

# Spatial Analysis for the Environmental Mapping of the Šumava National Park

6<sup>th</sup> Annual PGS Conference  
Charles University in Prague,  
Institute for Environmental Studies  
Prague, Czech Republic

Polina Lemenkova

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# Table of Contents

1. Introduction
  - Research Aim
  - Presentation Structure
  - Summary
2. Environment and Geography
  - Geographic Location
  - Geobotanical Settings
  - Vegetation Zones
  - Environmental Settings
  - Environmental Problems
3. Data
  - Data Capture. Raster Layers.
  - Data Quality
  - Data Unpacking and Storage
  - Data Preview
  - Data Read Into GIS Project
  - Data Pre-processing
  - Spectral Bands of Landsat TM
4. Methods
  - Techniques
  - GIS Project
  - Geographic Coordinate System
  - Activating RS Tools in QGIS
  - Generating Contours from DEM
  - Clipping Contours
  - Creating False Color Composite
    - Landsat TM image (1991). Bands 4-3-2
    - Landsat TM image (2009). Bands 4-3-2
  - Raster Mosaicking and Clipping
  - Classification
    - Classification Parameters
    - K-means Clustering
  - Classification Output: 1991
  - Classification Output: 2009
5. Results
  - Maps of 1991 and 2009
6. Discussion
7. Conclusion
8. Literature
9. Thanks
10. Bibliography

## Research Goal

Assessment of natural and human-induced changes in the vegetation of important floristic locations in South-West Bohemia: a GIS analysis

## Significance

Significance: Since 1990 the Šumava National Park (further ŠNP) has been the protected Biospherical Reserve of UNESCO and Natura 2000 protected area: the Bird EU Directive and Habitat EU Directive

## Approaches

1. Literature review of the research area (geography, ecological settings, botanical characteristics, environmental problems etc)
2. Data capture from various sources
3. Technical organizing of GIS project, compatibility of data.
4. Remote sensing data processing and spatial analysis

## Examples

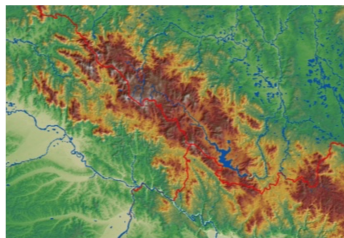
Purpose Current presentation shows these results of the Remote sensing data analysis for pattern recognition of the land cover types in Šumava National Park (time span 1991-2009).

Current presentation consists of 2 parts:

1. Overview of the environmental research problem and biogeographical characteristics of Šumava National Park. Consequences of anthropogenic and climatic impacts on land cover patterns
2. Detailed technical description of the workflow (GIS part): remote sensing data capture, pre-processing, algorithm processing, image classification and spatial analysis.

The presentation is formed by two logical parts.

- ▶ Part 1 (ecological overview of study area)
- ▶ Part 2 (GIS spatial analysis workflow)



## Study Area

Study Area: Šumava National Park, Czech Republic, spatial segment of  $48^{\circ}$ -  $49^{\circ}$ N,  $12^{\circ}$ -  $13^{\circ}$ E

## Study Aim

Study Aim: spatio-temporal analysis of land cover changes in study area during 18 years (1991-2009)

## Examples

Research Objective Research Methodology: application of geoinformatics tools (QGIS), remote sensing data (satellite images Landsat TM) and spatial analysis for environmental analysis

## Characteristics

Special features of ŠNP: topographic location in 3 boarding countries (Czechia, Germany and Austria) and climatic-geographic settings. ŠNP is the largest of the four national parks (68,064 ha).

## Topography

ŠNP spreads from the northeast to the southeast. It is located at the heights between 600 m (Otava River valley at Rejštejn) and 1378 m (top Plechý, the highest mountain of the Czech Bohemian Forest). The highest peak on the Czech side is mountain (1456 m).

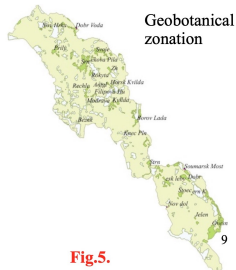
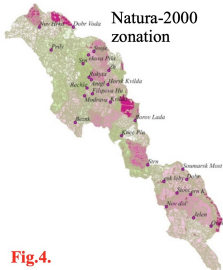
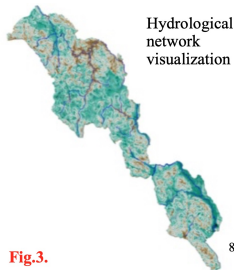
## Geomorphology

Study area covers Šumava plains, uplands Železnorudsko, Boubínská, Želnavskou, the Šumava mountains and Vltava furrow.

## Hydrology

The ŠNP is the principal European division between the North and the Black Sea. It includes most of the drainage area (springs and bogs, rivers, glacial lakes and artificial waters) to the North Sea, the Elbe River Basin with major rivers Vltava and Otava. Climatic settings, wetlands, peatlands and forests affect positively the accumulation of water in the area and their control runoff. The ŠNP is included in the protected areas of natural water accumulation (CHOPAV), designed to prevent the reduction of the water potential, and negative changes in water quality and conditions.

ŠNP belongs to the Bohemian Forest, which is split into two national parks (Czech Republic and Germany). It forms a unique protected forested area in Central Europe and one of the largest forested areas between the Atlantic Ocean and Ural. The habitats of the ŠNP are represented by diverse biotops and host numerous rare and protected flora and fauna species.

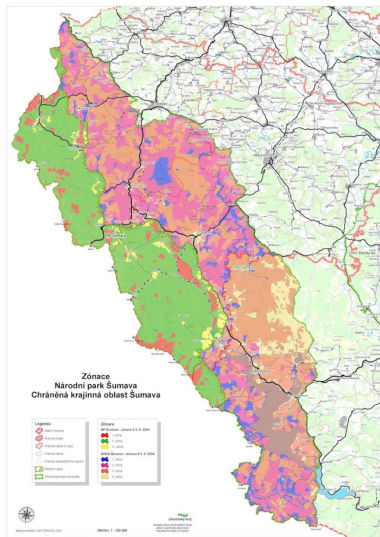


The area is represented by following main vegetation types:

- ▶ vast wooded areas
- ▶ mountain spruce forests
- ▶ fir-beech and spruce fir-beech
- ▶ mixed forests of various ages
- ▶ peat bogs, grasslands, heaths, debris
- ▶ meadows biotops, secondary shrubs
- ▶ moors, lakes, streams, springs, wetlands
- ▶ habitats modified or affected by humans

Altogether, they create a unique mosaic of biotopes, which is a habitat for a variety of rare, endemic and endangered species, e.g. lynx, pearl mussel, owls, diverse songbirds, etc.





## Habitats

Unique mosaic of natural and secondary habitats of exceptional natural value of European-wide significance.

## Biodiversity

High biodiversity value, unique landscape and wilderness attributes of ŠNP. Large area is a significant part of the Natura 2000 network in Czech Republic and Germany.

## Examples

Endemic Species Advantageous conditions for habitation of rare and endemic species. Special regime of the environmental protection => unique biological communities.

## Anthropogenic Pressure

Human activity reached its peak at the end of the 19th and beginning of the 20th century. During that period, the original floodplain forests were fragmented and deforested land was managed mostly as regularly-cut meadows.

## Ecosystem

During last decades some ecosystems components are being gradually, changed, or degrading, or under extinction. For example, the number of populations of rare plant species *Gentianella praecox* subsp. *bohemica*. (endemic to semi-natural grasslands in central Europe) declined rapidly in the last 60 years

## Examples

Endangered Species The extinction of some endangered, rare, unique and important species can be inevitable within several decades without management: even very large populations (1000 flowering individuals) can disappear before 2060.

## Dynamics

The future of nature conservation in the ŠNP caused discussions about zoning of the Park, which has undergone significant changes since establishment.

# Data Capture. Raster Layers.

Global Land Cover Facility  
Earth Science Data Interface

Home Map Search Product Search Path/Name Search Workspace Login Help Contact Us GLCF

TM  
WRS 2, Path 193, Row 036  
1991-08-07  
EarthSat  
Orbita, GeoCover  
Austria, Czech Republic, Germany  
Orbita: 613-884  
Compressed Size: 562 MB; Actual Size: 453 MB

View 1 of 27 below to Preview and Download. Click on the preview above to see a larger browser image.

[ID]	Status	[WRS, P/R]	[Acq. Date]	Dataset	Producer	Attr.	Type	Location
612-883	Online	2: 193/025	1991-07-06	TM	EarthSat	Orbita, GeoCover	GeoTIF	Czech Republic, Germany, Poland
612-884	Online	2: 193/026	1991-08-07	TM	EarthSat	Orbita, GeoCover	GeoTIF	Austria, Czech Republic, Germany
612-885	Online	2: 193/027	1992-08-09	TM	EarthSat	Orbita, GeoCover	GeoTIF	Austria, Germany, Italy
612-886	Online	2: 193/025	1992-08-03	TM	EarthSat	Orbita, GeoCover	GeoTIF	Czech Republic, Germany
617-731	Online	2: 191/025	1992-07-09	TM	USGS	L1G	BSQ	Czech Republic, Germany, Poland
617-732	Online	2: 191/025	1984-07-11	TM	USGS	L1G	BSQ	Czech Republic, Germany, Poland

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TM  
WRS 2, Path 193, Row 036  
2009-08-28  
USGS  
Orbita  
Austria, Czech Republic, Germany  
Orbita: 293-026  
Compressed Size: 197 MB; Actual Size: 489 MB

View 1 of 27 below to Preview and Download. Click on the preview above to see a larger browser image.

[ID]	Status	[WRS, P/R]	[Acq. Date]	Dataset	Producer	Attr.	Type	Location
293-042	Online	2: 191/026	2011-08-22	TM	USGS	Orbita	GeoTIF	Poland
293-044	Online	2: 191/027	2011-08-23	TM	USGS	Orbita	GeoTIF	Austria, Czech Republic, Germany
293-075	Online	2: 192/025	2009-08-24	TM	USGS	Orbita	GeoTIF	Austria, Germany, Slovenia, Czech Republic, Germany, Poland
293-076	Online	2: 192/026	2009-08-24	TM	USGS	Orbita	GeoTIF	Austria, Czech Republic, Germany, Poland
293-077	Online	2: 192/027	2011-08-01	TM	USGS	Orbita	GeoTIF	Austria, Germany, Italy
293-105	Online	2: 193/025	2009-08-31	TM	USGS	Orbita	GeoTIF	Czech Republic, Germany
293-106	Online	2: 193/026	2009-08-31	TM	USGS	Orbita	GeoTIF	Czech Republic, Germany

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Source: GLCF

2 Landsat TM images were downloaded from the GLCF Earth Science Data Interface.

## Spatial Mask

To select target area, a spatial mask of coordinates ranging from 48°00'-49°00'N, 12°00'-13°00'E.

## Examples

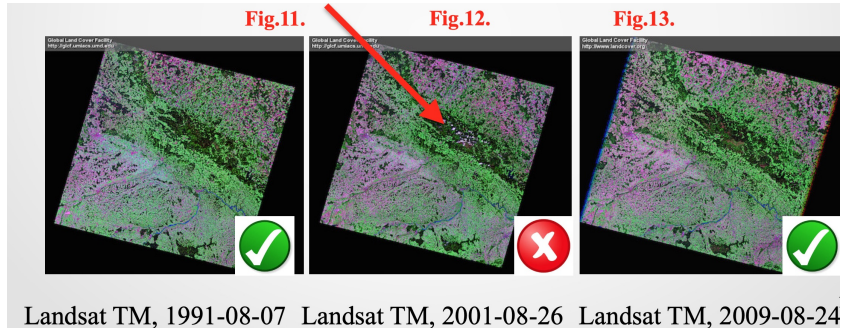
Target Images: Chosen on 1991 and 2009 years: reasonable time span of 18 years, summer period, technical availability of cloudless images.

## Geodetic Background

Data were stored in a GIS project in World Geodetic System WGS 84, ellipsoid Bessels, Křovák's Projection with 2 pseudo-standard parallels (oblique case of Lambert conformal conic projection made in 1922 for Czech Republic).

# Cloud Coverage

The main important issue for remote sensing (RS) data: 'the less clouds the better'. Other point for vegetation classification is 'clouds nature and their location: images with clouds above non-forest (urban) area is Ok, but clouds above forest area make otherwise good image useless.



# Data Unpacking and Storage

**Fig.14.**

**Fig.15.**

The Landsat search parameters were tailored using GLCF website:

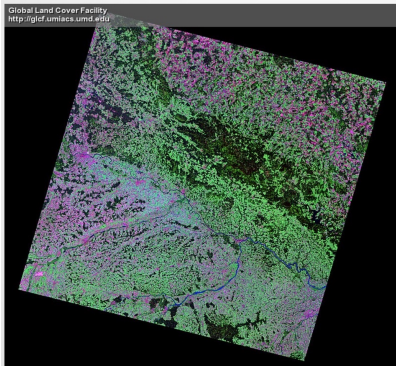
- ▶ Selecting region on a map and entering coordinates
- ▶ Entering place name (Šumava National Park).
- ▶ Selection option 'Landsat 4-5 TM', 'Landsat Orthorectified ETM+' and parameters of cloud-cover% and range of dates
- ▶ Data were downloaded using the provided path
- ▶ Final step includes data unpackage and storage

Индекс «ftp://ftp.glcfl.umd.edu/glcfl/Landsat/WSR52p/02r026p192r26\_5119910807.TM-EarthSat-Orthorectified/»

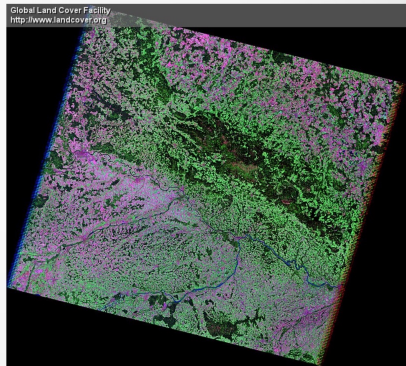
Перейти в каталог на уровень выше

Имя	Размер	Последнее изменение
p192r26_5119910807_742.browse.jpg	514 КБ	6/14/06 12:00:00 AM
p192r26_5119910807_742.preview.jpg	13 КБ	6/14/06 12:00:00 AM
p192r26_5119910807_browse.jpg	463 КБ	6/14/06 12:00:00 AM
p192r26_5119910807_hdr	2 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_net	29 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_preview.jpg	12 КБ	6/14/06 12:00:00 AM
p192r26_5119910807_tar_742.jpg	78 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_tar.jpg	78 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn1.tif.gz	23398 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn2.tif.gz	19474 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn3.tif.gz	22485 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn4.tif.gz	32153 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn5.tif.gz	31495 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn6.tif.gz	18939 КБ	8/13/02 12:00:00 AM
p192r26_5119910807_rn7.tif.gz	25226 КБ	8/13/02 12:00:00 AM

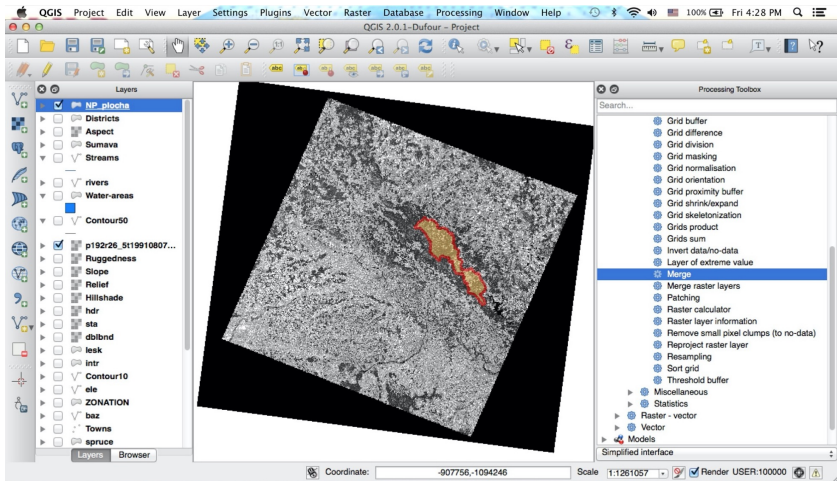
## Landsat TM, 1991-08-07



## Landsat TM, 2009-08-24



# Data Read Into GIS Project

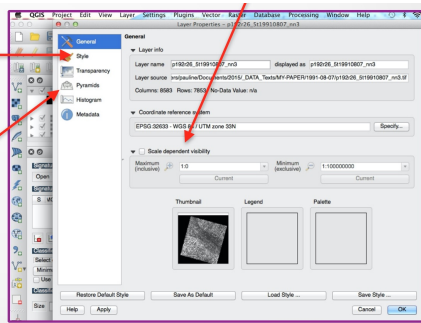


# Data Pre-processing

The GeoTiffs of all Landsat layers were loaded into project one by one as separate raster layers. To apply contrast enhancements, the minimum and maximum display values were set in properties by double clicking the layer name.

These settings were used from the *Symbology* menu in the *Layer Properties* window that appears.

Transparency, raster histogram, zoom pyramids, metadata and other information and settings were adjusted from the *Layer Properties* window (Fig. right).





# Spectral Bands of Landsat TM

Dataset includes: metadata file and Landsat TM spectral bands (16 bit raster) with a spatial resolution of 30 meters:

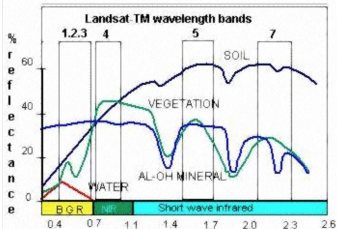


Table Source:  
<http://landsat.usgs.gov/>

Thematic Mapper (TM)	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

- Band 1 = Blue;
- Band 2 = Green;
- Band 3 = Red;
- Band 4 = Near-Infrared;
- Band 5 = SWIR (Short Wavelength Infrared 1);
- Band 6 = Thermal
- Band 7 = SWIR (Short Wavelength Infrared 2).

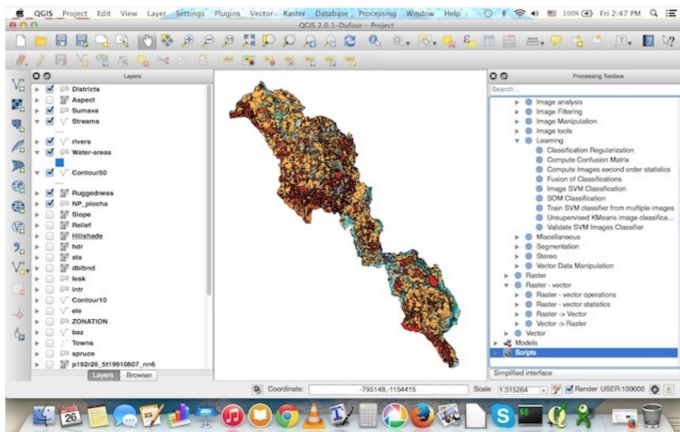
Methods used in the current work include following steps:

1. Data capture, unpacking and storage.
2. Organizing GIS project.
3. Geo-referencing and re-projection.
4. Activating GDAL and GRASS remote sensing plugins.
5. Preliminary data processing.
6. Generating contour layers from DEM
7. Color composition from 3 Landsat TM bands
8. Defining Region of Interest: raster mosaicing and clipping
9. False color composites (bands 4-3-2)
10. Setting up parameters for classification
11. Image classification using K-Means algorithm
12. Pattern recognition
13. Spatial analysis

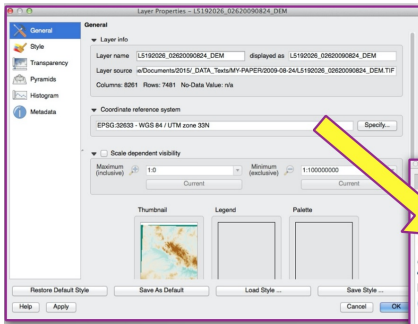
- ▶ The research was performed using Quantum GIS (QGIS) software using Landsat TM images for 1991 and 2009 (18- year time span).
- ▶ The landscapes in study area at both Landsat TM images were classified into different land cover types
- ▶ The area covered by each land cover class is compared and dynamics is analyzed for respecting years.
- ▶ The changes in the selected land cover types were analyzed and the environmental modifications within landscapes detected.
- ▶ Finally, classified land cover types across study area were compared at both maps of land cover types for the years 1991 and 2009, respectively.
- ▶ GIS layers used for the spatial analysis include various vector layers in ArcGIS shape-file (.shp) format.
- ▶ Data content: basic and geographic info: hydrological network, municipalities and cities, roads, borders, relief, geomorphic contours, zone boundaries, NATURA 2000.

## Advantages of QGIS:

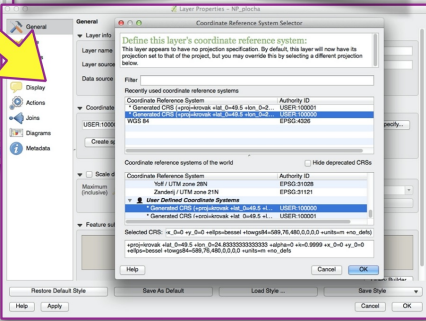
- ▶ Open source
- ▶ Variety of modules and plugins for complex GIS analysis
- ▶ Compatibility and similarity to ArcGIS (data exchange, conversion and GUI)



# Changing Geographic Coordinate System



```
+proj=krovak +lat_0=49.5  
+lon_0=24.83333333333333 +alpha=0  
+k=0.9999 +x_0=0 +y_0=0 +ellps=bessel  
+towgs84=589,76,480,0,0,0,0 +units=m  
+no_defs
```

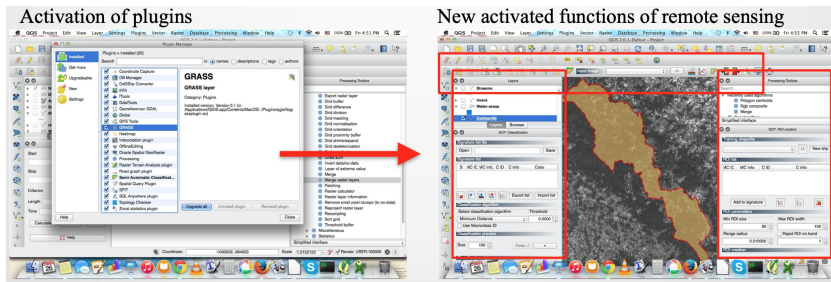


To change projection of Landsat TM sciences I enabled “*on the fly*” projection by clicking on the *CRS Status* button in the *Status Bar* and chose *Enable ‘on the fly’ CRS transformation*

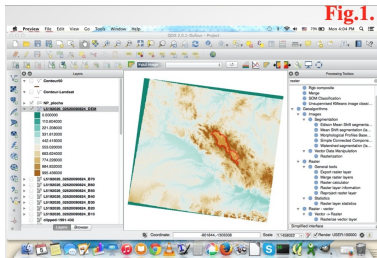
Fig.20.

# Activating RS Tools in QGIS

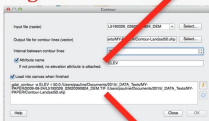
To activated RS functioning, I activated and updated the GDAL and GRASS plugins (figure below) using the 'Manage Plugins' (Plugins menu) and selected all useful ones. GUI changed to active image processing menu.



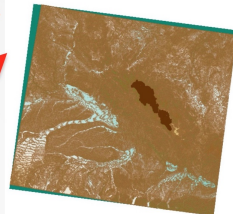
# Generating Contours from DEM



**Fig.2.**

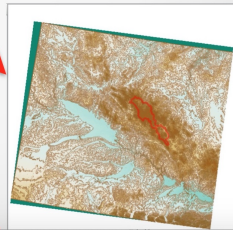


**Fig.3.**



- The relief contours were created from the auxiliary Digital Elevation Model file Landsat TM (*L5192026\_02620090824\_DEM.TIF*): **Fig.1**
- Set up parameters for extraction using activated terrain plugin of *QGIS GdalTools*: **Fig.2**
- Generation of contours (10-meters step) using options *Raster-Extract-Contour*: the resulted layer is shown on **Fig.3** (10-m) and **Fig.4** (50-m)

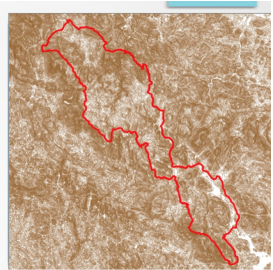
**Fig.4.**



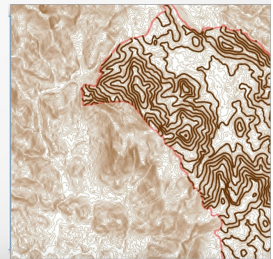
# Clipping Contours

- Next step was clipping the contours using mask of study area and repeating the same procedure for contours with 50 meters step: **Fig.1** and **Fig.2**
- The generated relief is shown on **Fig.3.** and **Fig.4** of current slide

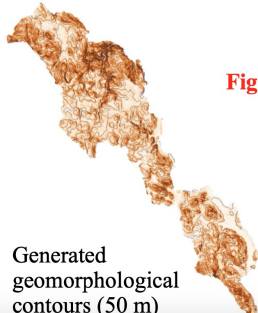
**Fig.1.**



**Fig.2.**



**Fig.3.**



**Fig.4.**



Relief of study area

Generated geomorphological contours (50 m)



# Creating False Color Composite

Color composites from two images were created using combination of bands 4-3-2:

- ▶ band4VNIR(VisibleNearInfraRed)-0.76-0.90 $\mu m$
- ▶ band3red-0.61-0.69 $\mu m$
- ▶ band2green-0.51-0.60 $\mu m$

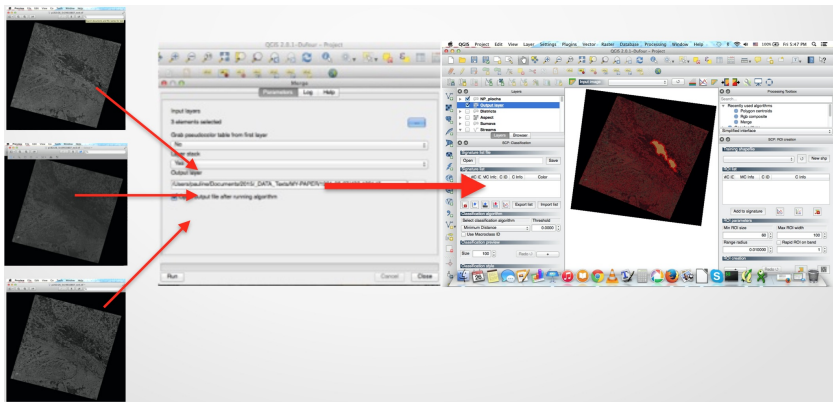
These three bands are usually being merged for 'traditional' false color composite. This combination makes vegetation appear as reddish colors. An RGB 4-3-2 color composite of Landsat TM 7 scene is useful for interpretation of vegetation, as healthy vegetation reflects a large part of the incident light in the near-infrared wavelength. Band 4 gives high reflectance peak from vegetation which enables detection of vegetation types and discrimination land from water.

Colors of land cover types:

- ▶ Blue: water (shallow or with high sediment concentrations)
- ▶ Black to dark blue: deep waters
- ▶ White: soils with no or sparse vegetation (sandy areas)
- ▶ Greens/browns: organic matter content depending on moisture and chemical settings
- ▶ Blue to gray: urban areas
- ▶ Brighter red 'fresh, young' vegetation.

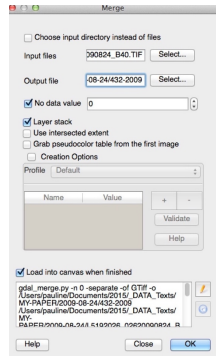
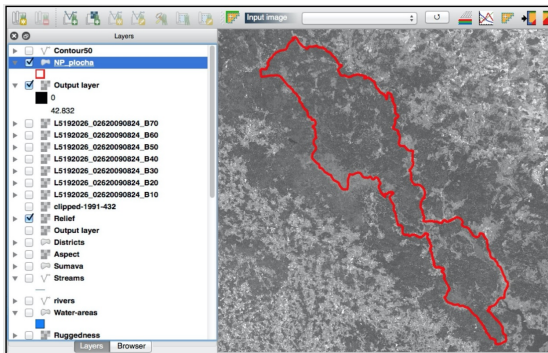
## Landsat TM image (1991). Bands 4-3-2

A color composite images for both data (1991 and 2009) were created using 'Raster/General Tools/ Merge'. The input image layers (Bands 4-3-2) were selected using the Input Files>Select button. An output filename was assigned. The Layer Stack box was activated to create stack of image bands and the process was executed :



# Landsat TM image (2009). Bands 4-3-2

The same procedure was repeated for the second Landsat TM image (2009). Layers were displayed in the RGB composite using Layers workspace. Stretches and other basic image processing functions were applied for better visualization. The Layer Stack box was used to create stack of image bands representing ŠNP area.



# Raster Mosaicking and Clipping

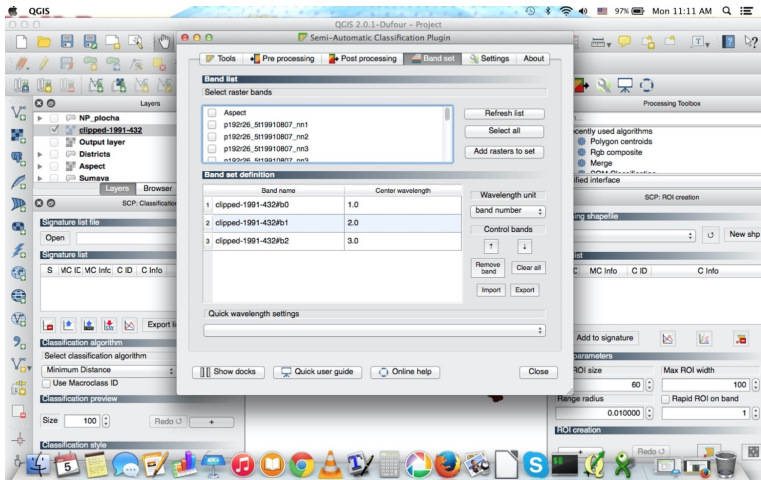
The necessary area was clipped from the the whole Landsat TM scene using mask of vector layer (.shp of ŠNP) by *Raster / Extraction / Clipper* menu

The same procedure was repeated for the second file (Landsat TM image, 2009)

32

# Classification

The Classification of the image has been performed using Semi - Automatic Classification Plugin The Classification Plugin allows supervised classification of Landsat TM images, providing tools to execute the classification process :

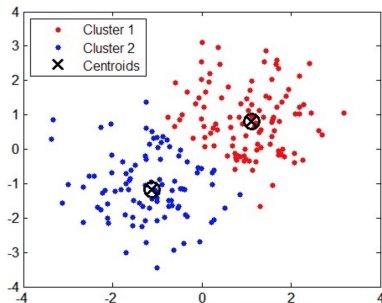
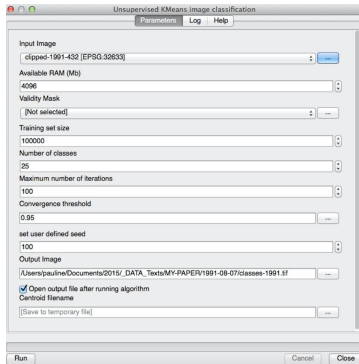


# Classification Parameters

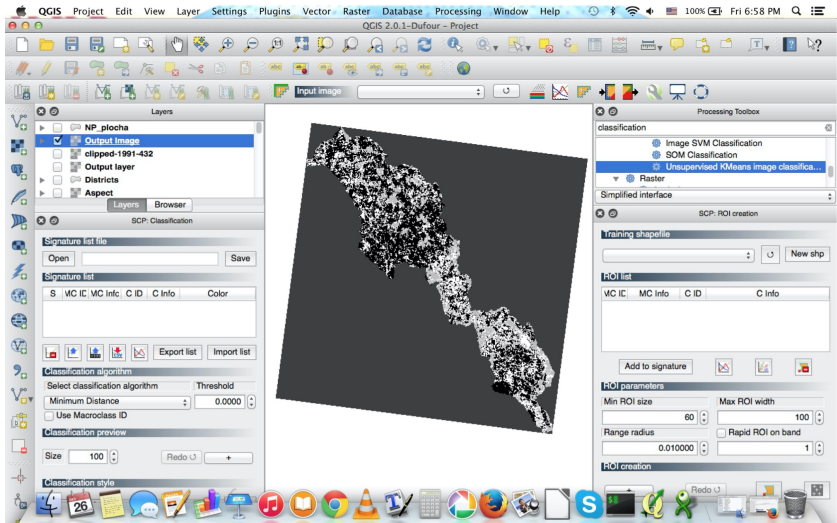
1. Input image: The layer stack of ŠNP resulting from the gdal merge function (done during previous step).
2. Available RAM (computer memory): I've set this very high as the calculation of distance matrices can take much memory on the computer, especially for large sample size of ŠNP
3. Validity mask: Since the area of ŠNP is already clipped I am not using a validity mask. Therefore, this option is skipped
4. Training set size: As the layer stack has a lot of pixels I use a large value here (100.000), to have a good training sample
5. Number of classes: 30, to differentiate vegetation classes better. Afterwards they can be merge (e.g. double classes)
6. Maximum number of iterations: 100. It means, if more than 1-95 is changing the class during one classification step, a new iteration will be repeated
7. Convergence threshold: 95%, as 95% of the training sets will not change classes from one iteration to another
8. Set user defined seed: input image will be divided into 100 lines for better computation

# K-means Clustering

1. *K-means* is a flat clustering algorithm often used as a classification technique
2. *K-means* minimizes average squared Euclidean distance between the cluster centers (the means)
3. *K-means* separates pixels into clusters by defining the mathematical centroids of all pixel groups with similar values of spectral reflectance (digital number, DN's)
4. *K-means* separates raster pixels in  $n$  clusters (groups of equal variance) by minimizing the 'inertia' criterion

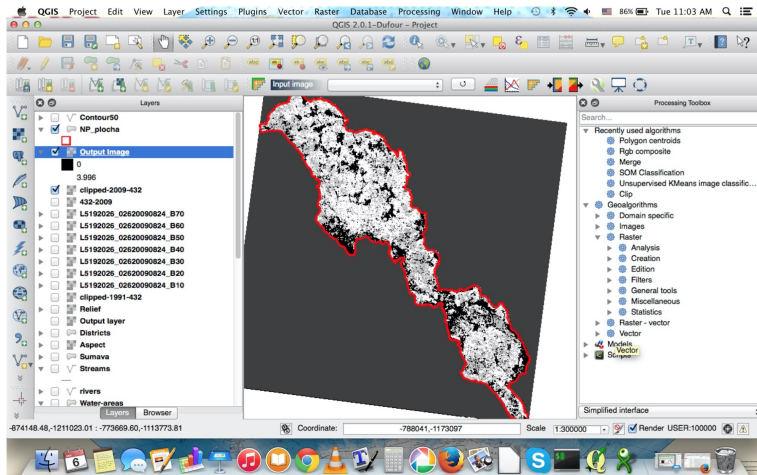


# Classification Output: 1991

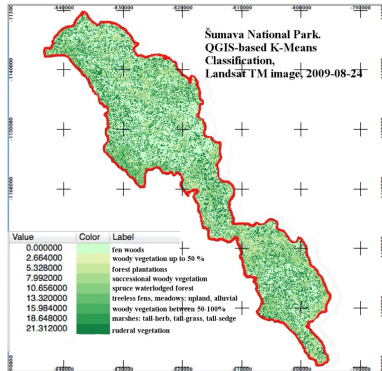
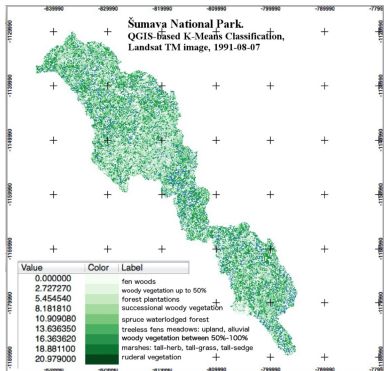




# Classification Output: 2009



# Maps of 1991 and 2009



Research steps included:

1. collecting, organizing and sorting data
2. studying, reading and analyzing relevant literature
3. develop a GIS project and methodology for spatio-temporal analysis of the land cover types and mapping change detection
4. mapping data land cover types for 1991 and 2009

Recommendations for further studies:

- ▶ improving approach (comparison of various methods) discrimination of land cover types in the study area, combining and comparing results from various classifier approaches with data on vegetation and terrain characteristics
- ▶ analyzing misclassification in forest areas to reduce possible spectral confusion
- ▶ assessing and improving accuracy for 1991 and 2009 images
- ▶ environmental analysis of the 'triggers-consequences': degradation of land cover types can be explained by environmental changes and external effects.

# Conclusion

- ▶ Methodologically, current research step highlighted techniques of spatial and temporal RS data analysis and GIS tools for detecting land cover changes
- ▶ GIS and RS data were successfully used for the environmental monitoring since 1970s
- ▶ Combination of remote sensing data and GIS tool for pattern recognition is proved to be effective tool for geo-botanical research
- ▶ Spatial analysis by QGIS enabled using satellite images for geobotanical studies.
- ▶ Spatio-temporal analysis applied to Landsat TM images on 1991 and 2009.
- ▶ Built-in functions of the mathematical algorithms in QGIS enabled to process raster Landsat TM images and to derive information
- ▶ Image processing was used to analyze changes in geobotanical land cover types of the ŠNP area
- ▶ Results proved changes in structure, shape and configuration of landscapes in ŠNP since 1991

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*Thank you for attention !*

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