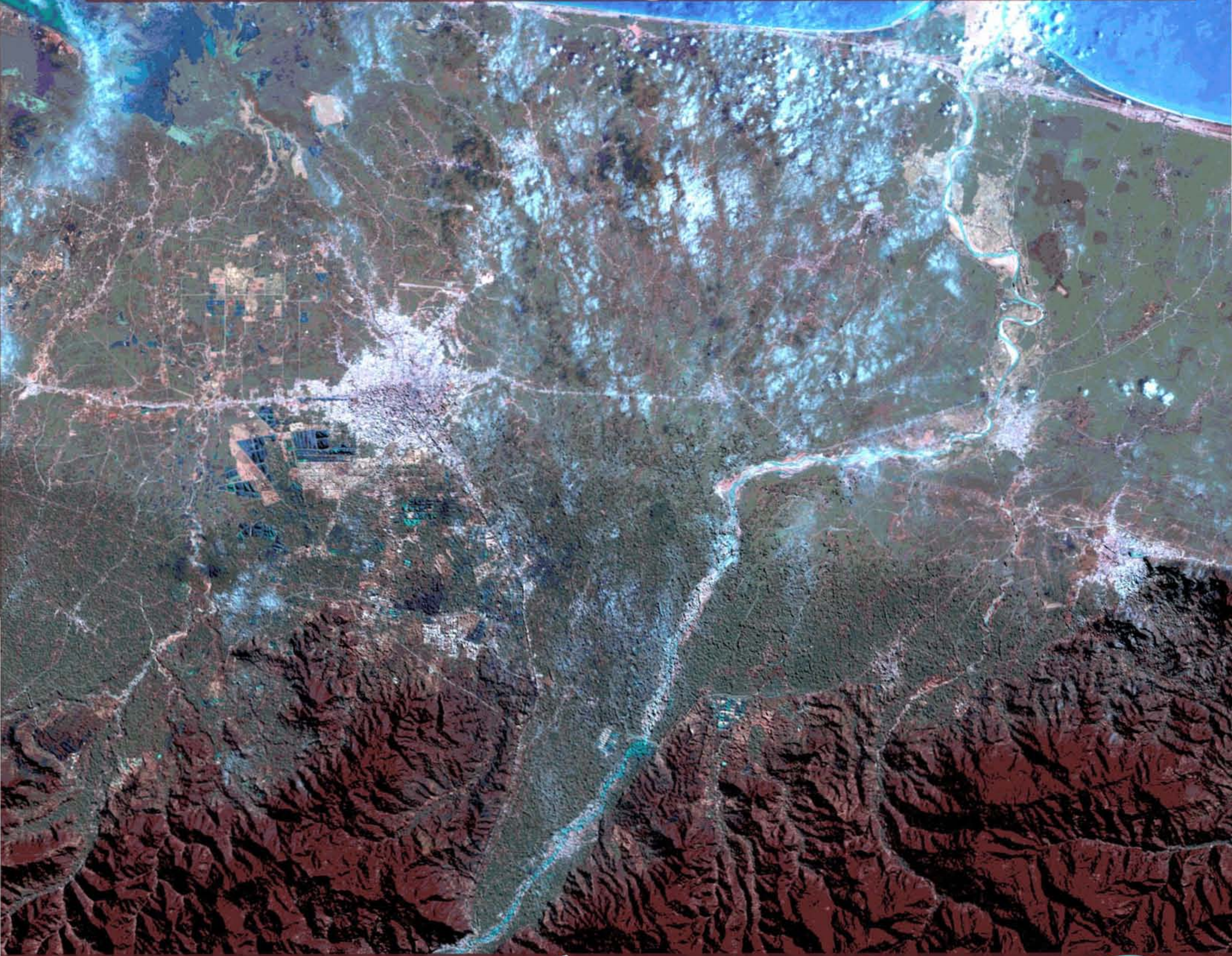
Technical Report
March 2014

Change Detection of Forest Cover From 1980 to 2013 Using Satellite Images



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Spatial Sciences Innovators Consulting Engineering

The Iranian Spatial Sciences Innovators Consulting Company was established in 2013. The primary focus of SSI is Geo- Spatial and Geo-Information products generation and providing the appropriate consultant for different projects. The scope of SSI projects has recently increase by doing projects outside of country (e.g. Iraq, Afghanistan). We are providing intellectual solution for different leading organization across the private, public and social sectors. Our approach is to setup a participatory framework to get the most from both our clients' potentials and our capabilities. We welcome individuals with leadership potentials and a creative mind who are able to face the toughest challenges.

SpatialAcademy.com

The origin of Spatial Academy would back to 2002. At the time, the lack of educational content for learning the GIS softwares and concepts has led Abbas Goli Jirandeh to develop freely application based learning packages. In the early years, the packages were sent to student via postal mails, however by 2009 and the growth of internet, the educational channel GIS4EDUCATIOM was lunched in YouTube with more than 400 videos covering different aspects of GIS. Considering the rapid growth of group the GIS4EDUCATION have decided to lunch the spatialacademy.com website which act like NGOs with freely available educational materials and providing an environment for related discussions. The primary aim of the Spatial Academy is to find creative and enthusiastic students and experts who are focusing on Entrepreneurship, innovation and problem solving.

GoogleSpatial.com

Nowadays there are lots of sources that produce tremendous amounts of data. The challenge here is the Geo-Spatial data are multidisciplinary which could be useful for other scientists outside of geographical communities and thus it would be hard for them to process these data. Thus Google Spatial would facilitate this process by lunching googlespatial.com website. The primary aim of this site is to process raw Geo-Spatial data and producing second level information for scientists who are interested to the application of such data rather their generation. The site would be a participatory and open to other interested individuals who like to contribute to the development of site. In addition to second level data production another goal of this website is to provide a simple user interface for current Geo-Spatial models. This UI would take the required inputs from users and present the outputs. However our primary concern here is to make the procedure as simple as possible for users, but the behind the scene of the models would be discussed in Forums and Blogs put in the GoogleSpatial.com. We hope in a few years this website become a reference for all researcher in GIS and related topics.

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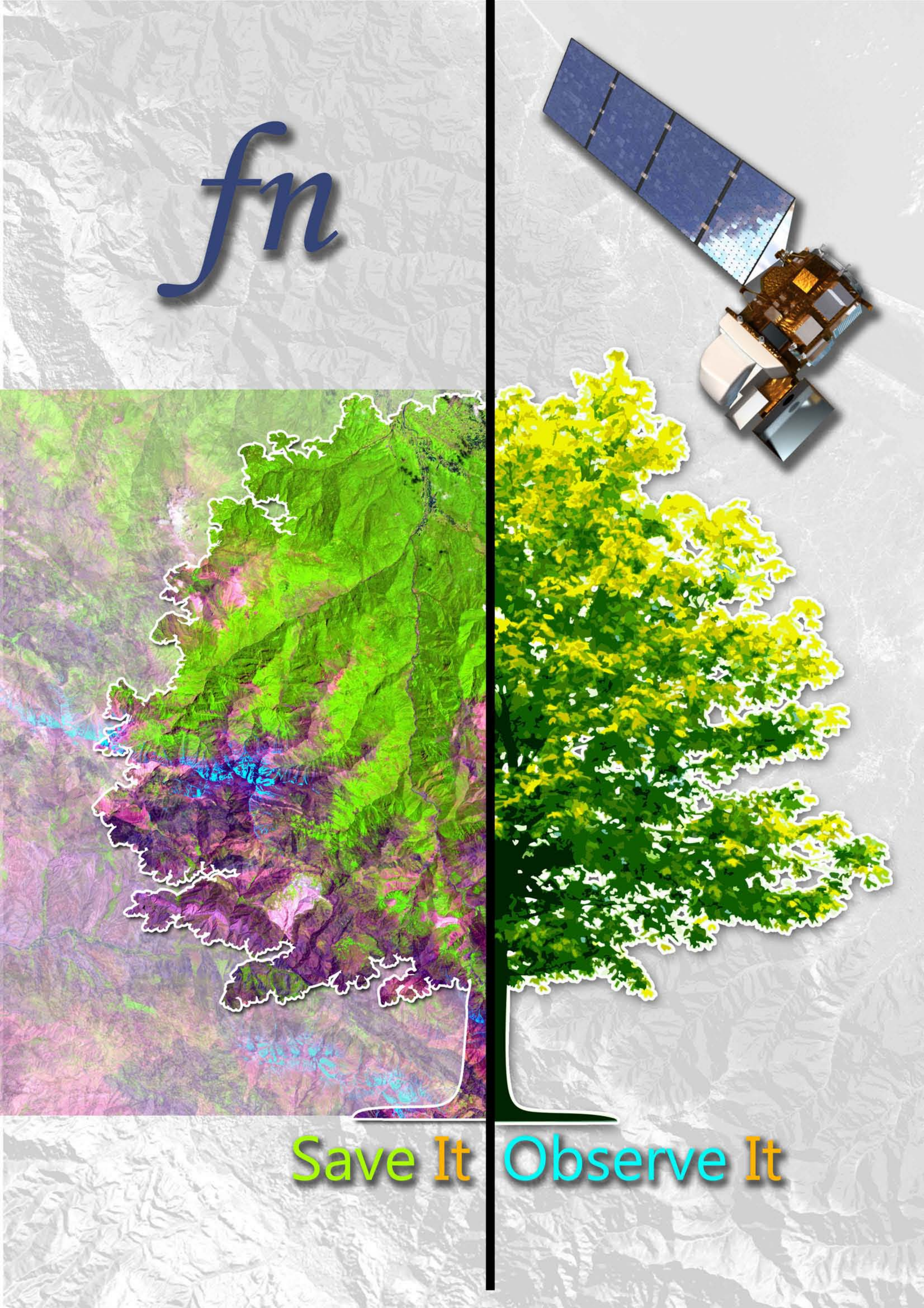
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Save It Observe It

Technical Report March 2014

Change Detection of Forest Cover From 1980 to 2013 Using Satellite Images

Spatial Sciences Innovators Consulting Engineering Company

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The gift of
Our ancestor
Our gift for
Posterity

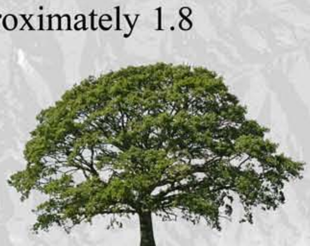
Summary

An ongoing project titled as "Building a Multiple-Use Forest Management Framework to Conserve Biodiversity in the Caspian Hyrcanian Forest Landscape" has been underway within Iranian Northern forest since May 2013. The primary aim of this project is "to put in place a collaborative governance system and know-how for managing a mosaic of land uses in the Caspian Hyrcanian forest that provides habitat integrity and helps maintain landscape level ecosystem functions and resilience" as stated by UNDP. One important aspect of the project is change detection of forest area during last decades and also estimation of current forest canopy density. Low cost satellite imagery have been used to determine forest changes which happened during last three decades. Also forests density maps were produced by classification of forest into 5-10, 10-25, 25-50, 50-75 and more than 75 percentage of canopy. Considering the lack of updated base maps in the study area, the 1:25000 of Iranian National Cartographic Center were updated with the help of available High Resolution Web Based satellite images.

This report would cover all the technical aspect of the project in addition to produced maps including forest cover maps, forest changes maps, density maps and 1:25000 updated maps.

1.Introduction

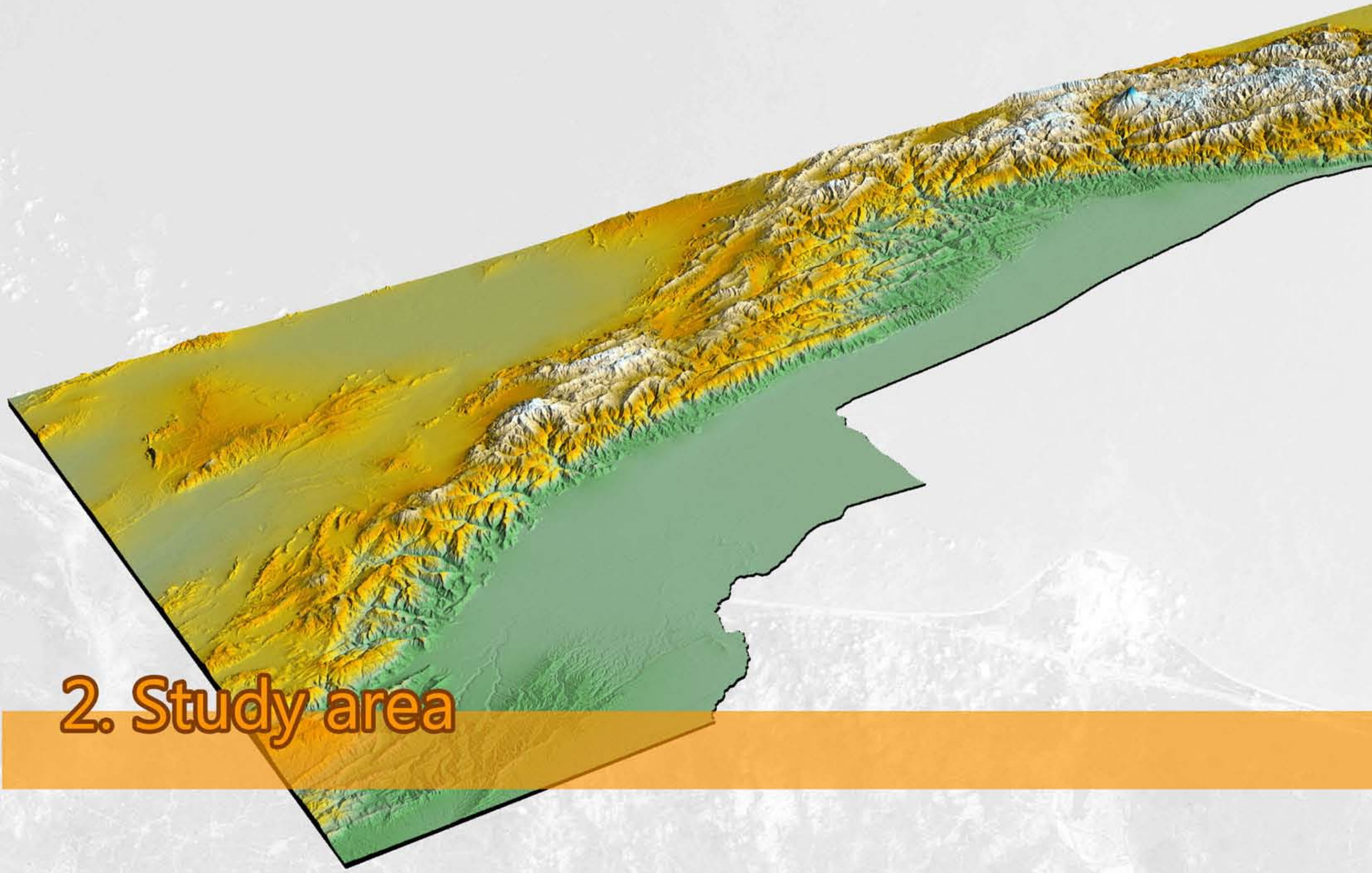
According to National Biodiversity Strategy and Action Plan (NBSAP, 2006), until recently, Iran's biodiversity was well protected, both through the formal protection system and through traditional management practices. However, in recent years, population growth, natural resource management practices and sectorial policies have adversely affected biodiversity. The loss of biodiversity was not only through forest conversation and associated loss of habitat but also forest degradation and habitat fragmentation. Thus to overcome these problems a multi-purpose project titled as "Building a Multiple-Use Forest Management Framework to Conserve Biodiversity in the Caspian Hyrcanian Forest Landscape "has been defined and seek three goals: i) to establish a forest management policy and accompanying regulations in support of biodiversity conservation within multiple-use forest landscape; ii) to build the capacities of forests, rangelands and watershed management organization and department of environment and their staff so that they are able to apply and enforce the new policy and regulatory frameworks developed under this project; and iii) to build knowledge among local communities relevant to adjust land uses. The ultimate outcome of all these goals would be conservation of biodiversity in key landscapes within the Caspian Hyrcanian broadleaf deciduous forest ecoregion, which cover an area of approximately 1.8 million hectares.



The ecoregion is recognized for its high levels of endemism; it is also an important storehouse of threatened species. The project will work at both the landscape level and the pilot site level. At the pilot level, the project expects to facilitate the upgrading of policy and regulatory frameworks for managing multiple use forest landscapes to ensure that biodiversity conservation mainstreaming measures can be implemented, though management plan and actions across~800,000 ha of forests by the end of the project, and ultimately lead to mainstreaming being adopted more broadly in the whole landscapes of 1.8 million ha as well as seeing lessons learnt being carries over to other forested areas of the country.

To achieve all above mentioned goals, it is important to know how and where the forest cover has been changed during last decades. According to Iranian Forests, Range and Watershed Management Organization (FRWO) the amount of forest cover is decreased by humanitarian or natural reasons in comparison to 40 years ago. Beside of canopy cover, canopy density for its contribution to a more realistic estimation of forest productivity, must be estimated as precise as possible.

Considering the vast distribution of Hyrcanian Forests and also the lack of previous maps and data, traditional approaches like ground surveying would not lead us to an understanding of the past and current situation of forests. Since the launching of the first earth-observation



2. Study area

Iranian Northern Forest known as Hyrcanian Forests is located in Northern Iran along the southern coast of the Caspian Sea and northern slopes of Alborz Mountains (Figure 1). It covers parts of five provinces of Iran from east to west including Northern Khorasan, Golestan, Mazandaran, Gilan and Ardabil provinces. All the analysis were done in six parts introduced by the client. The location of these sites with their corresponding codes are demonstrated in Figure 2.

Figure 1
Hyrcanian Forests

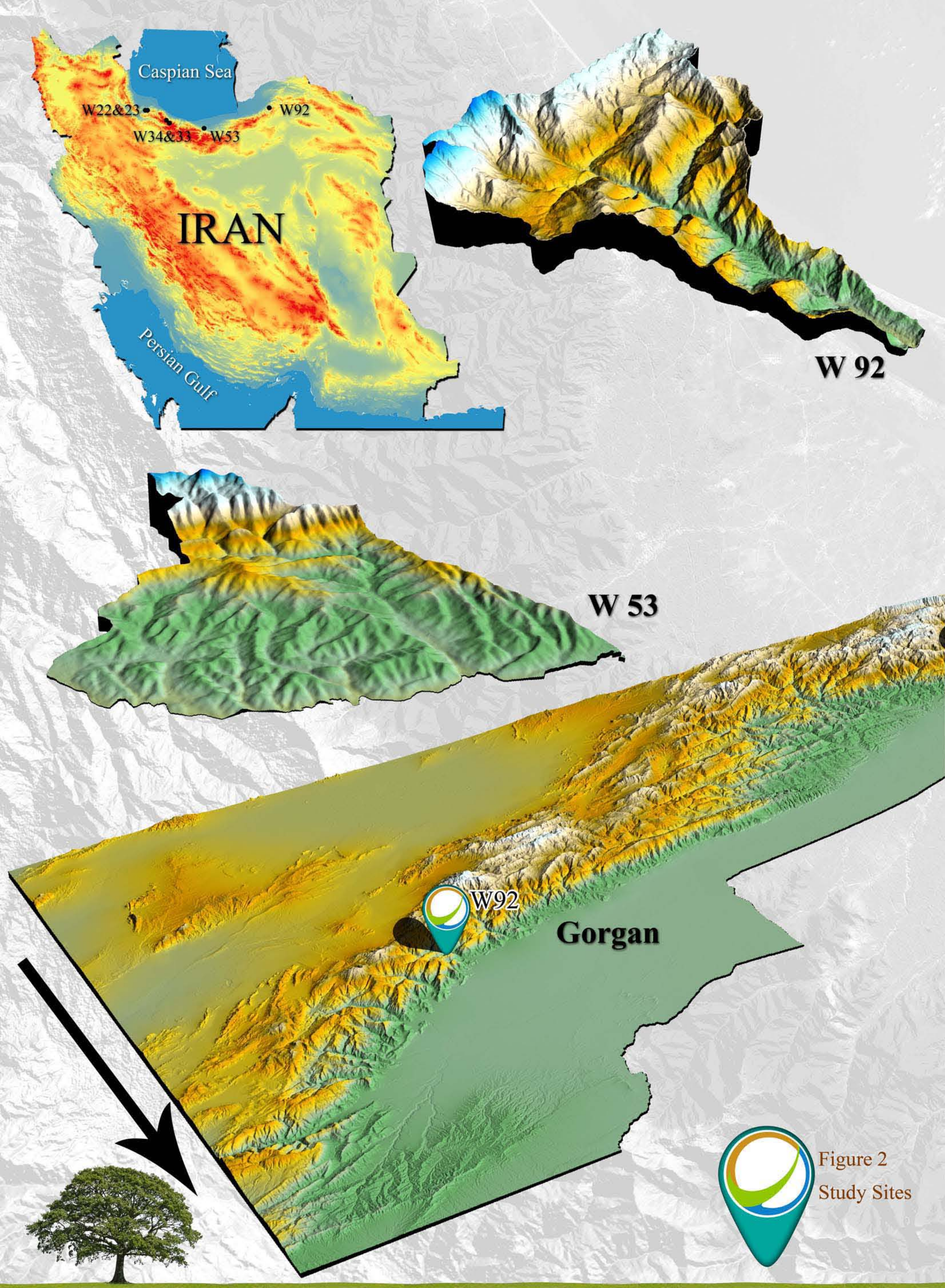
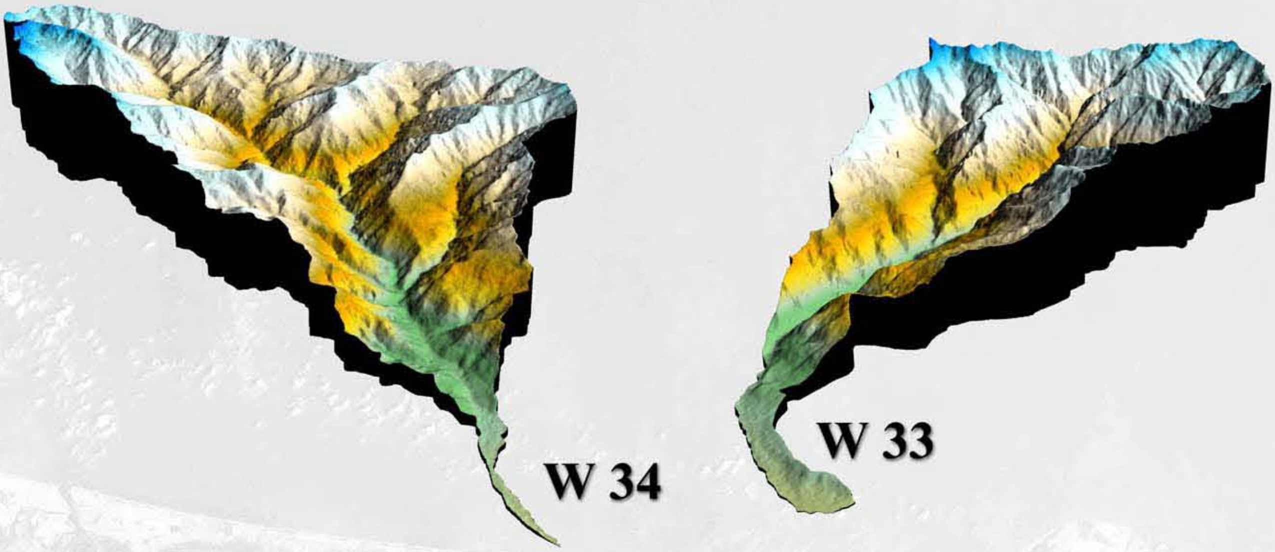
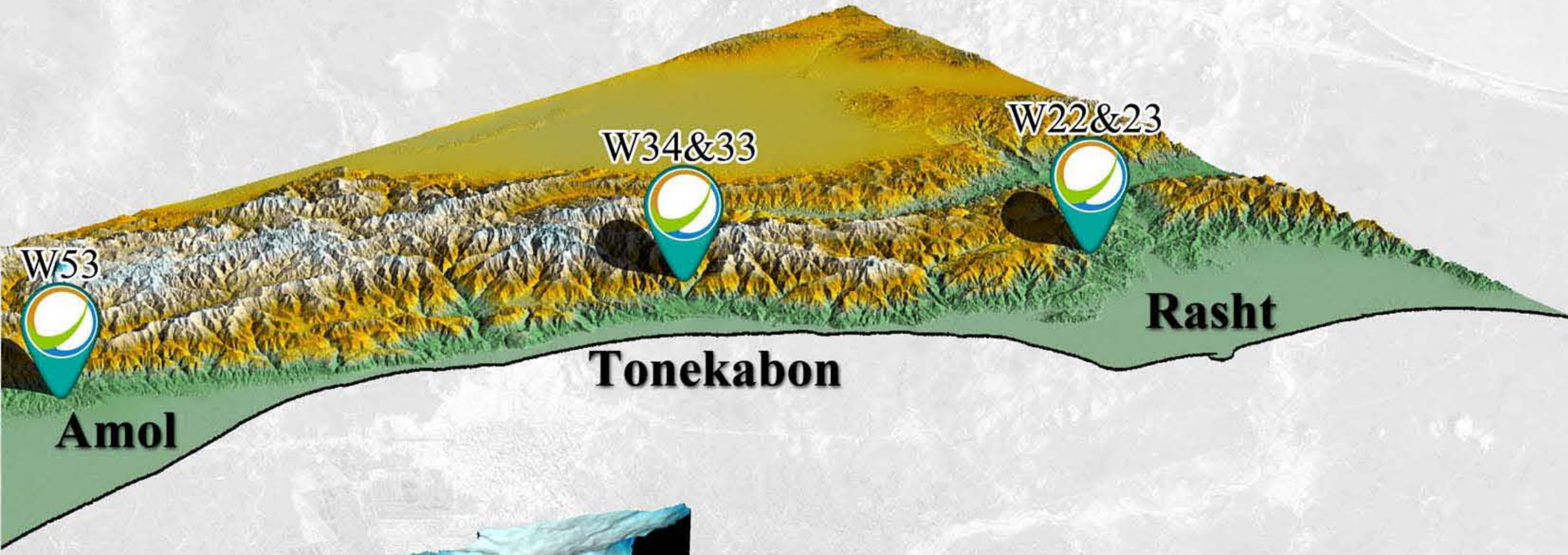
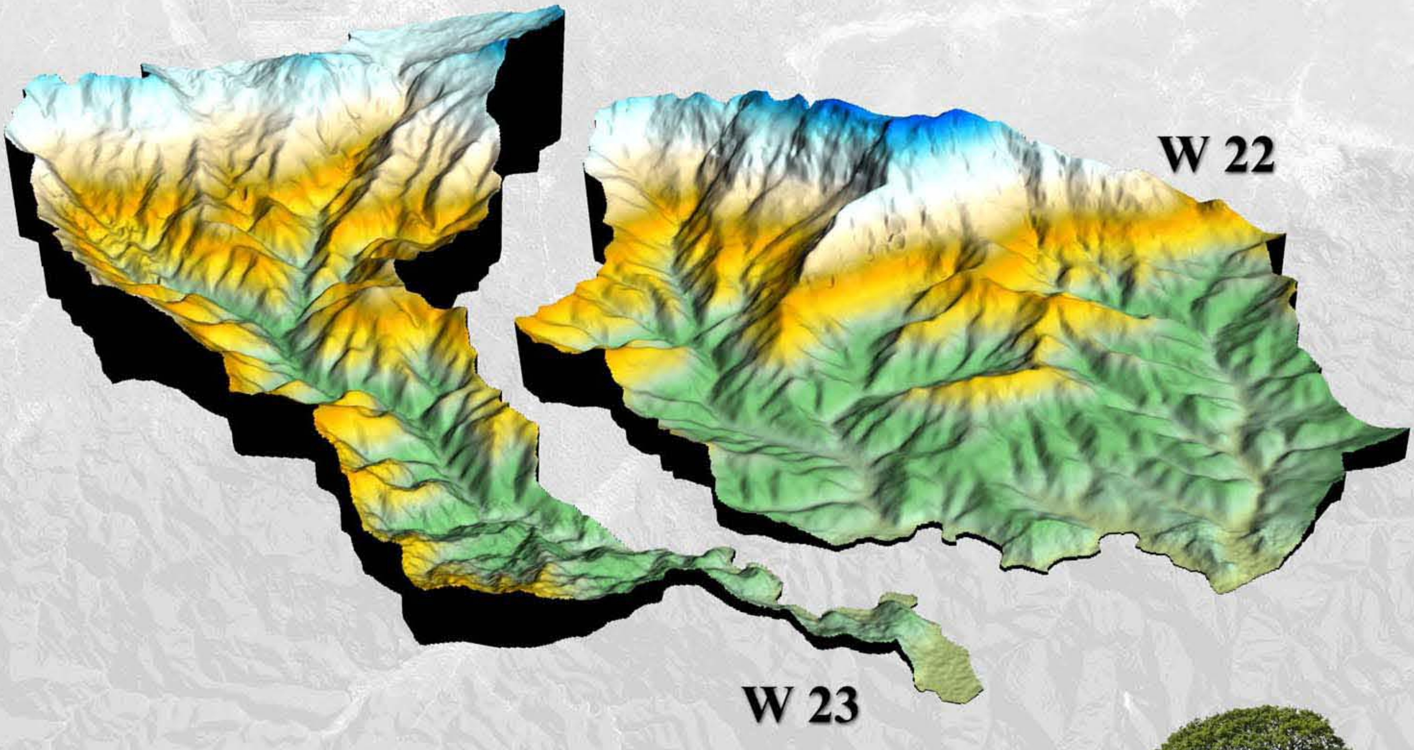
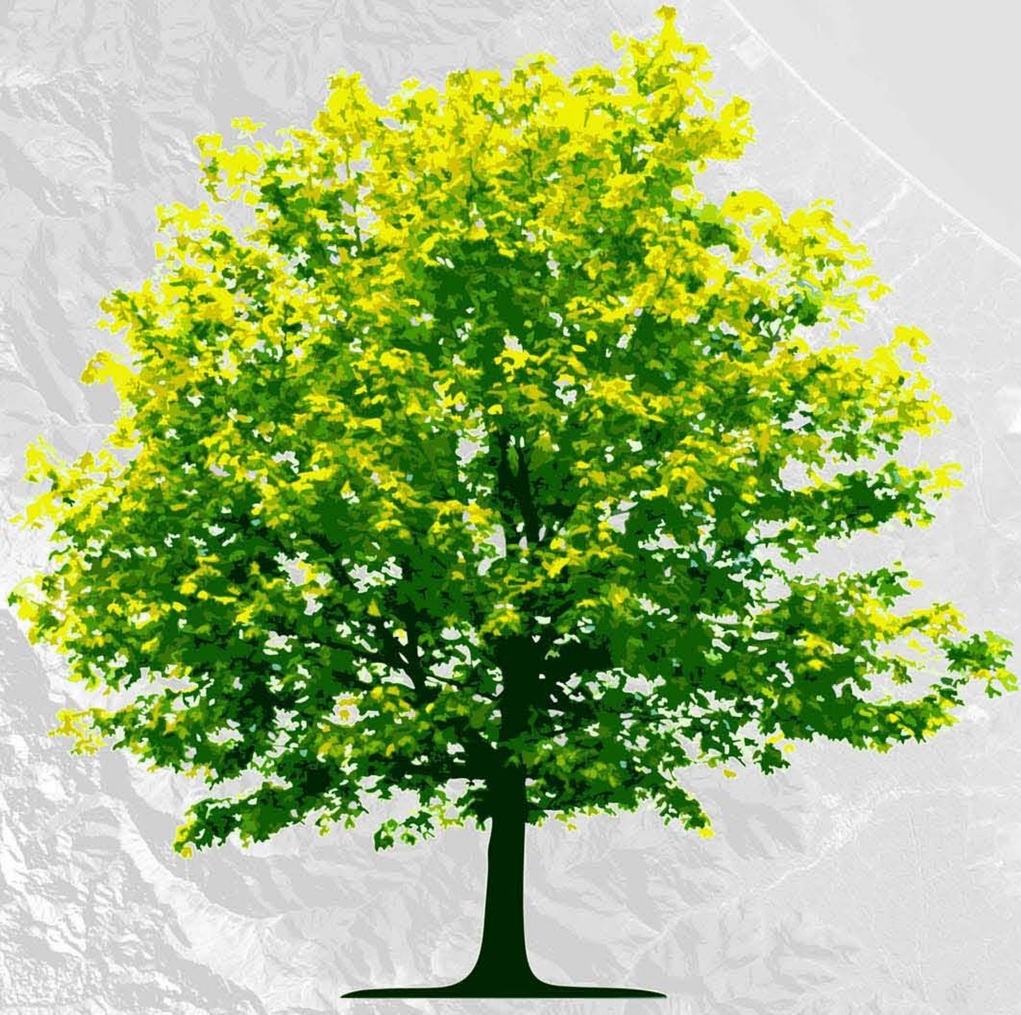


Figure 2
Study Sites


W 34
W 33


W53
W34&33
W22&23
Amol
Tonekabon
Rasht


W 22
W 23



The area's topography ranges from flat to steep-sided terrain, with elevations ranging from zero at sea level along the coastal plain, to approximately 5600 m in Alborz Mountain Ranges. Most of the flat area occupied by agricultural activities while in some places due to governmental restriction some spots of forest are conserved.

The natural forest vegetation is temperate deciduous broadleaved forest. 32.7 percent of volume of Hyrcanian forest is of Oriental Beech (Fagus orientalis). A main feature of the region is the lack of conifers; only relics of coniferous species are present, which include European yew (Taxus baccata), Junipers (Juniperus spp.), Mediterranean Cypress (Cupressus sempervirens var. horzontalis) and Chinese Arborvitae (Platycladus orientalis).

Hyrcanian forest contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

The location of indivisual sites and their characteristics are presented

•The western sites are two neighbor sites W22 and W23. These sites are located in Gilan province and is approximately 35 Kilometers south of Rasht, the capital of Gilan. The total area of these two sites is 30542 Hectares and this area is mostly covered by forest. Figure 3 shows the sites imagery and their boundary:

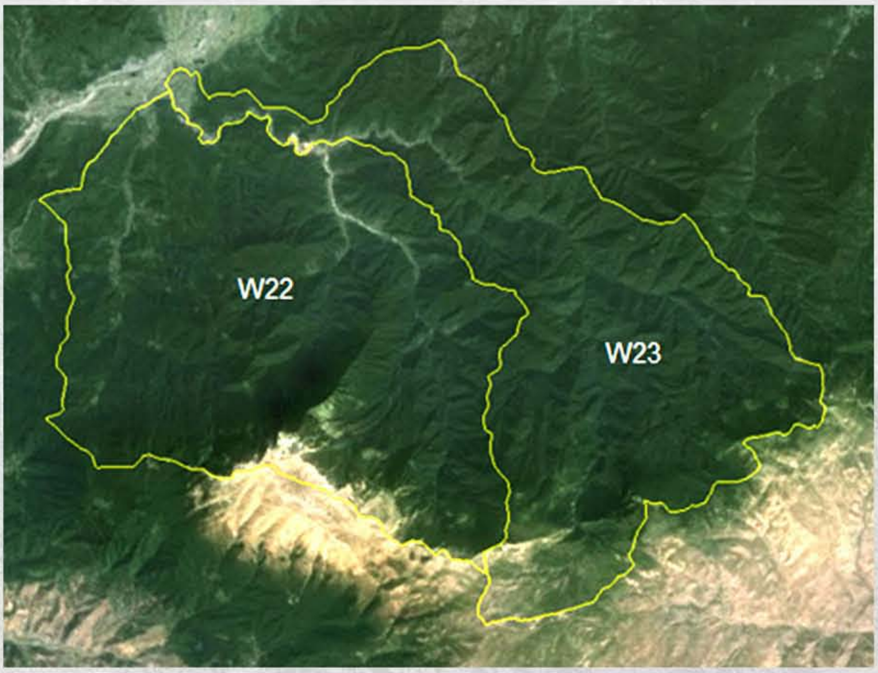


Figure 3
sites W22 and W23

•The western sites are two neighbor sites W22 and W23. These sites are located in Gilan province and is approximately 35 Kilometers south of Rasht, the capital of Gilan. The total area of these two sites is 30542 Hectares and this area is mostly covered by forest. Figure 3 shows the sites imagery and their boundary:

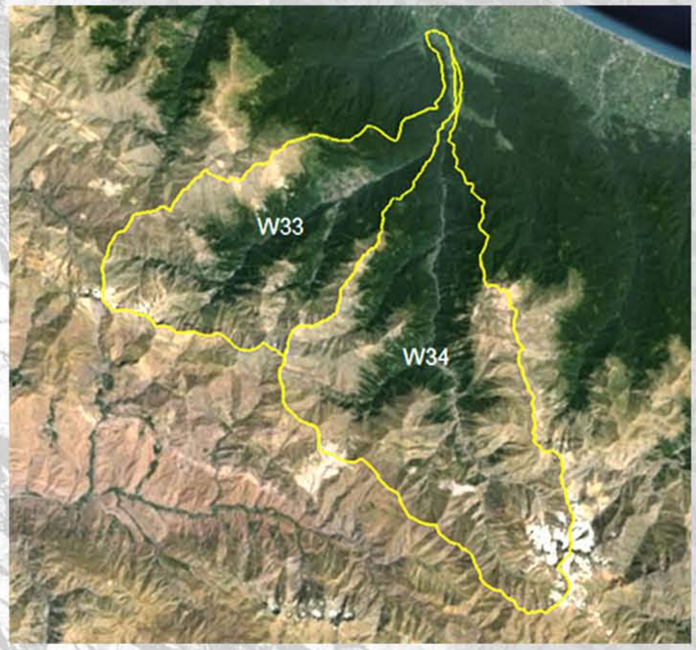


Figure 4
sites W33 anda W34

•Next site is W53 which is located in Mazandaran province and is about 57 Kilometers east of Sari, the capital of Mazandaran. The area of this site is 21425 Hectares and is mostly covered by forest and to some extend agricultural lands. Figure 5 shows this area:

Figure 5
site W53

•The last site W92. This site is located on Golestan province and is about 90 Kilometers east of Gorgan the capital of Golestan. The area of W92 is 25952 Hectares and this region is covered by a mixture of both forest and intense agriculture activities. Figure 6 shows this site:

Figure 6

site W92

3.Methodology

3.1. Data

3.1.1. LANDSAT satellite

The aim of every change detection studies is the determination of changes occurring in a long time for a specific land cover. Unfortunately, usually forest maps of long time ago are not available or have poor quality or low resolution. One of the main sources for forest mapping in such situation is to use satellite images. LANDSAT satellite is one of the most successful project that could help scientists in this context.

The Landsat program is the longest running enterprise for acquisition of satellite imagery of Earth. Imagery from the Landsat satellites has been acquired since 1972, with a variety of characteristics to consider. There have been seven operational Landsat satellites, with four different useful sensors. The MSS sensor provides the oldest and lowest quality Landsat data from 1972 – present. The TM sensor has improved quality and is available from 1984 – present. The ETM+ sensor on the Landsat 7 satellite was the best quality of all, until a mechanical anomaly occurred on the sensor in May, 2003. Landsat 7 imagery is still being collected, even with this unfortunate defect. The OLI sensor which is on board LANDSAT 8 is available from January 2013 with extra bands and special radiometric enhancement. Specification of these sensors is presented in table 1 through 4

Table 1: Landsat Multispectral Scanner (MSS) images consist of four spectral bands with 60 meter spatial resolution. Approximate scene size is 170 km north-south by 185 km east-west (106 mi by 115 mi). Specific band designations differ from Landsat 1-3 to Landsat 4-5 (U.S. Geological Survey).

Multispectral Scanner (MSS)	Landsat 1-3	Landsat 4-5	Wavelength (micrometers)	Resolution (meters)
	Band 4	Band 1	0.5-0.6	60
	Band 5	Band 2	0.6-0.7	60
	Band 6	Band 3	0.7-0.8	60
	Band 7	Band 4	0.8-1.1	60

Table 2: Landsat Thematic Mapper ™ images consist of seven spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7. Spatial resolution for Band 6 (thermal infrared) is 120 meters, but is resampled to 30-meter pixels. Approximate scene size is 170 km north-south by 183 km east-west (U.S. Geological Survey).

Thematic Mapper ™	Landsat 4-5	Wavelength (micrometers)	Resolution (meters)
	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.76-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	120* (30)
	Band 7	2.08-2.35	30

Table 3: Landsat Enhanced Thematic Mapper Plus (ETM+) images consist of eight spectral bands with a spatial resolution of 30 meters for Bands 1 to 7. The resolution for Band 8 (panchromatic) is 15 meters. All bands can collect one of two gain settings (high or low) for increased radiometric sensitivity and dynamic range, while Band 6 collects both high and low gain for all scenes. Approximate scene size is 170 km north-south by 183 km east-west (U.S. Geological Survey).

Enhanced Thematic Mapper Plus (ETM+)	Landsat 7	Wavelength (micrometers)	Resolution (meters)
	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.77-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	60 * (30)
	Band 7	2.09-2.35	30
	Band 8	.52-.90	15

Table 4: Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. New band 1 (ultra-blue) is useful for coastal and aerosol studies. New band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters. Approximate scene size is 170 km north-south by 183 km east-west (U.S. Geological Survey).

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 – Coastal aerosol	0.43 – 0.45	30
	Band 2 – Blue	0.45 – 0.51	30
	Band 3 – Green	0.53 – 0.59	30
	Band 4 – Red	0.64 – 0.67	30
	Band 5 – Near Infrared (NIR)	0.85 – 0.88	30
	Band 6 – SWIR 1	1.57 – 1.65	30
	Band 7 – SWIR 2	2.11 – 2.29	30
	Band 8 – Panchromatic	0.50 – 0.68	15
	Band 9 – Cirrus	1.36 – 1.38	30
	Band 10 – Thermal Infrared (TIRS) 1	10.60 – 11.19	100
	Band 11 – Thermal Infrared (TIRS) 2	11.50 – 12.51	100

Landsat satellites acquire imagery in a regular, tiled fashion, following the World Reference System (WRS1 for MSS, WRS2 for TM, ETM+ and OLI). The Landsat satellites follow a repetitive, circular, sun-synchronous, near earth orbit. Please visit the Landsat program for further details.

3.1.1.1. LANDSAT Data Acquisition

The parameters important for ordering the LANDSAT images are, sensor tilt angle, time of acquisition, date and cloud cover. Table 5 shows the attribute of images and corresponding site used in this study.

Table 5: The attribute of images of corresponding site.

Image ID	Sensor	Year	Date (Julian)	Assigned Site (Code)
LM21780341978191AAA04	MSS	1978	191	W22-W23
LT41660341989183XXX02	TM	1989	183	W22-W23
LT51660341991165XXX03	TM	1991	165	W22-W23
LE71660342000182SGS00	ETM	2000	182	W22-W23
LC81660342013209LGN00	OLI	2013	209	W22-W23
LM21780341978191AAA04	MSS	1978	191	W30-W32
LT51650341991206XXX03	TM	1991	206	W30-W32
LT51650351991206XXX03	TM	1991	206	W30-W32
LE71650342000207SGS00	ETM	2000	207	W30-W32
LE71650352000207SGS00	ETM	2000	207	W30-W32
LC81650342013170LGN00	OLI	2013	170	W30-W32
LM21760351977194AAA04	MSS	1977	194	W53
LT41640351988263XXX04	TM	1988	263	W53
LE71640352000200SGS00	ETM	2000	200	W53
LC81640352013227LGN00	OLI	2013	227	W53
LM21750341977157AAA05	MSS	1977	157	W92
LT41620341988249XXX03	TM	1988	249	W92
LE71620342000202SGS00	ETM	2000	202	W92
LC81620342013229LGN01	OLI	2013	229	W92

The LANDSAT images are delivered with a metadata file. For now the only software which is able to open the LANDSAT MTL file is ENVI 5.03. Thus all the processes of preprocessing were done in ENVI Environment.

3.1.2. High Resolution Web-Based Images

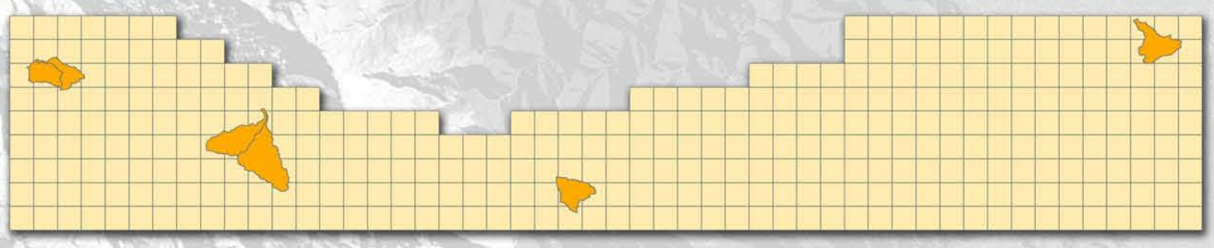
Updating of base maps is essential step in this project. LANDSAT images are not capable of providing the required spatial resolution for this procedure. Thus the only option is to use high resolution images. Considering the limitation of buying such images, we were forced to use available web based satellite images provider such as Bing or Google. These services usually use WorldView-2 and GeoEye images with 50 cm resolution.

3.1.3. 1:25000 Maps

All available base maps were collected in two formats, DGN and Shapefile and the all layers of interest were extracted from them. The landuse of each map layer were identified by referring to the legend of the map in a DGN file or its attribute table in the case of using shapfiles .There are always some imperfection in the required map layers , for example lack of some specific layers in certain area, that will be recovered in updating phase.

Base maps formatted as DGN files are divided into sheets with a specific sheet index. All the studied sites and the network of the sheets (with scale 1:25000) are presented in figure 7:

As you can see every sheet is labeled with a triple name indicating the corresponding base map name.



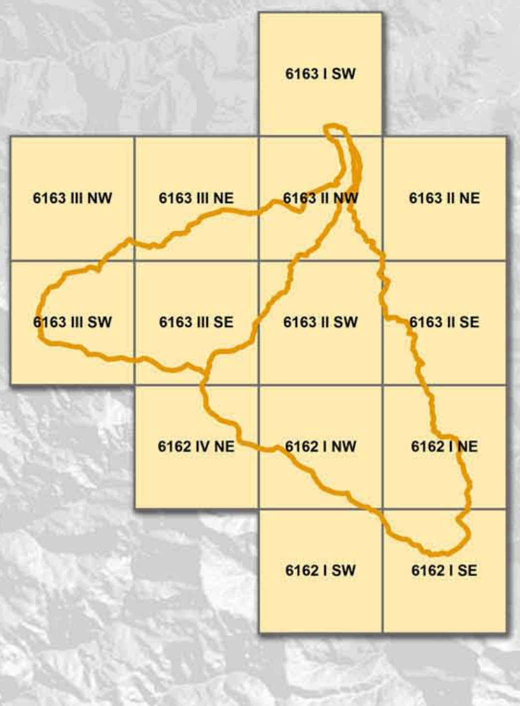


Figure 7-study area with respect to grid of 1:25000 map sheets

3.2. Digital Image Processing

3.2.1. Georeferencing

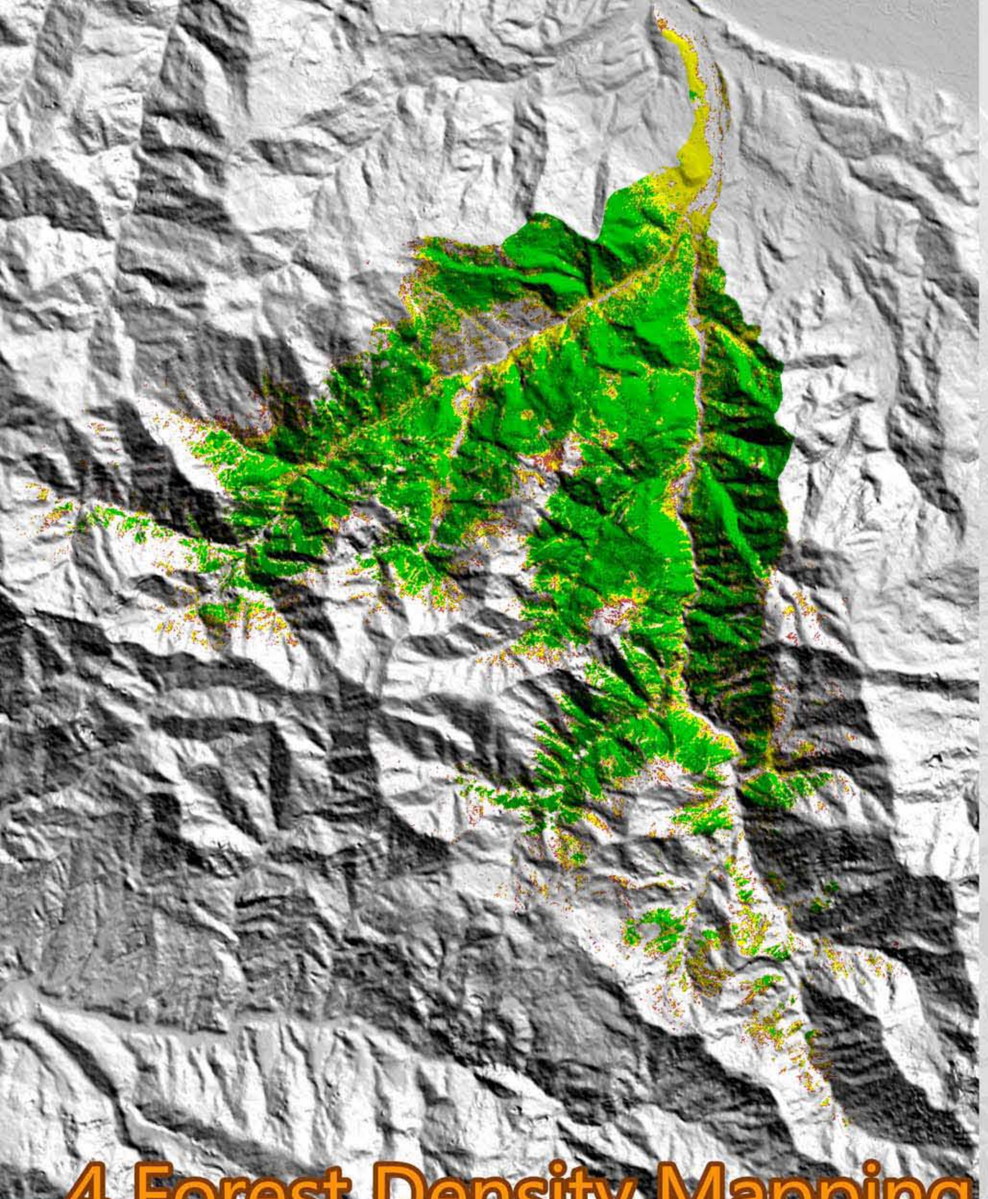
Aerial photos and satellite images do not show features in their correct locations due to displacements caused by the tilt of the sensor and terrain relief. Georeferencing transforms the central projection of the photograph into an orthogonal view of the ground, thereby removing the distorting effects of tilt and terrain relief. Georeferencing is the process of transforming raw imagery to an accurate orthogonal projection, as against the perspective projection of the raw image. The product of this step is an image with all object placed in correct coordinates. Without Georeferencing, scale is not constant in the image and accurate measurements of distance and direction cannot be made.

The product of this step is an effective tool for use in resource management, municipal planning, cadastral mapping, and geographic information systems (GIS). It is not only true in scale and area, but like a conventional aerial photograph it is easily interpreted.

3.2.2. Radiometric Correction

The reflectance at a given wavelength of an object measured by a remote sensing instrument varies in response to several factors, including the illumination of the object, its reflectivity, and the transmissivity of the atmosphere. Furthermore, the response of a given sensor may degrade over time. With these factors in mind, it should not be surprising that an object scanned at different times of the day or year will exhibit different radiometric characteristics. Such differences can be advantageous at times, but they can also pose problems for some image processing process such as mosaic adjoining images together, or to detect Parcels for cadastral mapping. To cope with such problems, analysts have developed numerous radiometric correction techniques, including Earth-sun distance corrections, sun elevation corrections, and corrections for atmospheric haze.

Radiometric correction of satellite imagery falls into two broad categories, absolute and relative. Absolute radiometric correction converts the digital number of a pixel to a percentage reflectance value using established transformation equations. Relative radiometric correction normalizes multiple satellite scenes to each other. Absolute radiometric correction needs lots of information, since this information were not available we use Dark Subtraction Method which need only information that could be extracted from image itself.



4.Forest Density Mapping

4.1.Literature Review

Forest canopy cover, also known as canopy coverage or crown cover, is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns. It has been demonstrated that satellite images are proper to assess forest canopy density. Many literature have reported successful results in the last decade.

Huang et al., 2001, proposed a method for estimating tree canopy density using Landsat 7 ETM and high resolution images. They developed a strategy for estimating tree canopy density at a spatial resolution of 30 m. This strategy was based on empirical relationships between tree canopy density and Landsat data, established using linear regression and regression tree techniques.

They also used one-meter digital orthophoto quadrangles to derive reference tree canopy density data needed for calibrating the relationships between canopy density and Landsat spectral data. This strategy was tested over three areas of the United States. The regression tree was found more robust than linear regression and the authors interpreted this due to its capability of approximating complex non-linear relationships.

Sandy et al., 2003, compared three approaches of specifying Forest Canopy Density. They compared visual interpretation, object oriented image segmentation and biophysical modeling and found the third method to be the most functional one. They reported biophysical modeling was better in terms of accuracy, efficiency and high correlation with ground estimates.

Chandrashekhar et al., 2005, mapped forest canopy density using satellite remote sensing data and biophysical spectral response modelling. They also compared object oriented image analysis approach and visual interpretation method with the Forest Canopy Density (FCD) Mapper semi expert system. They showed forest canopy density is effectively stratified through linear multi-parametric approach by utilizing advanced vegetation index, bare soil index, shadow index and thermal index. They reported Isodata cluster analysis of forest canopy density map derived from FCD Mapper and conventional methods were shown similar results with respect to percent area of forest and non-forest.

Deka et al., 2013 show the ability of FCD model to detect the temporal change in forest canopy density. They use Landsat data in their study (TM and ETM+ sensors).they reported overall accuracy of 84.0 % with kappa coefficient of 0.77.they finally concluded FCD mapping and monitoring model prove to be an effective means for measuring forest cover assessment in a very short period and also with less information of ground validation.

Since for this projects there was not a trustable ground truth dataset and also most of the empirical approaches are not stable, we decided to use forest canopy density mapper. FCD originally was developed by Chandrashekhar and proof its capabilities in estimation of forest density.

4.2. Forest Density Mapper

4.2.1. Concept of Forest Density Mapper and Semi Expert Systems

In this project Forest Canopy Density Mapper as both technique and tool is utilized to specify the forest canopy density. FCD mapper is a software that leverages the FCD model which needs less information of ground truth (ground truth information is just used for accuracy analysis). In general FCD Mapper algorithm employs four biophysical indices as follows:

- Advanced Vegetation Index(AVI)
- Bare soil index(BI)
- Thermal Index(TI)
- Shadow Index(SI)

This model uses Landsat TM satellite imagery data. The model is based on growth phenomena of forest and spectral response of area. Finally it produces forest canopy density maps which shows the density in percentage (e.g. 10%, 20%, 30% and so on).

4.2.2. Characteristics of Four Indices

Forest Canopy Density Mapping Model uses vegetation, bare soil, shadow and thermal indices. Figure 9 shows how this indices affect the forest canopy density. According to the Figure vegetation and shadow parameters are correlated with each other. Also similarly bare soil and temperature are correlated. When forest density increases, tree vegetation makes more shadow that lead to greater SI. As the vegetation quantity decreases Thermal index increases.

Figure 8

relations between different indices and FCD

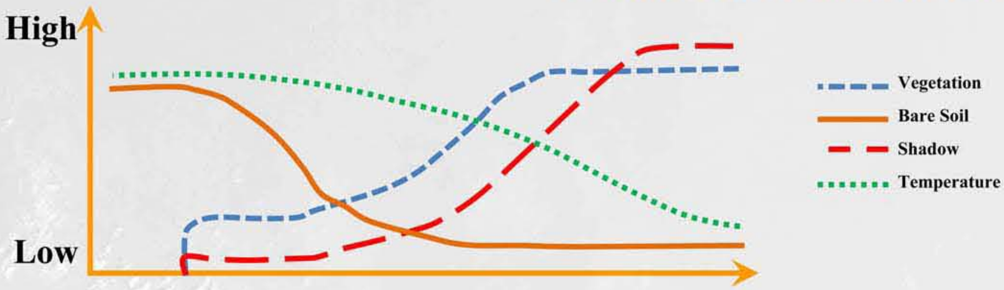


Table 6: relations between different indices and FCD

	Hi-FCD	Low-FCD	Grass Land	Bare Land
AVI	Hi	Mid	Hi	Low
BI	Low	Low	Low	Hi
SI	Hi	Mid	Low	Low
TI	Low	Mid	Mid	Hi

4.2.2.1. Advanced Vegetation Index (AVI)

NDVI and AVI are known as vegetation indices; but it is proven that since NDVI is saturated in dense vegetation. Thus in comparison to NDVI, AVI is more sensitive to forest density. AVI is calculated using this equations:

$$AVI = [(B4 + 1)(256 - B3)(B4 - B3)]^{1/3}$$

AVI = 0 If B4<B3 after normalization

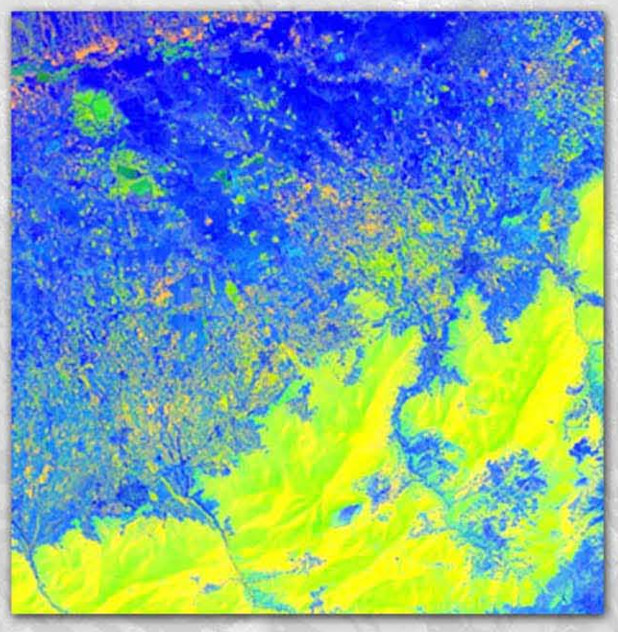


Figure 9

Advanced Vegetation Index of Hyrcanian forest

4.2.2.2. Bare Soil

Medium infrared information is used for formulating soil index. Bare soil areas, follow lands, vegetation with marked background response are enhanced by this index. Similar to AVI, bare soil index (BI) is a normalized index of the deference sums of two bands separating the vegetation with different background. The status of forest from high vegetation to exposed soil condition is inferred by combining vegetation and soil indices. BI formulation is presented as follows:

$$\mathrm{BI}=\frac{(\mathrm{B5}+\mathrm{B3})-(\mathrm{B4}+\mathrm{B1})}{(\mathrm{B5}+\mathrm{B3})+(\mathrm{B4}+\mathrm{B1})}$$

4.2.2.3. Shadow Index

Due to the three dimensional nature of forest this index can’t be ignored. Mature forest area has a greater shadow index and also greater FCD and young and aged areas correspond with smaller index. This index is calculated by this equation:

$$\mathrm{SI}=\sqrt[3]{(256-B_1)(256-B_2)(256-B_3)}$$

Where B1. B2 and B3 are the LANDSAT bands.

4.2.2.4. Thermal Index

Shielding effect of forest canopy which obstacle the sun energy and evaporation from surface of vegetation’s leaves account for low temperature of a forest. Formulation of the thermal index is based on this phenomenon. The source of thermal information is the infrared band of TM data (band6).

The temperature data only has been used to separate soil and non-tree shadow. The color images produced from Landsat TM raw bands 4, 3, 2 and 5, 4, 3 provide valuable information on the forest cover type distribution. The normalization operation is not conducted for band 6 due to treatment of temperature calibration. The temperature calibration of the thermal infrared band into the value of ground temperature has been done using these equation:

$$L = L_{min} + ((L_{max} - L_{min})/255) * Q$$

$$T = K2 / (\ln (K1/L + 1))$$

Where:

L: value of radiance in thermal infrared

T: ground temperature (k).

Q: digital record.

K1, K2: calibration coefficients.

K1=666.09 watts / (meter squared * ster* μm)

K2=1282.71 Kelvin

Lmin= 0.1238 watts / (meter squared * ster* μm)

Lmax= 1.500 watts / (meter squared * ster* μm)

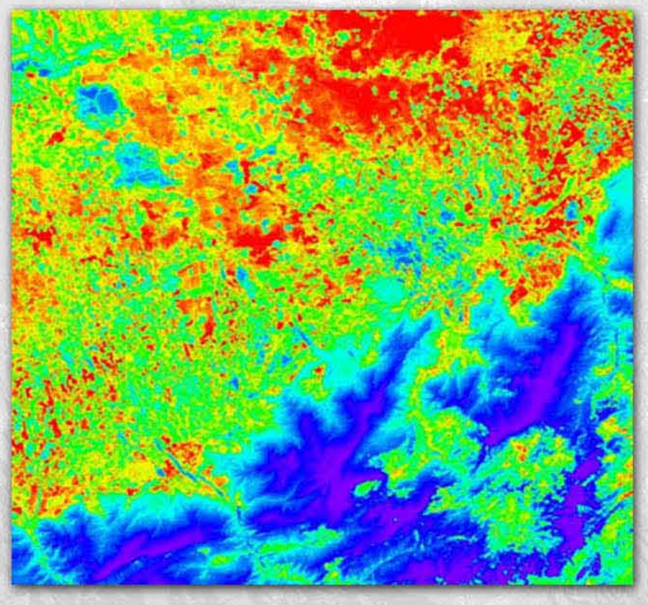


Figure 10

thermal index of Hyrcanian Forest

4.2.3. The Procedure of FCD Model

The flowchart of the procedure for FCD mapping model is illustrated in figure 10. As illustrated in this Figure two other indices, VD and BI would be produced by combining the above mentioned indices (Figure 10).

4.2.3.1. VD and SSI

VD is the procedure to synthesize VI and BI. Processing method is using principal component analysis. Because essentially, VI and BI have high correlation of negative. The shadow index (SI) is a relative value. Its normalized value can be utilized for calculation with other parameters; The SSI was developed in order to integrate VI values and SI values. In areas where the SSI value is zero, this corresponds with forests that have the lowest shadow value (i.e.0%). In areas were the SSI value is 100, this corresponds with forests that have the highest possible shadow value (i.e.100%). SSI is obtained by linear transformation of SI. With development of the SSI one can now clearly differentiate between vegetation in the canopy and vegetation on the ground.

4.2.3.2. Integration process

Integration of VD and SSI means transformation for forest canopy density value. Both parameter has dimension and has percentage scale unit of density. It is possible to synthesize both indices safely by means of corresponding scale and unit of each.

$$\text{FCD}= \sqrt{VD * SSI + 1} - 1$$

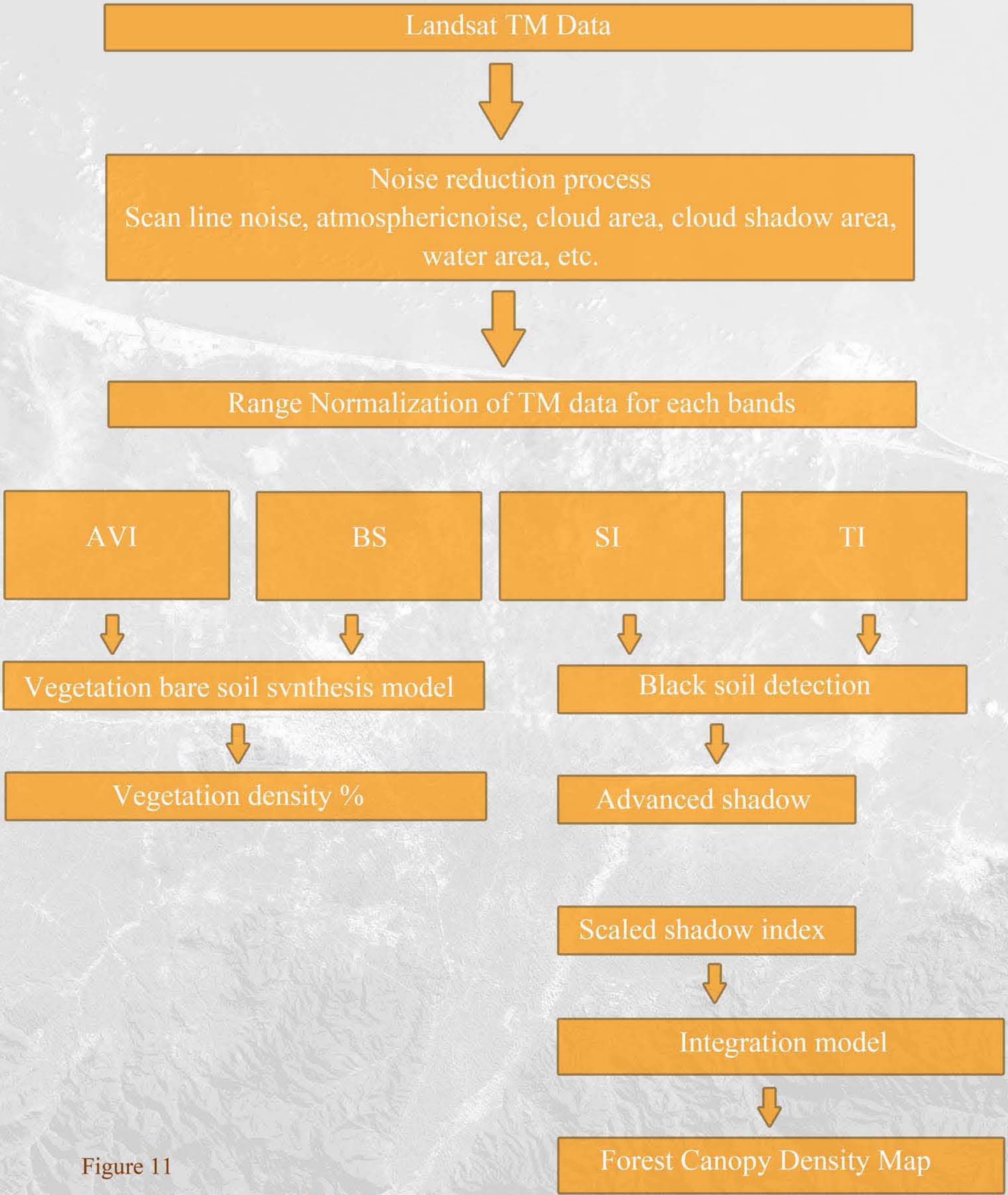


Figure 11
process of producing FCD Map

4.3. Accuracy Assessment

Assessment of the accuracy of input maps is essential step for all remote sensing projects. In general accuracy would be estimated with cross referencing of some random point that are collected from field with classes retrieved from images. The result of this study is presented in a table known as the matrix of errors. The average of pixels that are classified correctly is a common way of accuracy assessment which is called overall accuracy.

4.4. Forest Canopy Density Map and change detection

Based on vegetation indices the study area is divided into two category, Forest and Non-Forest areas. Then based on this classification scheme, the changes of forest area with approximately 10 years time steps were detected. The forest distribution maps and their changes and also current canopy density maps of the study area are presented in this section

The area of forests in different years are presented in table 7 :

Table 7: area of forests for different years

Forest Distribution	W22	W23	W33	W34	W53	W92
1978	15,455.97	12,526.47	12,626.02	15,662.08	20,567.88	**15,077.16**
1989	15,064.65	12,064.14	12,748.86	15,149.70	20,740.50	**15,155.28**
2000	15,260.40	12,573.63	11,760.39	14,054.04	20,532.24	**13,891.50**
2013	15,325.47	12,679.20	11,851.38	13,892.31	20,751.75	**12,932.82**

Between different landscapes we choose site 92 to represent the results. Other landscapes will be added in finalized report.

4.4.1. Site W92

4.4.1.1. Forest Distribution

Forest distribution maps of W92 in 1977, 1988, 2000 and 2013 (Figure 12 - 15).

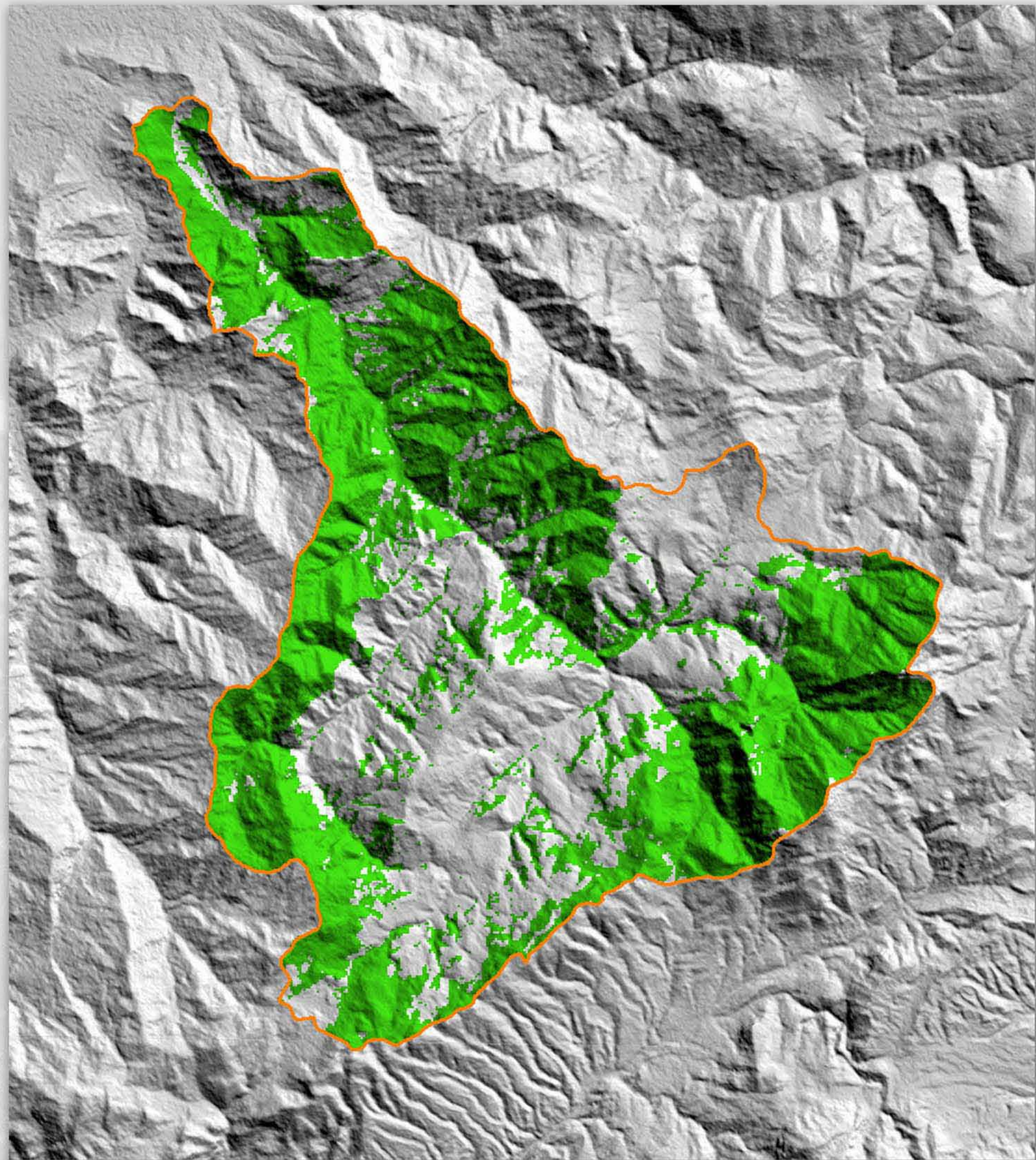


Figure 12

Forest Distribution in 1977

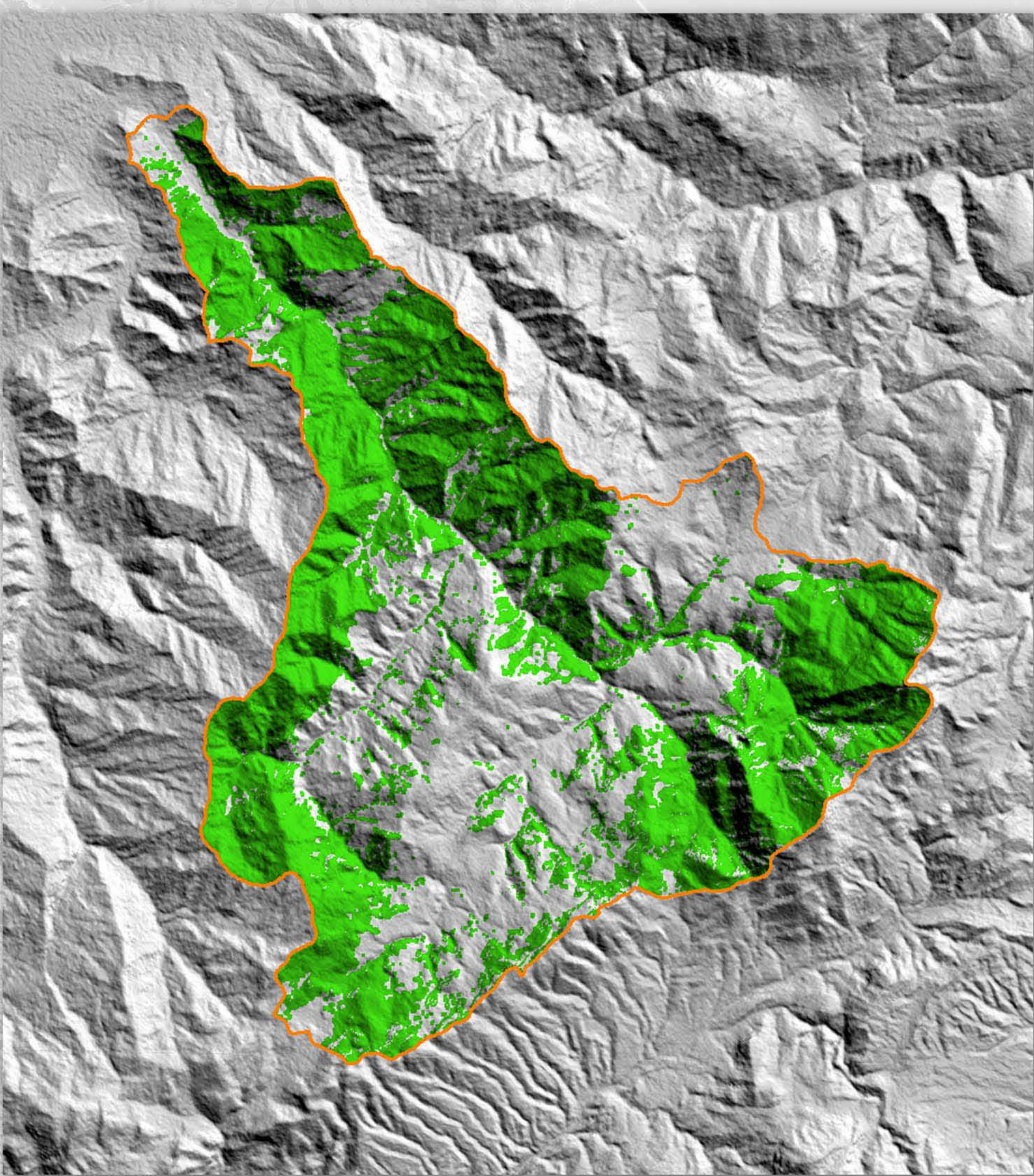


Figure 13

Forest Distribution in 1988

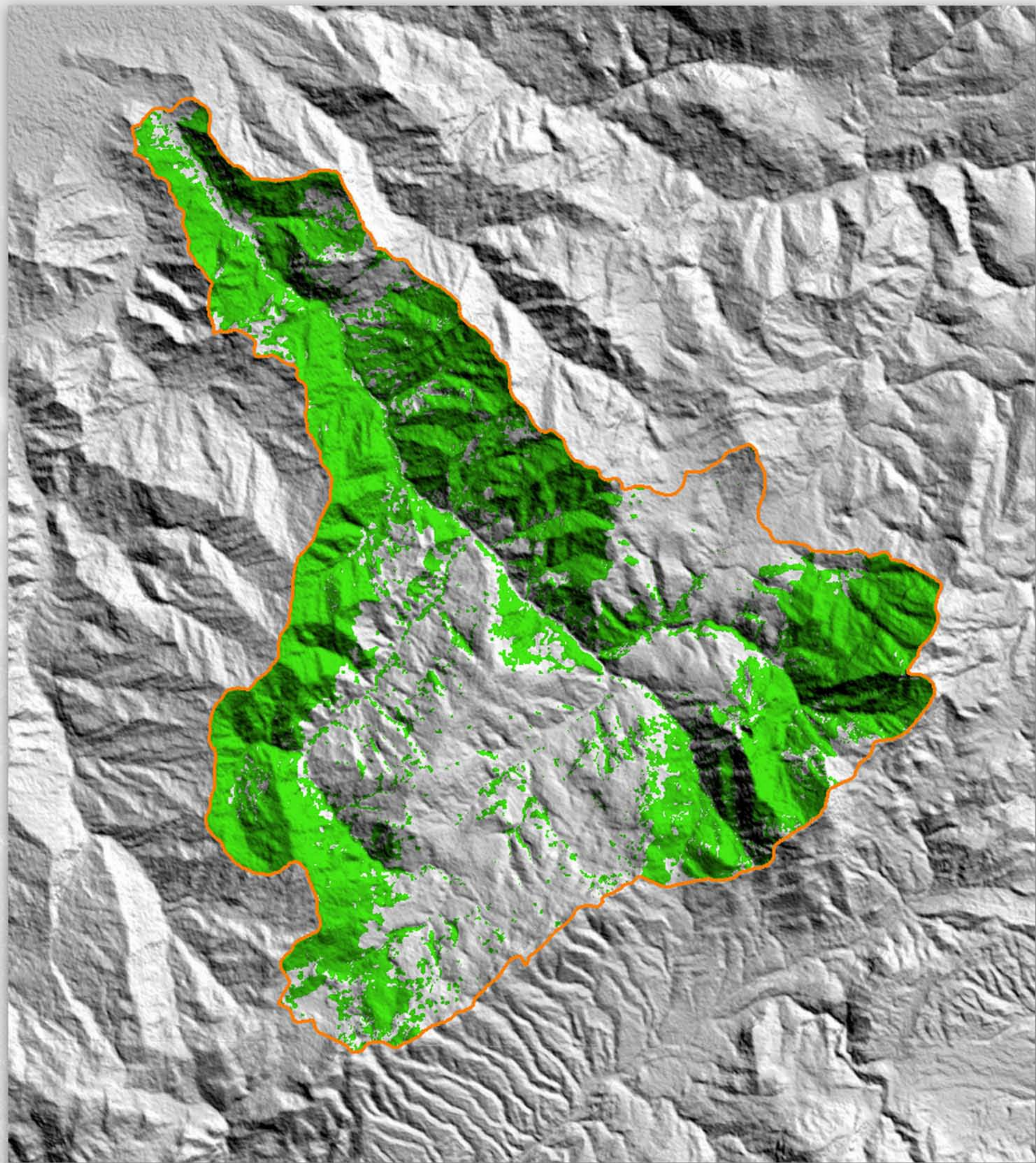


Figure 14
Forest Distribution in 2000

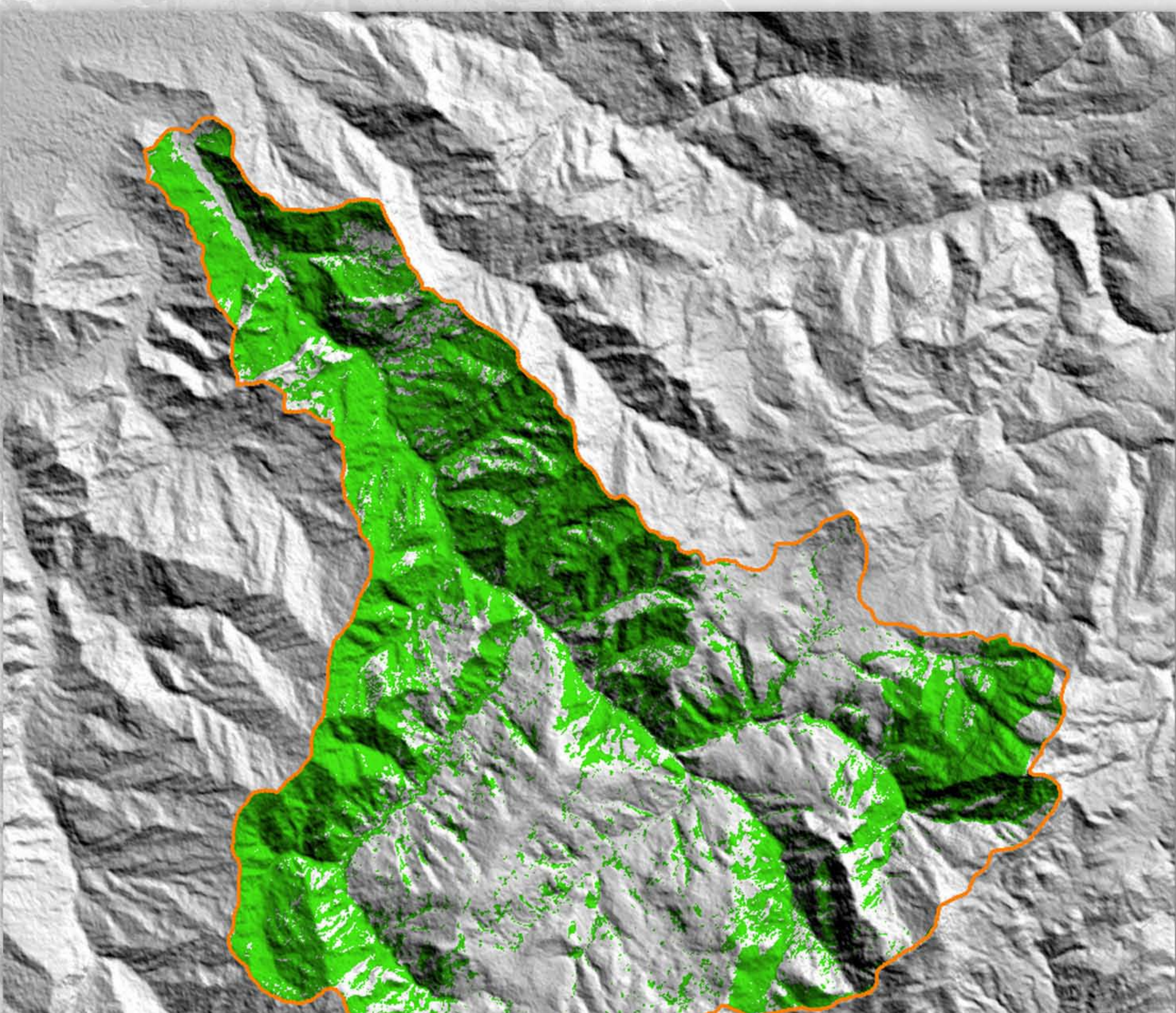


Figure 15
Forest Distribution in 2013

4.4.1.2. Forest Change Detection

The change detection maps of W92 from 1978 to 1988, 1988 to 2000 and 2000 to 2013 are presented by figure 17 to 20.

Table 8: Statistics of change detection for site W92

Site	Period	pixel counts	percentage	area
W92	1977-1988	868	0.518	78.12
	1988-2000	-14042	-8.339	-1263.78
	2000-2013	-10652	-6.901	-958.68
	1977-2013	-23828	-14.224	-2144.52

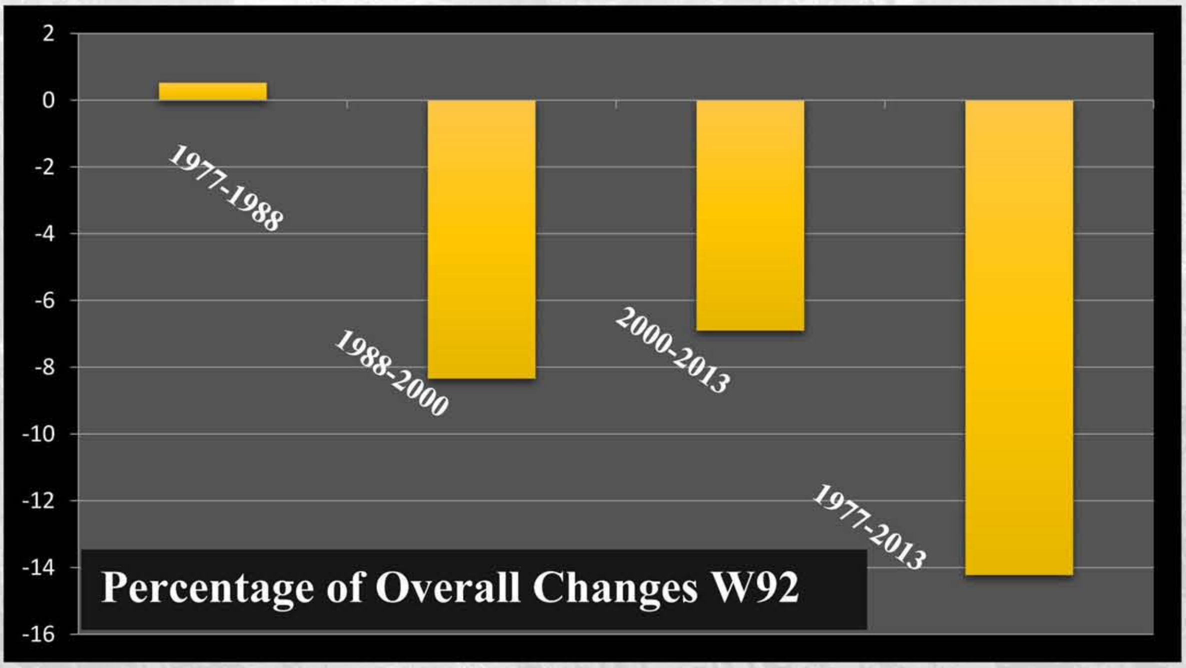


Figure 16
Graph of Overall Changes

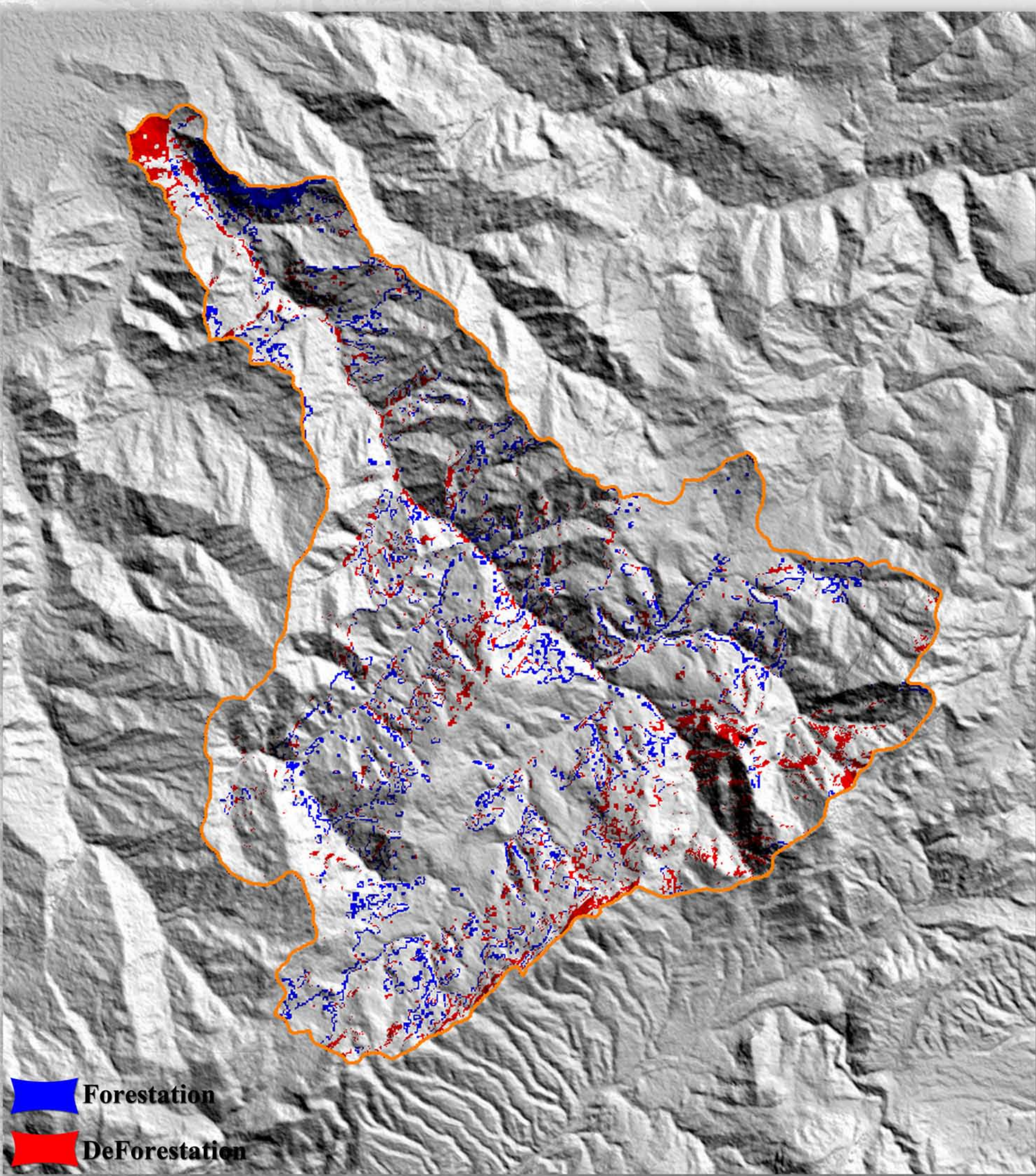


Figure 17

Forest Change Detection from 1978 to 1988

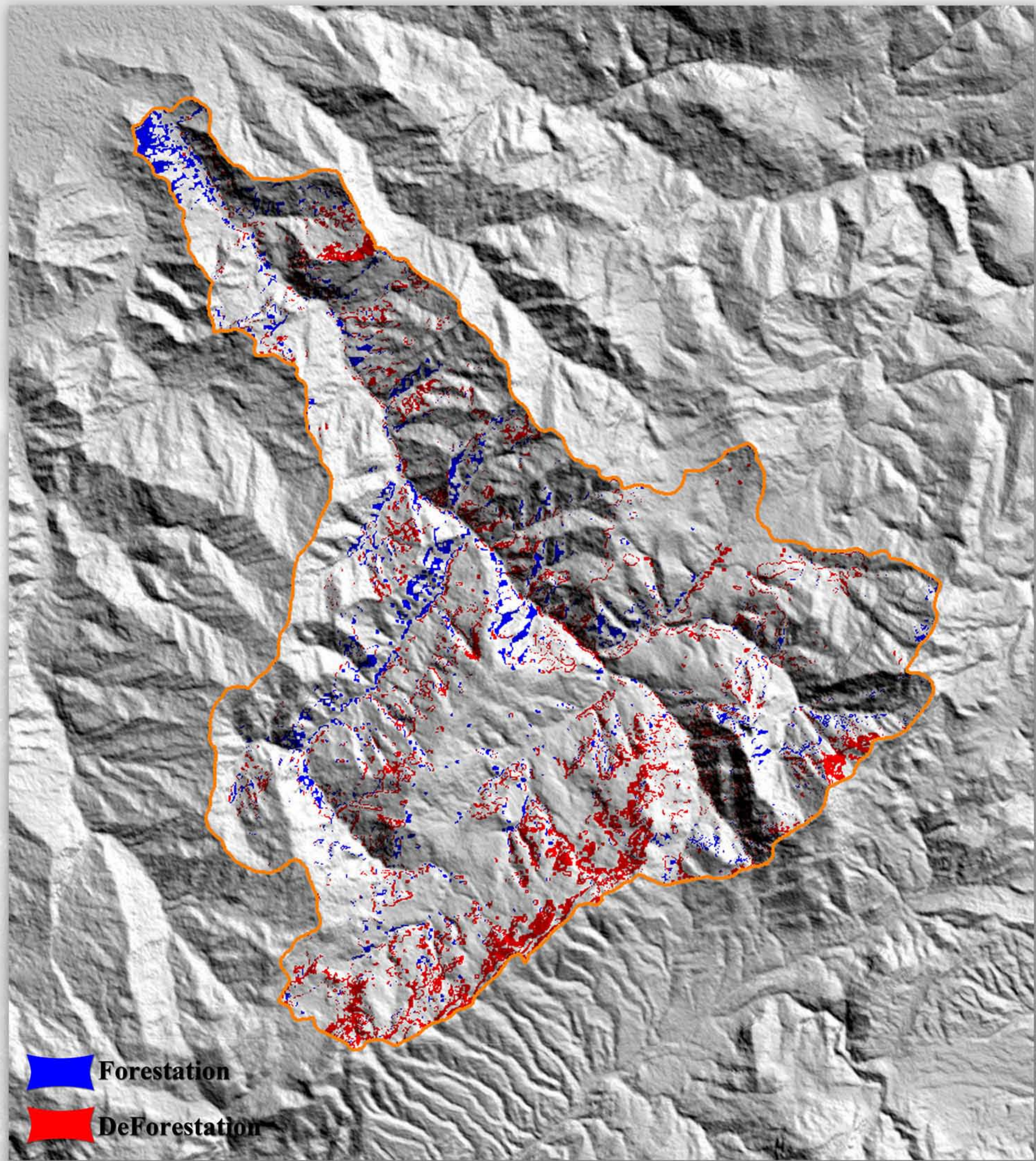


Figure 18

Forest Change Detection from 1988 to 2000

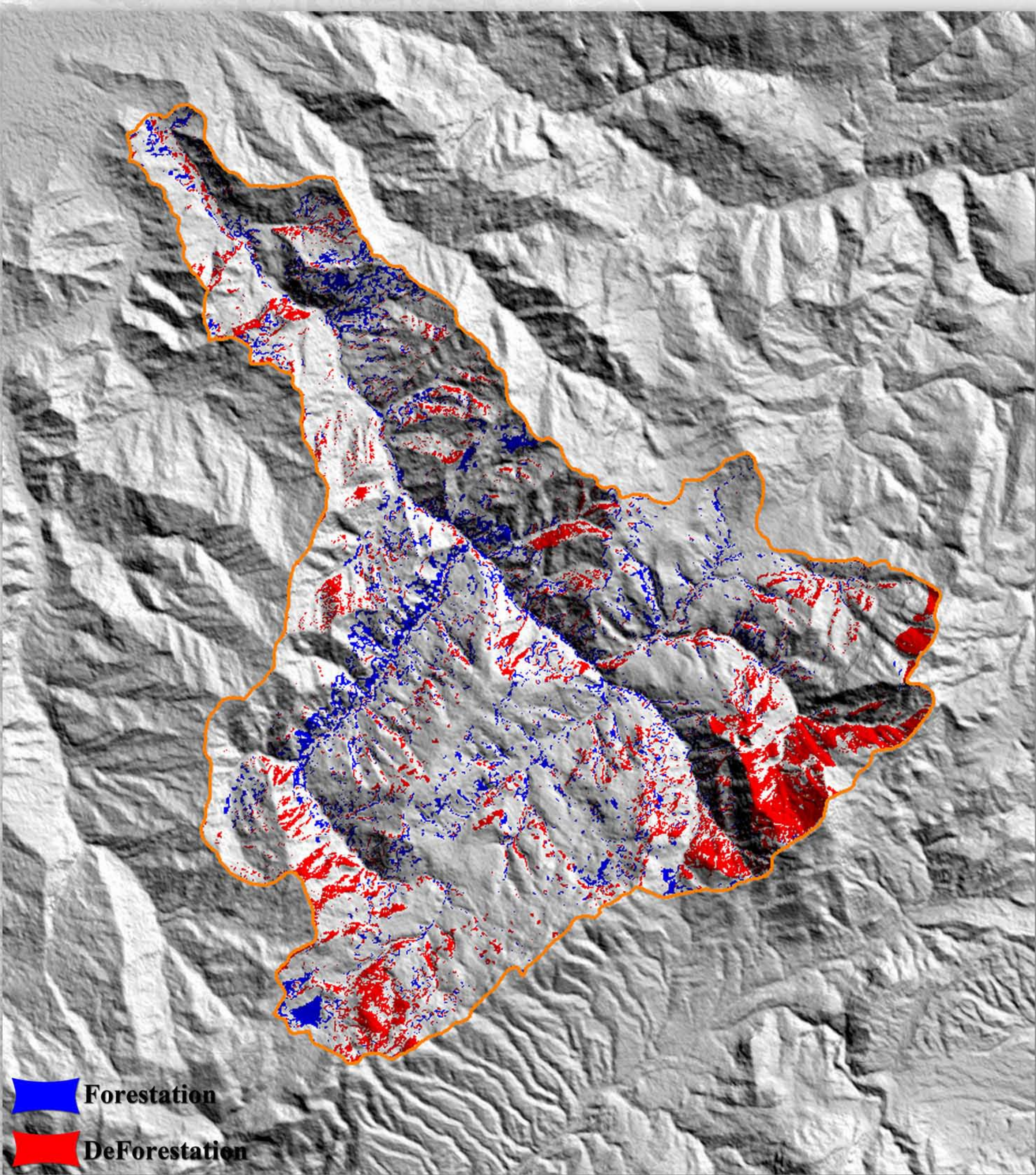


Figure 19

Forest Change Detection from 2000 to 2013

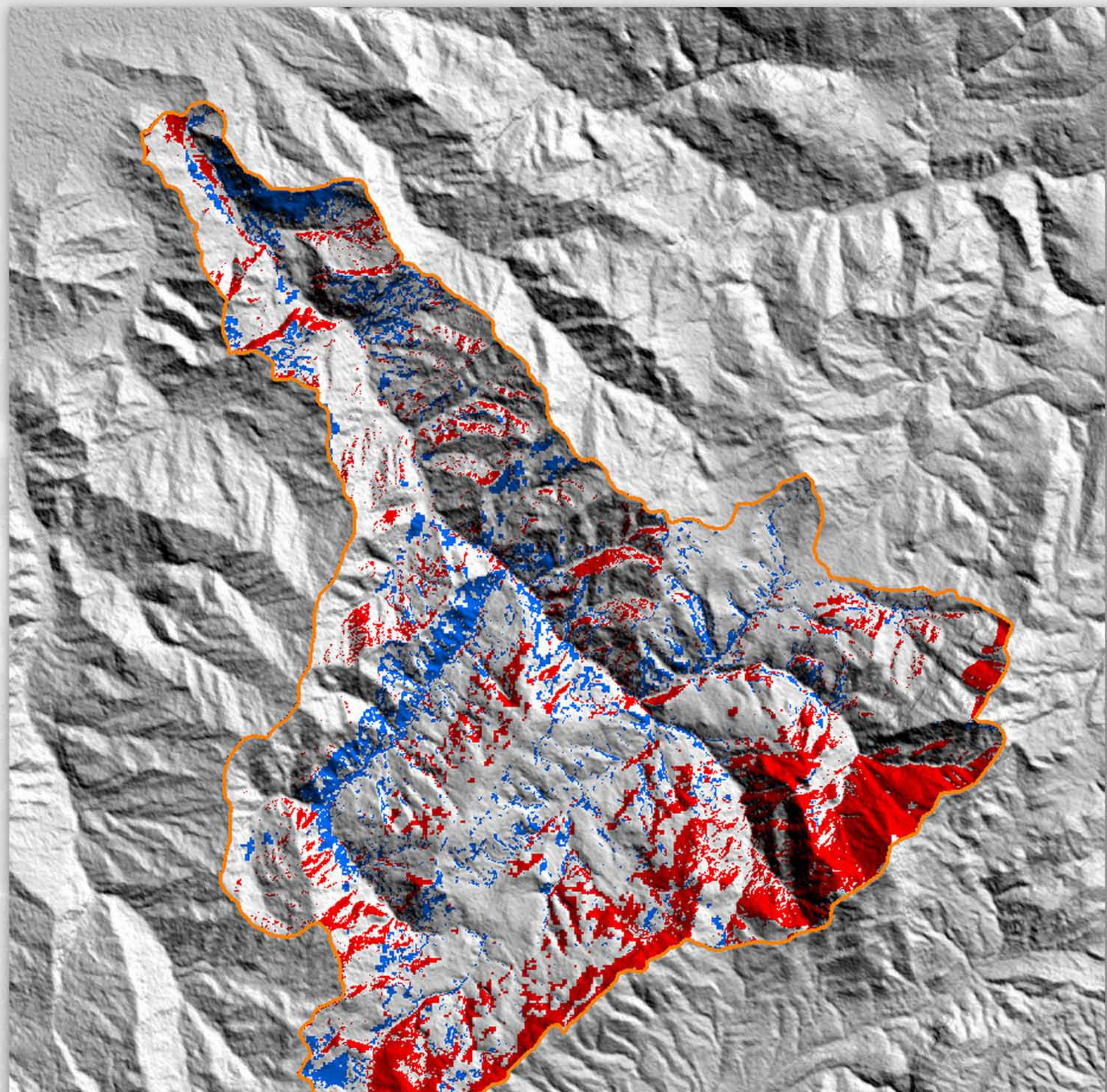


Figure 20

Forest Change Detection from 1977 to 2013

4.4.1.3. Forest Canopy Density

The forest canopy density map of the W92 was produced by FCD model. The classes in percentage are 5-10, 10-25, 25-50, 50-75 and more than 75 percent. Following pictures, diagrams and table present FCD for this site:

Table 9: FCD in different years

W92	1988	2000	2013
5-10	249.47	169.91	333.45
10-25	1794.38	980.35	1,252.26
25-50	5854.94	4827.51	3,357.54
50-75	7021.95	7555.64	7,332.48
75-100	201.77	330.11	657.09

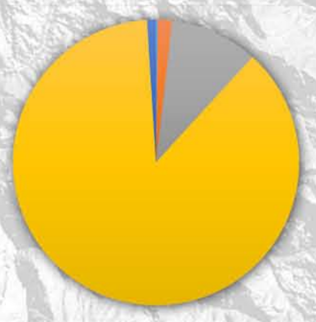


Figure 21: FCD in 1989

Figure 22: FCD in 2000

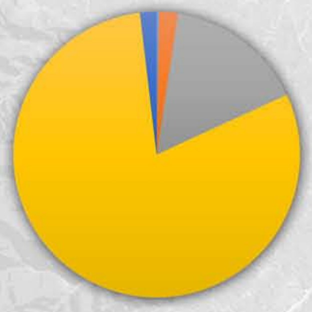


Figure 23: FCD in 2013

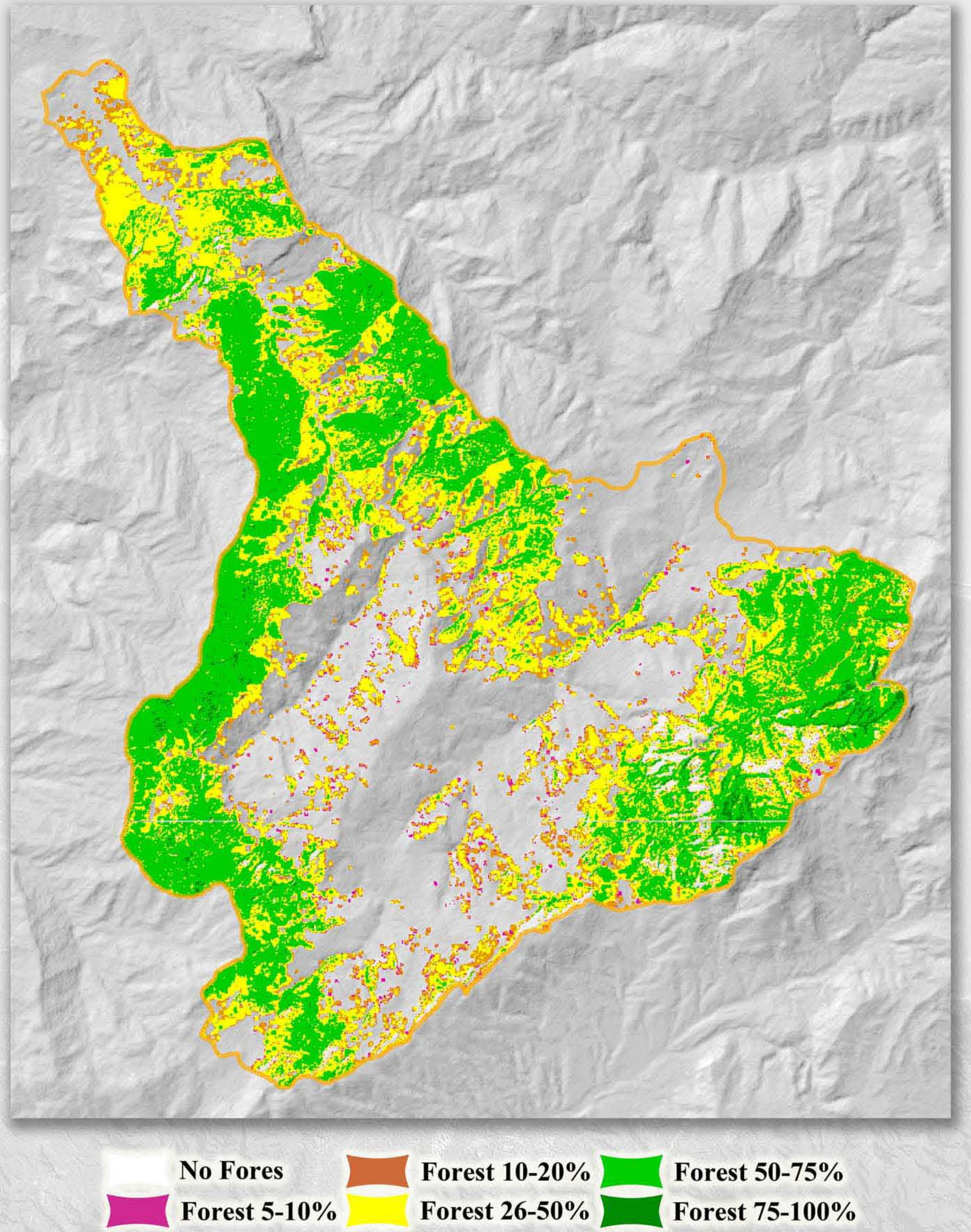


Figure 24

Forest Canopy Density in 1989

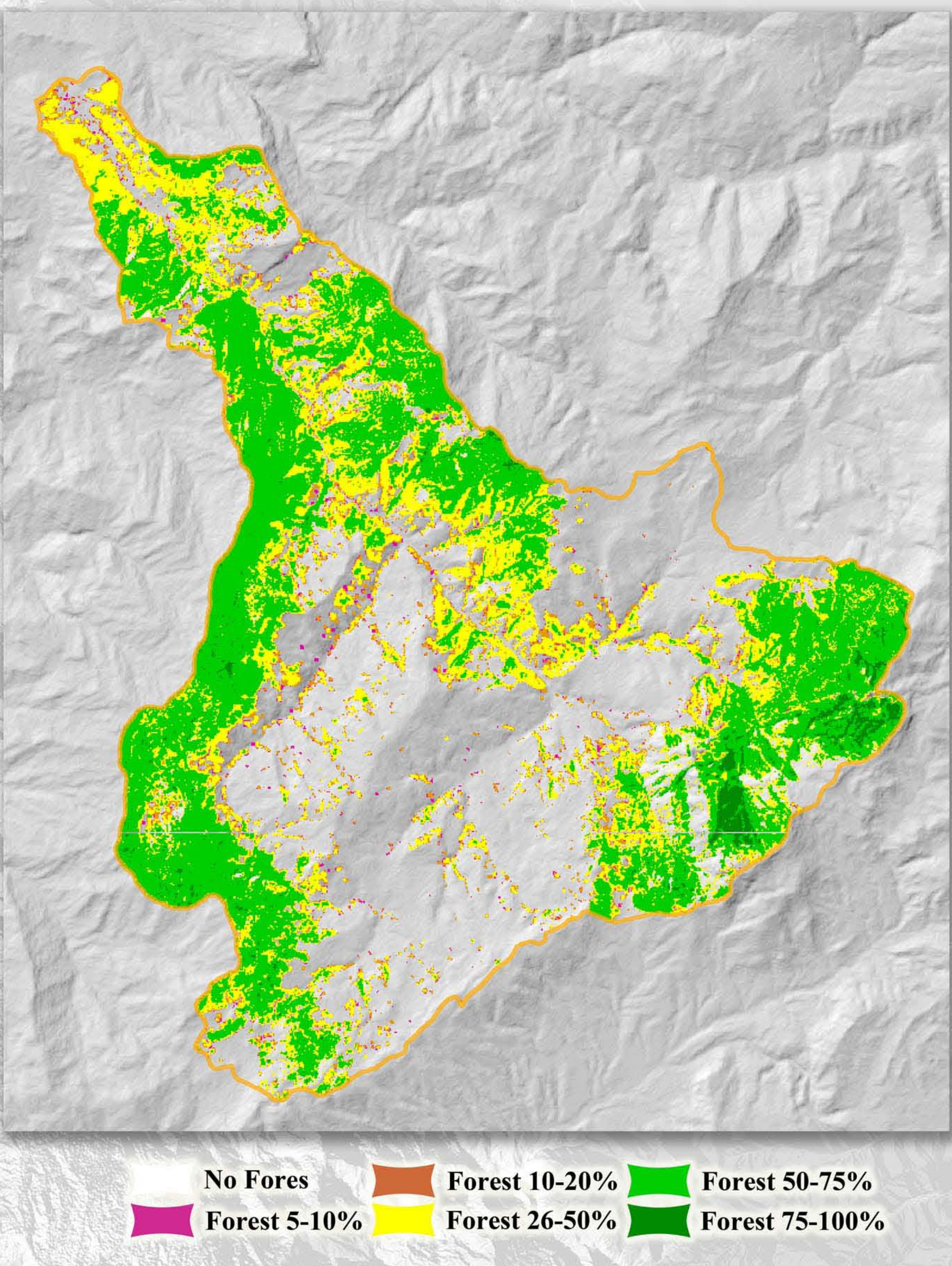
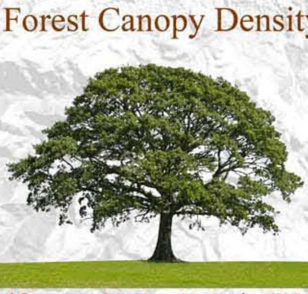


Figure 25

Forest Canopy Density in 2000



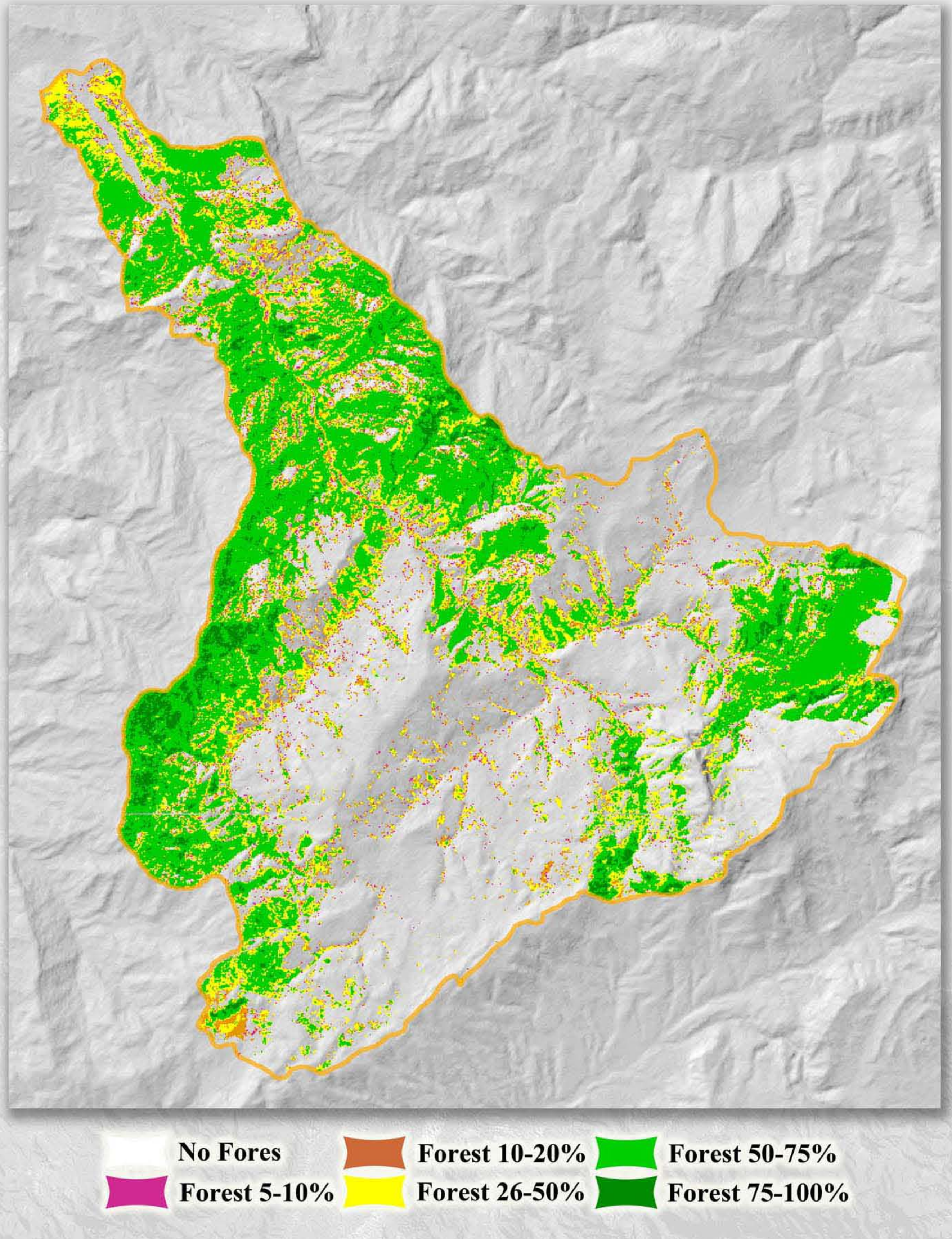


Figure 26

Forest Canopy Density in 2013

4.4.1.4. Forest Density Change Detection

Table 10: Density Class changes from 1989 to 2013

Area in Hectare		1989						
		5-10	10-25	25-50	50-75	75-100	Row Total	Class Total
2013	Unclassified	187.02	885.06	1894.59	1354.32	47.34	4368.33	44353.08
	5-10	6.21	32.67	80.55	67.05	0.54	187.02	333.45
	10-25	12.51	95.58	302.49	321.84	3.51	735.93	1252.26
	25-50	28.35	349.83	1067.58	958.95	21.06	2425.77	3357.54
	50-75	15.66	419.85	2389.77	3689.19	99.18	6613.65	7332.48
	75-100	0.45	14.58	130.59	471.78	30.33	647.73	657.09
	Class Total	250.2	1797.57	5865.57	6863.13	201.96	0	0
	Class Changes	243.99	1701.99	4797.99	3173.94	171.63	0	0

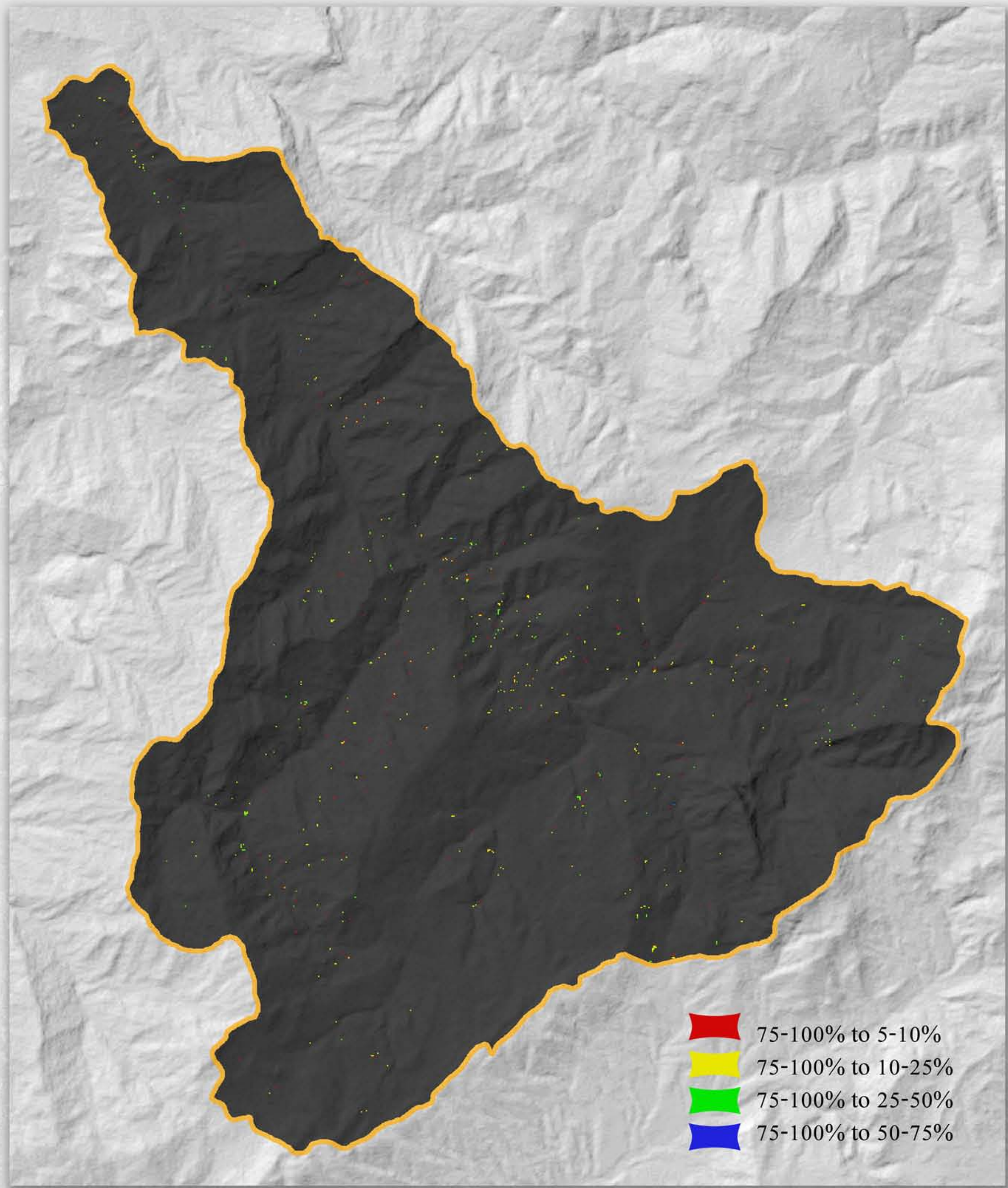


Figure 27

Forest canopy density changes from 5-10% class to other classes (1989 to 2013)

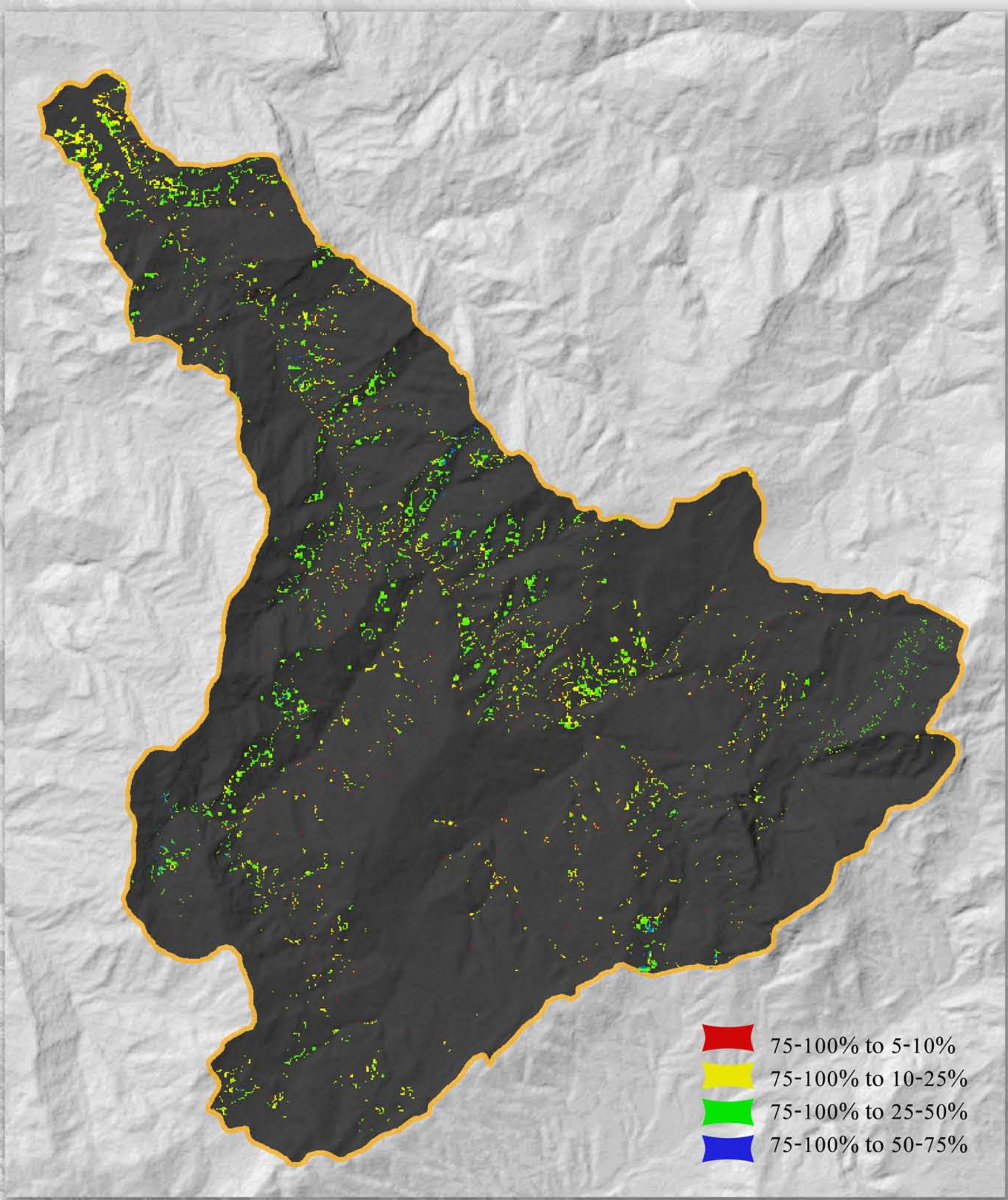


Figure 28

Forest canopy density changes from 10-25% class to other classes (1989 to 2013)

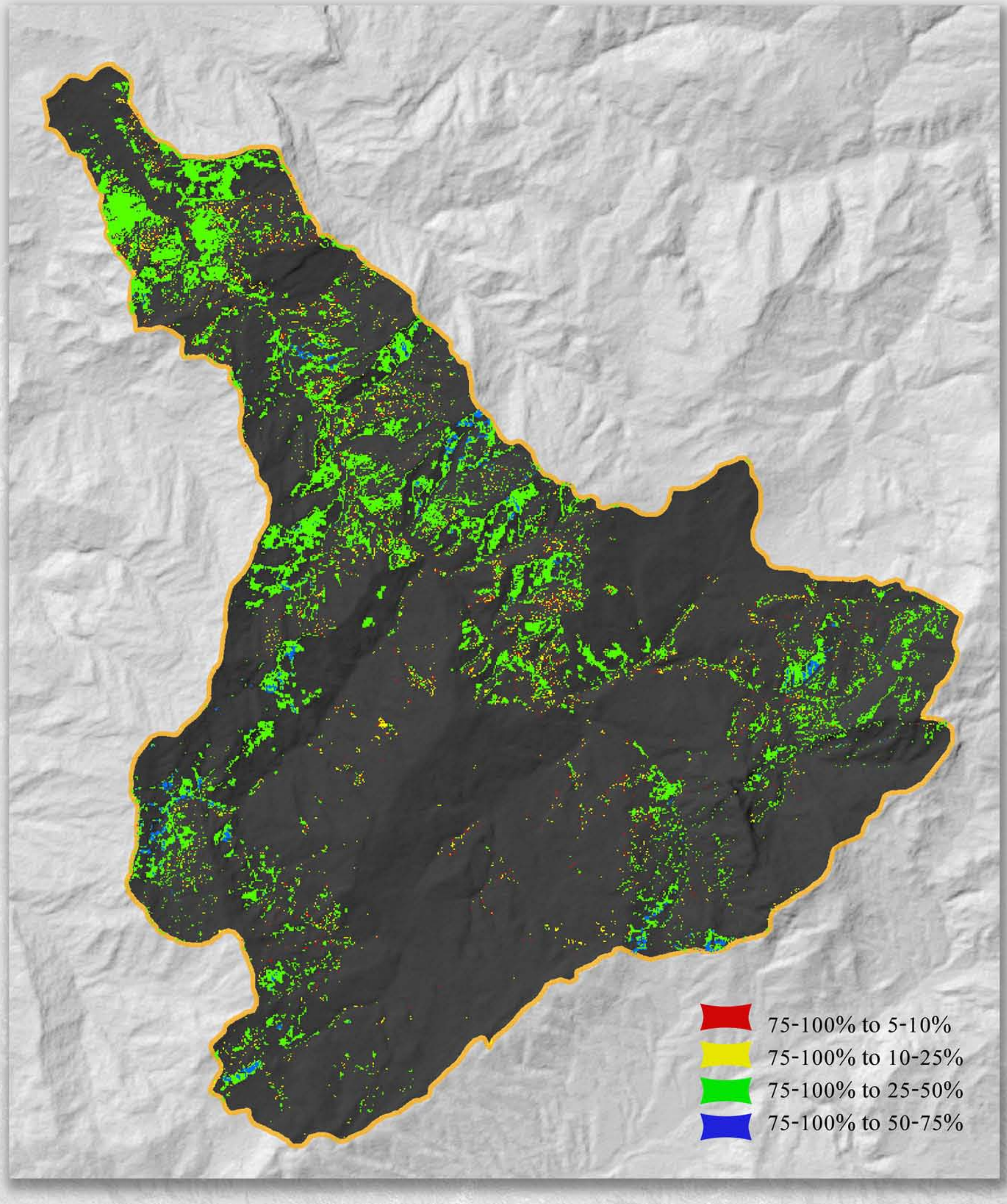


Figure 29

Forest canopy density changes from 25-50% class to other classes (1989 to 2013)

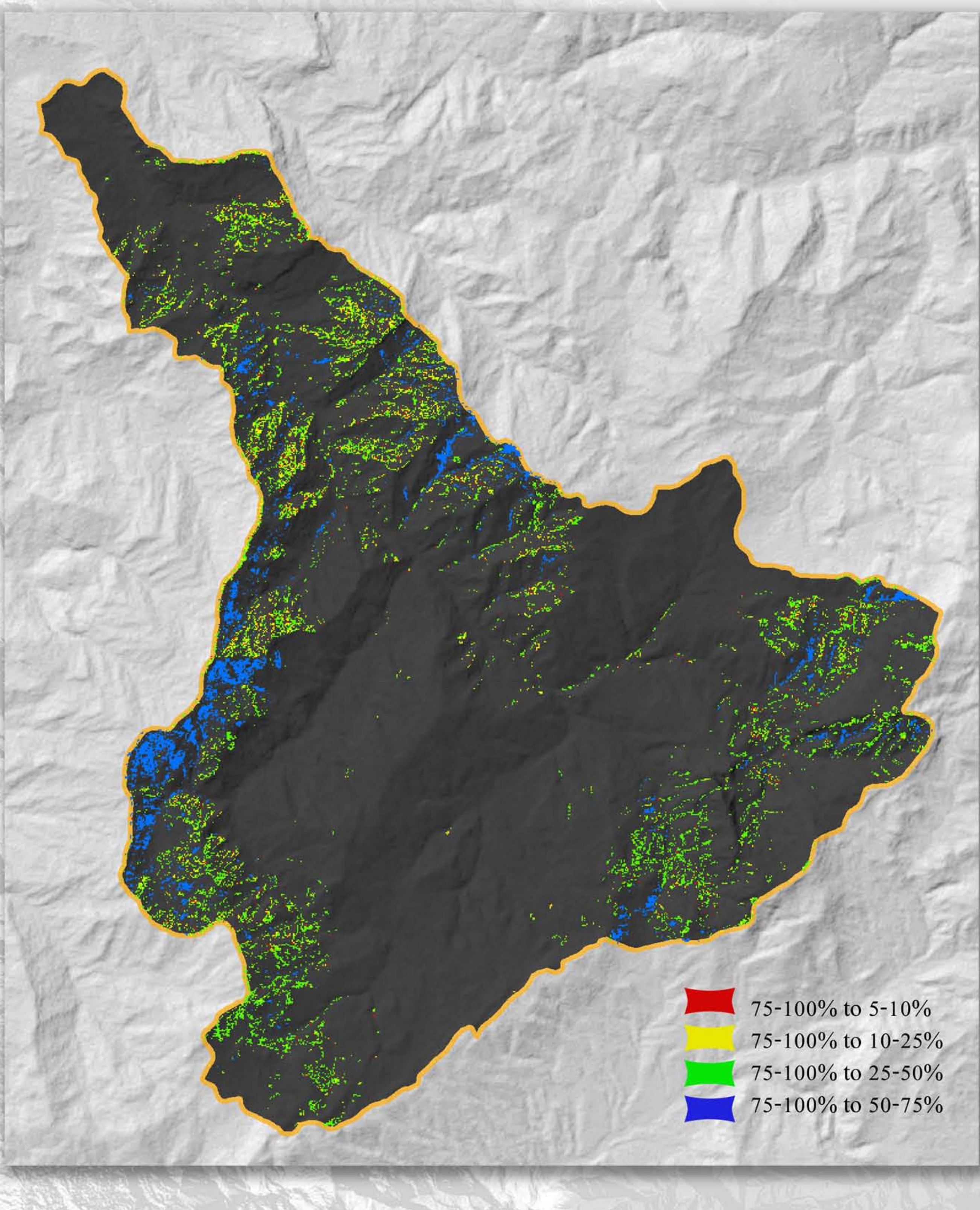


Figure 30

Forest canopy density changes from 50-75% class to other classes (1989 to 2013)

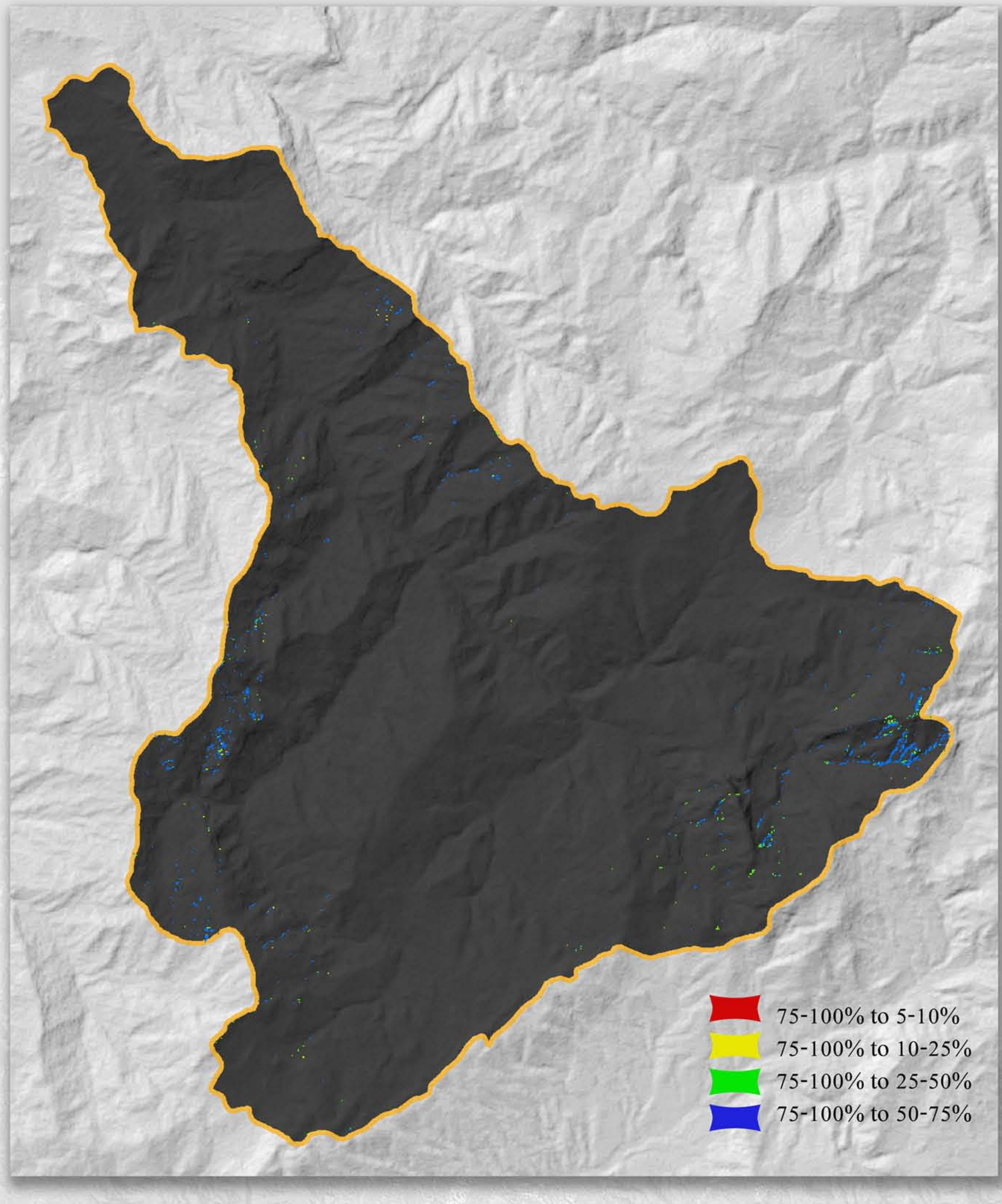
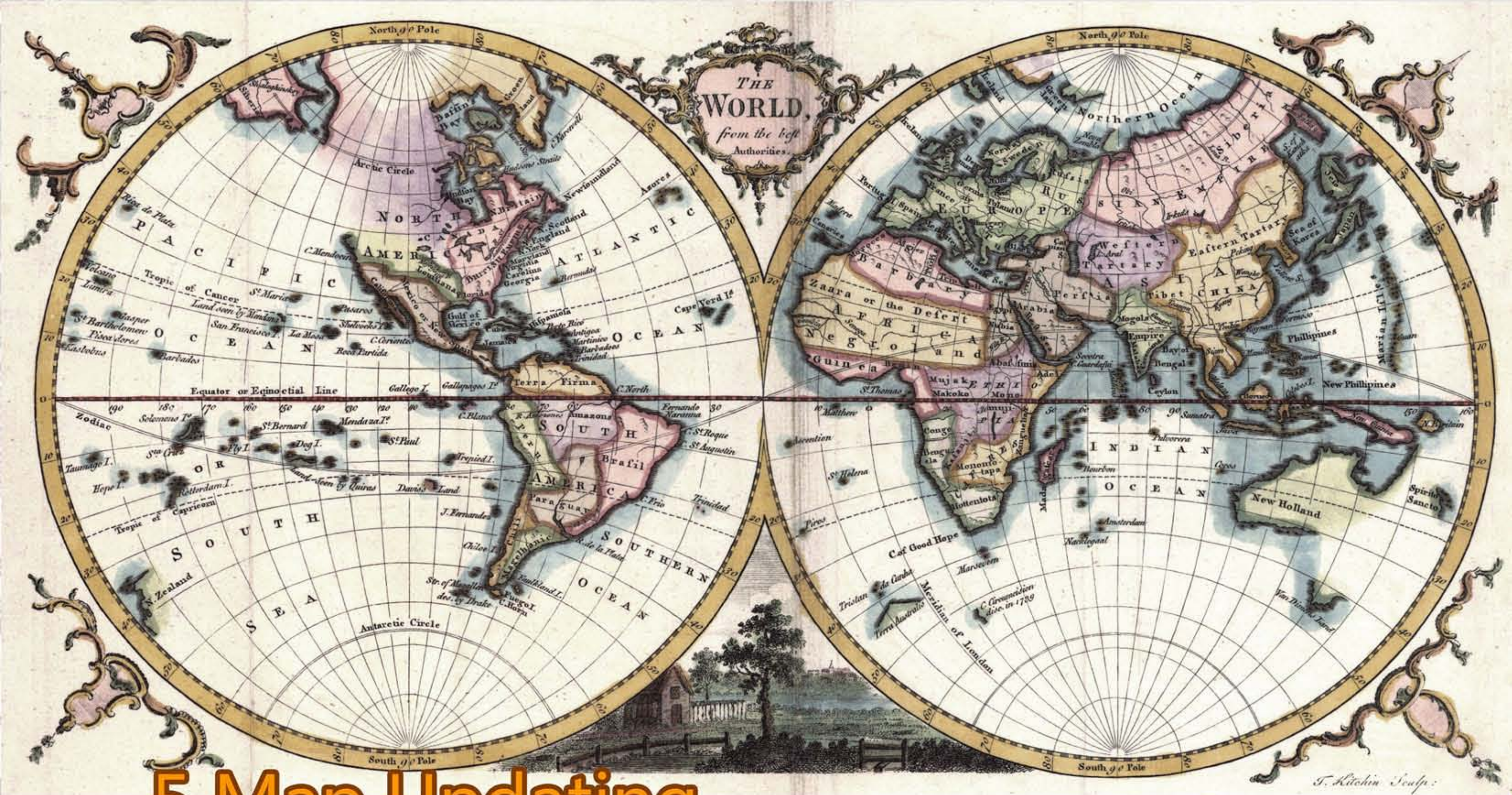


Figure 31

Forest canopy density changes from 75-100% class to other classes (1989 to 2013)



5.Map Updating

After identifying and extracting the layers of interest, the next task is to update base maps. As mentioned satellite imageries are utilized in this step and changes in land cover -caused by changes in landuse or its extent- is recognized and updated. Another issue is the list of layers that must be updated. Generally depending on which site is argued the set of layers is deferent. For example one may include water body layer while another one doesn't; but the layers below are almost common in most of sites:

- Garden
- Shrubbery
- Agriculture
- Building
- Pastureland
- Forest
- River
- Road

5.1. Validation of Raw Data

Since 1:25000 maps provided by Iranian National Cartographic Center are not in appropriate format for GIS analysis, we decided to perform a validation procedure on all maps. In general the main goal of preprocessing and editing of layers for importing to GIS is to control the symbology of layers, topology of objects, removing repeated objects and mosaicking of two adjacent maps.

5.2. Digitizing

First of all a suitable vector data format is needed. ESRI Shapefile was chosen due to its ubiquitous acceptability by geoinformation software and also its functionality to be distributed on web for the potential future tasks. The technique that was used for updating the terrain features is on-screen digitizing. After representing the georeferenced images in software environment desired map layers from base maps are also added to the screen view. There are three major kind of operations in this concept:

- Creating new features that don't exist in the current maps
- Refining current features by means of moving its boundary elements (e.g. vertices), expanding its extent by adding new polygon (or line) next to it or limiting its extent by changing its geometry elements
- Deleting features that don't exist any more

All the process of updating is accomplished under relevant standards. We chose to implement the U.S National Archives and Record Administration (NARA) standard that covers a variety of parameters and to-dos including zooming level, minimum eligible area, cartographic tips and etc.

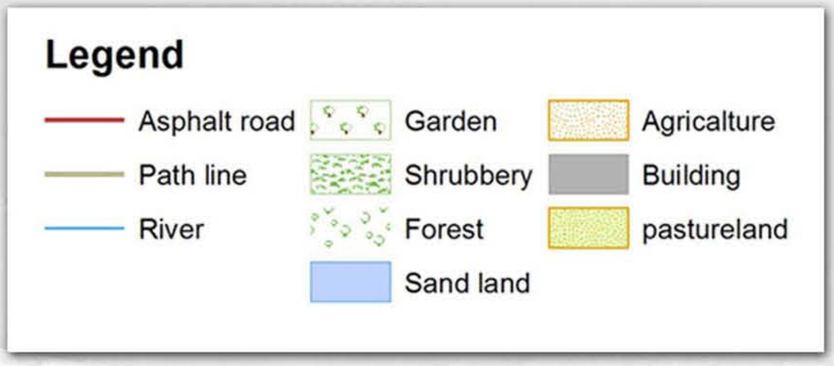
Updating step is thoroughly done in ARCGIS Arcmap software environment duo to its powerful functionality and flexibility. Figure 66 shows the process of creating a new feature (building block):

Figure 32
process of creating a new feature

After updating train features in previous step next is to represent them appropriately. Correcting the topographic defects (eliminating slivers and gaps), projecting layers to suitable coordinate system, choosing symbology and designing map layout and its components are among tasks in this step. All the topographic defects was removed considering priority hierarchies. For example in the context of topographic correction, hierarchy of building layer is higher than agriculture's one. UTM coordinate system was chosen as the projected coordinate system and a grid network was created in the map layout to boost map interpretation.

Other elements of map layout also was added to it. A map legend was added to the layout that illustrates the layers that exist in the map (figure 67).

Figure 33
map legend



Three scale bar also was added to layout configuration which represent the map scale for three length units including kilometer, mile and yard. For the maps on a scale of 1:25000 an index was also put in layout to indicate the position of corresponding area whit respect to adjacent map sheets. Figure 68 indicates the index used in the map:

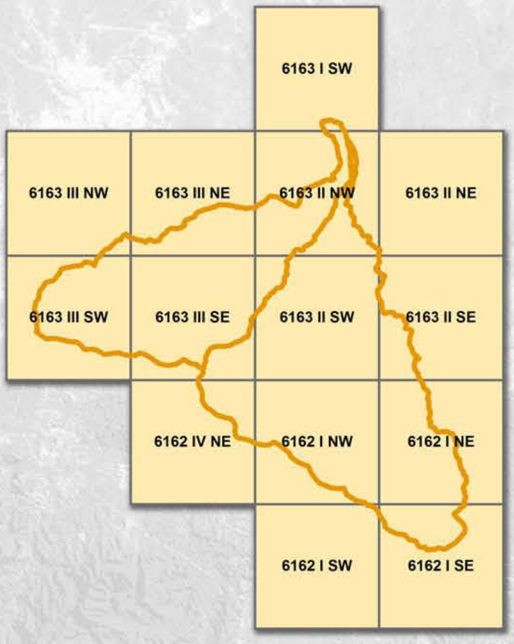


Figure 69 shows the map at scale 1:25000; you can see the configuration of map layout in this figure:

Figure 34
index of 1:25000 base maps

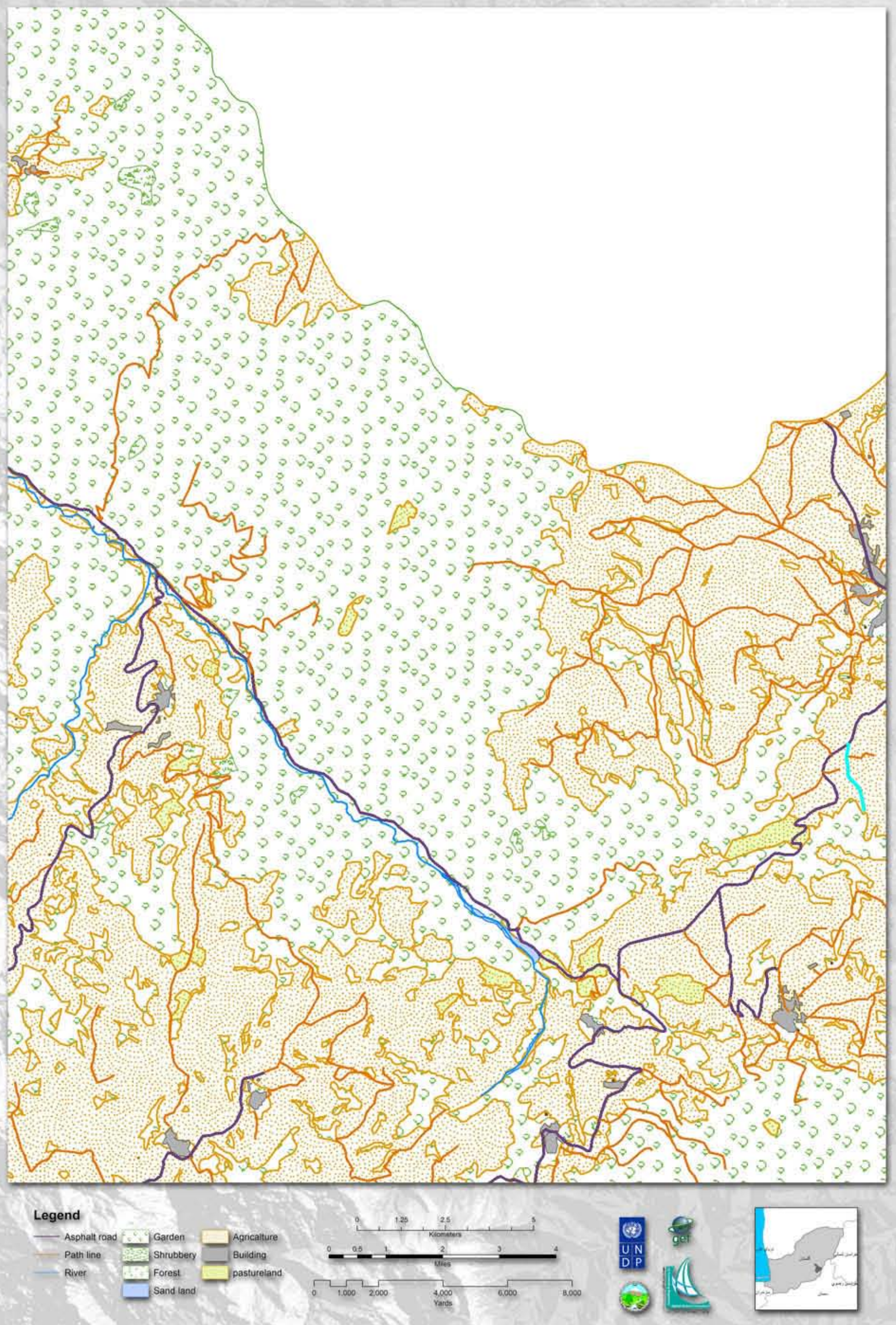


Figure 35
map at scale 1:25000

5.3 Map Updating

Finally based on satellite images and common standards original maps were updated.

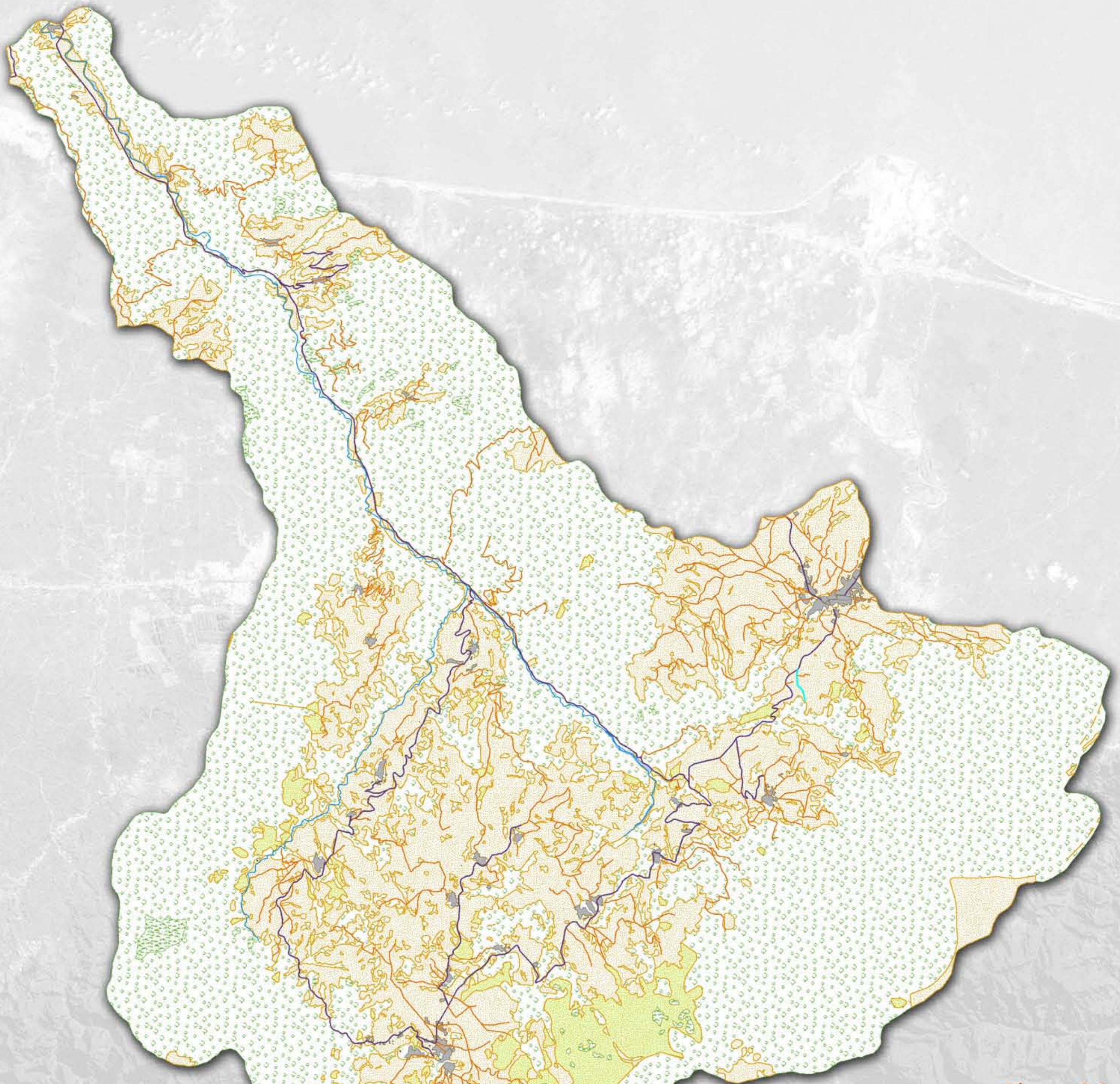


Figure 36

Updated map, W92

5.4. Area of different land-use

As mentioned before, land-use of the sites may differ from one to another. For example there is no fishery area in site W23 and consequently the assigned area to this site in front of the fishery (in the table) is zero. Area of different land-use is presented here:

Land use 1:25.000	Area (Hectares)					
	W22	W23	W33	W34	W53	W92
Forest	16038.47	13135.7	15559	17830.9	20543.7	16340.6
agriculture	266.85	209.1	988.58	348.7	573	7355.6
pastureland	273.5	327.9	11621.35	27975.36	0	1499.8
Shrubbery	22.9	26.26	2224.14	364.12	40.5	364.5
Garden	0	0	292.6	26.45	80.5	128.1
River area (Sand-land)	57.7	51.75	5.2	72.49	24	32.4
Building	42.5	50.2	180.69	66.3	109	140.1
Water body	1.14	7.17	0	0	8.5	0
Dam	7.5	2	0	0	42.35	0
Dam area	11.5	10	0	0	0	0
incult	0	0	0	0	3.5	0
Fishery	0	0	3.36	2.68	0	0
SUM	13820.08	30874.92	30874.92	46687	21425	25861.1

Table 11: area of different land-use

Spatial Sciences Innovators Consulting Engineering Company's Teams

Abbas Goli Jirandeh (A. Goli. J.)

CEO at Spatial Sciences Innovators Consulting Engineering Company
Administrator of SpatialAcademy.com
Spatial Analyst at GoogleSpatial.com

Hadi Alizadeh

RS and GIS
Time Series Analysis
Image Processing

Amir Hossein fadaie tehrani

Environmental Planning & Management
Surveying
GIS Modeling
Spatial Statistics

Roozbeh Foroozandeh

GIS
Spatio-Temporal analysis
Real time control systems
Expert systems and optimization algorithms.

Abdolhamid Dashti Ahangar

RS and GIS
Quantitative remote sensing
Image processing

Najme Sadeghi

Software Engineering
Web-GIS Developer
IT administrator

Padideh Khatibi Damavand

Environmental Impact Assessment
Land Use Planning
Sustainable Development
Environmental Science

Alireza Karbalaei Mirza

Mechanical Engineering – Energy Conversion
Renewable energy

Siavash Sedghi

Software Engineering
Web-GIS Developer

Majid Mohammady

Watershed Management Engineering
Landslide
Land Use Management

Mohsen Rahimipour

Urban design & planning
3D modeling
Web-GIS Developer
Mobile Services

Vahidreza Jalali

Soil Physics
Spatial and Temporal variability
Data Mining
Geo-Statistics

Saeid Varamesh

Forestry
Radiative Forcing
Climate Change

Hosein Lotfi

Meteorology - Agrometeorology
Numerical Weather Prediction Models
Statistical Modeling

Hamid Reza Pourghasemi

Watershed Management Engineering
Landslide susceptibility and Hazard Modeling

Mehdi Aminipour

Spatial Data Analyst
Urban Planning and Management

Nooshin Mohebali

Environmental Impact Assessment
GIS and RS

Address: Unit 10, 4th floor, No.5 , 1st Golestan Alley Sadeqie Sq. Tehran , Iran. Postal Code: 14716-96331.
Phone: +9821 44962614, Fax: +9821 44961613, WebSite: http://SSIec-co.com, Email: Info@SSIec-co.com

According to National Biodiversity Strategy and Action Plan (NBSAP, 2006), until recently, Iran's biodiversity was well protected, both through the formal protection system and through traditional management practices. However, in recent years, population growth, natural resource management practices and sectorial policies have adversely affected biodiversity. The loss of biodiversity was not only through forest conversation and associated loss of habitat but also forest degradation and habitat fragmentation. Thus to overcome these problems a multi-purpose project titled as "Building a Multiple-Use Forest Management Framework to Conserve Biodiversity in the Caspian Hyrcanian Forest Landscape "has been defined and seek three goals: i) to establish a forest management policy and accompanying regulations in support of biodiversity conservation within multiple-use forest landscape; ii) to build the capacities of forests, rangelands and watershed management organization and department of environment and their staff so that they are able to apply and enforce the new policy and regulatory frameworks developed under this project; and iii) to build knowledge among local communities relevant to adjust land uses. The ultimate outcome of all these goals would be conservation of biodiversity in key landscapes within the Caspian Hyrcanian broadleaf deciduous forest ecoregion, which cover an area of approximately 1.8 million hectares. The ecoregion is recognized for its high levels of endemism; it is also an important storehouse of threatened species. The project will work at both the landscape level and the pilot site level. At the pilot level, the project expects to facilitate the upgrading of policy and regulatory frameworks for managing multiple use forest landscapes to ensure that biodiversity conservation mainstreaming measures can be implemented, though management plan and actions across~800,000 ha of forests by the end of the project, and ultimately lead to mainstreaming being adopted more broadly in the whole landscapes of 1.8 million ha as well as seeing lessons learnt being carries over to other forested areas of the country.

To achieve all above mentioned goals, it is important to know how and where the forest cover has been changed during last decades. According to Iranian Forests, Range and Watershed Management Organization (FRWO) the amount of forest cover is decreased by humanitarian or natural reasons in comparison to 40 years ago. Beside of canopy cover, canopy density for its contribution to a more realistic estimation of forest productivity, must be estimated as precise as possible.

Considering the vast distribution of Hyrcanian Forests and also the lack of previous maps and data, traditional approaches like ground surveying would not lead us to an understanding of the past and current situation of forests. Since the launching of the first earth-observation satellite in 1972 (ERTS1), satellite remote sensing has been used for gathering synoptic information on natural resources. For large areas such as Hyrcanian Forests the role of remote sensing is critical. Fortunately, low cost satellite images of LANDSAT, not only provide the required material for current situation of the forest, it also provide historical records appropriate for forest monitoring and change detection. However LANDSAT is not able to provide the required spatial resolution for updating of 1:25000 maps, thus for this project the updating process was done with the help of high resolution satellite images.

Address: Unit 10, 4th floor, No.5 , 1st Golestan Alley Sadeqie Sq. Tehran , Iran.
Postal Code: 14716-96331, Phone: +9821 44962614, Fax: +9821 44961613
WebSite: http://SSIec-co.com
Email: Info@SSIec-co.com