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THE USE OF DIGITAL TERRAIN MODEL IN THE STUDY OF DISTRIBUTION OF CULTURAL LANDSCAPE ELEMENTS BASED ON THE EXAMPLE OF SILESIA BESKID

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Abstract. Digital Terrain Model (DTM) and maps based on it, are very valuable tool in investigations of distribution of cultural landscape elements. Connection DTM with a digital land cover maps, clearly illustrate factors determinate location of various landscape elements. The paper presents the applicability of Digital Terrain Model to detect the influence of topographic attributes on landscape elements distribution and to determinate the landscape's structure in the different altitudinal zones. Presented results, are the effect of the first phase of cultural landscape elements distribution research and they are starting point to look for other factors which could effect on structure of the landscape.

Keywords: GIS, Digital Terrain Model, cadastral maps, Spatial Analyst, V-LATE, cultural landscape, Silesia Beskid

Introduction

We have seen increasing interest in studies of cultural landscape recently. It mostly applies to the issue of natural circumstances of evolution of cultural landscape, which was taken at the beginning of landscape researches (Soczyński 2011). It is a very difficult task to determine the role of the factors which shape the cultural landscape. This is due to the fact, that all the forces which have an influence on landscape transformation are not only an object, but also a subject of the changes and they are transform continuously. There is no cause and effect's between the factors transforming the geographic base and this base, but much more complicated system of mutual interdependence (Dobrowolska 1976). The interdependence of the individual factors which shape the cultural landscape is difficult to disentangle clearly and compeled to considerable caution in drawing conclusions about their role.

On the other hand, there are a whole new research methods using Geographic Information System (GIS) with additional tools. Their application allows for unprecedented results until now. A Digital Terrain Model can be one of these tools. It gives information about the relationship between distribution of cultural landscape elements and morphometric's parameters which describe the topography. However, it should be remembered, that results cannot be directly interpreted, because they are only the result of the one research phases about the conditions of cultural landscape elements distribution.

Aims and the choice of study area

The basic work aim was to present the possibilities of Digital Terrain Model's application and to identify its role in the study of the cultural landscape elements distribution. The specific geographical environment should be a starting point for this kind of studies as a distinctive base of the economic activity's formation. The social and political content accumulate on this base only secondarily. The factors which determinate the distribution of individual landscape elements are the result of particular human activity and they play an important role during this kind of activity. This assumption and the availability of the cartographic materials determined the study area's choice. It is a part of cadastral commune Ostre within the administrative boundaries from the half of 19th century. This commune is located within Żywiecczyzna which is a geo-cultural region. That cultural landscape was being formed by the shepherding and agriculture activity from the end of 15th to 19th century. According to J. Kondracki (2009) study area is located in the eastern part of Silesia Beskid (Fig. 1).

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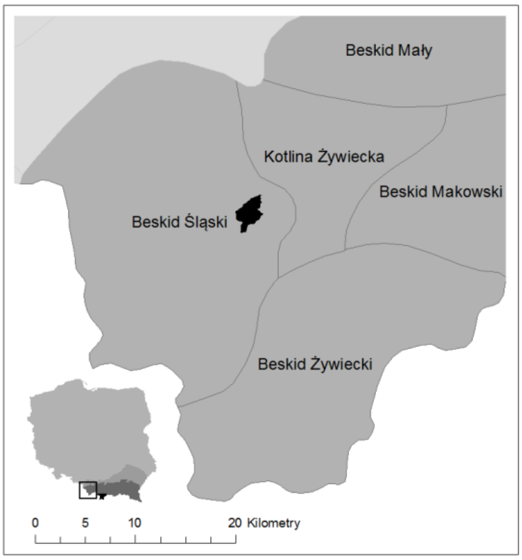

Fig 1. Location of study area

The paper presents work stages, from material's acquisition, their preparation and processing to a form suitable to analyse, to analysis and results visualization.

Materials

The research materials used in this works are: Digital Terrain Model from Provincial Centre of Geographic's and Cartographic Documentation in Katowice and cadastral maps made for Ostre commune in 1845 which are stored in Record Office in Katowice, Żywiec department.

Digital Terrain Model was constructed on the basis of RGB color aerial photographs from 2009, which precision (scale) is equal 0.20 m lenght on a pixel. It is available in three digital's formats: TIN file (ESRI), TTN file (INTEGRAPH) and ASCII text file. In this work the TIN files were used. They are complaint with ESRI standards and they are used for storing triangulated irregular network. The individual files correspond ranges of sheets in "1992" coordinate system. (http://www.codgik.gov.pl).

Cadastral maps are available in digital format (scans). The maps for the study area were made in 1845 in the scale 1:2880. They were made probably in a Cassini-Soldner map projection or in heterogeneous one, only based on Cassini-Soldner map projection. The original cadastral maps characterized by a high correctness and low shrinkage of sheets (1%). Rich content of these maps is an invaluable source of information about the spatial structure of landscape (Wolski 2000).

The preparation of the materials for analyses

Digital Terrain Model. The preparation of the Digital Terrain Model for the analyses required conversion from TIN files to raster files. Mosaicking was the next step which allows to take more raster datasets and combine them into a single file. It was made by "blend" method which is suggested for continuous data. The output files were clipped to the boundaries of the study area. As a result the processed files are ready for analyses.

Cadastral maps. The preparation of the cadastral maps is much more time-consuming. To accomplish this aim, the program ArcGIS 9.3 was used.

A raster image (obtained by scanning the paper's map) is distorted and devoid of information about the spatial relation. The information about map datum and projection is essential to accurate georeferency. This information is not entered into GIS applications, but there is a possibility to enter manually the parameters. The exact discussion of the georeferencing methods of archival paper using GIS presents A. Affek (2012). The affine transformation was performed firstly by using the coordinates of the corners of the map's sheets. This is a transformation which preserves straight lines and ratios of distances between points lying on a straight line. Required formulas to calculate the coordinates of the map's corners gives S. Goraj (1982). The average root mean square error (RMS) for the individual maps did not exceed 4,91 meters. The maximum allowable RMS error adopted arbitrarily by J. Wolski (2007) is 10 meters. The next step is to transform the historical map datum to modern coordinate system – in this case it was "1992". To accomplish this aim, the simplified-Molodensky transformation was used. The method of implementation presents A. Affek (2012).

The next step of the work was onscreen digitization using a method called "snapping". It is recommended for creating a polygon object. This method consists in capturing the cursor position by linear elements of the existing objects, so that the coordinates of new object are identical with the coordinates of existing ones by which they were captured (Urbański 2010). This provided the data in vector format. The onscreen digitization accompanied database creation about land cover forms locate in study area.

The errors are usually generated during the onscreen digitization. The most common topological error types in spatial vector data are: floating or short lines, overlapping lines, overshoots and undershoots, unclosed, weird and sliver polygons (Maras *et al* 2010). The topology tool was used to detection and elimination of these errors.

The last stage of the cadastral maps preparation consisted in converting the vector data structure to raster data structure. The analyses were carried on raster and vector files by ArcGIS 9.3.

The preliminary analyses

The preliminary analyses consisted in select the elements of cultural landscape and the identification of the potential natural environmental factors determining their distribution, as well as obtaining the output used for further analyses.

Terrain analysis is possible by calculating the morphometric parameters from the Digital Terrain Model. This parameters are also called topographic attributes. J. Urbański (2010) divides them into primary and secondary topographic attributes. In this work the following topo-

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graphic attributes were used: slope, aspect and altitude. The results of analysis are shown in Fig. 2.

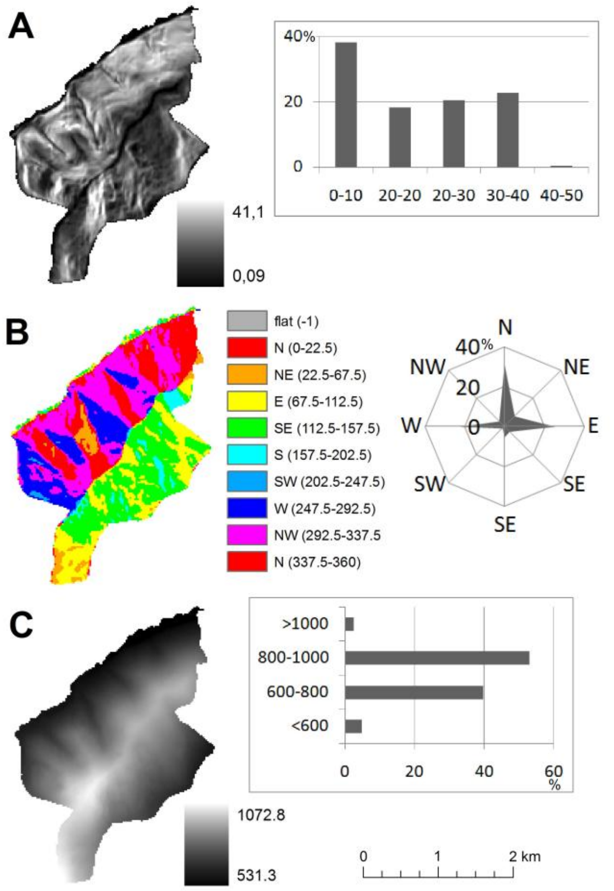

Fig 2. Characterization of topographic features based on Digital Terrain Model: A – slope (degrees^0), B – aspect (degrees^0), C – altitude (m a.s.l.). Graphs show the percentage values.

Land cover analysis. It consists in the calculation of the total surface of the study area and the surface of the various forms of agriculture land cover (Table 1, Fig. 3). In this end the extension V-LATE application of ArcGIS was used. The calculations were based on the vector layer which presents the land cover. The arable field and grassland (pastures and meadows) were selected for detailed analysis.

Table 1. The structure of the agricultural land in the study area

Agricultural land form	Area [km^2]	Percentage of agricultural land
arable field	0,19	23,5%
grassland	0,61	76,5%
total	0,80	100%

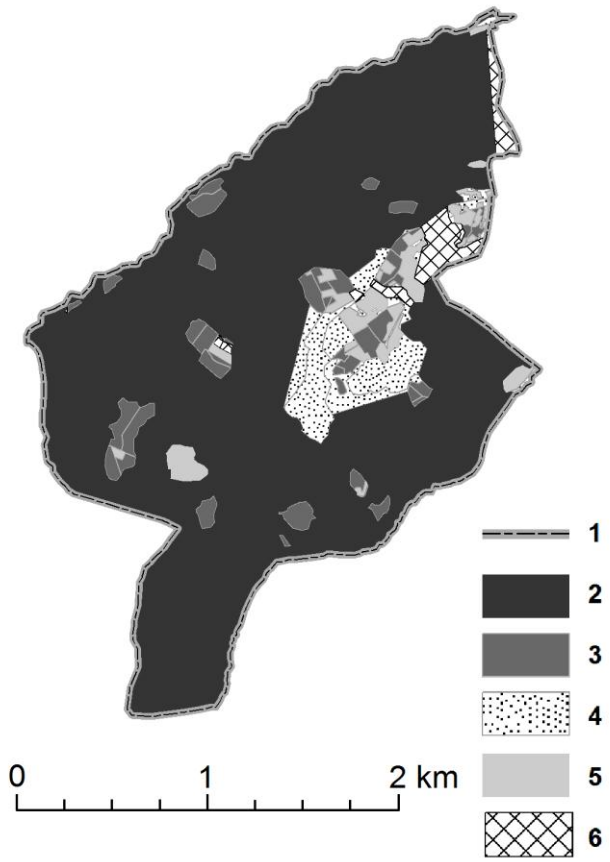

Fig 3. Land cover map. 1 – border of the study area, 2 – forests areas, 3 – meadows, 4 – pastures, 5 – arable fields, 6 – areas of secondary succession.

The determination of the influence of topographic attributes on landscape elements distribution

It was necessary to determine the optimal conditions of agricultural lands distribution to indicate to what extent the terrain influences on it. This problem has been widely described in the literature (Adamczyk *et al.* 1980, Jagła *et al.* 1981, Kostuch 1976, Kulik *et al.* 1959, Starkel 1972). The criteria of optimal location of agricultural land in the Carpathians were selected on the basis of this literature (Table 2).

For the analyses Spatial Analyst toolbox was used. The raster layers which present the areas of the optimum localization were created for each topographic attribute by the Reclassify tool. The areas contained all three conditions of the optimal location were created by the Raster Calculator (Fig. 4).

Subsequently, it was determined what percentage of the agricultural area is located in areas with optimal conditions for their location. It was done by Cut (Management) tool and V-LATE extension. The results are summarized in Table 2.

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Table 2. The percentage of the surface of selected landscape elements in areas of optimal conditions for their location

Location factor	Criterion	Area [m^2]	Percentage of area
arable field			
slope	<10^0	26909.5	14.2%
aspect	112.5^0-247.5^0	75416.8	39.9%
altitude	<1000 m	186856.5	98.8%
total		7552.5	4.0%
grassland			
slope	<20^0	532717.8	86.5%
aspect	beyond 112.5^0-247.5^0	367946.0	59.8%
altitude	<1200 m	615742.3	100%
total		299650.2	48.7%

The determination of the landscape structure in the different altitudinal zones

Digital Terrain Model gives also possibility to check if the landscape structure in each altitudinal zones is appropriate from an economic point of view. The raster layers which present the land cover in four altitudinal zones were created by the Reclassify and Cut (Management) tools. The agricultural land's structure was determined for each altitudinal zone by the V-LATE extension. The optimal structure of the agricultural land to the Carpathians is presented by L. Starkel (1972). The results are summarized in Tab. 3.

Table 3. The structure of agricultural land in each altitudinal zones

Agricultural land form	Area [m^2]	Percentage of agricultural land	Recommended percentage of agricultural land
altitudinal zone 300 – 600 m a.s.l.*			
arable field	3214.5	18.0%	50%
grassland	14687.3	82.0%	50%
altitudinal zone 600 - 800 m a.s.l.			
arable field	14761.5	23.9%	25%
grassland	46982.3	76.1%	75%
altitudinal zone 800 - 1000 m a.s.l.			
arable field	168880.5	23.7%	10%
grassland	544105.6	76.3%	90%
altitudinal zone > 1000 m a.s.l.			
arable field	1776.0	17.0%	0%
grassland	8675.8	83.0%	100%

*- the lowest place in study area is situated at a height of 531,3 m a.s.l.

The interpretation of results

The slope, aspect and altitude were the significant factors of the location only in the case of grassland. However, all three factors are applied only for 48.7% of their surface. The altitude was the only significant factor in the location of arable fields. It is noteworthy that the influence of slope is small. Only 4% of the surface of arable land is in these areas where meet all three criteria simultaneously.

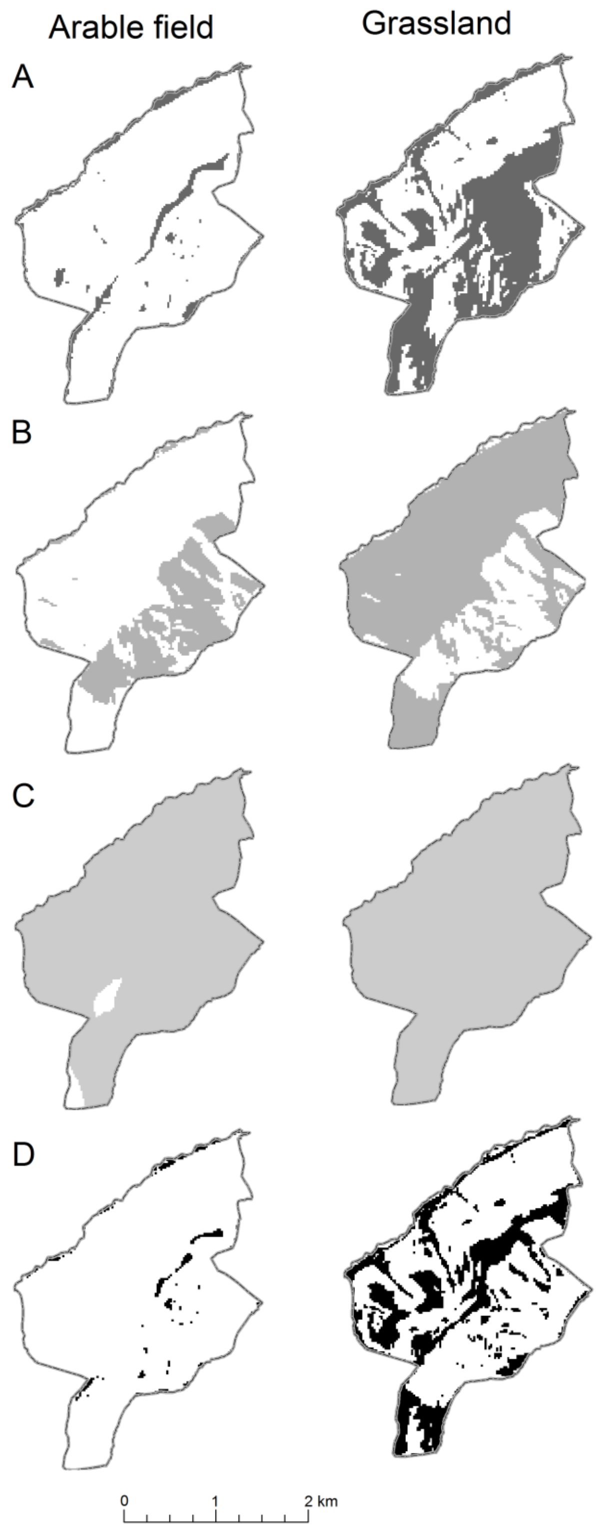

Fig 4. The areas of the optimum localization for arable field and grassland. Location factor: A – slope (degrees^0), B – aspect (degrees^0), C – altitude (m a.s.l.). D – all criterions together

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The structure of the agricultural land is suitable only in the altitudinal zone between 600 and 800 m a.s.l. The data about the lowest zone are not comparable due to the lack of information about the structure of agricultural land in the entire range of altitude. It is noteworthy that as much as 88.6% of the agricultural land is located between 800 and 1000 m a.s.l. Meanwhile, agricultural area should decrease with the altitude. The arable field have relatively large proportion of the area also above 1000 m a.s.l. The analyses of the slope and aspect's impact on the of the landscape elements distribution may be helpful to explain the variability of landscape structure with altitude. The information about the participation of the various classes of the slope and aspect in the total area may be also important. The method of their implementation has been presented above.

Conclusion

Digital Terrain Model (DTM) and maps based on it are a very valuable tool in studying cultural landscape elements distribution. In conjunction with a digital map of land cover, they illustrate clearly the factors which determinate the location of the various elements of the landscape. They allow to determine significance of these factors too. They constitute a starting point to look for other factors that could affect the structure of the landscape. The examples mentioned above represent only several possibility of using Digital Terrain Model in the analyses of landscape.

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Abstrakt

Numeryczny model terenu i jego mapy pochodne stanowią bardzo cenne narzędzie badania rozmieszczenia elementów krajobrazu kulturowego. W połączeniu z cyfrową mapą pokrycia terenu, pozwalają na czytelne zobrazowanie czynników warunkujących lokalizację poszczególnych elementów krajobrazu oraz określenie ich znaczenia. W pracy przedstawiono możliwości zastosowania numerycznego modelu terenu do określenia wpływu wybranych atrybutów topograficznych na rozmieszczenie elementów krajobrazu kulturowego oraz do określenia jego struktury w poszczególnych strefach wysokościowych. Zwrócono uwagę, iż uzyskane za pomocą numerycznego modelu terenu wyniki są efektem jednego z etapów badania uwarunkowań rozmieszczenia elementów krajobrazu kulturowego i stanowią bazę wyjściową do poszukiwania innych czynników, które mogły wpływać na jego strukturę.

Słowa kluczowe: GIS, numeryczny model terenu, mapy katastralne, Spatial Analyst, V-LATE, krajobraz kulturowy, Beskid Śląski

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