THE RESULTS OF THEORETICAL RESEARCH ON LAND LEVELING OF IRRIGATED LANDS

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Abstract. *The article deals with the improvement of office work in the design of land leveling works. On the basis of field experiments, the authors obtained results on determining the number of profiles depending on the accuracy; they propose methods for calculating land leveling work with a rectangular grid for a minimum amount of earthwork, as well as hydraulically optimal slopes. The authors propose the land leveling quality coefficient depending on the quality of the field surface and the uniform distribution of soil density.*

Key words: *field land leveling, office work, capital and operational land leveling, minimum amount of earthworks, quality factor of the layout, hydraulically optimal slope.*

1. INTRODUCTION:

Up to the present time, the frequently used methods for drawing up projects for a irrigated fields land leveling include: a method for designing a relief in small flat areas V.Martensen [2]; design method from the condition of the balance of work on the diameter N.Samsonova [9]; A.Vavilov's method [3]; the design method for the conditions of the balance of work on lanes and platforms of different size and shape by Kh.Gaziev [4]; the design method under the ruled surface and under the inclined surface of A.Lyapin [6]; design method for standard one-hectare sites G.Tsivinsky.

The design technique with all these methods boils down to the fact that the designer gradually selects the desired position of the project surface, correcting it in the course of computational work to obtain a balance. Below we consider some of these methods used in practice at present under production conditions.

1. Design along the longitudinal stripes. The design developed by the Uzgiprovodkhoz method [6] is based on the principle of selecting a project surface for drawn longitudinal profiles, taking into account the balance of the volume earth work for cutting and filling in each strip. The final position of the design surface on the profiles is not achieved immediately, but in several successive techniques by gradual approximation.

2. Design by contour. This design method was developed by S.Krivovyaz [5] and A.Vavilov [3], where this method was based on the direction of natural black horizontals in red, in design relief. To obtain a volume balance for cutting and embankment of soils, red horizontals are applied so that the cut areas and embankments between the black and red horizons are approximately equal to each other. The first applied project horizons usually do not provide the necessary balance of earth work, therefore the designer slightly modifies the outlined initial relief forms and gradually achieves this balance.

3. Design by the method of topographic surface command. This method was developed by Y.Batrakov and I.Dzyadivich [8]. The design method is based on the transfer of natural elevations in descending order along the longitudinal and transverse directions. In accordance with the intended direction and lead furrows, the designer determines the marks of the topographic surface of the command. This work is carried out in the following sequence:

a) the marks of the natural surface on the plan are labeled for each gauge in the accepted direction of irrigation in descending order (mark “b”).

b) then marks “b” are rewritten again in descending order along perpendicular alignments in the direction of the exit furrows (mark “b”).

4. Design under the inclined plane. For the first time, a design under an inclined surface was described by V.Martenson [2]. The basis for drawing up a design plan using this method is the determination of the total surface slope along the length and width of the planned surface, which are determined by the evenness of the extreme marks along the longitudinal and transverse directions. After determining the slopes of the design inclined surface, the average mark of the natural surface is determined, and assuming that the average mark on the planned area occupies a central position, an inclined surface with corresponding slopes is drawn through this mark. In the future, the balance of the volumes of earth masses is supplemented by additional calculations and adjustment of the project surface.

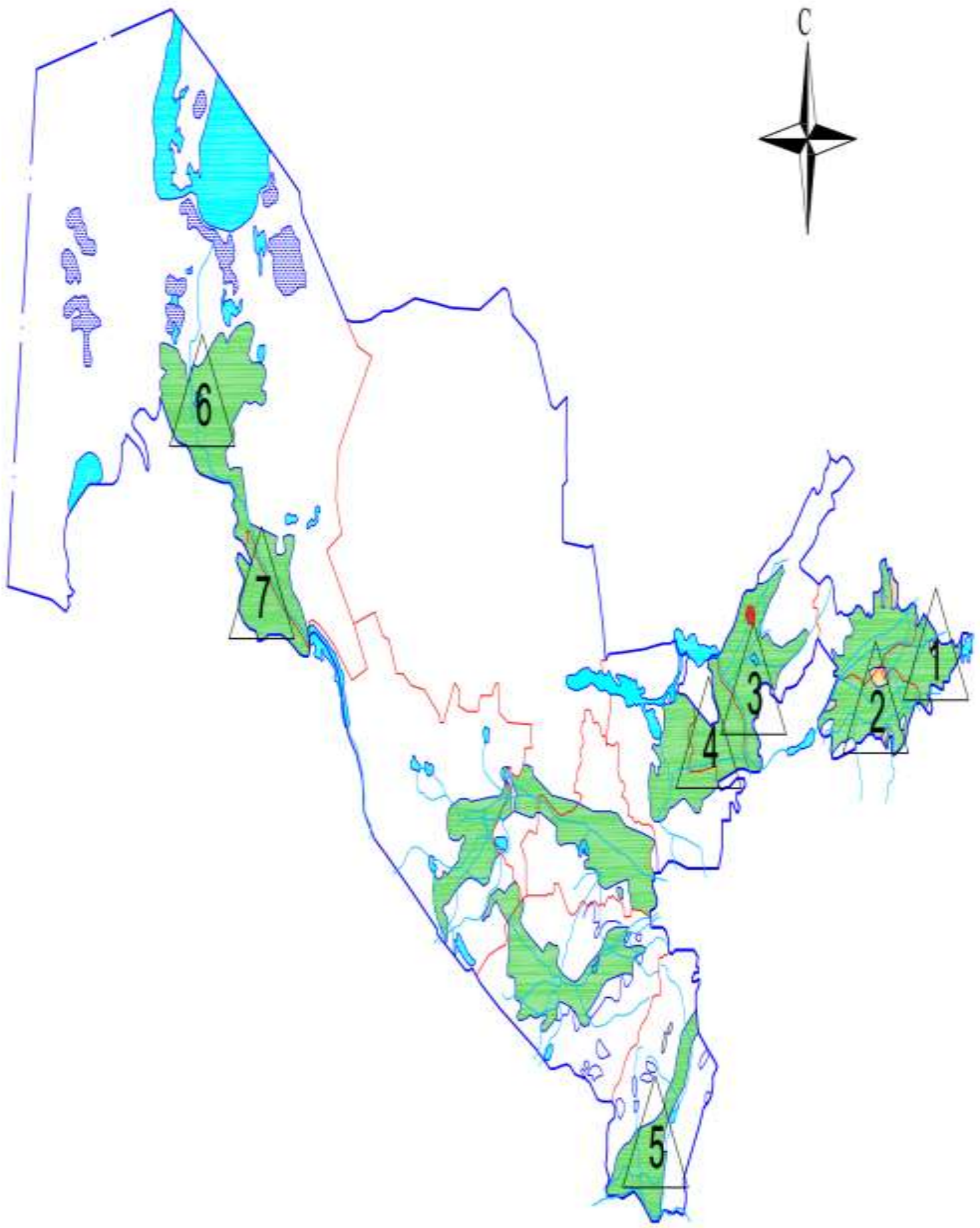
5. Designing a relief under a linear surface. This relief design method was developed by A.Lyapin [6]. The process of drafting relief layouts with this method is accompanied by cumbersome arithmetic calculations, and the theoretical basis of this method has many conventions and is inapplicable to computers.

6. Developed by R.Bazarov the **method of designing the surface of the irrigated area**, allows to determine the slopes of the land surface for a minimum amount of earthwork, as well as taking into account the hydraulic parameters

of the irrigation system. However, in the proposed R.Bazarov method of planning does not take into account the configuration of irrigation fields and the errors associated with them in determining the slopes of the field, which is very important in the conditions of the transitional period of Uzbekistan.

2. MATERIALS AND RESEARCH METHODS:

Research Objects. The objects of research were selected irrigated fields, where land leveling was carried out (1-fig.) Subject of research is the methodology for calculating leveling work.



1- WCA M. Yusupov, Kurgantepa district of Andijan region;
2– WCA Akbarobod, Kuva district of Fergana region;
3 - WCA A.Navoiy, Buka district of Tashkent region;
4 - WCA Yangiabad, Mirzaabad district of Syrdarya region;
5 - WCA N.Mirzaev, Djarkurgan district of Surkhandarya region;
6 - WCA Uysalang, Ellikkala district of the Republic of Karakalpakstan;
7 - WCA Buston, Khazorasp district of Khorezm region.

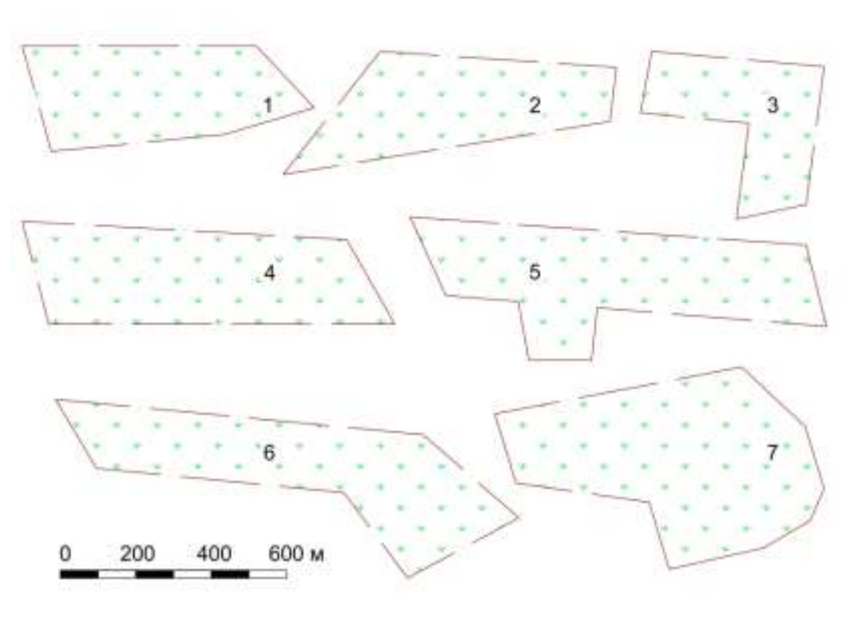
Fig.1. Location of objects of study

The main parameters of the fields and their configuration are presented in Table 1.

3. RESEARCH METHODS:

The shape of the fields has a significant impact on the accuracy in determining the slopes of the abscissa and ordinate. To study the accuracy of the longitudinal and transverse slopes, we used the results of field studies of topographic surveys of the above objects with the size of square grids of 50x50 m, 40x40 m, 30x30 m, 20x20 m with data at 10x10 m.

1-table. Fields main geometric parameters of



№	Field length, m	Field width, m	Area, ha
1	724	287	16,1
2	878	279	16,5
3	459	348	11,6
4	918	244	21,4
5	1058	372	23,6
6	1241	344	22,7
7	765	497	27,8

The slope relative error is determined by the following relationship:

$$\varepsilon = \frac{[I_{10x10} - I_{\alpha x\alpha}]}{I_{10x10}} \cdot 100,\ \% \qquad (1)$$

Where I_{10x10} – is a certain slope when measuring square grids 10x10m; I_{axa}– certain slope when measuring square grids a_h meters; a – 10, 20, 30, 40 and 50 meters; $a = \frac{a}{L} \cdot 100$ - relative length (inversely proportional to the number of profiles),%; L - field measurements (length or width)..

4. RESEARCH RESULTS:

Consider as an example the Saodat farm field in the Water Consumers Association (WCA) N.Mirzaev of the Djarkurgan district of the Surkhandarya region located in the floodplain of the Surkhandarya river has a length of 1058 m and a width of 372 m. When conducting surveys on existing planning design methods, the field was divided by a square grid of 40x40 m, that is, 26 transverse abscissa profiles and 9 longitudinal ordinates were taken. Otherwise, the accuracy of the field slope will depend on the 26 profiles on the abscissa, and 9 longitudinal profiles on the ordinate, that is, the error on the ordinates will be somewhat larger than on the abscissa.

Similarly, we determine the number of longitudinal and transverse profiles for the objects of research, which are given in table 2.

Table 2. Comparative table to determine the slopes accuracy

№	Indicators	Field number						
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	Field length, m	724	878	459	918	1058	1241	765
2	Field width, m	287	279	348	244	372	344	497
3	Sizes of a square grid, m	30	30	20	30	40	50	40
4	Number of profiles in width	24	29	23	31	26	25	19
5	Number of profiles in length	10	9	17	8	9	7	12

The error analysis of the design slopes depending on the size of the square grids for the above objects of study is given in fig. 2

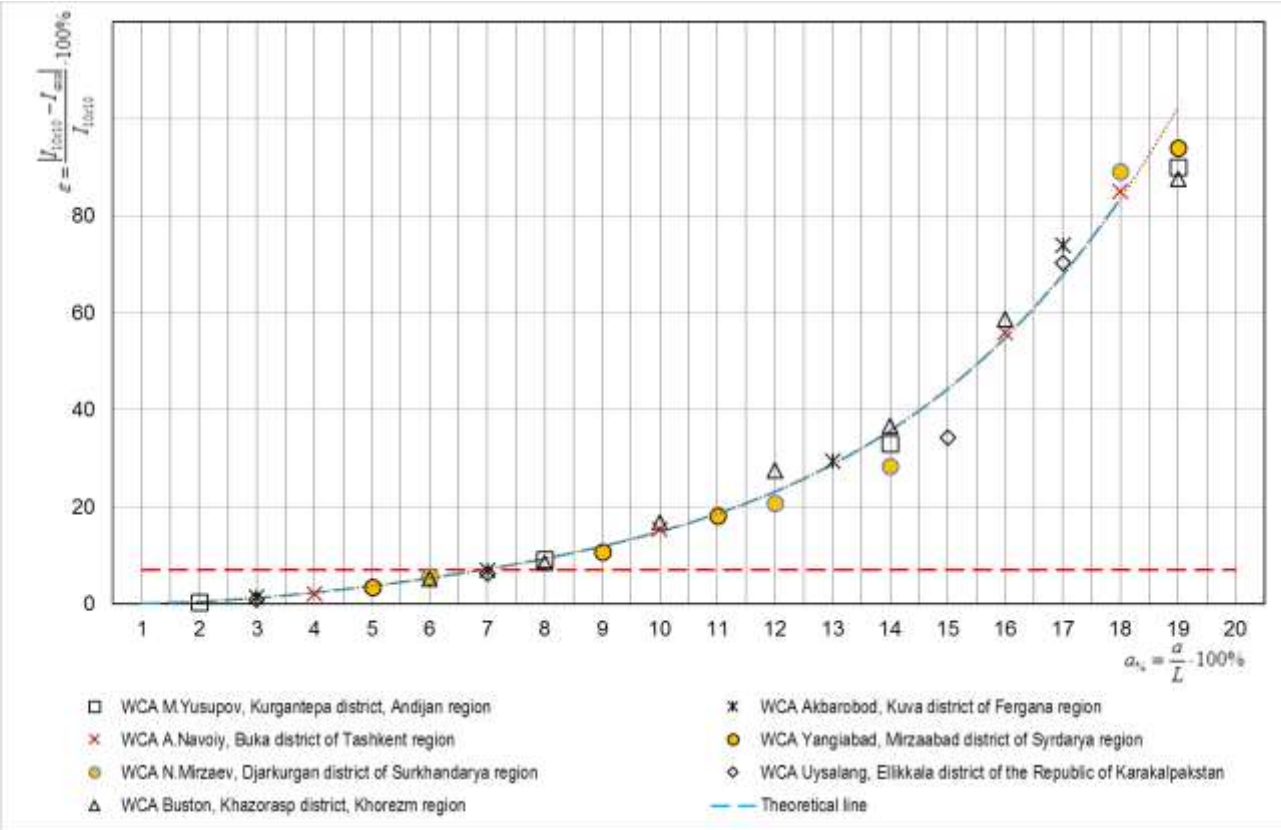


Fig. 2. Comparison of the sizes of square grids to the accuracy of design slopes.

The formula for the theoretical curve between the relative bias of the gradient and the relative length (R = 0.982) is as follows:

$$\varepsilon = 0{,}0015\,a^4 - 0{,}03a^3 + 0{,}36a^2 - 0{,}51a + 0{,}23 \qquad (2)$$

The graph (Fig. 2) shows that the relative length in the planned field of the slope to be determined should be less than $a_{\%}$ = 7.2%, which is possible if there are more than 14-16 profiles, and that the accuracy does not depend on the grid size.

In accordance with the results in Table 3, we calculate the dimensions of a rectangular quadrangular grid using the examples given above (Table 2).

Table 3. Definition of the sizes of a rectangular quadrangular grid by the field size

№	Indicators	Field number						
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	Field length, m	724	878	459	918	1058	1241	765
2	Field width, m	287	279	348	244	372	344	497
3	Grid length, m	30	30	20	30	40	50	40
4	Grid width, m	20	15	20	15	20	20	30
5	Number of cross profiles	24	29	22	30	26	24	19
6	Number of longitudinal profiles	14	18	17	16	18	17	16

The transition from a traditional square grid to a rectangular quadrilateral grid requires an improvement in the methods of calculating the field slope, which are given below.

The method of determining the ordinate of the slope of the field on a hydraulically acceptable slope marked in a rectangular quadrangular grid. In the implementation of capital planning land works, along with planning works, irrigation and moisture removal networks are re-designed. In this case, the slope of the irrigation systems is established less than the slope of the blurring, more than the slope of sedimentation. For even irrigation work throughout the field, the water level should be even from the ground level. That is, in this case, the slope of the field should correspond to the slope of the irrigation network.

The area is leveled on one slope plane, and the water level in the irrigation canal has an adequate supply of control of the planned field, that is, we assume that it can be taken into account when planning the field (Fig. 3).

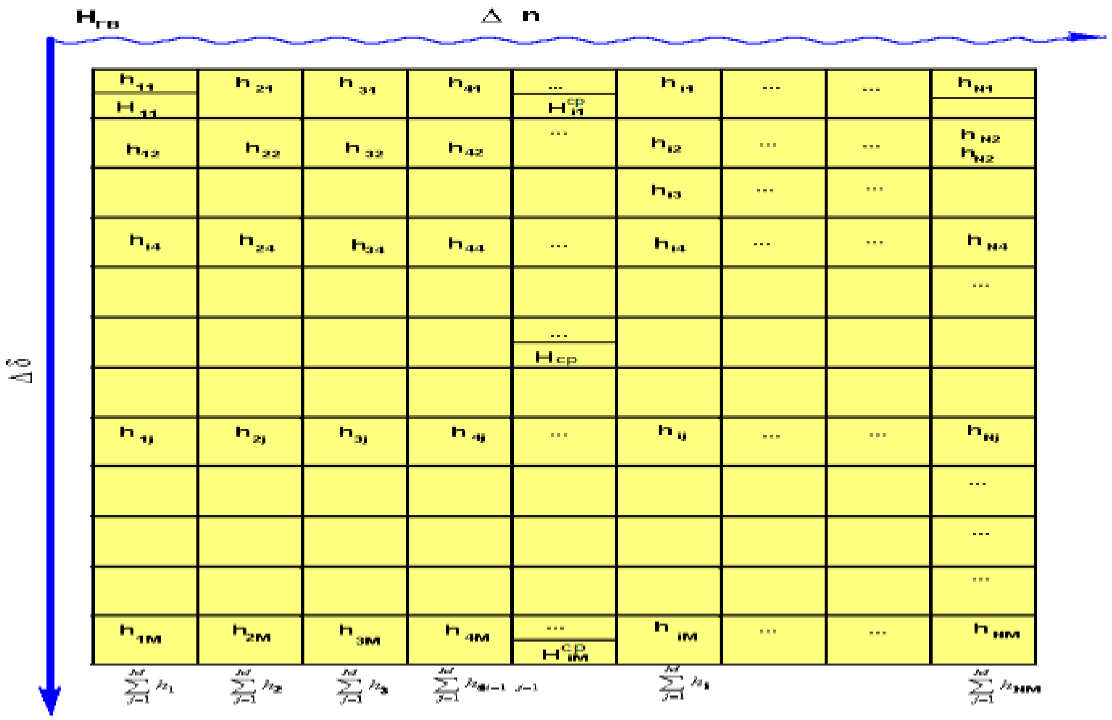


Fig. 3. The draft land leveling plan of the irrigated field with a minimum amount

The definition of the field slope in a rectangular quadrilateral grid on a hydraulically acceptable slope is carried out in the following form:

1) Determine the average height of the surface of the planned field:

$$\bar{h} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} F_{ij} h_{ij}}{N \sum_{i=1}^{n}\sum_{j=1}^{m} F_{ij}} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} F_{ij} h_{ij}}{N\Omega} \quad (3)$$

Here h_{ij} is the elevation of the earth at the corners of a rectangular quadrilateral grid, m; F_{ij} – area attached to a point, m^2; $\Omega=\sum F_{ij}$ - the area of the planned field, m^2; N –number of the ends of a rectangular quadrilateral grid.

2) Determine the coordinates of the centers of the field along the axis of abcissi:

$$\bar{x} = a_x \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} F_{ij} x_{ij}}{\Omega} \quad (4)$$

3) Determine the coordinates of the field centers along the ordinate axis:

$$\bar{y} = b_y \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} F_{ij} y_{ij}}{\Omega} \quad (5)$$

Here x_i and y_i are the ordinal numbers of the ends of a rectangular quadrilateral grid; a_x and b_y - dimensions of a quadrangular grid, m

4) Determine the height of the lowest point of the field ($H_{x,y}$):

$$H_{x,y} = H_{1,1} - I_x \cdot \bar{x} - I_y \cdot \bar{y} \quad (6)$$

Here $H_{1.1}$ is the ground level at the beginning of the field, m; I_x - hydraulically acceptable slope.

Or

$$I_y = \frac{H_{1,1} - I_x \cdot \bar{x} - H_{x,y}}{\bar{y}} \quad (7)$$

5) The average height of the surface of the land leveled field is half the sum of the ground level at the beginning of the field and the height of the lowest point of the field:

$$\bar{h} = \frac{H_{1,1} + H_{x,y}}{2} \quad (8)$$

The height of the lowest point of the field ($H_{x,y}$) will be as follows:

$$H_{x,y} = 2\bar{h} - H_{1,1} \quad (9)$$

6) If we put (9) the equation in formula (7), then the slope along the ordinate axes will be as follows:

$$I_y = \frac{2(H_{1,1} - \bar{h}) - I_x \cdot \bar{x}}{\bar{y}} \quad (10)$$

The given (10) formula makes it possible to design a field with a certain accuracy along the ordinate axes, based on the slope along certain abscissa axes of different configurations.

The quality of land leveling and types of earth works. The correct assessment of the quality of the planned field on the one hand, along with the quality assurance of the work performed, enables the organization that performed the work to determine its value, and on the other hand provides the land owners (farmer, contractor, etc.) to take quality work and select the right organization in the labor market.

Antonov E.V. [1] proposed to determine the coefficient of the field defect when assessing the flatness of rice fields according to the following:

$$K_\partial = \frac{S_{cp} + S_H}{S} \quad (11)$$

here S_{cp}, S_H, S –cutting, filling and total area.

Salimov T.O. [10] in his studies suggested the coefficient of defectiveness of the irrigated area:

$$K_\partial = K_1 \cdot K_2 \quad (12)$$

Here $K_1 = \frac{\omega - \omega_{fs}}{\omega}$ is the coefficient estimating the field surface defects, ha; ω_{fs} - area of the field in which precipitation and bulges are observed above the norm, ha; $K_2 = \frac{\omega - \omega_{com}}{\omega}$ - coefficient evaluating the active layer's defectiveness; ω_{com} is the area of the field, with a compacted subsoil layer.

However, these formulas proposed by T.Salimov do not make it possible to assess the quality of the laser land leveling technology. Because when evaluating the field surface coefficient of defectiveness for modern laser land leveling, the admissible error at a distance of 800-1200 meters is 3-5 cm. Also, the coefficient of defectiveness in the active layer also does not give a complete prediction ability of how the field surface changes after irrigation.

The irrigated area coefficient of defectiveness should include the density of the soil layers in depth (arable and subsoil) and their area. Therefore, it is advisable to determine the quality coefficient at different stages of the land leveling technology as follows [11–13]:

$$K_c = K_1 \cdot K_2 \quad (20)$$

Here K_1– coefficient estimating the quality of the field surface layout or quality coefficient.

$$K_1 = \frac{\omega_n}{\omega} \quad (21)$$

ω - surface of the leveled area, ha; ω_n – field surface that meets the requirements (norm), ha;
K_2 – uniform density coefficient [14, 15]:

$$K_2 = 1 - \frac{\sqrt{\frac{\sum_{i=1}^{n}\left(\bar{\rho} - \rho_i\right)^2}{n-1}}}{\bar{\rho}} \quad (22)$$

ρ - initial soil density before planning, kg/m^3; ρ_i – is the average point density of the irrigated area, kg/m^3.

$$\rho = \frac{\rho_{up} + 3 \cdot \rho_{0,2h} + 3 \cdot \rho_{0,2h} + 2 \cdot \rho_{0,2h} + \rho_{down}}{10} \quad (23)$$

h – maximum depth, based on the technological process stage, m. As a given depth during the design of land planning works:

$$h = 1{,}1 \cdot h_{rip} \quad (24)$$

Determine amount of arable layer (h_{rip}) and the maximum height of filling (h_{fill}^{max}) after performing works on laser land leveling

$$h = 1{,}1 \cdot \left(h_{rip} + h_{fill}^{\max}\right) \tag{25}$$

After the implementation of deep plowing is determined by the height of the deep ripping or subsoiling (h_{ss}):

$$h = 1{,}1 \cdot h_{ss} \tag{26}$$

The quality coefficient in turn, of course, affects the earthworks volume, the choice of equipment and technologies and the definition of the work cost. When studying the relationship between the earthworks volume and the quality coefficient, we will review the land leveling projects discussed above. When determining the earthworks volume, we use the formula proposed by R.Bazarov [7]:

$$V_{EW} = \frac{V_{fill} + V_{cut}}{2} \tag{27}$$

here $V_{fill} = \sum_{i=1}^{n} h_{fill}^{i} \cdot \omega_i$ - filling volume, m^3; h^i_{fill} – filling height, m; ω_i – filling area, m^2; $V_{cut} = \sum_{i=1}^{n} h_{cut}^{i} \cdot \omega_i$ - cutting volume, m^3; h^i_{cut},– cutting height, m;; ω_i – cutting area, m^2.

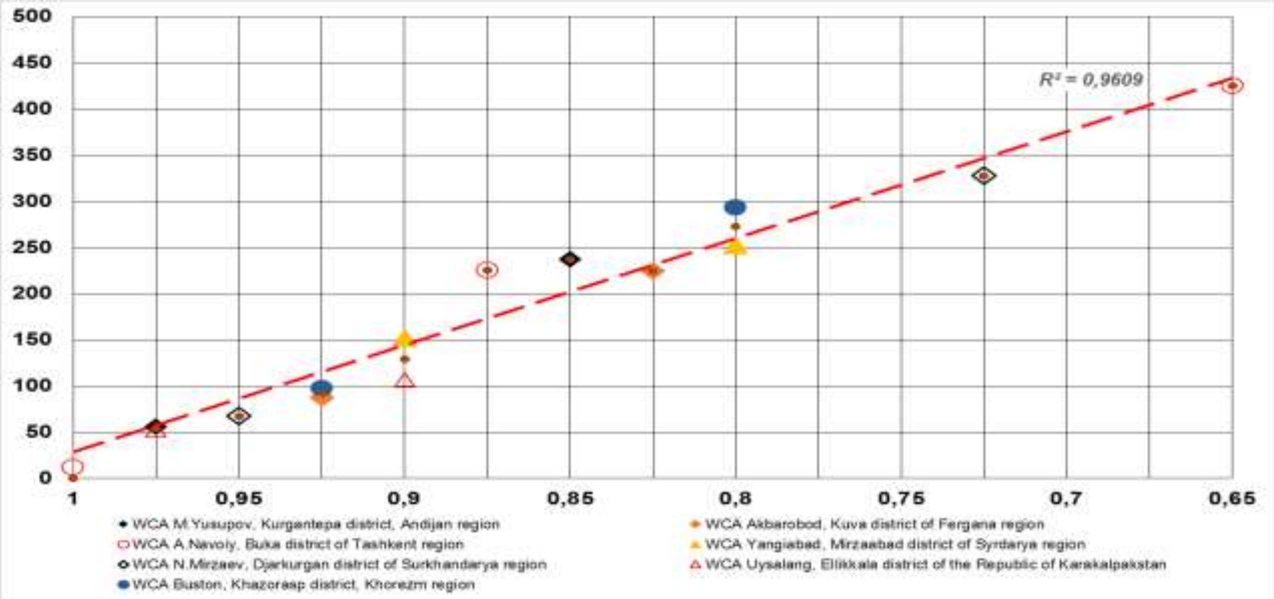


Fig.4 Graph of the relationship of the quality coefficient with the earthworks volume

Using Microsoft Excel for processing the experiment results, the following relationship between the quality coefficient and the earthworks volume (R = 0.896) was determined:

$$V_{EW} = 1156{,}3 \cdot \left(1 - K_c\right) \tag{3.26}$$

In the literature [4, 9, 20] works on land leveling are divided into two: the current (light) and capital. The following table 4 expresses the approaches of various authors to this problem:

Table 4. Classification of ground planning works by volume

№	Author	Current land leveling	Capital land leveling
1.	Samsonova N.	200-250 m^3/ha	200-250 m^3/ha
2.	Titov I.	100-200 m^3/ha	more than 200 m^3/ha
3.	Ukraine Institute of Water Problems and Land Reclamation	till 150 m^3/ha	more than 150 m^3/ha
4.	Uzbekistan Scientific Research Institute of Irrigation and Water Problems (former SANIIRI)	250 m^3/ha	more than 250 m^3/ha
5.	Gaziev H.	150-200 m^3/ha	more than 200 m^3/ha
6.	Uzgiprovodhoz	till 200 m^3/ha	more than 200 m^3/ha
7.	Kramer W., Shieldson S.	less than 300 m^3/ha	300-1000 m^3/ha
8.	FAO	till 200-250 m^3/ha	more than 200-250 m^3/ha

From table 4 it can be seen that nowadays there is no exact classification by volume of current and capital earthworks. Also, current and capital land leveling works are not assessed by the complexity of the applied technological solutions.

According to the FAO recommendation [20], the maximum amount of the current layout was proposed 200-250 m^3/ha, for this reason it is advisable to set the maximum boundary value of the current layout to 220 m^3/ha. In the proposed classification, according to the complexity of the technological solution, they were divided into 3 types - light, medium and heavy (Table 5).

Table 5. Classification of work on the current and capital planning

№	Land leveling types	Degree of difficulty	Kc	V, m^3/ha
1	No need		0,94-1,0	0...70
2	Current	Light	0,90-0,93	80...120
3	Current	Medium	0,85-0,89	130...170
4	Current	Heavy	0,81-0,84	180...220
5	Capital	Light	0,74-0,80	230...300
6	Capital	Medium	0,67-0,73	310...380
7	Capital	Heavy	Less than 0,66	More than 390

The graphic and table give the opportunity to choose the original equipment and technology and determine the cost of work in the field.

5. CONCLUSIONS:

By comparing the studies with other methods of designing the layout of irrigated areas, we can draw the following conclusions:

1. Now, when designing land leveling works, the field shape is not sufficiently taken into account, and when determining the field surface slope, a square grid is created and the report is taken from the squares top. Such an approach, on the one hand, increases the office work volume, and on the other hand, the slopes accuracy remains not high, which complicates the land leveling works design and implementation.

2. It was determined that in order to correctly determine the field slope the profiles number in the field should not be less than 14-16, and the relative slopes accuracy does not depend on the square grids size, the relationship between the relative slope error and the relative grid length was also revealed.

3. The proposed method of establishing the rectangular grid allows you to assign the optimal hydraulic slope, i.e. the slope of the field corresponds to the slope of the irrigation network.

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