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Барщевська Н. М. **Аналіз новітньої геодинаміки, в зв'язку з формуванням рельєфу території басейну р. Інгул.** В статті розглянуті неогеодинамічні умови формування рельєфу території басейну р. Інгул. Охарактеризовані сумарні амплітуди неотектонічних рухів земної кори, виділені окремі необлоки з різною неотектонічною активністю. Поданий аналіз неотектонічної активності лінійних морфоструктур – розломних зон та окремих розломів.

Ключові слова: неотектонічні рухи, необлоки, активні розломи та розломні зони, сумарні амплітуди неотектонічних рухів земної кори

Barshchevska N. **Analysis of modern geodynamics in relation to the formation of the relief area of the Inhul basin.** The article analyzes the neogeodynamics conditions of formation of the relief area of the Inhul basin. One has characterized the total amplitude of neotectonic movements of Earth crust; one has singled out separate neoblocs with different neotectonic acivities. One has provided an analysis of neotectonic activity of linear morphostructure - fracture zones and separate fractures.

Keywords: neotectonic movements, neoblocs, active fractures and fracture zones, total amplitudes of neotectonic movements of Earth crust.

Барщевская Н. Н. **Анализ новейшей геодинаміки, в связи с формированием рельефа территории басейна р. Ингул.** В статье рассматриваются неогеодинамические условия формирования рельефа территории бассейна р. Ингул. Охарактеризованы суммарные амплитуды неотектонических движений земной коры, выделены отдельные необлоки с разной неотектонической активностью. Дан анализ неотектонической активности линейных морфоструктур – разломных зон и отдельных разломов.

Ключевые слова: неотектонические движения, необлоки, активные разломы и разломные зоны, суммарные амплитуды неотектонических движений земной коры.

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USE OF DIGITAL ELEVATION MODELS AND ORTHOPHOTOMAPS IN IDENTIFYING ANTHROPOGENIC MOUNDING OF RIVER VALLEYS (KIELCE, POLAND)

ВИКОРИСТАННЯ ЦИФРОВИХ МОДЕЛЕЙ РЕЛЬЄФУ ТА ОРТОФОТОПЛАНІВ ДЛЯ ВИЗНАЧЕННЯ АНТРОПОГЕННИХ НАСИПІВ РІЧКОВИХ ДОЛИН (КЄЛЬЦЕ. ПОЛЬЩА)

Keywords: digital elevation model, map algebra, difference analysis, anthropogenic mounds

Introduction. Digital Elevation Models (DEM) are nowadays widely used source of terrain morphology data. DEMs allow to perform sophisticated spatial analysis concerning terrain morphology, including natural and anthropogenic conditions. Recently significant growth of the number and availability of very accurate DEMs is observed. This situation leads to new analytical possibilities. One of them is comparative analysis of DEMs created in different time periods, which allows to investigate relief changes in specified periods of time. Such analysis was used, for example, to investigate landslides dynamics, cliff erosion or quantify changes in mine mounds. Examples of DEM comparative analysis were published by Kaminski (2012). Nevertheless, there is a lack of works describing the use of comparative DEMs analysis to investigate landforms changes in floodplains of urbanized areas.

Aim, materials and methods. The main aim of this paper was an assessment of utilizing different high-resolution digital elevation models, made with photogrametric and LIDAR methods in 2003 and 2011, to investigate anthropogenic mounding of floodplains in river valleys and estimate horizontal and vertical dimensions of the mounds. Author also puts another question – can photogrametric DEM of relatively smaller resolution be compared with currently most accurate LIDAR DEM to bring out satisfying results in analyzing terrain morphology changes in large scales?

Analysis was carried out in flood areas delimited in Kielce city for floods of 1 % probability for Bobrza, Sufraganiec, Silnica and Lubrzanka rivers (Biernat et al. 2006, 2007a, 2007b, 2007c, BCE 2008), which are presented in figure 1.

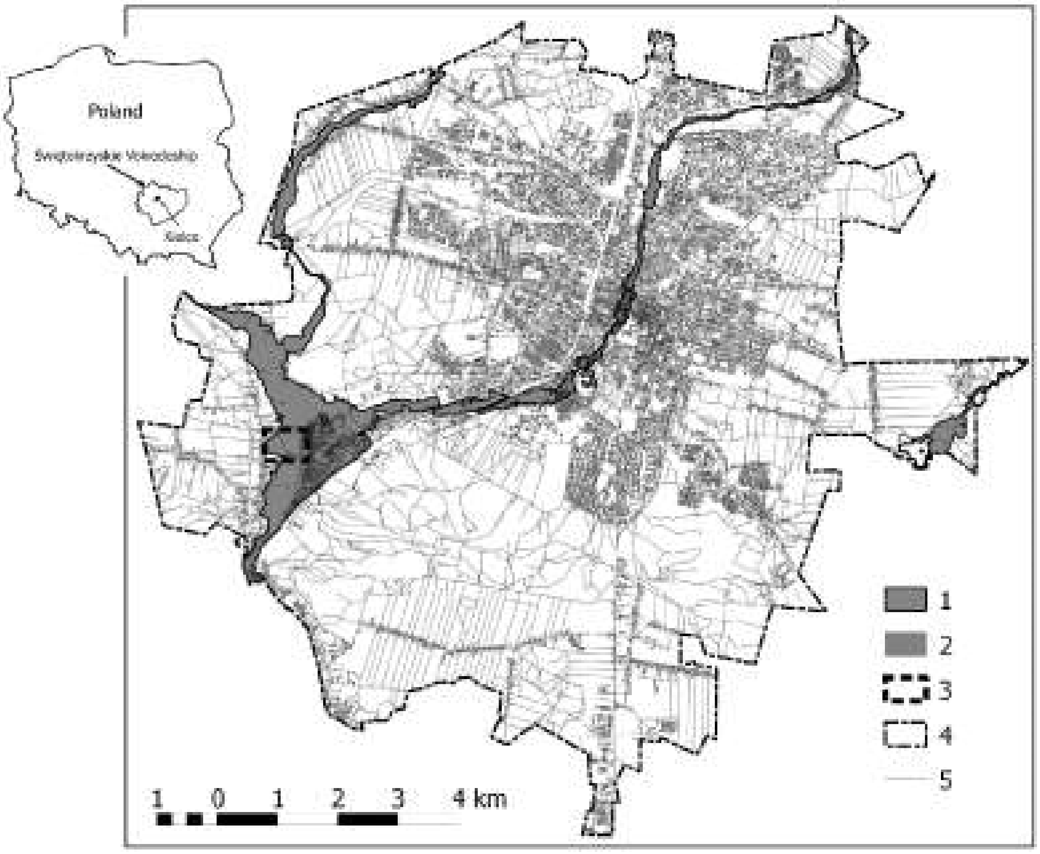

Fig. 1 – **Location of investigation area**
1 - floodplains, 2 - buildings, 3 - field verification polygon, 4 - Kielce borders, 5- road network

Research material consisted of two high resolution DEMs made in different time periods, which are accessible in Central Department of Geodetic and Cartographic Documentation in Poland. Those models are only high resolution DEMs created for the investigated area. Older DEM was made mostly with photogrammetric methods from aerial photography in 2003 contributed with points of known elevation, younger by airborne laser scanning technique (als LIDAR) in 2011.

Additionally two orthophotomaps made in the same periods as DEMs in 2003 and 2011 were used as a reference to site conditions. To enable comparative analysis of DEMs a standardization were performed. Taking into consideration spatial accuracy of both DEMs - higher in LIDAR than in photogrametric DEM, they were converted to a raster format (*.tiff) with 1 meter spatial resolution in polish 1992 Coordinate System (EPSG 2180).

Investigation of terrain morphology changes between 2003 and 2011 was performed using the difference analysis on standardized DEMs in ArcGIS 10.1. This raster data analysis belongs to a group of Map Algebra methods (Tomlin 1983, Bruns, Egenhofer 1997, Longley i in. 2006).

Results. As a result of the difference analysis a raster map with 1 m spatial resolution showing differences between values (in meters) on both used DEMs was created (fig. 2). Those values suggest possible differences in terrain morphology between 2003 and 2011. Positive values show areas where elevation could have increased, negative values - areas where elevation could have decreased in the investigated period. Author named this map as Elevation Difference Map.

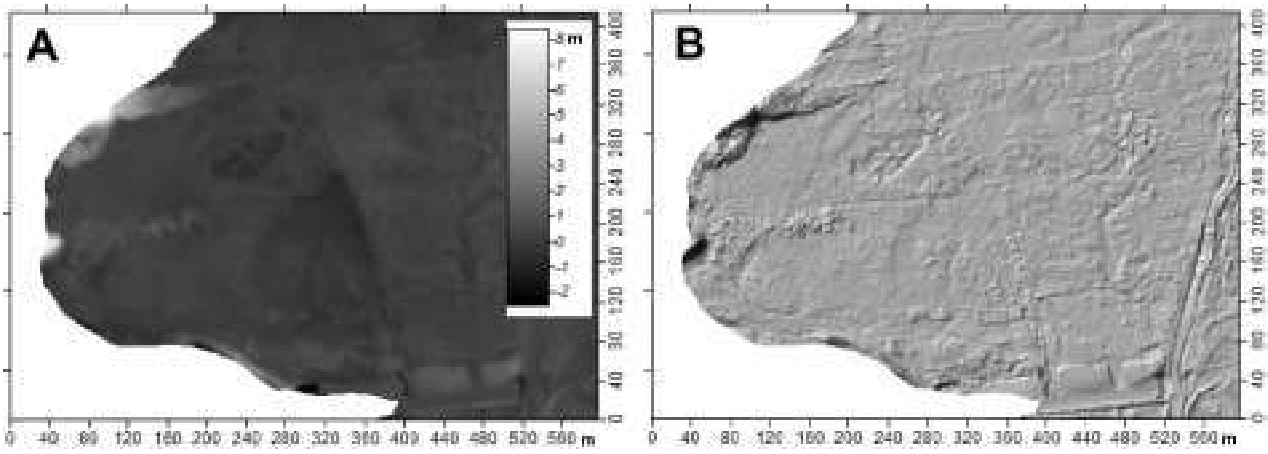

Fig. 2 – **Part of Elevation Difference Map** (A) **and shaded relief of presented area** (B)

The Elevation Difference Map values extent was varying from -7.12 to +12.49 m. Taking into consideration horizontal and vertical errors in used DEMs, apparently higher in photogramethric than in LIDAR DEM, positive or negative elevation changes were generated in almost all area of analyzed floodplains. In order to assign areas of anthropogenic potential new mounds, an estimation of threshold value on Elevation Difference Map was performed. It was done by analyzing histogram of Elevation Difference Map values along borders of mounds that were created between 2003-2011 and are visible on the orthophotomap from 2011. At first, mentioned borders of visible new mounds were digitized in vector format (*.shp), than converted to a 1 m raster format (*.sgrd). Values from Vertical Difference Map were assigned to this raster, finally its histogram was created. Analysis of the histogram showed that most of the raster cells had a value near +1 m. As a reason of that, the value of +1 m was chosen as a threshold value in the following reclassification procedure. If a value on Elevation Difference Map in some area exceeds the threshold value this area is treated as a potential new mound. Areas of adequate potential new mounds created by reclassification of Elevation Difference Map using the threshold value of +1 m were almost identical to areas and borders of existing mounds created between 2003-2011, which are visible on 2011 orthophotomap (fig. 3).

As a result of DEMs errors, reclassification procedure also generated areas of artifact new mounds. Final identification of existing new mounds and non-existing artifact new mounds was supported by orthophotomaps analysis and field survey in appointed verification polygon with an area of 3 650 000 m^2 (fig. 4). Performed field survey showed that every potential new mound in verification polygon generated on areas of high vegetation were an artifact. This was especially visible along the river bed and valley edges and could be explained by high vertical errors of photogramethric DEM in vegetated areas, especially on existing there areas of high vegetation (trees and high shrubs). Potential new mounds generated on open land were identified as existing, both by field survey and orthophotomaps analysis.

Fig. 3 – **Mounds areas generated with the threshold value of +1 m (white line) corresponds to new mounds visible on the orthophotomap from 2011, additionally a group of generated artifact, non-existing mounds is visible**

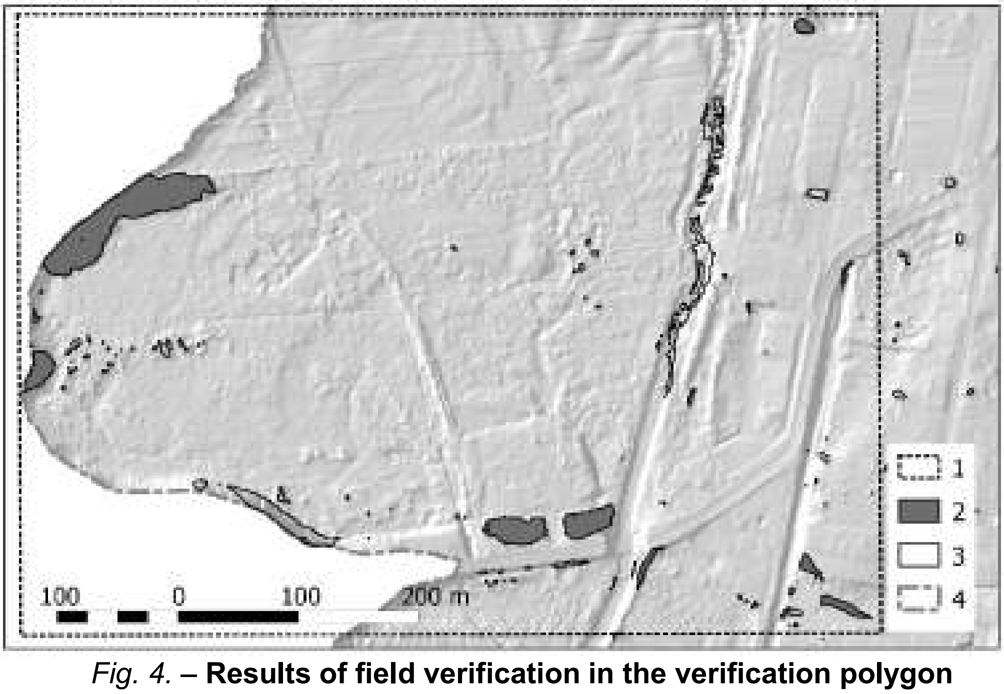

Fig. 4. – **Results of field verification in the verification polygon**
1 - verification polygon, 2 - existing mounds, 3 - non-existing mounds, 4 - floodplain border

Total number and areas of generated potential mounds in the analyzed floodplains and investigation polygon, followed by their basic statistics are shown in table 1. The results of field verification are also presented showing statistics for existing and non-existing, artifact mounds in the verification polygon. The number of existing new mounds after field verification in verification polygon (11) is relatively small in comparison to the total number of potential new mounds in this area (147). This difference could be explained by the big number of one or two-cell potential new mounds with an area of 1 or 2 m^2, generated after the reclassification procedure using a threshold value. After the data analysis it is possible that this proportion could be adequate to existing and non-existing potential new mounds in the whole area of analyzed floodplains.

Table 1 – **Basic statistics for generated potential new mounds**

	Floodplains (total)	Investigation polygon (total)	Existing mounds in investigation polygon	Non-existing mounds in investigation
Total number	3 112	147	11	136
Total area (m^2)	208 215	9 972	6 677	3 296
Area of the biggest mound (m^2)	100 590	3 760	3 760	899
Area of the smallest mound (m^2)	1	1	20	1

The biggest potential new mound generated in the area of analyzed floodplains has an area of almost half of total area of all mounds generated (100 590 m^2). Data analysis showed that this potential mound is located exactly in the area of long existing water reservoir and is an outcome of different ways of presenting elevation in the areas of water bodies in used DEMs.

Analysis of horizontal dimensions of existing new mounds performed in GIS was accurate to field measurements. Vertical differences between values Generated by the GIS analysis and field measurements reached 2 m in case of the biggest existing mounds, with height exceeding 12 m. Those differences result most likely from both DEM errors.

In specific field conditions, particularly high LIDAR DEM vertical errors could occur because of the time of scanning. In the analyzed area scanning was performed in September 2011, while vegetative cover was still present. This could have influenced laser scanner by blocking the signals in reaching the ground level. Field investigation, including measurements of existing mounds, were performed in a place where particularly dense, low vegetative cover were occupying reach in nutrients bottoms of river valleys. This could explain possible LIDAR DEM errors.

Summary and conclusions. The aim and scope of this paper was to analyze the possibility of using different elevation data sources to investigate in detail terrain morphology changes in the bottoms of river valleys, in this case anthropogenic mounding. Research material consisted of two DEMs and two orthophotomaps made in different time periods, accessible in Central Department of Geodetic and Cartographic Documentation in Poland. Older DEM was made mostly with photogrammetric methods from aerial photography in 2003, contributed with points of known elevation, younger by airborne laser scanning technique (als LiDAR) in 2011. Orthophotomaps were created in the same periods as DEMs.

Research has shown that presented data sources could be used in this kind of analysis, but when doing so, one should consider following conclusions:

DEMs should be spatially standardized to allow their comparison in GIS environment. This standardization should be performed with consideration of their spatial resolution in which they were originally created.

Resulting from difference analysis Elevation Difference Map is strongly influenced by DEMs errors so estimating of the threshold value is essential to the results of investigation.

As a reason of apparently fast mound growing ratio and if orthophotomaps are used as a reference material, they should be made in the same period of time as DEMs. Otherwise, high errors may occur in estimating threshold values, verifying generated mounds and measuring their dimensions.

If using photogrametric DEM, investigated terrain should be covered with low or no vegetation, if not there would be a lot of artifact mounds generated in vegetated areas.

Even if using high resolution orthophotomaps, a field survey is needed to verify the results of GIS analysis.

Presented GIS procedure allowed to delimit accurate horizontal dimensions of anthropogenic mounds, which were validated by the field verification. Generated vertical dimensions of the mounds diverged up to 2 m from field measurements.

Key role in the quality of performed analysis had less accurate and older photogrammetric DEM. Investigation has shown that because of its vertical errors (resulting from technical restrictions in production of this kind of DEMs), this model could be used only in areas of low or no vegetation in the difference analysis. Areas like that frequently exist on floodplains so the analysis of anthropogenic mounding of the bottoms of river valleys could be possible using this kind of data.

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Валек Ґ. **Використання цифрових моделей рельєфу та ортофотопланів для визначення антропогенних насипів річкових долин (Кельце, Польща).** Метою роботи є оцінка використання різних цифрових моделей рельєфу високої здатності, виконана у 2003 і 2011 pp., з метою дослідження антропогенних насипів в річкових долинах та визначення їх розмірів. Аналіз проводився в заплавах річок Бобжа, Суфраганец, Сільниця і Лубжанка в межах міста Кельце. У результаті порівняльного аналізу різночасових матриць висот та їх польової верифікації показано, що вони можуть бути успішно використані для дослідження рельєфу днищ долин з незначною рослинністю.

Ключові слова: цифрова модель рельєфу, алгебраїчні карти, диференційний аналіз, антропогенні насипу.

***Walek G.* Use of digital elevation models and orthophotomaps in identifying anthropogenic mounding of river valleys (Kielce, Poland).** The aim of this paper is assessment of utilizing different high-resolution digital elevation models, made in 2003 and 2011, to investigate anthropogenic mounding of river valleys and estimate chosen dimensions of the mounds. The analysis was carried out in flood areas delimited in Kielce city for floods of 1 % probability for Bobrza, Sufraganiec, Silnica and Lubrzanka rivers. Research material consisted of LiDAR and photogrammetric DEM and two orthophotomaps from 2003 and 2011. As a result of comparative analysis of both DEMs and its field verification it is shown that they can be successfully used to investigate landforms changes in the valley bottoms with low vegetation. The most important factor that influenced results of the analysis was the quality of photogrammetric DEM. Presented procedure implementing difference function from map algebra analysis enables to specify correct range of the mounds and to perform their measurements. Horizontal dimensions of the mounds measured by presented GIS analysis doesn't vary much from the field measurements, vertical differences can reach 2 m.

Keywords: digital elevation model, map algebra, difference analysis, anthropogenic mounds.

***Валек Г.* Использование цифровых моделей рельефа и ортофотопланов в определении антропогенных насыпей речных долин (Кельце, Польша).** Целью данной работы является оценка использования различных цифровых моделей рельефа высокого разрешения, сделанные в 2003 и 2011 году, для исследования антропогенных насыпей в речных долинах и оценке их размеров. Анализ проводился в поймах рек Бобжа, Суфраганец, Сильница и Лубжанка в черте города Кельце. В результате сравнительного анализа разновременных матриц высот и их полевой верификации показано, что они могут быть успешно использованы для исследования рельефа днищ долин с незначительной растительностью.

Ключевые слова: цифровая модель рельефа, алгебраические карты, дифференционный анализ, антропогенные насыпи.

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