International Journal of Advance Scientific Research

ARTICLE

# VERTICAL LEVELLING BASED ON GIS AND CAD

[1] Jamolzhon Khudaykulovich Djumanov, [2] BafoUsmanovich Khaitov

[1]D Sc, Professor, Head of the Department of Computer Systems, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Uzbekistan

[2] PhD, Associate Professor of the Department of Descriptive Geometry and Engineering Graphics of the Bukhara Engineering and Technological Institute, Uzbekistan

(Received 05 December 2021; Accepted 10 December 2021; first published online 16 December 2021)

**Abstract**

A method of vertical planning is proposed by the graphic-analytical method for determining the line of the average slope of a flat curve. Initial data (ID) for modeling the design surface are determined by means of the Google Earth program with open access to the Internet. By setting the lines of the average slope along all the longitudinal and cross-sections of the relief, the relief plane is determined for which the vertical layout can be designed.

**Keywords:** design surface, vertical leveling, initial data, plane of relief, line of average slope of a flat curve.

## 1. Introduction

Vertical terrain planning in real time is in demand in the practice of engineering design, in particular, in the development of projects for agricultural land. Known scientific work on integrated GIS technology and CAD. The Google Earth program with open access to the Internet is used as publicly available GIS programs [1, 2]. The problem of developing a design solution in real time is the lack of an integrated design methodology based on modern geographic information systems (GIS) and computer-aided design (CAD) systems. There are also known methods of graphical-analytical determination of the general slope of a plane curve [3-5]. It is proposed on the basis of graphic-analytical methods for determining the line of the average slope of a flat curve, which are the lines of the profile and cross-section of the relief, to determine the design surface - the plane of the relief.

## 2. Materials and methods

**Definition-1.** The straight line drawn by the mean values of the flat curve will be called the "the line of average slope" [3].

Since the initial data are selected discretely, it is possible to solve the problem of determining the line of average slope by the method of finite differences. If we have a matrix of height values of some surface:

$$A \equiv \begin{pmatrix} Z_{11} & Z_{12} & & \cdots & Z_{1n-1} & Z_{1n} \\ Z_{21} & Z_{22} & & \cdots & Z_{2n-1} & Z_{2n} \\ \cdots & \cdots & \cdots & & \cdots & \cdots \\ Z_{m-11} & Z_{m-12} & \cdots & & Z_{m-1n-1} & Z_{m-1n} \\ Z_{m1} & Z_{m2} & \cdots & & Z_{mn-1} & Z_{mn} \end{pmatrix} \equiv (Z_{ij}) (1)$$

where each row or column of the matrix is one flat curve - a longitudinal or cross-section of the relief, then the average value of heights - $\delta Z_{1j}$ of the line of average slope of the one row will be [3]:

$$\delta Z_{1j} = \frac{Z_{11} + Z_{12} + \ldots + Z_{1n-1} + Z_{1n}}{n} = \frac{\sum_{k=1}^{n} Z_{1k}}{n}; \qquad (2)$$

The amount of raw data in a column or row of a matrix can be even or odd. It was found that the graphic-analytical determination of the line of the average slope of a flat curve for an even and an odd amount of initial data is different. If, in equation (2) n is even, then it is enough to determine the position of one more point N (or M) belonging to the line of average slope (Fig. 1), since a straight line can be drawn through two points.

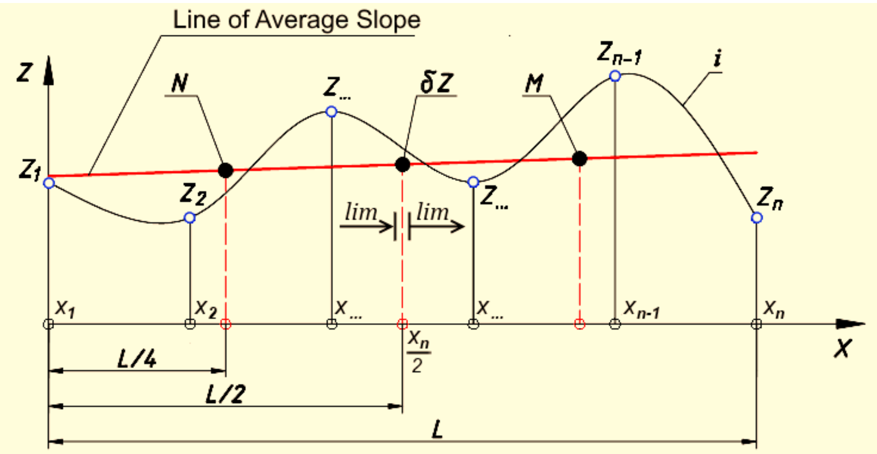


Figure 1. Line of average slope of a curve with an even amount of data

The next point N (or M) of the general slope line with an even amount of initial data n will be (see Fig. 1) [3]:

$$N = \frac{Z_{11} + Z_{12} + \cdots + \lim\ \delta Z}{n/2}; \quad \text{or} \quad M = \frac{\lim \delta Z + \cdots + Z_{1n-1} + Z_{1n}}{n/2}; \qquad (3)$$

here limδZ is the condition for the summation limit of the amount of Z from x1 to xn / 2 (or after xn / 2 to xn), while the value of δZ itself is not taken into account at xn / 2.

If, in equation (2) n is odd then the position of the point N (or M) of the line of general slope (Fig. 2) will be [3]:

$$N = \frac{Z_1 + Z_2 + \cdots + \delta Z_k}{(n+1)/2}; \quad \text{or} M = \frac{\delta Z_k + \cdots + Z_{n-1} + Z_n}{(n+1)/2}. \qquad (4)$$

here

$$\delta Z_k = \frac{\delta Z + Z_k}{2} \quad (5)$$

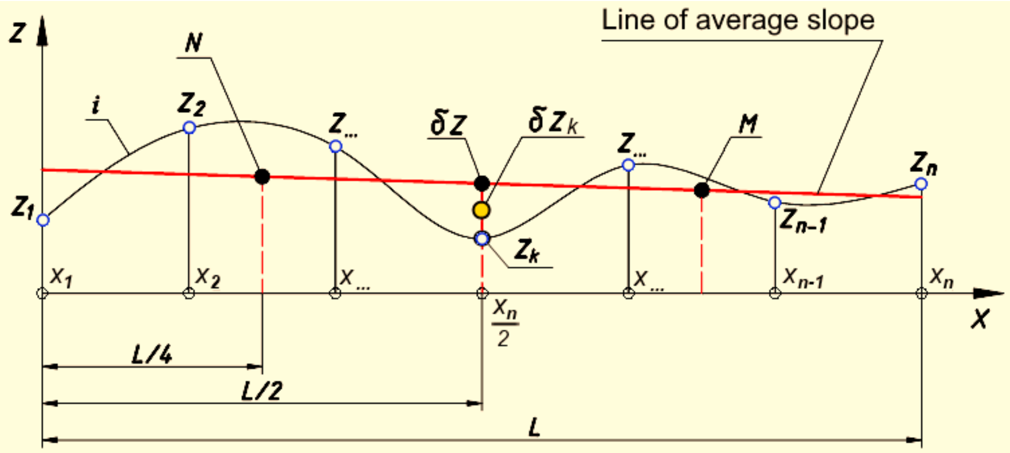

Figure 2. Line of general slope of a curve with an odd amount of data

By inserting (5) into equation (4) and performing transformations, we finally have:

$$N = \frac{2(Z_1 + Z_2 + \cdots) + \delta Z + Z_k}{n+1}; \text{or } M = \frac{\delta Z + Z_k + 2(\ldots + Z_{n-1} + Z_n)}{n+1}. \quad (6)$$

Definition - 2. The plane drawn according to the average values of the elevation points of the relief surface will be called the "Plane of Relief" (the plane of average slope) [4, 5].

The plane of relief contributes to the optimal conduct of design surface, taking into account the natural slope of the entire territory, minimal transformation and anthropogenic impact on the biobalance of the environment, the greatest preservation of the fertile soil layer.

To determine the geometric position of the plane of relief, two mutually intersecting straight lines should be determined, which are the lines of average slope of the longitudinal and cross sections of the relief.

Set the average value for each rows and columns of the matrix (1), we form two flat curves c and d (Fig. 3):

$$\begin{cases} c = (\Delta Z_{1k} \quad \Delta Z_{2k} \quad \ldots \quad \Delta Z_{m-1k} \quad \Delta Z_{mk}) \\ d = (\Delta Z_{n1} \quad \Delta Z_{n2} \quad \ldots \quad \Delta Z_{ni-1} \quad \Delta Z_{ni}) \end{cases} \quad (7)$$

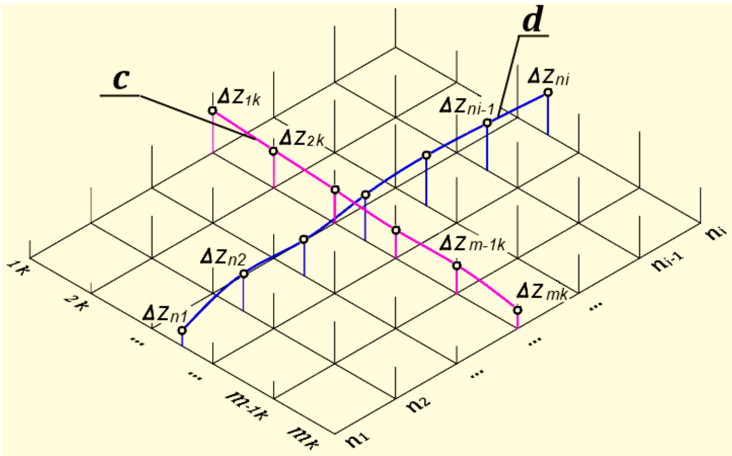


Figure 3. Formation of gentle curves by the average values of rows and columns of the elevation matrix

Sequentially applying equations 2 - 6, taking into account the even and odd initial data of the columns and rows of the matrix (1), the lines of average slope of two plane curves ci and di are determined [4, 5] (Fig. 4). It is characteristic that two lines of average slope mutually intersect and have a common point ΔZ, which is also the mean point of the initial data of the matrix (1) and determines the plane.

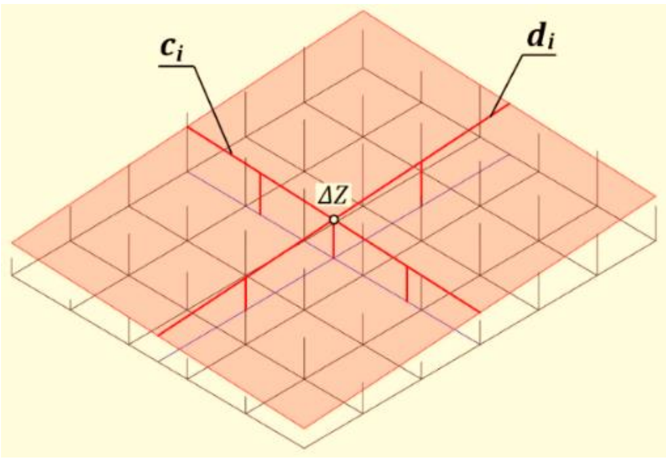


Figure 4. Plane of relief

## 3. Results

On the basis of graphic-analytical methods for determining the line of the mean slope of a flat curve, a draft of the vertical leveling of the field for an inclined plane - the plane of the relief for the farm "Khursanbibi" was developed (Fig. 5). Field dimensions: 285 × 145 m. Location: 40°9'56.15"N 64°26'55"E.

The purpose of the research was to develop a methodology for a vertical planning project using publicly available software tools in real time. As a publicly available software, a GIS program was chosen - Google Earth with open access to the Internet for collecting IDs about the terrain, as well as CAD AutoCAD (v.2018) for processing IDs and drawing up a vertical planning project taking into account the balance of earthworks.

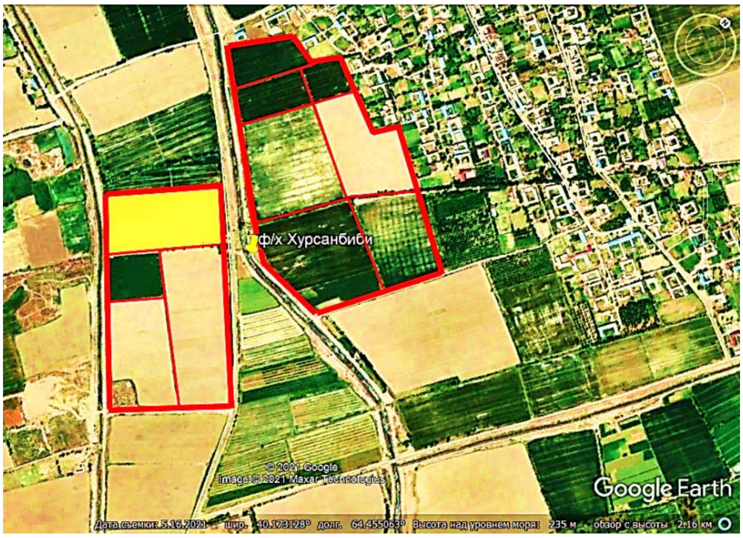


Figure 5. Location of the farm "Khursanbibi", Bukhara, Republic of Uzbekistan

Data collection. The original field data was collected from a regular rectangular grid in Google Earth. The parameters of the regular network were the field perimeter 285 × 145 m, which were rounded at 280 × 140 m with an alternation of 20 m nodes. The dimension of the regular network m × n was 15 × 8 = 120 nodes.The rectangular regular grid was drawn in CAD AutoCAD with subsequent conversion to png (or jpg) file. This file served as a background for overlaying in Google Earth using the "Add Image Overlay" tool (Fig. 6).

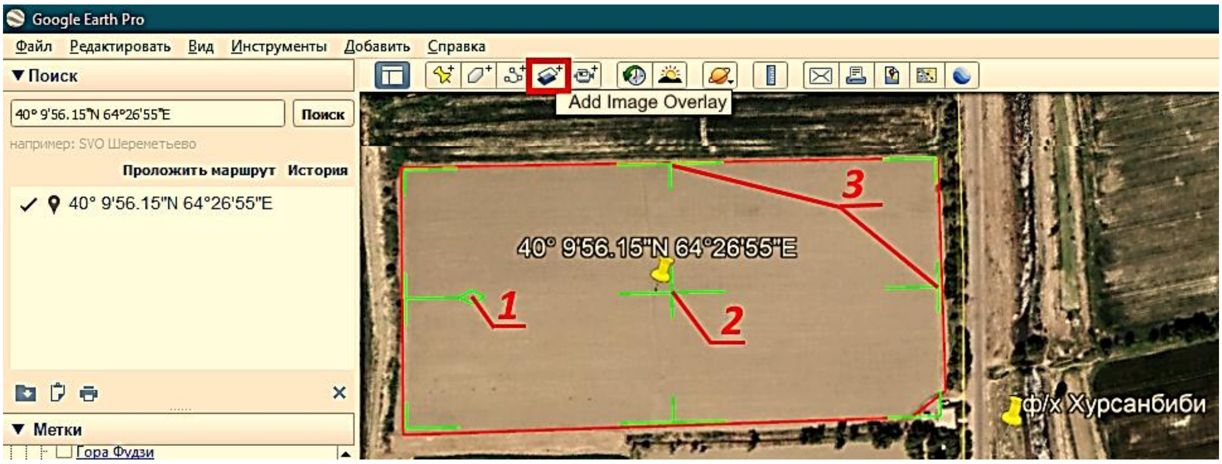


Figure 6. Varying the dynamic mesh for the image matte: 1 – rotation; 2 – moving; 3 – change perimeter.

Selecting the "Show ruler" tool and going to the "Path" tab sets the trajectory of one profile section by indicating the first and last node of one line of the regular grid. On the "Path" tab, the "Show Elevation Profile" switch is turned on (Fig. 7).

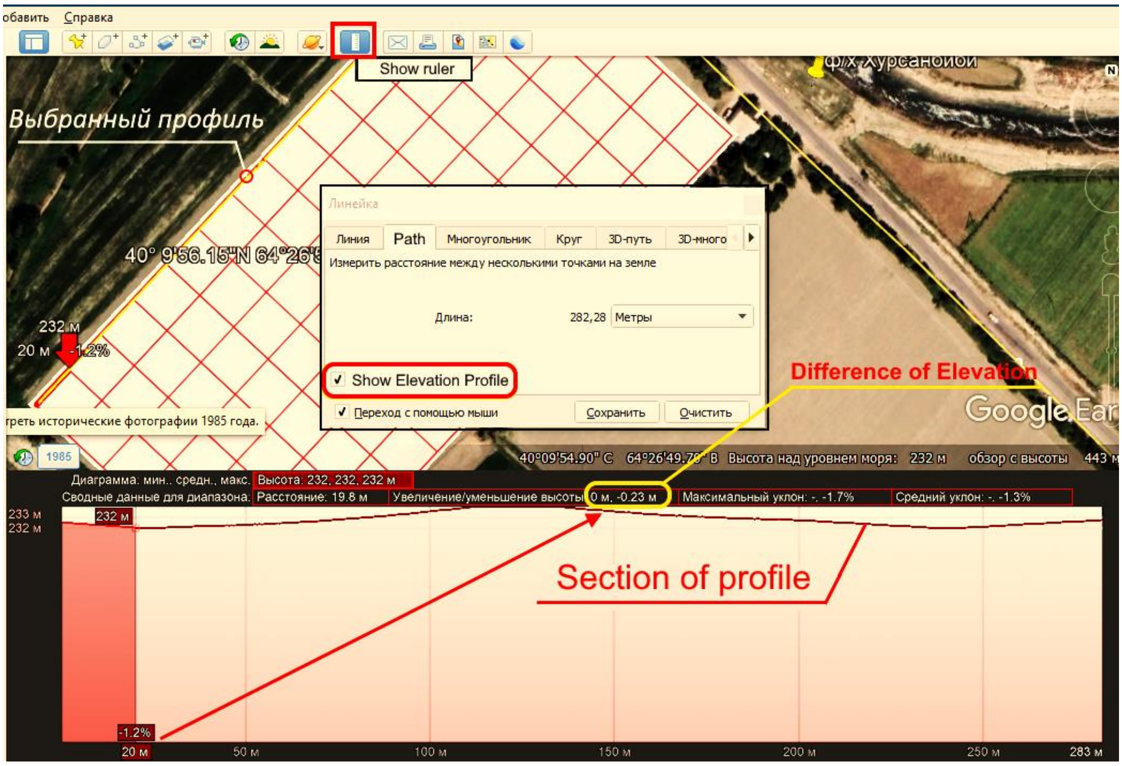


Figure 7. Determination of the heights of the profile section of the relief

By moving the cursor along the profile section, you can determine the value of the height in this interval in the form of the difference in heights relative to the beginning of the area under consideration (see Fig. 7). All data should be consistently recorded (for example, in Microsoft Excel). By repeating the selection of the "Path" tool, the trajectory of the next profile section is set and the values of all subsequent values of the heights of the grid nodes are also determined. The operation is repeated until the last profile section of the substrate. All fixed data of elevation values form a table of initial data (table 1).

**Table 1. Table of elevation values determined by Google Earth**

| ΔX=ΔY=20 m.Columns-n=15, Rows-m=8. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Zmn** | **$Z_{n1}$** | **$Z_{n2}$** | **$Z_{n3}$** | **$Z_{n4}$** | **$Z_{n5}$** | **$Z_{n6}$** | **$Z_{n7}$** | **$Z_{n8}$** | **$Z_{n9}$** | **$Z_{n10}$** | **$Z_{n11}$** | **$Z_{n12}$** | **$Z_{n13}$** | **$Z_{n14}$** | **$Z_{n15}$** | **$\Delta Z_m$** |
| **$Z_{m1}$** | 0,28 | 0,00 | 0,11 | 0,33 | 0,54 | 0,85 | 1,05 | 0,99 | 0,71 | 0,54 | 0,46 | 0,26 | 0,07 | 0,27 | 0,47 | 0,46 |
| **$Z_{m2}$** | 0,03 | 0,18 | 0,42 | 0,67 | 0,88 | 1,01 | 1,01 | 1,01 | 0,93 | 0,76 | 0,56 | 0,36 | 0,16 | 0,04 | 0,37 | 0,56 |
| **$Z_{m3}$** | 0,11 | 0,27 | 0,44 | 0,60 | 0,77 | 0,92 | 0,92 | 0,92 | 0,92 | 0,84 | 0,64 | 0,44 | 0,25 | 0,26 | 0,35 | 0,58 |
| **$Z_{m4}$** | 0,11 | 0,29 | 0,55 | 0,83 | 1,00 | 1,04 | 1,04 | 1,04 | 1,04 | 1,04 | 1,03 | 0,83 | 0,76 | 0,86 | 0,96 | 0,83 |
| **$Z_{m5}$** | 0,04 | 0,21 | 0,54 | 0,80 | 0,96 | 1,04 | 1,04 | 1,04 | 1,04 | 1,04 | 1,04 | 0,94 | 0,87 | 0,90 | 1,00 | 0,83 |
| **$Z_{m6}$** | 0,07 | 0,30 | 0,63 | 0,88 | 1,04 | 1,07 | 1,07 | 1,07 | 1,07 | 1,07 | 1,07 | 1,07 | 1,03 | 1,06 | 1,17 | 0,91 |
| **$Z_{m7}$** | 0,32 | 0,44 | 0,56 | 0,69 | 0,69 | 0,69 | 0,69 | 0,69 | 0,69 | 0,69 | 0,69 | 0,69 | 0,69 | 0,86 | 1,06 | 0,68 |
| **$Z_{m8}$** | 0,58 | 0,69 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 | 1,01 | 0,80 |
| **$\Delta Z_n$** | 0,19 | 0,30 | 0,51 | 0,70 | 0,84 | 0,93 | 0,95 | 0,95 | 0,90 | 0,85 | 0,79 | 0,68 | 0,58 | 0,63 | 0,80 | **ΔZ= 0,705** |

Data transformation. In CAD AutoCAD, vertical lines are placed at the nodes of the regular grid according to the values of the heights. Using the spline command, the end nodes of the elevation values are sequentially interpolated along the rows and columns of the regular grid, forming a wireframe surface model.

To determine the plane of the relief, the following are required: the average value of all initial data - ΔZ, the average value for the rows - ΔZm, the average value for the columns - ΔZn. Table 1 they are already given in the form of ΔZ, ΔZm and ΔZn values.

Project development. Based on the values of ΔZm and ΔZn, the average cross-section and longitudinal sections of the relief are determined in the form of flat curves.

The intersecting straight lines are determined by the graphoanalytical method for determining the line of the average slope, taking into account the even and odd number of IDs. As you know, mutually intersecting straight lines define a plane. The mutual intersection of the surface and the plane gives an idea of the unevenness of the relief (Fig. 8).

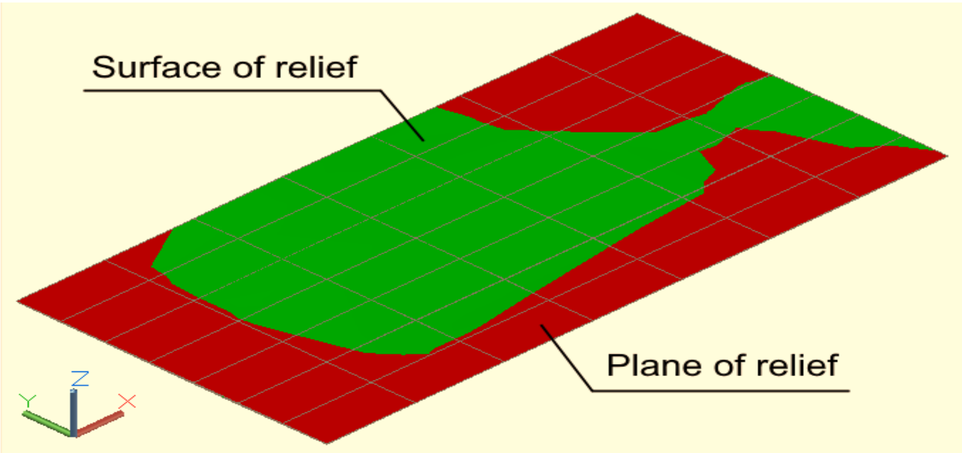


Figure 8. Mutual intersection of the surface and the plane of relief.

By varying the plane of the relief, the balance of the earth's masses is established. The cut and embankment will be balanced.

## 4. Conclusion

On the basis of graphical-analytical methods for determining the plane of the relief using GIS technologies and CAD, a project of vertical levelling for an inclined plane for surface irrigation in the fields of the farm "Khursanbibi" in the Bukhara region of the Republic of Uzbekistan was designed.

## References


1. Rusli N., Majid M. Digital Elevation Model (DEM) Extraction from Google Earth: a Study in Sungai Muar Watershed. https://www.researchgate.net/publication/341078813_Digital_Elevation_Model_DEM_Extraction_from_Google_Earth_a_Study_in_Sungai_Muar_Watershed
2. Safanelli J.L., Poppiel R.R., Chimelo Ruiz L.F., Bonfatti B.R., ets. Terrain Analysis in Google Earth Engine: A Method Adapted for High-Performance Global-Scale Analysis. International Journal Geo-Information. 2020. 9. https://www.mdpi.com/2220-9964/9/6/400
3. Khaitov B. About one geometric method for determining the line of the general slope of a plane curve. Young Scientist: Monthly Scientific Journal. - Kazan, 2015. - №10(90). – pp.340-342. https://moluch.ru/archive/90/17360/
4. Khaitov B. Graphic-analytical method for determining the plane of the relief in problems of vertical levelling. Development of science and technology: Scientific and technical journal. - Bukhara, 2019. - №3. – C.126-130. https://journal.bmti.uz/
5. Khaitov B. Graphic-analytical method of relief plane definition. Landscape architecture and regional planning. – New York: Science Publishing Group, USA. 2016. DOI: 10.11648/j.larp.20160101.12. ISSN Online: 2637-4374. 2016. 1(1): 13-17. http://article.sciencepublishinggroup.com/html/10.11648.j.larp.20160101.12.html
6. Olimov, S. S., &Mamurova, D. I. (2021). Graphic Information Processing Technology and its Importance. EuropeanJournalofLifeSafetyandStability (2660-9630), 10, 1-4.
7. Mamurova, D. I. ELECTRONIC METHODOLOGICAL INSTRUCTIONS ON COMPUTER GRAPHICS PREPARATION METHODOLOGY.
8. Djalolovich Y. N. et al. IMPROVING THE PROFESSIONAL TRAINING OF FINE ART TEACHERS //European science. – 2021. – №. 2 (58). – С. 44-46.
9. Мамурова Д. И. и др. УЧЕБНАЯ ДЕЯТЕЛЬНОСТЬ СТУДЕНТОВ ПО РЕШЕНИЮ РАЗЛИЧНЫХ ДИДАКТИЧЕСКИХ ЗАДАЧ В РАЗВИТИИ ПРОСТРАНСТВЕННОГО ВООБРАЖЕНИЯ СТУДЕНТОВ //Europeanscience. – 2021. – №. 2 (58). – С. 29-31.