SPATIAL ANALYSIS OF WATERSHEDS - A CASE STUDY FROM CZECH REPUBLIC

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Abstract
Digitised ortho-photomaps of 1995 (1: 10 000 scale) and other spatial data were utilized for studies on land use interpretation and characterisation of three watersheds of Southern Moravia, Czech Republic. The major land uses identified in watersheds are: Vseminka – forests (48.2%), meadows and pastures (24.2%) and arable lands (9.3%); Frystak- forests (45.4%), arable lands (37.1%) and meadows and pastures (6.1%); Drevnice- forests (81%), meadows pastures (9%) and arable lands (2.7%). From topographical analysis of a digital elevation model in Vseminka, it was found that about 33% of the area falls in 5-10% slopes, while 29% and 18% of the area falls in 10-15% and 15-20% slope ranges respectively. From the analysis of Drevnice watershed, about 36% of the area was in the 10-15% slope category, 22% was in the 5-10% category, 21% in the 15-20% category, and 12% in the 20-24% slope category respectively. In Frystak watershed, the major landscapes (35% of the area) had slopes in the range of 5-10%, followed by 28% of the area with 0-5% slope and 19% of the area with 10-14% slope. From the temporal analysis of the Vseminka watershed, a tremendous change of land use between years 1965 and 1997 was found in arable lands and meadows, indicating conversion of arable lands into meadows. Comparison of data from 1955 and 1995 indicated there was a four-fold decrease in agricultural area.

Additional Keywords: digital elevation model, orthophoto-maps, temporal analysis, topographical analysis.

Introduction
GIS tools for spatial analysis can be used to identify problems and to evaluate the spatial distribution of natural resources, land use/land cover data and for preparation of various thematic maps (Burrough, 1986). Evaluation of the spatial and temporal data of each parameter can give a clear picture of various resources of a watershed. Historical aerial photographs can be used as a major data source for studying landscapes through a computer based approach (Kadmon and Kremer, 1999). Digital photogrammetry, computerized image processing and geographical information systems have opened new possibilities for the extraction of data on vegetation changes from aerial photographs. With this background and view, a research study was conducted to characterize the landscapes of Vseminka watershed using digitized spatial data like orthophoto-maps and digital elevation models (DEMs).

Materials and Methods
Study area
Three watersheds selected for the research investigation were Vseminka, Drevnice and Frystak – sub-catchments of the river Morava. These watersheds are located in the eastern part of Zlin district of Southern Moravia, Czech Republic. The elevations of the watersheds range between 276 to 735 m. above mean sea level. The study area is part of the White Carpathian region. A great variety of parent rocks and soil types characterize these watersheds. Crystalline rocks (granite, gneiss, granodiorites) prevail in the Hercynian region (Frystak watershed), while the Carpathian part is created by specific flysch series of strata of sandstone and clay stone (Drevnice and Vseminka watersheds). All the three watersheds are named after the tributaries of which they are formed *viz*., Drevnice, Vsemina and Frystak. Drevnice and Frystak are the tributaries of river Morava while Vsemina is a sub-tributary of Drevnice. Drevnice and Frystak are watersheds of third order, while Vseminka is of fourth order.

Methodology
A GIS coverage was created for the investigated watersheds of Southern Moravia using orthophotos, DEM and other thematic maps. A spatial database for all the watersheds was assembled using Arc View GIS program. The data layers comprise digitized orthophoto-maps from 1995 (1:10000), digitized geology, pedology maps, forest cover map (digitized), DEMs and cadastral maps (digitized).

Interpretation of digitized orthophoto-maps
Digitized orthophoto-maps (1:10000 scale) of the watersheds were obtained as multi-band images. The orthophoto-maps were marked with the watershed boundaries and further interpreted for the delineation of various geomorphologic features and land use changes. Land use and land cover features were delineated using GIS techniques and topographical and other reference data. These were verified in the field. GIS coverages were created

for the watershed of southern Moravia using advanced mapping techniques, including the integration of orthophotos, a high-resolution DEM, and aerial characterization. A spatial database for the watershed was assembled using ArcView GIS. The data layers comprise digitized orthophoto-maps of year 1995 (1:10 000), DEMs and drainage/stream networks. The vector layers extracted through interpretation of ortho photomaps were overlaid with the watershed boundary for the identification of various geomorphologic features and land use changes. Land use and land cover features were delineated using GIS techniques and topographical and the other reference data. These were verified in the field.

Results and Discussion

Delineated land use categories of the individual watersheds are presented in Table 1. On the basis of these figures, Drevnice can be identified as primarily a forest watershed with agricultural land use, while the other two watersheds are used primarily for agriculture, with less than 50 percent forested area. In Frystak watershed agricultural lands are mainly arable whereas in Vseminka meadows and pastures are dominant. From this data it can be assumed that Frystak is the most intensively used watershed with a possible negative influence on the water regime. The orthophotos were found to be more helpful for land use and landform interpretation (Sumerall *et al.*, 1995; Maitre *et al.*, 1993; Liu *et al.*, 1997; Baker and Barnes, 1998).

Table 1. Land use categories of watersheds (% area)

Land use category	Vseminka	Frystak	Drevnice
Arable lands	9.3	37.1	2.7
Meadows, permanent grazed lands	24.2	6.1	9.0
Public parks, gardens, etc.	5.5	3.9	2.9
Built areas and intravilans	4.3	5.5	0.8
Shrubs, etc.	8.5	2.0	3.6
Forest	48.2	45.4	81.0

Topographical analysis of watersheds

Topographical analysis of the watersheds was carried out using a DEM. The various topographical parameters computed were elevation grid, slope classes, aspect, and contours. The digital elevation grid data with elevation classes were created using Arc View GIS 3.2 with Arc View Spatial Analyst and Arc View 3-D Analyst extensions. The digital elevation models were used to compute the slope and aspect features. The slope values are presented in Table 2.

Table 2. Slope (%) categories and extent of the watersheds

Slope class (%)	Area (%)		
	Vseminka	Drevnice	Frystak
0-5	12	5	28
5-10	33	22	35
10-15	29	36	19
15-20	18	21	9
20-25	6	12	6
25-30	1	3	2
30-35	0	1	0

For computation of slope values of the watersheds, the elevation grid derived from the DEM was converted to slope data using the slope process. Similarly, the grid data was used for computation of aspect. These topographical features, namely, elevation, slope and aspect were transferred to 3-D scenes for presentation in 3 dimensional view. From the topographical analysis of Vseminka DEM, it was found that about 33% of the area falls in 5-10% slopes while 29% and 18% of the area falls in 10-15% and 15-20% slope ranges respectively. From the analysis of Drevnice watershed, about 36% of the area was in the 10-15% slope category, 22% was in the 5-10% category, 21% in the 15-20% category, and 12% in the 20-24% slope category respectively. In Frystak watershed, the major landscapes (35% of the area) had slopes in the range of 5-10%, followed by 28% of the area with 0-5% slope and 19% of the area with 10-14% slope. Since Frystak watershed has more agricultural land it is logical to find relatively more areas under 0-5% slopes as compared to the other two watersheds. Similar results were reported for Block Island and Rhode Island at a scale of 1: 40, 000 using terrain model to derive slope and aspect for each pixel (Duhaime *et al.*, 1997). Digital elevation models are one of the important spatial data for landscape analysis especially in GIS systems. Topographic features including aspect, slope steepness, slope configuration (i.e. convex, straight or concave) and slope position (i.e., ridge top to valley bottom) were computed from USGS digital elevation models for the alpine areas of Lasses Volcanic National Park in the Cascade Range of northern California, (Pincer *et al.*, 1997).

Estimation of potential erosion of watersheds

The soil erosion maps of the watersheds show that the maximum area falls in the category of extreme erosion (Table 3). From the erosion map of Vseminka, it was found that about 39 % of the area falls in the extreme erosion category. In Drevnice watershed about 14 % of the area falls in the extreme erosion category. The highest area under Frystak watershed falls in extreme erosion (30 %) followed by slight erosion (14 %). The erosion values for the forest areas were not computed.

Table 3. Erosion categories of watersheds (% area)

Erosion category	Soil loss (Ton/ha / year)	Vseminka	Drevnice	Frystak
No erosion	< 1.5	6	1	9
Slight erosion	1.6 – 3.0	2	1	14
Moderate erosion	3.1 – 4.5	2	1	1
Severe erosion	4.6 – 6.0	1	-	-
Very severe erosion	6.1 – 7.5	2	-	1
Extreme erosion	> 7.5	39	14	30

Temporal analysis of Vseminka watershed

Monitoring of landscape changes, especially using temporal data of aerial photographs and satellite images is more advantageous with the help of remote sensing and GIS techniques. To evaluate the land use changes of the watershed Vseminka, cadastral data of 1965, black and white aerial photograph of year 1955 and colour orthophoto-map of the year 1995 (1:10 000) were used. The first temporal data used was cadastral data for the years 1965 and 1997. The area of each land use category is listed in Table 4.

The second data used for the comparison of changes in land use was non-rectified aerial photos of year 1955 and orthophoto-map of 1995. The number of polygons of agricultural lands in 1955 was 2140 as compared to 535 in 1995. Land use situations between the periods of 1981 and 1995 were compared with the help of landform features map of 1981 and orthophoto-maps of 1995. There were no significant differences observed, except less significant increase in residential habitat, decrease of forests, which are converted either, to meadows or orchards. The number of polygons showing the meadows and shrubs vary from each other in both the maps. As the number of polygons indicating the meadows and shrubs category is higher in the year 1995 (ortho photomap). This indicates that some lands are gradually being converted to meadows and pastures over the years, as also seen from the data of years 1963 (cadastral data) and 1955 (aerial photo).

Table 4. Land use classes of Vseminka watershed of the years 1965 and 1997 (hectares)

Land Use	1965	1997	Change
Total area	2003	2024	21
Arable land	558	251	307
Gardens	43	70	27
Fruit orchards	24	10	14
Meadows	196	437	241
Pastures	296	190	106
Total agricultural land	1118	962	156
Forest land	999	1025	26
Water bodies	17	23	6
Built areas	27	38	11
Other areas	100	234	134

In a similar study Lipsky (1999) studied the changes that occurred in the land use of Czech Republic in the last century. He observed that the decrease in arable land was more significant as compared to other land uses (Table 5). Land use changes are also evident from the studies in the heavily polluted mountains of Krusne Hory on the border between the Czech Republic and Germany. The extent and rate of deforestation including some spatial properties were studied (Ardo *et al.*, 1997) in these mountains. Over 50% of the coniferous forest was disappeared during the period 1972 to 1989.

Table 5. Changes in agricultural and forestlands of Czech Republic in the 20th Century (%) (Lipsky, 1999)

Land use categories	Year					Change 1989-99
	1900	1948	1968	1989	1999	
Arable lands	51.7	44.8	42.3	41.1	39.3	-1.8
Permanent grass lands	14.3	13.6	11.9	10.4	11.3	+0.9
Total agricultural land	67.5	60.2	56.8	54.5	54.3	-0.2
Forest lands	28.6	30.5	33.0	33.3	33.4	+0.1

References

Ardo-J; Lambert-N; Henzlik-V; Rock-BN., 1997: Satellite- based estimations of coniferous forest cover changes: Krusne Hory, Czech Republic 1972-1989.Ambio. 26:3 pp. 158-166.
Baker-ME; Barnes-BW., 1998: Landscape ecosystem diversity of river floodplains in northwestern Lower Michigan, USA. Canadian-Journal-of-Forest- Research.28: 9, 1405.
Burrough, P.A., 1986: Principles of Geographic information systems for land resources assessment. Clarendon Press, Oxford.
Duhaime-RJ; August-PV; Wright-WR., 1997: Automated vegetation mapping using digital orthophotography. Photogrammetric-Engineering-and –Remote-Sensing. 63: 11, 1295-1302.
Lipsky, Zdeněk, 2000: Sledování změn v kuluturní krajině. Department of Applied Ecology, Kostelec nad Černými lesy, Faculty of Forestry, Czech University of Agriculture, Prague.
Liu, J.; Chen, J.M.; Cihlar, J. and Park WM, 1997: A process based boreal ecosystem productivity simulator using remote sensing inputs. Remote Sensing of Environment. 62: 2, 158-175.
Maitre, Le D.C., van Wilgen, B.W. and Richardson, D.M., 1993: A computer system for catchment's management: Background, concepts and development Journal of Environmental Management Vol.39 (2), pp.121-142.
Pincer-JE; Kroch-GC; White-JD; May-AMB., 1997: The relationship between Vegetation type and topography in Lassen Volcanic National Park. Plant –Ecology. 131:1, 17-29.
Sumerall-RM; Lloyd-FT; Edwards-MB, 1995: GIS as a design tool for biological studies. Proceedings of the Eighth Biennial Southern Silvicultural Research Conference, Auburn, Alabama, 1-3 November 1994. General-Technical-Report -Southern-Research-Station, -USDA-Forest-Service. No. SRS-1, 36-41;