Using Landsat Satellite Imagery to Determine Land Use/Land Cover Changes in Međimurje County, Croatia

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This study evaluates Land Use and Land Cover (LU/LC) changes in Međimurje County, Croatia, from 1978-1992, 1992-2007 and 1978-2007 using Landsat satellite images. Spatial dynamics of LU/LC changes were quantified using three Landsat satellite images: MSS, TM and ETM+. Three series of the LU/LC maps of 1978, 1992 and 2007 were produced. Based on the Anderson classification system, LU/LC are classified as: water bodies, forest land, barren land, agricultural land and urban built-up land. Error matrices were used to assess classification accuracy. Significant buildings construction, construction of the reservoir lakes on the Drava River and construction of a highway were major drives of LU/LC changes in Međimurje County over the study period. This study showed a continuous decrease in agricultural lands in Međimurje County. Consequently, the urban built-up area and the water area increased.

Key words: land use/land cover, land use/land cover changes, satellite imageries, Međimurje County

Upotreba satelitskih snimaka Landsat za utvrđivanje promjena u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji u Hrvatskoj

U radu se procjenjuju promjene u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji u Hrvatskoj u razdobljima 1978. – 1992., 1992. – 2007. i 1978. – 2007. upotrebom satelitskih snimaka Landsat. Prostorna dinamika promjena načina upotrebe zemljišta i pokrova kvantificirana je upotrebom triju serija satelitskih snimaka Landsat. Izrađene su tri serije karata načina upotrebe i pokrova zemljišta, za 1978., 1992. i 2007. godinu. Na temelju Andersonova klasifikacijskog sustava način upotrebe i pokrov zemljišta klasificirani su kao vodene površine, šumske površine, golo tlo, poljoprivredne površine i urbano područje. Za ocjenu točnosti klasifikacije poslužila je matrica pogrešaka. Značajna izgradnja zgrada, izgradnja akumulacijskih jezera na rijeci Dravi i autoceste najznačajnije su promjene u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji tijekom promatranog razdoblja. Istraživanje pokazuje kontinuirano smanjenje poljoprivrednog zemljišta u Međimurskoj županiji, zbog čega su građevinsko zemljište i vodene površine povećani.

Ključne riječi: upotreba zemljišta, promjene upotrebe zemljišta, satelitske snimke, Međimurska županija

INTRODUCTION

It is well known that there are only few places on the Earth that are still in their natural state and that have not been affected by human activity in some way. These human activities result in significant land use changes at regional and local scales together with ecological, socio-economic and aesthetical impacts. Timely and precise information about change detection of Earth's surface is extremely important for understanding relationships and interactions between human and natural phenomena (Lu et al., 2004). Determining the effects of land use change on the Earth system, especially biodiversity, depends on the understanding of past land use practices, current land use patterns, and projections of future land use, as affected by human institutions, population size and distribution, economic development, technology, and other factors (Jingan et al., 2005). Viewing the Earth from space is crucial to the understanding of the influence of human activities and human impacts on land use changes over time. Information on LU/LC at regional scales derived from observations of the Earth from space provides objective information of human utilization of the landscape. Such information is required to support environmental policy, physical planning purposes and sustainable land use and land development.

Remote sensing at regional and local scales has become an essential tool in wide areas. The classification of multi-spectral images has been a successful application that is used for classification of land cover maps (Lunetta and Balogh, 1999; Oettera et al., 2000; Yuan et al., 2005), urban growth (Yeh and Li, 1997; Zhang et al., 2002), forest change (Vogelmann and Rock, 1988; Hall et al., 1991; Coppin and Bauer, 1994), monitoring change in ecosystem condition (Lambin, 1998; Weng, 2002), monitoring assessing deforestation and burned forest areas (Potapov et al., 2008), agricultural expansion (Woodcock et al., 1993; Pax-Lenney et al., 1996), mapping corn (Maxwell et al., 2004), real time fire detection (Dennison and Roberts, 2009), estimating tornado damage areas (Myint et al., 2008), estimating water quality characteristics of lakes (Lillesand et al., 1983; Lathrop et al., 1991; Dekker and Peters, 1993), geological mapping (Mostafa and Bishta, 2004; Bishta, 2010), estimating crop acreage and production (Liu et al., 2005), monitoring of environmental pollution (Zhu and Basir, 2005), monitoring and mapping mangrove ecosystems (Kuenzer et al., 2011).

Međimurje County, the northernmost and the most densely populated county in the Republic of Croatia has witnessed remarkable expansion, growth and development activities such as significant buildings construction, construction of two reservoir lakes on the Drava River and construction of a highway through the central part of the county. Such a rapid increase of land consumption and modifications on LU/LC changes resulted in lack of attempts to map and evaluate these changes. Therefore, the aim of this study was to produce LU/LC maps of Međimurje County and to identify and analyze general trends in LU/LC changes taking place in Međimurje County over a period of 29 years using Landsat Satellite Imagery and GIS based technique.

STUDY AREA

Međimurje County is a triangle-shaped county in the northern part of the Republic of Croatia and covers the plains between two rivers – the Mura and the Drava (Fig. 1).
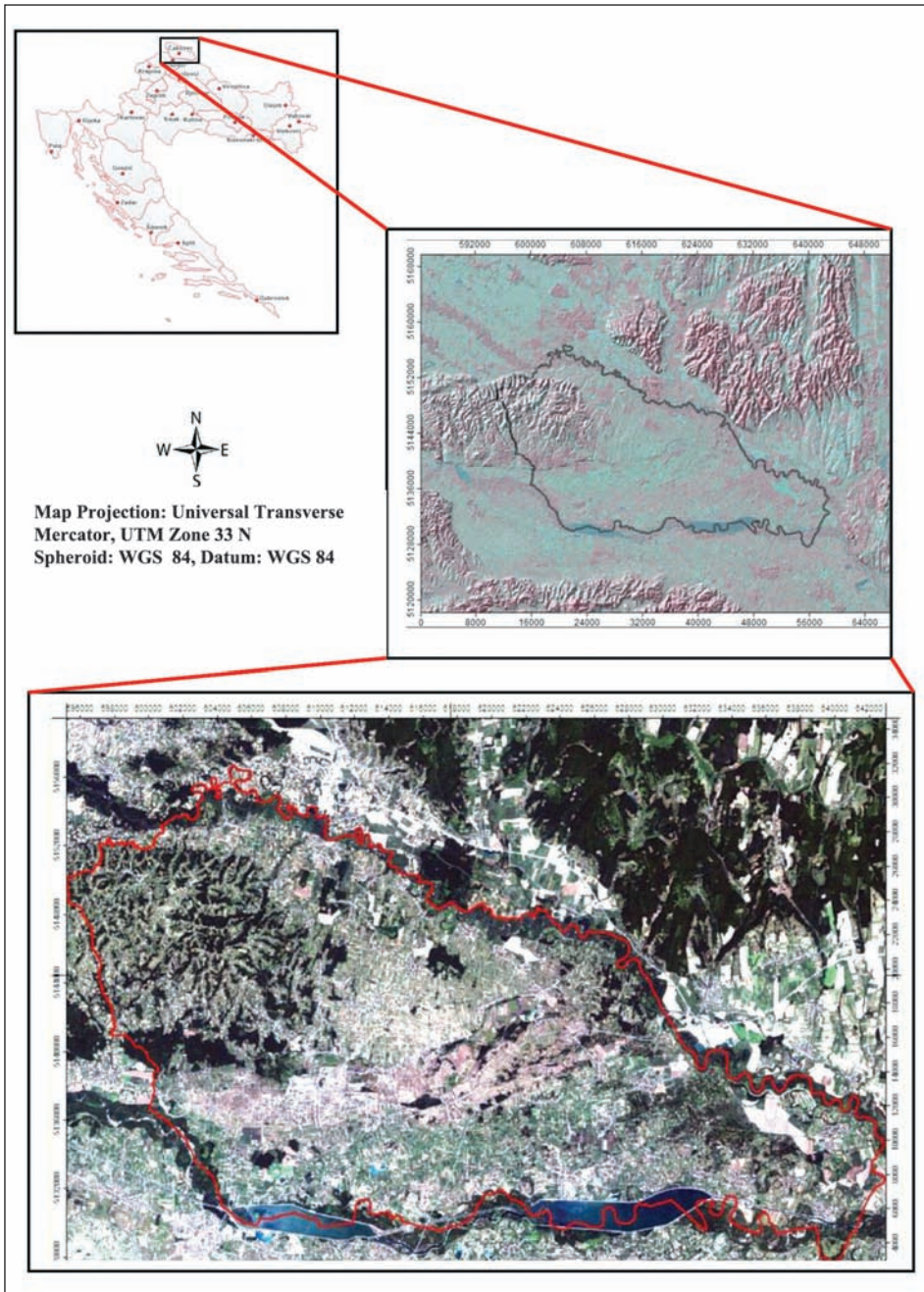
Fig. 1   The geographic location of the research area
Sl. 1.   Geografska lokacija istraživanog područja

The elevation of Međimurje County ranges between 120 and 344 metres above sea level. The total area of Međimurje is 729 km^2 and it is the most densely populated county in Croatia. Almost 120,000 inhabitants live on 729 km^2 in 3 towns, 22 municipalities and cca. 120 villages, amounting to the population density of 164.2 inhabitants/km^2. The population of the Međimurje County accounts for 2.5 % of the total population of The Republic of Croatia. In the last 30 years there have been significant changes in environment such as:

– Construction of two reservoir lakes on the Drava River – Lake Varaždin and Lake Dubrava - both built to serve the two hydroelectric power plants.

– Construction of a highway through the central part of the Međimurje County.

– The rapid urbanization and industrialization, especially in the eastern part of the county.

METHODOLOGY, DATASETS AND SOFTWARE USED

The methodology used in the study includes the following stages: image pre-processing, the design of classification scheme, image classification, accuracy assessment and analysis of the LU/LC changes. The workflow diagram for the methodology used in this study is shown below (Fig. 2).

For the purpose of this study the multispectral Landsat satellite images of following were used (Tab. 1): Landsat 4-MSS of August 23, 1978, Landsat 5-TM of August, 28 and Landsat ETM$^+$ of June 2007. The study area is contained within the Landsat path 204, row 028 for Landsat MSS and path 189, row 028 for Landsat TM and ETM$^+$. All three series of the Landsat data images are created into global data set - Global Land Survey (GLS). The dates of the Landsat images were chosen to be as close as possible to the same vegetation season.

Tab. 1 Detail characteristics of the Landsat satellite imageries used in this study
Tab. 1. Detaljne karakteristike satelitskih snimaka Landsat upotrijebljenih u istraživanju

ID	WRS:P/R	Acq. Date	Dataset	Producer	Attribute	Type
231-497	1:204/028	1978-08-23	MSS	USGS	Ortho, GLS1975	GeoTIFF
205-327	2:189/028	1992-08-28	TM	USGS	Ortho, GLS1990	GeoTIFF
220-573	2:189/28	2007-07-21	ETM+	USGS	Ortho, GLS2005	GeoTIFF

The Landsat data images are georeferenced by the EROS Data Centre (Sioux Falls, South Dakota) to less than ½ pixel root mean square error, registered to Universal Transverse Mercator coordinates, zone 33N, WGS84 Datum. To ensure consistency among Landsat satellite images, all three series of the Landsat data images were re-sampled to a common nominal spatial grid of 30 meters resolution using nearest neighbour transformation to avoid altering the original values (Jensen, 1996; Yang and Lo, 2002). All three Landsat satellite images series are downloaded from the Global Land Cover Facility at the University of Maryland.

The following ancillary data (Tab. 2) were procured: high resolution colour aerial photographs acquired between 2008 and 2009, black and white aerial photographs acquired in 1984 and 2002, topographic maps of 1:25,000 scales acquired in 1967 and 2001.
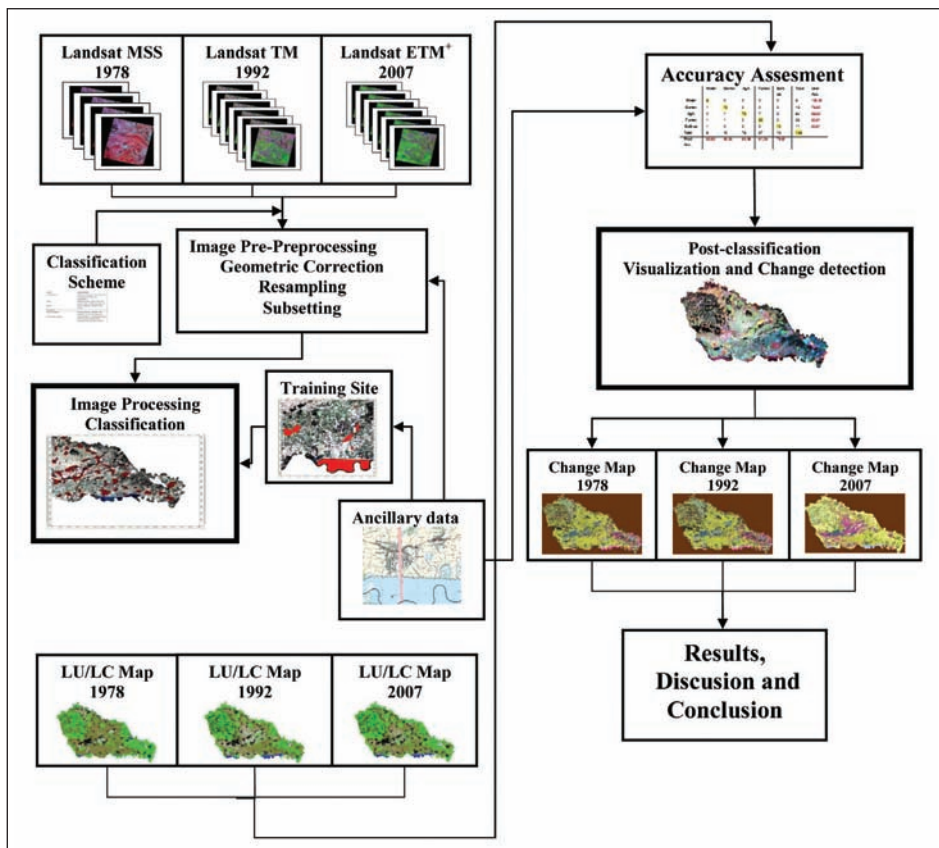
Fig. 2   Workflow diagram for methodology of the research
Sl. 2.   Metodologija istraživanja – dijagram toka

All procured ancillary datasets were used for "ground-truth" information required for classification and accuracy estimation of classified Landsat satellite images.

Tab. 2   Ancillary data used in this study
Tab. 2. Pomoćni podaci upotrijebljeni u istraživanju

Data	Date of Acquisition	Band/Colour	Map Scale	Source
High resolution colour aerial photographs	2008-2009	GeoTIFF	1:5,000	State Geodetic Administration
Black and white aerial photographs	1984 2002	GeoTIFF	1:5,000	State Geodetic Administration
Topographic maps, black and white	1967-1970 1995-1997	GeoTIFF	1:25,000	State Geodetic Administration
Topographic maps, colour	2001-2003	GeoTIFF	1:25,000	State Geodetic Administration

The System for Automated Geoscientific Analyses (SAGA) GIS software (v. 2.0.7) has been used for the preliminary data processing, extracting the study area, unsupervised and supervised classification and producing change detection maps. SAGA is a Free Open Source Software (FOSS). SAGA's analytical and operational capabilities cover geostatistics, terrain analysis, image processing, georeferencing and various tools for vector and raster data manipulation (Conrad, 2006).

Typical steps of pre-processing of the data are: geometric, radiometric and atmospheric corrections, re-sampling and sub-setting. Geometric correction of the data is critical for performing a LU/LC change detection analysis. Once the various data have been obtained, they have probably different projections, and the next necessary step is to project it. Thus, all obtained spatial data sets of a study belong to one single coordinate system. In this study the geometric correction of the Landsat satellite data has not been performed because the data had already been orthorectified and georeferenced to the UTM Zone 33N coordinate system. Accordingly, the Universal Transverse Mercator (UTM) projection, Zone 33N, Spheroid WGS84 and WGS84 Datum was used with that as the primary coordinate system. We have a different situation with ancillary data obtained from the State Geodetic Administration (SGA). Because the ancillary data are in three different coordinate systems to ensure consistency among the Landsat satellite images and ancillary data, we have to make geometric correction of the ancillary data. The geometric correction of all ancillary data that are used for this study has been done with SAGA and Proj 4. library. Proj 4. library work for raster and vector data and provide various projections for free definable cartographic parameters (Conrad, 2006). After the geometric correction of ancillary data, visual comparisons with a ground control point selected from topographic maps, as well as image-to-image comparisons showed that the images were geometrically correct.

In addition, the Landsat scenes and ancillary datasets are much larger than the study area and it is beneficial to reduce the size of the image files to include only the study area in the work process. This reduction of data is known as sub-setting, and this reduction eliminates the extraneous data in the file and speeds up processing due to the smaller amount of data to process. The sub-setting of all datasets has been done with SAGA as well. The primary classification scheme used for this study was based on the Anderson *et al*. (1976) land-use/cover classification system for a level one classification, along with the author's good knowledge of the terrain. The derived final LU/LC classification scheme utilized five classes: Urban/Built Up, Water, Barren, Agricultural and Forest (Tab. 3).

Tab. 3   The classification scheme for the study
Tab. 3. Klasifikacijska shema istraživanja

Class	Descriptions
Urban/Built-Up	Includes all residential, commercial, and industrial developments and transportation.
Water	Includes all water bodies (rivers, lakes, gravels, streams, canals and reservoirs).
Barren	Includes barren or sparsely vegetated areas, stubbles.
Agricultural	Includes all agricultural lands.
Forest	Includes all forest vegetation types (evergreen, deciduous and wetland), and non-forest vegetation futures that are not typical of forest (pasture grasslands and recreational grasses).

According to Meyer (1995), every parcel of land on the Earth's surface is unique in the cover it possesses. Land Use and Land Cover are distinct yet closely linked characteristics of the Earth's surface. Land Cover and Land Use are sometimes used as terms with the same meanings. Actually they have different meanings. The mixing of the concepts of LU/LC has been present for at least the last 25 years (Anderson et al., 1976). The difference in LU/LC is acknowledged in many documents (Anderson et al., 1976; Campbell 1981, Di Gregorio and Jansen, 2000; Cihlar 2000). Land cover is the physical material on the surface of the Earth. It is the material that we see in direct interaction with electromagnetic radiation and causes the level of reflected energy that we observe as the tone or the digital number at a location in an aerial photograph or satellite image. Land use, by contrast to land cover, is a description of how people use the land. (Fisher et al., 2005). Land cover categories include: grass, asphalt, cropland, water, snow, deciduous forests, bare soil, wetlands and pasture. Examples of land use include: agricultural land, urban and recreation areas, grazing and mining.

Training area selection is an important step in the classification. Training areas must be homogeneous and represent LU/LC classes. There are many ways to collect training data which include: collecting from field information (ground survey), on screen selecting training data as polygons, and on screen seeding of training data (Jensen, 2005). In this study, the obtained ancillary data, aerial photographs and topographic maps were used during the selection of training samples for "ground truth" information required for classification, and for accuracy assessment of achieved classified LU/LC maps. Also, the training areas were based on the author's good knowledge of the study area, and on visual comparison of the natural and false colour composite images. Areas depicting the various defined land covers were heads-up digitized from that aerial photography and topographic maps. At least 25 training areas for the defined classes (except for urban areas) were created for the 1978, 1992 and 2007 Landsat MSS, TM and ETM+ respectively, to train the images for supervised classification. It is obvious that collecting ground truth data through aerial photographs has an advantage over the conventional method of survey because of its speed, accuracy, and cost effectiveness.

Urban surface is heterogeneous and typically composed of a complex combination of features that are smaller than the spatial resolutions of the sensors (buildings, roads, grass, trees, soil, water), (Jensen, 2000). This characteristic of urban landscapes makes mixed pixels a common problem in medium spatial resolution data (between 10 to 100 m spatial resolutions) such as Landsat MSS, TM and ETM+. Such a mixture becomes especially prevalent in residential areas where buildings, trees, lawns, concrete, and asphalt can all occur within a pixel (Lu and Weng, 2005). For this reason, in this study, the approach recommended by Robinson and Nagel (1990), Harris and Ventura (1995), Reese et al., (2002) was used. With this approach, the urban areas, due to confusion with the bare soil, can be classified more accurately if it is done separately from the rural areas. Careful manual delineation on the topographic maps 1:25,000 and high area photographs was done around all urban areas of the Međimurje County. More than 150 polygons greater than 100 contiguous pixels, (with size of the surface larger than 9 ha) were obtained. Obtained urban areas were then clipped out of the image data and classified separately from other data with an unsupervised classification. Pixels classified as low or high density urban

were masked out of the others Landsat data, while non-urban pixels were "put back" into the Landsat image data for further supervised classification.

In all classification methods the resulting images of the classification are probably speckled, which means that individual, isolated pixels of one class are surrounded by pixels of another class, and classified images usually have to be post-processed before integration into a geographic information system (GIS). For this reason, filters are usually applied to smooth or generalize the final classification images. With a majority filter, each pixel is recoded to the majority class of a neighbourhood defined by the filter (Stuckens *et al.*, 2000). Majority filters   reduce the "salt-and-pepper" effect typical for traditional per-pixel. In this study, a majority filter was used and applied for all three classification maps. An improvement of 3.47 % compared to a per-pixel classifier was achieved.

In a variety of studies, post-classification change detection has been considered to be one of the most suitable and commonly used methods for change detection (Singh, 1989; Mas, 1999, Jensen,1996; Peterson et al., 2004). Post-classification is a term describing the comparative analysis of spectral classifications for different dates produced independently (Singh, 1989). This method involves comparing two independent classified LU/LC maps from images of two different dates. In this study, the post classification technique was used based on a hybrid classification approach comprised of unsupervised classification based on "hill climbing" cluster algorithm and supervised classification based on the Maximum Likelihood Classifier (MLC) and introduction of human-knowledge from field experience to determine the amount of change over the study period.

The error matrix is the most widely used approach for image classification accuracy assessment and can be used to derive a series of descriptive and analytical statistics (Congalton and Mead; 1983; Congalton, 1991; Congalton and Green, 1999; Smits et al., 1999; Congalton and Plourde, 2002; Foody, 2002; Liu et al., 2007). In this study, accuracy assessment was performed for the classified maps of all three time steps. Error matrices were used to assess classification accuracy using four measures of accuracy: overall accuracy, user's accuracy, producer's accuracy and Kappa statistics. The meaning of and calculation for these terms have been explained in detail in many studies (Congalton 1991; Smits et al., 1999; Plourde and Congalton, 2003; Foody 2002).The user's accuracy indicates the probability that a pixel on the image actually represents that class on the ground (Story and Congalton, 1986). It is calculated for each class by dividing the correctly classified pixels by the row total for that class. The producer's accuracy is defined as the probability of a pixel being correctly classified and is mainly used to determine how well an area can be classified (Story and Congalton, 1986). Over the past 15 years, Kappa statistics has become a standard part of evaluating classification accuracy. Kappa statistics is a discrete multivariate technique used to evaluate the accuracy of change detection and classification maps by measuring the agreement between the two images (Story and Congalton, 1986). Kappa statistics is a measure of the difference between the actual agreement between the reference data and an automated classifier and the chance agreement between the reference data and a random classifier.

Achieved results for the accuracy of all three years are summarized in Tabs. 4, 5 and 6. For the accuracy assessment in this study, simple random sampling was adopted. A total

of 146, 163 and 131 random pixels from the classified images of 1978, 1992 and 2007 respectively, without any consideration of informational class were selected. The pixels were verified using ancillary data. The overall accuracies for 1978, 1992 and 2007 were, respectively, 87.67 %, 88.96 % and 90.84 %. Kappa statistics were 80 %, 84 % and 83 %. User's and producer's accuracies of individual classes were relatively high, ranging from 74 % to 94 % which indicates a good agreement between thematic maps generated from images and the reference data. The achieved accuracies of classification turned out to be better than expected.

Tab. 4 The achieved accuracies of classification for 1978
Tab. 4. Rezultati klasifikacije za 1978.

	Water	Barren	Agricultural	Forest	Built-up	Total	User Acc.
Water	5	0	0	0	0	5	100,00
Barren	1	10	2	0	0	13	76,92
Agricultural	0	1	73	7	3	84	86,90
Forest	1	1	2	30	0	34	90,91
Built-up	1	0	0	0	10	11	90,91
Total	8	12	77	37	13	147	
Prod. Acc.	83,83	83,33	93,59	81,08	76,92		
Overall classification accuracy:				87.67			
Kappa statistics:				80 %			

Tab. 5 The achieved accuracies of classification for 1992
Tab. 5. Rezultati klasifikacije za 1992.

	Water	Barren	Agricultural	Forest	Built-up	Total	User Acc.
Water	7	1	0	0	0	8	87,50
Barren	1	17	3	0	0	21	80,95
Agricultural	0	1	75	4	1	81	92,59
Forest	0	4	0	31	0	35	88,57
Built-up	0	0	3	0	15	18	83,33
Total	8	23	81	35	16	163	
Prod. Acc.	87,50	73,91	92,59	88,57	93,75		
Overall classification accuracy:				88.96			
Kappa statistics:				84 %			

Tab. 6   The achieved accuracies of classification for 2007
Tab. 6. Rezultati klasifikacije za 2007.

	Water	Barren	Agricultural	Forest	Built-up	Total	User Acc.
Water	6	0	0	0	0	6	100,00
Barren	0	7	2	0	0	9	77,78
Agricultural	1	1	78	2	2	84	92,86
Forest	0	0	3	17	0	20	85,00
Built-up	0	0	1	0	11	12	91,67
Total	7	8	84	19	13	131	
Prod. Acc.	85,71	87,50	92,86	89,47	84,62		
Overall classification accuracy:				90.84			
Kappa statistics:				83 %			

DISCUSSION

The most important LU/LC changes that have occurred in the Međimurje County over the study period from 1978 to 2007 were first analyzed by visual interpretation. Visual interpretation can give a general idea about the LU/LC changes. Using the Landsat satellite images natural and false colour, composite images were generated. Natural and false colour composites were chosen as a very easy, but very useful technique to extract visually information from Landsat satellite images and to achieve a general description of LU/LC changes. For Landsat TM and ETM[+] data, band 3 (red), band 2 (green), and band 1 (blue) were used to create a ''normal colour'' composite. Landsat MSS data do not have a blue band, and therefore they cannot be used to generate a true normal colour composite. However, the normal colour composite can be simulated using the following formula: Red=MSS2, Green=(MSS1*3 + MSS2) / 4 and Blue=MSS1.

For example, by comparing the three composite images from 1978, 1992 and 2007 we can see how the urban areas grow for the city of Prelog (Fig. 3). Further, we can see the expansion (Fig. 4) of the water surface due to the exploitation of the gravel over the years (images 1992 and 2007). On the time series of the three composite images (Fig. 5) we can see the construction of a reservoir lake on the Drava River built to serve the Čakovec hydroelectric power plant. All these changes detected by visual interpretation show us that there have been significant changes in LU/LC over the investigated time.

The LU/LC classification maps of 1978, 1992 and 2007 were generated (Figs. 6, 7 and 8). Corresponding classification was also represented as a chart. The total area of each land cover class for the entire study was compared (Tab. 7), using three classified images from 1978, 1992 and 2007. Međimurje County is predominantly a rural region.
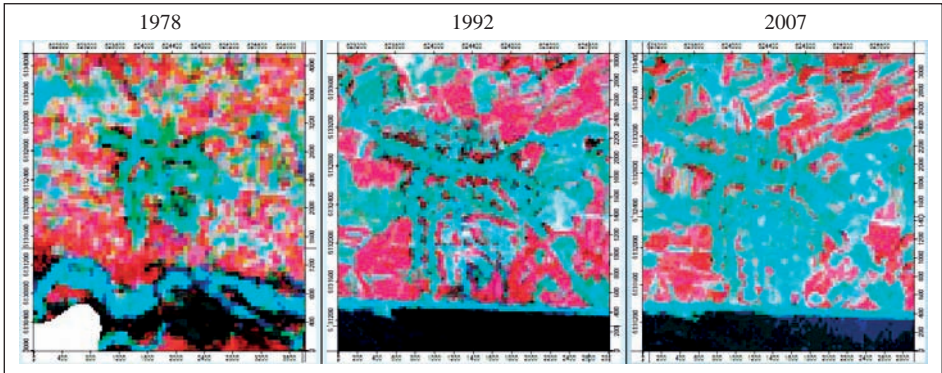
Fig. 3   Urban growth for the city of Prelog
Sl. 3.   Urbani rast grada Preloga
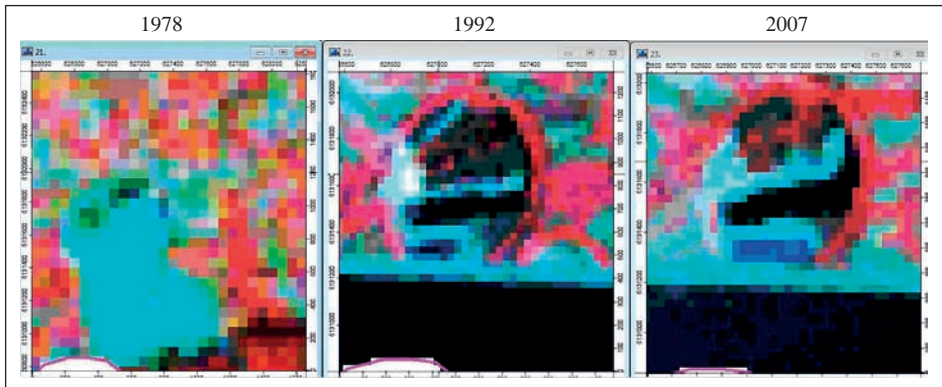
Fig. 4   Conversion of agricultural lands to gravel
Sl. 4.   Pretvorba poljoprivrednog zemljišta u šljunčaru
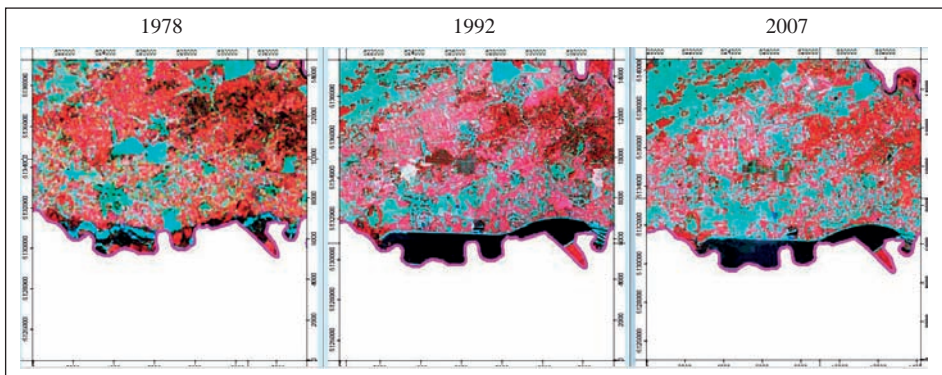
Fig. 5   The construction of a reservoir lake on the Drava River
Sl. 5.   Izgradnja akumulacijskog jezera na rijeci Dravi

Land Use / Land Cover Map 1978

Built up (6 %)
Forest (21 %)
Agricultural (65 %)
Barren (6 %)
Water (2 %)

Coordinate System:WGS 1984 UTM Zone 34N
Projection: Universal Transverse Mercator
Author: Zlatko Horvat
Date: 01/09/2011.
Sensor:Landsat MSS (1978)
Source: Global Land Cover Facility

0   20   km

Fig. 6   LU/LC map of the Međimurje County (1978)
Sl. 6.   Karta načina upotrebe i pokrova zemljišta u Međimurskoj županiji (1978.)

Fig. 7   LU/LC map of the Međimurje County (1992)
Sl. 7.   Karta načina upotrebe i pokrova zemljišta u Međimurskoj županiji (1992.)

Land Use / Land Cover Map 2007

Built up (10 %)
Forest (22 %)
Agricultural (55%)
Barren (10 %)
Water (3 %)

Coordinate System:WGS 1984 UTM Zone 34N
Projection: Universal Transverse Mercator
Author: Zlatko Horvat
Date: 01/09/2011.
Sensor:Landsat ETM+ (2007)
Source: Global Land Cover Facility

N
W E
S

0   20   km

Fig. 8   LU/LC map of the Medimurje County (2007)
Sl. 8.   Karta načina upotrebe i pokrova zemljišta u Međimurskoj županiji (2007.)

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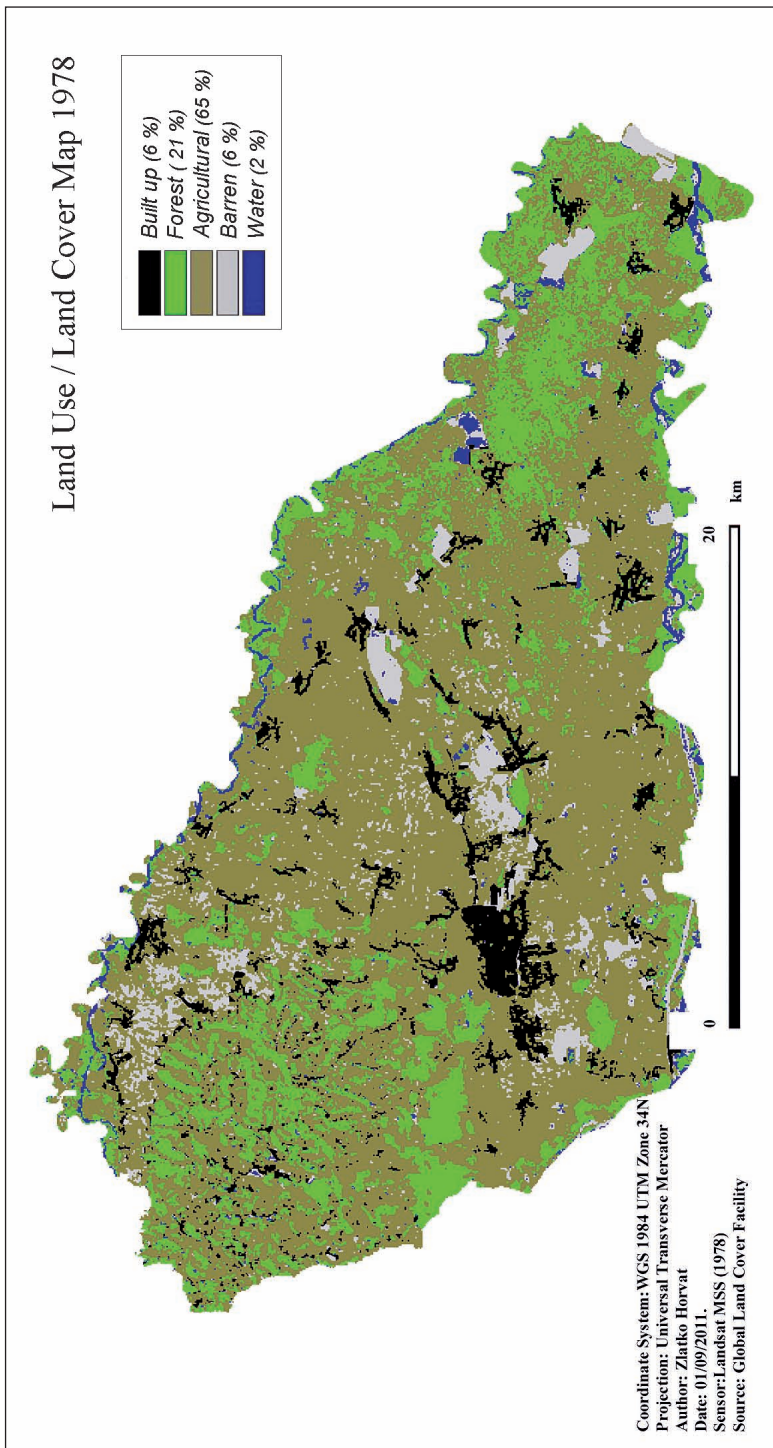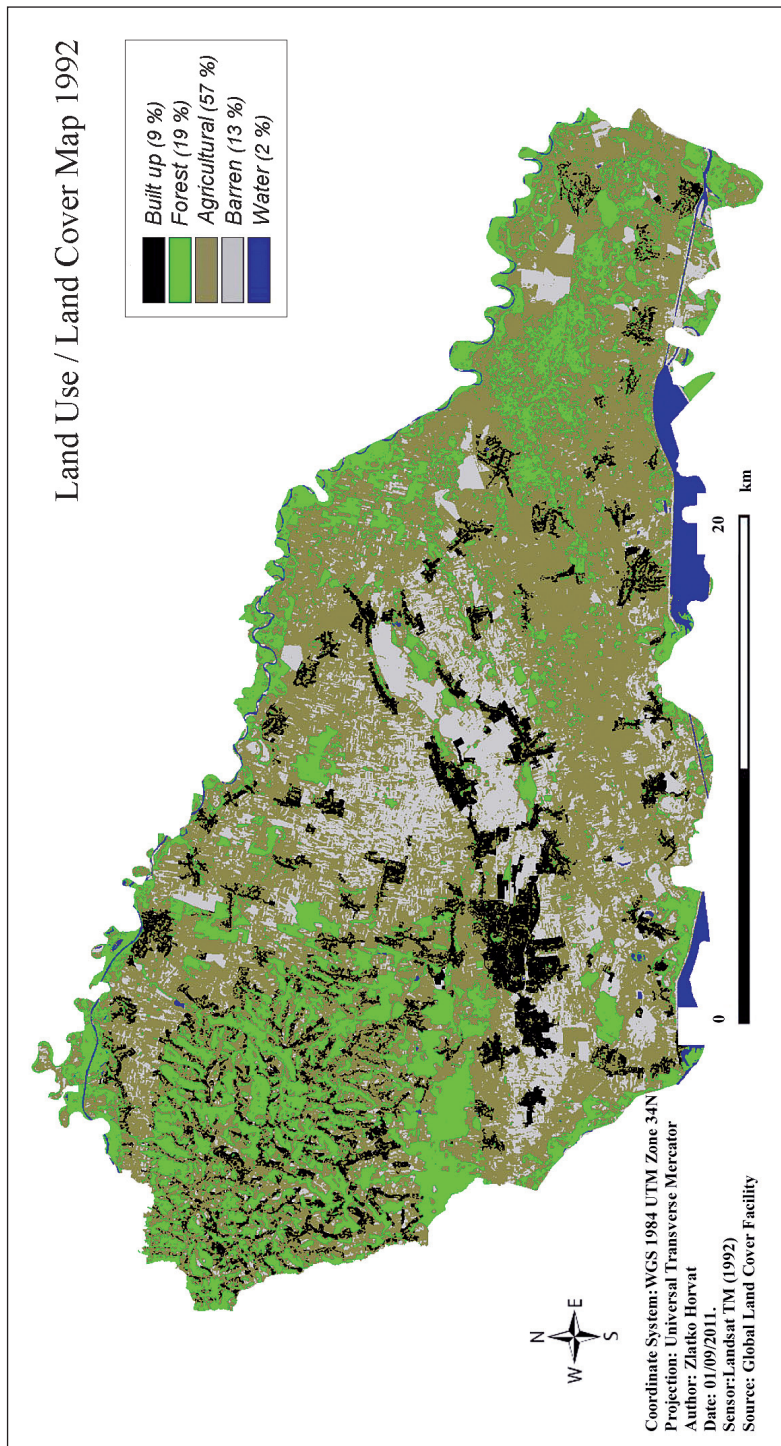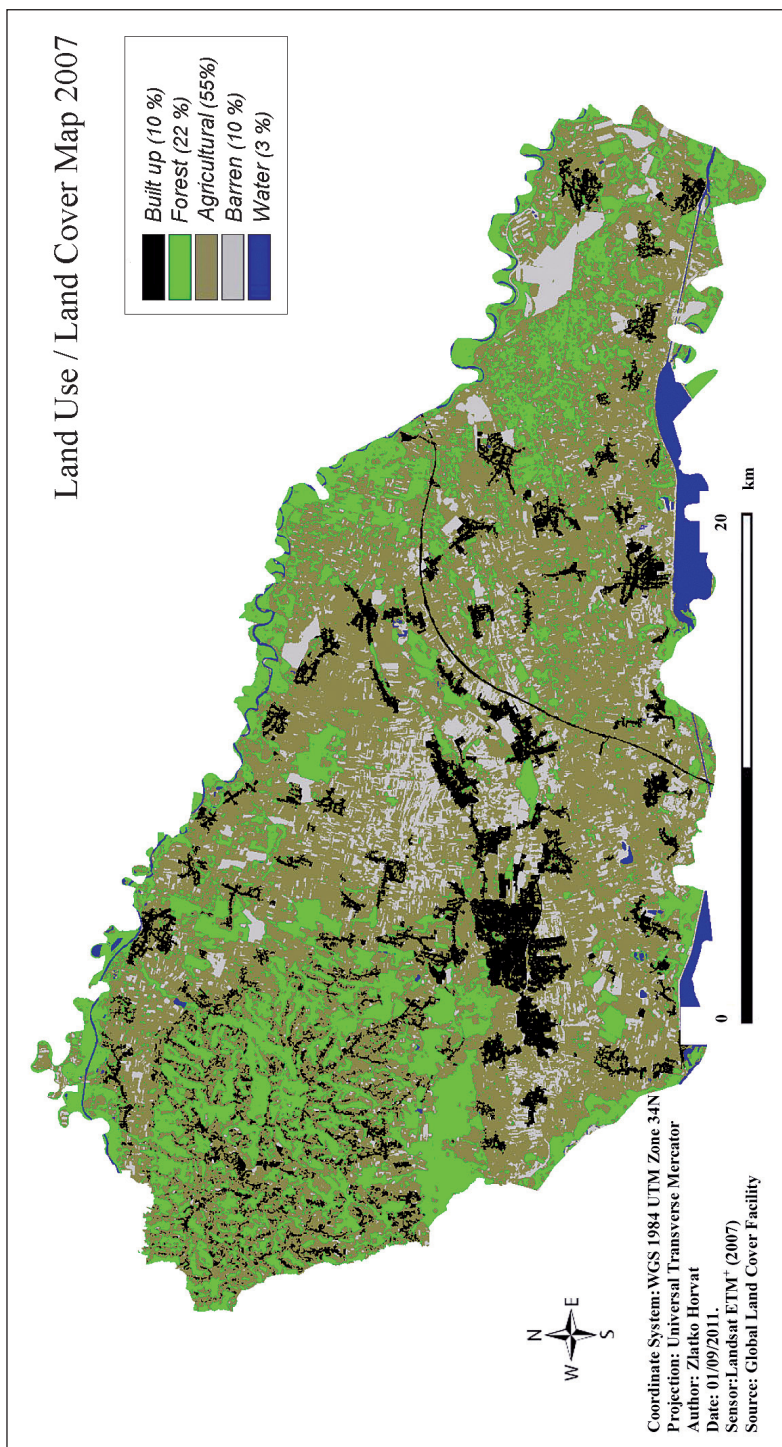Tab. 7   Land Use/Land Cover Distribution (1978, 1992 and 2007)
Tab. 7. Distribucija načina upotrebe i pokrova zemljišta (1978., 1992. i 2007.)

Land Use/Land Cover Categories	1978		1992		2007	
	Land Use/Cover		Land Use/Cover		Land Use/Cover	
	(ha)	%	(ha)	%	(ha)	%
Water	1617,30	2,22	1776,42	2,44	1843,74	2,53
Barren	4679,28	6,42	9698,85	13,31	6979,77	9,58
Agricultural	46456,47	63,77	40520,61	55,61	40685,94	55,84
Forest	15425,01	21,17	13973,49	19,18	16180,38	22,21
Built-up	4676,13	6,42	6891,66	9,46	7170,57	9,84
Total	72854,19	100	72861,03	100	72860,40	100
Agricultural and Barren	51135,75	70,19	50219,46	68,92	47665,71	65,42

LU/LC changes maps for 1978-1992, 1992-2007 and 1978-2007 were derived (Figs. 9, 10 and 11). The post classification technique was used to determine the amount of change over the study period. The total area of each land cover class for the entire study was compared (Tab. 8) using three classified images from 1978, 1992 and 2007. Based on the results of this study, there is strong evidence that changes in the Land Use and Land Cover occurred in the Međimurje County during the last three decades. The changes in Land Use were determined for Međimurje County as follows: increase in water body areas by 10 % from 1978-1992 and by 4 % from 1992-2007; significant decrease in agricultural land by 13 % from 1978-1992, and very small increase from 1992-2007; increase in barren land by 107 % from 1978-1992, and decrease by 28 % from 1992-2007; constant increase in the built-up category by 10 % from 1978-1992, and by 4 % from 1992-2007; decrease in forest by 9 % from 1978-1992 but increase by 16 % from 1992-2007.

Generally, from 1978 to 2007, urban area increased approximately 53 %, while agriculture decreased 12 %, whereas water, forest and barren land also increased by 14 %, 5 % and 49 % respectively. Achieved LU/LC change maps showed that urban land area increased 53 % due to urbanization that resulted from high-speed economic development, especially in the period from 1978 to 1992, water increased 14 % mainly due to the construction of reservoir lakes on the Drava River and land conversion in the gravels. Consequently, forest area decreased 9 % from 1978 to 1992, but increased from 1992 to 2007, especially along the border of the existing forest areas. Since the early 1990s, the share of agricultural population is constantly decreasing, and therefore there was more abandoned land which, after a while, becomes a forest. In total, the forest land in the study area has increased by slightly less than 1000 ha. Increase in urban and forest areas resulted in a substantial reduction in the area of agricultural land. Looking at the barren and agricultural land as a single class, total agricultural land decreased by 2 % during 1978-1992 and the significant
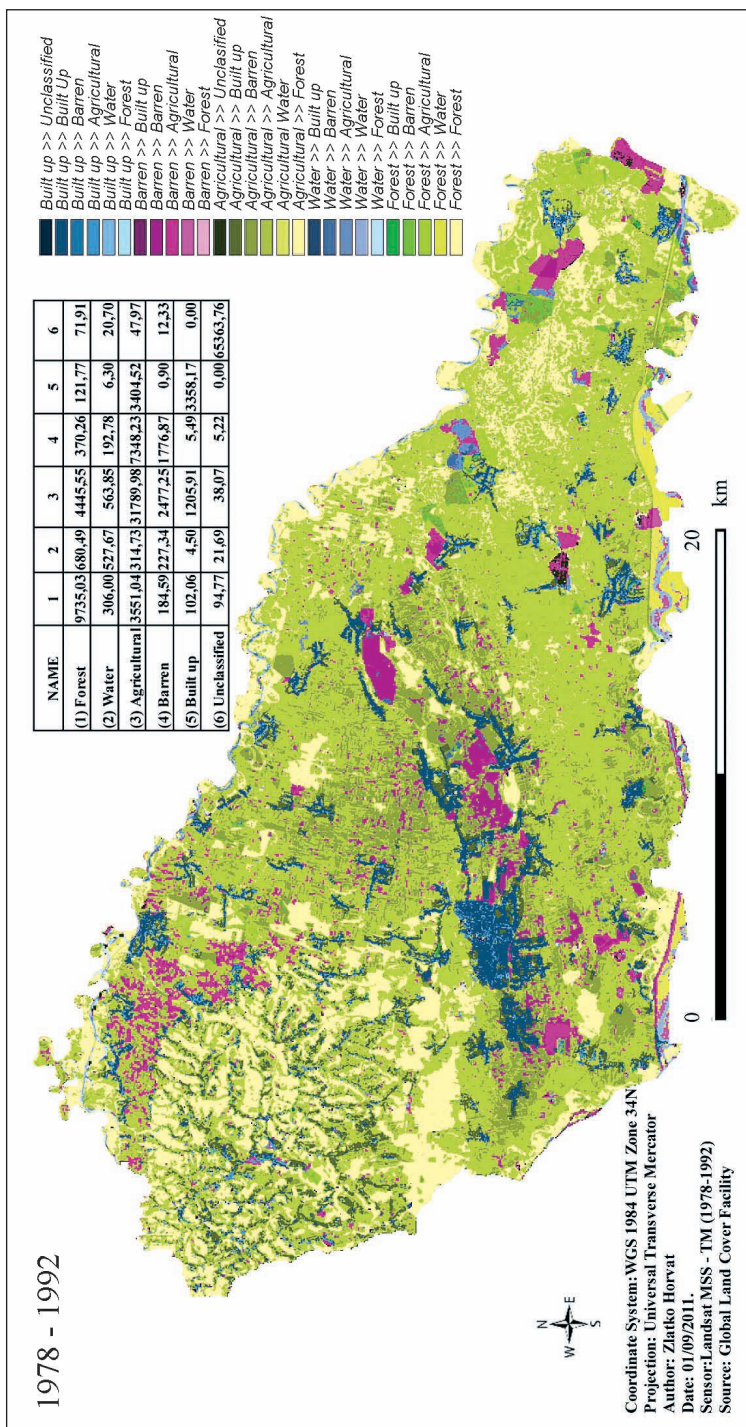
1978 - 1992

NAME	1	2	3	4	5	6
(1) Forest	9735,03	680,49	4445,55	370,26	121,77	71,91
(2) Water	306,00	527,67	563,85	192,78	6,30	20,70
(3) Agricultural	3551,04	314,73	31789,98	7348,23	3404,52	47,97
(4) Barren	184,59	227,34	2477,25	1776,87	0,90	12,33
(5) Built up	102,06	4,50	1205,91	5,49	3358,17	0,00
(6) Unclassified	94,77	21,69	38,07	5,22	0,00	65363,76

Legend:

Built up >> Unclassified
Built up >> Built Up
Built up >> Barren
Built up >> Agricultural
Built up >> Water
Built up >> Forest
Barren >> Built up
Barren >> Barren
Barren >> Agricultural
Barren >> Water
Barren >> Forest
Agricultural >> Unclassified
Agricultural >> Built up
Agricultural >> Barren
Agricultural >> Agricultural
Agricultural >> Water
Agricultural >> Forest
Water >> Built up
Water >> Barren
Water >> Agricultural
Water >> Water
Water >> Forest
Forest >> Built up
Forest >> Barren
Forest >> Agricultural
Forest >> Water
Forest >> Forest

0   20   km

N S E W

Coordinate System:WGS 1984 UTM Zone 34N
Projection: Universal Transverse Mercator
Author: Zlatko Horvat
Date: 01/09/2011.
Sensor:Landsat MSS - TM (1978-1992)
Source: Global Land Cover Facility

Fig. 9 LU/LC change map 1978-1992

Sl. 9. Karta promjena u načinu upotrebe i pokrovu zemljišta 1978. – 1992.

NAME	1	2	3	4	5	6
(1) Forest	11300,04	105,84	2376,45	98,82	92,34	0,00
(2) Water	69,03	1609,56	87,48	8,64	1,71	0,00
(3) Agricultural	4569,12	80,82	30251,97	3627,27	1991,16	0,27
(4) Barren	197,73	47,25	6100,20	3243,87	109,80	0,00
(5) Built up	44,46	0,27	1869,84	1,17	4975,56	0,36
(6) Unclassified	0,00	0,00	0,00	0,00	0,00	65516,67

Legend:
- Built up >> Unclassified
- Built up >> Built Up
- Built up >> Barren
- Built up >> Agricultural
- Built up >> Water
- Built up >> Forest
- Barren >> Built up
- Barren >> Barren
- Barren >> Agricultural
- Barren >> Water
- Barren >> Forest
- Agricultural >> Unclassified
- Agricultural >> Built up
- Agricultural >> Barren
- Agricultural >> Agricultural
- Agricultural Water
- Agricultural >> Forest
- Water >> Built up
- Water >> Barren
- Water >> Agricultural
- Water >> Water
- Water >> Forest
- Forest >> Built up
- Forest >> Barren
- Forest >> Agricultural
- Forest >> Water
- Forest >> Forest

1992 – 2007

Coordinate System: WGS 1984 UTM Zone 34N
Projection: Universal Transverse Mercator
Author: Zlatko Horvat
Date: 01/09/2011.
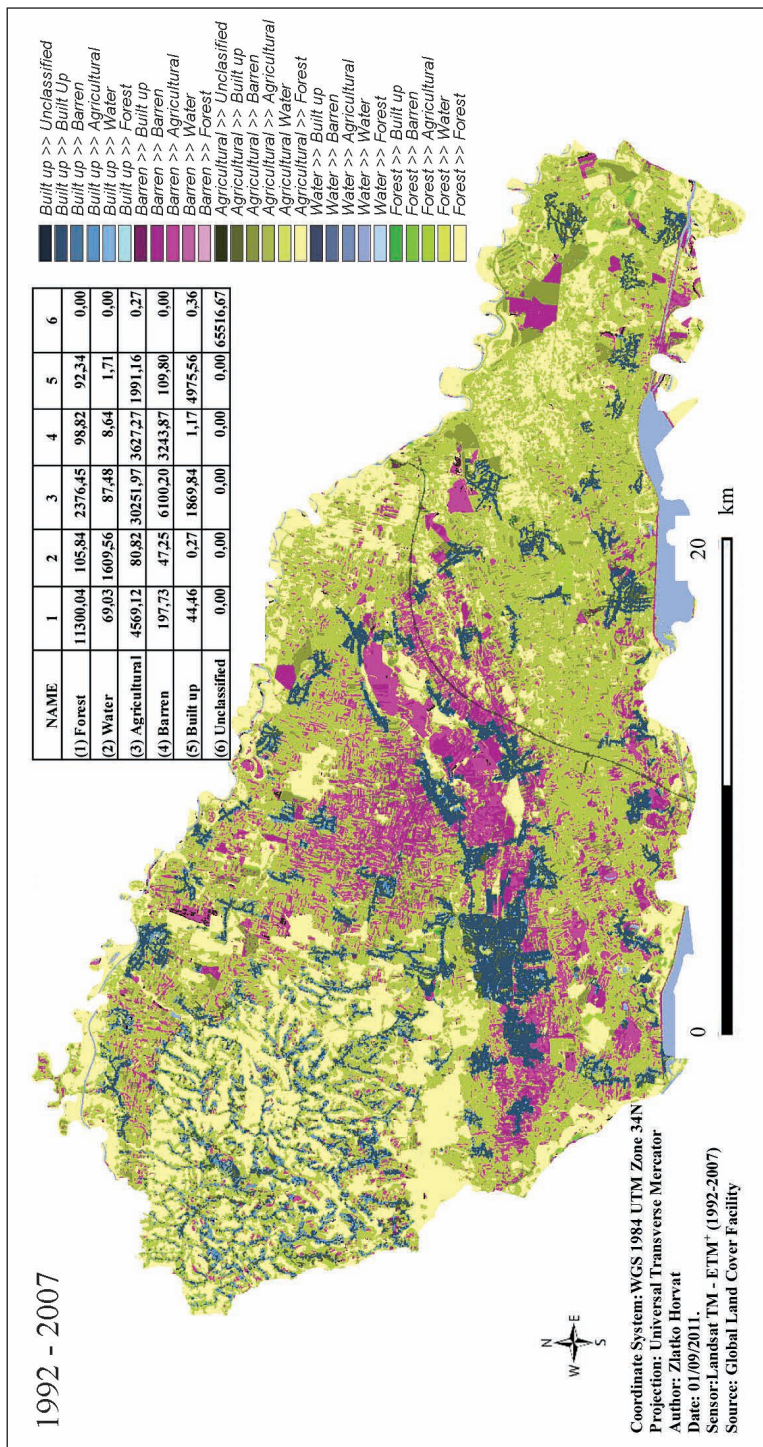**Sensor: Landsat TM - ETM+ (1992-2007)**
Source: Global Land Cover Facility

0   20   km

Fig. 10 LU/LC change map 1992-2007
Sl. 10. Karta promjena u načinu upotrebe i pokrovu zemljišta 1992. – 2007.

21

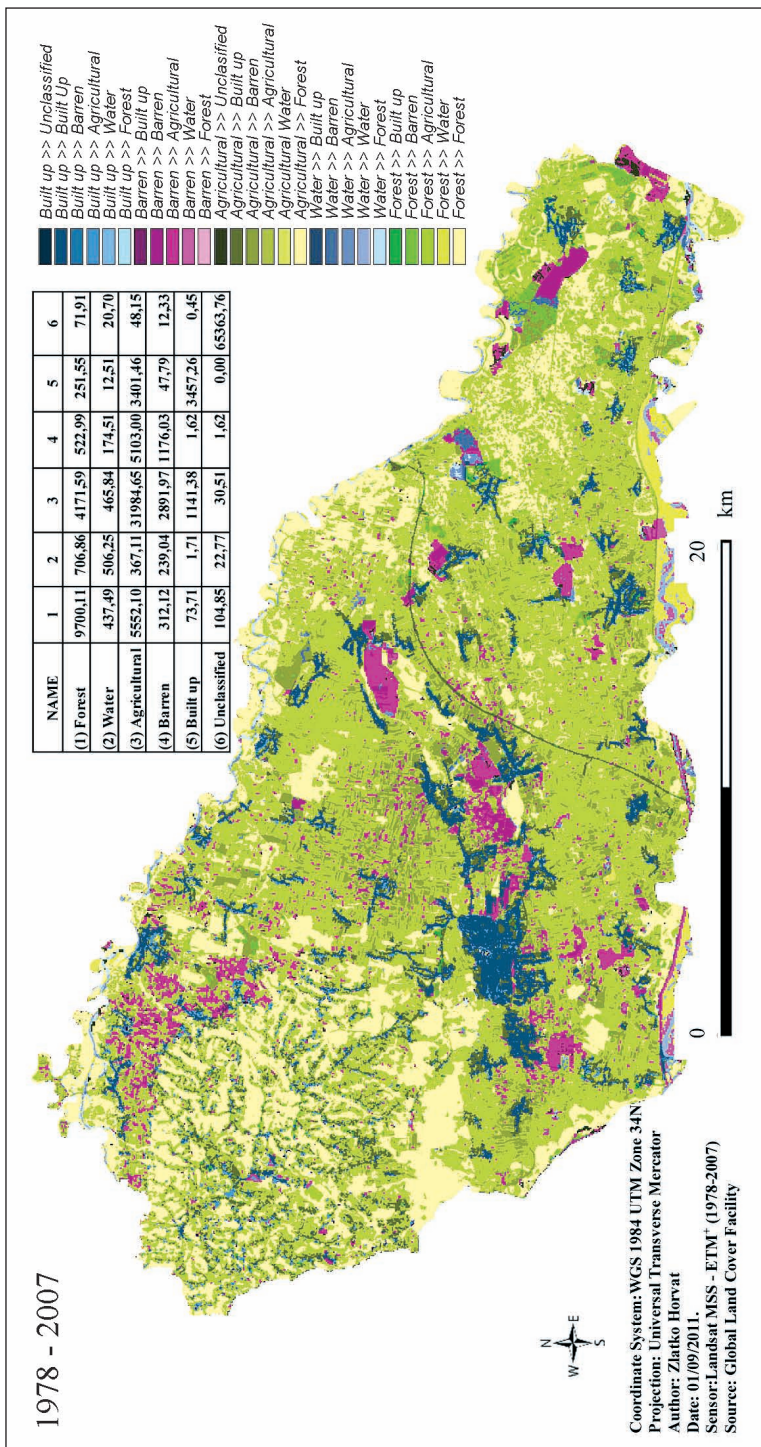| NAME	1	2	3	4	5	6
(1) Forest	9700,11	706,86	4171,59	522,99	251,55	71,91
(2) Water	437,49	506,25	465,84	174,51	12,51	20,70
(3) Agricultural	5552,10	367,11	31984,65	5103,00	3401,46	48,15
(4) Barren	312,12	239,04	2891,97	1176,03	47,79	12,33
(5) Built up	73,71	1,71	1141,38	1,62	3457,26	0,45
(6) Unclassified	104,85	22,77	30,51	1,62	0,00	65363,76

Coordinate System: WGS 1984 UTM Zone 34N
Projection: Universal Transverse Mercator
Author: Zlatko Horvat
Date: 01/09/2011.
Sensor: Landsat MSS - ETM⁺ (1978-2007)
Source: Global Land Cover Facility

Fig. 11 LU/LC change map 1978-2007
Sl. 11. Karta promjena u načinu uporabe i pokrova zemljišta 1978. – 2007.

decrease by 5 % was from 1992-2007. Total reduction in agricultural land over the study period was 7 %, indicating a permanent reduction of agricultural land in Međimurje County.

Tab. 8 LU/LC changes of the Međimurje County (1978, 1992 and 2007)
Tab. 8. Promjene u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji (1978., 1992. i 2007.)

Land Use/Land Cover Categories	1978-1992		1992-2007		1978-2007	
	Area change		Area change		Area change	
	(ha)	%	(ha)	%	(ha)	%
Water	159,12	10	67,32	4	226,44	14
Barren	5019,57	107	–2719,08	–28	2300,49	49
Agricultural	–5935,86	–13	165,33	0	–5770,53	–12
Forest	–1451,52	–9	2206,89	16	755,37	5
Built-up	2215,53	47	278,91	4	2494,44	53
Agricultural and Barren	–916,29	–2	–2553,75	–5	-3470,04	–7

CONCLUSION AND RECOMMENDATION

The aim of this study was to produce LU/LC maps of Međimurje County and to identify and analyze general trends in LU/LC changes. An effective approach for making LU/LC maps and detecting changes in Međimurje County was presented without using a complex methodology such as fuzzy classification or object-based methodology. Basically, the use of the traditional per-pixel based classification in combination with a separate classification of the urban areas approach, a good knowledge of the research area, GIS tools, availability of quality ancillary data for the selection of training samples for "ground truth" information required for classification and for accuracy assessment of achieved classified LU/LC maps, demonstrate the potential of multi-temporal Landsat satellite imagery to provide LU/LC maps and to analyze changes in LU/LC. Such results can be used as inputs to land management and policy decisions, to the development of sustainable urban land use planning decisions and for governmental or non-governmental organizations in a variety of purposes as up-to-date information. The key findings of this study are as follows:

Međimurje County is predominantly a rural region. Over half of the county is used for agriculture. In the study periods covered, the major identified Land Use and Land Cover classes of Međimurje County included agriculture, forest, barren land, built-up areas and water.

Significant buildings construction, construction of the reservoir lakes on the Drava River and construction of a highway were major drives of LU/LC changes in Međimurje County over the study period from 1978 to 2007. This study showed a continuous decrease in agricultural lands in Međimurje County. Consequently, the urban built-up area and the water area increased.

The remarkable changes in land use classes have occurred from 1978 to 1992, but the changes were not so significant during 1992 to 2007.

The remote sensing and classifications of the Landsat satellite imagery can be used as an economical and accurate way to produce Land Use and Land Cover change maps in the Međimurje County that can be used as inputs for regional analyses, formulating effective environmental policies and resource management decisions as useful up-to- date information. One of the most interesting questions when considering future work is the usefulness of high-resolution (spatial and spectral) satellite and airborne sensors, for detailed map and research of LU/LC changes. It would be very interesting in future work to use a combination of high resolution remote sensing imageries such as Quickbird and IKONOS, GIS and Landsat satellite imagery in order to improve the mapping, to detect changes in Međimurje County and for creating detailed Land Use and Land Cover maps.

REFERENCES

Anderson, J.R., Hardy, E.E., Roach, J.T. and Witmer, R.E., 1976: *A Land Use and Land Cover Classification System for Use with Remote Sensor Data*. Government Printing Office: Washington, DC, USA

Bishta, A.Z., 2010: Assessing Utilization of Multi-Resolution Satellite Imageries in Geological Mapping, A Case Study of Jabal Bani Malik Area, Eastern Jeddah City, Kingdom of Saudi Arabia*, Earth Sciences* 21 (1), 27-52

Campbell, J.B., 1981: Spatial correlation-effects upon accuracy of supervised classification of land cover, *Photogrammetric Engineering and Remote Sensing* 47 (3), 355–363.

Cihlar, J., 2000: Land cover mapping of large areas from satellites: status and research priorities, *International Journal of Remote Sensing* 20 (6), 1093-1114.

Congalton, R., 1991: A review of assessing the accuracy of classifications of remotely sensed data, *Remote Sensing of Environment* 37, 35-46.

Congalton, R. G. and Green, K., 1999: *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices,* Boca Raton, FL, USA: CRC/Lewis Press.

Congalton, R.G. and Mead, R.A., 1983: A quantitative method to test for consistency and correctness in photo-interpretation, *Photogrammetric Engineering and Remote Sensing* 49, 69-74.

Congalton, R. G. and Plourde, L., 2002: Quality assurance and accuracy assessment of information derived from remotely sensed data. *In Manual of Geospatial Science and Technology, edited by J. Bossler, London: Taylor & Francis*, 349–361.

Conrad, O., 2006: SAGA - Program Structure and Current State of Implementation. in: Böhner, J., McCloy, K.R. & Strobl, J. [Hrsg.]: *SAGA - Analysis and Modelling Applications. Göttinger Geographische Abhandlungen, Bd.115, S.39-5*. Available at: http://www.saga-gis.org/en/about/references.html (1.10.2012).

Coppin, P. R., and Bauer, M. E., 1994: Processing of multitemporal Landsat TM imagery to optimize extraction of forest cover change features, *IEEE Transactions on Geoscience and Remote Sensing* 32 (4), 918–927.

Dekker, A. G. and Peters, S. W. M., 1993: The use of the thematic mapper for the analysis of eutrophic lakes - a case-study in The Netherlands, *International Journal of Remote Sensing* 14 (5), 799-821.

Dennison, P.E. and Roberts, D.A., 2009: Daytime fire detection using airborne hyperspectral data, *Remote Sensing of Environment* 113, 1646–1657.

Di Gregorio, A. and Jansen, L.J.M., 2000: Land Cover Classification System (LCCS): *Classification concepts and user manual, Environment and Natural Resources Service,* SDRN, FAO, Rome.

Fisher, P., Comber, A. J. and Wadsworth, R., 2005: *Land Use and Land Cover: Contradiction or Complement. Re-presenting GIS Edited by P. Fisher and D. Unwin* © 2005 John Wiley & Sons, Ltd.

Foody, G.M., 2002: Status of land cover classification accuracy assessment, *Remote Sensing of Environment* 80, 185–201.

Hall, F. G., Botkin, D. B., Strebel, D. E., and Goetz, S. J., 1991: Large-scale patterns of forest succession as determined by remote sensing, *Ecology* 72, 628– 640.

Harris, P. and Ventura, S., 1995: The integration of geographic data with remotely sensed imagery to improve classification in an urban area, *Photogrammetric Engineering and Remote Sensing*, 61:8, 993-998.

Jensen, J.R., 1996: *Introduction to Digital Image Processing: A Remote Sensing Perspective*, Practice Hall, New Jersey.

Jensen, J.R., 2000*: Remote Sensing of the Environment: An Earth Resource Perspective*, Prentice Hall, Upper Saddle River, New Jersey.

Jensen, J. R., 2005: *Introductory Digital Image Processing: A Remote Sensing Perspective*, Third edition. New York: Prentice Hall.

Jingan, S., Jiupai, N., Chaofu, W. and Deti, X., 2005: Land use change and its corresponding ecological responses: a review, *Journal of Geographical Sciences* 15 (3), 305-328.

Kuenzer, C., Bluemel, A., Gebhardt, S., Vo Quoc, T. and Dech, S., 2011: Remote Sensing of Mangrove Ecosystems: A Review, *Remote Sensing* 3, 878-928

Lambin, F., 1998: Change detection at multiple temporal scales: Seasonal and annual variations in landscape variables, *Photogrammetric Engineering and Remote Sensing* 62, 931-938.

Lathrop, R.G., Lillesand, T. M., and Yandell, B.S., 1991: Testing the utility of simple multi-date Thematic Mapper calibration algorithms for monitoring turbid inland waters, *International Journal of Remote Sensing* 12, 2045-2063.

Lillesand, T. M., Johnson, W. L., Deuell, R. L., Lindstrom, O. M. and Meisner, D. E., 1983: Use of Landsat data to predict the trophic state of Minnesota lakes, *Photogrammetric Engineering and Remote Sensing* 49*,* 219-229.

Liu, C., Frazier P., Kumar, L., 2007: Comparative assessment of the measures of thematic classification accuracy, *Remote Sensing of Environment* 107, 606–616.

Liu, J.Y., Liu, M.L., Tian, H.Q., Zhuang, D.F., Zhang, Z.X., Zhang, W., Tang, X.M. and Deng, X.Z., 2005: Spatial and temporal patterns of China's cropland during 1990-2000: an analysis based on Landsat TM data, *Remote Sensing of Environment* 98, 442–456.

Lu, D., Mausel, P., Brondizio, E. and Moran, E., 2004: Change detection techniques, *International Journal of Remote Sensing* 25 (12), 2365-2401.

Lu, D. and Weng, Q., 2005: Urban classification using full spectral information of Landsat ETM_ imagery in Marion County, Indiana, *Photogrammetric Engineering and Remote Sensing* 71 (12), 1275–1284.

Lunetta, R. S. and Balogh, M., 1999: Application of multi-temporal Landsat 5 TM imagery for wetland identification, *Photogrammetric Engineering and Remote Sensing* 65, 1303–1310.

Mas, J.F., 1999: Monitoring land-cover changes: a comparison of change detection techniques, *International Journal of Remote Sensing* 20 (1), 139-152.

Maxwell, S.K., Nuckols, J.R, Ward, M.H. and Hoffer, R.M., 2004: An automated approach to mapping corn from Landsat imagery, *Computers and Electronics in Agriculture* 43, 43–54.

Meyer, W.B., 1995: Past and Present Land-use and Land-cover in the U.S.A, *Consequences*, 24-33.

Mostafa, M.E. and Bıshta, A. Z., 2004: Significance of lineament patterns in rock unit classification and designation: A pilot study on the Gharib-Dara area, Northern Estern Desert, Egypt, *International Journal of Remote Sensing* 26 (7), 1463-1475.

Myint, S. W., Yuan, M., Cerveny, R. S. and Giri, C.P., 2008: Comparison of Remote Sensing Image Processing Techniques to Identify Tornado Damage Areas from Landsat TM Data, *Sensors* 8, 1128-1156

Oettera, D. R., Cohenb, W. B., Berterretchea, M., Maierspergera, T. K., and Kennedy, R. E., 2000: Land cover mapping in an agricultural setting using multiseasonal Thematic Mapper data, *Remote Sensing of Environment* 76, 139–155.

Pax-Lenney, M., Woodcock, C. E., Collins, J. and Hamdi, H., 1996: The status of agricultural lands in Egypt: the use of multitemporal NDVI features derived from Landsat TM, *Remote Sensing of Environment* 56, 8 –20.

Peterson, D. L., Egbert, S. L., Price, K. P. and Martinko, E. A., 2004: Identifying historical and recent land-cover changes in Kansas using post-classification change detection techniques, *Transactions of the Kansas Academy of Science* 107 (3/4), 105–118.

Plourde, L. and Congalton, R.G., 2003: Sampling method and sample placement: How do they affect the accuracy of remotely sensed maps?, *Photogrammetric Engineering and Remote Sensing* 69, 289–297.

Potapov, P., Hansen, M.C., Stehman, S.V., Loveland, T.R. and Pittman, K., 2008: Combining MODIS and Landsat imagery to estimate and map boreal forest cover loss, *Remote Sensing of Environment* 112, 3708–3719.

Reese, H. M., Lillesand, T.M., Nagel, D.E., Stewart, J.S., Goldmann, R.A., Simmons, T.E., Chipman, J.W. and Tessar, P.A., 2002: Statewide land cover derived from multiseasonal Landsat TM data, A retrospective of the WISCLAND project, *Remote Sensing of Environment* 82, 224–237.

Robinson, R. and Nagel, D., 1990: Land cover classification of remotely sensed imagery and conversion to a vector-based GIS for the Suwannee River 85 water management district, *In Proceedings: 1990 GIS/LIS, Anaheim, California*, pp. 219-224.

Singh, A., 1989: Digital change detection techniques using remotely - sensed data, *International Journal of Remote Sensing* 10 (6), 989–1003.

Smits, P.C.; Dellepaine, S.G. and Schowengerdt, R.A., 1999: Quality assessment of image classification algorithms for land cover mapping: a review and a proposal for a cost based approach, *International Journal of Remote Sensing* 20, 1461–1486.

Story, M. and Congalton, R.G., 1986: Accuracy assessment: a user's perspective, *Photogrammetric Engineering and Remote Sensin,* 52, 397-399.

Stuckens, J., Coppin, P. R. and Bauer, M.E., 2000: Integrating Contextual Information with per-Pixel Classification for Improved Land Cover Classification, *Remote Sensing of Environment* 71, 282–296.

Vogelmann, J. E. and Rock, B. N., 1988: Assessing forest damage in high elevation coniferous forests in Vermont and New Hampshire using Thematic Mapper data, *Remote Sensing of Environment* 24, 227– 246.

Weng, Q., 2002: Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modeling, *Journal of Environmental Management* 64, 273-284.

Woodcock, C. E., Collins, J., Jakabhazy, V. D. and Macomber, S. A., 1993: Technical manual: forest vegetation mapping methods designed for Region 5 of the US Forest Service*, Technical Paper Number 7*, Boston University Center for Remote Sensing, 105 pp.

Yang, X. and Lo, C., 2002: Using a time series of satellite imagery to detect land use and land cover changes in the Atlanta, Georgia metropolitan area, *International Journal of Remote Sensing* 23 (9), 1775-1798.

Yeh, A. G. and Li, X., 1997: An integrated remote sensing and GIS approach in the monitoring and evaluation of rapid urban growth for sustainable development in the Pearl River Delta, China, *International Planning Studies* 2(2), 193-210.

Yuan, F., Bauer, M. E., Heinert, N. J. and Holden, G., 2005: Multi-level land cover mapping of the Twin Cities (Minnesota) metropolitan area with multi-seasonal Landsat TM/ETM+data, *Geocarto International* 20 (2), 5 –14.

Zhang, Q., Wang, J., Peng, X., Gong, P. and Shi, P., 2002: Urban built-up land change detection with road density and spectral information from multi-temporal Landsat TM data, *International Journal of Remote Sensing* 23 (15), 3057–3078.

Zhu, H.W. and Basir, O., 2005: An adaptive fuzzy evidential nearest neighbor formulation for classifying remote sensing images. *IEEE Transactions on Geoscience and Remote Sensi*ng *43*, 1874–1889.

SAŽETAK

Upotreba satelitskih snimaka Landsat za utvrđivanje promjena u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji u Hrvatskoj

Zlatko Horvat

Pravovremene i točne informacije o otkrivanju promjena na Zemljinoj površini iznimno su važne za razumijevanje povezanosti i interakcije ljudskih i prirodnih fenomena. U radu se procjenjuju promjene u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji u Hrvatskoj u razdobljima 1978. – 1992., 1992. – 2007. i 1978. – 2007. upotrebom satelitskih snimaka Landsat. Prostorna dinamika promjena načina upotrebe zemljišta i pokrova kvantificirana je upotrebom triju serija multispektralnih satelitskih snimaka Landsat: Landsat 4-MSS, Landsat 5-TM i Landsat 7-ETM$^+$. Većina odabranih satelitskih snimaka snimljena je u isto doba godine (kolovoz) i za vedra neba. Dobavljene su preko web-servisa Sveučilišta Maryland (Global Land Cover Facility).

Izrađene su tri serije karata koje prikazuju način upotrebe i pokrov zemljišta za 1978., 1992. i 2007. godinu. Metodologija upotrijebljena u istraživanju uključuje pretprocesiranje satelitskih snimaka, oblikovanje klasifikacijske sheme, klasificiranje satelitskih snimaka, analizu promjena načina upotrebe i pokrova zemljišta i ocjenu točnosti. Za izradu karata i klasifikaciju snimaka poslužio je slobodni program otvorenoga koda SAGA GIS. Kako su snimke Landsat mnogo veće od područja istraživanja, smanjene su (*sub-setting*), što je znatno ubrzalo obradu. Satelitske snimke dobivene su različitim senzorima te svedene na zajedničku nominalnu prostornu rezoluciju od trideset metara metodom najbližeg susjeda. Kao primarni koordinatni sustav u radu je upotrijebljen univerzalni referentni sustav (*Universal Transverse Mercator* – UTM) projekcije za zonu 34N na osnovi elipsoida WGS84.

Primijenjena je postklasifikacijska tehnika temeljena na hibridnoj klasifikaciji koja se sastoji od nenadzirane klasifikacije, nadzirane klasifikacije i primjene ljudskog iskustva u poznavanju terena. Budući da su urbana područja uglavnom heterogena i sastoje se od objekata koji su manji od prostorne rezolucije satelitskih senzora (zgrade, ceste, drveće, trava), najprije je provedena pomna ručna digitalizacija svih urbanih područja Međimurske županije na topografskim kartama 1 : 25.000 i zračnim snimkama visoke rezolucije. Urbana područja potom su izdvojena iz snimaka i klasificirana odvojeno od ostalih podataka primjenom nenadzirane klasifikacije. Na temelju Andersonova klasifikacijskog sustava način upotrebe i pokrov zemljišta klasificirani su putem nadzirane klasifikacije kao vodene površine, šumske površine, golo tlo, poljoprivredne površine i urbano područje. U nadziranoj klasifikaciji potrebno je prvo definirati homogena područja za koja je poznat način upotrebe ili pokrov zemljišta („trening" područja). Izlučivanje homogenih, „trening" područja napravljeno je ručnom digitalizacijom na pomoćnim kartama – avionskim snimkama visoke rezolucije i topografskim kartama. Za svaku klasu izlučeno je najmanje 25 „trening" područja. Nakon nadzirane klasifikacije standardnom metodom *majority filter*

rezultati su prostorno generalizirani s obzirom na pojedinačne piksele, izvorno svrstane u klasu različitu od okolnih piksela da bi se izbjegao efekt *salt and papper*.

Za ocjenu točnosti klasifikacije upotrijebljena je matrica pogrešaka, iz koje su izračunati indeksi točnosti: ukupni (*overal accuracy*), proizvodni (*producer's accuracy*) i korisnički (*user's accuracy*), te parametri statistike *Kappa*. Proizvodna i korisnička točnost pojedinačnih klasa relativno je velika, od 74 do 94 posto, što upućuje na dobru povezanost generiranih karata i referentnih podataka. Ukupna točnost za 1978. godinu iznosi 87,67 %, za 1992. godinu 88,96 % i za 2007. godinu 90,84 %. Najvažnije promjene u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji tijekom promatranog razdoblja najprije su analizirane vizualnom interpretacijom, koja daje opću predodžbu o promjenama i napravljena je na kartama koje su dobivene simultanim prikazom triju spektralnih pojasa „stvarnim sastavljanjem boja" (*true color composite*) i „lažnim sastavljanjem boja" (*false color composite*).

Rezultati istraživanja pokazuju da su nastale značajne promjene u načinu upotrebe i pokrovu zemljišta u Međimurskoj županiji tijekom posljednja tri desetljeća. Prema rezultatima analize, od 1978. do 2007. urbano područje poraslo je za otprilike 53 %, dok se poljoprivredno zemljište smanjilo za 12 %. Vodene površine, šumske površine i golo tlo porasli su za četrnaest, pet i 49 posto. Karte promjena pokazuju da je urbano zemljište povećano za 53 % zbog urbanizacije koja je posljedica visokoga ekonomskog rasta, posebno od 1978. do 1992. Vodena površina povećana je za četrnaest posto najviše zbog izgradnje akumulacijskih jezera na rijeci Dravi i pretvaranja zemljišta u šljunčare. Zbog toga je šumsko zemljište smanjeno za devet posto od 1978. do 1992., ali i poraslo od 1992. do 2007., posebno duž rubnih granica već postojećega šumskog zemljišta. Od početka devedesetih udio poljoprivrednog stanovništva u neprekidnom je padu i stoga se pojavljuje sve više neobrađenog zemljišta, koje s vremenom postaje šumsko. Šumsko zemljište ukupno se povećalo za nešto manje od tisuću hektara. Porast urbanog i šumskog zemljišta rezultirao je smanjenjem poljoprivrednog zemljišta. Ako usporedimo golo tlo i poljoprivredno zemljište kao jedinstvenu klasu, poljoprivredno zemljište smanjeno je za dva posto od 1978. do 1992. i značajno smanjeno za pet posto od 1992. do 2007. Ukupno smanjenje tijekom promatranog razdoblja za poljoprivredno zemljište iznosi sedam posto (3470 Ha), što upućuje na stalno smanjenje poljoprivrednog zemljišta u Međimurskoj županiji.

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