

Evaluation of Possible Cartographic and Remote Sensing Methods for Detecting Temporal Changes in the Urban Area in the Alpine Region

MASTER PROJECT

at Institute of Cartography and Geoinformation of
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ABSTRACT

This project explores the potential of Cartographic and Remote Sensing approaches in the study of Alpine urban region in order to detect the temporal changes. Both approaches give an opportunity to find the most efficient type of representation of the spatial characteristics of urban phenomena. Furthermore this analysis of different methods provides the following main outputs: a dynamic framework to represent the evolution of the urban form; defines the change in planning data and information; gives the opportunity of systematical analysis of the wildland urban development processes.

The result of this work gives an opportunity to consider, that both of approaches are giving not just relevant information about temporal changes, but also provide the results with significant value of accuracy. A discussion of all the fundamental contribution of these methods is then presented.

ABSTRAKT

Dieses Projekt erforscht das Potential der Kartografie und Fernerkundung zur Erforschung alpiner Regionen und deren Entwicklung. Beide Ansätze bieten die effizienteste Art räumliche Eigenschaften städtischer Phänomene zu untersuchen. Diese Analyse unterschiedlicher Methoden hat folgende Resultate: ein dynamischer Rahmen zur Darstellung städtischer Entwicklungen; Planungsänderungen von Daten und Informationen; systematische Analyse unterschiedlicher städtischer Entwicklungsprozesse.

Das Resultat dieser Arbeit zeigt nicht nur, dass beide Ansätze relevante Informationen über Entwicklungen wiedergeben, sondern diese auch mit höherer Genauigkeit tun. Eine Diskussion aller wesentlichen Aspekte beider Methoden folgt.

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1. INTRODUCTION

The current work is a part of WUI-CH (Wildland-Urban Interface) project. The WUI is a term, using for indicating the areas, where the houses and other human infrastructure interact with the wild land vegetation. Therefore there are a lot of problems, associated with WUI. The most relevant are the fire hazards, while in the dense populated areas there regime of fire ignition is mostly anthropogenic-induced (Oleggini et al., 2011). Therefore the WUI-CH project is aimed to evaluate and develop the model for further implementation of fuel management programs. The WUI project is now on the second phase, where are processing more detailed investigations in order to assess better characteristics of the spatial and temporal evolution of WUI. The region, where this research was applied is Alpine environment, while so far before there were no existing attempts in this region, which refers to WUI problems (Oleggini et al., 2011).

Nowadays the Remote Sensing (RS) and Geographic Information System (GIS) with different cartographic information are providing new tools for advanced land cover management (Wilkie and Finn, 1996). Therefore an attempt will be made in this study to define the most relevant method for detecting the changes that have taken place in the build-up areas.

1.1. Motivation and Goal

The aim and purpose of this project is to derive and establish the best method for distinguishing the temporal changes in Alpine region, in order to enrich WUI thematic contents with specific cartographic outputs. The motivation for this research has been identified due to the lacking functional information content of the temporal changes in Alpine environment. This master project shows the potential that exists in achieving this aim, and how this project will give an opportunity and initiate new uses of the result data.

The hypothesis of this research is that there are two main approaches in order to detect the temporal changes: Cartographic and Remote Sensing. Both of them use different types of analysis. The research problem, therefore, deals with linking both results by using spatial configurations (georeferencing) in order to compare them and evaluate the best method.

1.2. Paper Structure

The following master project paper structure is divided into five main parts. The first one is the introduction, where the main targets of the project are described, the purposes explained and the information about the hypothesis is given.

The second part is the analysis of methodology. It is also divided into several steps. The first step is a review on previous research papers in this field with the discussion of their results and main drawn conclusions. The second step is an explanation of the needs of the current project with the definition of the case study area. The third step is the definition of the concept of the methodology, where the input data and the software used in the project are discussed.

The third part is the definition of the cartographic approach's implementation, where the main implementation of different methods in order to detect temporal changes is described.

The fourth one is the definitions of the implementation of the Remote Sensing approach with the description of the implemented methods.

The fifth part of the project is the evaluation of the results. Mainly it is a comparison of two approaches, with the proposed identifying the best method. After achieving all these steps mentioned above, in the fifth part of the project the discussion about the future implementation of the results also presented, defining the possibilities of applying the detected method for the whole alpine region in Switzerland.

2. ANALYSIS OF METHODOLOGY

2.1 Literature Review of Related Works

In order to evaluate the methodology for the master project, the literature, related to the current work was analyzed. The main problem, which occurred while analyzing the literature was, that there was no common term for the change detection methods. Therefore was decided to separate them in the literature review according to the main types approaches, which were discussed in the introduction part (Cartographic and Remote Sensing).

Mainly, the change detection can be described as a process of identifying differences in the state of an object by observing it at different times (Singh, 1989). There are several applications to investigate temporal changes, nowadays the main one is the digital change detection. This process helps to determine the understanding relationships and interactions between human and natural phenomena in order to promote better decision making (Lu et al., 2003). Change detection method is very useful for different types of applications: land use and land cover, urban sprawl, different spatial and temporal analyses (Ramachandra et al., 2004).

Methods within change detection approach can be divided into post representation (map-to-map) and spectral (image-to-image) (Lunetta, 1999; Mas, 1999). In other words, post representation can be understood as a Cartographic approach, where the input data are maps and different vectorized layers of the map and as spectral- the Remote Sensing approach along with digital image processing techniques. Usage of one or another method depends on different aspects: application tasks, changes to be detected, available data, required accuracy, etc.

2.1.1 Cartographic approach (post-representation)

Cartographic analysis is the method of application of the maps for scientific and practical researches. This analysis includes retrieving different qualitative and quantitative characteristics of the phenomena or of the processes by using the maps. Within cartographic analysis in order to get temporal changes are used raster- and vector-based methodologies.

Raster-based methodology

For the raster methodology there are not that many works, describing raster approach in order to distinguish temporal changes. Several of them represent the analysis of the methods, which might be used in the current work in order to implement this type of method.

One of the recent works, partly related to this analysis, was done by Andreas Sidler in 2010. This work was a master project, where the main aim was to reconstruct the

glacier's elevation model. Therefore the first part of the work was analysis of incoming raster data (maps) in order to get the relevant information about the relief. Therefore by using *Color separation* method the relief layer was detected on the map and created as a new outcoming data, which allowed further analysis. This method can be relevant for current work in order to separate the urban zones form other types of objects, represented on the map.

Further analysis of results, which can be relevant in order to detect temporal changes was described in Bare and Travis research (2008), where in order to visualize the changes for the raster file was applied *Raster Calculator* algorithm. The main idea of this algorithm was to calculate the new value for each pixel, which automatically gives the value 0 if there is no spectral change on the image and value 1, where there are. The result of this work is a successful representation of changed and non-changed land cover areas. The other advantage of this algorithm is, that it can be applied in mostly all geoinformation software.

Vector-based methodology

This is the another opportunity of analysis of cartographic data. The main idea of this method is to vectorize the raster data by using different vectorizing algorithms. The new vector layer will allow to apply some analysis with the data. One of the big advantages of this method is, that it allows also the user to receive statistical information about the changes. The disadvantage is, that this method can be time-consuming and strongly depends on the type of vectorization process, which will be done (automatic or manual).

In order to find the most relevant method for current work were decided to analyze previous works, based on vector type of analysis. For the vector approach the main aspect is the type of vectorization, which is going to be used in the project. There are two different types: automatic method and manual one (Janssen et al., 1994). The advantage of the manual vectorization is, that the user controls the results, while in the automatic one the user control the outcome only on the stage of defining of parameters. But in automatic approach there is one very important advantage- the process is very fast. Therefore in most of the works the vectorization process is partly automatic and partly manual (Janssen et al., 1997). Mostly the vectorization process for the build up areas (urban zones) is very important for the cadastral surveyors. Therefore there are a lot of works related to our topic in order to distinguishing and representing the results of this kind of approach.

For example in the work of Katona et al. (1997) and Simunek (2011) one of the main step was recognizing buildings contours on the cartographic map by using automatic vectorization process. The problem, which occurred while applying the proces, was the distinguishing parcel lines (areas of the territory next to the building) from boarders of a single building. Therefore was additionally written an algorithm, which could utilize the information offered by recognizing the connection of the edges. If

there were two intersections along one line, the algorithm recognized the object as a building. If there were one intersection, then the objects were recognized as borders of the parcels (simple lines). At the end it allowed to receive the relevant results and vectorize the buildings contours. The disadvantage of this method is that this algorithm is time-consuming and relevant only for the small areas.

To summarize the cartographic approach results from the previous works it can be said, that there are two main methods of analysis, based on incoming data: raster and vector and both of them have advantages. As an advantage for the raster data- it gives fast relevant visualization of changed and unchanged zones. As an advantage for the vector data- it allows the user to implement different types of possible analysis after vectorization process, which can increase evaluation of the results. The disadvantage of the raster approach is that this method needs the evaluation of the accuracy of the results, while detected changes might be just the mistakes in georeferencing the maps. The disadvantage of the vector approach is, that if the vectorization process is done automatically then it needs additional improvement of the results. And if the process is done manually then it is time-consuming and not acceptable for the big areas.

2.1.2 Remote Sensing approach (spectral method)

Nowadays Remote Sensing data combining with GIS (Geoinformation systems) has been widely applied and been recognized as a powerful and effective approach in detecting temporal changes (Burrough 1986, Weng, 2002; Ehlers et al., 1990; Harris and Ventura, 1995, Lu, et al. 2004, Ormeci et al., 2006; Rumasheuskaya, 2007). Satellite imagery has been used to monitor discrete land cover types by applying different types of spectral classifications (Weng, 2002). The remote sensing satellite data in multispectral means to provide spatial information for land cover and land use at different levels for various aspects as built-up land, agricultural land, forests, water bodies etc. (Laymon, 2005). This interest growing from the various range of applications in which change detection methods can be used, like environmental monitoring, urban studies and forest monitoring. There are two main types of Remote Sensing change detection techniques: supervised (with ground truth) and non-supervised (without ground truth) (Pacifici et al., 2007).

Supervised change detection technique:

Mainly to the supervised technique belongs one method, which calls *Post Classification* approach (or Classification Difference) (Pacifici et al., 2007). This method can be divided into two, depending on which type of classification afterwards is using (supervised or non-supervised). Standard created classifiers are used to classify the images for different dates independently. Changes can be detected while comparing this classified images. There are several advantage of this method: it is intuitive and what is more important, it provides a change matrix and does not need any additional corrections to the atmospheric conditions or to the sensor differences between the acquisitions (Potter, 1974; Kawata et al., 1990). There is also a big

disadvantage of this method: it is strongly depends on the accuracy of the chosen classification (Pacifici et al., 2007). The types of classification, chosen within the technique strongly depends on the outcoming results and on the time, while unsupervised classification can be performed in a shorter period of time.

In order to estimate the most relevant classification type within the supervised technique, which is going to be used in the project, were analyzed the results of previous works. In order to obtain possible results after applying Post-classification approach were analyzed five works on this topic. The main difference of these works was in the type of classification, which was used. Thereby there are two main types of classification: supervised and non-supervised. In the works of Rymasheuskaya (2007), Goksel et al. (2005), Musaoglu et al. (2005), was used unsupervised classification, while in the works of Ramachandra et al. (2004) and Song et al (2001) was used supervised classifications.

The main aim in the work of Rymasheuskaya (2007) was determination of the land cover change detection in northern Belarus. As an input data 5 SPOT satellite images were used. As classification *Maximum likelihood* and *Neural networks* methods were used, which presented quite high accuracy (83% and 86%). The results of this work were classified images with the values of area for each class. The main research issue for the further researches after analyzing the results of this work were, that for example, a lot of false changes were detected. Among false changes there are linear features next to the edges of the objects. The reason of that can be the misregistration of the images in spite of quite high co-registration accuracy, inconsistency in spectral characteristics on the edge of objects. Therefore the agricultural area, which was distinguished as a class on the satellite image, appeared to produce large amount of false changes. It is caused by the difference mainly in crops and moisture. Nevertheless significant land cover change was detected at the study area during the period 1994 – 2002. And overall post-classification comparison proves the ability to be used for detecting land cover changes but the amount of errors and uncertainties requires additional study. First of all it is needed to improving images' co-registration by introducing larger number of control points; testing other image fusion algorithms like wavelet analysis enabling better preserving of spectral information; using another types of classification algorithms.

The work of Golsel (2005) was focused on detecting land use/land cover changes in Cavusbasi region, Turkey. The approach, which was used in the work is similar to Rymasheuskaya (2007), the main difference is the algorithm for unsupervised classification. The *ISODATA* classification technique was applied to classify the remotely sensed images. Three land cover types for the study site were identified and used in the study: forest, water and others. The digital image classification conducted with GIS has proved its ability to obtain comprehensive information on the direction, magnitude and location of land cover changes. To assess the accuracy of chosen method of classification the error matrix was created, which showed, that the overall

accuracy was 88%. The main result of this work is (after comparison of the results with the ground truth data and statistical information), that the algorithms which were used are the most convenient techniques in order to collect the information for chosen area.

In the work of Musaoglu et al. (2005) was used absolutely the same unsupervised algorithm in order to detect environmental change on the northwest of Istanbul. Classification procedure also was done by using *ISODATA* algorithm. The improvement, which was significant for previous work was the number of channels, which can be used in order to classify the image. In the previous work were used only three (R,G,B) in this work were used 5 spectral bands: R,G,B,NIR, MIR, TIR. This improvement allowed researchers to increase the resulted accuracy up to 90 % for the same number of classes.

After analyzing three works, based on unsupervised classification technique, it is possible to consider, that the *ISODATA* algorithm for unsupervised classification is the most significant in order to obtain temporal changes. Another, very important conclusion from previous works is , that after increasing the number of spectral bands for classification it is possible to enhance the accuracy of resulted classification.

Another classification method, which is also widely used in temporal change detection -supervised classification. Thereby in the research of Ramachandra (2004) one of the main aims was the suing the supervised classification in order to achieve the high accuracy results. The method, which was used *Maximum likelihood* algorithm. The evaluation of the results showed that the supervised classification gave the accuracy which was 92 %, after comparison of the result with the ground truth data. In the work of Song (2001) the comparison of two possible classifications' types (supervised and unsupervised) was compared and the result of the discussion was, that it strongly depends on the accuracy of not only the classification but also of the ground truth data. Therefore some mistakes, which occurred while using this classification method, also were followed from the georeferencing process.

After analyzing of the supervised type of classification it is possible to say, the analysis, in order to detect temporal changes needs to be done, while using both classifications: supervised and unsupervised. In the first one the user decides the future class while using the *a-priori* knowledge while for example in unsupervised classification the human mistake is excluded, because the computer investigates the signatures. Afterwards creating the error matrix, allows the user to establish the classification accuracy, can check both results.

Unsupervised change detection technique:

In unsupervised technique there are several types of methods:

- Image math
- Transformations

- Change vector

Image Math:

This method identifies changes through computation of differences or ratios between image bands. This method is mostly works on single bands or from derived different vegetation indices. The result of this method is a difference image (Pacifci et al., 2007). There is one and the most important advantage of this method- it is simply and fast. One of the main disadvantages- this method does not provide the change matrix and very sensitive to changes due to other factors.

Transformations:

In other words this method calls Principal Component Analysis (PCA). This method consists of two steps. First step is performing the data from both dates and then analyzing the components. Then performing each image separately and subtract the second-date principal component image from the first date (Pacifci et al., 2007). This method reduces the redundancy, but one of the main disadvantages is, that the resulted image is strongly scene dependent and it can be difficult to interpret the results, furthermore this method also as a previous one does not provide the change matrix. Therefore this method mainly used as an additional to the image math in order to increase the accuracy.

Change Vector:

Determines in n-dimensional spectral space, the length and direction of the vector between Image 1 and image 2. This method also produces an intensity image and a direction image of change (Bolovo, 2007). The direction image can be used to classify change. Change vector approach is typically used when all changes need to be investigated, it also works on multispectral data. The results most of the time are comparable to the *Image Math* method.

To summaries the advantages and disadvantages of unsupervised technique, there are several aspects, which need to be noticed. First of all, in unsupervised technique the separation between changed and unchanged classes is done on the magnitude of the resulting spectral change vectors by means of empirical or theoretical well founded thresholding strategies (Bruzzone, 2000, Pacifci et al., 2007). Secondly, these methods are not dependent from ground truth data. As a disadvantage, all methods are sensitive to atmospheric effects and sensor differences; also all techniques results in a difference image require additional interpretation.

The unsupervised technique is normally used as an additional method to the supervised technique. Mostly of the works, which were analyzed for checking this approach had used the NDVI (Normalized Difference Vegetation Index) in order to get the result from above mentioned methods (Ramachandra 2004, Lunetta et al. 2006, Morawitz et al. 2006). In all these three research projects as a result the most relevant approach was *Image math*. This technique took into account the difference of

radiance values of pixels between two different NDVI images. One of the main advantages in using NDVI images is, that from the image was already excluded the difference in atmospheric condition, sensor calibration and moisture condition. Therefore this technique is better suited for such cases when changes in radiance in the object scene are larger compared to changes due to the other factors. In Lunetta et al. (2006) and Morawitz et al. (2006) projects were compared two methods: *Image math* and *Change vector*, the results had the same accuracy, which allows us to assume, that these two techniques give comparable results, while the change vector method is more time-consuming. In also needed to be mentioned, that for example in Ramachndra (2004) approach it was used additionally *FCC* (False Color Composite) technique in order to highlight the changes between two dates. This method gives only qualitative representation, but it allowed to obtain fast results in order to decide whether it is needed the further the analysis to be done or not.

To summaries the result, obtained from the unsupervised technique it is possible to say that these change detection methods, applied for NDVI image, allows the user to get fast and relevant result for the changed area. It is also reasonable before starting the analysis qualitatively visualize possible changes by using *FCC*.

2.2 Concept of Methodology

2.2.1 Study area

The case study area is mostly situated in the Gorduno municipality, on the south of Switzerland in the Canton Ticino (Fig.1)¹. This region covers an area of 9.22km². The municipality is located in the Bellinzona district, on the right bank of the Ticino river. Geography of the municipality consists mainly on the forested area (72 %), 7.0% of the territory is used for agricultural purposes, 2,7 % of the territory are rivers and lakes, 11,3 % of the area is unproductive land and the rest – 7 % is the urban zone (including roads and buildings) (FSO, 2011).

Out of the forest area, more than 97 % is the strong vegetation, and just about 3% of the territory is covered with the small vegetation types of trees. In the agricultural land, 62,5 % of the territory is mainly used for growing crops, where 37,5 % is used for alpine pastures. The urban zone has a bit more diverse representation, 43% of the urban zone are build up areas, with houses and buildings; 57 % of the rest area are roads and other transportation infrastructure.

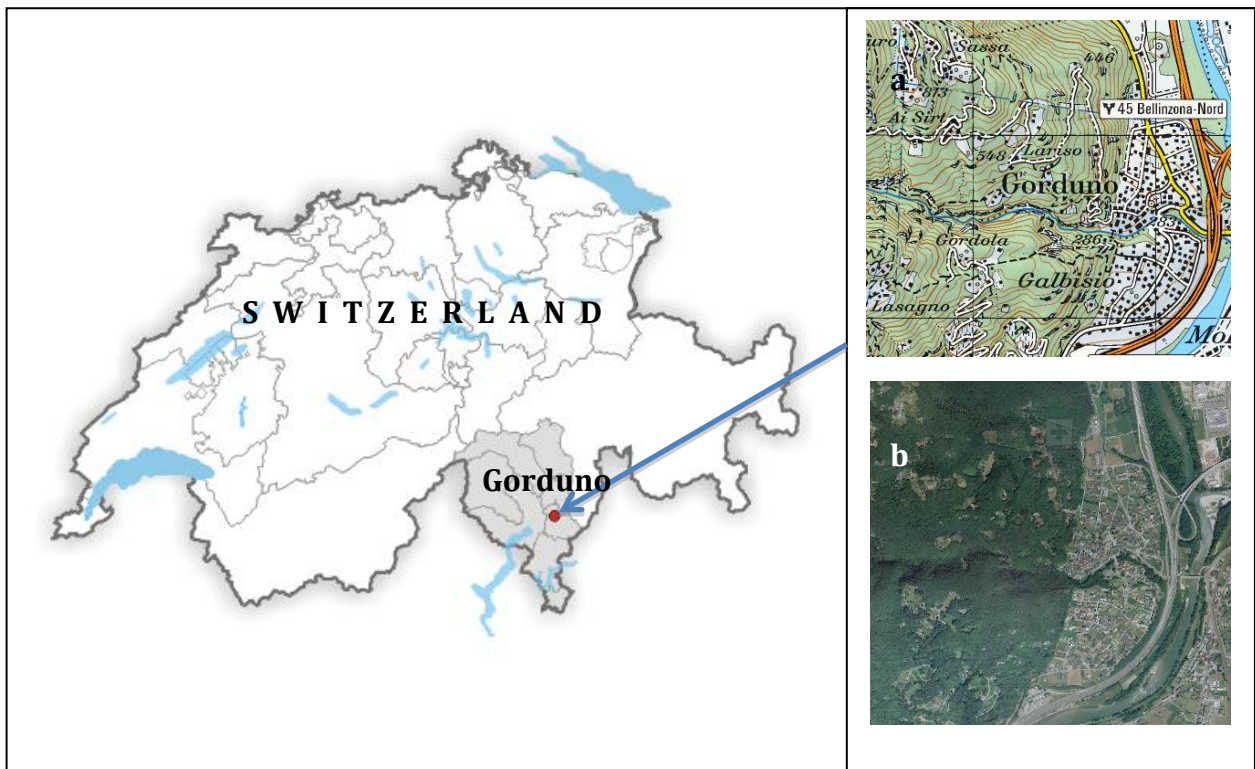


Figure 1: Study area- Gorduno municipality region, Canton Ticino, Switzerland (a- fragment from the map original scale 1: 50 000, b-fragment from satellite image, SPOT, original resolution 20 m)¹.

¹ <http://map.geo.admin.ch/>

2.2.2 Input Data

In the project were used two types of input data:

- Cartographic data;
- Remote Sensing data.

Cartographic data:

Topographic maps were produced by *swisstopo* and used as an input for the generation the cartographic approach analysis. The scale of input maps was 1: 50 000. Raster maps from the years: 1995 and 2006 were used in this project.

Additionally to the cartographic data some results from the first phase of the project were considered. The distances of 270/185/85 m from the closest building were identified as the areas including 90/70/60 % of the fire ignitions. These distances have been adopted for the buffer generation process in order to better analyze the changes of urban area.

Remote Sensing data:

In the first phase of the WUI-CH project the Remote Sensing (RS) information for 17 different satellite Landsat TM images was derived from USGS online archive of Landsat data for the years from 1984 to 2010. The advantage of having Landsat TM images is, that the satellite has the Thematic Mapper (TM) on board, which is a multi-spectral mechanically scanning optical imager operating in the visible and infrared ranges (Kramer, 2001). For our analysis are consider all the 7 bands representations of Landsat TM (Tab.1).

Table 1. Band specifications of Landsat TM bands (on the basis of Kramer 2001)

Band N	Wavelength (µm)	Spectral light	Pixel/ Ground resolution (m)
1	0,45 - 0,52	Blue	30
2	0,52 - 0,60	Green	30
3	0,63 - 0,69	Red	30
4	0,76 - 0,90	Near Infrared (NIR)	30
5	1,57 - 1,78	Shortwave infrared 1 (MIR1)	30
6	10,40 - 12,50	Thermal infrared	120
7	2,08 - 2,35	Shortwave infrared 2 (MIR2)	30

While analyzing the incoming data for the study area the number of satellite images was reduced, because of the cloud cover on the study area. Therefore two main satellite images for the following dates were selected: 09.07.1990 and 05.07.2003. All incoming data was pre-processed (geometric correction, radiometric calibration in *ERDAS Imagine* software). This step was very important, in order to establish more direct linkage between the data and biophysical phenomena, removal of data acquisition errors, image noise (Coppin et al., 2004).

Additionally to the Landsat Data from the first phase of the project in current work the calculated NDVI (Normalized Difference Vegetation Index) images for the study area for the same dates as Landsat images were used: 09.07.1990 and 05.07.2003. NDVI – is a simple quantitative measure of photosynthetically active biomass (usually called a vegetation index). This is one of the most common indices, which is used to solve problems using quantitative estimation of vegetation cover.

$$NDVI = (NIR-RED)/(NIR+RED) \quad [1]$$

, where

NIR – value of spectral reflectance in the near-infrared channel

RED - value of spectral reflectance in the red channel

According to this formula, the active biomass of vegetation (NDVI) at a certain point on the image is the difference of the spectral reflectance in the red and infrared channel, divided by the sum of their spectral reflectance. NDVI calculation is based on the two most stable (independent of other factors) sections of the spectral reflection curve of vascular plants. In the red spectral region (0.6-0.7 microns) the maximum absorption of solar radiation by the chlorophyll of higher vascular plants takes place. The infrared (0.7-1.0 microns) is the region of maximum reflection of the cellular structures of the leaves. This high photosynthetic activity (associated usually with dense vegetation) leads to less reflection in the red spectral channel and more in the infrared. The ratio of these parameters to each other can clearly distinguish the plant from other objects on the satellite image. Usage of the normalized difference between the minimum and the maximum of reflection not only increases the accuracy (in comparison with just using reflection on the red band), but also reduces the impact of such phenomena as differences of the light, between two images, clouds and haze, the absorption of radiation by the atmosphere, etc. The process of calculation NDVI was done for both images by using the same algorithm, which makes them comparable between each other.

2.2.3 Overview of Methodology

From above-mentioned literature review on related works it was considered to derive the most relevant approaches for the methodology. First of all in the current work two main approaches of analysis will be used: cartographic and remote sensing.

Cartographic approach:

Within the cartographic approach in order to apply two types of raster and vector analyses should be used three following steps:

- Georeferencing (will make the topographic maps comparable between each other spatially);
- Color separation (will separate the urban object on the map (houses, buildings, roads));
- Raster Cleaning (will create a raster layer only with houses and buildings object).

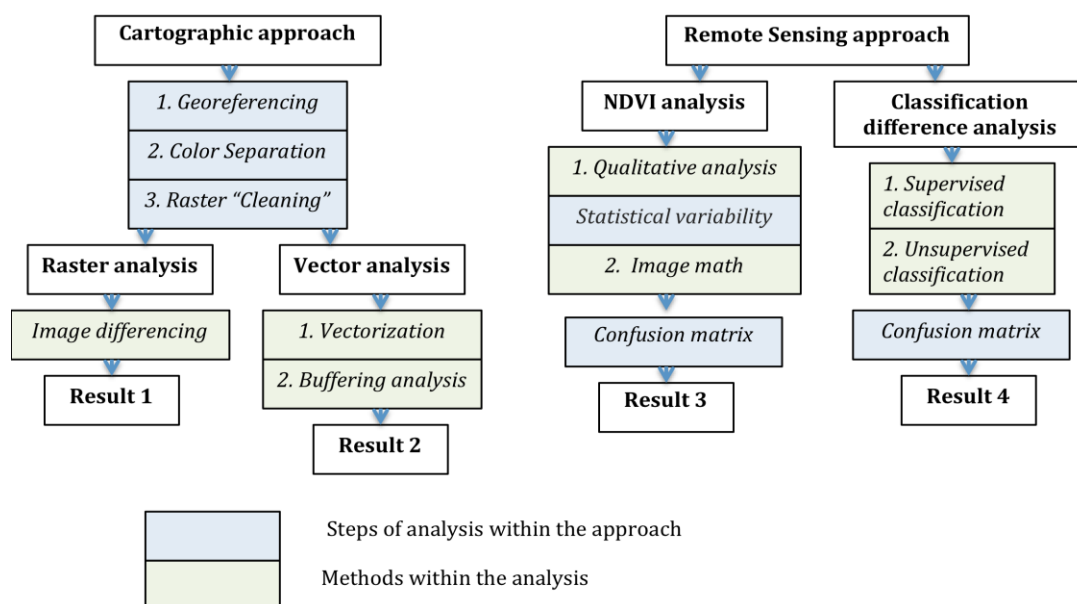
Further temporal investigations within cartographic approach will be done by using two different types of analysis: raster and vector. Raster analysis will be performed by using image differencing method, vector analysis will be divided into two steps: first- vectorization of raster map and second -buffering analyses in order to investigate the distance, where the new buildings were built.

Remote Sensing approach:

For Remote Sensing approach two types of change detection possibilities will be used (supervised and unsupervised). As incoming data for unsupervised approach NDVI images and for Supervised- resulted classified images will be used. Within the unsupervised approach will be done:

- qualitative analysis (*FCC* (False Color Composite) technique, which will visualize the changed areas);
- statistical variability (*PCA* (Principal Component Analysis), which will increase the results of further step);
- Image math (subtractive difference, in order to get the difference map).

For supervised approach two types of classifications will be used: supervised and unsupervised. The last step in both Remote Sensing approaches will be calculation of confusion matrix (error matrix) in order to verify the correctness of chosen methods.



last step will be the comparison and evaluation of the results in order to exploit them further for the mentioned purposes.

2.2.4 Software

In the project two types of software will mainly be used: Graphical and GIS software.

As a Graphical software *Adobe Photoshop CS4* (PS) and *Adobe Illustrator CS4* (AI) will be used. PS will be needed in order to implement the Color Separation method in the cartographic approach. AI will be used within all analysis to visualize the results (representation of the images), while this software includes a lot of functions for vector and raster editing.

As GIS software *ArcGIS* and *Erdas Imagine* will be mainly used. In *ArcGIS* analysis of the vector data, such as vectorization, buffering analysis will be mostly done. In *Erdas Imagine* software all types of analysis for the Remote Sensing approach will be done (all types of classification, qualitative analysis, calculation of PCA and Image math).

3. CARTOGRAPHIC APPROACH

3.1 Methodology of Cartographic Analysis

As incoming data for the cartographic approach there are two topographic maps from different years. There are two main approaches of further cartographic analysis: calculating the difference by using raster data or converting the data into vector format. Both of these types of analysis correspond to the cartographic approach. In order to implement these types of analysis different methods are used but the first 3 steps for both analyses are the same: Georeferencing the data, Color Separation and Raster Cleaning.

Georeferencing:

Georeferencing is needed to be done in order to be able obtain spatially comparable data for the further analysis. For this step the *ArcGIS Georeference* application is used. This application allows the user to manually detect the control points on the image and by giving the real coordinates to the chosen point to automatically align the target data. There is also the possibility to control the correctness of chosen point by looking at the RMS values (the total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error). This technique is adopted for both images. As the result there are two georeferenced (aligned) between each other images.

Color Separation:

Color Separation is the process of separating an image into a set of colors. This process can be done by using *Adobe Photoshop* software. The *Color Range* tool allows separating several different colors on the image in order to create the new file with just one color representation on it. In order to detect the urban zones it is needed to use the techniques for detecting the black color, because on the topographic map the urban zones (houses, buildings and roads) have the black color.

Raster Cleaning:

After Color separation and Georeferencing techniques the next step is an additional raster “cleaning”. This methodology is needed to be done in order to get the information layer only about only houses and buildings on the map. As a result this method excludes other “black colored” objects from the raster file (some classes of the roads and labels). This method can be implemented by using *Raster Cleaning tool* in *ArcGIS* software. This extension allows to keep the data georeferenced and at the same allows user to edit them. This step needs to be done manually in the program, to control the result. At the end of raster “cleaning” step there is a new raster file with only black colored buildings’ objects.

After the implementation of the three above-mentioned steps it is possible to get the two images, which are aligned within each other, and consists only with the data,

corresponding to the needs of the project. Next steps of analysis is strongly depending on the decision of converting the data into vector, or continuing with the raster representation.

Raster data approach:

The further step for raster data approach is the Image Differencing. After Raster cleaning the resulting images are binary files. This let the user to use the application in *ArcGIS* software- *Map Algebra*, which will evaluate the difference between two images. The new calculated values for each pixel will represent the changing parameter. The binary file will correspond to the changing parameters, where “1” will be equal “no change” and “0” will be equal “changes”.

Vector data approach:

Vector data approach consists of following steps:

- vectorization of raster layer;
- buffering of changed zones.

Vectorization:

Vectorization process can be done by using *ArcScan* tool in *ArcGIS* software. This is an automatic type of vectorization, which can involve a series of procedures to achieve an acceptable raster-to-vector conversion (ESRI, 2011a). *ArcScan* supports two types of vectorization methods in automatic mode: centerline and outline. The centerline vectorization method allows the generation of vector line features at the center of the raster cells, while the outline vectorization method allows the generation of vector polygon features at the borders of the raster cells. The centerline vectorization method is the most common type and easiest type in implementing, because it requires less incoming parameters (ESRI, 2011a). *ArcScan* also supports tools that allow vectorizing a user-defined portion of the raster. This provides flexibility in such cases where it is needed to convert a certain area of the raster. Automatic vectorization process in *ArcGIS* has several parameters, which have to be defined before creating the layer. There is also a possibility to choose the cell selection tools and use them together with the Generate Features command to vectorize only the currently selected raster cells (ESRI, 2011a). After defining the vectorization type the process of automatic creation of vector layer with all the polygons can be realized.

Buffering:

After creating the vector file where each object has an attribute (unique ID number), the next approach can be creating the buffering zones of changes. This can be easily implemented in any GIS software. The result of this step will be investigated distances, where the new buildings were built.

3.2 Implementation of the Methods

Georeferencing:

Georeferencing in the project was done by using *ArcGIS Georeference Toolbar* application. First of all control points for both raster images were detected. The control points were used to build a polynomial transformation that will convert the raster dataset from its existing location to the spatially correct location. The connection between one control point on the raster dataset (the from point) and the corresponding control point on the aligned target data (the to point) is a link which allows the user to see, how the map will be modified. After defining the control points the mathematical equation of the first-order transformation was used, after this step each raster point was exactly mapped to the target location.

While using georeferencing tool Nearest neighbor assignment has been chosen. Nearest neighbor assignment is the fastest resampling technique and is appropriate for categorical or thematic data, since it does not alter the value of the input cells (ESRI, 2011d). Once the location of the cell's center on the output raster dataset is located on the input raster, nearest neighbor assignment determines the location of the closest cell center on the input raster and assigns the value of that cell to the cell on the output raster. The next step was to update the georeferencing, afterward as a result we have two raster images, which are georeferenced between each other.

Color Separation:

On the cartographic maps the buildings (the main target of the urban areas) have the black color; the choice of the technique for the color separation step was mainly depending from the chosen color. The process of color separation was done in *Adobe Photoshop CS4* software, by using the adjustment tools of the program. There are three main techniques in order to extract the black color, but the first step in all three possibilities is the same. It is needed to transfer the input raster data from RGB color model to CMYK by using the following steps: *Image - Mode - CMYK Color* (Fig.2). As a result the image in the CMYK Color mode will give the possibility of further process.

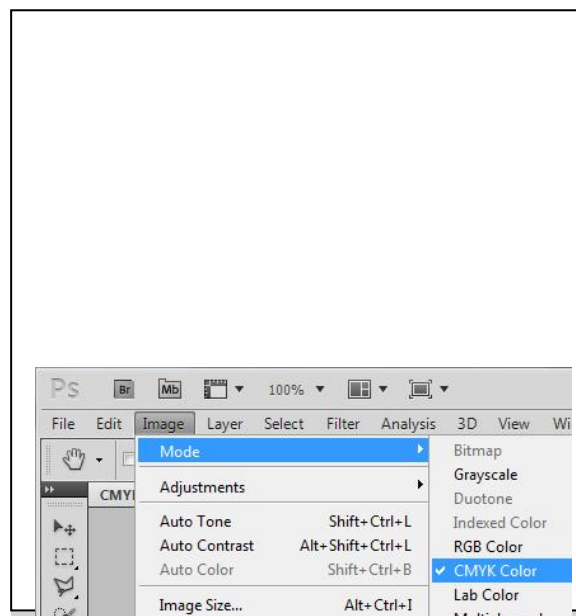


Figure 2: Steps of converting RGB mode of the image into CMYK mode

The first possibility to separate the black color consists in using the *Color Range* command. This function allows the selection of a specified color or color range within an existing selection or an entire image by using the *Eyedropper pointer* and selecting the objects (color) of interests. As the result of this step all the black colored object were detected and separated from the cartographic map.

Second possibility in using the approach, is based also on *Color Range* command. The main difference is, that the current approach uses the color separation for all colors, except black. After extracting each colors one by another one, the resulted image consists only of the black-colored objects.

The third approach is based on the *Calculation* function. While implementing this step is creating the mask for this layer. Afterwards by adding the blending option, changing the opacity, offset and scale of the new document the following mask consists only with the black color can be created.

All three above mentioned methods have been given the same results, therefore were decided to use the first one, as it is the fastest way in detecting the color and still efficient (Fig.3).

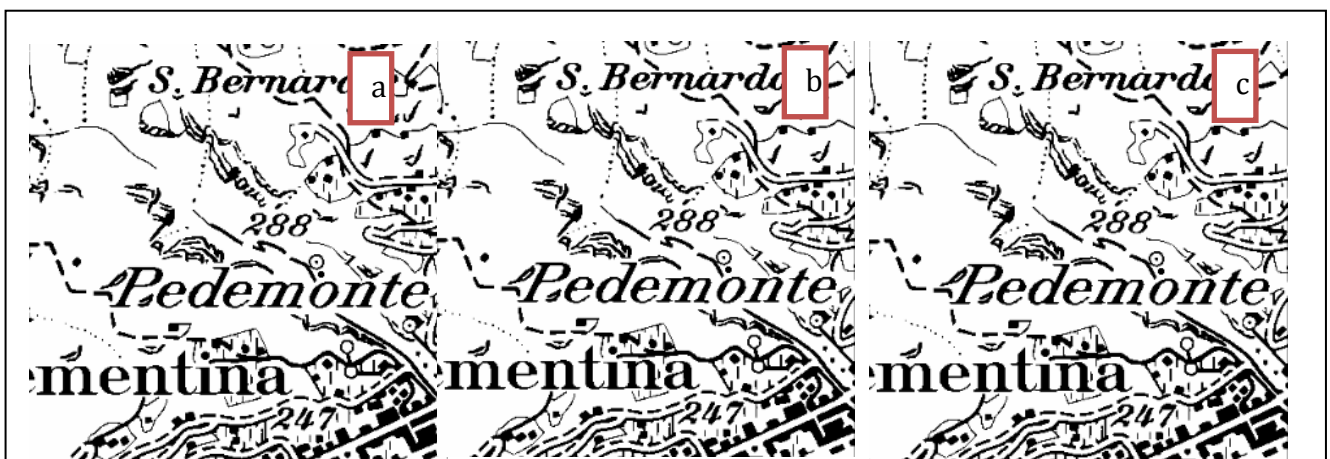


Figure 3: Results of color separation methods: a- Color Range, b- CMYK separation, c- CMYK separation (2)

The first steps of color separation method let visually detect the changes in urban area (Fig.4). From the following comparison of two fragments of the maps (for the year 1995 and 2006) we can obtain the areas (red circles), where the new buildings are detected. This kind of visual analysis gives an opportunity to talk about the reason of further analysis of temporal changes.

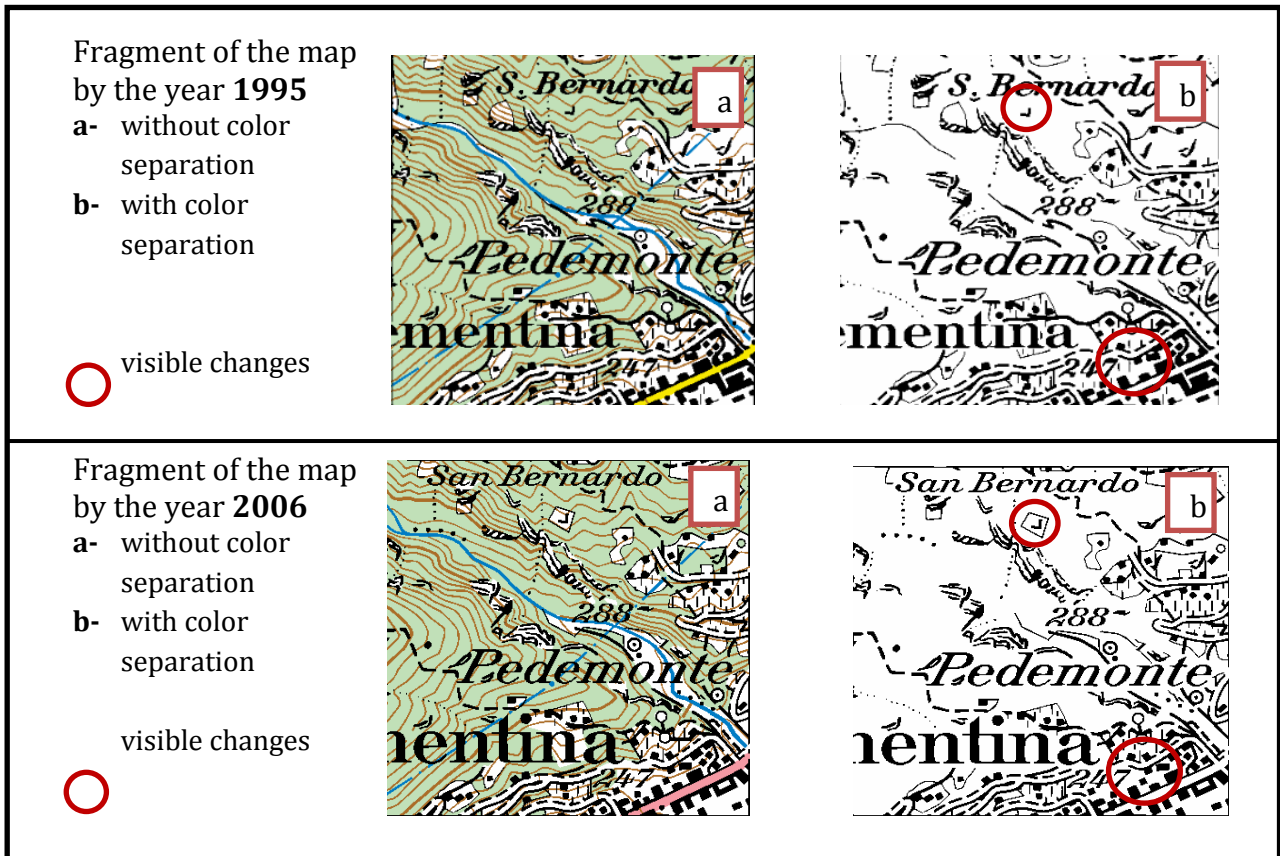


Figure 4: Visible changes after using Color Range Separation method

Raster Cleaning:

Raster cleaning process was done with *ArcGIS* software with *Raster Cleaning* tool in order to working with georeferenced data.

ArcGIS software allows the user to do a raster cleaning step automatically, but apparently while using this tool some problems were appeared. The automatic algorithm detects the font for urban zones. This class of features includes roads and buildings as the same feature type and merge them, therefore it is hard afterwards to distinguish the difference between both of them. Also the layer with the labels (detected after color separation method, because they also had black color) was impossible to separate from the buildings, for example the letter “i” (Fig.5).



Figure 5: Problems, which occurred during automatic raster cleaning (a- representation of the letter "i"; b- bold lines and the buildings)

Therefore in order to avoid this problem it was decided to use manually *Cleaning Raster* tool in *ArcScan* application, which allowed us to create two raster files where only the buildings' objects were presented (Fig.6). Both created files are binary files, which allows further analysis.

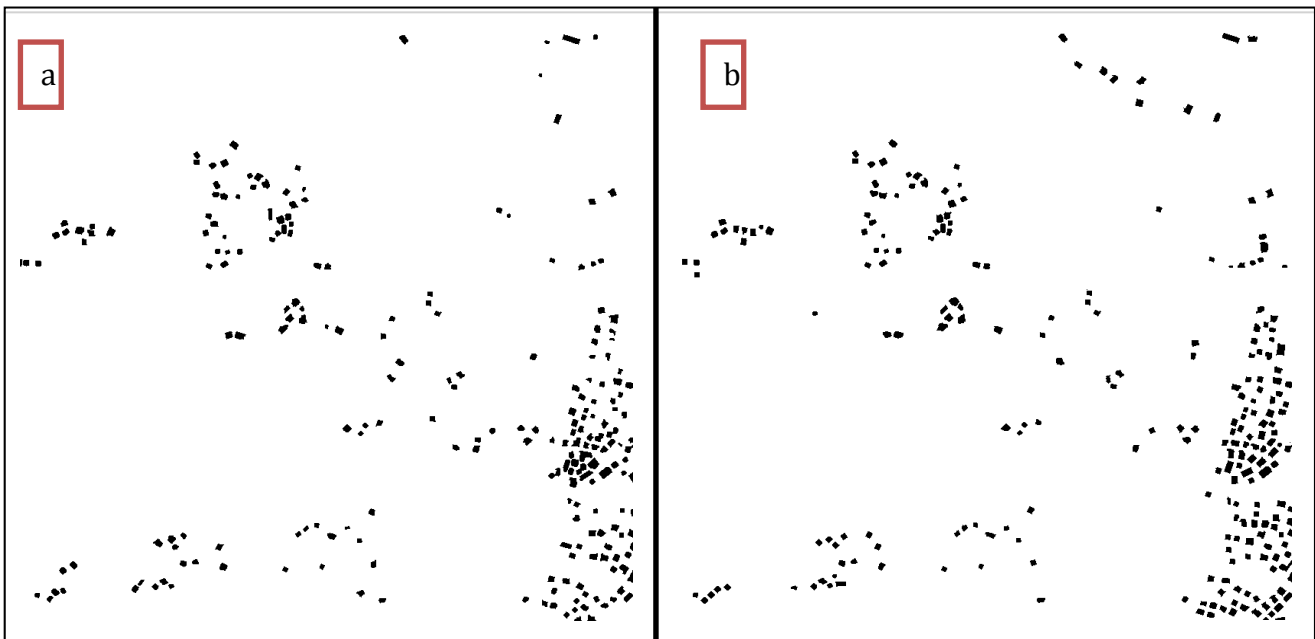


Figure 6: Representation of two raster files with only buildings structure (a- for the year 1995, b- for the year 2006)

The Raster Data Approach was implemented by using *ARC GIS* software. Therefore in the *Spatial analyst* tool *Map Algebra* application was used, which let us manipulate the raster data. The main idea was to calculate the new value for each pixel, which at the end represented the changed areas. The Raster Calculator equation was represented in the following form: "2006 = 1995" and returns 1 if the two cells are

equal and 0 if they are not. This image then showed all the areas where category "1" (green) were the same for both years and "0" (red), where it was different (Fig.7).

While implementing this step some problems had occurred. The image difference algorithm was strongly dependent from the incoming data. The main question, which occurred after analysis of the result, was if the previous step of georeferencing had been done right. The reason of this doubt were the extra small areas, next to already existing buildings, which were detected as a new one's repeated the form of the houses (Fig.8).

Therefore the georeferencing step was checked again in order to avoid these mistakes. But the resulted image had the same representation. Thereby it is possible to say that one of the changes between two maps is also the change of the symbol on the map for the buildings representation.

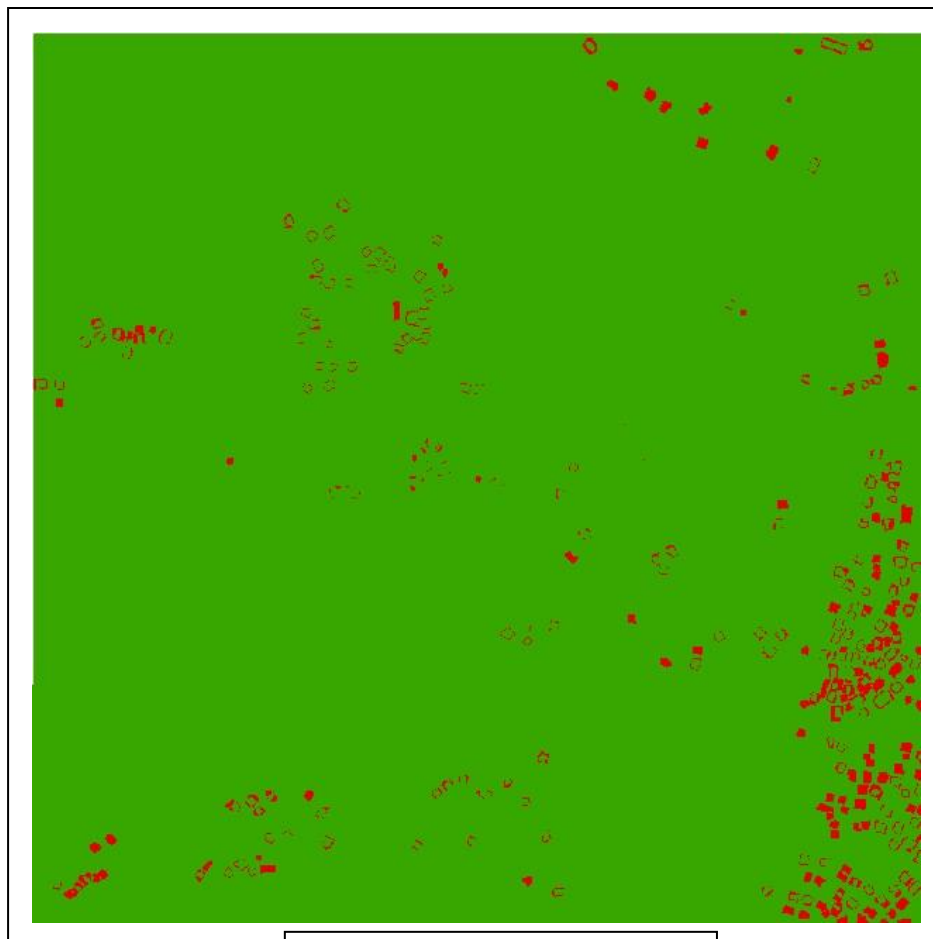


Figure 7: Representation of Raster Data



Figure 8: Representation of the "extra" areas next to existing buildings

3.2.2 Vector Data Approach

The first step in vector data approach was to “prepare” the raster image for the further edits, this was necessary in order to process the data with the *ArcScan* extension of ArcGIS. First of all according to the new parameters of the *ArcScan* extension the vectorization is only possible if it is using .tiff, .img or .grid formats. Therefore after color separation the next step was to convert the file into .img (Erdas Imagine) format. This procedure was made in *FME Desktop SP4* software, where our incoming cartographic map was georeferenced into following coordinate system: CH1903 LV03.

Once the file was prepared the next step was to ensure that the raster’s layer symbology displays as two colors. The *ArcScan* toolbar becomes active once the symbology is changed. This is required since *ArcScan* only supports binary raster imagery. *ArcScan* supports any two colors so long as they are unique colors with unique color values. Therefore the *Unique Values Rendering* option was used to display the raster as two unique colors.

ArcScan supports two types of vectorization methods. In the project it was decided to use centerline vectorization method, therefore the next step was to choose the parameters of vectorization tools. With vectorization settings it is possible to control the intersections and number of vertices (which are used to construct a line feature). Additionally it is possible to control the smoothing, which could be applied to the lines as well as whether to close gaps or not. Vectorization settings apply to both raster tracing and automatic vectorization. The vectorization settings can be entered and applied through the Vectorization Settings dialog box (Tab.2). Vectorization settings consist of the following parameters, which could be changed (ESRI, 2011b):

Table 2. Parameters of vectorization settings in *ArcScan* extension (quoted from ESRI, 2011b)

Intersection Solution setting	There are three different types: Geometrical, Median, and None. The Geometric intersection - preserve angles and straight lines. The Median intersection works with nonrectilinear angles. The None intersection is designed for rasters that have
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		nonintersection features.
Maximum Line Width setting		It is possible to specify the width of the linear elements, which will be used for raster tracing. All the lines, which have a width less than or equal to the maximum line width value will be eligible for centerline vectorization. All other raster linear elements will be vectorized as polygon.
Compression Tolerance setting		Reduces the number of vertices of line features that are generated during the vectorization process. The Compression Tolerance value represents an intensity level of the generalization.
Smoothing Weight setting		Smooths the line features that are generated during the vectorization process.
Gap Closure Tolerance setting		The cells that represent lines in the raster may contain gaps. The gap closure tolerance is a distance in pixels that is used to jump over breaks in a raster line.
Fan Angle setting		Is used for the curved and gaps contained lines. Allows to search for raster lines when jumping over gaps.
Resolve Corners setting		Determines how ArcScan will deal with the corners, because in some moments the resolution of corners may not be as important as recognizing and defining sharp corner features in parcel maps.
Styles command		Provides the ability of retaining the settings. It is also possible to create new styles for various types of rasters.

After editing the parameters the automatic vectorization was performed. The final step in the automatic vectorization process was the generation of vector features. According to the needs of the project two main tools were chosen: *Generate Features Inside Area* and *Outline* tool (ESRI, 2011c). As a result it allowed interactively drawing a polygon shape on the map that is used to define the area inside. Once this procedure was done the shape file with the polygons were created.

Next step in Vector data approach was a buffering analysis. In the project this analysis was done by using *ArcGIS Buffering* tool. The buffering areas were chosen the same as for the first phase of the WUI-CH project in order to obtain the same comparable results. Therefore were chosen following distances: 85, 185 and 270 m.

Therefore three buffering zones were created around vectorized buildings' polygons. As a result it can be recognized of the image, that the majority of the new buildings were built in the radius of 270 meters in comparison with 185 m (Fig.9).

Additionally one more buffering analysis was done, within the 85m zone for both years. The result it illustrates the areas, where the new buildings were appeared and also the areas, where the buildings are not existing anymore (Fig.10).

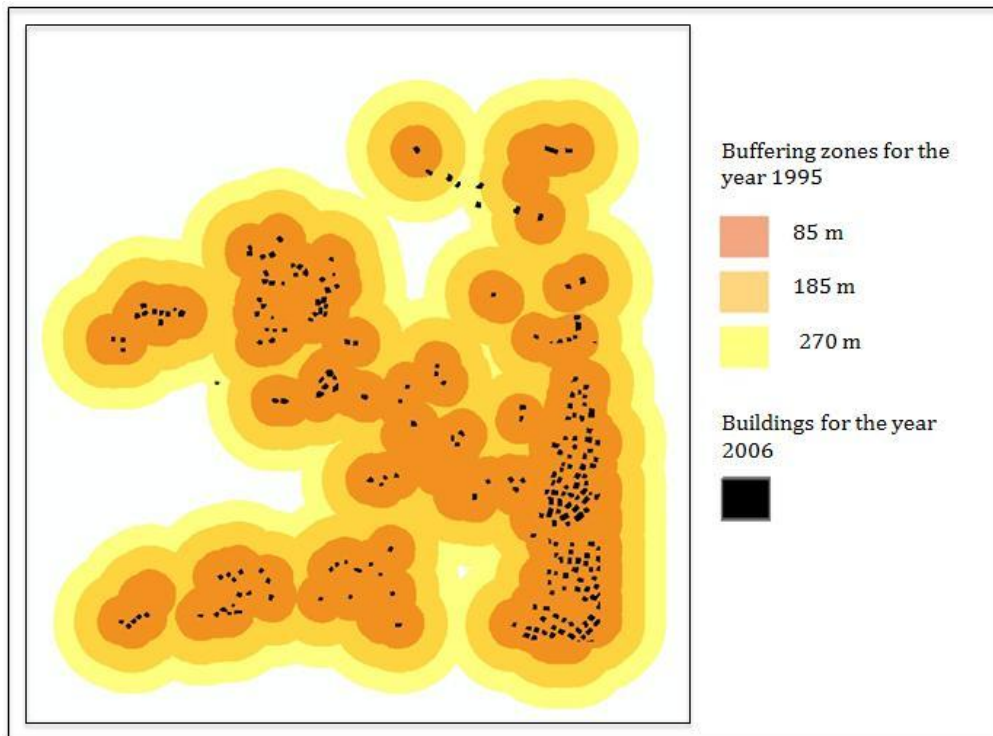


Figure 9: Buffering zones for the year 1995 around buildings for the year 2006

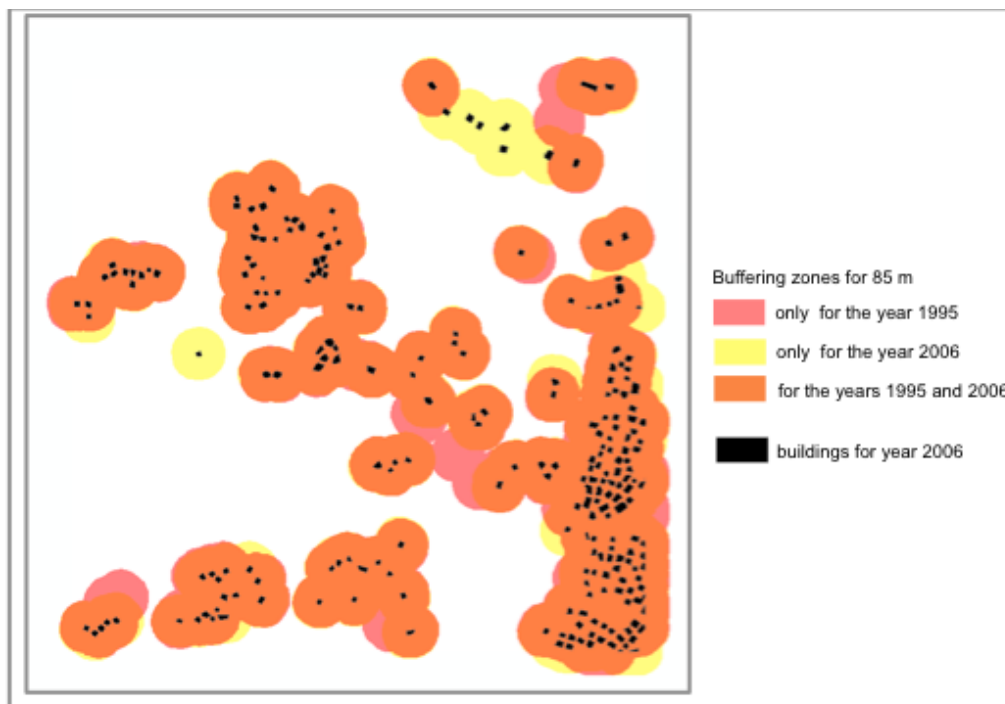


Figure 10: Buffering zones for both years 1995 and 2006 within 85m zone

3.3 Evaluation of Chosen Methods

To conclude about the results of cartographic approach it would be easier to separate them into two parts. The first part would be pre-processing, which includes: georeferencing, color separation and raster cleaning; the second part will be evaluation of the two approaches: raster and vector.

The need to separate the results into two parts is, that the first part leads to a lot of consequences, which might interfere to the future steps. The pre-processing step has first of all one big disadvantage: it is time-consuming. The georeferencing and color separation is not that time dependent, while for the manual raster cleaning a lot of time is needed. Therefore in the project it was decided to decrease the area of interests in order to obtain the results for the further steps. However the implementation of this pre-processing steps allowed us to achieve good results later. Georeferencing-allowed us to spatially compare the results. The color separation- gave us an opportunity to obtain the results only for urban zones and raster cleaning gave the information only about buildings.

The results of the second part of cartographic approach can represent relevant information about the changes in build up area from the year 1995 to 2006. Using raster approach is was possible to visualize the new build-up areas. This type of analysis was very fast and efficient in implementation, which can be very useful for the further steps of the WUI-CH project. The vector approach allowed us to do some analysis, based on the input data. The results let us distinguish not only the distances, where most of the new buildings were built, but also realized the areas, where some buildings are not existing any more. There are several possibilities, why these buildings do not exist anymore. The first possibility is, that the old buildings just could be rebuilt. The second possibility is, that there might be a mistake while implementing the raster cleaning step, where the buildings were recognized wrongly and were deleted.

Therefore it can be said, that the cartographic approach gives relevant results in the visualization of changed objects and gives an opportunity to do the simple analysis with the data.

4. REMOTE SENSING APPROACH

As it was described above, there are two main types of analysis in order to detect temporal changes: supervised and unsupervised change detection techniques. For our project was decided to use as an input data for unsupervised methodology NDVI images and for supervised- classified Satellite Landast TM images.

4.1 Implementation of the Methods

4.1.1 NDVI

NDVI differencing technique was used to analyze the amount of change in vegetation (green) versus non-vegetation (non-green) with the two temporal data. In the present work two main possibilities of NDVI analysis were applied: qualitative and Image math.

- *Qualitative visualization (False Color Composite, FCC):* This method allows to visualize the difference between two images. The result is the colored image, where each color reflects the difference in NDVI values;
- *Image math:* This method reflects the analysis of change, which simply subtract one image from the other and report the differences.

Qualitative visualization (False Color Composite, FCC):

In order to perform the results of qualitative visualization all analysis was done in *ERDAS Imagine* software. In the viewer a three band image was added, afterwards by modifying the raster's band combinations for the red band the oldest NDVI file, for the blue and green bands- the newest NDVI image was selected. As the "old" NDVI file in the project the satellite image with the NDVI values by the year 1990 and as the new NDVI image- by the year 2003 was selected. This 2 images difference allows us to discuss possible changes in the vegetation and non-vegetation areas on the satellite image.

As the result the unchanging areas were presented as a gray and grayish color; reddish tinted items are the areas, which have changed with higher values in the old NDVI and blue or cyan tinted areas changed with higher values in the new NDVI (Fig. 11).

Analysis of the qualitative visualization can show that there are several changes in pre- Alpine region in urban zones. The advantage of this method is, that it allows fast and efficient visible analysis of the results, but the disadvantage is that there is no statistical information in order to calculate the changes. Therefore was decided to use the further method to complete the analysis.

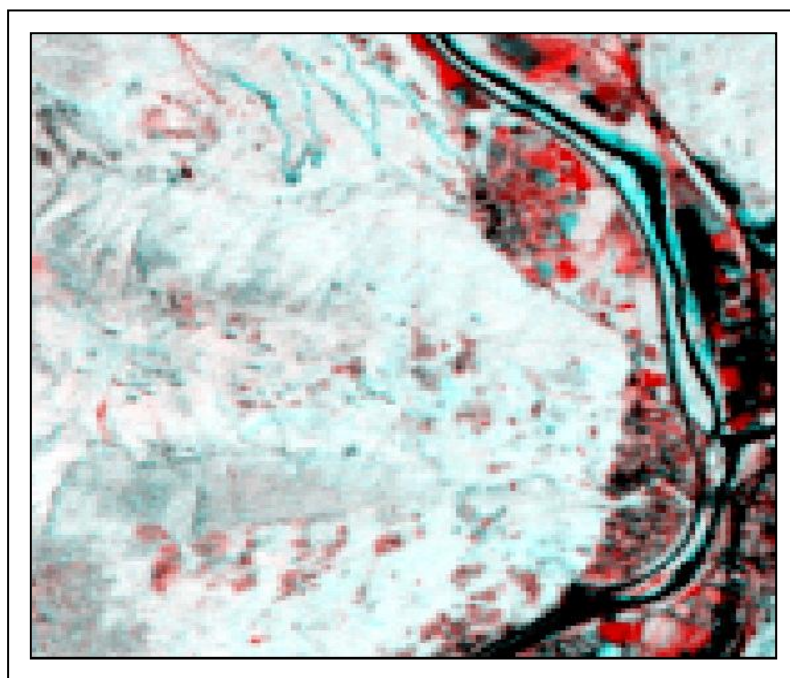


Figure 11: Representation of qualitative analysis (FCC)

Image math:

In order to implement this method, the first step, which has to be done is calculating statistical variability (*Principle component analysis*). Principal Components Analysis (PCA) is a spectral enhancement, which is used for compression the content of a multispectral data (Sabins, 1997). It uses different mathematical algorithms in order to convert m bands of correlated data into m principal components, which are not correlated. The first principal component defines most of the variation of the brightness values for the pixels of the original bands (Jensen, 2005) (Fig. 12).

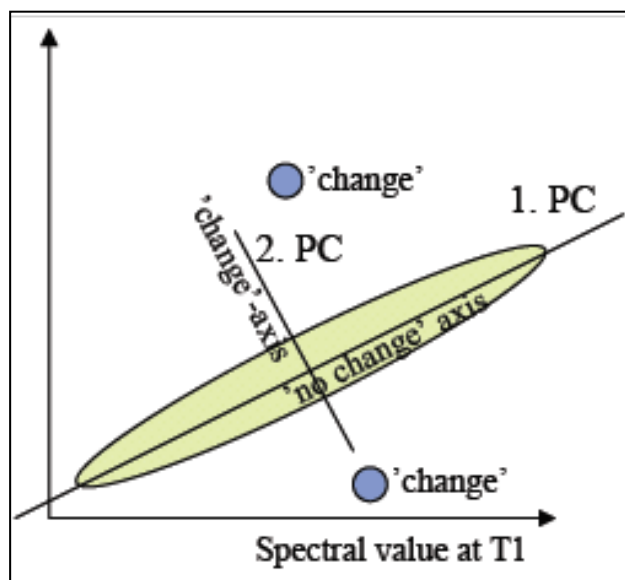


Figure 12: Principle Component Analysis

The main benefit of principal components analysis is that it reduces the amount of data (bands) without losing much of the information and typically reducing redundancy (Jensen, 2005). After running a principal components analysis on the given NDVI bands the majority of the information contained within the bands would be explained by PC-1. Thus, this one layer of data replaced the two original bands without much loss of information. This allowed to reduce the number of layers from two to one with minimal loss of information.

In order to implement PCA *ERDAS Imagine* software was used. The first step was “*Layerstack*” of two NDVI images. Therefore by using Model Maker extension tool of the Spatial Modeler the model was presented (Fig.13). After implementing the model, in the result file we have an image with two corresponding layers. The next step was computing the Principle Component Analysis by using *Spectral Analysis* function in ERDAS Imagine. After running the process an image was created, where areas that have light red value have not been changed dark red values are the areas, which have been changed with the higher values in the old NDVI and Blue or Cyan tinted areas changed with higher values in the new NDVI (Fig. 14). The result of the enhancement is comparable with the FCC result. This allows us to say, that the enhancement has been done correctly.

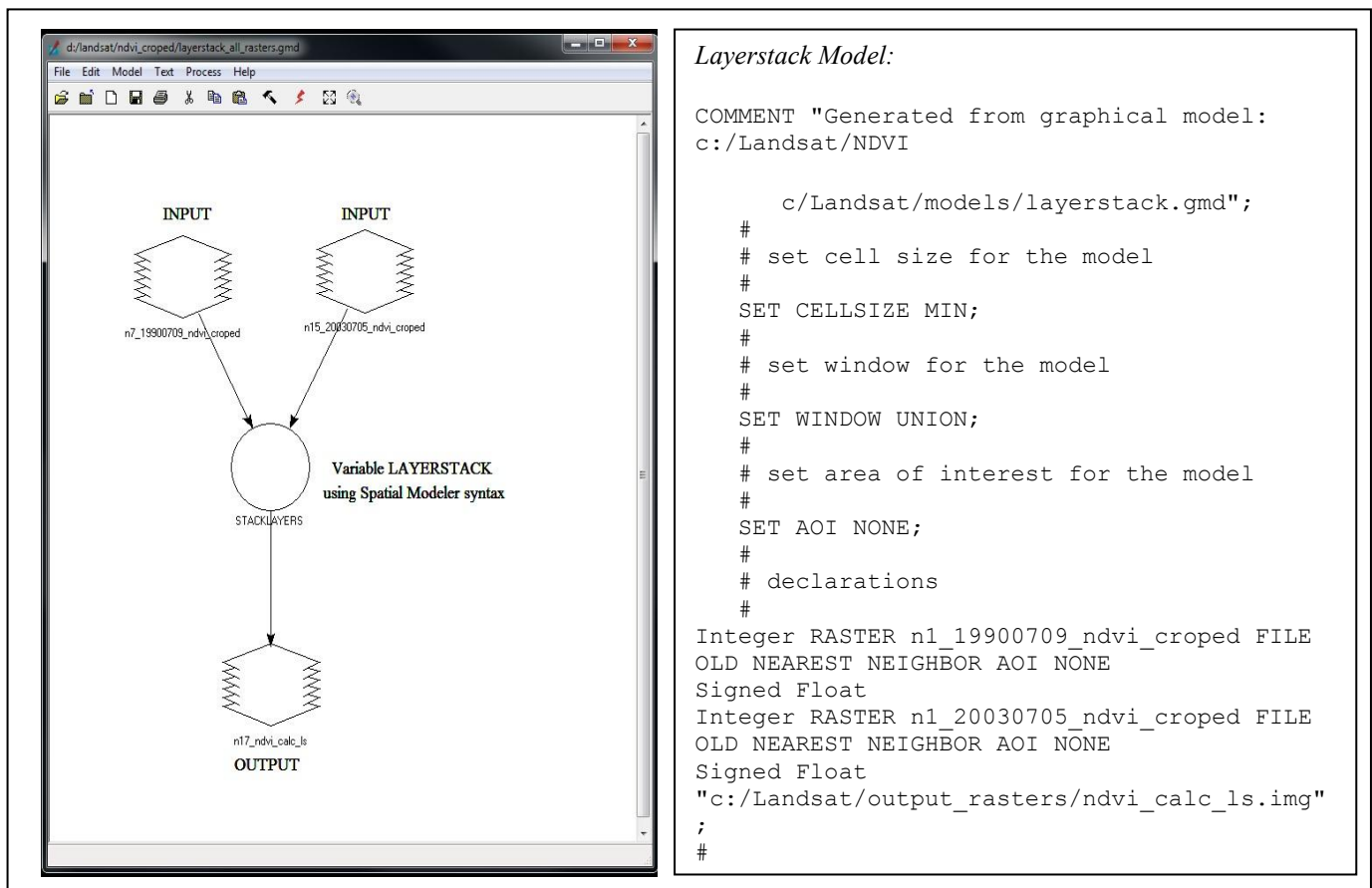


Figure 13: Representation of the "Layerstack model" (left) and the code of the model (right)

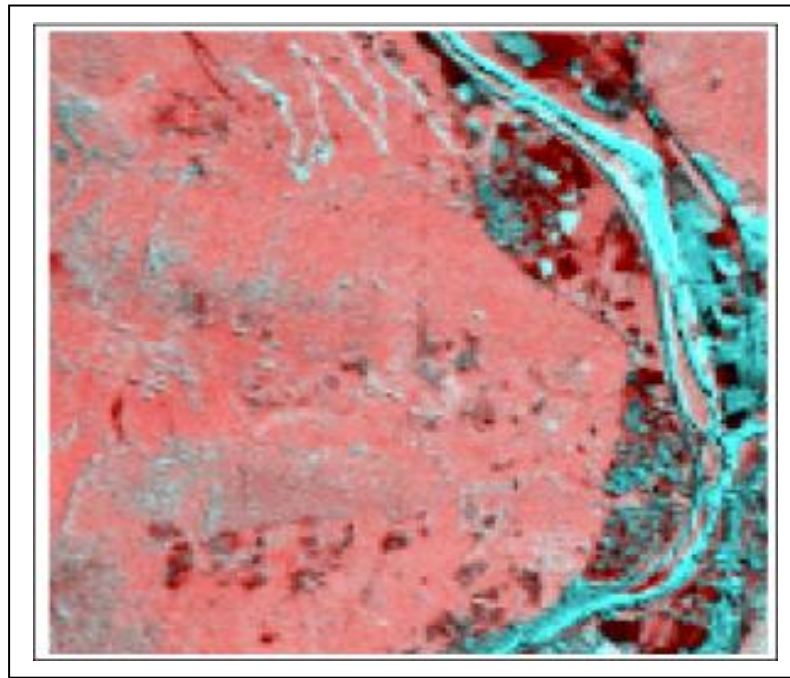


Figure 14: Representation of Principle Component Analysis (PCA)

After applying the enhancement for the images, was done the second analysis of the data: *Image math*. This method calculates the difference between two images. This analysis was done by using *ERDAS Imagine* software.

The difference can be represented in the following equation:

$$DNDVI = (NIR-R)/(NIR+R)_{t1} - (NIR-R)/(NIR+R)_{t2} \quad [2]$$

, where

t1 and t2 in the equation denote the two different dates, where t1 is for the year 2003 and t2 for 1990.

This technique takes into account the difference of NDVI values of pixels between two different dates. Differences in atmospheric condition, differences in sensor calibration, moisture condition, illumination condition also affect the radiance of the pixels. Frequency analysis of the image show that the pixels with the changes are found in the tails of the distribution while non-radiance change pixels tend to be grouped around the mean (Fig.15). This method allowed us to calculate all possible changes, which had happen on this territory, including changes in vegetation and agriculture. Therefore for the further analysis it was decided to find the threshold for the build-up area in order to distinguish the changed area only for this class. For this purpose the created georeferenced maps for the cartographic approach were used. After evaluation of this method it was possible to get statistical information about the changes difference between two dates. In the following table the values of the area, where the value of NDVI was increased and decreased are presented (Tab. 3).

Table 3. Changes between two NDVI images

	Area (ha)	Area (%)
Area in total	21734,4 ha	100 %
Decreased NDVI	291,33 ha	1,34 %
Increased NDVI	325,89 ha	1,49 %
Total change	617,22 ha	2,83 %

The process of distinguishing the threshold of the build up area was done in *ArcGIS* software. The first step was to overlap two images (one with the map representation, another one- NDVI values). The next step was manually reclassifying the NDVI values in order to visualize just two types of classes: build-up and others (Fig. 16).

As a result for each image was found the value of the threshold, the difference in values between two years was not very high, therefore it was possible to assume, that the general threshold for the build-up area is within this interval: 0.3-0.62 μ m. The lower and the higher values belongs to the class “others”, which in the reality represent the water bodies and different types of vegetation and agriculture.

Afterward by using the same Image math analysis the map of difference was created only for the class of build- up area (Fig. 17).

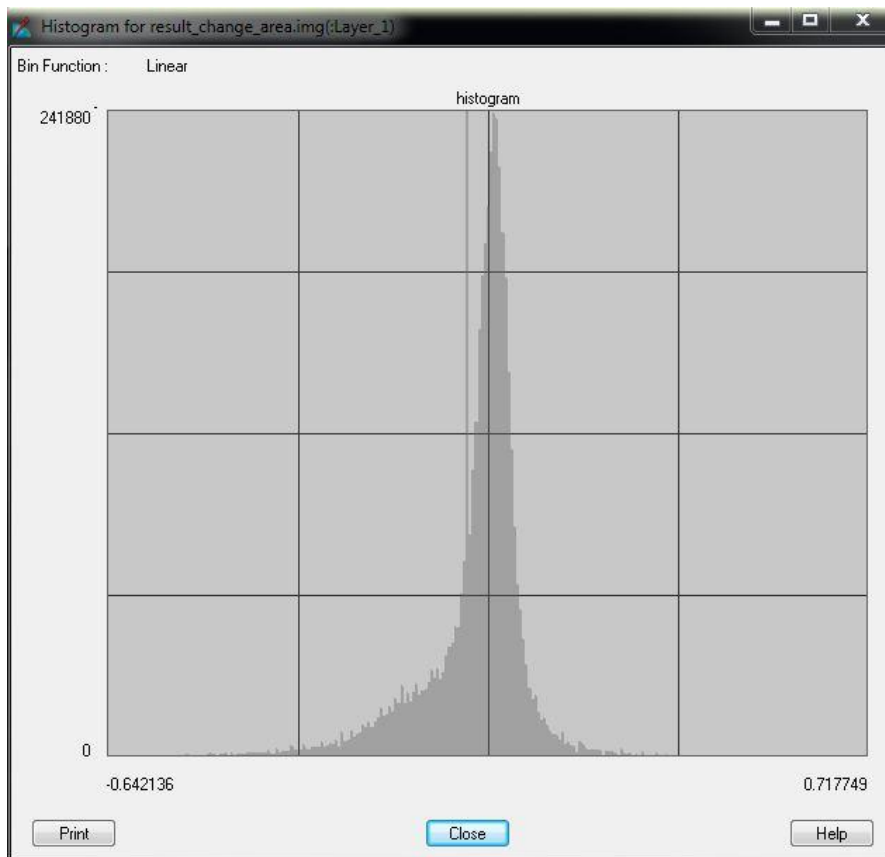


Figure 15: Histogram of distribution of the radiance values for NDVI image for the year 1990

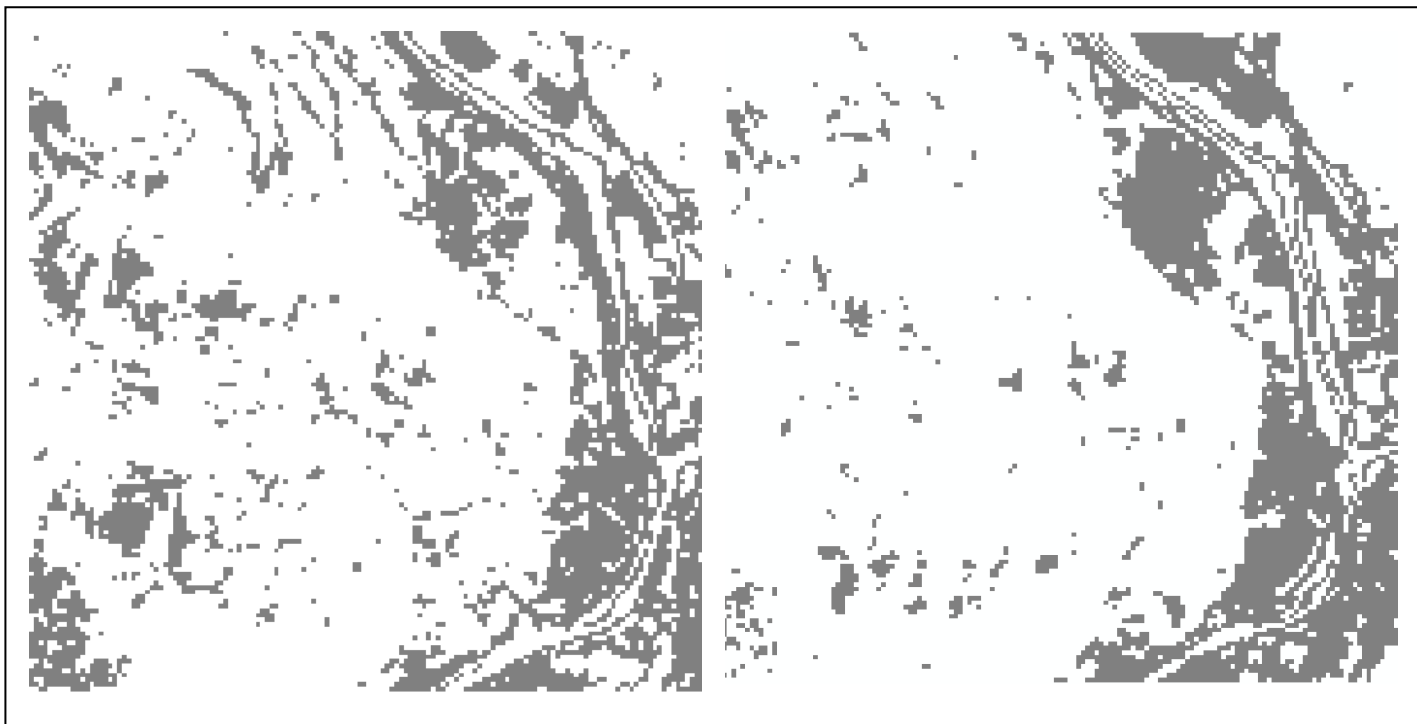


Figure 16: Representation of the threshold value classification for the build-up area (left- for the year 1990, right- for the year 2003)

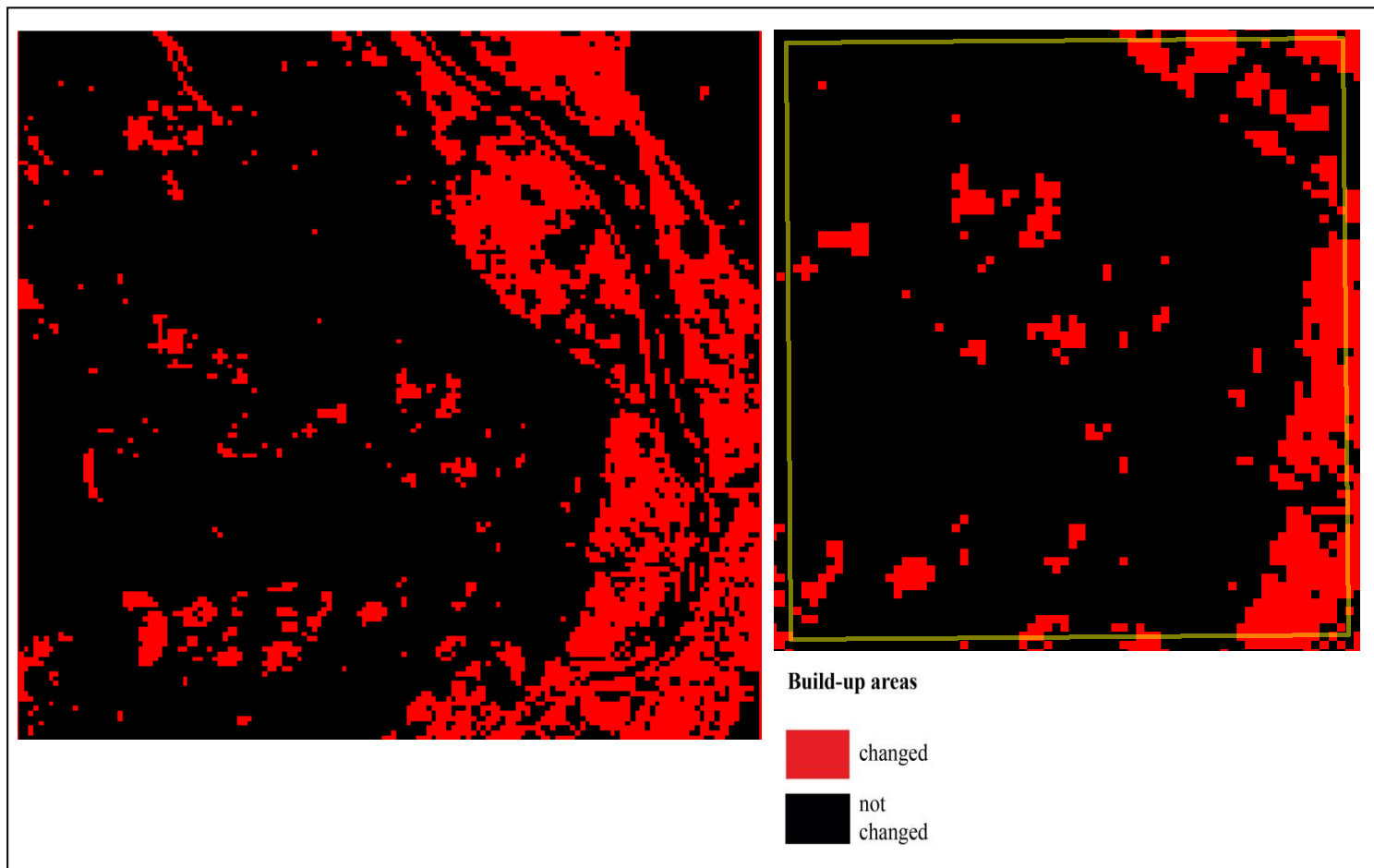


Figure 17: Representation of the changes in the build-up area for the fragment of the whole image left and for the study area- right

4.1.2 Classification Differencing

As an supervised approach was chosen Classification Difference method (or Post-classification). In the project was decided to implement two types of classifications in order to find the most relevant for detecting temporal changes. Therefore further analysis will be divided into two parts: evaluation of supervised classification and evaluation of unsupervised classification. Representation of analysis was done in *ERDAS Imagine* software by using 7 bands of Landsat TM satellite images.

Supervised classification.

Supervised classification analysis consisted of several steps. First of all is was needed to define the categories of classes, which could be detected on image. After analysis were decided to use six main types of classes: water and shaded areas, strong vegetation, vegetation, agriculture, build-up area and soil. The next step was creating the training data (signature file). This file would allow the computer to find the pixel corresponding to each class (within the area of interest (AOI)). These areas of interests were used further as a training samples to categorize the image and combine the pixels with the same reflectance characteristics into one class. Defining the training data allowed the *Signature editor* tool in *ERDAS Imagine* software to create the ground truth classes, it was also possible to analyze the signatures, which were created by using *Signature plots* tool in order to control the chosen clusters (Fig. 18).

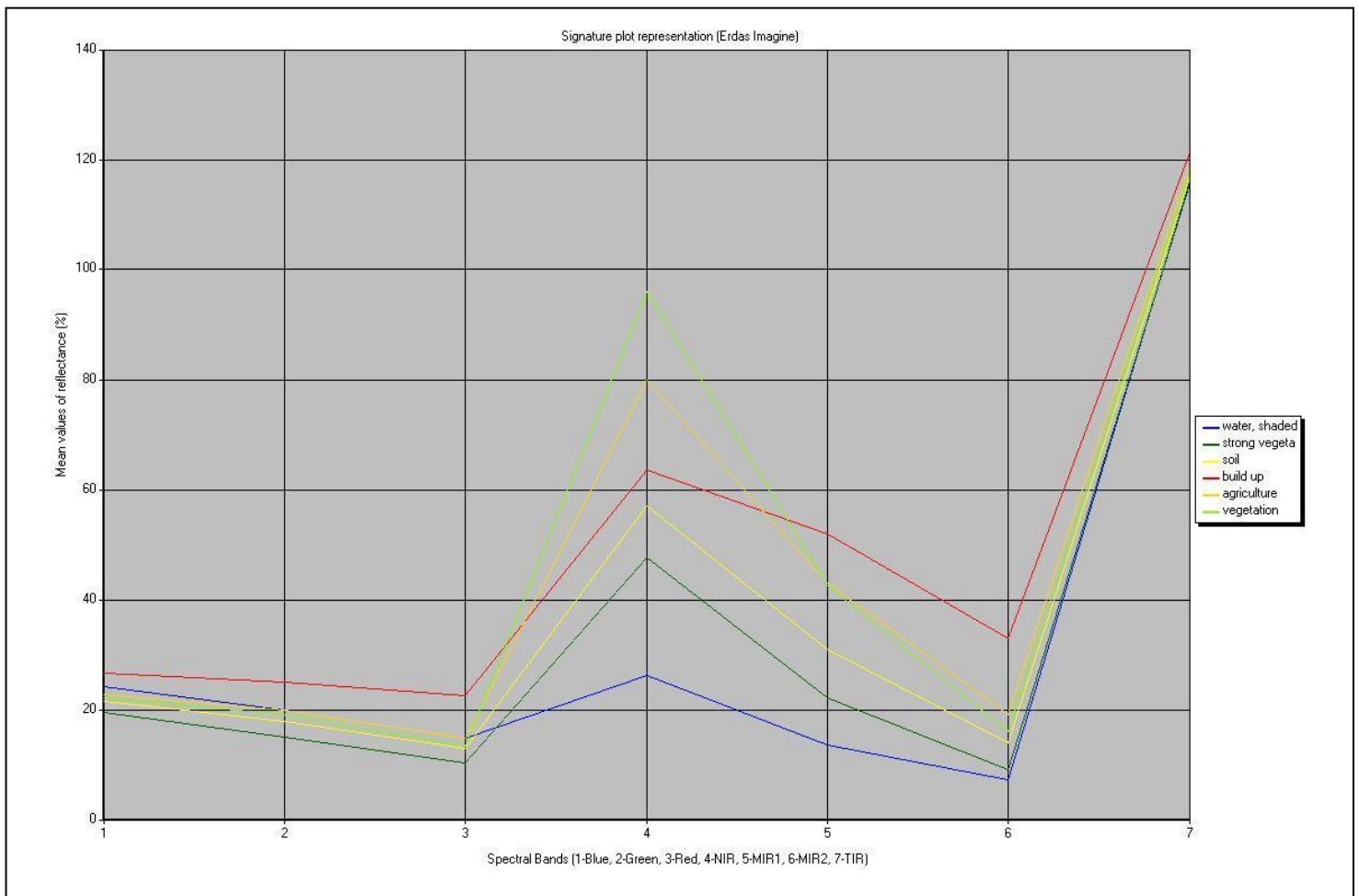


Figure 18: Result of signature plots by using supervised classification

It is clear from these plots that most of the signatures are different from each other over the 7 bands, even though some are close-spaced over intervals.

The next step was the realization of supervised classification, for this purpose Maximum likelihood supervised classifier (MLC) was used. Based on statistics (mean; variance/covariance), a (Bayesian) Probability Function was used to distinguish the new classes based on the inputs of training sites (signatures). Each pixel had then been assigned as to the class to which it most probably belongs. The result estimated the number of pixels and area for each class with the following statistics (Tab. 4).

Table 4. Value for the areas after supervised classification (ha)

Categories of classes	1990	2003
Water and the shaded areas	56,16	44,55
Soil	221,94	240,57
Build-up areas	126,4	157,23
Agriculture	139,5	214,92
Vegetation	142,47	306,99
Strong vegetation	1208,16	953,37

For the further analysis it were decided, that the two vegetation classes can be combined into one single class, since this distinction is not relevant for current work. Therefore in visualization the performed classification has only 5 classes. (Fig. 19).

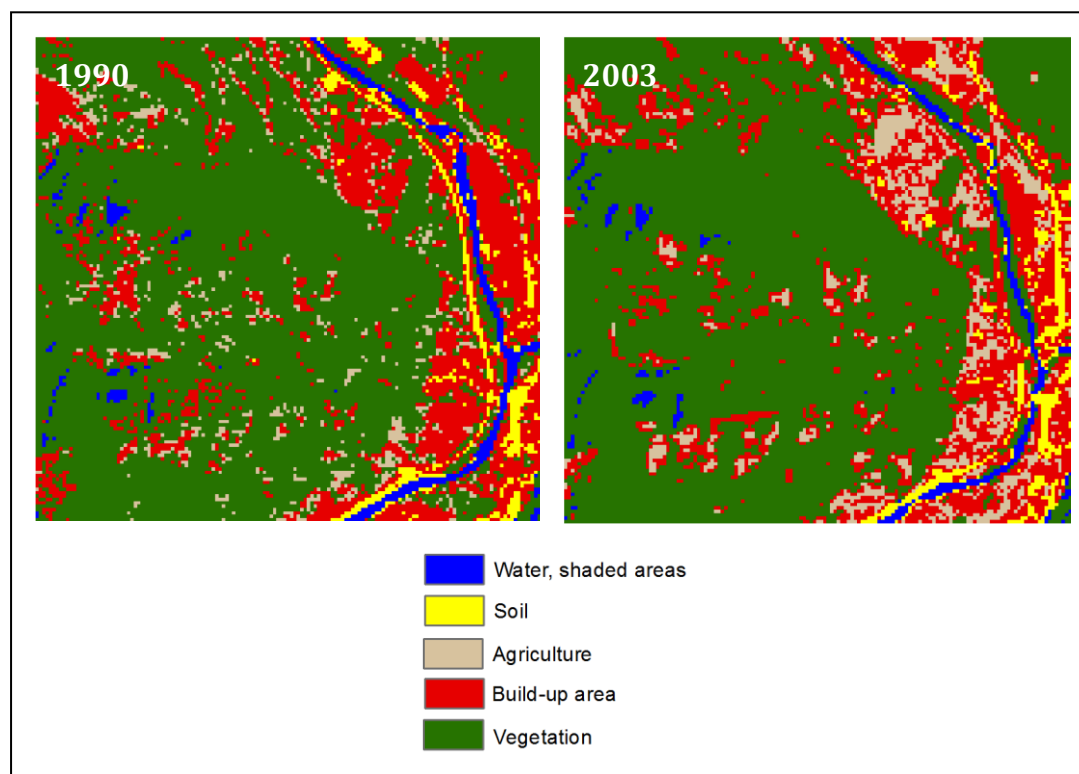


Figure 19: Visualization of the supervised classification

After comparison of the value of the built up area on the two classified images the result shows, that the total amount of a built up area was increased up to 2.41 %.

Unsupervised classification.

For the unsupervised classification the ISODATA algorithm was used. The interpretation and analysis of the Landsat imagery was done using *ERDAS Imagine* software. The algorithm used the spectral reflectance value of the land surface to identify land cover and applied unsupervised classification procedures to locate the spectral classes. Two input images were run through the ERDAS Imagine ISODATA algorithm using six iterations each, to create signature sets (ERDAS, 2011). As fit has been done for the supervised classification the signature plots representation was generated (Fig. 20).

As a result the algorithm categorized for both images 18 classes using the minimum spectral distance formula to form clusters, beginning with arbitrary cluster means. All classes corresponded to the spectral signatures of the dominant land-use and land-cover types. Additionally in order to obtain the result in comparable type with the supervised classification it was decided to use a masks, which at the end will combine several detected classes into one (Fig. 21).

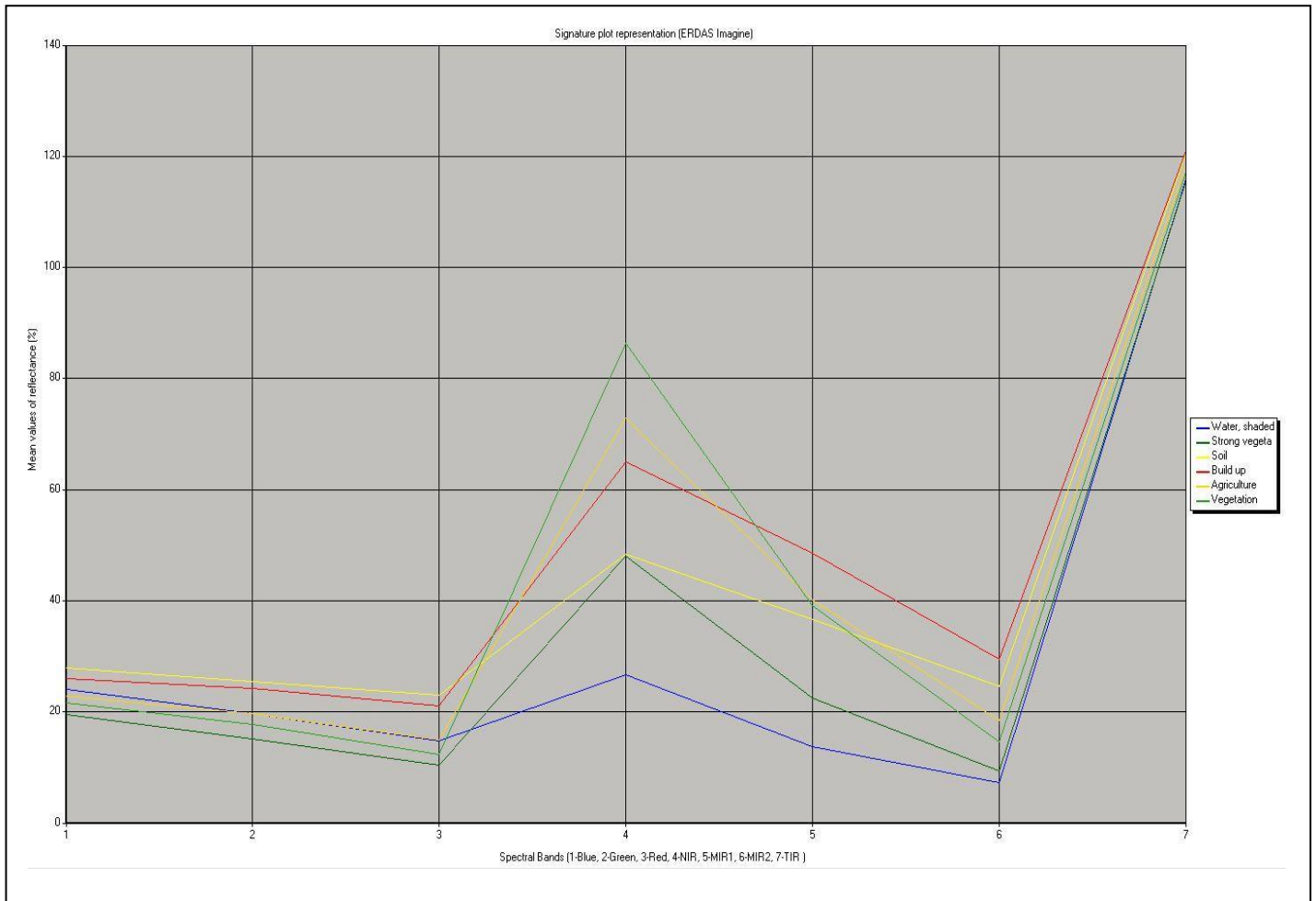


Figure 20: Result of signature plots by using supervised classification

The result also contains the statistical values, therefore the table with the corresponding value of changes for each generated class was performed (Tab. 5).

Table 5. Value for the areas after unsupervised classification (ha)

Categories of classes	1990	2003
Water and the shaded areas	58,32	56,88
Soil	254,61	130,68
Build-up areas	91,26	122,76
Agriculture	285,21	332,37
Vegetation	457,2	393,21
Strong vegetation	771,03	881,73

The result of unsupervised classification shows, that the build-up areas have been changed by 2,06 %. This parameter is lower in comparison with the supervised classification. A possible explanation is, that for the supervised classification the signatures were used, which were created not only based on spectral characteristics, but also on the *a priori* information about the data. For the visualization it were decided (as for the supervised classification) to combine two types of the vegetation.

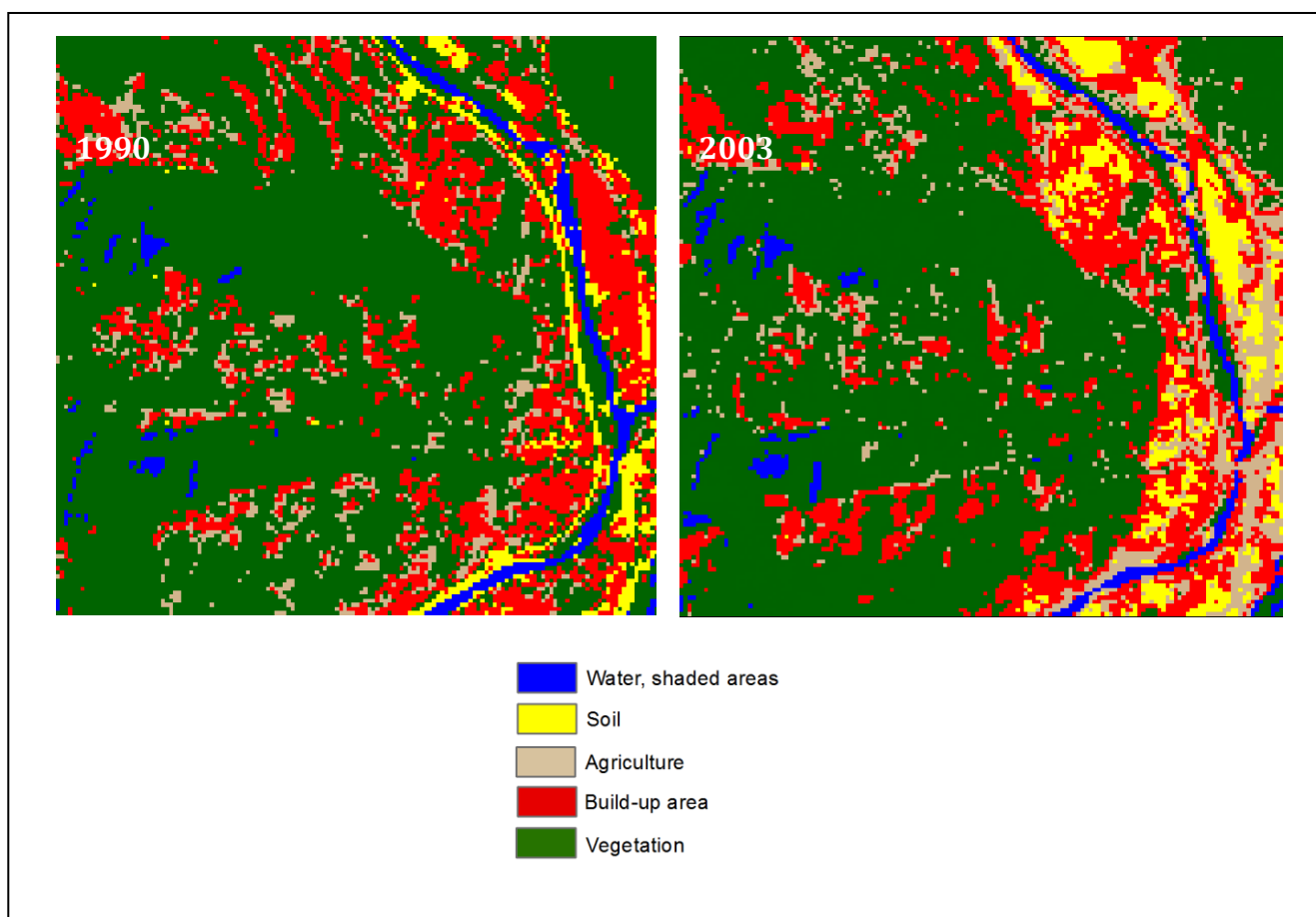


Figure 21. Visualization of unsupervised classification

For the evaluation of the results of the classification difference method were decided to create an image of the changed area. To do this and in order not to lose the georeference information this has been done in *ERDAS Imagine* software. The *Recode* tool was used, it allowed us to create new attributes for already existing classes. Therefore all the classes except build-up area were combined into one in order to do further analysis with the relevant classes for the current research. On the resulted image the red color reflects to changed areas, and the black color reflects the areas without changes (Fig. 22).

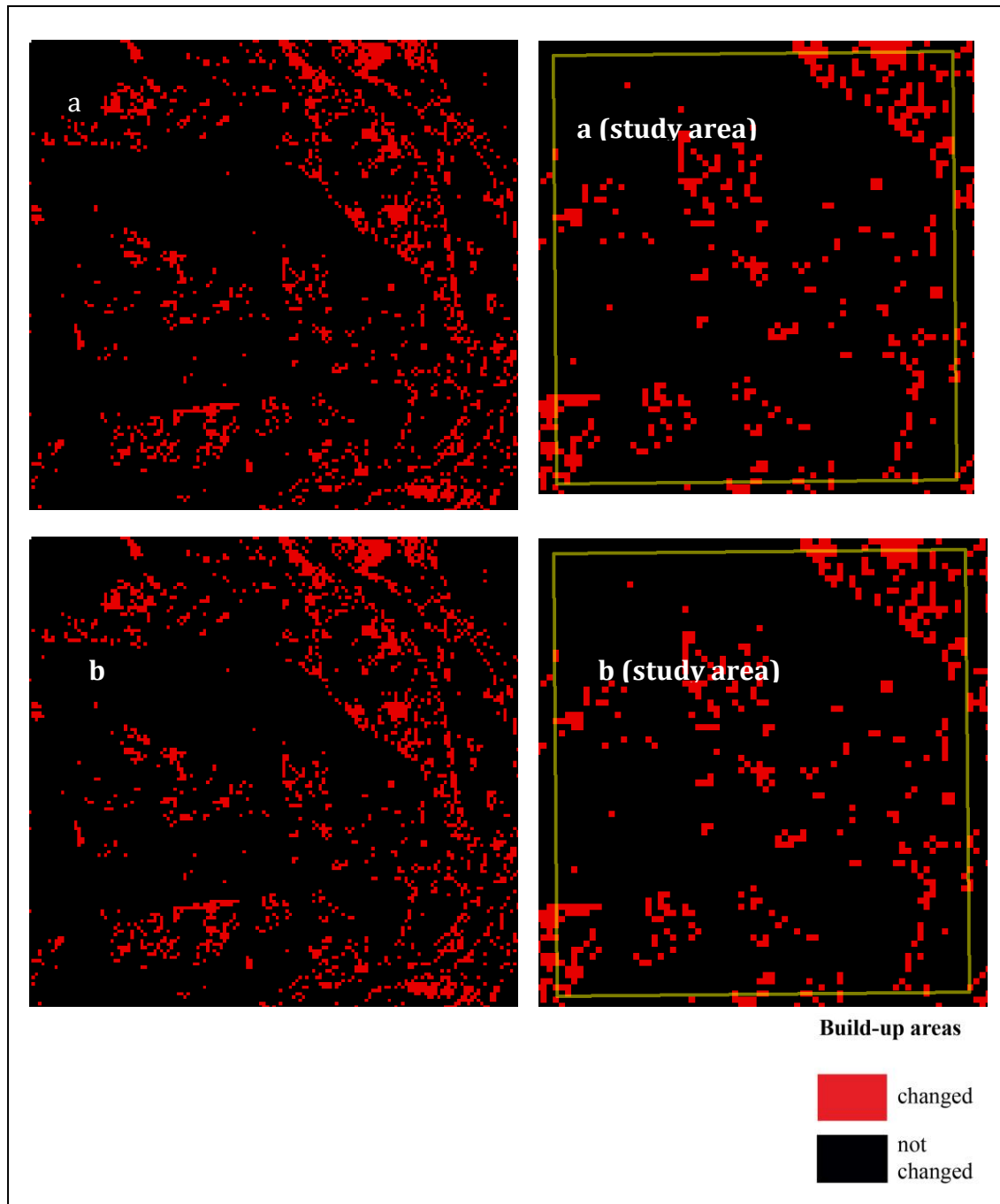


Figure 22: Representation of changed build-up areas after using classification difference analysis (a- based on supervised classification, b- based on unsupervised classification)

4.2 Evaluation of Chosen methods

In order to evaluate the results of the Remote Sensing analysis it was decided to estimate the accuracy of the results. The goal was to quantitatively determine how effectively pixels were grouped into the correct land cover classes. The procedure is relatively simple. Pixels are randomly selected throughout the image using a specified random distribution method. This method was applied by using *ArcGIS* software by using *Random Point Tool*.

In *ArcGIS* 100 points on the images were randomly created, with the condition not to be closer than 30 m to each other (in cause of the resolution of the image) (Fig. 23). Afterwards by applying function *Extract Multi Values to Point* the values for attribute table of point class were created. As the ground truth data the map for the year 1995 was used, because on the map for the year 2006 there might be the changes, which still have not took place in the year 2003. Afterwards this ground truth data was compared with the four classifications maps (for both types of classification and for both years) and with the two NDVI images with the classes of build-up area.

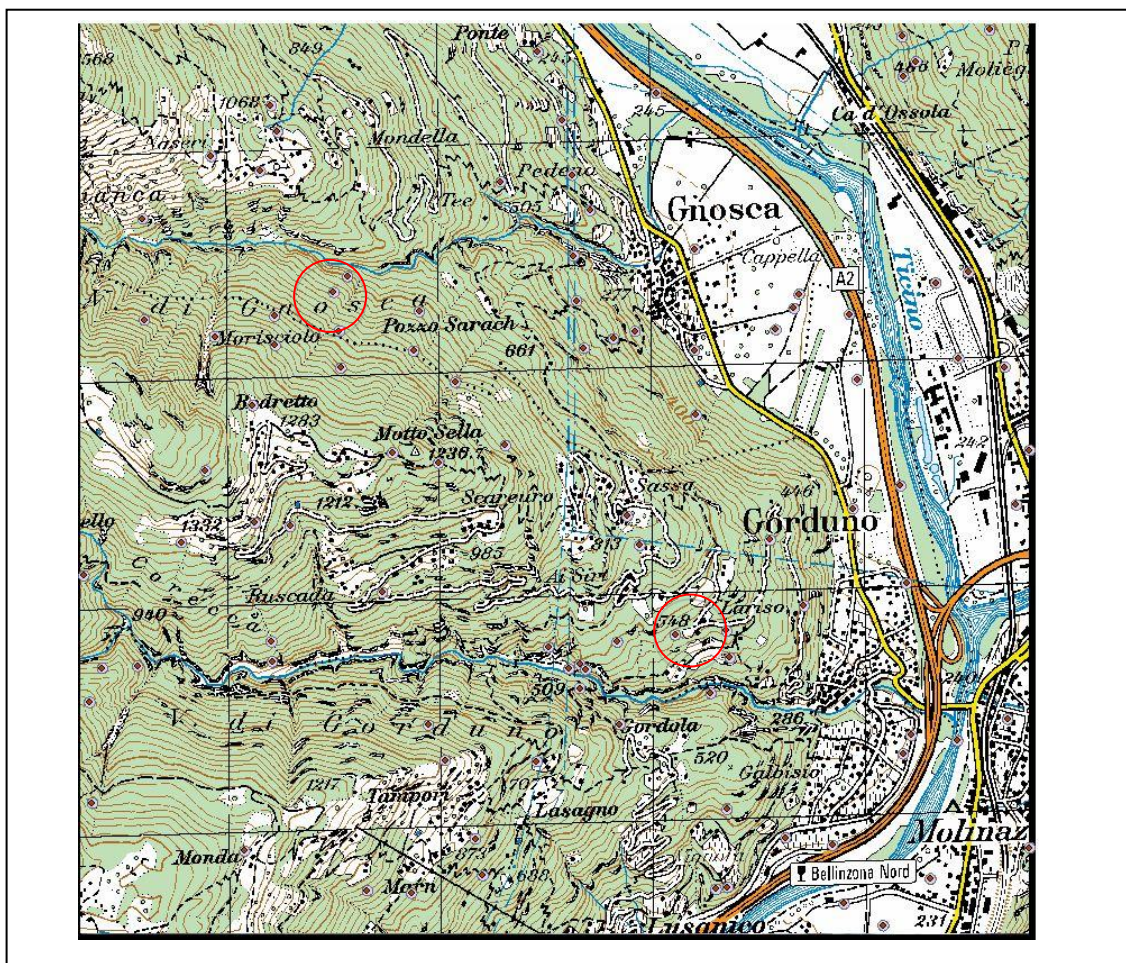


Figure 23: Representation of Random points for accuracy assessment (inside red circles)

If the pixel on the ground truth map and on the classification match, then the classification of that pixel was considered as being accurate (Figure 24).

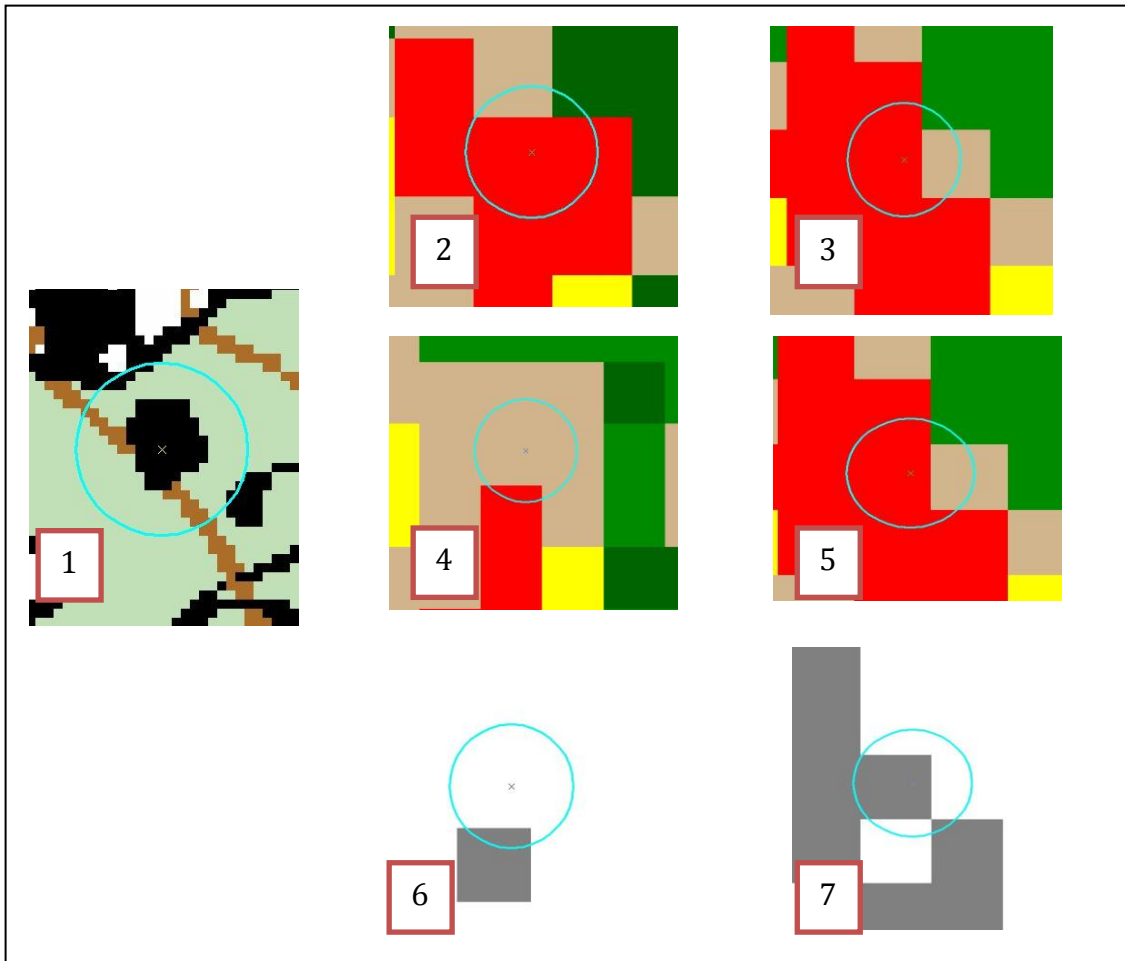


Figure 24: Correspondence of control point between ground truth and classified images (1- ground truth map for the year 1995, 2- supervised classification 1990, 3- supervised classification 2003, 4- unsupervised classification 1990, 5- unsupervised classification 2003, 6- NDVI for 1990, 7- NDVI for 2003)

In order to be more accurate in the given approach it was decided to use buffering zones of 25m while detecting the correspondence of pixels on the ground truth and classified images. This corresponds more to the resolution of the Landsat satellite images. Given that enough random pixels are checked, the percentage of accurate pixels gives a fairly good estimation of the accuracy of the whole map. The result of representation of the accuracy assessment are the error matrixes (confusion matrix), which indicate how many pixels were associated with each class both in terms of the classification and the ground truth (Tab. 6,7,8,9,10,11). In these confusion matrixes, the system predicted that there were several number of objects (e.g. build-up areas), and part of these recognized class was vegetation, it predicted that within this vegetation one was soil and another agriculture. After creating the matrix it is seen that the system in question has trouble distinguishing between build-up areas and vegetation, but can make the distinction between soil and agriculture pretty well. All

correct guesses are located in the diagonal of the table, so it's easy to visually inspect the table for errors, as they are represented by any non-zero values outside the diagonal (Story et al., 1986).

Table 6. Error matrix for supervised classification, year 1990

		map derived from image classification (supervised 1990)						Total	Errors of omission	Accuracy
Map of reference of "ground truth" data 1995		Water, shaded areas	Soil	Build up areas	Agriculture	Vegetation				
	Water, shaded areas	1					1	0 %	100 %	
	Soil		12				12	0 %	100 %	
	Build up areas		1	9		1	11	18.2 %	81.8%	
	Agriculture		2		8	4	14	42.85 %	57.15%	
	Vegetation		1	1	2	58	62	6.45 %	93.55 %	
	Total	1	16	10	10	63	100			
Accuracy		100 %	75 %	90 %	80 %	82.07 %				
Error of commission		0 %	18.75 %	10 %	20 %	7.93 %				

Total accuracy: 88 %

Table 7. Error matrix for supervised classification, year 2003

		map derived from image classification (supervised 2003)						Total	Errors of omission	Accuracy
Map of reference of "ground truth" data 1995		Water, shaded areas	Soil	Build up areas	Agriculture	Vegetation				
	Water, shaded areas	1					1	0 %	100 %	
	Soil		11	1			12	8.3 %	91.7 %	
	Build up areas		2	8		1	11	27.3 %	72.7 %	
	Agriculture		1		9	4	14	35.7 %	64.3%	
	Vegetation		2		2	58	62	6.45 %	93.55 %	
	Total	1	16	9	11	63	100			
Accuracy		100 %	31.25 %	89 %	81.8 %	82.07 %				

			%			%			
Error of commision		0 %	18.75 %	11 %	18.2 %	7.93 %			

Total accuracy: 87 %

Table 8. Error matrix for unsupervised classification, year 1990

		map derived from image classification (unsupervised 1990)								
Map of reference of "ground truth" data 1995		Water, shaded areas	Soil	Build up areas	Agriculture	Vegetation	Total	Errors of omission	Accuracy	
	Water, shaded areas	1					1	0 %	100 %	
	Soil		8	1	2	1	12	33.4 %	66.6 %	
	Build up areas		2	6	2	1	11	45.5 %	54.5 %	
	Agriculture		3	1	6	4	14	57.15 %	42.85 %	
	Vegetation		2		4	56	62	9.77 %	90.32 %	
	Total	1	15	8	14	62	100			
Accuracy		100 %	53.4 %	75 %	42.85 %	90.32 %				
Error of commision		0 %	46.6 %	25 %	57.15 %	9.77 %				

Total accuracy: 77 %

Table 9. Error matrix for unsupervised classification, year 2003

		map derived from image classification (unsupervised 2003)								
Map of reference of "ground truth" data 1995		Water, shaded areas	Soil	Build up areas	Agriculture	Vegetation	Total	Errors of omission	Accuracy	
	Water, shaded areas	1					1	0 %	100 %	
	Soil		7		4	1	12	41.66 %	58.34 %	
	Build up areas		2	8		1	11	27.28 %	72.72 %	

	Agriculture		3	2	6	3	14	57.15 %	42.85 %
	Vegetation	1	1		5	55	62	11.3 %	88.7 %
	Total	2	13	10	15	60	100		
Accuracy		50%	53.8 %	80 %	40 %	84.02 %			
Error of commission		50 %	46.2 %	20 %	60 %	15.98 %			

Total accuracy: 77 %

Table 10. Error matrix for NDVI image, year 1990

	map derived from NDVI 1990			Errors of omission	Accuracy	
		Urban	Not urban			Total
map of reference of "ground truth" data, for the year 1995	Urban	6	5	11	46 %	54 %
	Not urban	2	72	89	0 %	100%
	Total	8	92	100		
Errors of commission		25 %	20 %			
Accuracy		75%	80 %			

Total accuracy: 78%

Table 11. Error matrix for NDVI image, year 2003

	map derived from NDVI 2003			Errors of omission	Accuracy	
		Urban	Not urban			Total
map of reference of "ground truth" data, for the year 1995	Urban	8	3	11	27 %	73 %
	Not urban	0	89	89	0 %	100%
	Total	8	92	100		
Errors of commission		0 %	4 %			
Accuracy		100%	96 %			

Total accuracy 97%

To conclude the evaluation of remote sensing approach after analysis of the error matrixes it is possible to assume, that the total accuracy almost for all results is quite high. This allows us to assume, that the analysis was done correctly and gave the relevant results for further researchers, but anyway there are still a lot of other inaccuracies, according the detection of forest and non-urban areas.

Within the approaches it is needed to be noticed, that for example the accuracy of unsupervised classification is in total lower then for the supervised. This may be due to the possibility of the user to control the created classes, which might give at the end more relevant results. The other possibility is, that the classification algorithm, which was used in the classification is the most relevant for these types of data.

After analysis of the NDVI threshold for build-up area it is possible to assume, that the result for the year 2003 is much more accurate. There are two possible reasons why the result is lower for the year 1990. First, this could be due to the buildings, which are existing on the map for the year 1995 either are not existing in the year 1990 yet or some of the building from the year 1990 are not existing in 1995 any more. Second possibility is, that the meteorological conditions for the year 1990 were drier as for the year 2003 and some parts of the territory (agriculture and soil) were detected as buildings in cause of similar reflectance parameters.

5. EVALUATION OF CHANGE DETECTION METHODS

In order to evaluate the results from the two approaches of change detection methods it is necessary to mention that in the project the goal was to evaluate different methodologies. As declared in the methodology phase, every approach needs to have a result, representing the temporal changes. As a consequence there are four main results, for the further discussion.

Result 1: Cartographic approach, raster analysis.

The result of this method is the raster image with changed (red) and non-changed (green) areas (Fig.7, p.26). This image qualitatively allowed us to distinguish the areas, which were changed. While analyzing this image it was possible to distinguish, that the symbol for the buildings on the map for the year 2006 has been changed by changing its thickness. Therefore there are some areas, which were detected as the new buildings, but in a reality it is still the same building. But the result still represents the buildings, which have been built between years 1995 and 2006.

To conclude, this method requires a lot of manual work, which can not be done automatically. Therefore it strongly depends from the cartographer, his knowledge of the territory, while further improvement of the results might need to manually exclude not build-up objects.

Possible further evaluation of the result can be the opportunity of calculating the changed cells in order to derive the value for the changed areas.

Result 2: Cartographic approach, vector analysis.

This type of analysis gave the opportunity to obtain two types of results. The first is the image with the buffering zones, where the resulting analysis shows, that the main distance, where the new buildings were built is 270 m. Second approach of buffering analysis allows the distinction of the zones, where new buildings have been built or also it is possible to obtain the zones, where buildings are not existing anymore.

These types of results are most relevant for the WUI-CH project. They give a relevant representation of current and past situation. The only disadvantage of this work analysis is, that in order to get statistical information additional steps are needed to be done. However, the achieved results allow us to receive relevant information about the territory.

Result 3: Remote Sensing Approach, NDVI analysis.

For the NDVI it was decided to define the threshold for the urban zones. For each image the value of the threshold was found, but, the difference in values between two years was not very high. However, it was possible to assume, that the general threshold for the build-up area is within this interval: 0.3-0.62 μm . Afterwards the

confusion matrix was done, where the value of total accuracy was calculated for both years, for the year 1990 the value of total accuracy was 78 %, which might be explained by the fact, that the year of publication of the map is 1995 and can therefore include recent information about newer objects. Therefore in order to be sure about the results it were decided to overlap the images with the NDVI threshold for build-up area and the raster map (Fig. 25).

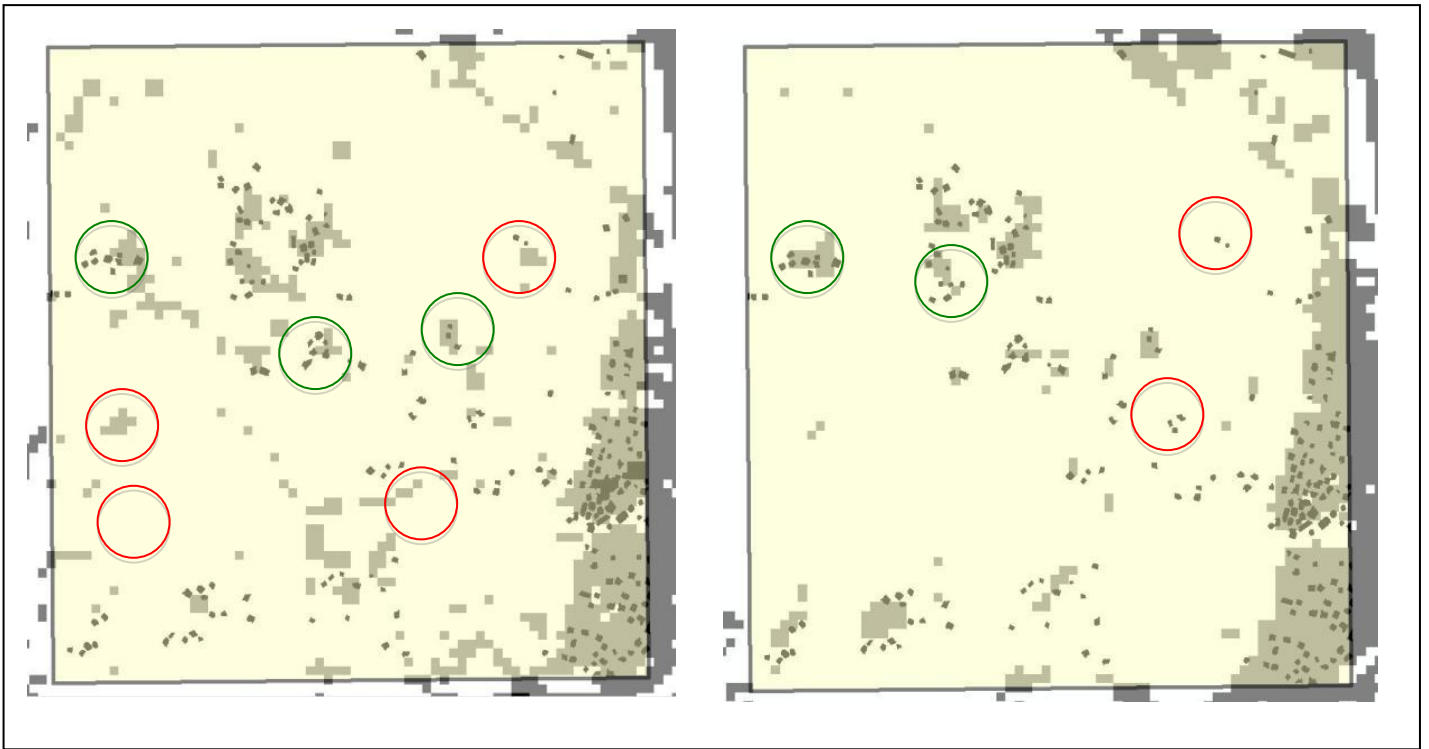


Figure 25: Overlapped images of NDVI and raster map with build-up area (left- for the year 1990, right- for the year 2003)

On the images there are areas, which we could very good distinguish on classified NDVI image (green circles) and also there were some areas, which were wrongly recognized on the image and belonged to the class “others” (red circles). Visual analysis allowed us to conclude, that the results of the classification reflect the calculated value of accuracy (around 45 % of the buildings were detected correct for the year 1990 and 70% for the year 2003). This also allowed us to assume, that the build up area for the year 1990 are not corresponding with the map data for the year 1995, in cause of several possibilities. The first one, it might possibility, that the buildings are not existing anymore for the year 1995. The second possibility might be, that that the meteorological conditions for the year 1990 were drier and some parts of the territory (agriculture and soil) were detected as buildings in cause of similar reflectance parameters.

Result 4. Remote Sensing Approach. Classification Difference.

After analyzing the confusion matrixes were decided to further consider only of the supervised classification, because the total accuracy was 88% for the year 1990 and

87% for the year 2003.

The usage of classification difference method allowed us to distinguish the difference in build-up detected classes. One of the advantages of this method also is that it is possible to get the statistical information about build-up area for each year, which allowed us afterwards to calculate the difference and distinguish the values of changes. In order to analyze the result it was decided to compare qualitatively the obtained classification.

For analysis was decided to use ground truth map for the year 1995, because the map for the year 2006 could contain more recent objects, for the period 2003-2006, which will lead to the wrong results (Fig. 26). Therefore the results of supervised classification and ground truth map were overlapped. On the resulting images it is possible to see the areas, which were recognized correctly (green circles) and incorrectly (red circles).

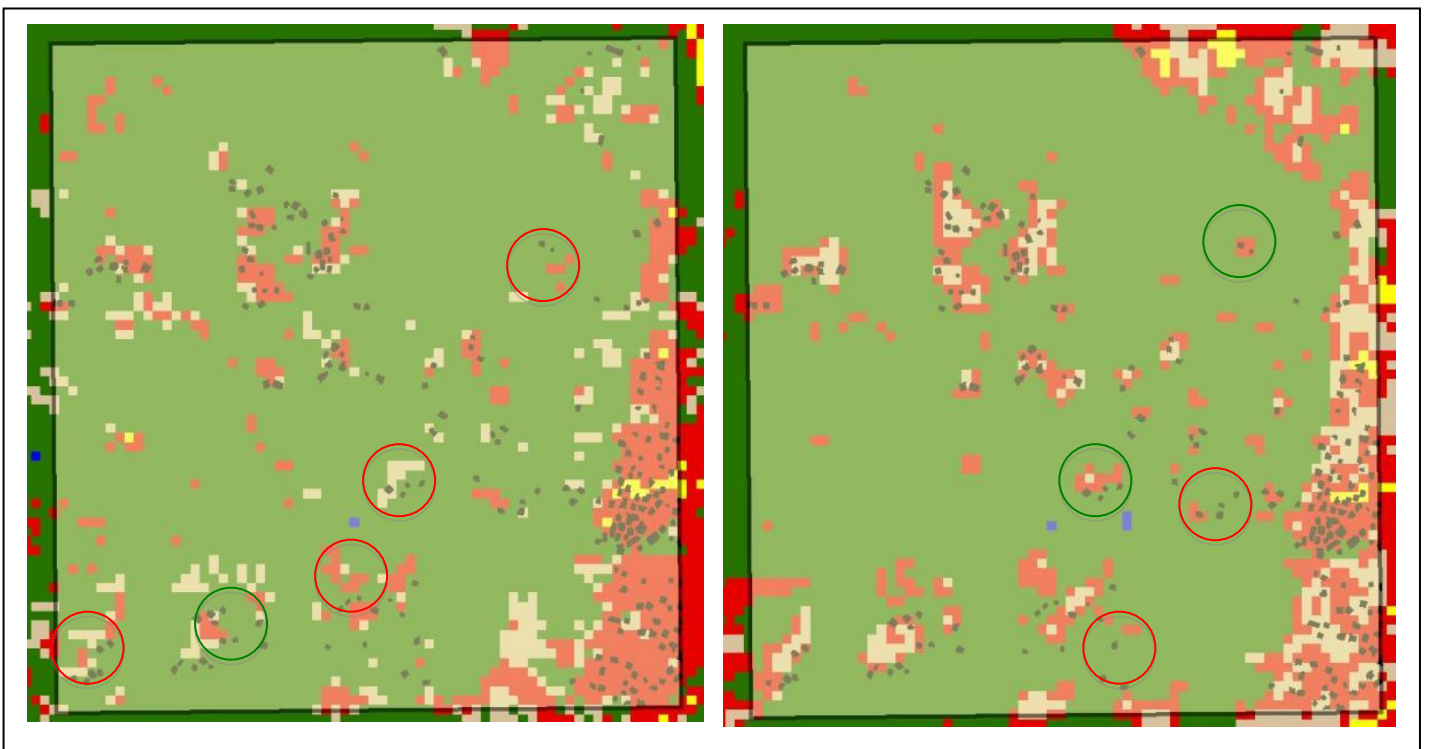


Figure 26: Overlapped images of supervised classification and raster map with build-up area (left- for the year 1990, right- for the year 2003)

On the resulting image it is possible to see, that as for the NDVI approach, the results for the year 1990 recognized much more territory wrong as a build-up area, or recognized some areas as vegetation or agriculture classes, while it should be build-up areas. This allows us to say, that the hypotheses, that the meteorological conditions were drier for the year 1990 and made the comparison not relevant.

Additionally in order to distinguish the reason of the big difference in the results between cartographic approach for the year 1995 and both NDVI and Classification approach for the year 1990, it were decided to compare qualitatively the build-up areas on the map and on the input satellite image. On the resulting image it is possible to obtain, that there are areas (red circles), which have the same reflectance value as build-up areas and were therefore recognized as a wrong classes (Fig. 27). The conclusion of qualitative analysis is proving the result, mentioned above.

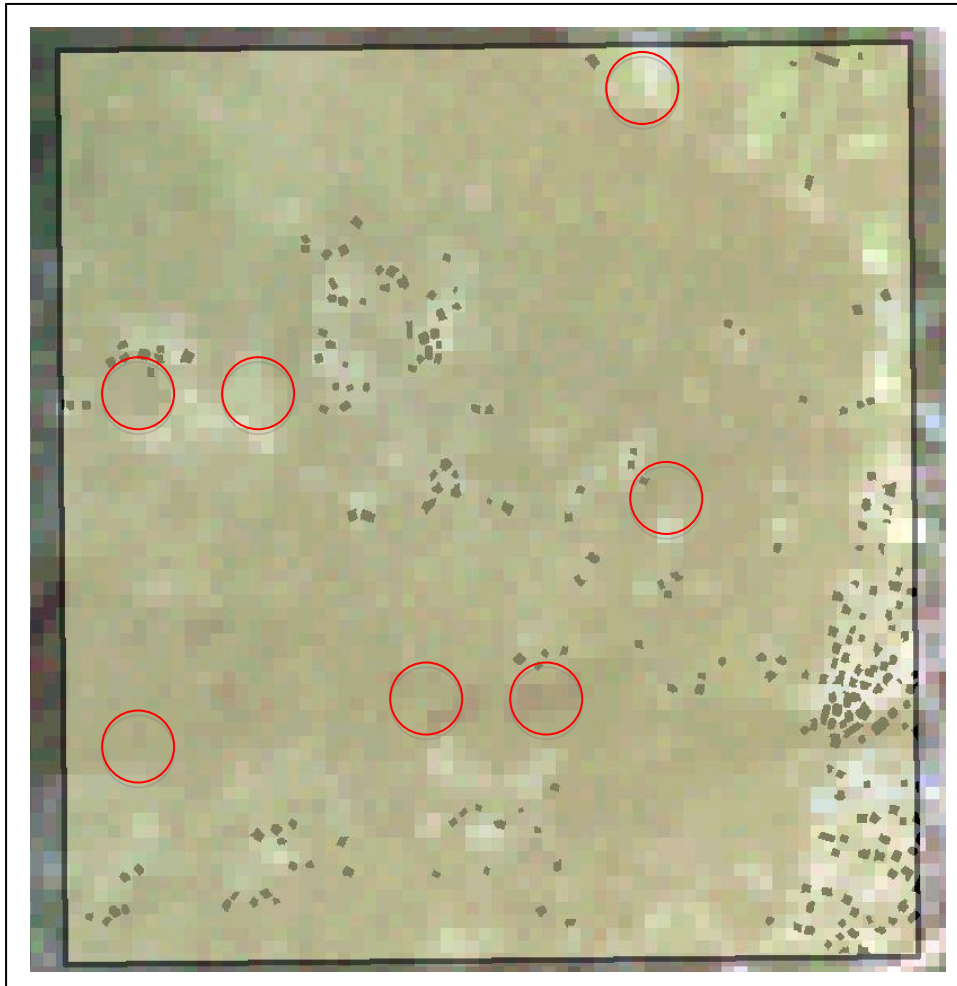


Figure 27: Visualization of the overlaid layers of satellite image for the year 1990 and map for the year 1995

5.1 Future implementations

The results of the study show, that by using these two types of approaches it is possible to achieve the results. However there are several improvements, which might be implemented in order to achieve better results. These implementations should take place in different steps of the project.

Input Data:

First of all it is needed to select the input data with approximately the same dates in order to exclude the mistakes in further analysis. This might be a problem, when the classification results are not comparable only in cause of the long time period between the data.

For this study area it was possible to use only Landsat images as an input remote sensing data, therefore the further analysis was strongly depending on the resolution of the satellite image. In order to decrease such dependence it might be more useful to use for such small study areas high-resolution satellite imagery.

Cartographic approach:

In the cartographic approach in order to decrease the time of raster cleaning it could be possible to investigate a new automatic method for input data (color separated images). On the other hand it can be suggested to employ more advanced classification techniques. For example for the raster approach result an algorithm can be implemented, which will exclude the areas of changes, which are less then parameter (for example width-parameter), this can be distinguished after evaluating the symbol size.

Remote Sensing approach:

The potential of using this approach was demonstrated in the current work, but there are still possibilities, which can increase the result. For both NDVI and Classification difference approaches it could be possible to implement more techniques for images enhancement. This could increase the accuracy of further analysis. For the Classification Difference analysis it could be possible to improve the results with adequate fieldwork data in order to define better information about spectral classes. Moreover it can be possible to improve classification results while using another more advanced types of classification algorithms.

6. CONCLUSION

This research work demonstrates the potential of using two approaches (Cartographic and Remote Sensing) in order to investigate temporal changes. Attempts were made to detect build-up area as it changes through time as accurate as possible. As a result it can be concluded, that both selected approaches can be used in order to estimate the changes. However, both analyses have their advantages and disadvantages.

The Cartographic approach gives an opportunity of extracting the information about every single building with the opportunity of further analysis. As a disadvantage this type of method is time consuming, therefore it is hard implementing for the big areas of interest.

Remote Sensing approach gives fast representation of temporal changes. One of the disadvantages is, that the accuracy of the results in this approach is strongly depends on the algorithms, which are used within this approach, while most of them are done automatically.

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