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Spatial Analysis for Environmental Mapping of Šumava National Park

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Lemenkova Polina

**SPATIAL ANALYSIS
FOR ENVIRONMENTAL MAPPING
OF ŠUMAVA NATIONAL PARK**

Content of Presentation

- Planned PhD work: *Assessment of natural and human-induced changes in the vegetation of important floristic locations in South-West Bohemia: a GIS analysis*
- Results of the 1st year include:
 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
- Current presentation shows these results (1st part of the PhD work, year 1): *“Remote sensing data analysis for pattern recognition of the land cover types in Šumava National Park (time span 1991-2009)”*.

Structure of Presentation

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 **46 slides**, two logical parts.

- Part 1 (ecological overview of study area): **12 slides**,
- Part 2 (GIS spatial analysis workflow): **34 slides**.

Proposed time: 15 min (~3 slides / min)

Summary

Research area: Šumava National Park, Czech Republic, spatial segment of 48°-49° N, 12°-13° E

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

Research objective: application of geoinformatic tools of QGIS, remote sensing data (satellite images Landsat TM) and spatial analysis methodology for ecological study

Part I

**Part I:
Environment and Geography
of the Study Area**

Study Area: Overview

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



Fig.1.

Characteristics: the fundamental features of ŠNP include its topographic location in **3 boarding countries (Czech Republic, Germany and Austria)** and climatic-geographic settings. The study area is **the largest of the four national parks** (68,064 hectares) located in the south-west of Czech Republic, on the border with Germany.

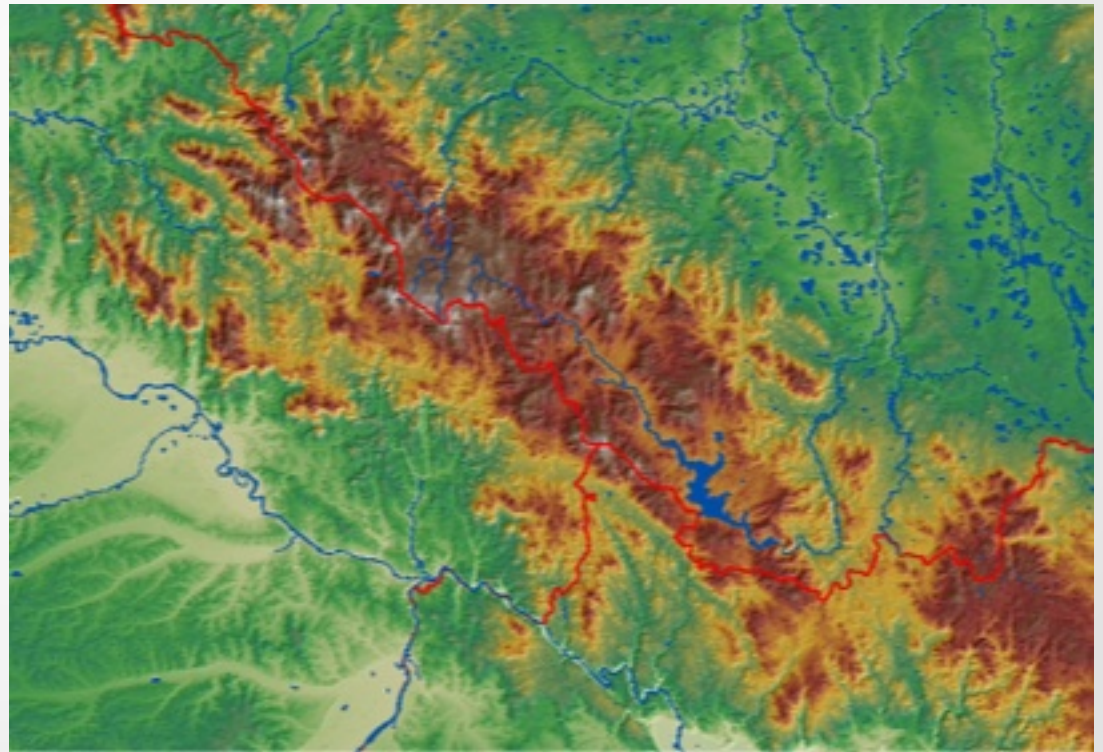
Geographic Location

Topographically, the 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).

Geomorphologically, the study area covers *Šumava* plains, uplands *Železnorudsko*, *Boubínská*, *Želnavskou*, the *Šumava* mountains and *Vltava* furrow (Barešová & Hanusová, 2010).

Fig.2.



Hydrological Settings

The ŠNP is **the principal European division between the *North* and the *Black Sea***. Hydrologically, 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*.

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.

Climatic settings, wetlands, peatlands and forests affect positively the accumulation of water in the area and their control runoff.

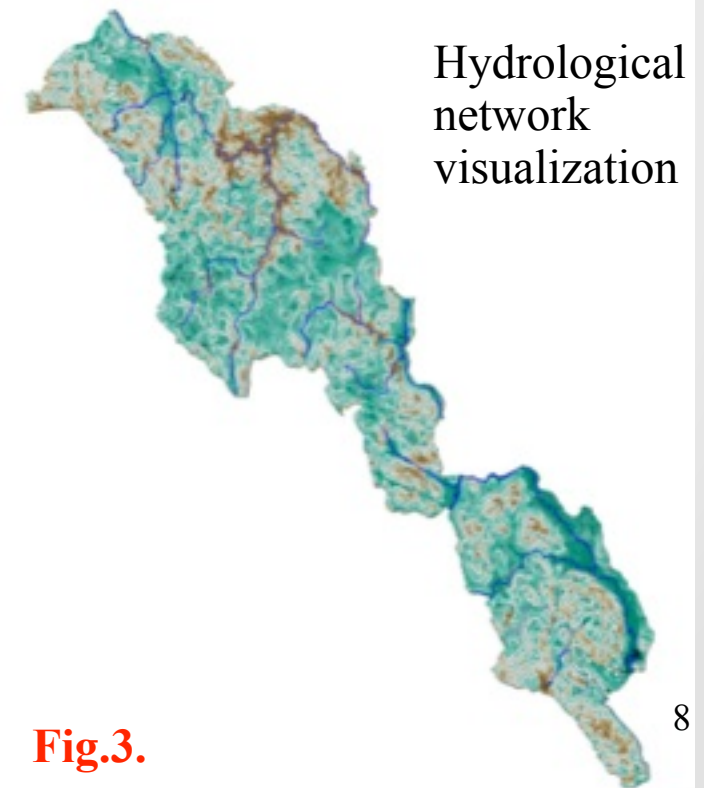


Fig.3.

Geobotanical Settings

Geobotanically, the 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 (*Krenova and Hruska, 2012*).

The habitats of the ŠNP are represented by diverse biotops and host numerous rare and protected flora and fauna species.

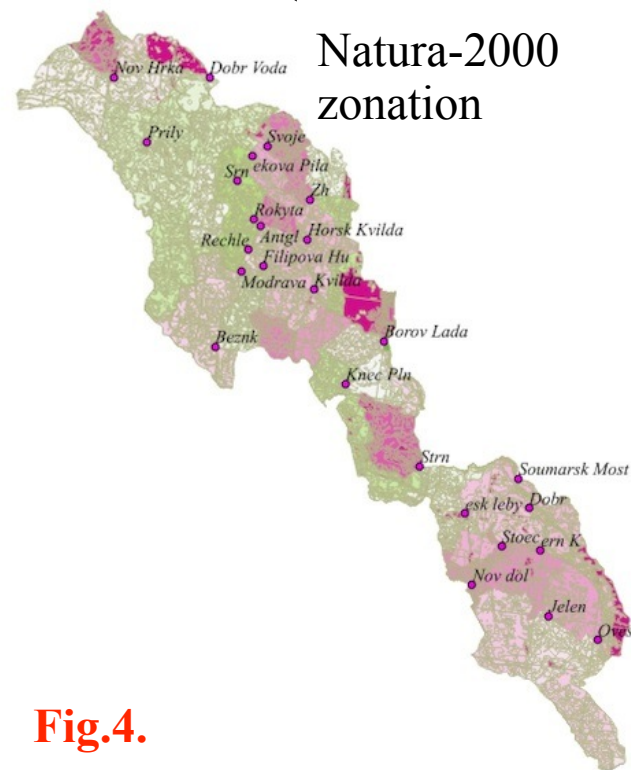


Fig.4.



Fig.5.

Vegetation Zones

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.

Environmental Settings

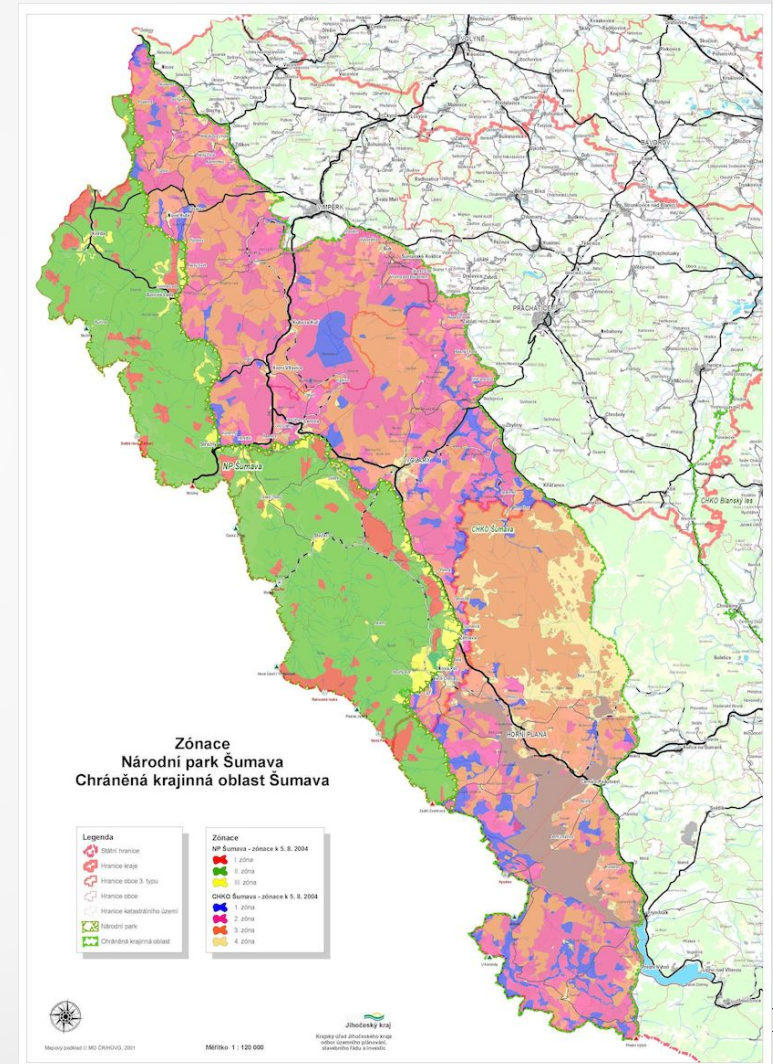
- A unique mosaic of natural and secondary habitats of exceptional natural value of European-wide significance.
- The high biodiversity value and unique landscape and wilderness attributes of ŠNP

The components of the ŠNP represent is the **largest terrestrial significant part of the Natura 2000 network** in both countries: Czech Republic and Germany.

This provided advantageous conditions for habitation here for **rare and endemic species**.

It is established as a **special regime of environmental protection** having **unique biological communities** that are the most precious objects of protection.

Fig.6.



Examples of Environmental Problems

- 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 (Schreiber 1924, Holubicková 1960).
- 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 (Bucharová et al. 2012).
- 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
- The future of nature conservation in the ŠNP caused discussions about zoning of the Park, which has undergone significant changes since establishment (Křenová and Hruška 2012).

Part II

Part II: Remote Sensing Data using Quantum GIS

Methods

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

Techniques

- 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.

Data Content. Vector Layers.

The data used in the current work consist of **2 parts: vector and raster layers.**

Vector layers: GIS layers used for the spatial analysis include various vector layers in ArcGIS shape-file (.shp) format.

Content: basic and geographic info: hydrological network, municipalities and cities, roads, borders, relief, geomorphic contours, zone boundaries, NATURA 2000, etc.

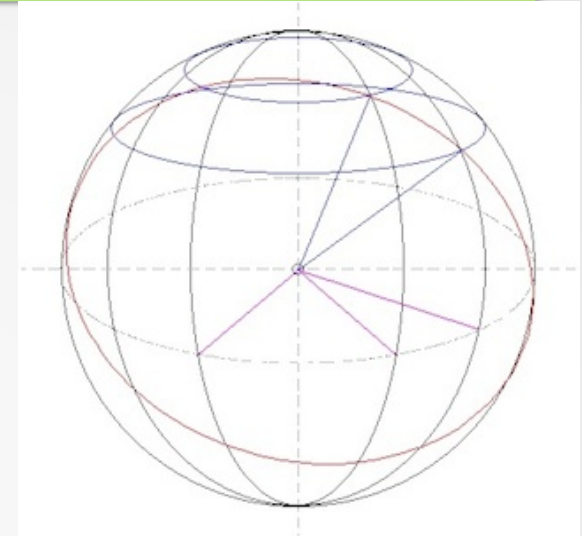


Fig.7.

Geodetic background of vector layers: the data were stored in a GIS Project with the following coordinate system and mathematic projection: *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)

Preview of the GIS Project. Choice of QGIS

Advantages of QGIS software and reasons for choosing it:

- Fully functioning Geographic Information System
- Compatibility and similarity to ArcGIS (data exchange, conversion and GUI)
- It is an open source software available for everyone
- A variety of modules and plugins which enable to do complex GIS analysis

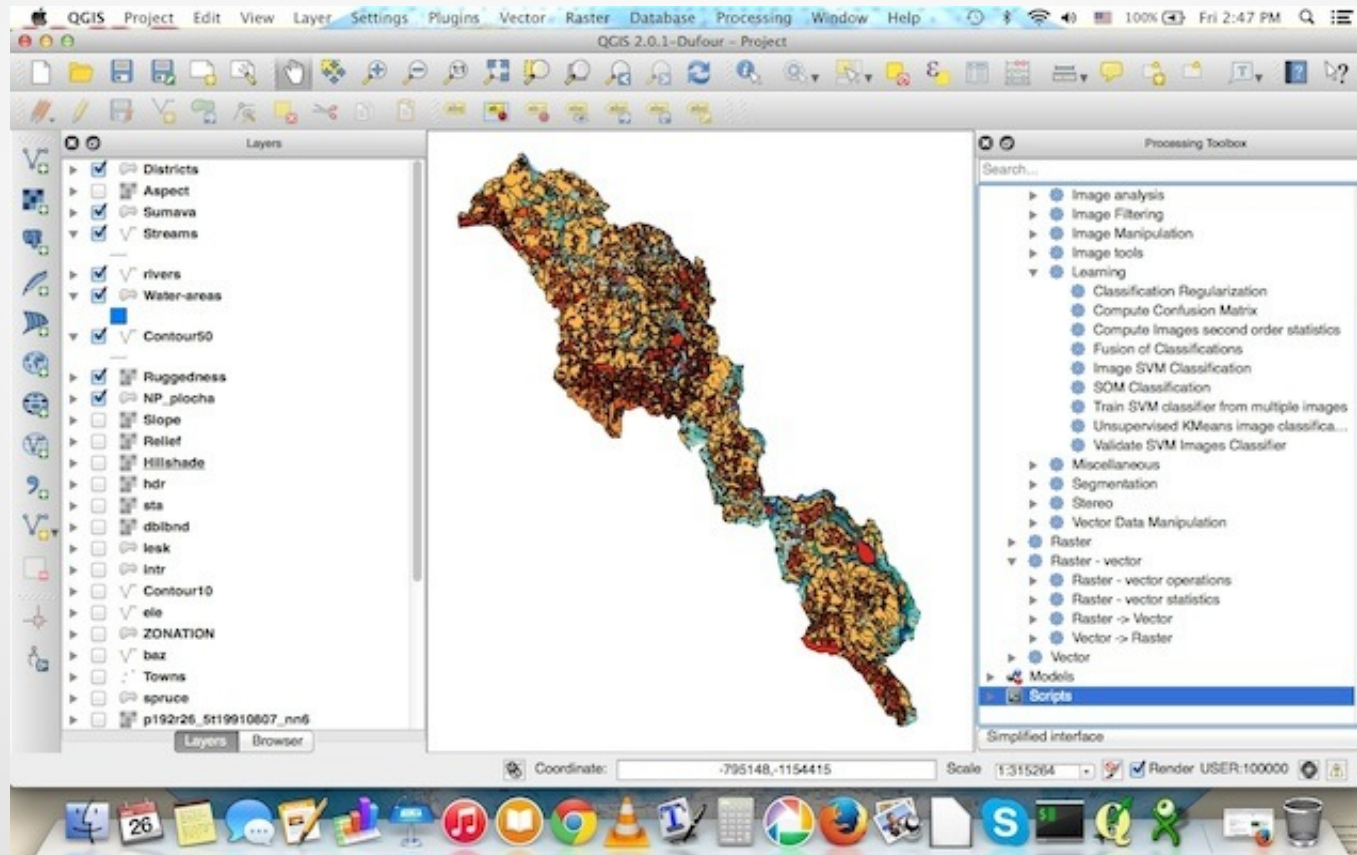


Fig.8.

Data Capture. Raster Layers.

Two Landsat Thematic Mapper (TM) images were downloaded from the Global Land Cover Facility Earth Science Data Interface website (<http://glcfapp.glcf.umd.edu>).

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

The target images were chosen on 1991 and 2009 years due to 3 reasons (reasonable time span of 18 years, summer period, technical availability of cloudless images).

Capture of Landsat TM, 1991

ID	Status	WRS: P/R	Acq. Date	Dataset	Producer	Attr.	Type	Location
012-883	Online	2: 192/025	1991-07-06	TM	EarthSat	Ortho, GeoCover	GeoTIFF	Czech Republic, Germany, Poland
012-884	Online	2: 192/026	1991-08-02	TM	EarthSat	Ortho, GeoCover	GeoTIFF	Austria, Czech Republic, Germany
012-885	Online	2: 192/027	1992-08-09	TM	EarthSat	Ortho, GeoCover	GeoTIFF	Austria, Germany, Italy
012-898	Online	2: 193/025	1990-08-03	TM	EarthSat	Ortho, GeoCover	GeoTIFF	Czech Republic, Germany, Poland
012-751	Online	2: 191/025	1992-07-09	TM	USGS	L1G	BSQ	Czech Republic, Germany, Poland
012-752	Online	2: 191/025	1984-07-11	TM	USGS	L1G	BSQ	Czech Republic, Germany, Poland

Fig.9.

Capture of Landsat TM, 2009

ID	Status	WRS: P/R	Acq. Date	Dataset	Producer	Attr.	Type	Location
293-043	Online	2: 191/026	2011-08-23	TM	USGS	Ortho	GeoTIFF	Poland
293-044	Online	2: 191/027	2011-08-23	TM	USGS	Ortho	GeoTIFF	Austria, Czech Republic, Germany
293-075	Online	2: 192/025	2009-08-24	TM	USGS	Ortho	GeoTIFF	Austria, Germany, Slovenia, Czech Republic, Germany, Poland
293-076	Online	2: 192/026	2009-08-24	TM	USGS	Ortho	GeoTIFF	Austria, Czech Republic, Germany
293-077	Online	2: 192/027	2011-10-01	TM	USGS	Ortho	GeoTIFF	Austria, Germany, Italy
293-105	Online	2: 193/025	2009-08-31	TM	USGS	Ortho	GeoTIFF	Czech Republic, Germany, Poland
293-106	Online	2: 193/026	2009-08-31	TM	USGS	Ortho	GeoTIFF	Czech Republic, Germany

Fig.10.

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.

Fig.11.

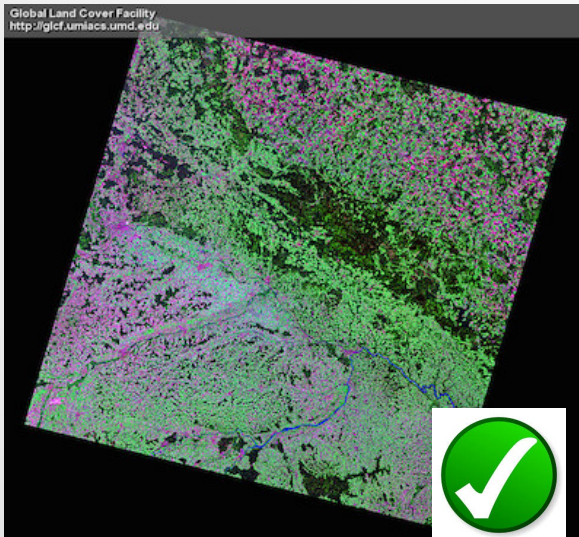


Fig.12.

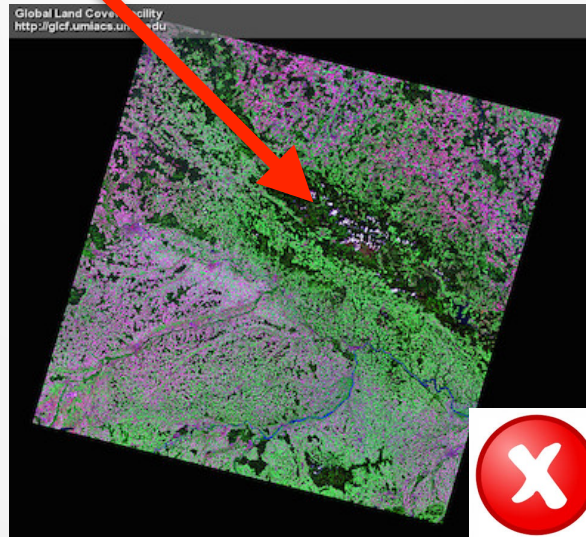
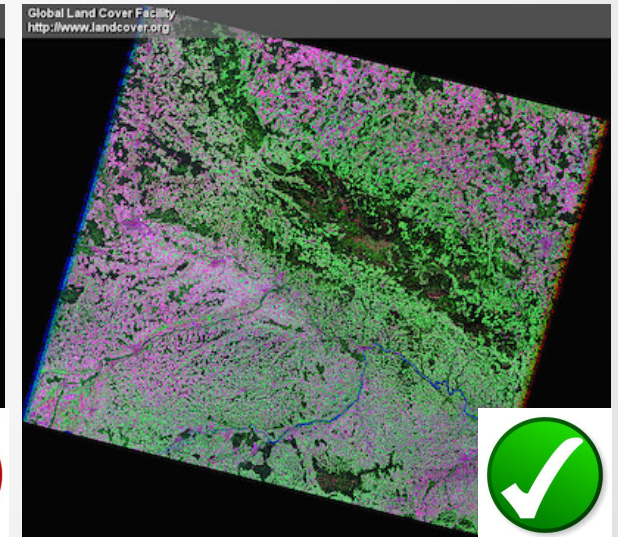


Fig.13.



Landsat TM, 1991-08-07 Landsat TM, 2001-08-26 Landsat TM, 2009-08-24¹⁹

Data Unpacking and Storage

Fig.14.

```
p192r26_5t19910807.TM-EarthSat-Orthorectified

=====
Welcome to the
Global Land Cover Facility
University of Maryland, College Park, USA
=====

Visit our website at http://glcf.umd.edu
If you have any questions, contact us at glcfumd.edu
All files ending with .gz have been compressed using GNU zip

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services or circumvention of established controls will result in
the ban of your IP address or domain without any notice.
Thank you.

Path: ftp://ftp.glcf.umd.edu/glcf/Landsat/WRS2/p192/r026/p192r26_5t19910807.TM-EarthSat-Orthorectified/

File Name                Download Size  Actual Size  Last Modified
p192r26_5t19910807.742.browse.jpg  525946 bytes  Wed Jun 14 03:49:33 EDT 2006
p192r26_5t19910807.742.preview.jpg  12390 bytes  Wed Jun 14 03:49:33 EDT 2006
p192r26_5t19910807.browse.jpg      474099 bytes  Wed Jun 14 03:49:33 EDT 2006
p192r26_5t19910807.hdr              1457 bytes   Tue Aug 13 19:47:04 EDT 2002
p192r26_5t19910807.met              28710 bytes  Tue Aug 13 19:47:05 EDT 2002
p192r26_5t19910807.preview.jpg     11658 bytes  Wed Jun 14 03:49:33 EDT 2006
p192r26_5t19910807.tar.742.jpg     79241 bytes  Tue Aug 13 19:50:50 EDT 2002
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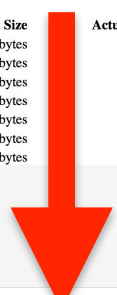


Fig.15.

Индекс «ftp://ftp.glcf.umd.edu/glcf/Landsat/WRS2/p192/r026/p192r26_5t19910807.TM-EarthSat-Orthorectified»

Перейти в каталог на уровень выше

Имя	Размер	Последнее изменение
p192r26_5t19910807.742.browse.jpg	514 KB	6/14/06 12:00:00 AM
p192r26_5t19910807.742.preview.jpg	13 KB	6/14/06 12:00:00 AM
p192r26_5t19910807.browse.jpg	463 KB	6/14/06 12:00:00 AM
p192r26_5t19910807.hdr	2 KB	8/13/02 12:00:00 AM
p192r26_5t19910807.met	29 KB	8/13/02 12:00:00 AM
p192r26_5t19910807.preview.jpg	12 KB	6/14/06 12:00:00 AM
p192r26_5t19910807.tar.742.jpg	78 KB	8/13/02 12:00:00 AM
p192r26_5t19910807.tar.jpg	73 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn1.tif.gz	22359 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn2.tif.gz	19474 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn3.tif.gz	22485 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn4.tif.gz	32153 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn5.tif.gz	31495 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn6.tif.gz	10939 KB	8/13/02 12:00:00 AM
p192r26_5t19910807_nn7.tif.gz	25226 KB	8/13/02 12:00:00 AM

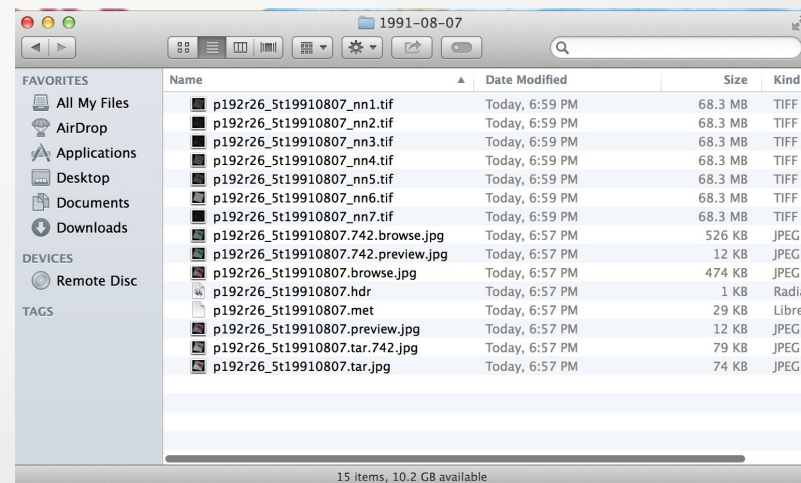


The Landsat search parameters were tailored using GLCF website:

- selecting a region on a map,
 - entering coordinates, and
 - entering a place name (Šumava National Park)
- Additionally, the option to choose data set was used (“Landsat 4-5 TM”, “Landsat Orthorectified ETM+”) and then parameters of acceptable cloud-cover % and the range of desired acquisition dates were selected. After that using the provided path (Fig. left) the data were downloaded.

Final step includes data unpackage and storage (two bottom figures).

Fig.16.



Data Preview

Landsat TM, 1991-08-07

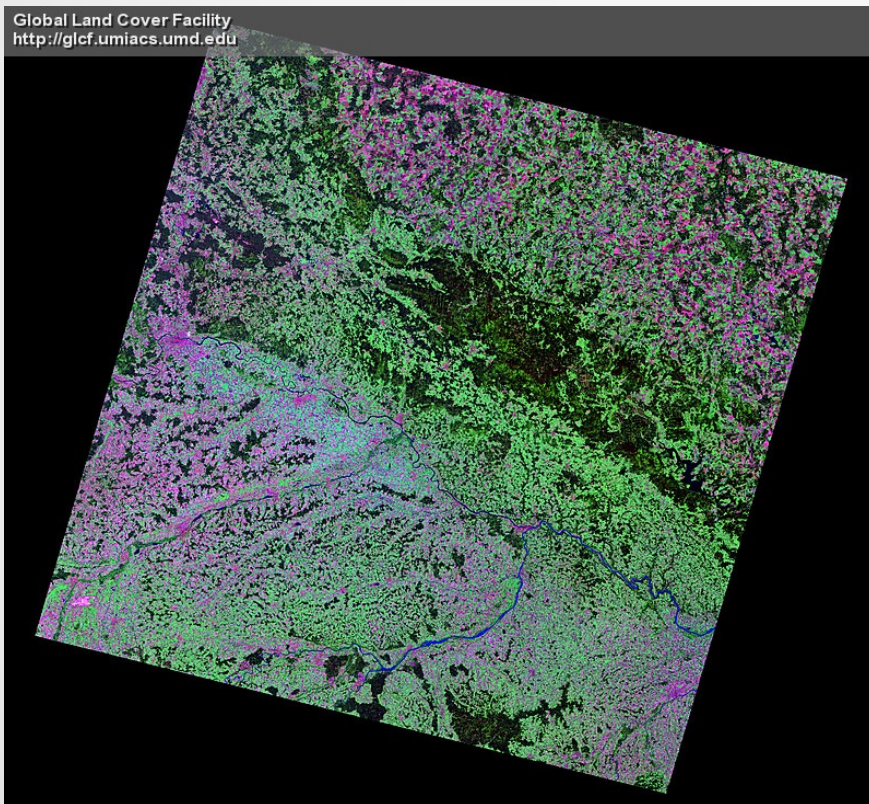


Fig.17

Landsat TM, 2009-08-24

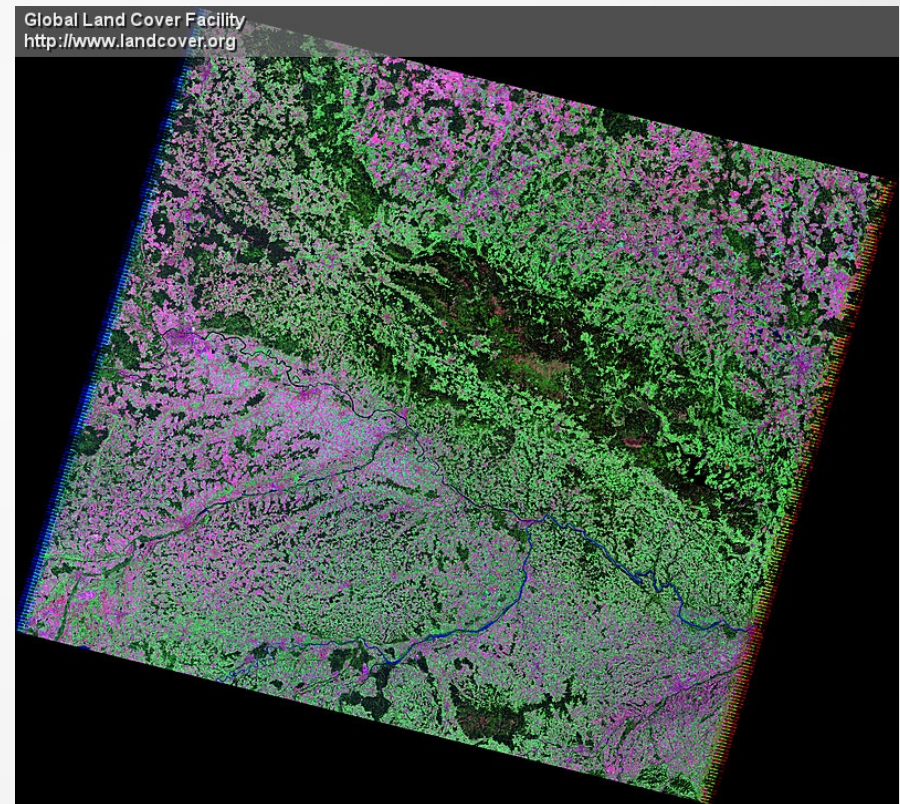
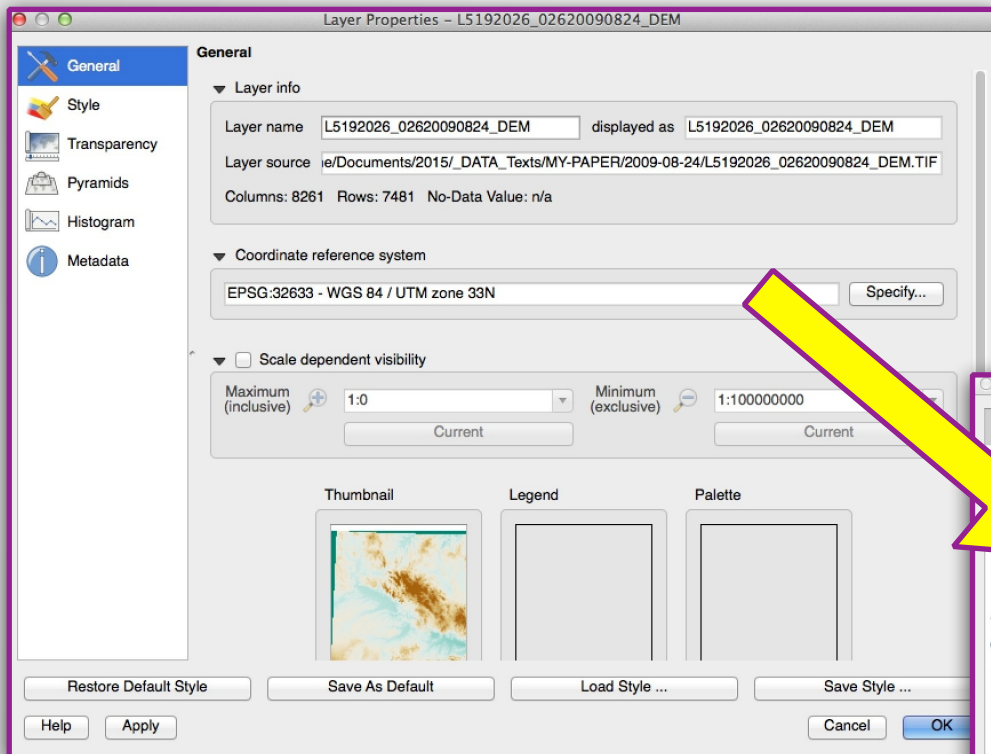


Fig.18

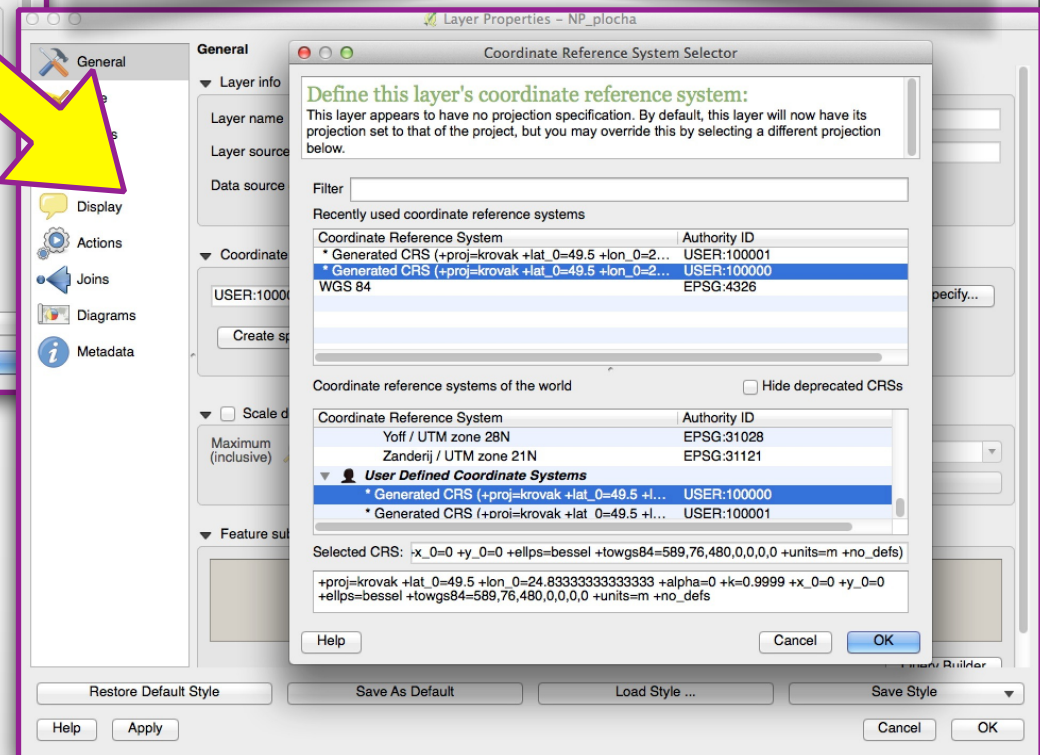
Changing Geographic Coordinate System

Fig.19.



```
+proj=krovak +lat_0=49.5  
+lon_0=24.833333333333333 +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
```

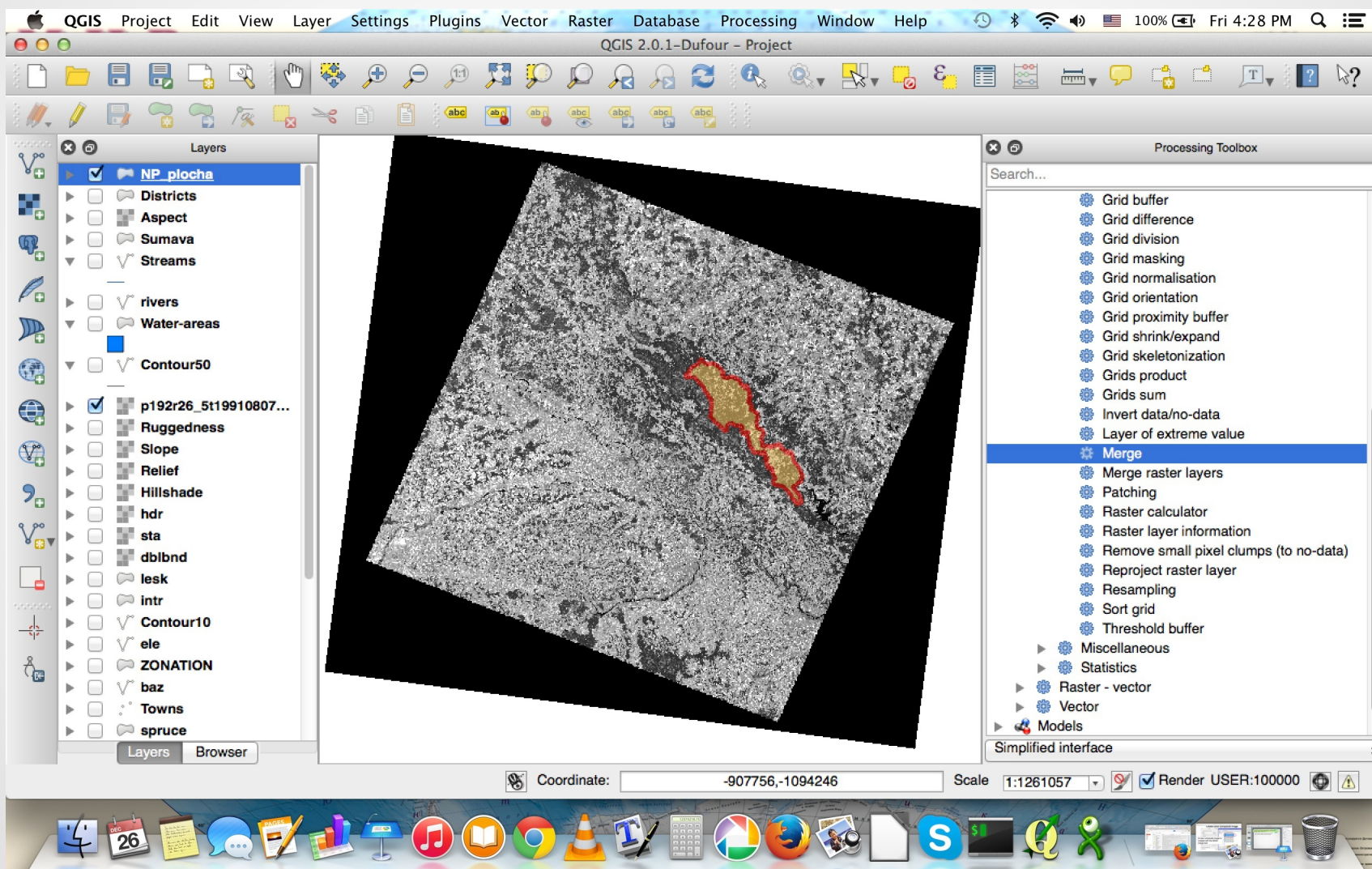
Fig.20.



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*

RS Data Read Into Project

Fig.21



Landsat TM Satellite Images

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

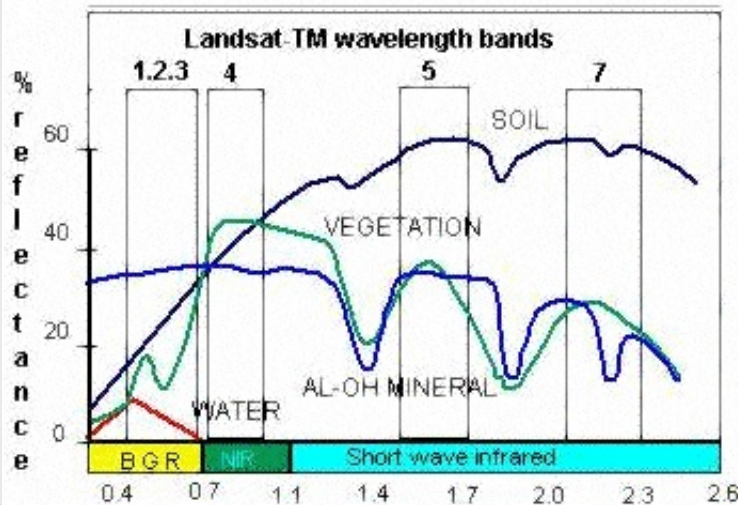


Table Source:

<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

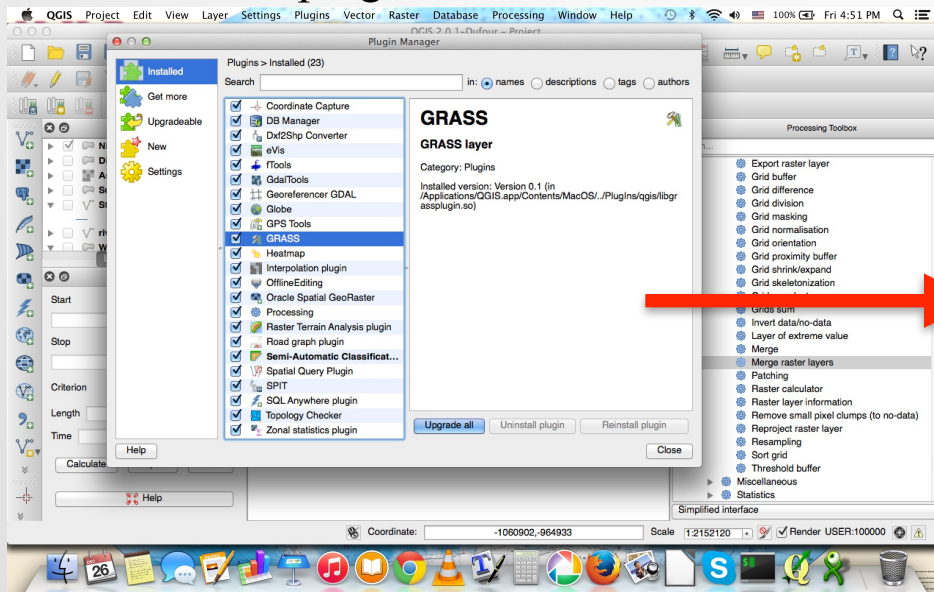
- Band 1 = Blue;
- Band 2 = Green;
- Band 3 = Red;
- Band 4 = Near-Infrared;
- Band 5 = SWIR (Short Wavelength Infrared 1);
- Band 6 = Thermal
- Band 7 = SWIR (Short Wavelength Infrared 2).

Activating RS Tools in QGIS

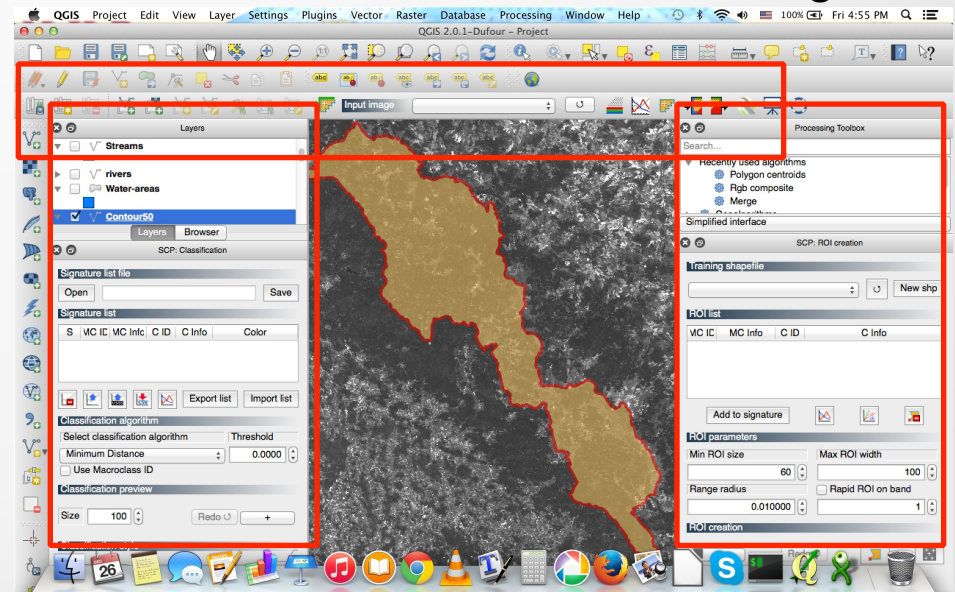
To activated remote sensing (RS) functioning, I activated and updated the GDAL and GRASS plugins (figure below) using the “*Manage Plugins*” (Plugins menu) and selected all useful ones.

After that the GUI changed to active image processing menu (next step)

Activation of plugins



New activated functions of remote sensing



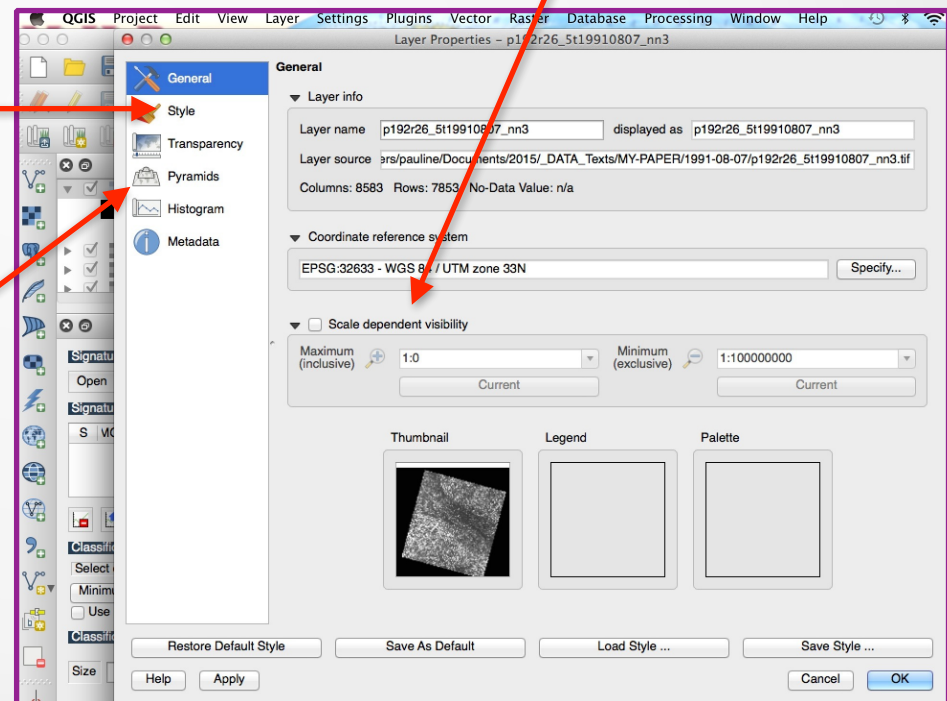
Preliminary Data Processing

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).



Generating Contours from DEM (1)

Fig.1.

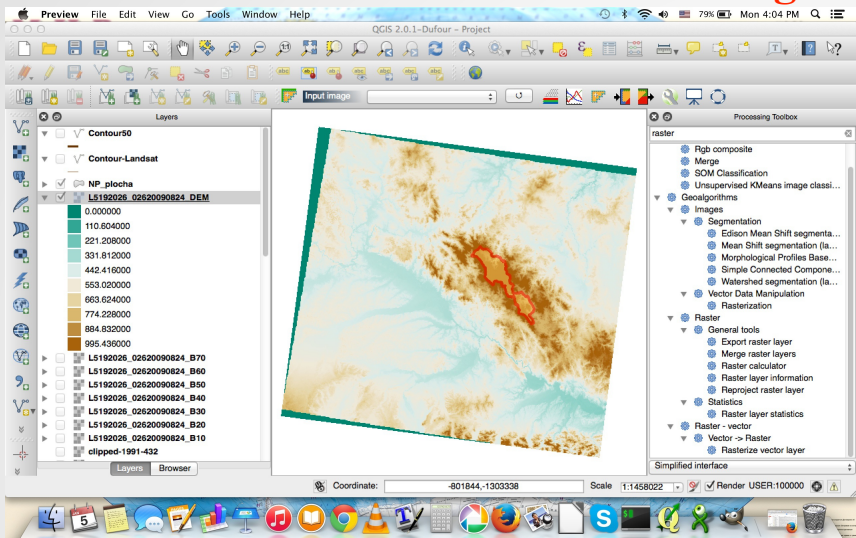


Fig.3.

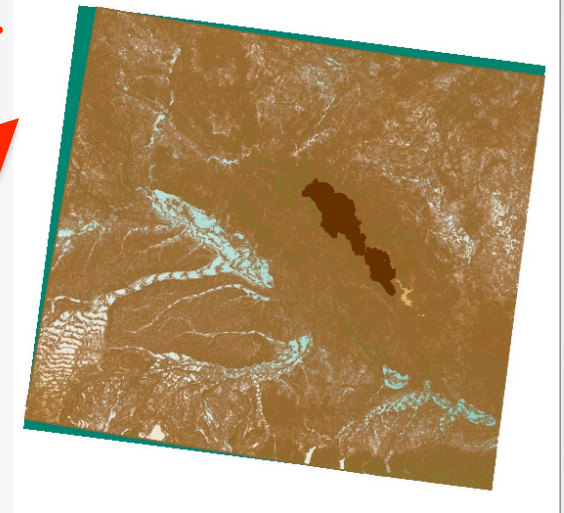
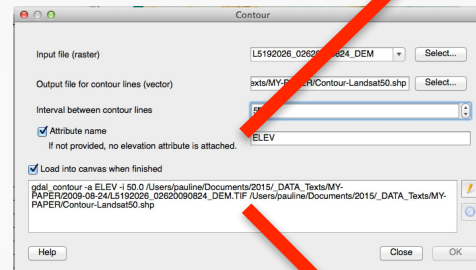
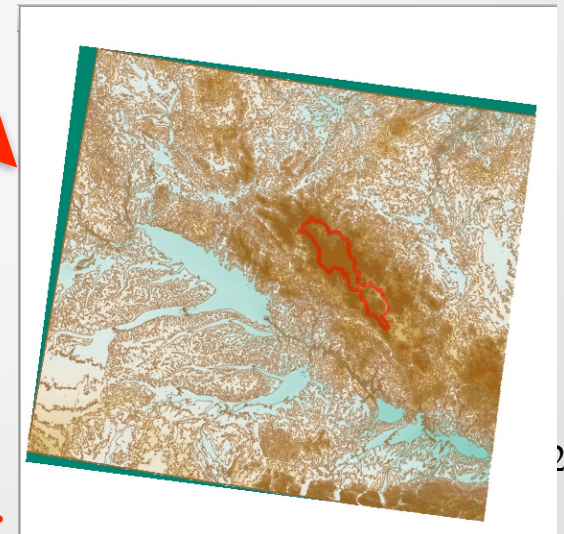


Fig.2.



- 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.**



Generating Contours from DEM (2)

- 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.4.

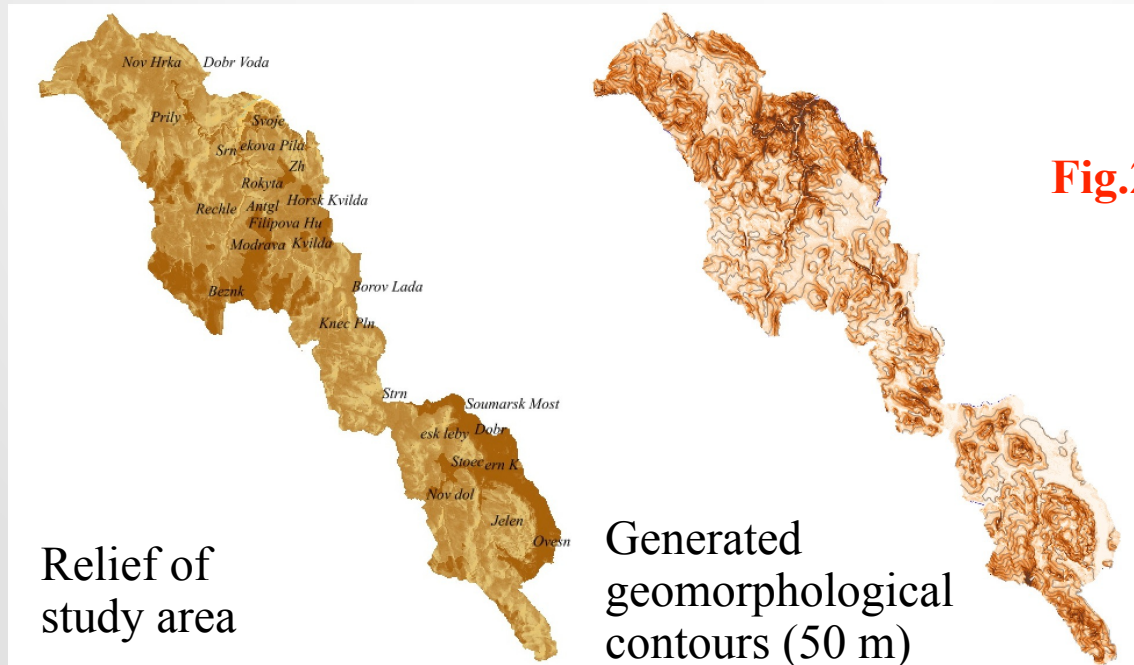


Fig.3.

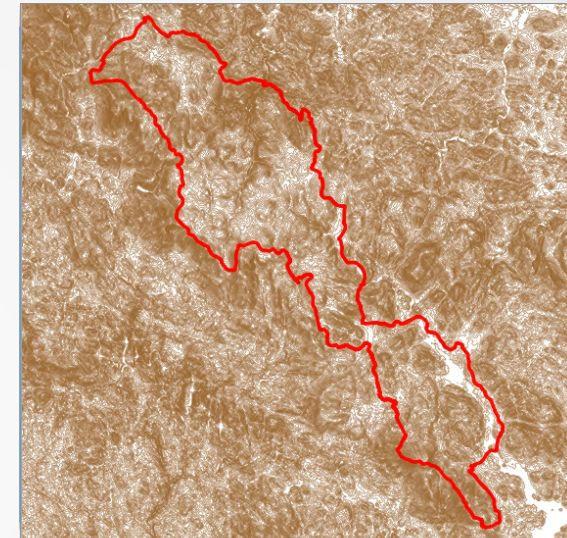
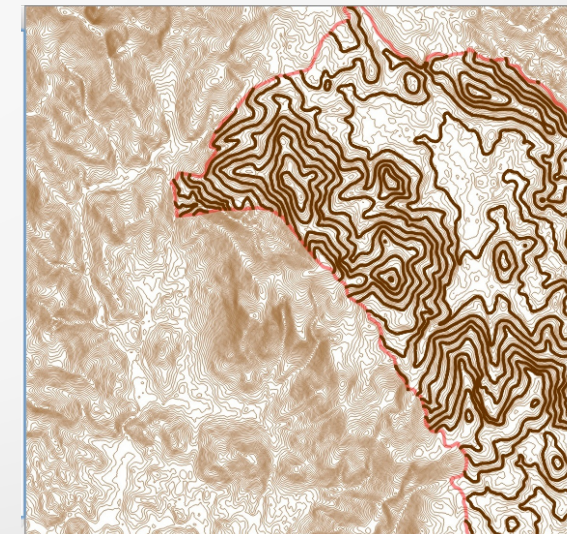


Fig.1.

Fig.2.



Creating False Color Composite

To create false color composites from two images I used combination of **bands 4-3-2**, i.e. combination of:

- band 4 VNIR (Visible Near Infra Red)- 0.76 - 0.90 μm
- band 3 red - 0.61 - 0.69 μm
- band 2 green - 0.51 - 0.60 μm

These three bands are usually being merged for '**traditional**' **false color composite**. This false color combination (4-3-2) makes vegetation appear as **reddish colors**.

A color composite of the image **RGB = 432** for Landsat TM 7 is useful for interpretation of vegetation, because healthy vegetation reflects a large part of the incident light in the **near-infrared** wavelength.

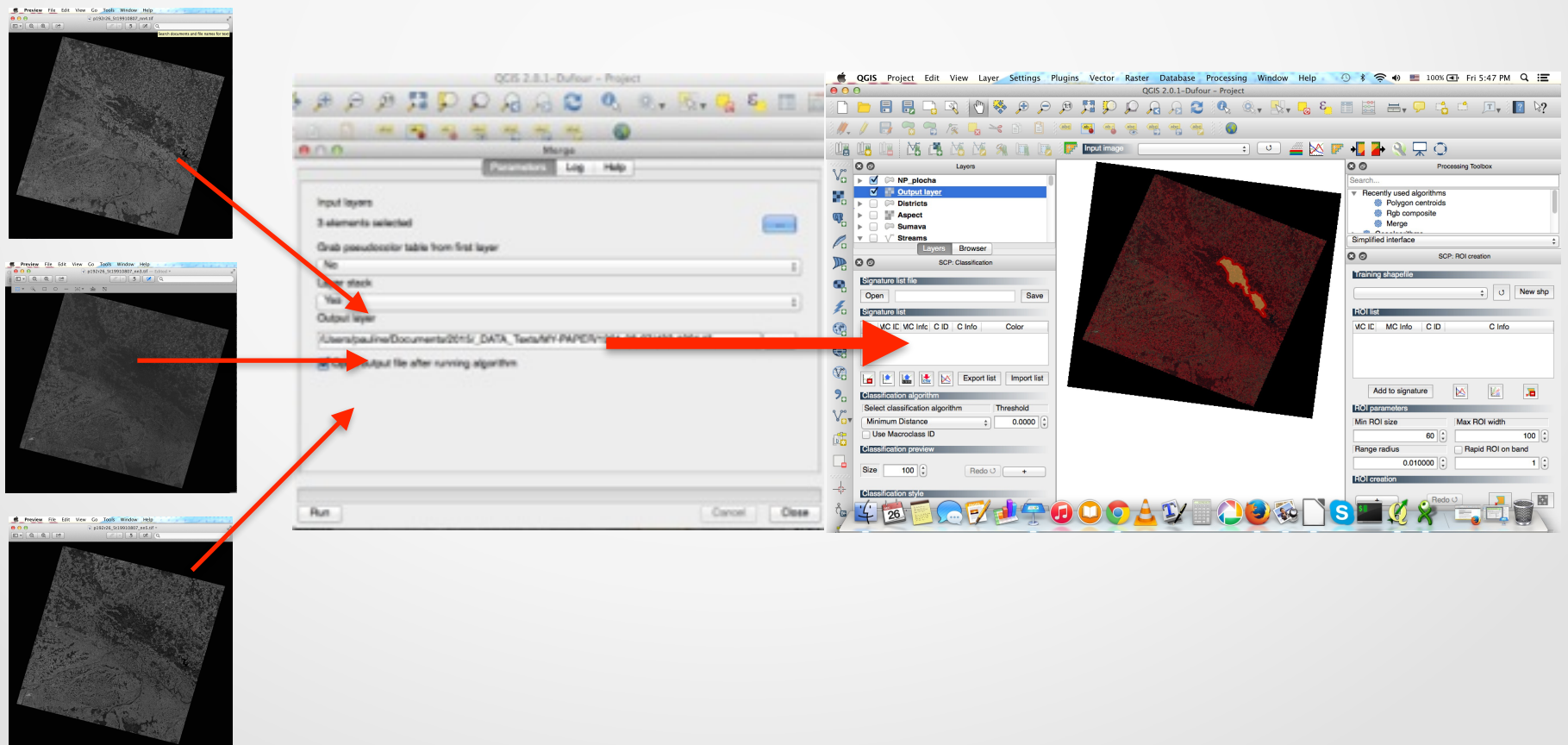
Band 4 gives high reflectance peak from vegetation which enables detection of **numerous vegetation types** and discrimination land from water. Brighter red indicates more growing ("fresh, young") vegetation.

Other land cover types: **Water** is colored blue (shallow or with high sediment concentrations), deep waters - black to dark blue), **soils** with no or sparse vegetation - white (sandy areas), greens or browns depending on moisture and chemical settings (organic matter content). **Urban areas** - blue to gray.

Creating False Color Composites. 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*”.

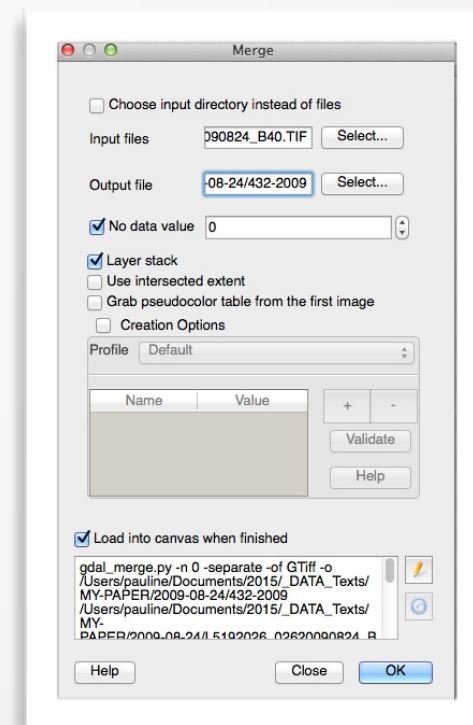
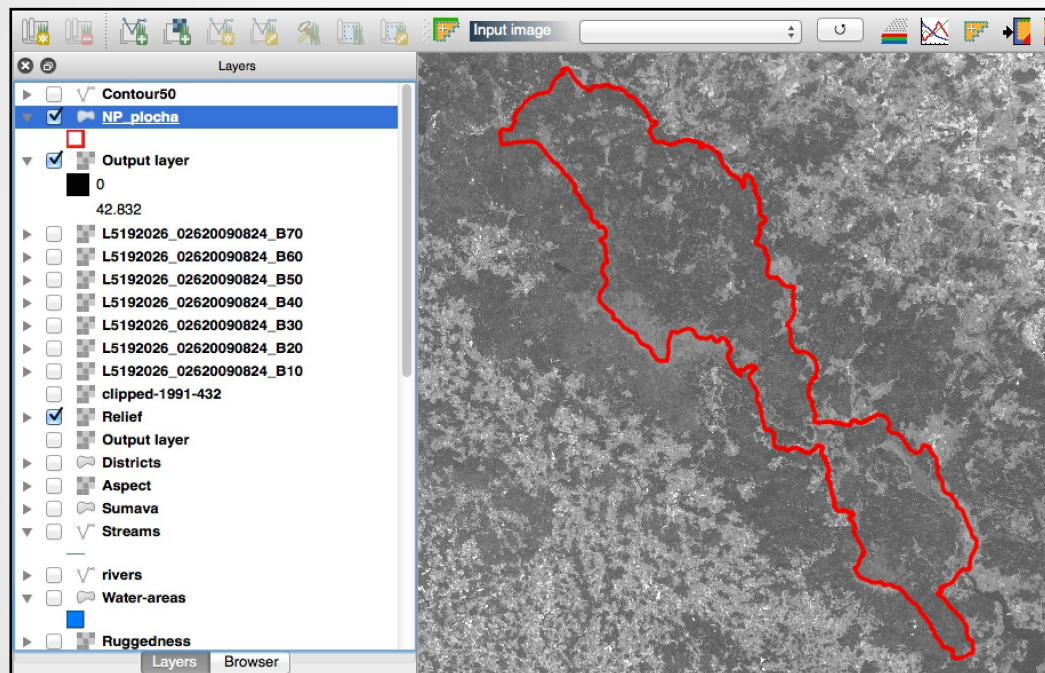
The input image layers (Bands 4-3-2) were selected using the *Input Files>Select* button. An output filename was assigned. The *Layer Stack* box was activated to create stack of image bands and the process was executed :



Creating False Color Composites. Landsat TM image (2009). Bands 4-3-2

The same procedure was repeated for the second file
(Landsat TM image, 2009) (Fig.1)

The Layer Stack box was used
to create stack of image bands
representing *SNP* area.



- Layers were displayed in the RGB composite using *Layers* workspace.
- *Stretches* and other basic image processing functions were applied for better visualization.

Raster Mosaicing and Clipping

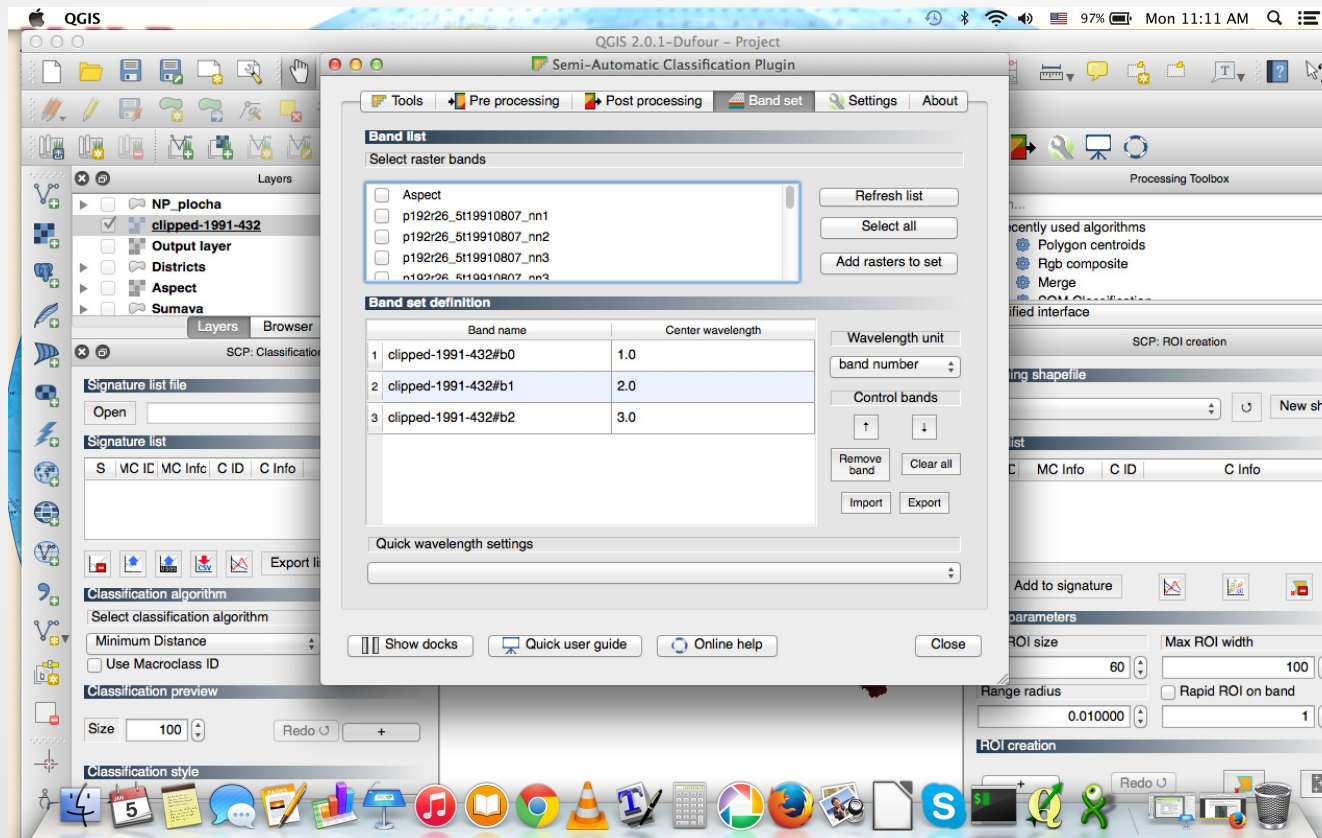
Using *Raster / Extraction / Clipper* menu the necessary area was clipped from the the whole Landsat TM scene using mask (vector layer .shp of Šumava National Park)

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

Classification

The Classification of the image has been performed using *Semi - Automatic Classification Plugin*

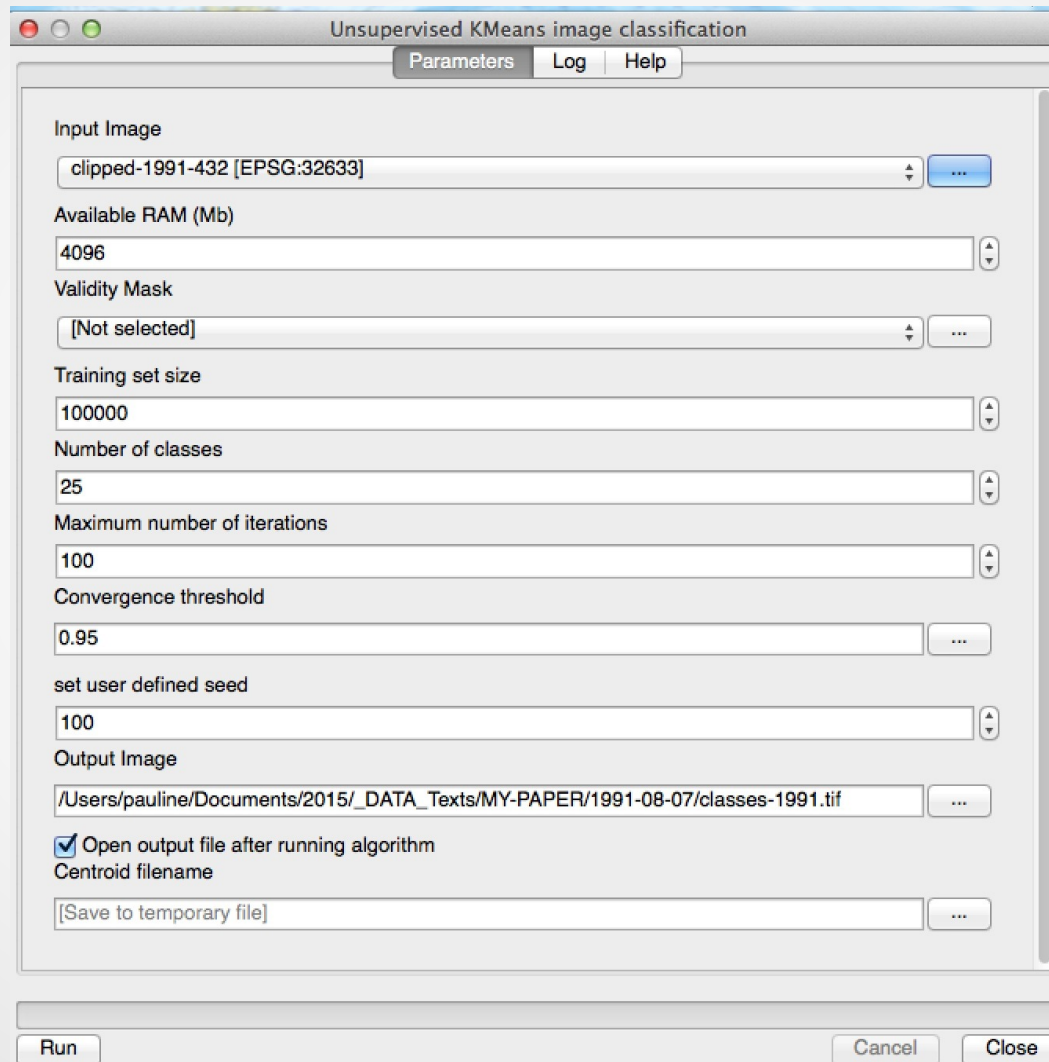
The Classification Plugin allows supervised classification of Landsat TM images, providing tools to execute the classification process :



Parameters for Classification

- **Input image:** The layer stack of $\check{S}NP$ resulting from the gdal merge function (done during previous step).
- **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 $\check{S}NP$
- **Validity mask:** Sine the area of $\check{S}NP$ is already clipped I am not using a validity mask. Therefore, this option is skipped
- **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.
- **Number of classes:** The number is set up as 30, so I could differentiate vegetation classes better. Afterwards I can merge them in case if necessary (e.g. double classes)
- **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.
- **Convergence threshold:** 95%, as 95% of the training sets will not change classes from one iteration to another.
- **Set user defined seed:** input image will be divided into 100 lines for better computation

Parameters for Classification: GUI of QGIS

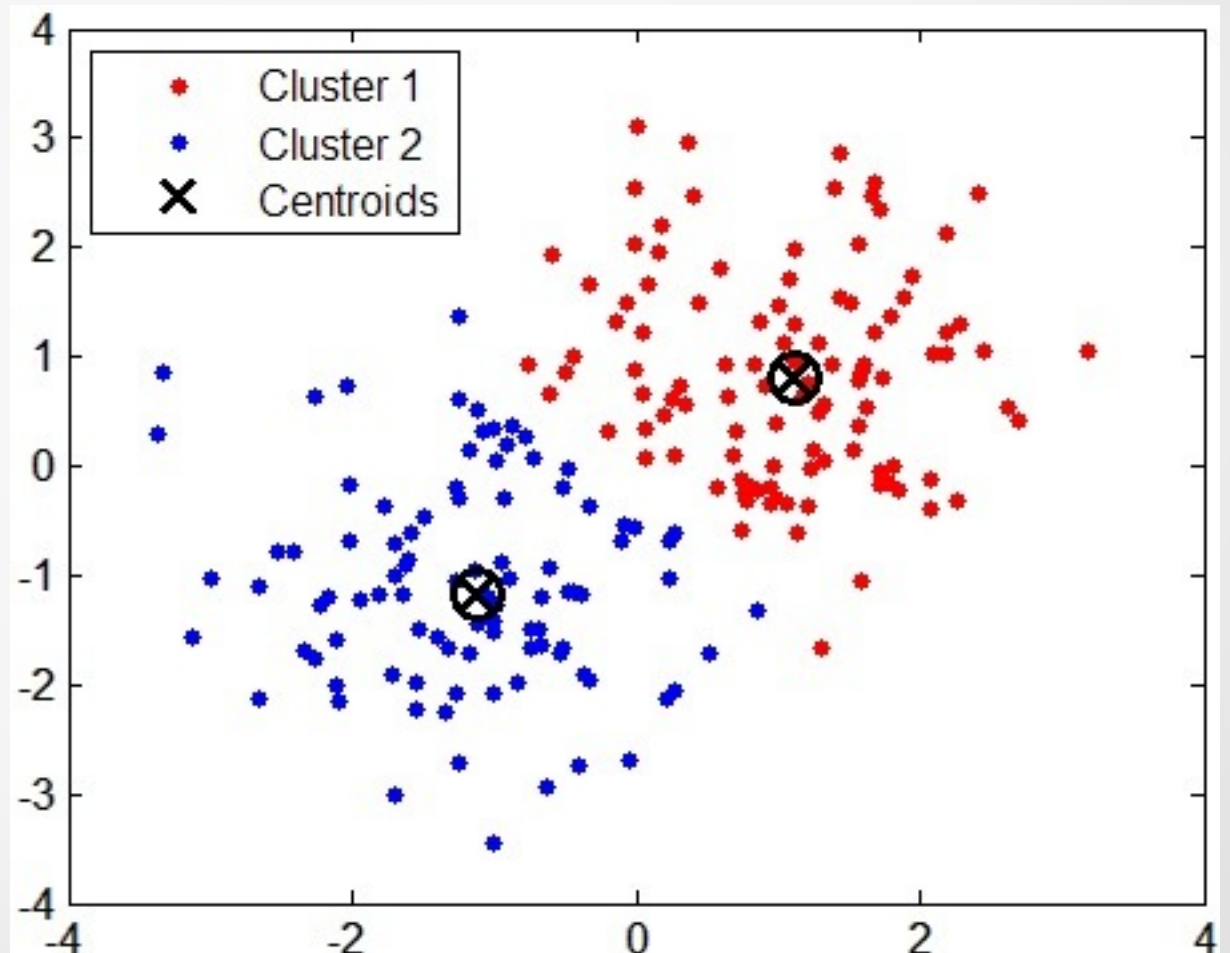


K-Means classification: a general idea.

K-means is a flat clustering algorithm which is often used in classification techniques.

The objective of K-means:

to **minimize** the average squared Euclidean **distance** between the **cluster centers** (the means).



K-Means clustering: a mathematical approach

The K-means analysis separates pixels into various clusters by defining the mathematical centroids of all clusters groups of pixel with similar values of spectral reflectance (digital number, *DNs*):

$$J(X, C) = \sum_{i=0}^n \min_{\mu_j \in C} (||x_j - \mu_i||^2)$$

The K-means separates raster pixels in n clusters (groups of equal variance) by minimizing the '*inertia*' criterion.

Classification Output: 1991

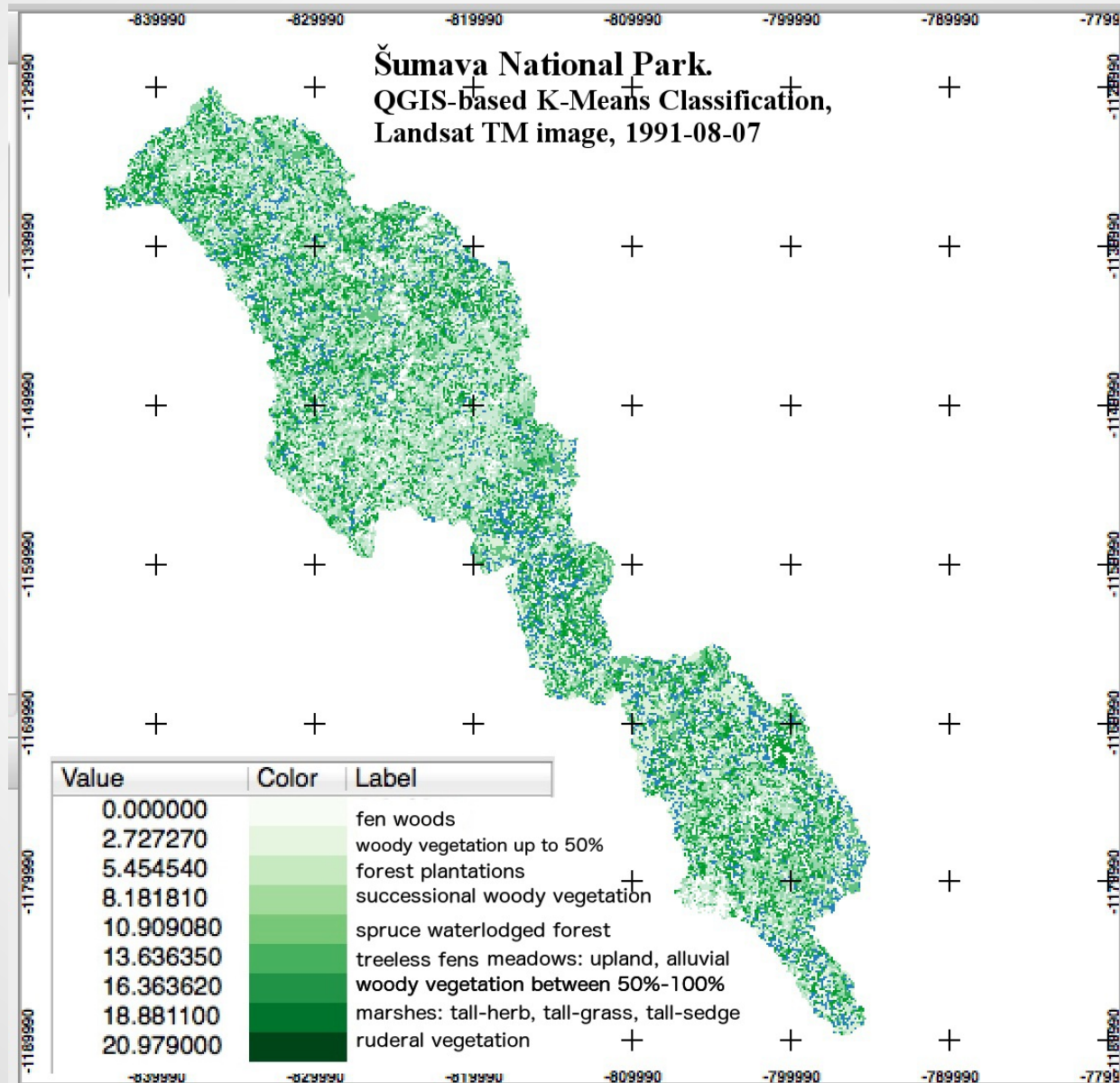
The screenshot displays the QGIS 2.0.1 interface with the following components:

- Layers Panel:** Lists layers including NP_plocha, Output Image (selected), clipped-1991-432, Output layer, Districts, and Aspect.
- SCP: Classification Panel:** Contains settings for signature list files, a signature list table, classification algorithm selection, and a classification preview.
- Processing Toolbox:** Shows the 'classification' process with options for SVM, SOM, and Unsupervised KMeans, and the 'SCP: ROI creation' process with training shapfile, ROI list, and ROI parameters.
- Map View:** Displays a grayscale classification output map of a geographical area.
- Bottom Panel:** Shows the 'Classification style' section with a size of 100 and a 'Redo' button.

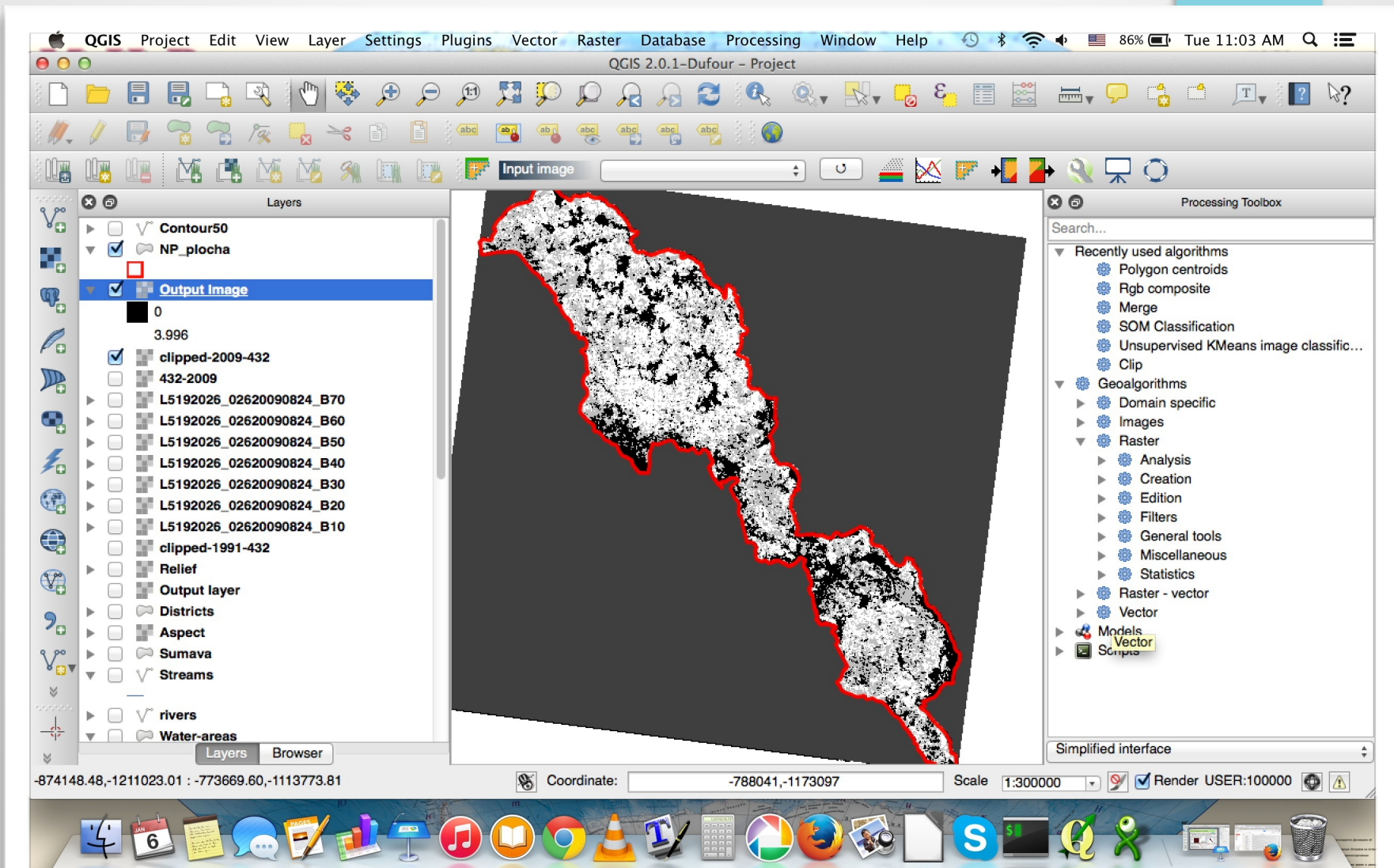
S	VC IC	MC Info	C ID	C Info	Color

VC IC	MC Info	C ID	C Info

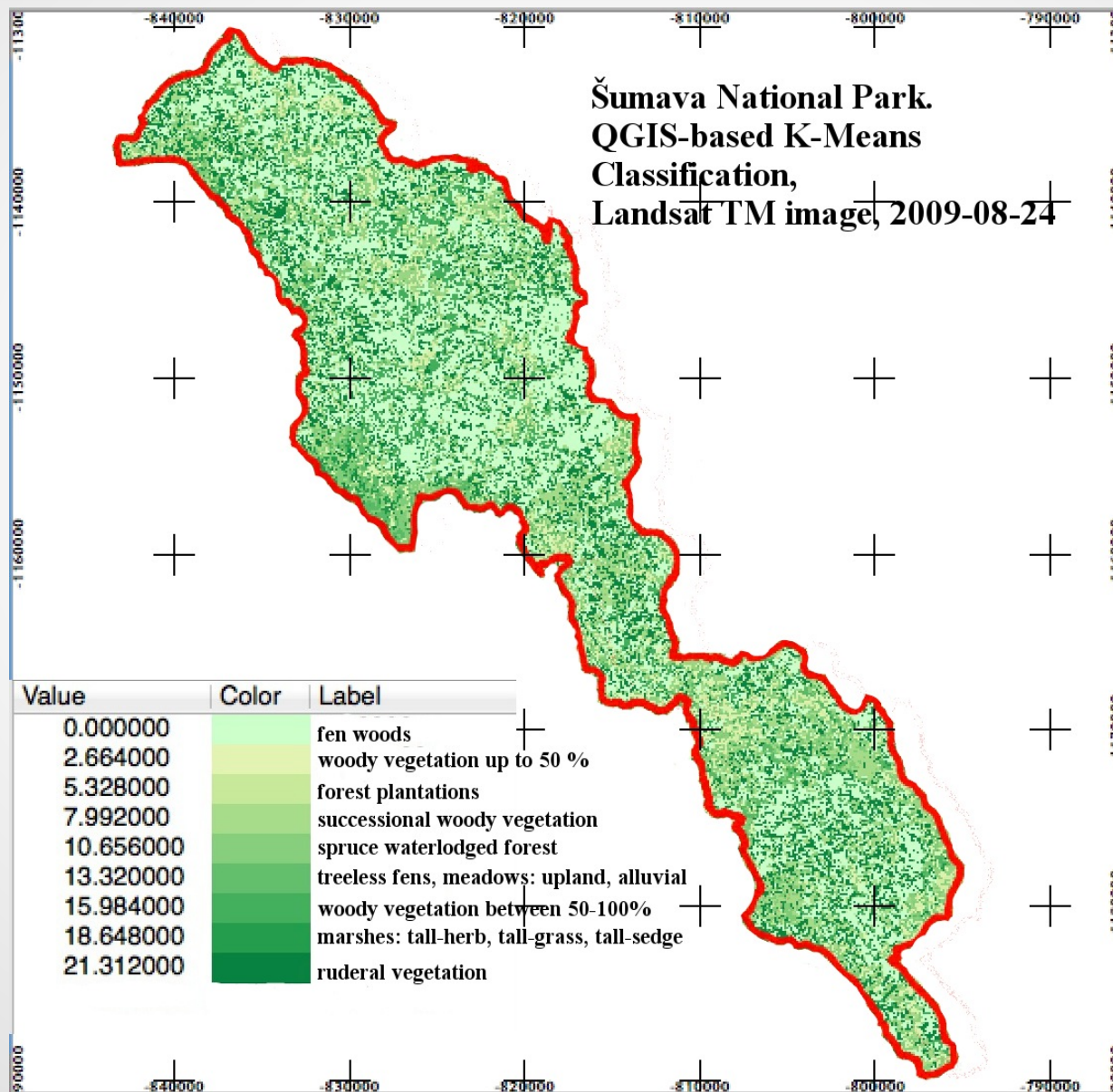
Classification Results: Map of 1991



Classification Output: 2009



Classification Results: Map of 2009



Conclusions (I)

Current research steps included... :

1. to collect, organize and sort data for research
2. to study, read and analyze relevant literature on research topic
3. to develop a tentative GIS method (algorithm) for producing spatio-temporal land cover maps for change detection analysis.
4. to receive preliminary results for available data (1991 and 2009)

Next steps will include...:

- 1) development of improved approach (comparison of various methods) discrimination of land cover types especially in the selected section of the study area, combine and compare the results from various algorithms with knowledge of vegetation and terrain characteristics
- 2) analyze any misclassification of forest areas (e.g. to reduce the problem of possible spectral confusion)
- 3) assessing and improving accuracy of both 1991 and 2009 images.
- 4) environmental analysis of “triggers-consequences”. For example, the depletion of certain land cover types can be attributed to environmental changes and (or) anthropogenic effects.

Conclusions (II)

Methodologically, current research step also revealed the importance of spatial and temporal remote sensing data and GIS tools for detecting changes of the environment

The importance of the GIS and remote sensing (RS) data were successfully used for the environmental monitoring since 1970s (rapid development of Earth observation satellite systems and launch of the Landsat TM program).

Therefore, the combination of remote sensing data and GIS tool for pattern recognition is proved to be effective tool for geo-botanical research

The spatial analysis performed by means of open source QuantumGIS enabled to use satellite images for geobotanical studies.

The spatio-temporal analysis was applied to Landsat TM images taken at 1991 and 2009. Built-in functions of the mathematical algorithms of QGIS enabled to process raster Landsat TM images and to derive information from them.

The classification of the images was used to analyze changes in the ŠNP area that consist in different geobotanical land cover types

The results of image processing demonstrate that structure, shape and configuration of landscapes in ŠNP changed since 1991

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Final Slide

Thank you for attention.
Questions ?