitude and 75º 45’ to 79º 0’ N latitude. The coordinate system parameters for Himachal Pradesh are as follows.

The coordinate system parameters for the maps of the Himachal are as follows:

• Projection:	Albers Equal Area Conic
• Ellipsoid:	WGS 84
• Datum:	WGS 1984
• False easting:	0.0000000
• False northing:	0.0000000
• Central meridian:	82° 30’E
• Central parallel:	0° 0’ N
• Latitude of first parallel	20° N
• Latitude of second parallel	35° N

The minimum and maximum X and Y values required in the above geo-referencing system in the Himachal area falling in Grid Zone II B are:

- Min X,Y: -646838.500, 3298325.500
- Max X,Y: -328038.500, 3623225.500

Altogether 110 topographic map sheets cover the whole of Himachal (Fig. 8). The digital topographic map (ARC digitized Raster Graphics (ADRG) published in January 1996 by the National Imagery and Mapping Agency (NIMA) and Defense Mapping Agency (DMA) of the U.S. Government at the scale of 1:500,000 with same projection parameter as mentioned above were procured to be used in the study.

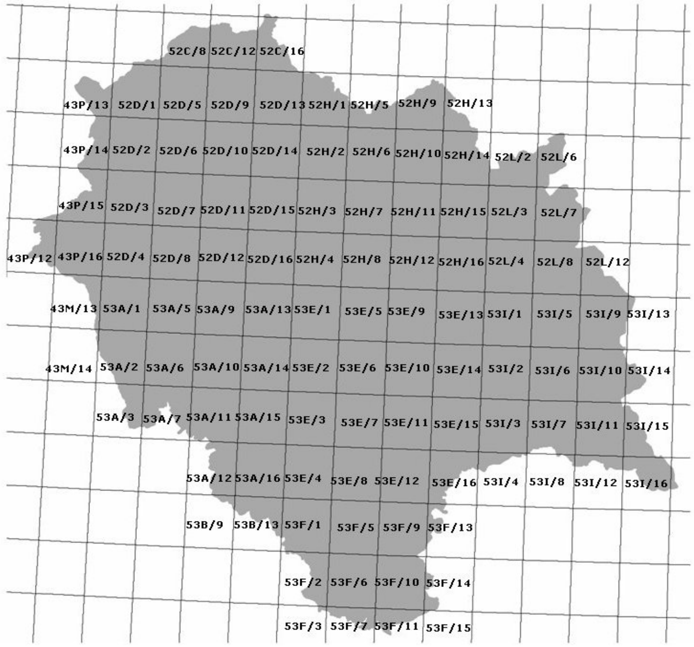


Fig. 8 Index map for the 1:50,000 scale topographic maps of Himachal Pradesh

3.2.2 Satellite imagery of Himachal Pradesh

IRS1D LISS3 images of 1999–2000 with least cloud cover have been acquired from National Remote Sensing Agency (NRSA) Hyderabad. The images acquired are given in Table 1.

Table 1. IRS1D LISS3 satellite images of Himachal Pradesh

S. No.	**Path**	**Row**	**Date**
1	094	047	19 October 1999
2	095	047	19 September 1999
3	094	048	19 October 2001
4	095	048	06 October 2000
5	096	048	03 October 2001
6	095	049	06 October 2000
7	096	049	03 October 2000

LISS3 sensors on board IRS1C/D satellites provide multi-spectral data collected in four bands of VNIR (visible and the near infrared) and SWIR (short wave infrared) regions (Table 6) LISS3 images cover an area of 124 by 141 km for the VNIR bands (B2, B3, B4) and 133 by 148 km for the SWIR band (B5) sensed from an altitude of 817 km (IRS1C) to 780 km (IRS1D) with repetitive coverage of 25 days. The spatial resolution of

VNIR bands is 24m and that of SWIR is 71m. The mosaic of satellite images of different bands of IRS1C LISS3 1D of Himachal Pradesh area is given in Figure 9.

Table 2. IRS-1C/1D LISS3 Wavelength range.

Band	Wavelength
Green	0.52–0.59 µm (B2)
Red	0.62–0.68 µm (B3)
NIR	0.77–0.86 µm (B4)
IIR	1.55–1.75 µm (B5)

The satellite images have to be geometrically rectified based on the appropriate geo-referencing system and cell sizes. The same geo-reference system is required for the integration and analysis of the remote sensing satellite data in the GIS database. The image resolutions and geo-reference system should be the same for better results.

3.2.3 Contour lines

These are digitized from 1:50,000 scale topographic map (Survey of India). Fig. 9 shows a sample of organised contour map of Himachal Pradesh.

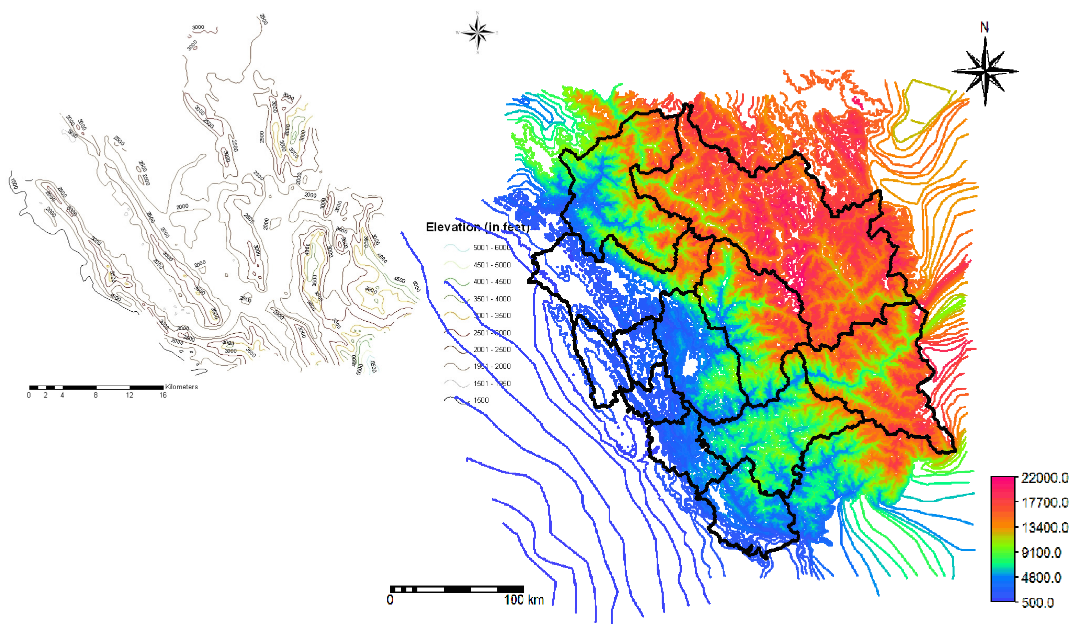


Fig. 9 A sample organized contour map of Himachal Pradesh

3.2.4 Digital Elevation Model of Himachal Pradesh

The Digital Elevation Model (DEM), as shown in Fig. 10, is derived from the interpolation of contour lines (Fig. 6) and spot heights. The TOPOGRID method was used to interpolate the DEM. The output resolution of the DEM is 50m.

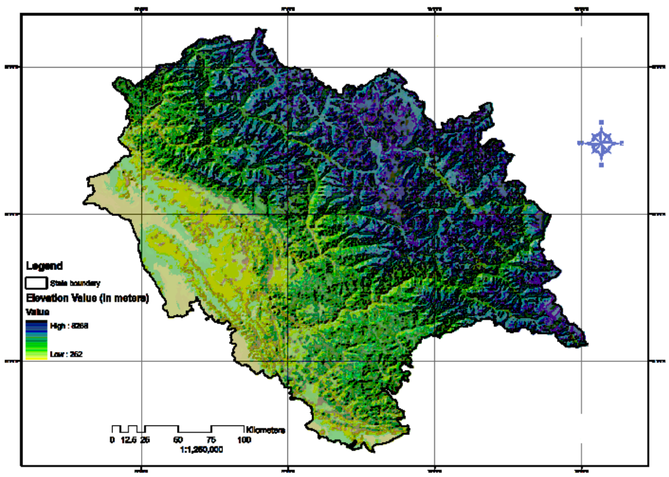


Fig. 10 Digital elevation model of Himachal Pradesh

3.2.5 Image Processing software

ArcGIS 9, ArcView 3.2 and ERDAS Imagine software were used for image processing.

3.3 Calculations of 3-D surface area of Himachal Pradesh.

The contour lines were digitized (exact contour map not shown in the report) from the Survey of India topographic maps of the study area. The contour lines thus provided a mechanism to establish the heights of the region. The contours were utilized in the creation of Triangulated Irregular Network Surface (TIN surface) which is a series of connected triangles accurately representing a surface with less data points than other data models.

3.3.1 The TIN model

The tin surface model is available through the 3-D Analyst extension of ArcView GIS.. The Triangulated Irregular Network (TIN) model is a significant alternative to the regular raster surface of a DEM, and has been adopted in numerous GISs and automated mapping and contouring packages. The TIN model was developed in the early 1970's as a simple way to build a surface from a set of irregularly spaced points. The commercial systems using TIN began to appear in the 1980's as contouring packages, some embedded in GIS. The TIN model is attractive because of its simplicity and economy. In addition, certain types of terrain are very effectively divided into triangles with plane facets and this is particularly true with sloppy landscapes. It works best in areas with sharp breaks in slope, where TIN edges can be aligned with breaks, e.g. along ridges or channels. As compared to the DEM, it is simple to find slope and aspect at some location using a TIN - the slope and aspect attributes of the containing triangle can be easily observed.

In a TIN model irregularly spaced sample points can be adapted to the terrain, with more points in areas of rough terrain and fewer in smooth terrain. An irregularly spaced sample is therefore more efficient at representing a surface in a TIN model, the sample points are connected by lines to form triangles within each triangle the surface is usually represented by a plane by using triangles it is ensured that each piece of the mosaic surface will fit with its neighboring pieces - the surface will be continuous - as each triangle's surface would be defined by the elevations of the three corner points. It might make sense to use more complex polygons as mosaic tiles in some cases, but they can always be broken down into triangles for example, if a plateau is eroded by gullies, the remaining plateau would be a flat (planar) area bound by an irregular, many-sided polygon. In the TIN model it would be represented by a number of triangles, each at the same elevation. For vector GISs, TINs can be seen as polygons having attributes of slope, aspect and area, with three vertices having elevation attributes and three edges with slope and direction attribute. The TINs were created using both DEM and Contours as described here.

3.3.2 Creating TINS with DEM

Sample points were picked up from the DEM (normally, a TIN of 100 points will do as well as a DEM of several hundred at representing a surface). Triangles were built between all selected points. Then these points were connected into triangles and surface was modeled within each triangle. Each contour surface is straight and parellered within each triangle, but sharply kinked at triangle edges. Consequently, some implementations of TIN represent the surface in each triangle using a mathematical function chosen to ensure that slope changes continuously, not abruptly, at the edges of the triangle (Fig. 11).

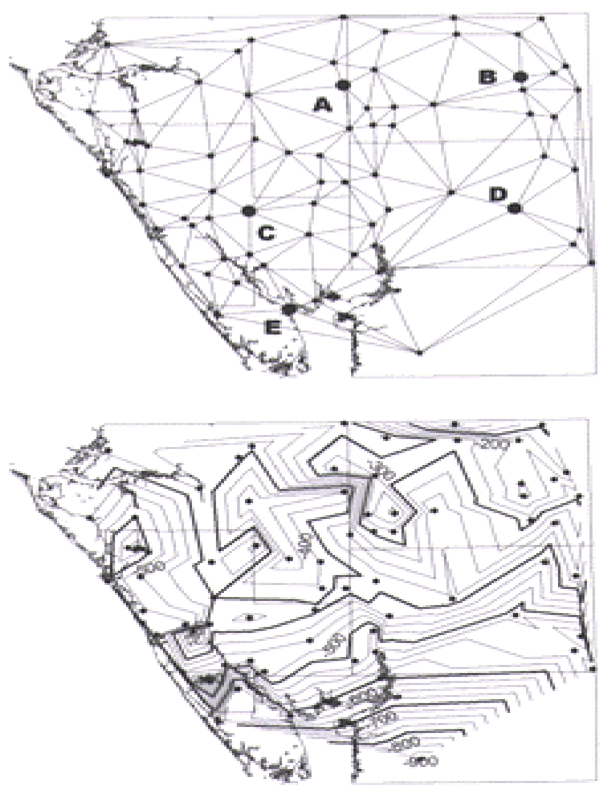


Fig. 11. Triangular TIN surface

3.3.3 Creating TINS with Contours

Contours are a common source of digital elevation data rather than convert from contours to a grid (DEM) and then to a TIN, it is more direct to obtain the TIN from contours directly. A TIN was created by selecting points from the digitized contour lines. Each selection created a triangle with three vertices on the same contour (at the same elevation) (Fig. 12).

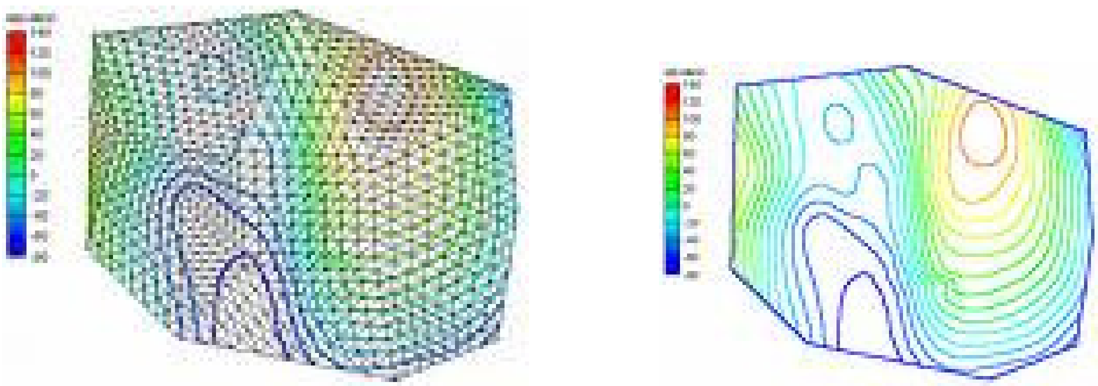


Fig. 12 TIN model with contours displayed.

TIN creation errors were analyzed generating a descriptive listing about the TIN surface followed by its graphic display. Invalid flat triangles occurring along streams and ridges were eliminated adding new intermediate points along the ridges and streams between the input contours. Additional sample points were entered between the contours in order to increase the distance between vertices on each contour arc, resulting in removal of invalid flat triangles. Weed tolerance and proximal tolerance were also adjusted to remove excess vertices forming flat triangles. The created TIN surface was transformed back to contour arc coverage

3.3.4 Finishing the TIN

The result of this process is a connected set of peaks, pits, passes, ridge lines and channel lines. The number of points in each ridge and channel line can be reduced by thinning using a standard thinning algorithm and it may be desirable to add additional points from the DEM which are not on ridges or channels if we can significantly reduce any substantial differences from the real surface. The resulting surface differed from the original DEM, substantially in some areas with more dimensionality. The TINS were stored in the form of triangles with a reference number for the triangle, the x,y,z-coordinates of the three vertices and the reference numbers of the three neighboring triangles.

To the surface model thus generated, several analytical procedures that provide important information such as the volume of the surface, and the degree and orientation of the slopes were applied and new terrain scenarios were generated and displayed in ArcView.

The TIN surface for district Kangra is shown in Fig. 13. The TIN model represents a surface as a set of contiguous, non overlapping triangles. With in each triangle the surface is represented by a plane.

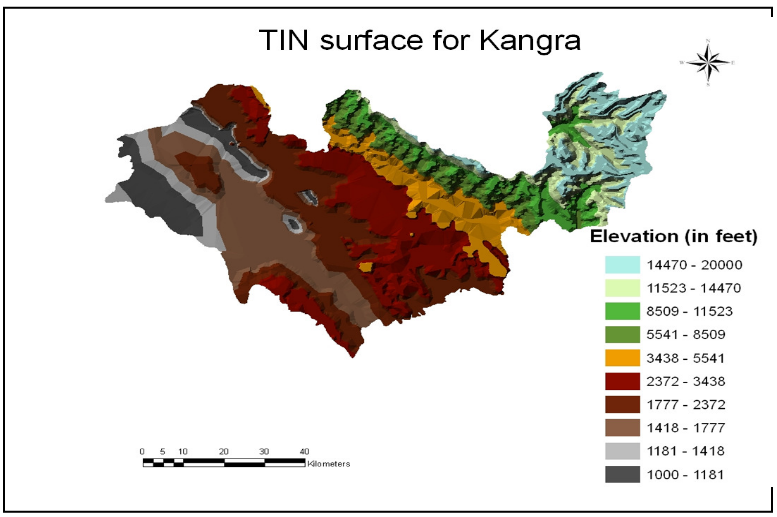


Fig. 13 TIN surface for District Kangra.

3.4 Outputs

The outputs are the area estimated as 2-D and 3-D surface files for Himachal Pradesh with detailed information regarding the area.

4. RESULTS

The total geographical area of Himachal Pradesh as per Govt. Office records is 55,673 sq. km. This estimation is however, two dimensional without involving the elevations i.e the undulating terrain conditions. The district wise 3-D dimensional area was calculated according to the procedure mentioned and is presented in Fig. 14-25. The difference in 2-D Area & 3-D area in districts covered by mountains is presented in Table 3.

Table 3. District-wise two dimensional (2-D) and three dimensional (3-D) surface area of Himachal Pradesh.

District Name	2D Area (sq km)	3D Area (sq km)
Bilaspur	1160.225	1327.025
Chamba	6479.872	11674.528
Hamirpur	1111.435	1146.642
Kangra	5567.224	7088.432
Kinnaur	6241.691	11762.311
Kullu	5495.392	9693.987
Lahaul Spiti	14001.709	22892.628
Mandi	3959.604	5402.766
Shimla	5084.421	7888.039
Sirmaur	2864.429	3654.497
Solan	1838.981	2284.508
Una	1537.805	1569.406
Total Area	**55342.79**	**86384.77**

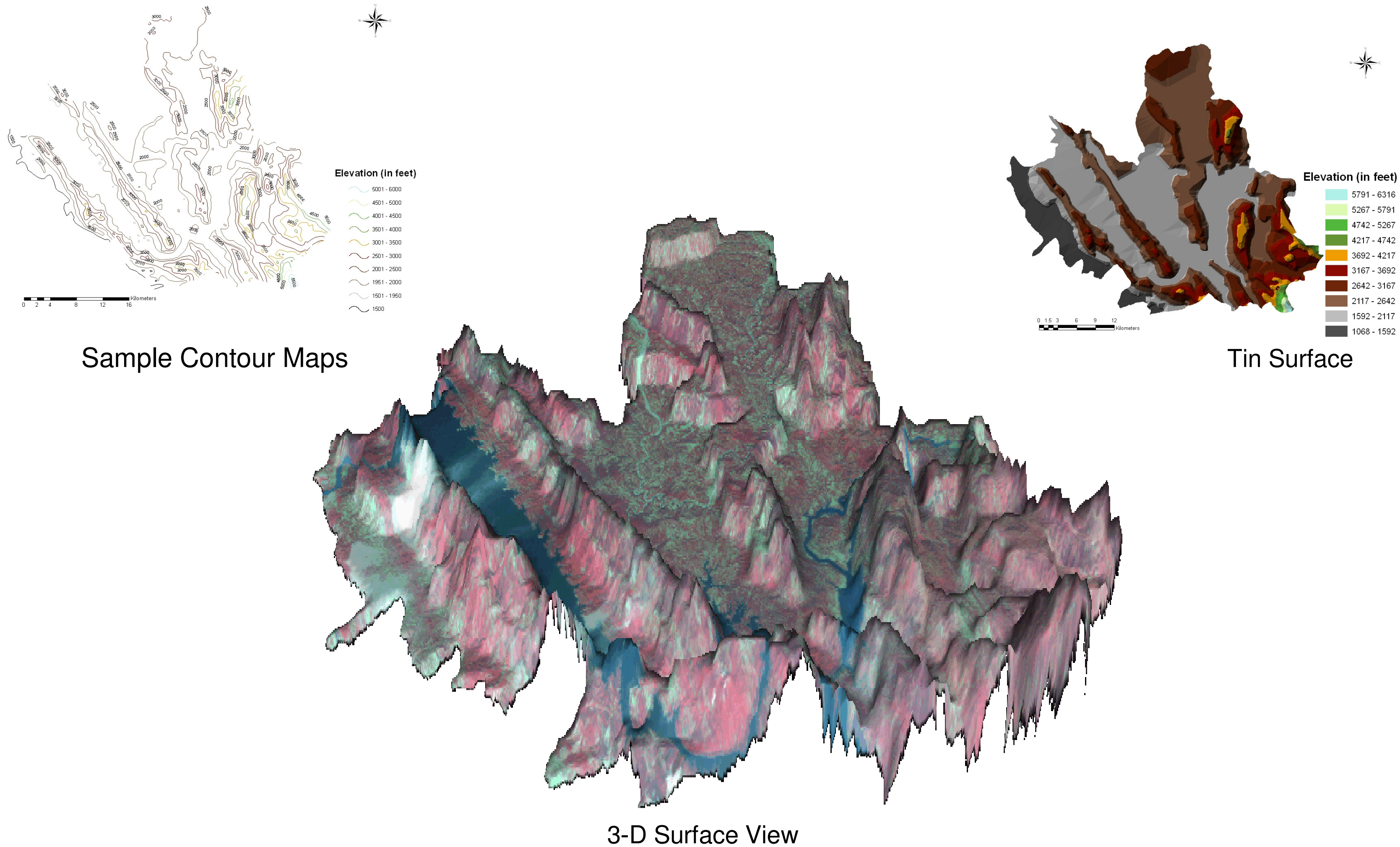
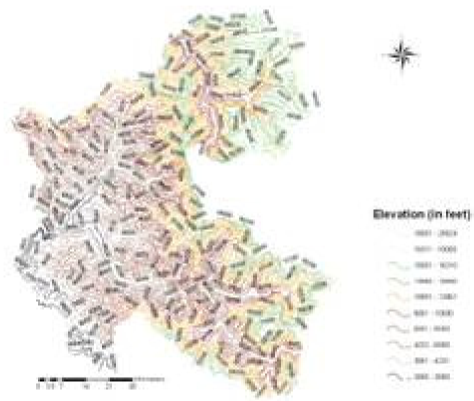
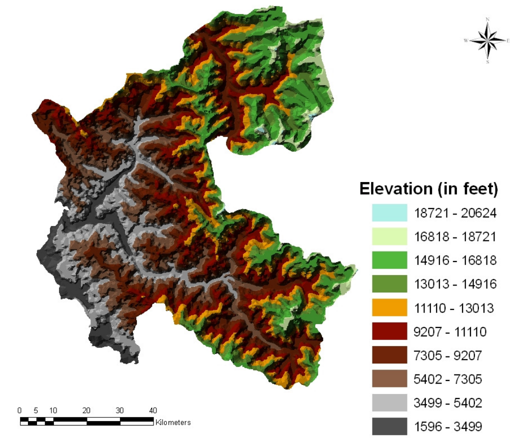


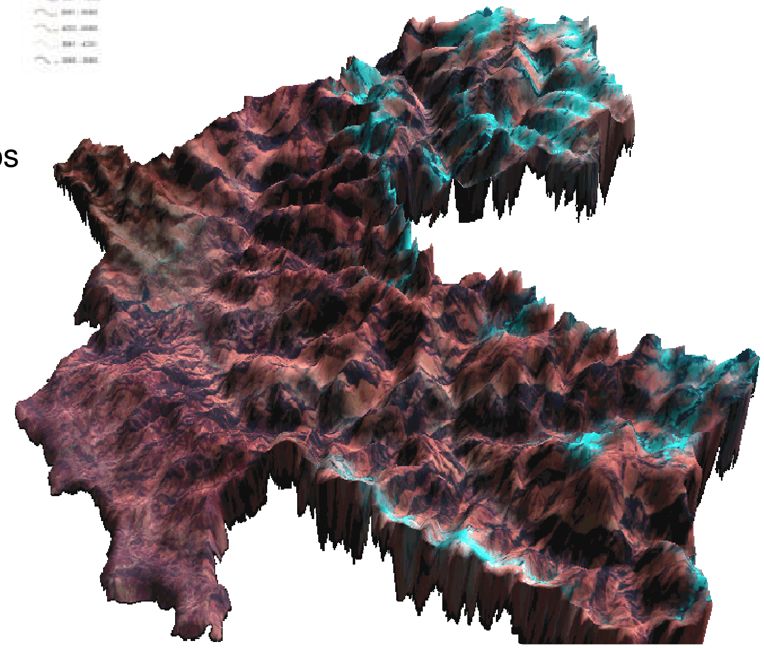
Fig. 14 Three dimensional (3-D) surface area of district Bilaspur.



Sample Contour Maps

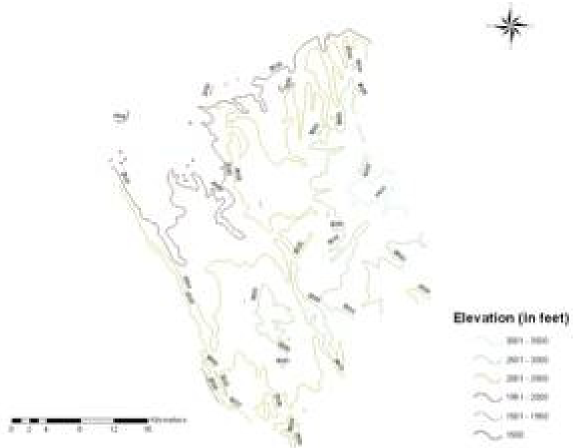


Tin Surface

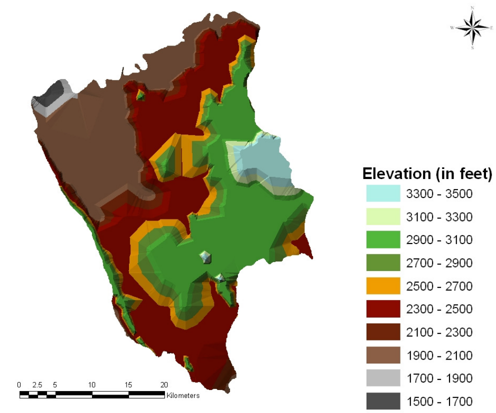


3-D Surface View

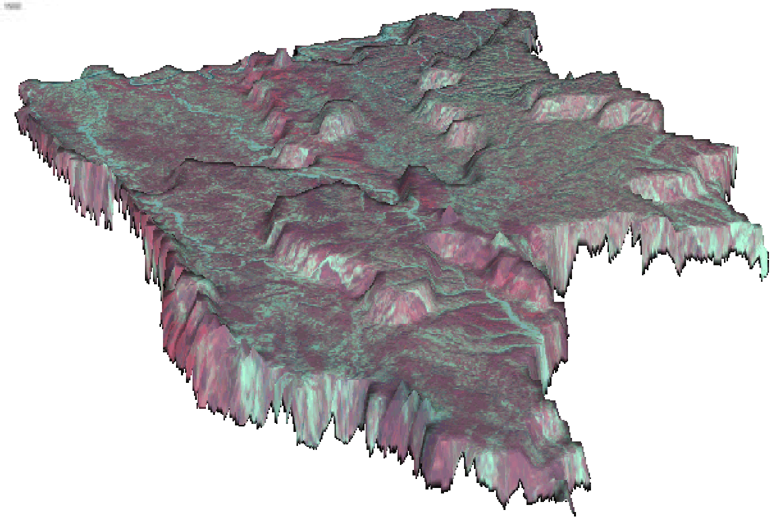
Fig. 15 Three dimensional (3-D) surface area of district Chamba.



Sample Contour Maps

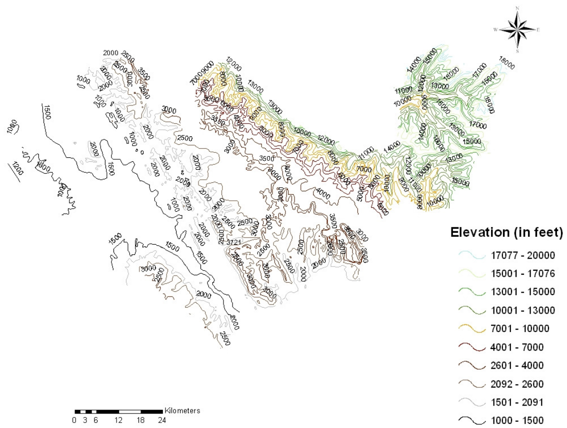


Tin Surface

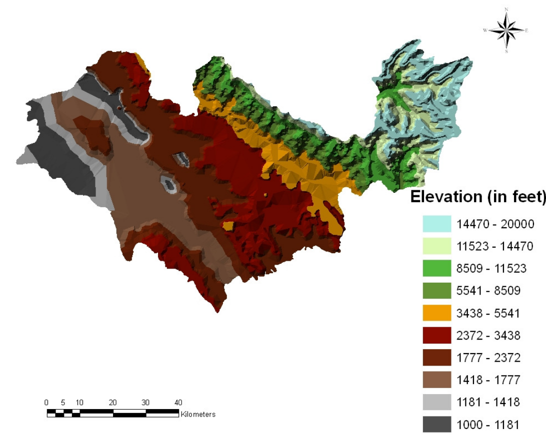


3-D Surface View

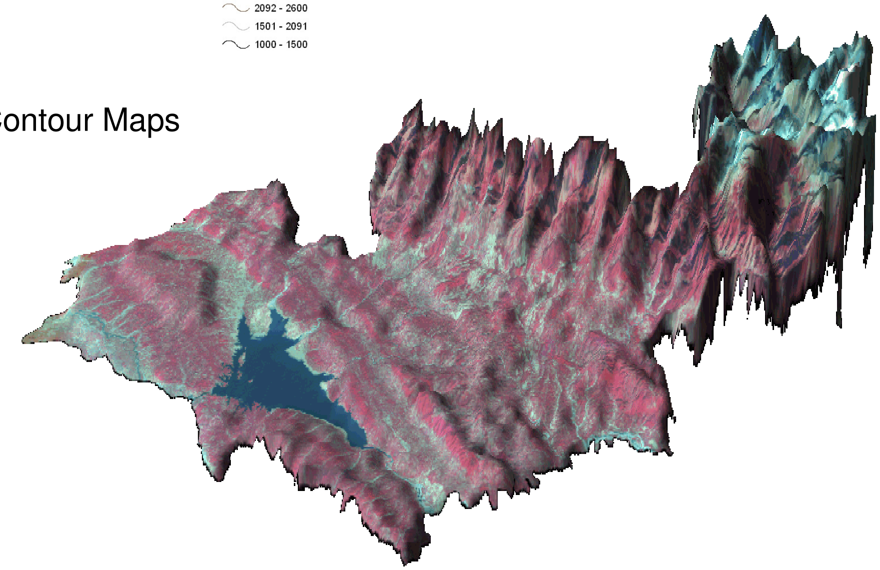
Fig. 16 Three dimensional (3-D) surface area of district Hamirpur.



Sample Contour Maps

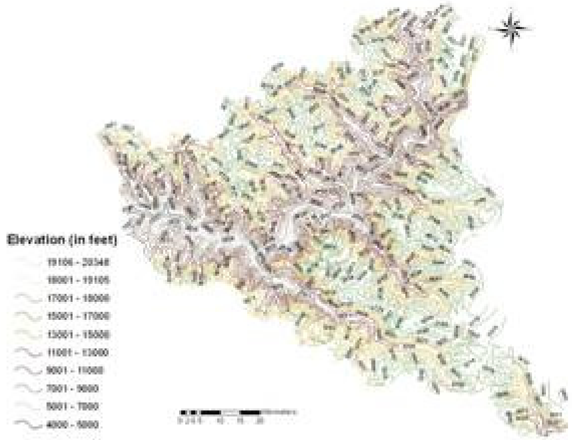


Tin Surface

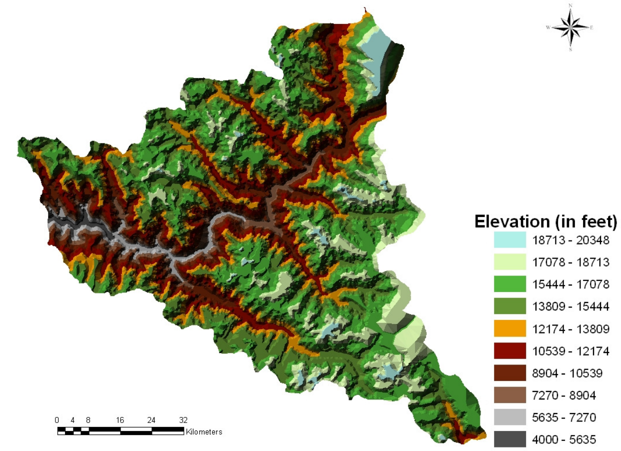


3-D Surface View

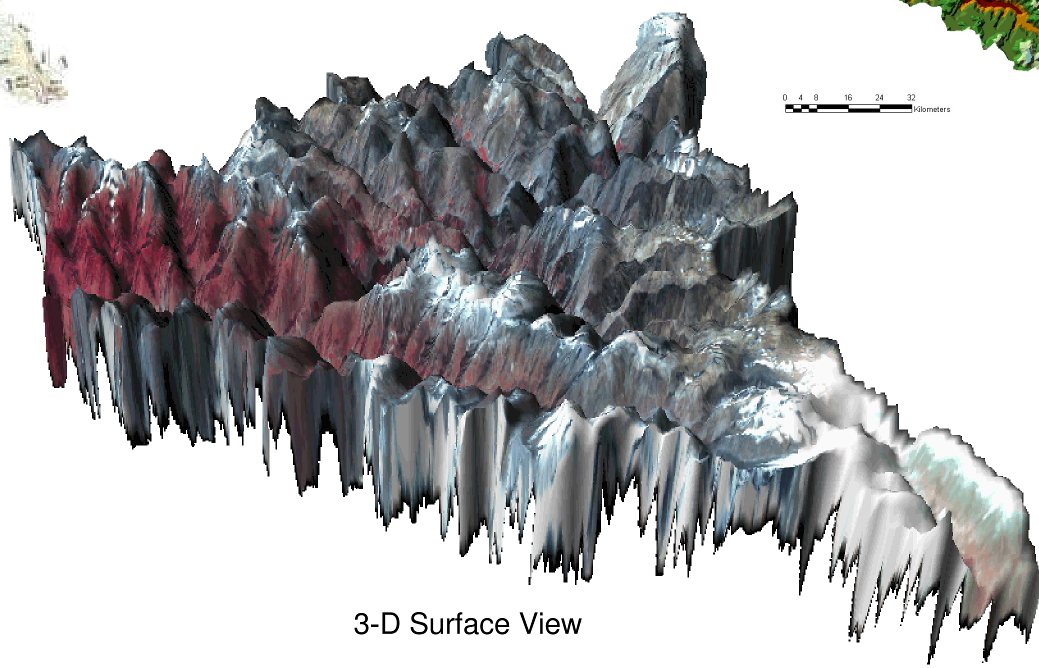
Fig. 17 Three dimensional (3-D) surface area of district Kangra.



Sample Contour Maps

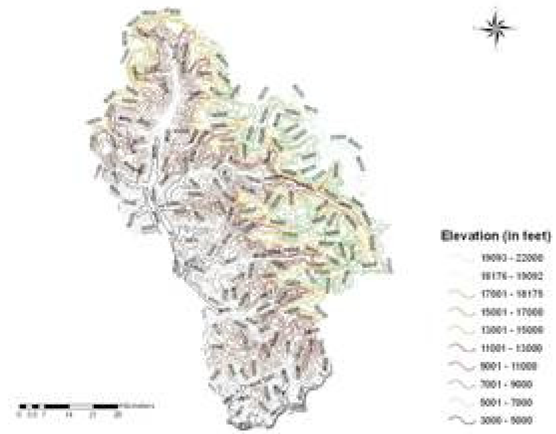


Tin Surface

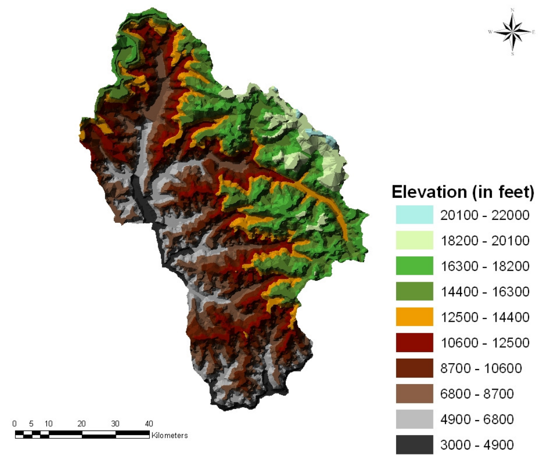


3-D Surface View

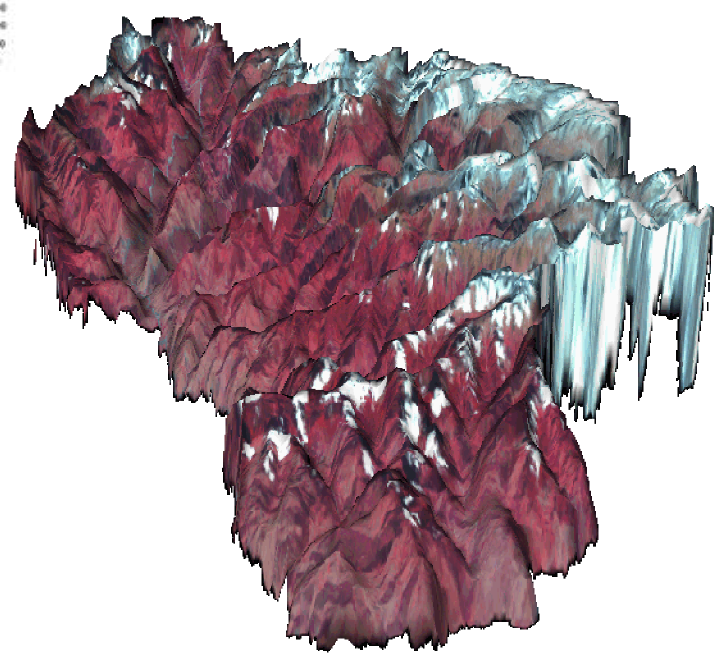
Fig. 18 Three dimensional (3-D) surface area of district Kinnaur.



Sample Contour Maps



Tin Surface



3-D Surface View

Fig. 19 Three dimensional (3-D) surface area of district Kullu.

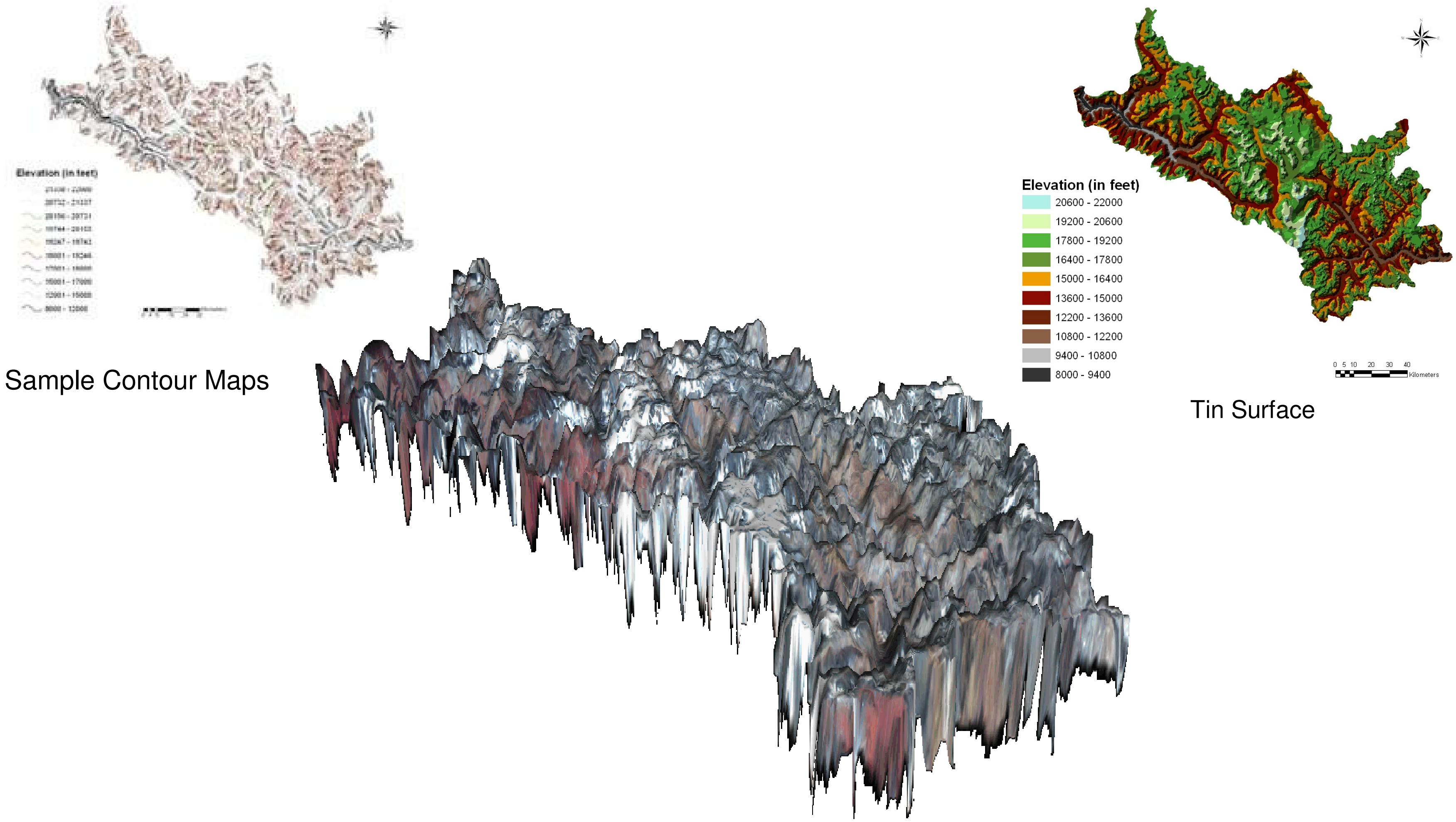
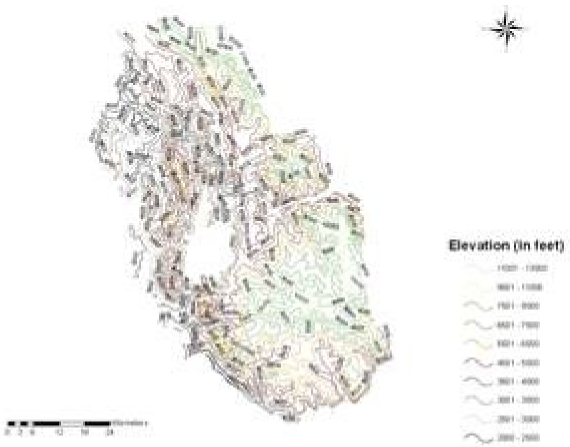
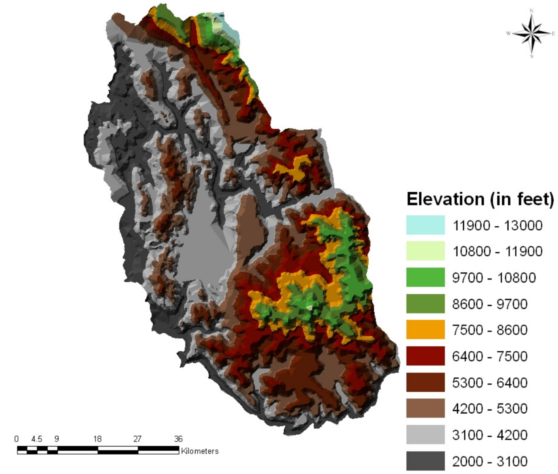


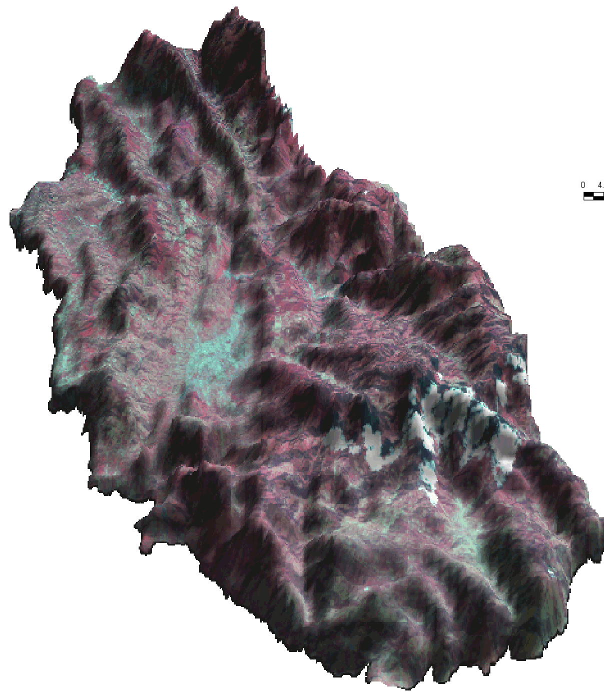
Fig. 20 Three dimensional (3-D) surface area of district Lahaul-Spiti.



Sample Contour Maps



Tin Surface



3-D Surface View

Fig. 21 Three dimensional (3-D) surface area of district Mandi.

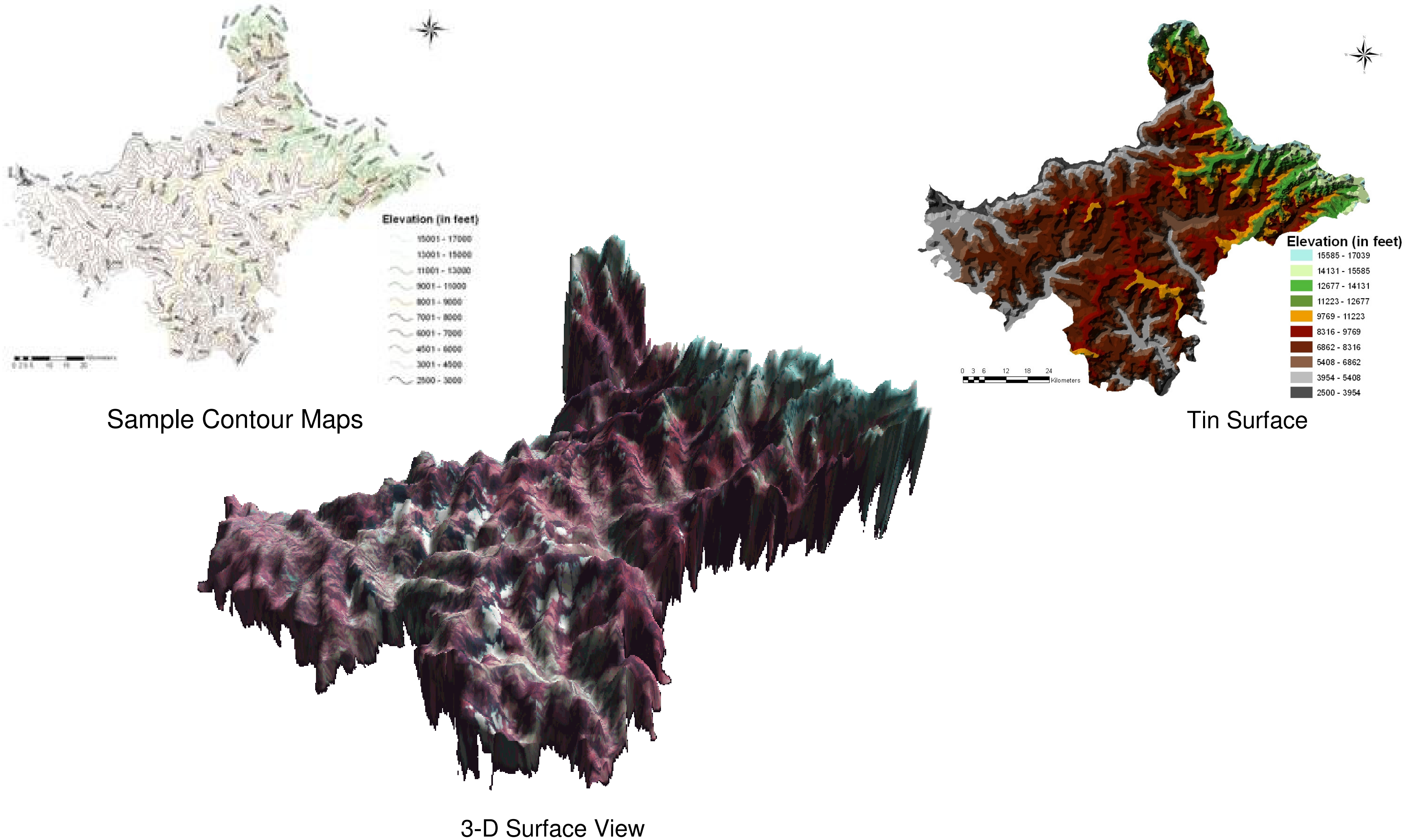
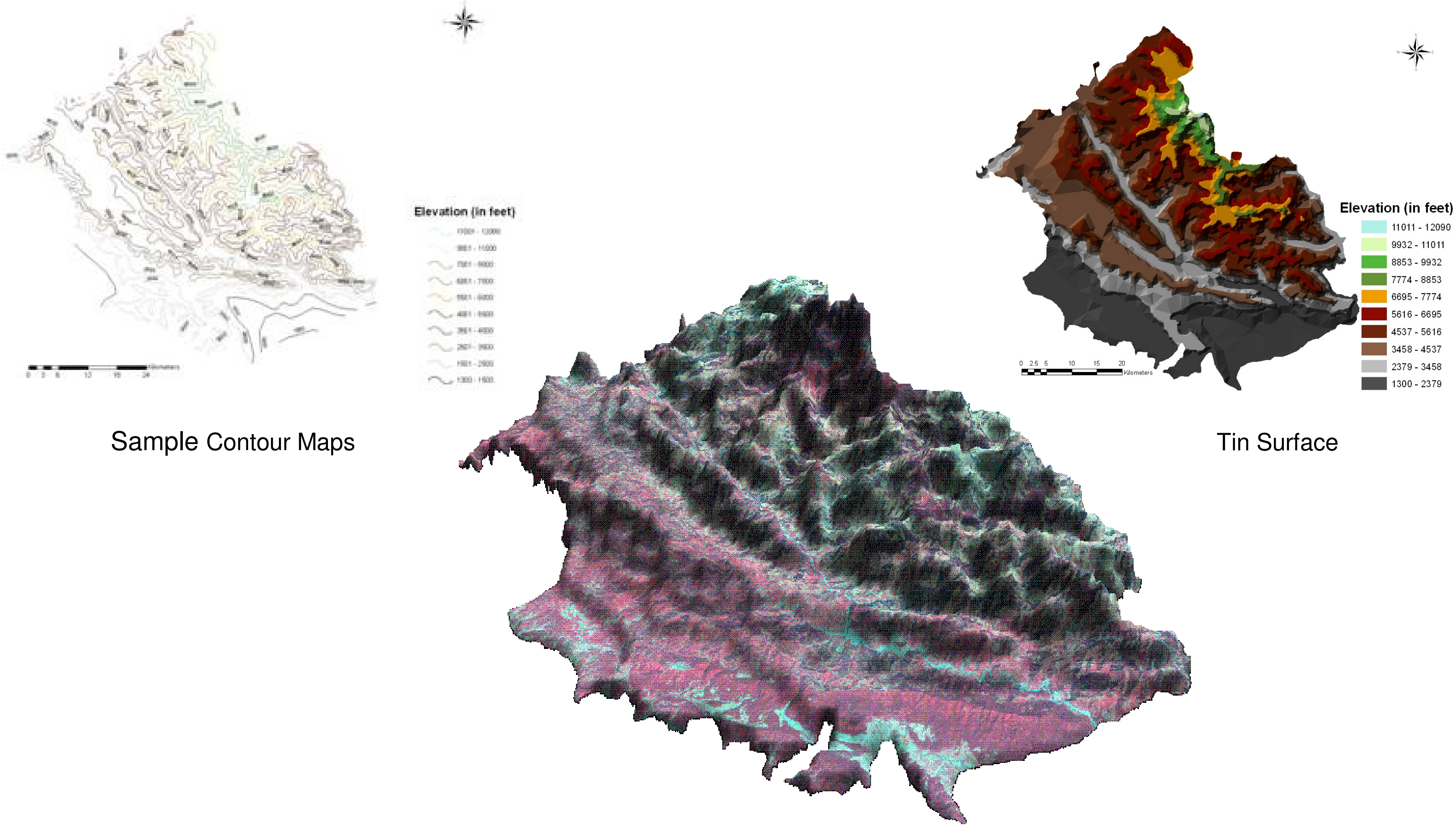


Fig. 22 Three dimensional (3-D) surface area of district Shimla.

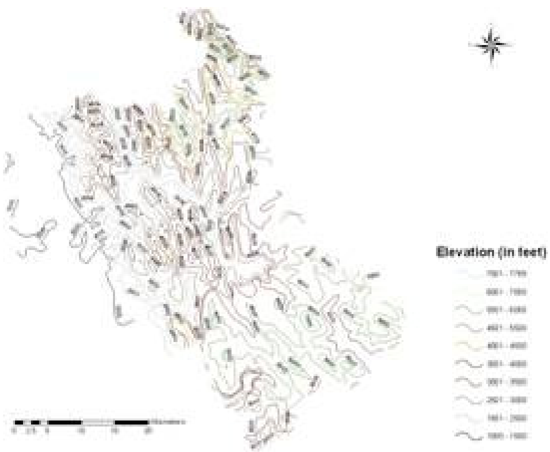


Sample Contour Maps

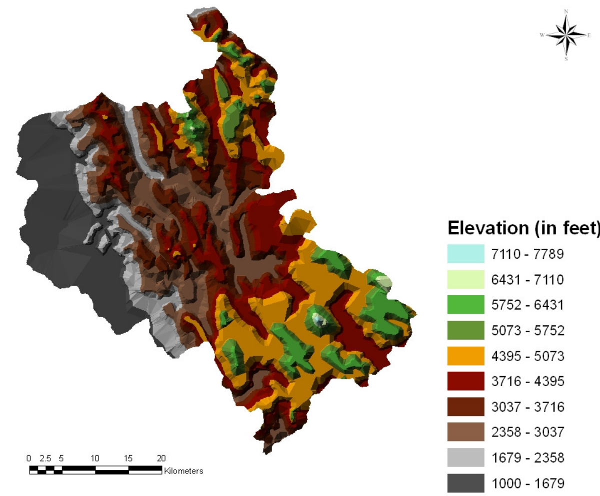
Tin Surface

3-D Surface View

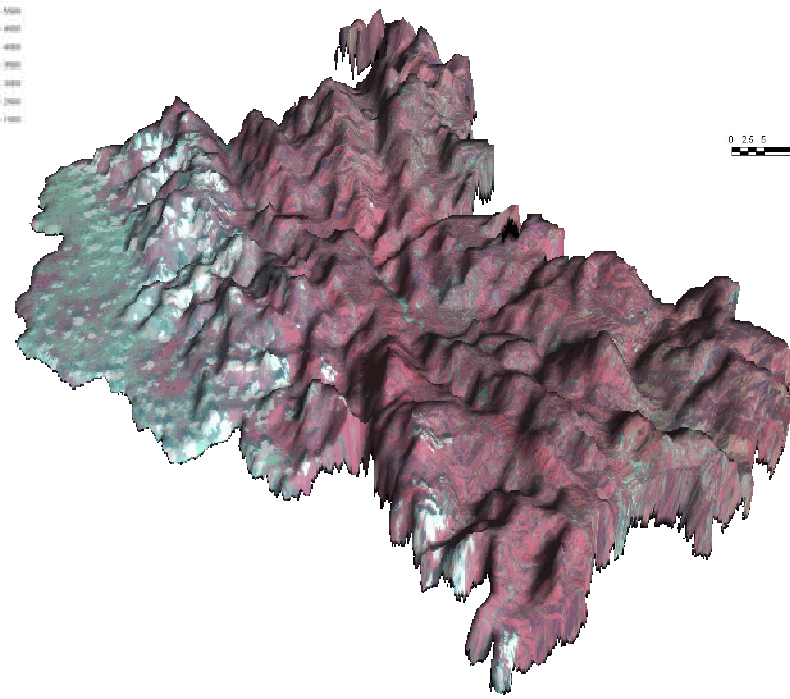
Fig. 23 Three dimensional (3-D) surface area of district Sirmaur.



Sample Contour Maps

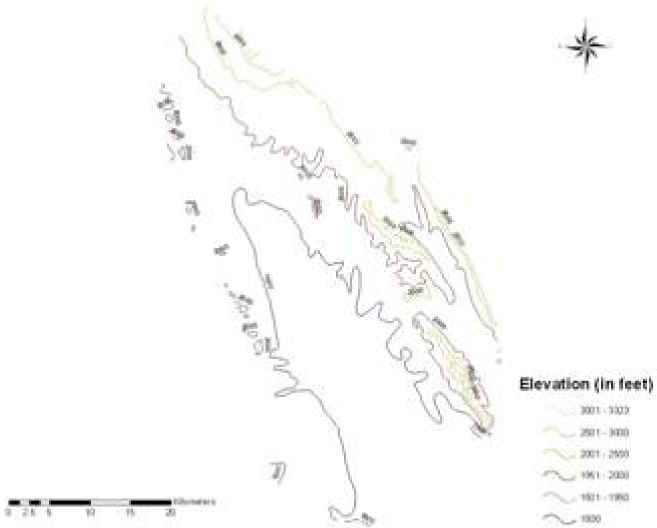


Tin Surface

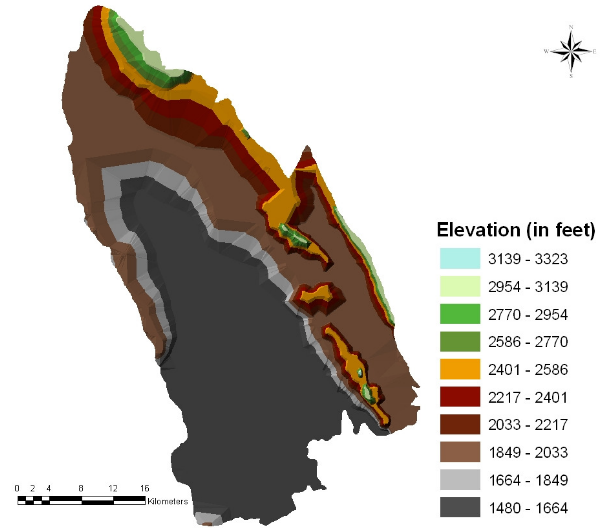


3-D Surface View

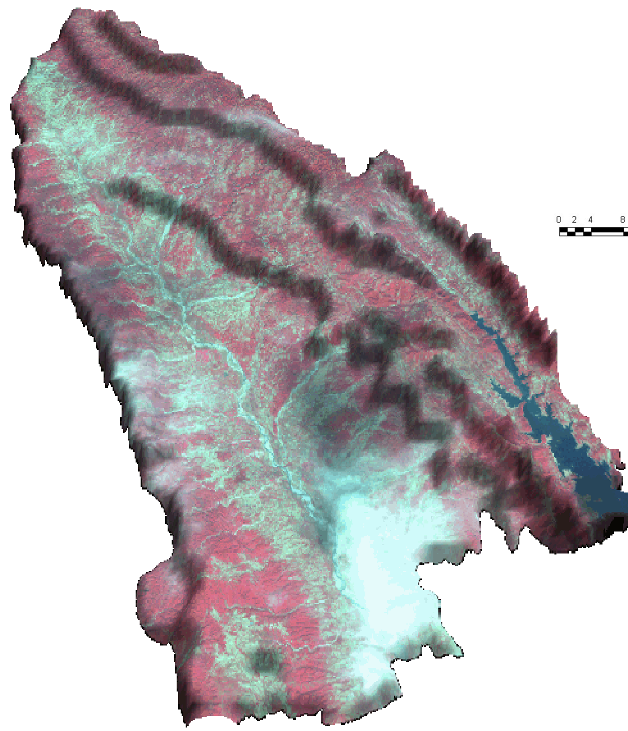
Fig. 24 Three dimensional (3-D) surface area of district Solan.



Sample contour maps



Tin Surface



3-D Surface View

Fig. 25 Three dimensional (3-D) surface area of district Una.

District Bilaspur

The Bilaspur district is situated in Satluj valley in the outer hills of Himachal Pradesh. A 3-D surface view of the area of district Bilaspur is presented in Fig. 14. The two dimensional surface area of district Bilaspur is 1160.225 sq. km and calculated 3-D area comes out to be 1327.025 sq km (Table 3). Therefore, an additional area of 166.8 sq. km has been reported to be present in the district.

District Chamba

Chamba is the northwestern district of Himachal Pradesh. Chamba is one of the oldest Native States in India. The two dimensional surface area of district Chamba is 6479.872 sq. km and calculated 3-D area is 11674.528 sq. km (Table 3). A supplementary area of as high as 5194.656 sq. km has been observed to be occurring in the district. 3-D surface view of the area of district Chamba is presented in Fig. 15.

District Hamirpur

It is situated at an altitude of 785 meters. District Hamirpur as visualized in a 3 dimensional mode is shown in Fig. 16. The 3-D area is just 35.207 sq. km more than 2-D area of the district (Table 3), which are 1146.642 and 1111.435 sq.km respectively.

District Kangra

The district is in the western part of Himachal Pradesh, in the low foothills of the Himalayas. The Dhauladhar range adjoins the district on one side. The Beas is one of the larger rivers of this district, and contributes to the fertility of the land here. District Kangra has geographical area (2-D) of 5567.224 sq. km which constitutes 10.31 per cent of the total area of the state. The estimated 3-dimentional area of the district is 7088.432 sq. km which is 1521.208 sq. km more than the 2-D area (Table 3, Fig. 17).

District Kinnaur

District Kinnaur lies in the extreme west part of the state enclosing high hills. The two dimensional area of the state is 6241.691 sq. km and three dimensional area is 11762.311 sq. km (Table 3). District Kinnaur has 5520.62 sq. km more area than the actually reported. The contour lines, TIN surface and 3-D view of the district is presented in Fig. 18.

District Kullu

A 3-D surface view of the area of district Kullu is presented in Fig. 19. The two dimensional surface area of district is 5495.392 sq. km and calculated 3-D area comes out to be 9693.987 sq km (Table 3). An additional area of 4198.595 sq. km has been reported to be present in the district.

District Lahaul Spiti

It is the largest district in terms of area in the state with minimum population density 2/sq. km. The 3-D surface area view of the state is shown in Fig. 20. The geographic area of the district is 14001.709 sq. km and calculated three dimensional area is 22892.628 sq. km. The district possesses about 8890.919 sq. km additional area.

District Mandi

District Mandi is situated between 31° 13'' to 32° 04' N and 76°37' to 77°23' E in the centre of Himachal Pradesh having total area 3959.604 sq. km. The three dimensional area of the district is 5402.766 sq.km (Table 3, Fig. 21). Hence an additional area of 1443.162 sq. km has been reported as veiled in the district.

District Shimla

A 3-D surface view, TIN surface and contours for district Shimla is presented in Fig. 22. The two dimensional surface area of district is 5084.421 sq. km and calculated 3-D area is 7888.039 sq km (Table 3). An additional area of 2803.618 sq. km . has been reported to be present in the district.

District Sirmaur

The district occupies relatively plain areas in the southernmost part of the state. A 3-D surface view, TIN surface and contours for district Sirmaur is presented in Fig. 23. The calculated 3-D area of the district is 3654.497 sq. km that is about 790.068 sq. km more than the reported 2-D area of 2864.429 sq. km.

District Solan

A 3-D surface view of the area of district Solan is presented in Fig. 24. The two dimensional surface area of district is 1838.981 sq. km and calculated 3-D area comes out to be 2284.508 sq km (Table 3). An additional area of 445.527 sq. km has been reported to be present in the district.

District Una

Una is a district of Himachal Pradesh which lies in its south western part. District Una is smallest district comprising of mainly the flat lands and geographical area of 1537.805 sq. km with not much difference of 31.601 sq. km than its three dimensional area which is 1569.406 sq. km (Table 3, Fig. 25).

Table 4. Percent increase in calculated district-wise 3- D area.

District Name	Percent increase in area
Bilaspur	14.38
Chamba	80.17
Hamirpur	3.17
Kangra	27.32
Kinnaur	88.45
Kullu	76.40
Lahaul Spiti	63.50
Mandi	36.45
Shimla	55.14
Sirmaur	27.58
Solan	24.23
Una	2.05
Himachal Pradesh	56.09

Table 4 represents the percent increase in calculated three dimensional areas for all the twelve districts of Himachal Pradesh. The increase was observed to be more in the districts which lie at the height of more than 1500 m with maximum increase of more than 88 per cent in the district with high hills e.g. district Kinnaur, Lahaul Spiti, Shimla, Chamba, Kullu and Kangra. In the districts with relatively flat lands e.g. Una, Hamirpur and Bilaspur the additional areas are comparatively less.

The surface area estimations carried out using vector data sets and polygons in the present study is inherently more accurate and precise than with raster data sets such as DEMs and surface-area grids. As the most accurate measure of the surface area within a polygon should include all the area within the polygon, raster data sets do not meet this criterion because cells in a raster data set do not sit perfectly within polygon boundaries. Further, the raster representations of polygons have a stair-stepped appearance incorporating some areas outside the polygon and missing some areas inside. Whereas the vector objects are not affected by the edge-effect problems that are unavoidable with raster-based methods and are considerably more reliable and accurate over areas with relatively low cell counts.

Present-day development efforts are a recent phenomenon in the hills. Generally these efforts are inspired and conceived outside and implemented in the hills. Often they involve pace, scale, priorities, and operating mechanisms not well known to the hilly areas and people. Most importantly, the development interventions are based on approaches and models which were not basically conceived or designed for hilly areas. Owing to this reason they proved less effective in handling the problems of hilly areas. Indicators of this ineffectiveness could be, poor economic performance, over-exploitation of hill resources, disregard of equity issues, and environmental distabilisation (Sanwal, 1989). Discontinuities, between conventional development approaches and hill conditions can be demonstrated at different levels of the developmental process (Sanwal, 1989).

A whole of 55.673 sq km area of Himachal Pradesh is divided into classes viz., forests, agriculture, grass/shrub, nonvegetation/rocks, glaciers and water bodies (Table 5, Fig. 26). According to recent remote sensing land cover estimates for the state indicate that 14 per cent of the total geographical area is cultivated land and the non-cultivated lands under different land covers viz., grass/shrubs (17%), non-vegetation (26%), forests (32%) and glaciers/snow and water bodies which collectively constitute the remaining 12 per cent (Bhagat *et al*. 2006).

Table 5. Spatial Distribution of Land Cover Classes of Himachal Pradesh

Class	Area_SqKm	Percent
Forest	17768.68	32
Agriculture	7828.28	14
Grass/Shrub	9293.94	17
Rocks/Non-vegetation	14364.99	26
Snow/Clouds	3807.15	7
Glaciers	1985.60	4
Water body	481.59	1
Total	**55530.23**	**100.00**

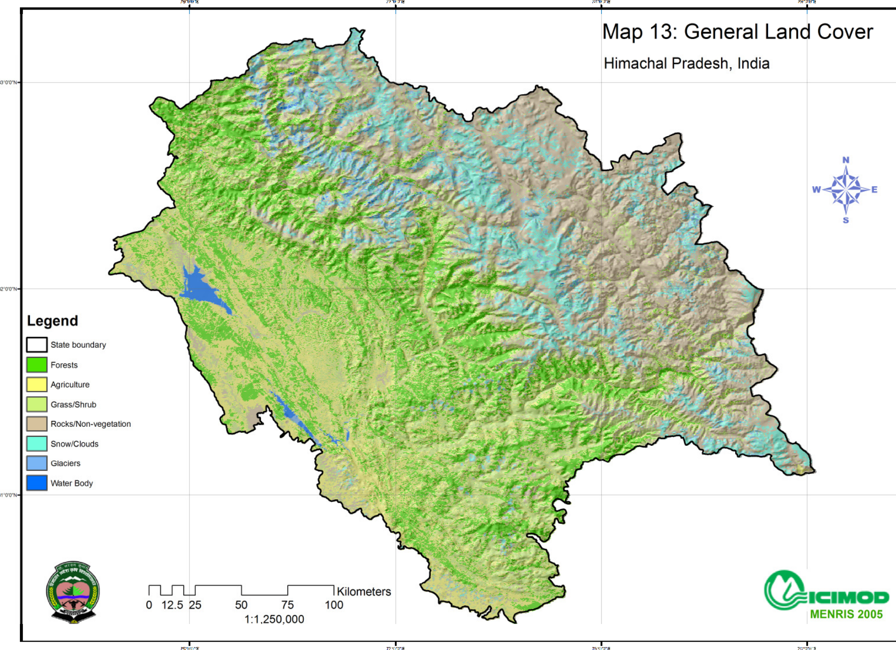


Fig. 26 General land cover of Himachal Pradesh.

These are the classes derived from 2001-2002 IRS 1D LISS3 data that indicate 32 per cent area of the state is forests. However, the recorded forest cover is 35, 409 km2 which is 63.60 per cent of the geographical area (Anon, 1997). The glaciated area in Himachal Pradesh is estimated to be about 4160.58 sq. km (Bhagat *et al*, 2004), however, land cover estimates show it to be 1985.60 sq. km. Similarly there are discrepancies between actual and documented data from revenue records in other classes too. The fact that there is no substantial new found land, these additional areas must be already in use, although misreported. There could be a possibility of adding more land to crop land or any other economically sound ecosystem.

The role of land resources is most crucial, in both situations in upgrading the productivity of all types of biomass systems. The present study clearly indicated that there are additional areas observed in each district of the state and there is a need to know the exact land cover class where these areas are currently locked up or can be further added. This can be achieved however, by integrating the land cover map for the state over the three dimensional surface area of Himachal Pradesh which is an intricated job and requires lots of resources further. Once these areas are identified, an updated landuse data base will thus be available with exact figures for lands under agriculture, forests, cultivated and non cultivated class, a scientifically back-up land use plan thus can be formulated.

With this, the scope for diversified activities, the presence of high potential areas and activities also increases and their required resource management practices, could help in designing appropriate strategies for sustainable development of hill areas. These changes may include patterns of resource use as well as types of production, consumption, and exchange activities, directly or indirectly conditioned by the above objective circumstances in hilly areas.

Hilly areas demand due considerations to complexity of varying degrees of the hill characteristics, their multiple dimensionality and their interrelatonships, would give a contextual perspective to decisions and actions in hilly areas. A sensitivity to such a hill perspective would determine the relevance and effectiveness of any development activity in hilly areas. Hence, the conventional plain area development approach is not applicable. The results obtained from the present study can be further projected under hill perspective framework which is different from flat lands and can be harnessed for demanding additional funding area wise from the centre for its sustainable development.

5. CONCLUSION

The study identifies that the actual surface area of entire Himachal Pradesh, calculated using modern Geo-IT tools, remote sensing and Geographical Information System (GIS) turns out to be 86384.77 sq. km which is about **56 per cent** more than the documented geographical area 55342.79 sq. km. This is because of the mountainous regions and extensive slopping valleys in Himachal Pradesh. Agriculture, infrastructure like industries, housing roads etc. are planned on these slopping lands and sometimes even on steep slopes in various mountain districts for which actual surface land area should be considered. Whereas generally the planning is done for the geographical area and as a result of it surface area on slopes are not considered for any developmental plan. The additional area so calculated might be included in different land cover classes that might result into opening new potential niches and production domains for mountainous crops, forests or pastures. Further, this may have a relevance of advancing development in Himachal Pradesh through augmented natural resources per unit area, demanding more finances from the Centre for general planning.

Appropriate analysis of the satellite imagery, digital elevation model, slopes and aspect of the surface area is required to be carried out for the identification of these locked additional areas. The land cover map derived from the satellite image can further provide information where exactly the additional surface area is present, which however, requires a further detailed study.

6. REFERENCES

- Anonymous (1981) FAO, UNEP-Tropical Forest Resources Assessment Project, Forest Resources of Tropical Asia. FAO, UNEP, 475 pp.
- Bhagat, R.M., Vaibhav Kalia, Chitra Sood, Pradeep Mool and S.R Bajracharya, 2004. Himachal Pradesh Himalaya – Inventory of glaciers and glacial lake outburst floods (GLOFs) affected by global warming in the mountains of Himalayan region. Technical report submitted to APN-START/UNEP, Japan.
- Bhagat, R. M., Singh, S., Kumar, V., Kalia, V., Sood, C., Pradhan, S., Immerzeel, W., Shrestha, B. (2006): "Developing Himachal Pradesh Agricultural Systems Information Files (HASIF) and Tools for Decision Support Systems for Niche Based Hill Farming", Project Report submitted to Department of Agriculture, Govt. of Himachal Pradesh, India.
- Burrough P.A. & McDonnell, R.A., 1998. Principles of geographical information systems: Spatial Information Systems and Geostatistics. OUP. Elghazali, M. S. & Hassan, M. M., 1986. A simplified terrain relief classification from DEM data using finite differences, Geo-Processing, v3 n2, 167-178.
- Foote, K. E. and Lynch,M. (1996). Geographic information systems as an integrating technology: context, concepts and definition. Austin, University of Texas.
- Ghosh, S (2001) GIS application for mountain terrains: some considerations and options. http://www.gisdevelopment.net/application/nrm/mountain/mount.pf.htm"
- Heywood, D.I. "Mountain regions and geographic information systems: an overview." Mountain Environments and Geographic Information Systems. Eds. Martin F. Price and D. Ian Heywood. Bristol: Taylor & Francis, Inc., 1994. 1-24.
- Kundu, S.N. and Pradhan, B. (2002) Surface area processing in GIS. http://www.gisdevelopment.net/technology/gis/ma03191abs.htm
- Marble, D. H., Calkins H. W. and Pequet D. J. (1984). Basic Readings in Geographic Information Systems. Williamsville, NY., SPAD System Limited.
- Sanwal, N. 1989. What We Know About Mountain Development: Common Property, Investment Priorities, and Institutional Arrangements". In Mountain Research and Development, 9 (1). Boulder, Colorado.

- Stocks, A.M., and D.I. Heywood. "Terrain modelling for mountains." Mountain Environments and Geographic Information Systems. Eds. Martin F. Price and D. Ian Heywood. Bristol: Taylor & Francis, Inc., 1994. 25-40.
- Strahler, A. N., 1952. Hypsometric (area-altitude) analysis of erosional topography, Geological Society American Bulletin, 63: 1117-1142.