COMPARATIVE ANALYSIS REGARDING GIS INTERPOLATION METHODS IN THE PROBLEMS OF SPATIAL ANALYSIS AND OBTAINING MDT

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***Abstract**: Interpolation methods are essential tools for generating the Digital Terrain Model (MDT). Making a comparison between different interpolation methods in the GIS environment, by using the Geostatistical Analyst function, will indicate the degree of accuracy of each method. The quality of the Digital Terrain Model (DTM) depends on the accuracy of the measured data, the techniques and software used in the measurement processing stage. In this paper, three interpolation methods available in ArcGIS software are analyzed: Inverse Distance Weighted (IDW), Local Polynomial Interpolation (LPI), and Kriging. Two scenarios were considered in the study: in the first, an area with a steep slope was analyzed, in the second scenario, a gently sloping area was analyzed. The techniques for performing topographic measurements were of the modern type, respectively the current use of satellite technology. Measurements for both scenarios were performed using GNSS technology and the RTK method for determining point coordinates in real time. The location of the studied areas is in Iași county, Miroslava commune.*

***Keywords**: ArcGIS, GNSS, MDT, interpolation methods.*

1. Introduction

The methods of representing the earth surface have experienced a gradual expansion. The elevation surface is a characteristic element of three-dimensional data, being used in a variety of geostatistical and spatial analyzes. In modern times, Digital Elevation Model (DEM) and Digital Terrain Model (DTM) are databases in many spatial analysis such as: 3D analysis and raster analysis in GIS [9].

Geografic Informational Sistem (GIS) uses the geospatial database as a model of the real world. The quality of Digital Terrain Model (MDT) depends on the data source or the techniques used to obtain it. Spatial interpolation methods used for the same data may provide different results [2].

Interpolation techniques are based on the principles of spatial autocorrelation, which assumes that the nearest points are similar to each other compared to the farthest ones [3].

Digital terrain models are used in many fields and applications such as: ortorectification of satellite images, modeling of spatial objects, representation of the slope land, hydrological modeling etc. There are several data acquisition techniques to create digital terrain models and these include: fotogrammetry, GNSS technology, radargrammetry, airborne interferometer scanner, classical topographic measurements, geodetic and cartographic digitization [8].

The use of Digital Terrain Model in civil engineering must be evaluated from a technical and financial point of view. The field data acquisition stage involves time and cost. For this reason, the data acquisition systems used are those that involve high accuracy, easy of use and low cost. GNSS technology and the use of the RTK method of data acquisition have been developed to become a tool that provides high reliability and accuracy [7].

The paper presents an analysis of three interpolation methods in ArcGIS software (Inverse Distance Weighting (IDW), Local Polinomial Interpolation (LPI) and Kriging) using two scenarios depending on the slope of the terrain.

2. Material and research methodology

The research material is composed of two land areas located in Miroslava commune, Iasi county, coresponding to the two scenarios analyzed: an area with a steep slope and an area with a gentle slope (Fig. 1).

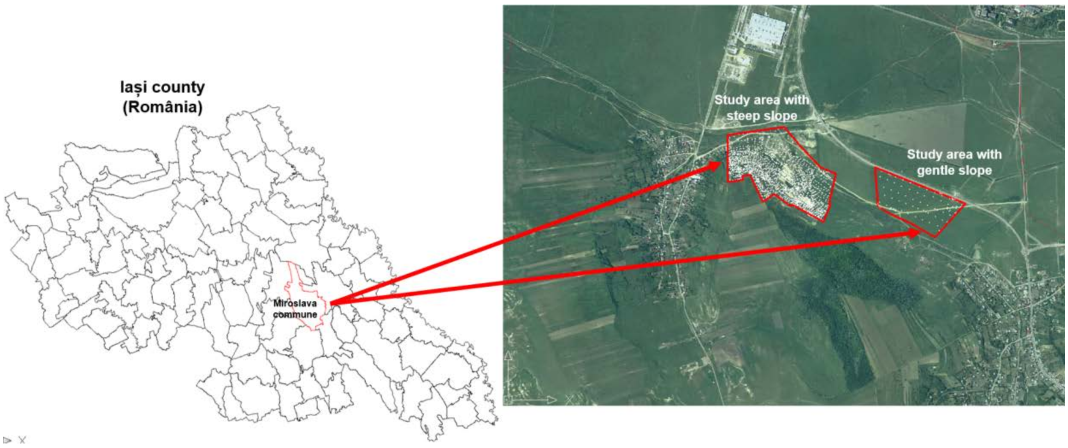


Fig. 1. Location of study areas, Miroslava commune, Iași county

The research methodology consists of the folllowing stages:

- Land recognition and performing measurements to take experimental data.
- Downloading and importing data into specialized CAD and GIS programs.
- Data processing in Autocad Map 3D, exporting it in shapefile data format and importing data into the ArcMap application.
- Creating the Digital Terrain Model with the 3D Analyst function.
- Creating the Digital Terrain Model with the Geostatistical Analyst function.

The acquisition of the experimental data consisted in performing topographic measurements coresponding to the analyzed areas. For the area with a steep slope, the coordinates of 1838 points were taken over an area of 23 ha and 111 points were measured for the gently sloping area.

The data acquisition stage took place over three days of observations (Fig. 2) and involved the use of GPS-Trimble R2 sistem which allows vertical positioning with an accuracy of 20mm ± 1ppm – double frequency. The projection system was Stereographic 1970 and the quotas were determined in the Black Sea reference system.

RTK method determines coordinaes and displays them during measurements [1].

a. b.

Fig. 2. View the study area: a – overview of the steep slope area;
b – taking data from the field [11]

3. Results – Case study

3.1. Basic data processing

After field topographic measurements, the data was exported from the receiver in „csv” format and then imported into Autocad Map 3D. After importing the points, the topology was created (Fig. 3).

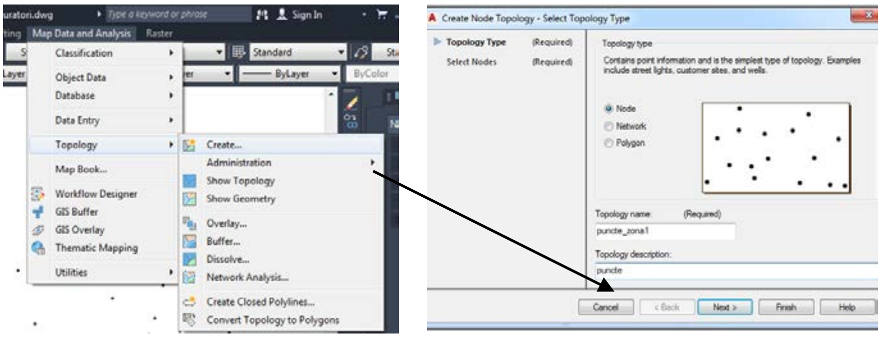


Fig. 3. Command to create topologies in Autocad Map 3D

The definition of a reference system and the correct intergration or positioning of a point in space depend on the geodetic datum. It describes how to attach the coordinate system to a reference surface [6].

Before exporting the data from Autocad Map 3D, the coordinate system used in the research was specified (Fig. 4).

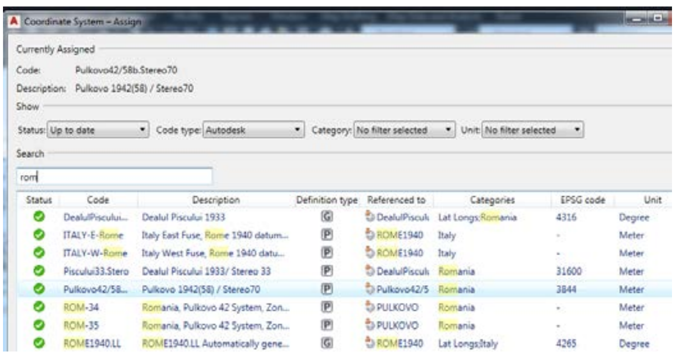
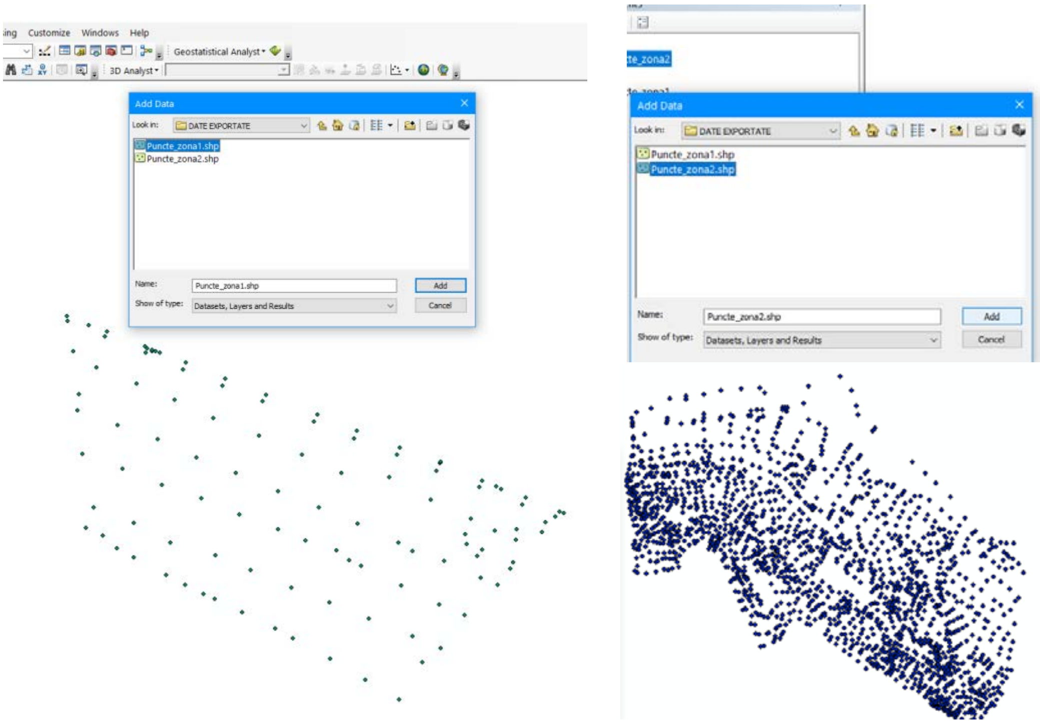


Fig. 4. Choosing the Stereographic 1970 coordinate system

With the new technologies of data integration through satellite measurements, a unification of the two components of the spatial position of a point has been achieved, and planimetric and altimetric determinations were included in a spatial geodetic datum defined in relation to a global coordinate system [4].

Files exported from Autocad Map 3D in shapefile data format were imported into ArcMap 10.5 (Fig. 5).



a. b.

Fig. 5. Import data into ArcMap: a – gently sloping area;
b – steep slope area [11]

The digital terrain model is a graphical representation of real terrestrial features in three-dimensional space. A 3D surface is usually derived or calculated using specially designed algorithms that convert point, line, polygon data into a three-dimensional digital surface [10].

Geographic Information Systems use geospatial databases as models for representing the real world and this highlights the fact that information about the Earth's surface is extremely important and therefore the generation of the Digital Terrain Model (DTM) is significant [2].

ArcGIS can create and store four types of surface models: raster, Irregular Triangular Network (TIN), terrain data sets and LSA data sets. The two main methods of creating the digital terrain model are: the triangulation method and the interpolation method [12].

3.2. Creating the Digital Terrain Model with the 3D Analyst function

The "create TIN" command has been accessed in the ArcMap program to obtain the Digital Terrain Model. This is a command of the 3D Analyst extension and is activated from the „Search" window available on the ArcMap program interface (Fig. 6).

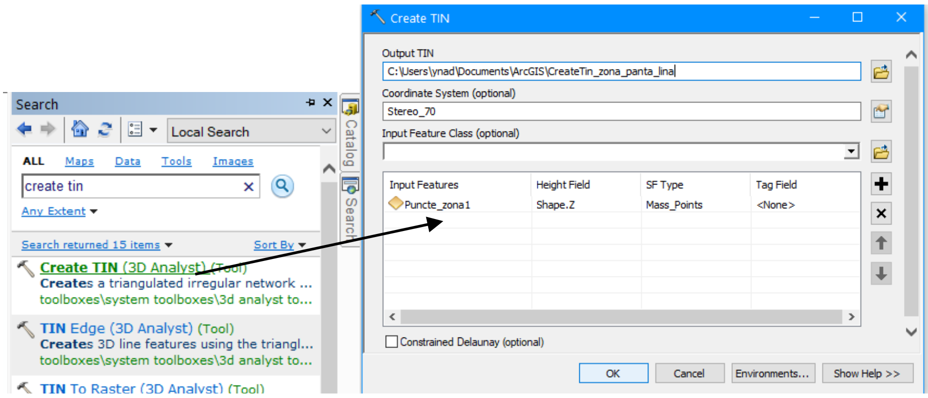


Fig. 6. Order given to obtain the Digital Terrain Model

Following the orders, the program will display the digital terrain model for the study area (Fig. 7 a,c). The three-dimensional vizualization of the digital model will be possible with the help of the ArcScene application (Fig. 7 b,d).

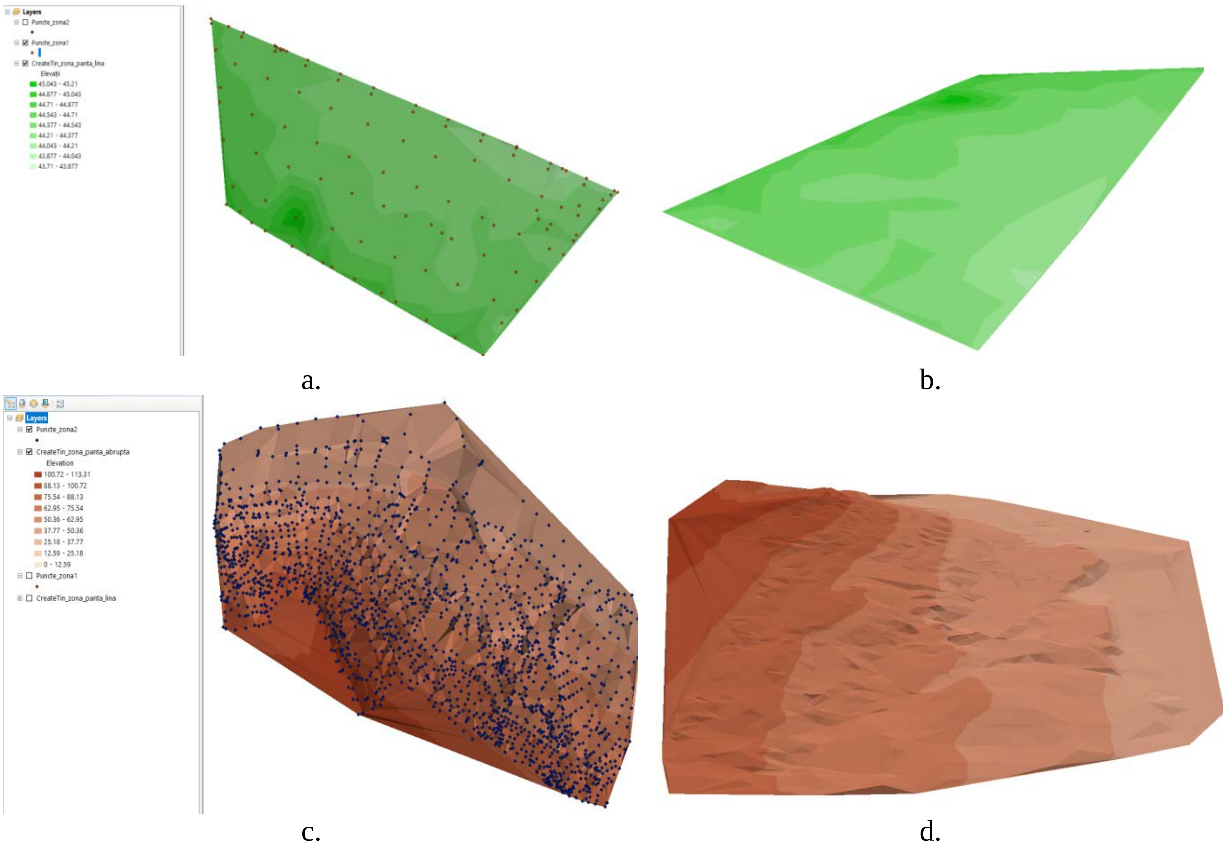


Fig. 7. Visualization of the Digital Terrain Model: a – ArcMap view of the gently sloping area; b – 3D view of the gently sloping area; c - ArcMap view of the steep slope area; d - 3D view of the steep slope area [11]

The 3D Analyst function is a relatively simple application that provides little control over the process of interpolating and creating the Digital Terrain Model [5].

The quality of the Digital Terrain Model depends on the techniques used to obtain it. Different spatial interpolation methods will be used for the same data that will provide different results. Because spatial interpolation is essential in creating DTM, it is important to perform a comparative analysis of the methods to find out which of them provide more accurate results compared to the areas studied [11].

3.3. Creating the Digital Terrain Model with the Geostatistical Analyst function

Geostatistical Analyst extension is a GIS tool used for surface generation, which has a number of advanced tools and control elements. These allow the selection of parameters that will lead to outstanding results and an interactive work environment [5].

The Geostatistical Analyst function is performed by checking it in the „extension” window of the ArcMap program (Fig. 8).

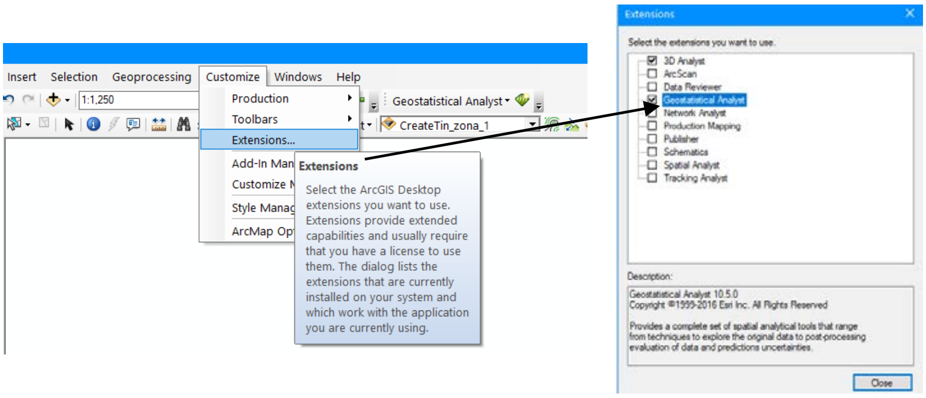


Fig. 8. Activating Geostatistical Analyst function

Geostatistical Analyst include specific graphs such as: histogram and Normal QQ Plot graph. These allow the analysis of the spatial components of the data set, providing information on abnormal data values, global trends and dominant directions in the development of an interpolation model.

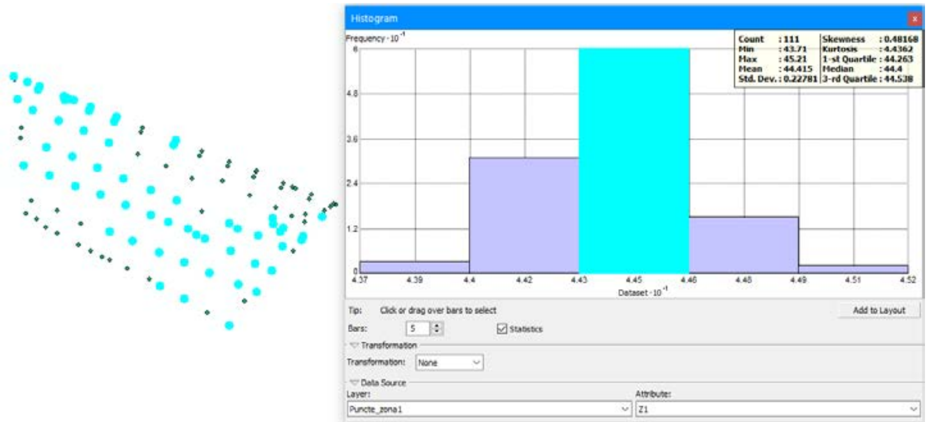


Fig. 9. View the histogram for the gently sloping area [11]

The histogram for the gently sloping area (fig. 9) indicates the minimum elevation values of 43,71 m and maximum of 45,21m. It can be observed that the point distribution is bell-shaped and the very close mean and median values indicate a normal point distribution. By selecting on the graph the column with the highest frequency, all the points that have the values of the quotas within the considered range were automatically highlighted. Most points have an elevation between 44,30 – 44,60 m and are distributed over most of the measured area [11].

Histogram for the steep slope study area (fig. 10) indicates the minimum elevation values of 45,18 m and maximum 113,31m. Very close mean and median values indicate a normal point distribution. By selecting on the chart the last column, all the points that have the values of the elevations in the range 106-113 m are automatically highlighted. The increased value of the standard deviation (Std.Dev.=14,732) is due to the slope of the terrain.

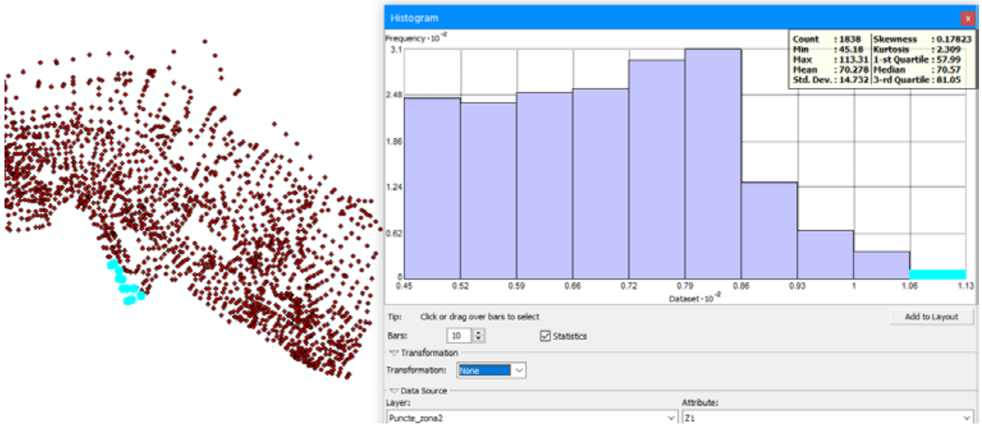
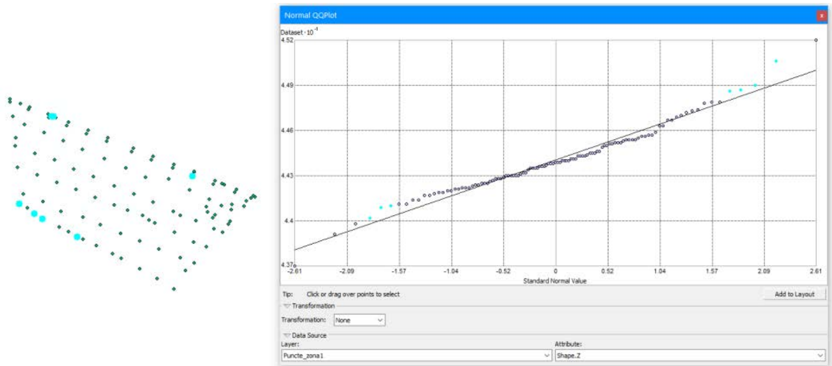
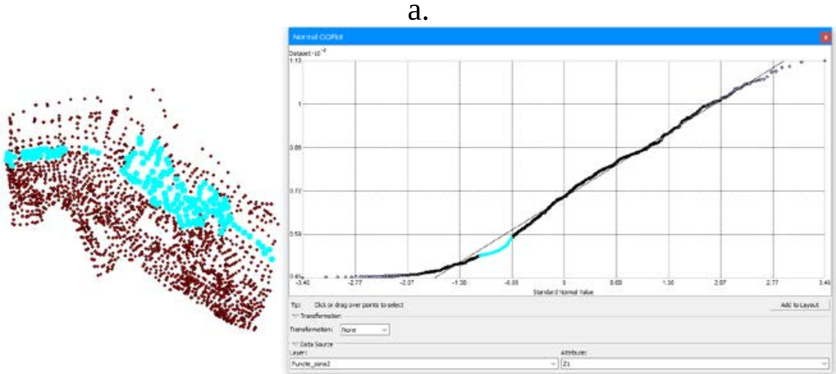


Fig. 10. View the histogram for the steep slope area [11]

Points in the QQPlot chart (Fig. 11) indicate the normality of the data set variation. For both areas can be observed normally distributed points which coincide or are very close to the reference line but also those that deviate from the reference line and do not indicate a normal distribution.



a.



b.

Fig. 11. View QQ Plot charts: a - gently sloping area; b - steep slope area [11]

In the case study, three interpolation methods were considered that will be applied to the studied areas:

- IDW – Inverse Distance Weighting
- LPI – Local Polinomial Interpolation
- Kriging

The parameters defined for the optimization of each interpolation method consisted of:

- Choosing the number of neighboring points used to estimate altitude at locations where no measurements were made;
- Specify the small radius and large radius of the ellipse which indicates the space within which the points used for interpolation must fit.
- Specify the number of sectors into which the ellipse will be divided.

Table 1. Parameters used in the data interpolation process

Interpolation method	Interpolation parameters			
	Max. neighboring points	Min. neighboring points	Sector type	Ellipse semiaxes (m)
Inverse Distance Weighting (IDW)	10	5	1 sector	50
Local Polinomial Interpolation (LPI)	10	10	1 sector	50
Kriging	5	2	4 sectoare	50

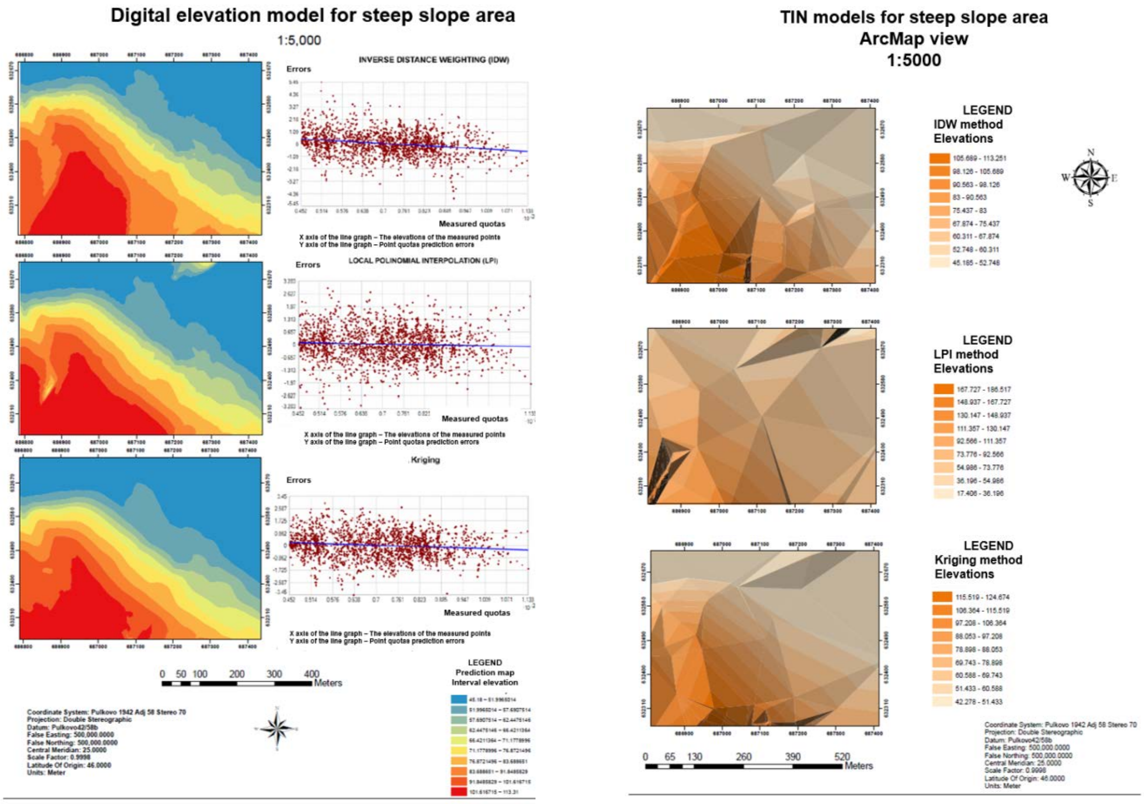
The fundamental principle of the IDW interpolation method is: the points that are close to each other are more similar than the farthest ones. So, to estimate a value for an immeasurable location, the IDW method uses the measured values around the prediction location [9].

The results obtained from the interpolation process by the three methods are represented in four thematic maps corresponding to the studied areas (Fig. 12, Fig. 13). Each map contains three elevation models obtained by the IDW, LPI and Kriging interpolation methods and the error distribution graphs for each method. For the two scenarious and the three methods of analysis, the root mean square were calculated (Table 2). The values of the root mean square were used for the comparative analysis in order to highlight the differences between the interpolation methods used in the case of the two types of studied areas.

Table 2. Root mean square depending on the studied area

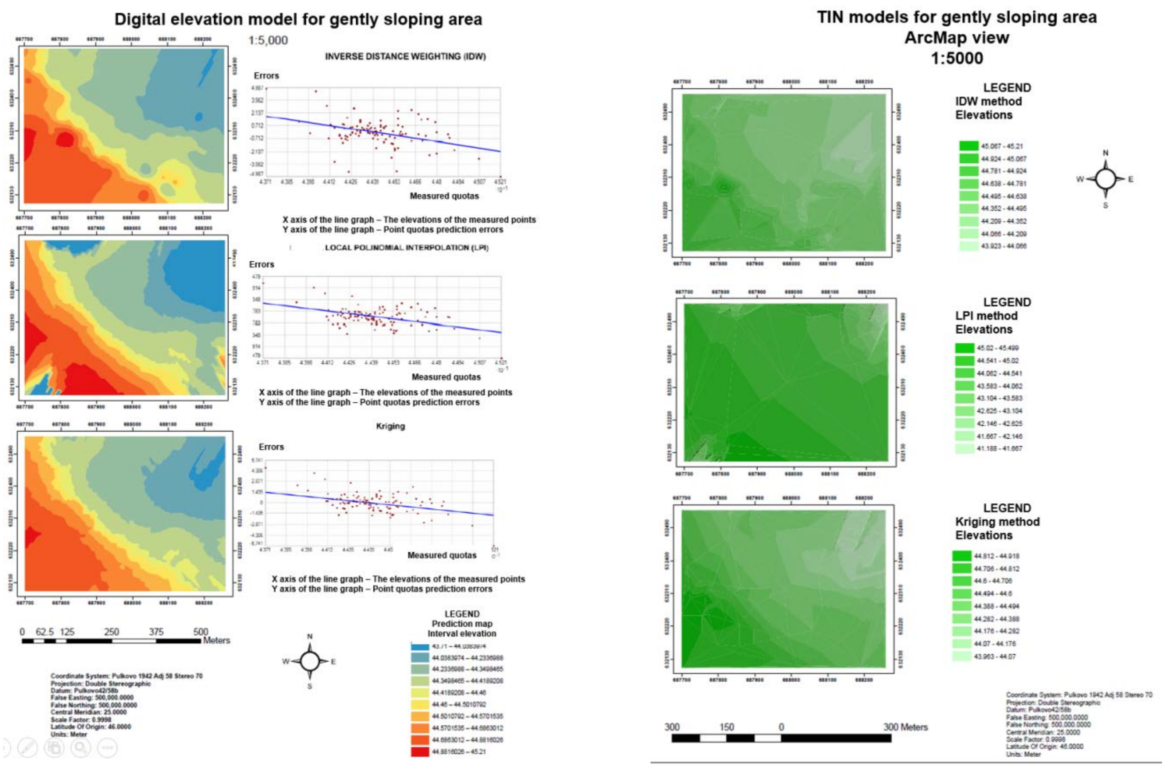
Interpolation method	Root mean square (RMS) (m)	
	Zone 1: gently slope	Zone 2: steep slope
Inverse Distance Weighting (IDW)	0,146	1,065
Local Polinomial Interpolation (LPI)	0,128	0,849
Kriging	0,130	0,922

The analysis of data presented in table 2 is highlighted that the smallest mean square errors (0,128) are given by the „Local Polinomial Interpolation (LPI)” in the case of gently sloping area. For steep slope area, „Local Polinomial Interpolation (LPI)” method shows the smallest errors (0,849). Inverse Distance Weighting (IDW) method presents the lowest estimation accuracy of the digital elevation model, with high values of the mean square error both for the gently sloping area and for steep slope area. Kriging interpolation method presents average estimation accuracy, which are between the accuracy of the LPI method and the IDW method respectively.



a. b.

Fig. 12. Digital Elevation Model for steep slope area: a – Elevation model; b – TIN model [11]



a. d.

Fig. 13. Digital Elevation Model for gently sloping area: a – Elevation model; b – TIN model [11]

4. Conclusions

Local Polinomial Interpolation (LPI) is the method that best estimates the elevation for both gently sloping area and steep slope area.

All three interpolation methods accurately estimate the gently sloping area versus the steep slope area.

IDW method provides the lowest estimation accuracy of the digital elevation model, recording the largest mean square errors both in gently sloping area and steep slope area. The higher slope of the land generates low precision of interpolation method.

Kriging interpolation method provides average estimation accuracy between LPI method and IDW method precisions.

The Digital Terrain Model varies depending on the algorithm of each interpolation method, the land topography and the distribution of the measured points.

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