Applied Geoinformatics in Forestry and Landscape Research and Education

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1. Introduction

Mendel University of Agriculture and Forestry in Brno (http://www.mendelu.cz), Czech Republic, named in honour of J. G. Mendel, founder of genetics, was established in 1919 as the first university of this type in former Czechoslovakia. Since its establishment the University has undergone a range of structural as well as curricular changes, and now provides top quality education to meet demand for graduates in spheres of agriculture, horticulture, forestry, landscape management, business and economics.
The University is divided into five faculties. Faculty of Agronomy, Faculty of Forestry and Wood Technology, Faculty of Business and Economics and Faculty of Regional Development and International Studies are all located in Brno. Faculty of Horticulture is located in Lednice, 50 km south of Brno. The total number of student enrolled at all five faculties reaches 9000.
Faculty of Forestry and Wood Technology offers research and education focused on renewable natural resources and wood technology. In accordance with the Bologna Process, students have at their disposition all three levels of education: bachelor, master, and doctoral. Basic bachelor level and consequential master level consist of four study programs: Forestry, Landscape management, Wood technology and Furniture. At doctoral level following fields of study are opened: Applied geoinformatics, Economy and management of renewable natural resources, Technology and mechanization of forest production, Forest ecology, Forest phytology, Forest management, Game management, Forest protection, Silviculture, Landscape management and protection, Wood processing technology, Processes of furniture creation.
Arriving Socrates students can choose from large number of courses in English (with exemption of one that is in German). All courses have particular ECTS credits. Concerning a geospatial domain, these courses comprise: GIS fundamentals, Remote sensing, Surveying and land records, Logging and transport of timber, Engineering and technology, Engineering drawing with CAD system, CAD/CAM application in wood-working industry. Besides to the Faculty staff teaching, Socrates students are supported by visiting professors from abroad. Students of the GIS fundamentals and the Remote sensing courses have been very much impressed by lectures of an American professor Barry Rock, visiting professor from the University of New Hampshire, USA. (Professor Rock belongs to founders of

modern applied remote sensing in forestry.)

Fig. 1. Visiting American professor Barry Rock of the University of New Hampshire with Socrates and doctoral students during field practices in the Masaryk Forest

He offered them not only very interesting theoretical lectures, but also practical exercises in a computer laboratory. For these exercises he has brought topical Landsat data of the Brno region and a free image processing software MultiSpec. In addition to that he has arranged practical lessons in the field (Fig. 1). During field trips in the Masaryk Forest students learned how to measure spectral properties of various surfaces, how to estimate amount of green in tree crowns and how to use obtained knowledge in image classification. In the end of the course all students elaborated their own case studies. Naturally, lessons of the professor Rock were visited not only by Socrates students from abroad, but also by ordinary doctoral students of the Faculty and by students of lower levels.

2. Applied Geoinformatics in Research of the Department of Geoinformation Technologies

Since 2005, the Faculty of Forestry and Wood Technology of the Mendel University of

Agriculture and Forestry in Brno have been working on a research program called "Forest and wood – support of a functionally integrated forest management and the use of wood as a renewable material" (Ministry of Education grant No. MSM 6215648902). One of its sections (01) is called "Alluvial forests – sustainable development management". The research concerns areas of the alluvial plains of the rivers Dyje/Thaya and Morava/March (region South Moravia) that are unique natural formations and have for a long time been under a significant anthropogenic pressure. The preservation of natural environment of alluvial forests and all their bio-types in equilibrium is thus of primary importance. It is also necessary to assess the effectiveness of revitalizing measures in the landscape and the optimization of forest management from the point of view of sustainable development of the area of interest. Section 01 is divided into 8 thematic projects, where part 8 is entitled "The use of geoinformation technologies in landscape planning" that has been elaborated by the Department of Geoinformation Technologies (DGT). This project is focused on the development of methodology and formalized process for the creation of a digital model of landscape (expert system) based on geoinformation technologies (GIT). The main goal is to quantify revitalization arrangements in the landscape with respect to sustainable forest management, to optimize and visualize results, as well as to provide geoinformation support for other tasks of the research program. Following pages refer to this research. The project is divided into several successive tasks where each task covers a certain thematic area. The common product will then be a digital geodatabase of the area of interest serving as a digital data source for other landscape analyses.

2.1 Ikonos and Quickbird satellite imagery processing

2.1.1 Data used

On May 2005, panchromatic and multispectral Ikonos data for the area of interest were ordered (via Czech company GISAT) from Space Imaging (today GeoEye) Eurasia, based in Ankara, Turkey. We requested data of August that would be most suitable for our purposes of vegetation interpretation. Nevertheless, imagery we have received was taken as late as 1st November 2005, fortunately it has been still utilizable. Area of our interest encompasses triangular territory from Nove Mlyny water reservoirs on Dyje river and from Hodonin on Morava river to Dyje and Morava confluence at Austrian border (see Fig. 9). This area was covered by 6 Ikonos scenes. Each of them consists of one panchromatic canal (450 - 900 nm, 1 m spatial resolution) and four multispectral canals (blue 450-520 nm, green 520-600 nm, red 630-690 nm, NIR 760-900 nm, 4 m spatial resolution). Because of high price of the data, only part of it, covering Dyje and Morava alluvial plains, could be bought in 2005. In 2007, when all this data become archive, 5 more partial Ikonos scenes were bought.

As no Ikonos data covered the important Palava Natural Reserve (northeast part of the Biosphere Reserve Lower Morava), archive QuickBird data (2003) for this area has been found on the Internet and bought, also in 2007. QuickBird scene, similarly to Ikonos, consists of one panchromatic canal (450 - 900 nm, 0.6 m spatial resolution) and four multispectral canals (blue 450-520 nm, green 520-600 nm, red 630-690 nm, NIR 760-900 nm, 2.5 m spatial resolution).

This satellite imagery was processed in three principal consecutive stages:

- Geometric corrections
- Mosaicking

- Preliminary classification

(First works on the Ikonos 2005 data were realized by Sustera, 2006).

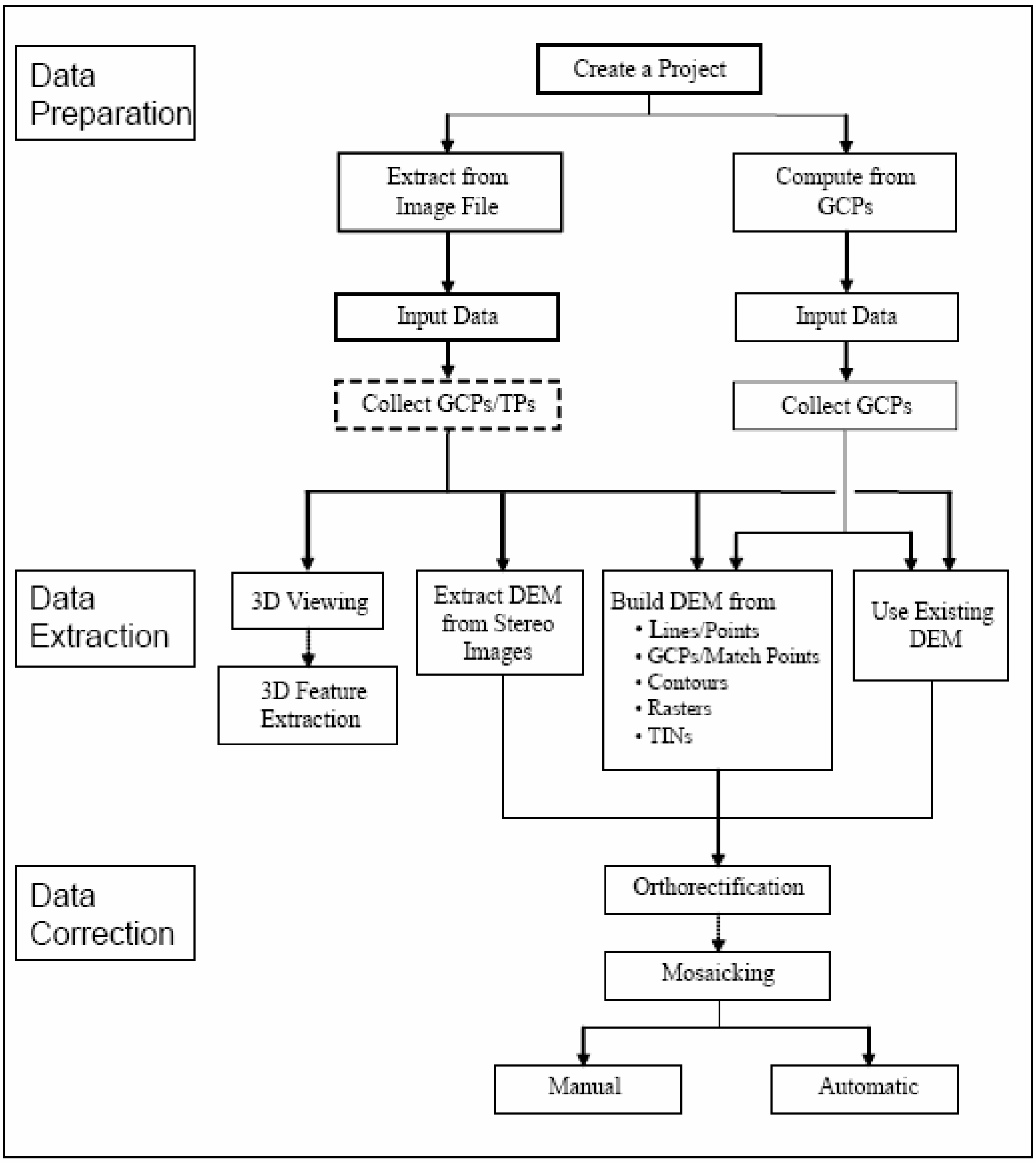

Fig. 2. Working scheme for Ikonos and QuickBird data orthorectification (after PCI Geomatics OrthoEngine Workbook, 2008)

2.1.2 Geometric corrections

For georeferencing and orthorectification, rational polynomial coefficients (RPC) provided with the image data, ground control points (GCPs) measured by GPS method, digital terrain

model (DTM, see 2.2) and analogue topographic maps 1 :10,000 were used.
Main part of geometric correction was realized in software Geomatica 10 OrthoEngin (product of PCI Geomatics). The project was based on the OrthoEngine generic projection Krovak negative (D211) and the Czech national civil geodetic system S-JTSK.
Mathematical model of rational polynomial functions was employed, where not only surface position but also elevation is considered. The model builds a correlation between the pixels and their ground locations using rational polynomial coefficients (RPC) that are provided with the image data. This solution was refined by adding measured ground control points. Rational polynomial coefficients reduce number of necessary GCPs for each satellite scene and increase transformation accuracy.

2.1.3 Ground Control Points

For the uncorrected image, pixel and line coordinates of each GCP must be determined manually using the crosshair. Option "Use point "stores the point in a GCP table; measured map coordinates (X, Y, Z) can be afterwards entered, and the point accepted.
According to value of computed root mean square (RMS) in pixel or ground units, point can be used as GCP point or check point. A GCP is used in computing the geometric model, whereas a check point is used to check the accuracy of the computed geometric model (it is not included in the bundle adjustment, mentioned later). The RMS should be kept below 1 pixel.

Fig. 3. GCP collection for the QuickBird image in OrthoEngine

GCPs were placed in the panchromatic image and used for corrections. Later they were used also for geometric corrections of multispectral imagery. In this case geodetic coordinates (X, Y, Z) remain the same, while image coordinates P (Pixel, i.e. Column) and L (Line) have to be dividend by four as the pixel in the multispectral image is four times larger than pixel in the panchromatic image. For this purpose, ground control points were exported from the OrthoEngine projects in IXYE format, which means that each row of text contained the following information: (1) the GCP ID (I), (2) the georeferenced East/West coordinate (X), (3) the georeferenced North/South coordinate (Y), (4) the elevation (E). The Pixel and Line position for each point were taken from the uncorrected image. Position identity of GPCs at panchromatic and multispectral imagery was checked, and corrected at the multispectral image, where needed.

Geodetic coordinates were measured using a Trimble GeoXT device. This high performance, sub meter GPS receiver is combined with a rugged handheld computer and equipped with the TerraSync Professional software. Advanced mission planning, field work and data dictionary creation and editing were quite easy with this tool. Measured data was stored in Standard Storage Format (SSF) file, which is Trimble standard data file designed for mapping applications. The Trimble GPS Pathfinder Office software that works with the TerraSync software was used for data dictionary creation, data transfer, data import and export, and for postprocessing. With GPS Pathfinder Office, files can be imported from a number of GIS and database formats.

2.1.4 Generation of ortho images

Orthorectification is the process of using a rigorous mathematical model and a digital elevation model (DEM) to correct distortions from the platform, the sensor, earth terrain and curvature and cartographic projection in raw images. The computation of a rigorous math model is often referred to as a bundle adjustment. The math model solution calculates the position and orientation of the sensor at the time when the image was taken. Once the position and orientation of the sensor is identified, it can be used to accurately account for known distortions in the image.

In Ortho image production schedule, several processing options are set up, in particular available digital elevation model (DEM) and appropriate resampling method must be chosen. For this function we have used as the DEM the digital terrain model (DTM) that is described in 2.2.

For resampling of images during orthorectification process two methods were used: (1) nearest neighbour interpolation and (2) cubic convolution. The nearest neighbour resampling option identifies the grey level of the pixel closest to the specified input coordinates and assigns that value to the output coordinates. Although this method is considered the most efficient in terms of computation time, it introduces small errors in the output image. The output image may be offset spatially by up to half a pixel, which may cause the image to have a jagged appearance. The result is suitable for automated classification.

The cubic convolution resampling option determines the grey level from the weighted average of the 16 closest pixels to the specified input coordinates and assigns that value to the output coordinates. The resulting image is slightly sharper than one produced by bilinear interpolation (not used here), and it does not have the disjointed appearance produced by nearest neighbour interpolation. It is suitable for visual interpretation and for field works.

2.1.5 Postprocessed differential correction

Measured GPS data of ground control points was imported into Trimble GPS Pathfinder Office software where post processed differential corrections were realized.

In post processed differential GPS (DGPS), the base station records the correction for each satellite directly to a file. The roving receiver also records its own positions. Once data collection is complete, the two files can be processed using the GPS Pathfinder Office software, producing differentially corrected GPS data as the output. Reference stations supply the base data required for differential correction.

In our research, correction data were received from the Czech network of permanent station for position determining (CZEPOS) that provides to GPS users correction data for exact positioning at the Czech Republic territory. CZEPOS is operated by the Czech Surveying Office. Data were transferred via Internet using RINEX - the Receiver Independent Exchange Format. Moravsky Krumlov (CMOK) station and hourly data files were used.

Measured GCP data were imported in SSF data format into Trimble Pathfinder Office, processed by standard base processing and exported as ESRI shapefiles, with GCP attributes position and elevation. It was found useful to transform resulting shapefile DBF data to Excel XLS files, as such results could be easily re-imported into OrthoEngine GCPs table.

After appropriate corrections, the orthorectification process in the OrthoEngine could be run again, this time providing the most precise georeferenced and orthorectified image output.

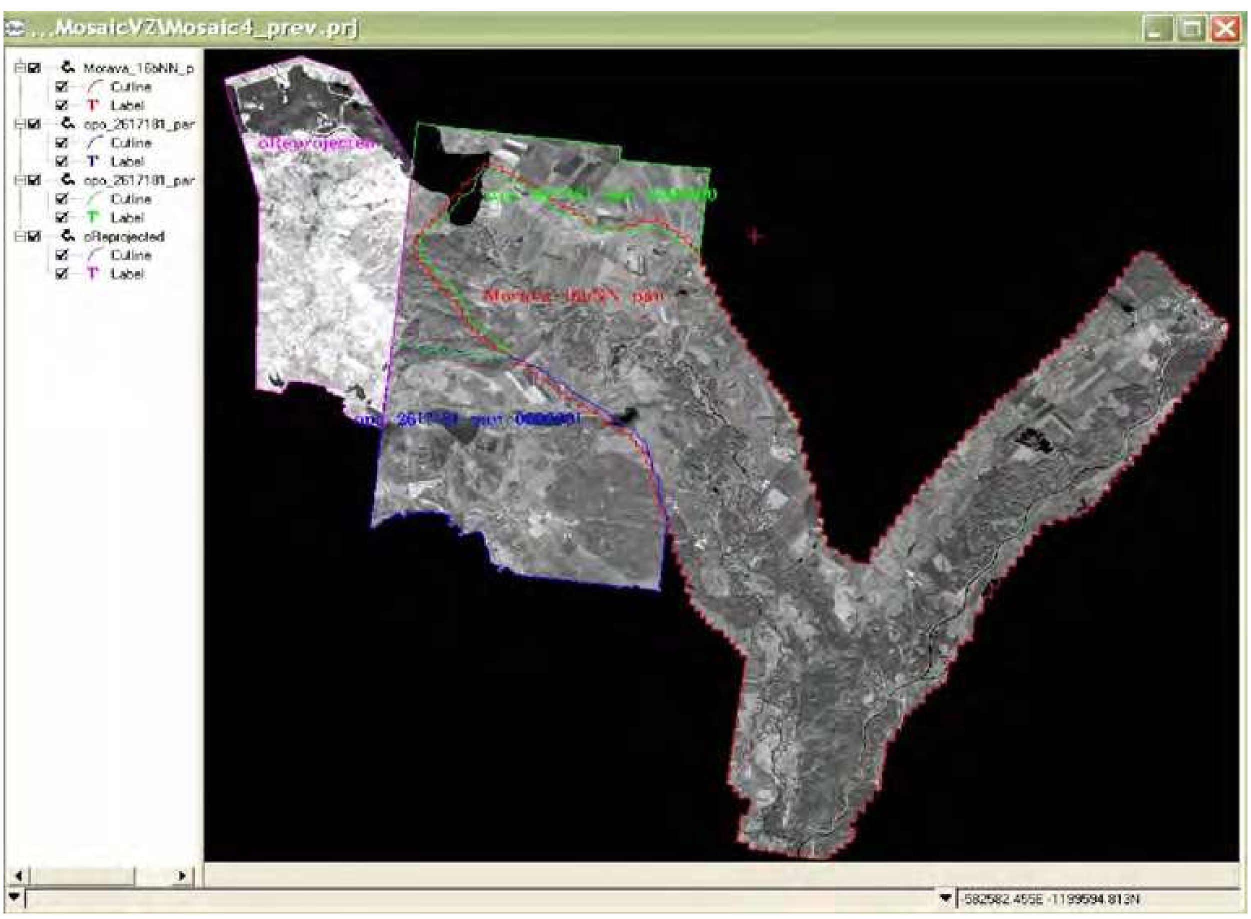

Fig. 4. Mosaic preview of the project, after joining QuickBird data, with cutlines of Ikonos archive and QuickBird scenes

2.1.6 Mosaicking

Georeferenced and orthorectified scenes were joined together using Automatic mosaicking as well as Manual mosaicking options of the OrthoEngine.

For originally ordered and for archive Ikonos data, Automatic mosaicking option in OrthoEngine was used for the bulk of the work (see Fig. 4). After defining a mosaic area, for each image included in the mosaic file, four steps in sequence were completed: selecting an image to add, collecting (and editing) the cutlines, adjusting the colour balance and adding the image to the mosaic.

QuickBird 2003 panchromatic data had to be first reprojected from 0.6 m spatial resolution to 1 m resolution and then added to the existing Ikonos mosaic. Manual mosaicking options of OrthoEngine was used in this case; otherwise it was difficult to reach the satisfactory contrast of both satellite data. With manual cutlines, proper colour balancing was achieved (Fig. 5), though some differences remain in the mosaic due to diverse years of data acquirement.

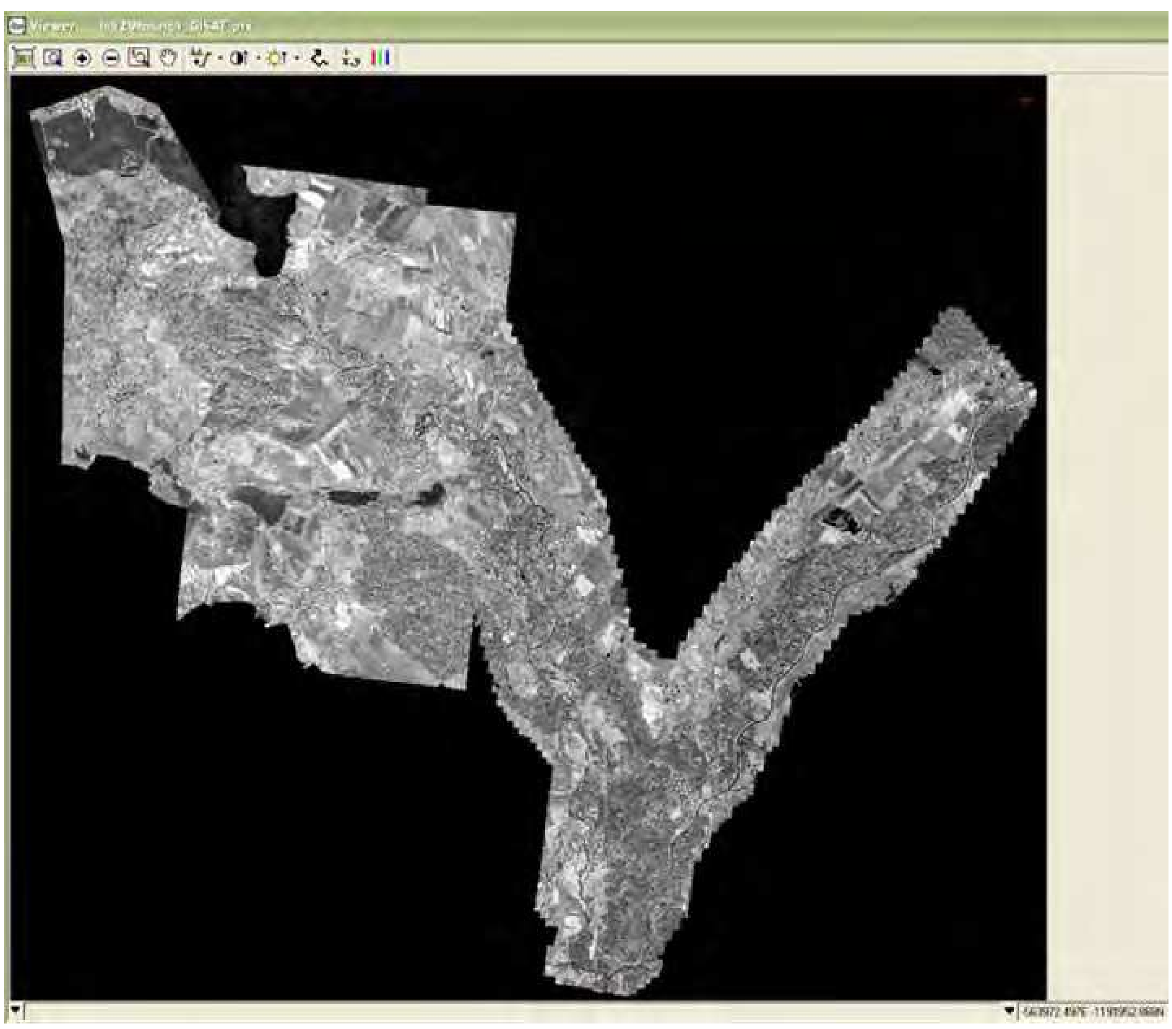

Fig. 5. Resulting mosaic of Ikonos and QuickBird data after contrast adjustment

2.1.7 Preliminary classification

To consider characteristics and bunching ability of the image data, dominant patterns of spectral reflectance were at first automatically extracted, using unsupervised classification modules of Idrisi version 15 (Andes). The unsupervised classification does not require the user to specify any information about the features contained in the images; it automatically creates groups of similar pixels using methods of cluster analysis.

For this purpose, a false colour composition from the multispectral Ikonos data was initially produced, a cut covering Lednice region (north-west part of the area of interest) created and used as reference basis for experimental classification of the imagery (Fig. 6).

Fig. 6. The Lednice region - NIR, R, G colour composition

This part of the image data (i.e. Lednice region) was then classified using following Idrisi Andes unsupervised classification modules: CLUSTER, ISOCLUST, KMEANS, MAXSET, SOM and Fuzzy ARTMAP. Later the same data has been segmented and experimentally classified in contextual object oriented image analysis software Definiens (eCognition) version 5. Best classification results have been obtained from CLUSTER, ISOCLUST, KMEANS and SOM modules. According to our experience, CLUSTER provided the best information on number of clusters existing in the imagery, as it is not necessary to define number of clusters in advance – the module detects it itself using a histogram peak technique. SOM output results (with maximum of 15 output clusters option) proved to be very close to information categories obtained by preliminary classification in Definiens (see Fig. 7). SOM undertakes unsupervised classification of remotely sensed imagery using Kohonen's Self-Organizing Map (SOM) neural network. The network algorithm is able to find characteristic objects in the image without any external information. The input layer represents the input feature vector with a separate neuron for each reflectance band. The output layer of the SOM is typically organized as a two-dimensional array of neurons. For unsupervised classification, competitive layer neurons are organized into classes through the use of a clustering procedure such as an agglomerative clustering or k-means procedure.

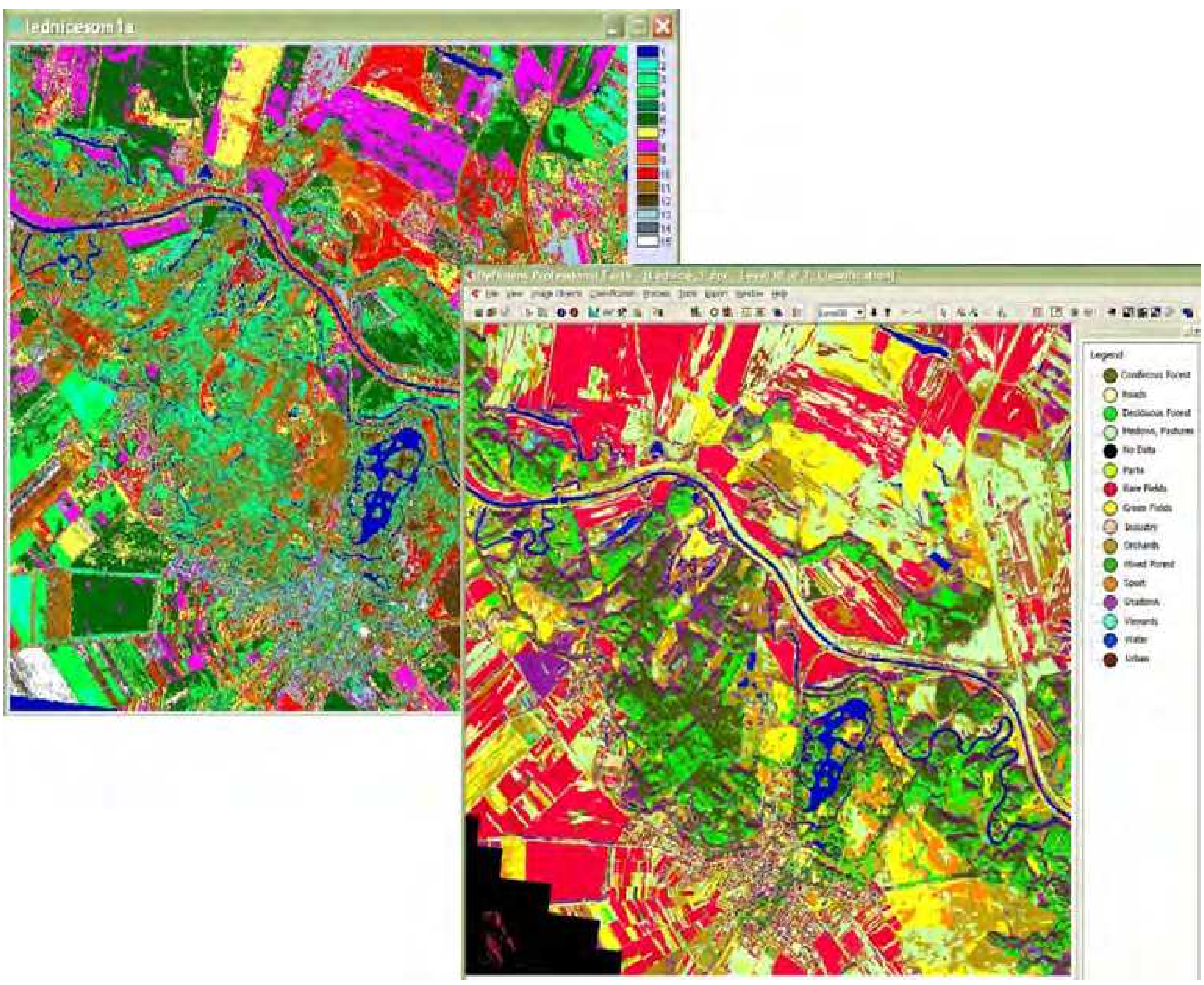

Fig. 7. Data classification of Lednice area by module SOM (15 clusters) compared with a preliminary classification result in object oriented software Definiens

Unsupervised classification output provides important objective evidence on imagery information capability that can be subsequently used in supervised and contextual classification. Especially creating training data sets and their identification in the field can be this way distinctively facilitated. More classification experiments using supervised and object oriented classification are planned for the nearest future.

2.2 Digital terrain model

The Digital Terrain Model (DTM) is one of the crucial layers for the Digital Landscape Model (DLM, see 2.5), as all environmental processes occur in relation to it. These models are usually based on two main data sources: (1) data from photogrammetric measurements, and (2) data from digital elevation sets. In the near future also DTM from laser scanning will be available, as its price gradually decreases. Quantitative parameters of the DTM are in the first case influenced by the way the data is obtained (the accuracy of determining terrain level from a photogrammetric analysis is limited by open visibility of the ground) and in the second case, the model is negatively influenced by the spatial distribution of contour lines and point elevations (Klimanek, 2006).

Due to the extent of the observed alluvial forest area, the hypsometry from the Fundamental Base of Geographic Data (ZABAGED) from the Czech Office for Surveying, Mapping and Cadastre (CÚZK) was used. Only contour lines contain the elevation data and they have two main disadvantages: they do not contain local maximum and minimum values (that is the point elevations on hill tops, mountain ridges but also in the valleys) and depending on the terrain shape the data is irregularly stratified which often leads to a shortage of elevation identifications (typically in longitudinal axes of ridges and valleys). The ZABAGED contour layer data come from maps of 1 : 10,000 scale and have the interval of 5 m (on some map sheets there is the interval of 2 m). The lines are not continual; in places of singularities they are interrupted. This might on the one hand cause complications to algorithms working primarily with lines, but on the other hand, it enables to identify these places with singularities in the terrain and thus make DTM more accurate. Another source represented data delivered by Geodis Brno Company, which come from stereophotogrammetric evaluation and contain point elements including lines of singularities. The density of this field of points is very varied, especially regarding the density of plant cover. The whole work was further complicated by the fact that the area of interest has quite small altitude differences (from 150 to 350 m above sea level) and at places almost a zero gradient. The creation of the DTM from such sources is usually solved by spatial interpolation, where the information from discrete point or line objects is interpolated into continual representation of the surface based on their attribute (in this case – the elevation above sea level).

Due to its availability common software GIS products were used - ESRI ArcGIS and GIS Idrisi, and their corresponding algorithms for the creation of DTM from contour layer data which provide best results – ArcGIS Desktop Topo to Raster, Idrisi Andes TIN. A good quality DTM, however, cannot be obtained by mere choice of suitable algorithm, it was also necessary to carry out the actual field measurement in order to provide data in areas of very low density of elevation and to verify the created DTM. Further, the source data was updated with additional information such as the lines of water courses, water areas and elevation (this data was obtained by vectorization of maps at scales 1 : 5,000 and 1 : 10,000).

Regarding the results obtained at the application of chosen methods of the DTM interpolation on our experimental site (and depending on input data), the use of specifically prepared algorithms proved to be the most convenient. Best results were obtained with the Topo to Raster tool. This algorithm uses modification of the spline method and hydrological characteristics in order to create the DTM as accurately as possible and it enables its further improvement by the application of additional data into the model (ground elevations and hydrological network). The algorithm is primarily designed for working with contour line data and the idea is based on the presumption that the main factors which model the shape of the terrain are hydrological processes. Depending on the type of interpolation, it is the discrete spline method which allows to model sudden changes in terrain relief. The created DTM of 5m spatial resolution serves mainly for satellite data orthorectification, for visual interpretation of other data sets and for further modelling. DTM is the key base for the Digital Landscape Model and it enables a number of other analyses, such as simple determination of categories of gradient and exposition, various landscape studies (visual sensitivity of landscape, visual exposure of landscape) or complicated hydrological or climatic modelling (Hadas et al., 2008).

2.3 Usage of GPS and testing of accuracy of GPS receivers

In specific phases of the research programme it was necessary to measure ground control points for geometric correction of satellite imagery, to determine exactly boundaries of Dyje and Morava floodplains and then to localize boundaries of other objects of interest – particularly experimental areas of other institutions. Mapping training sites for classification and updating data acquired from other sources was also realized. For these works GPS technologies enabling effective collection of thematic data in the field were used. The Department of Geoinformation Technologies disposes of a number of GPS receivers, ranging from common tourist (navigation) ones, through receivers for GIS applications, to accurate geodetic equipment. Most of these machines combine PDA and GPS and enable work with spatial data right in the field, such as the display of various raster maps, vector data, transformation of coordinate systems and so on.

Concerning this topic, tests were carried out regarding the accuracy of measurement of some GPS receivers for GIS application (in particular Trimble Juno ST a Trimble Recon, as they are often used by our students), primarily regarding the shade effects of forest canopy. It can be said that although the shade of forest canopy does influences the measurement, it is nearly always possible to proceed with the surveying (forest growth does not limit the use of the GPS to such an extent as, e.g., an adverse relief configuration does). The average PDOP value during the measurement under the forest canopy reached 3.5. No statistically significant relation between the PDOP value and the measurement error in the positional or altitudinal coordinates has been proven. In fact, despite the identical PDOP value, considerably varied measurement errors were generated. Often a higher PDOP value generated a greater measurement accuracy and vice versa. Therefore it cannot be declared that the PDOP value has a decisive impact on the measurement accuracy, but it should be only considered as a reference level, indicating situations when the measurement is not encouraged (i.e. PDOP values being higher than 10). Likewise, no statistically significant relation has been detected in species composition, stand density and the relief type. In contrast to it, the stand age does prove to be statistically significant, and in older stands higher average values of the mean square error in the position (XY) component of the coordinates (MSE XY) were observed, though depending on the stand density. These results may be interpreted in relation to the volume characteristics of the stand, where the wood substance blocks or modifies the received signal and thus reduces accuracy of the position located by the GPS.

Also recordings lasting 1, 2, 5 and 10 minutes were made in each point, with the 5-second recording frequency (i.e. 12, 24, 60 and 120 recordings). In individual selected time-lengths of the observations in tested points, a gradual decrease of the average MSE XY was detected up to the observation lengths of 5 minutes. With a 10-minute observation span, the error value grew equal to the one of a 2- minute observation (see Fig. 8). With a 1- minute observation, MSE XY already moves around a 5-metre limit, which is a value quoted by the manufacturer for the current technical equipment of the GPS receivers in the GIS application category. However, it needs to be emphasized that standard deviation is relatively high (3.5 m) and the local extreme values may reach triple value of the average. Not even the application of the post-process corrections generates any notable improvement. It results from the procured accuracy that the use of these GPS devices for forestry thematic mapping is debatable, when collecting basic data for forestry maps is considered. Forestry maps are regarded as thematic special purpose maps; they are described in § 5 No. 84/1996 of the Ministry of Agriculture regulations regarding forest management planning. Forestry maps must be based on the Cadastral Map or on the Derived State Map 1 : 5,000. If higher units of the spatial division of the forest are depicted, i.e. compartments and sub-compartments, geodetic accuracy of m = 0.0004*M is applied, where M is map scale. For forest management maps at 1 : 5,000 scale it means ± 2 m accuracy.

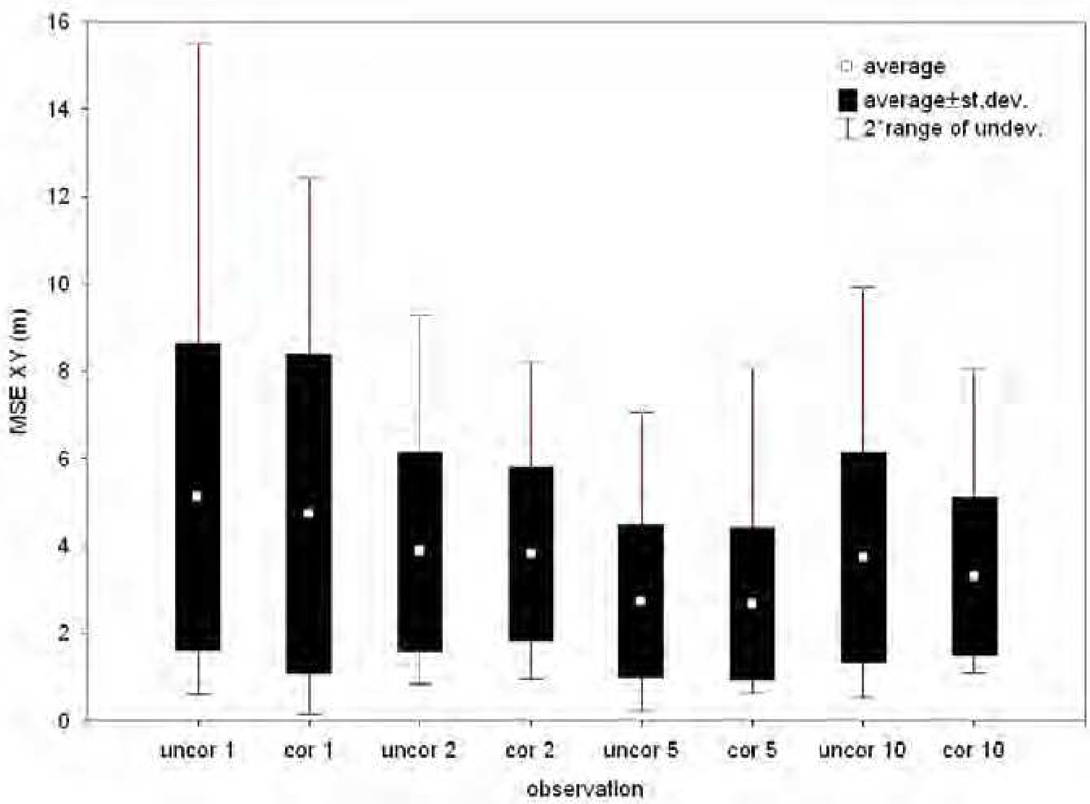

Fig. 8. Mean square error of the measurement of XY coordinates (MSE XY) without corrections (*uncor*) and with post-process corrections (*cor*) at 1, 2, 5 and10 minutes observations.

As a conclusion it follows that without corrections and depending on the length of the observation, tested GPS receivers may generate under the forest canopy mean square errors in the interval of 2.7 to 5.1 m. However, it must be taken into consideration that local extreme values my reach triple value of the quoted average. The measurement error of the elevation (Z) coordinate is approximately three times higher than the average MSE XY, with a substantially greater variance. The application of correction from referential stations appears ineffective. The measurements were intentionally carried out in the vegetation period, when maximal use of the GPS in the field research is expected, and forest canopy consisting of deciduous woody species contains foliage. It can be expected that under extreme relief conditions (deep and narrow mountain valleys, ravines and castellated rocks) the measuring accuracy may be further reduced; however, such conditions were not subject of the research.

2.4 The Lower Morava Biosphere Reserve

Within the frame of this research program, the Department of Geoinformation Technologies cooperates with a number of institutions operating in the given area – the most important one is the Lower Morava Biosphere Reserve (LMBR). This reserve is situated in the warmest region of the Czech Republic (see Fig. 9). Original Biosphere Reserve Palava originated in 1986 under authority of UNESCO Man and Biosphere (MAB) programme of ecological cooperation. In 2003 in Paris, the MAB International Coordination Committee approved to enlarge the Palava Biosphere Reserve by the Lednice-Valtice region and the alluvial forests on the confluence of the rivers Morava and Dyje. The reserve connects ecosystems of the Palava limestone barrier reef, the lowland alluvial forest (unique in central Europe) on the lower reaches of the Kyjovka, Dyje and Morava rivers and the cultural landscape of the Lednice-Valtice region. Since August 2004 the Lower Morava Biosphere Reserve Public Benefit Corporation became the administrative authority responsible for meeting the objectives and fulfilling the functions of the Lower Morava Biosphere Reserve.

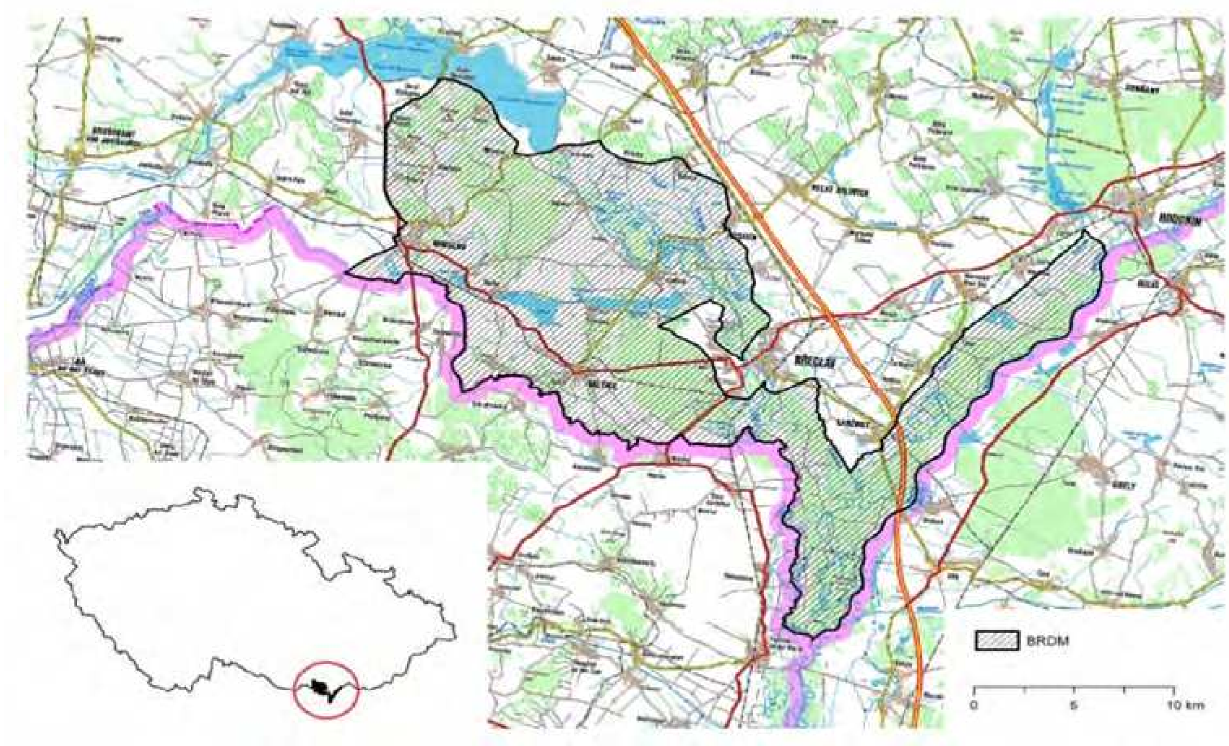

Fig. 9. The Lower Morava Biosphere Reserve (LMBR)

In the Czech Republic it is the very first time that a biosphere reserve was administered by a non-governmental organization In the LMBR area there is a number of territories of international importance – such as the territory of the Natura 2000 European system, protected regions such as the Protected Natural Reserve of Palava, the Lednice-Valtice region, the forested wetlands recorded by the Ramsar Convention on Wetlands of International Importance, two natural parks (the Dyje flood-plain and the Mikulcice alluvial forest) or the Protected region of the Post-tertiary (Quaternary) natural water storage of the Morava river.

2.4.1 Land cover map of the Lower Morava Biosphere Reserve

In order to conserve natural, cultural and aesthetic values of the biosphere reserve, the need to create a land cover database for long-term monitoring of landscape changes arise. The Department of Geoinformation Technologies has taken over this task as it falls within its research program and also owing to cooperation between the Mendel University and the LMBR management. The created database of land cover served, apart from already mentioned monitoring, also for the creation of a thematic map at scale 1 : 50,000. The chosen scale should assure spatial resolution of individual plots up to 0.25 ha (the smallest countable area and an area visible on the map). The database and the thematic map will be used for non-commercial presentation purposes and also will serve as the basis for future multi-criteria and multi-temporal analyses of land cover on the area of the LMBR.

If a database of precise surface area and positions had to be created for the area of interest, a special attention had to be paid both to the accuracy and the topicality of available data sources. This is why ZABAGED data (that is the most detailed data source with the most frequent updates in the Czech Republic) was chosen as input data, as it was in the case of the DTM creation. ZABAGED is a digital geographic (vector and raster) model of the Czech Republic that (regarding detail, accuracy and geographic representation) corresponds to the Base Map of the Czech Republic at scale 1 : 10,000 (ZM 10) in S-JTSK (or WGS-84 or S-42) system of coordinates and at the Baltic altitude system. Although this service has to be paid for, it offers safe data - both formally and factually; its use is limited by data supply contract. The Czech Office for Surveying, Mapping and Cadastre also provides ZABAGED data free of charge (in the limited amount of 10 ZM10 map sheets) for students´ semestral, bachelor and diploma works.

In the frame of our project, processing of the area covered with forest stands was based on forest maps and data of the Forest Management Plan (FMP) from the forest enterprise Zidlochovice. For needs of evidence of forest species composition, the woodland plots are divided into several categories according to the predominant species composition, with the smallest unit defined in the specification, regarding also units of forest spatial arrangement of the FMP. Forest stands thus can be divided into coniferous and deciduous stands, stands with natural species composition, monocultures, plantations, etc. Attribute table of FMP database records particular items, such as tree species representation, age, stand density and height which enables classification according to detailed (or even changing) requirements. Our update of maps and data was based on orthorectified and classified satellite imagery (Ikonos panchromatic and multispectral data of 1 m, respective 4 m spatial resolution) acquired in the end of 2005. The last phase encompassed the check of problematic places by field inspection and surveying (using GPS receivers Trimble GeoXT and ProXH).

In spite of all these efforts, the topological accuracy of the database and the whole resultant map remains doubtful, regarding combination of data from different sources. For example, lines of forest borders were digitized by a mensurational offices based on the Derived State Map 1 : 5,000, and therefore they are not identical with borders of woodland polygons in ZABAGED data. The reason rests with both the duplicate data creation in particular institutions and different requirements on accuracy of created data sets. When creating thematic forest or landscape data we could mention tens of such cases. For illustration: In the end of 2006, evaluation of the Czech State administration was carried out by the European Union authorities (as part of preparation for the INSPIRE regulation) and it was stated that technical facilities for data creation in the Czech Republic are good, but the coordination and infrastructure management are very bad, and that the financing of data creation is chaotic and unregulated. Thus we can only hope that the implementation of the INSPIRE regulation will bring improvement to this field.

For our project, the LMBR borders were more closely specified in cooperation with the management of the reserve, on order to avoid possible problems at the creation of the map of land cover (such as omitting a part of the LMBR, or, conversely, including areas outside the reserve). After the creation of geodatabase, area of each land cover category in the LMBR was computed see Table 1). This information is used for comparing with historical data and for periodic updates of land cover map. (It is envisaged that the land cover map updating could be harmonized with periodic Forest Management Plan updates).

The resultant geodatabase and resultant thematic map were printed in mid-2007 and there is a possibility that a planned LMBR map server could be based on this data.

Land cover	**Area [km^2]**	**Representation [%]**
Buildings and urban area	4.38	1.2
Forest stand	137.11	38.6
Permanent grassland	31.44	8.9
Garden, orchard and park	12.63	3.6
Arable land	131.71	37.2
Other anthropic land	3.85	1.1
Vineyards	21.70	6.1
Water area	11.72	3.3
	354.54	**100.0**

Table 1. Representation of main categories of LMBR land cover

2.4.2 Land cover changes analysis of the Biosphere Reserve Lower Morava

Monitoring of land cover changes based on old maps is usually done in several steps. The first one is digitization (or scanning) followed by geo-referencing of these maps. The second step is the derivation of mutually comparable vector layers from scanned and georeferenced maps. For manual vectorization several methods can be used. One of them is the method of "stepwise interpretation", another is the method of "backward interpretation" (Skokanova, 2008). The third step of monitoring the land cover change is the analysis of individual vector layers and layers created by their overlay. This enables the interpretation of changes made during period under observation.

A phase which is often underestimated in similar multi-temporal analyses is a mutual positional integration of the used layers (it concerns keeping identical borders of individual landscape types for the whole observed period). The integrity of the layers is a basic element in the resultant accuracy analysis, especially when maps of larger scales are processed. For the LMBR area, available data from five time periods (approximately from 1840, 1880, 1950, 1990 and 2006) was created by stepwise vectorization in the ESRI shapefile format (Malach, 2009).

Regarding the LMBR land cover, the method of automated geometric integration of vector layers was verified. It tries to imitate the process of backward vectorization, while it uses data obtained by stepwise vectorization that are simultaneously corrected. For this purpose a special toolbox „Land use change“ was created in ESRI ArcGIS Desktop, whose core is compound by tools „Layer Integrator“ and „Change Analysis“. The tools were created as models in application Model Builder so that the result is a sequence of tools contained in ESRI ArcInfo 9.3 functionality (Malach, 2009).

Like backward vectorization, the system of layer integration is also based on the most accurate layout vector layer representing current land use. Based on this layer, a layer from the previous period is integrated, and a layer from the next period, based on the newly created one (already integrated previous layer) is adjusted. Like that, the principle of automated geometric integration depends on the overlay of two time-contiguous layers (by means of the Union tool) that operates until all layers are processed. In the first phase, the Layer Integrator searches for all polygons in a combined layer that were created by the overlay and that can be, according to their parameters, considered as sliver polygons. These are polygons that do not represent a real change in land cover but were created as a result of different position of identical borders. This phase is crucial and its realization is based on the size of the created polygon and on other proportional characteristics (the ratio of perimeter and area, the ratio of the polygon area and area of a circle with the same perimeter). By means of the Dissolve tool it is possible to divide the borders of the polygons and, based on the attribute, a new layer free of detected sliver polygons is obtained.

The second tool called Change Analysis serves for creating land cover change maps. It enables to determine stable and unstable areas from the outputs of the Layer Integrator tool. The principle of the Change Analysis tool is again in the overlay of the Union type where all layers for the observed period are combined. Based on the differences of the land cover type codes, a field called Changes is created. The Changes field contains a value reflecting number of changes in the land use which took place on the given polygon.

From results verified on the LMBR area we can conclude that the outputs obtained with Layer Integrator tool are more similar to the data derived by means of the method of backward vectorization. The ability of the Layer Integrator to correct the geometry of the borders logically depends on the extent of mutual similarity of map sets from which the vector layers were derived. The crucial part here is played by the quality and the scale of the original surveying as well as the quality of digitization and georeferencing. Layer Integrator is able to correct the extent of position shifts that are limited by defined parameters of sliver polygons.

In relation to stepwise vectorization data, Layer Integrator outputs preserve a comparable relative area representation of particular land cover types. From this characteristic we can deduce that by the correction of the layers obtained by means of stepwise vectorization in

Layer Integrator tool, dramatic changes in the landscape structure do not occur. Statistical information carried by the original layers is thus well preserved. More accurate individual layers of stepwise vectorization naturally result in a more accurate map of land cover changes number that was created by layer overlay for the observed period. By the correction of layers using the Layer Integrator tool, the occurrence of sliver polygons was reduced almost four times during the creation of the land use change map for the whole LMBR area; this result indicates that these polygons were correctly localized. The difference in the land cover change maps obtained from the Layer Integrator outputs in comparison with the maps derived from stepwise vectorization data is noticeable also from the relative representation of stable and unstable areas.

The Layer Integrator tool thus well serves for the mutual geometric integration of vector layers. It uses layers obtained by means of stepwise vectorization as source data that are mutually compared and corrected. The aim is to preserve the most accurate position of identical borders over all the period of regarded time series; its function is limited by the extent of mutual position shift in source layers. For the LMBR area, especially for layers derived from maps of the 2nd (1840) and 3rd (1880) military surveying there are position shifts which the developed algorithm is unable to solve efficiently. There are also problems with polygons of a relatively large area connected with a sliver polygon. The present algorithm is unable to recognize and mark these polygons as slivers and this fault may give rise to new slivers. Throughout the layer integration it is therefore advisable to check the outputs visually and to remove mistakes, if necessary. This concerned also the water area land cover type that represents an important landscape element in the observed area. The results obtained confirm that the Layer Integrator tool represents a suitable tool for the multi-temporal land cover change analyses.

2.4.3 Visual exposure of the Lower Morava Biosphere Reserve landscape

Analyses of visibility belong to basic operations of specific geomorphometry at digital terrain model analyses and they use also data about objects on relief surface. Determining visual exposure differs from the analysis of visibility in a fact that it takes into consideration the human factor – a visually exposed area is exposed to the perception of an observer. Such analysis can thus serve as an additional tool for the classification of landscape character of an area a. Delimitation of visual horizons and determining their protected zones can be used as a quite practical result because changes in visually exposed areas have a large impact on cultural, historical and aesthetic value of the area.

For the evaluation of visual exposure, the crucial thing is the choice of input point field, which defines places the area is observed from. For the LMBR area, data in two alternative versions was used (Kuchynkova & Mikita, 2009). Initially (1) the data was generated in regular raster of 500 x 500 m and then (2) dots were used, representing places where people usually move over the area - that is all types of highways, roads, tourist routes, view points, urban areas, neighbourhood of water areas, gardens and orchards. The whole algorithm was processed in ESRI ArcGIS Desktop and five categories of visual exposure were determined (very low, low, average, high and very high). The DTM with the overlap of 5km behind the boundary of the modelled area was used as basic analytic raster; it was necessary to complete it by adding heights of objects on the surface. In order to create the whole model, it was necessary to make several simplifications. Data from the map of land cover was also used together with its database where mensurational data for forest stands are stored. Here each stand group has a height attribute of the most frequently represented tree species; this was used for the model. Heights of other objects were not investigated for each

particular element but were assigned an average value (e.g. 20 m for individually standing trees and 10 m for buildings). The digital surface model (DSM) this way created was analysed by means of Viewshed tool and a value of how many times a given pixel is seen from the sites of an observer was recorded in the resultant raster. In the alternative version where the input point field was a regular raster, higher values in of visual exposure categories were reached.
From the result described it follows that the first alternative is suitable for a preventive evaluation of visual exposure, while the second alternative represents better real landscape structure and it is more suitable for case studies of landscape changes (Kuchynkova & Mikita, 2009). The whole process can be effectively written as a macro or script and the model may be completed with other additional data, depending on the range of the area under observation and on available data sets (heights of objects or directly DSM from photogrammetric methods or laser scanning).

2.5 Geodatabase approach and Digital Landscape Model

For the correct functioning of the Digital Landscape Mode (DLM) it is necessary to get a large and above all the topologically accurate database of the area of interest. It is created by number of input data integrated into form of 3 layers – natural background, anthropogenic environment and a layer of development limits (see Fig. 10). Creating the layer of natural background is a very demanding process. This layer consists of following data components: geologic and soil map, forest type map and a map of classified soil-ecological units (in Czech BPEJ). Due to considerable generalization of the geological map and the soil map, the first task in this stage of our project was to re-make these maps in order to correspond as accurately as possible to real conditions. The created digital geologic and soil map was therefore re-made upon the Base Map of the Czech Republic 1 : 10,000 and ZABAGED data; terrain singularities were taken into consideration, so that the resulting map could be used for consequent data integration. Layers of anthropogenic impact and development limits were created using land cover plans of concerned villages. When data integration is completed and database updated, it is possible to carry out various spatial analyses and syntheses, e.g. the search for non-forest areas suitable for forestation that might be one of final results of our research project.
The Czech Republic disposes of detailed land documentation concerning both natural environment and socio-economic domain. The products of environmental thematic mapping are analytical (thematic) maps of particular elements of nature. Although parameters of the represented elements are always in mutual harmony in nature, in GIS it may happen that when the maps are overlaid, the expected concordance of thematic layers is quite delusive. This way a lot of combinations of individual parameters may come into existence that is impossible in nature. These problems may be avoided by logical integration of the data during construction of the Digital Landscape Model. Such DLM should only contain homogeneous multi-parametric areas such as typological natural (as well as anthropogenic) landscape elements with mutually well combined natural characteristics and human impact. From the formal point of view, DLM thus contains logically (not only by scale, format, projection or definition) integrated data layers representing newly conceived database where there is a low number of poly-thematic layers and the digital terrain model instead of great amount of overlaid mono-thematic data layers (Kolejka et al., 2003).
Following poly-attribute DLM layers then suffice for many tasks of spatial analyses and

syntheses accomplished in GIS:
- Integrated layer „natural background“
- Integrated layer „anthropogenic impact“
- Integrated layer „development limits“.

Such a database was already created in the frame of our project. It consists of several (few) synthetic maps with multi-parameter content where particular information is logically connected and all object positions are correct.

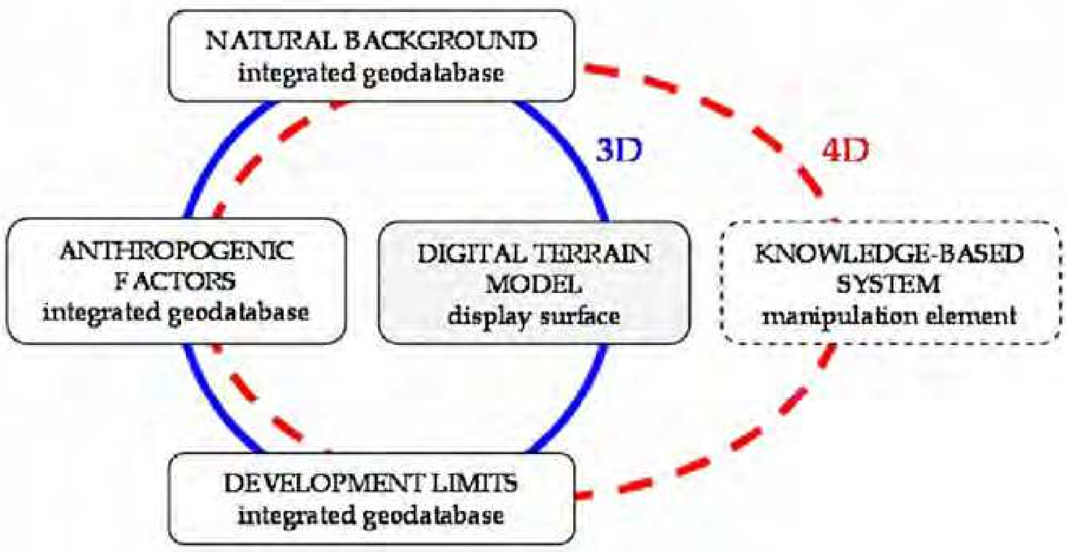

Fig. 10. Scheme of the Digital Landscape Model (After Kolejka et al., 2003)

2.6 Conclusion

Geoinformation support of the research programme of the Faculty of Forestry and Wood Technology is a complex matter consisting of particular projects and their tasks. Such a support is nowadays an essential part of most research projects and it is crucial for creating available and widely applicable results. The Digital Landscape Model created for the pilot area of interest pursues suitably (using a formalized access) these aims.

3. Geospatial Education the Department of Geoinformation Technologies

3.1 Courses and geospatial software packages in use

Importance of geoinformation technologies, enabling efficient processing of geospatial digital data, gradually increases at present-day society. Nevertheless, their effective applications require users' skills. These skills are difficult and expensive to achieve in practice. Providing students with necessary knowledge and skills is therefore an important task of educational institutions, mainly universities. Faculty of Forestry and Wood Technology provides education and research focused on renewable natural resources.

At bachelor level, students obtain general theoretical and practical knowledge of geospatial technologies in the GIS Fundamentals course. This compulsory GIS course is attended by more than 300 students per academic year. Tutorial materials on the Department's web pages (DGT, 2008) provide necessary educational support. Digital data of the University

Forest (the Masaryk Forest, 10,500 ha), are utilized in hands-on practices and individual projects. At the beginning of practical exercises students familiarize themselves with various spatial data formats, data models and corresponding file structures, as well as with basic GIS functions. Students solve spatial problems using database queries, distance and context operators, cost distances and least-cost pathways, map algebra and spatial database management system. Beside that they work individually on a complex project related to given area of the Masaryk Forest territory. At these specific plots they can demonstrate gained skills and produce operative results. Land use map and digital terrain model provide basic working data. Forest management maps and numeric data of the forest management plan are also available. Map of tree species composition optimized for a given vegetation zone according to altitude and aspect, model of flood caused by torrent precipitation, or design of new skidding track connected to forest road in a given forest stand, all these tasks represent typical practical outputs of individual student projects. Compulsory Surveying and land records course familiarizes students with basic surveying methods, Czech cadastral system and digital processing of surveying data. There is also an offer of optional courses: Cartography, Digital cartography, Digital photogrammetry and visualization, Digital terrain models, Geospatial data processing.

At master level, in the Remote sensing course, students are introduced to remotely sensed data processing, including multispectral data evaluation, vegetation indices, hard and soft classification methods, fuzzy signatures, etc. They also learn advanced GIS analysis methods – multi-criteria and multi-objective evaluation, risk analysis, change and time series analysis, decision support methods and statistical modelling. In the Integrated use of GIS course, they learn to use GIS in various fields of human activities connected with the exploitation of landscape space, with data modelling and GIS project management. A curriculum focused on integrated utilization of the landscape space and geospatial technologies has been accredited several years ago.

At doctoral level, new curriculum Applied Geoinformatics has been accredited at the beginning of 2007. Students at both master and doctoral levels usually use data of research projects for their theses and dissertations.

Since 1993, geoanalytic and image processing system Idrisi has been used as a main tool for essential education of students in geospatial technologies at bachelor level. For this purpose a networked 20 seat computer laboratory is used and some other computer labs are available at the University Information Centre. Raster oriented system Idrisi, in its 16th release (Taiga) is an innovative and functional geographic modelling technology that enables and supports environmental decision making for the real world. It also provides strong tool for image classification, e.g. soft classifiers, hyperspectral analysis and neural classifiers. The software has been developed by Clark Labs (Clark University, Worcester, Ma, USA). As a non-profit system Idrisi acquired a great many users all over the world. The software is supported by a network of 20 Idrisi Resources Centres (IRC); they are situated in Asia, Africa, Europe, North & Central America and South America. These centres offer Idrisi-related resources for users outside United States. They receive unlimited Idrisi licence and make available basic information about Idrisi, offer training in Idrisi, host Idrisi User Meetings, and represent Clark Labs at local conferences. Papers of last Czech and Slovak Idrisi conference are published in Klimanek & Misakova, 2009. IRC in Czech Republic has been established at Mendel University in 1997; it is jointly administered with Technical University Zvolen, Slovakia. Since than, a lot of remote sensing and GIS data was created and interesting results of practical applications of geospatial technologies were acquired. Educational data concern mainly Masaryk Forest. Research data cover also several Czech mountains (the Beskids, the Giant Mountains, the Bohemian Forest). We have been quite happy using Idrisi as a basic GIS teaching software for long years. Regrettably, Idrisi is rarely applied in a Czech professional practice.

In our country, ArcGIS, a product of the Environmental Systems Research Institute (ESRI) at Redlands, California is widely used by government and other official agencies, as well as by private companies. Effective marketing of a Czech company ArcData (dealer of ESRI products) and generally growing geospatial literacy in our country increased the demand for university graduates familiar with ArcGIS. According to Mrs. Melounova of ArcData (Melounova, 2006), ArcGIS is the leading GIS in Czech Republic. That is why ArcGIS became at our Faculty a primary GIS since 2007. ArcGIS desktop represents today a complex and integrated system of GIS products. There is a wide selection of literature on the product, and web information not only in English but also in Czech and other languages. ArcData, which distributes ArcGIS in our country, offers users a library of technical publications (ArcData, 2008). For basic practical exercises in 15-20 seat computer labs, the product ArcView, or ArcEditor, can be used, both offering students a variety of tools for creating, editing and analysing geospatial data. Several extensions of ArcGIS desktop, e.g. ArcGIS Spatial Analyst, ArcGIS 3D Analyst, ArcGIS Network Analyst and ArcGIS Business Analyst enhance the analytical scope of this software. Web services are provided by ArcGIS servers and ArcPad can be used for field work. ArcGIS desktop is rather complicated for an inexpert user. If you want to work successfully, you need to use the interface of three applications. ArcMap enables map editing and analysis, ArcCatalog enables data management and ArcToolboxes provide transformation, statistical and other tools. In addition, it is possible to use a graphic interface, ModelBuilder, for constructing geospatial models. Its complexity may be intentional on the part of its makers, as without professional training few users can use the system effectively.

As Czech forest management planning rapidly proceeds from analogue to digital methods, students also need to master a graphic environment of the most important software used in Czech forestry – GIS TopoL, product of Czech TopoL Software Company. TopoL native data format (BLK) serves as a standard for digital Czech forest data. Access to vector-oriented spatial data is based on database principles, raster operation are also supported. The newest product of the company is TopoL xT 9.0.

Open source/free software GIS GRASS is used for basic student education as an option. GRASS (Geographic Resources Analysis Support System) has been developed since 1982 to meet the needs of the US Army. Since the end of nineteen-eighties of the last century, the complete software package, including source codes, is available to the public. GRASS is run usually under the GNU/Linux operational system, but it can also work under UNIX, Mac OSX, MS-Windows and other platforms. Since GRASS is open-source/free software published under GNU General Public License, its users are not limited by its price and the program is readily accessible to students and private users. Neteler and Mitasova, 2004 published a useful and detailed textbook on GRASS. There is also a very good user support for GRASS on Internet, also in Czech language. The main advantage of GRASS is that it is freely available and that its user community is growing rapidly. But, in spite of all this, GRASS is little used by commercial and administrative organizations (usually it is used only at places where there are GRASS enthusiasts). This constitutes the main disadvantage of

GRASS, at least in Czech Republic. Nevertheless, we believe that more extensive use of open-source/free software is the way forward as it enables students to work on their projects easily at home using their own computers, without a need to pay for expensive geospatial software.

A networked version of software package Geomatica 10 from a Canadian company PCI Geomatics is used for remote sensing teaching and practical works of students at master level. In the field of remotely sensed data processing, Geomatica has the best set of raster analytic operations.

A very powerful (but also very expensive) software for image classification Definiens (eCognition), produced by a German company Definiens, is used by students at doctoral level (we have 2 licences). This software does not classify single pixels, but first segments the image into spectrally homogenous objects. With multi-resolution image segmentation providing a hierarchical network of image objects, users get a multi-scale, real-world view. Additional information, which can be derived from image objects, e.g. shape, texture, area, context, may be used for classification. Using Definiens knowledge-based classification function the user can formulate concepts and factual information about the relevant image content and use the result to process contextual information. The particular knowledge base can be created by means of inheritance mechanisms, concepts and methods of fuzzy logic, and semantic modeling. This way Definiens can recognize some characteristics that are typical for a human visual inspection.

A more detailed comparison of the above mentioned software is given by Zidek, 2007. In addition to these software packages, our advanced students can use also Bentley MicroStation, Intergraph GeoMedia, ER Mapper, MultiSpec, Czech surveying software Kokes and some other GIS and image processing systems.

3.2 Sharing of digital geospatial data

Sharing of digital geospatial data has been solved by implementing web mapping service (WMS) technology using open source environment of University of Minnesota MapServer (http://mapserver.mendelu.cz/mapserver). For users in our country there is an important advantage in its feasibility to read and display vector data from several coordinate systems (e.g. WGS-84, S-JTSK and S-42) and to display concurrently both raster and vector data. The application is equipped with standard web mapping functions, as zooming, panning, layer management and attribute querying. From start of its initial launch in 2002, our MapServer serves both Faculty teachers and students for many aims of their practical and research works.

For the purpose of distribution and use of geospatial data in public, Sumbera (2006) has developed a virtual application MapSnack (http://mapsnack.mendelu.cz). MapSnack (the term “snack” means “fast”) is a fully pre-installed and pre-configured geospatial virtual appliance that runs on any standard x86 machine in a self-contained, isolated environment. MapSnack consists of latest UMN MapServer and P.Mapper with sample dataset (see Fig. 11). A vision of MapSnack is to accompany raw geospatial data which comes in different formats with functionality to explore, query, share and manage content. That involves merging data with functionality logic to simplify their absorption by consumer.

MapSnack eliminates the installation, configuration and maintenance effort associated with deploying complex stacks of software for web mapping. (There are basically two approaches how to achieve that. First is traditional and nowadays very popular LiveCD appliance, second is a virtual appliance.) MapSnack serves georeferenced map layers (vector or raster based) to the browser. It is ready to be deployed as OGC compliant web server serving or consuming other WMS or WFS services. At present it provides maps of South Moravia alluvial plains. MapSnack got "Honorable Mention" sign by VMWare in 2006 "Ultimate Virtual Appliance Challenge" competition. MapSnack presentation can be seen at http://www.slideshare. net/sumbera/mapsnack-2007-presentation.

Both virtual geospatial appliances run on server MapBistro with VMware Server installed on Debian.

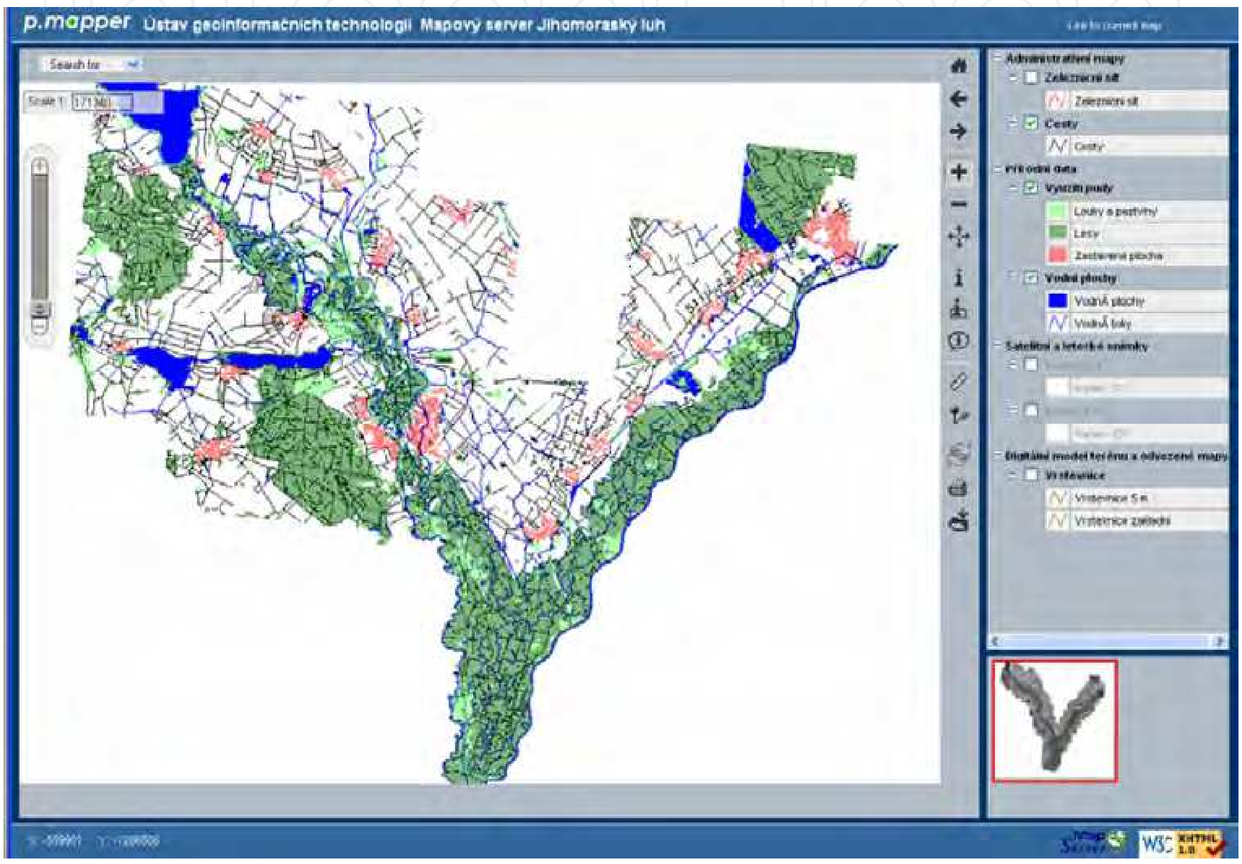

Fig. 11. MapSnack prototype with P.Mapper sample dataset on the web

New way for creating and sharing of digital maps in internet environment is presented by a community map portal MapShake created by Sumbera, 2008. MapShake is an integrator of map compositions and users can "shake" maps from different sources and share, remark and publish them. With MapShake it is possible to remove the default map content from the map viewer, add one's own content with a preferred projection, annotate it with particular custom ingredients, look-up spatially for other recipes and shake it up. This way the broad community can be served and the beauty of the web live cartography enjoyed. For users, Sumbera has published 5 key MapShake messages: (1) "Shake you map sources" – that is add any layer you find usable for your nice maps. Advanced – change styles; (2) "Use your ingredients" – that is add any annotation for your business, for fun, for share; (3) "Share your maps" – that is your maps are localizable, with simple permissions, your annotations are searchable by spatial queries; (4) "Search other maps" include other people annotations for your maps. Query for by simple spatial query; (5) "Use in your context" - your map compositions are accessible in the field through iPhone. MapShake at present runs in Czech language in technology preview mode on http://www.mapshake.cz.

Since January 2009, our team participates in Apple iPhone Development program for Universities. Kaminek, 2009, a postgraduate student of Applied geoinformatics has created a prototype for mobile accessing WMS layers within iPhone, using native Apple iPhone technology and interface. His project received a start-up grant from the Internal Grant Agency (IGA) of Mendel University and looks very promising. First presentation of his application WhatEverMap can be seen on http://mapserver.mendelu.cz/iphonelayers together with sample screencasts (see Fig. 12). Codename of the project is iPhoneLayers. MapShake can store all map compositions and users have various front-ends how to consume or shake their maps; iPhone can serve as a possible outlet where, based on the current GPS position, users can receive their pre-shacked maps from the MapShake store.

Fig. 12. Application WhatEverMap on iPhone with a specimen of Czech Environmental Information Agency (CENIA) data and a specimen of Czech cadastral data

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Since many decades Education Science and Technology has an achieved tremendous recognition and has been applied to variety of disciplines, mainly Curriculum development, methodology to develop e-learning systems and education management. Many efforts have been taken to improve knowledge of students, researchers, educationists in the field of computer science and engineering. Still many problems to increase their knowledge on daily basis so this book provides newly innovations and ideas in the field of computer science and engineering to face the new challenges of current and future centuries. Basically this book open platform for creative discussion for future and current technologies to adapt new challenges in education sector at different levels which are essential to understand for the students, researchers, academic personals and industry related people to enhance their capabilities to capture new ideas and provides valuable contribution to an international community.

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