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Research paper

Improving Landscape Spacious Development

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Abstract

The purpose of research resulted in recommendations development for landscapes spatial and territory organization improvement, in particular, on the basis of fields geometric parameters influence analysis. The conducted researches are focused on ordering of arable land territory, having spatial and territory unfavorable conditions for management. Analysis is carried out and estimation of fields geometrical parameters influence on mechanized cultivation is provided. The scale for assessing feasibility of crop rotation separating triangular form fields into trapezoidal form workspaces was formed. Different forms triangular plots (rectangular, equilateral, isosceles, scalene) and areas (from 6 to 72 ha) are considered during the study. For a comprehensive analysis of design decisions, economic indicators were used, namely: capital expenditures, annual expenses, additional products cost. Power polynomials were used to establish trends and describe the functional relationship between the different shapes of land plots area and the annual profit, resulted expenses and payback period. They were described by equations and graphs were constructed. Unprofitable, ineffective, expedient and optimal division of the triangular different types areas into trapezoidal form workspaces are presented in the table. The obtained results can be used in land management projects development for territories spatial development, territory organization, rational use organization and land protection.

Keywords: *annual profit, land tenure, payback period, resulted expenses, shelterbelt.*

1. Introduction

Providing scientifically grounded spatial landscapes territory development on land management projects background is the basis and foundation for environmentally safe implementation, socially oriented and cost-effective land use and should contribute to implementation of landscape main functions for self-regulation and self-healing inherent in natural ecosystems.

Today, landscapes are important component of environment integrated system. Land organization and territory regulation in agro landscapes is the basis for preserving soil fertility and the basis for ecologically safe and economically efficient land use, which in turn ensures the sustainable land tenure development.

Landscapes spatial development should provide for the most complete, rational and efficient all land plots use, creating favorable conditions for development of advanced technology land use. Land plots technological characteristics (fields and workspaces), involved in intensive use, become important in spatial development planning of landscape. Their dimensions, aspect ratio, form are determined according to appropriate technological process execution requirements. The most field (workspace) optimal form is a rectangle with 1:4 or 1:5 aspect ratio.

However, in practice it is not always possible to achieve corresponding geometric form in connection with territory existing organization, observance of recommended distances between shelterbelts, various ownership forms land plots mutual placement and use, etc. Therefore, improvement triangular shape land plots use requiring special attention in territory organization remains a topical issue, because their geometric form creates wedges and increases cost of idle race and reversals mechanized cultivation.

A number of domestic and foreign scientists' works are dedicated to solving landscapes spatial development problem. So, the works by D.S. Dobriak, O.P. Kanash, D.I. Babmindra, I.A. Rozumnyi, A.M. Tretiak, V.O. Leonts, V.M. Druhak [1 – 3] are devoted the issue of territory zoning and organization on ecological and landscape basis.

In works by V.M. Krivov, P.G. Kazmir, the issues of forming sustainable ecological framework, territory contour organization, optimal size and shape formation of fields are highlighted [4, 5].

P. Laterra, M.E. Orue, G.C. Booman, D.Le. Coeur, J. Baudry, F. Burel, C. Thenail, C. Stoate studied the issue of landscape spatial arrangement and interactions within it in order to improve its development [6 – 8].

L. Willemen, P.H. Verburg, L. Hein, van. Mensvoort paid attention to study of landscape functions and subsequent organization of its territory [9].

However, a number of issues regarding land use planning projects development that would ensure agro-landscapes spatial and territorial organization in modern conditions of management remain unresolved.

2. The Study Purpose

Proceeding from urgency and problem scientific solution degree, the study purpose is to develop recommendations for spatial and territorial landscapes organization analysis improvement, in particular, on the basis of fields and work area geometric parameters influence on their mechanization cultivation, to form a scale for assessing triangular form land plots feasibility division into trapezoidal form workspaces.

3. Results

Necessity of land relations regulation and territory organization on the ecological and landscape principles are mandatory conditions for rational land use, which requires land management projects development on the market economy basis [4].

The agro landscapes use in many cases is determined by the soil nature, their suitability for profit, and the presence of relevant limiting features such as erosion, salinity, overflow, light granulometric composition, etc. When establishing the most rational way of using land, it is necessary to take into account these features in order to promote, along with the maximum economic effect, contribute to conservation of soil and increase fertility. [10]

Necessity of spatial territory organization in agro landscapes is due to the following factors:

- technological factors (land plots use new technologies attraction, melioration, etc.);
- organizational and economic factors (territory arrangement, territory use planning, drawing up schemes and projects for protection of land from degradation processes, etc.);
- organizational and technical factors (involving a scientifically substantiated system of machines for performing technological operations);
- biological and environmental factors (conditions creation for dynamic interaction of wildlife and inanimate nature complexes, environmentally safe land use provision);
- social and economic factors (creation of conditions for ensuring economically efficient and socially oriented land use).

It should be noted that the above-mentioned factors concerning spatial landscapes development are not spontaneous or differentiated, but in complex, and only then, positive effect can be achieved in environmental, economic and social factors optimal combination.

In this regard, agro landscapes spatial development should provide for the most complete, rational and efficient all land use by establishing proper land structure, developing a set of measures for improving land, creating favorable conditions for agrotechnics advanced technologies development, increasing soil productivity warning and degradation processes termination, etc.

In developing land management projects, first of all, it is necessary to create a stable agro landscaping framework from the elements of the long-term action territory organization, in particular, to perform territory differentiation on corresponding zones with defined mode of land use and protection, formation on ground of main landscaping lands optimal structure, to justify placement of anti-erosion line elements and hydrotechnical structures, create ecological networks, etc. [5].

Land use territory spatial organization should be made taking into account the preservation of the agro landscape natural components, in particular small streams, rivers, plantations, hydrotechnical anti-erosion structures, field hydrographic system, natural and artificially created water courses, and sites for wild flora and fauna reproduction.

Land system is a very powerful tool for ensuring economically expedient, environmentally safe use and socially equitable land distribution; the land management system has gradually evolved to a multi-purpose role, which should, in particular, provide the basis for making decisions on optimizing human-nature relations.

When planning agro landscape spatial development, fields and workspaces technological characteristics become important. Fields size, sides ratio, form is established on implementation requirements basis of the relevant technological process. The most optimal field form is a rectangle with optimal width and length, which determine length of the working bout. Fields length and width depend on land use location in the natural agricultural zone. The most optimal is bout length of 1000 – 2000 m (the longer the field, the fewer the idle races and turns). But too large lengths create inconvenience in sowing, harvesting. The length ratio to width is recommended to take 1:4; 1:5; and for special crop rotation 1:1; 1:1.5.

If the relief allows the area, long fields sides are oriented from north to south, which helps to increase the crop productivity. In this case, the plants row deviation, as well as the field long side from the main direction, north-south, is allowed up to 20°. In combination with shelterbelts, in such a placement, the soil and crops from dust storms and dry hot wind are best protected. The workspace width must be consistent with the field-protective characteristics of the shelterbelts system.

It is recommended that the shelterbelts are placed within and between the fields, elongated along the field length. If a field road is located next to the shelterbelt, then it is projected from windward shelterbelt side, above the relief, from the less shaded side, which is better heated. Their location is determined taking into account the resulting wind direction vector, which is calculated on the basis of information about the winds (dry waves) per year repeatability, % [11].

The recommended distances between longitudinal field-protective shelterbelts when placed in different natural zones are set at 25 – 30 heights of adult tree plantations, thus the distance for the southern steppe will be 300 – 350 m (maximum 400 – 500 m).

There are three types of field-protective shelterbelts constructions: blowing, open-loop and not blowing. Protective shelterbelts width is determined depending on the adverse climatic factors. Thus, forest bands are projected in 3 rows with a total width of 9 – 10 m in the forest-steppe zone, and in the steppe zone, when the dust storms and drywaves occur, the number of rows increases to 4 – 5, increasing the shelterbelt to 10.5 – 12 m [12].

The optimal direction of shelterbelts location is perpendicular to the resulting vector (Fig. 1).

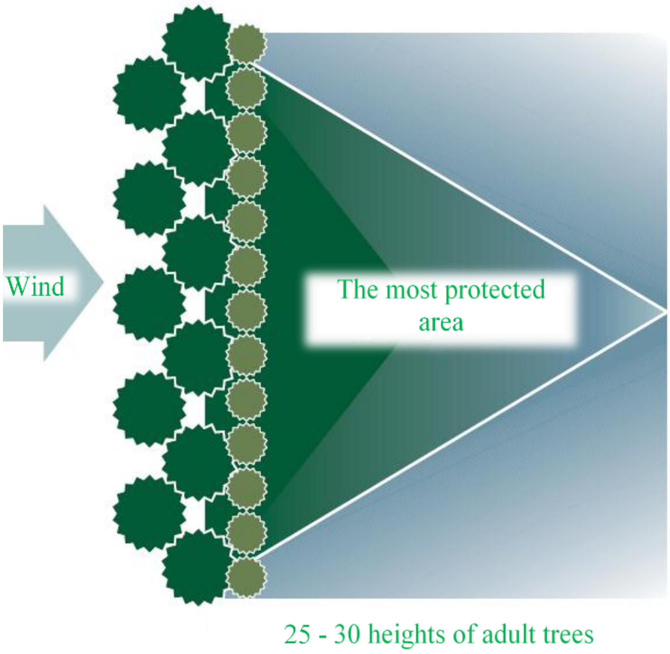

Fig. 1: The scheme of field-protective shelterbelts optimal placement relative to the dominant winds

However, in practice, it is not always possible to reach appropriate geometric shape, since existing ways system, meliorative channels, boundary contours has already been formed. The triangular shape areas cultivation remains a problem. They, in particular, are found where there are utility buildings, ravines or other obstacles. Triangular shape fields require special attention when organizing their use. Their geometric shape creates wedges and increases costs.

During study, we looked at triangular plots (Fig. 2), different in form (rectangular, equilateral, isosceles, scalene) and area (from 6 to 72 ha).

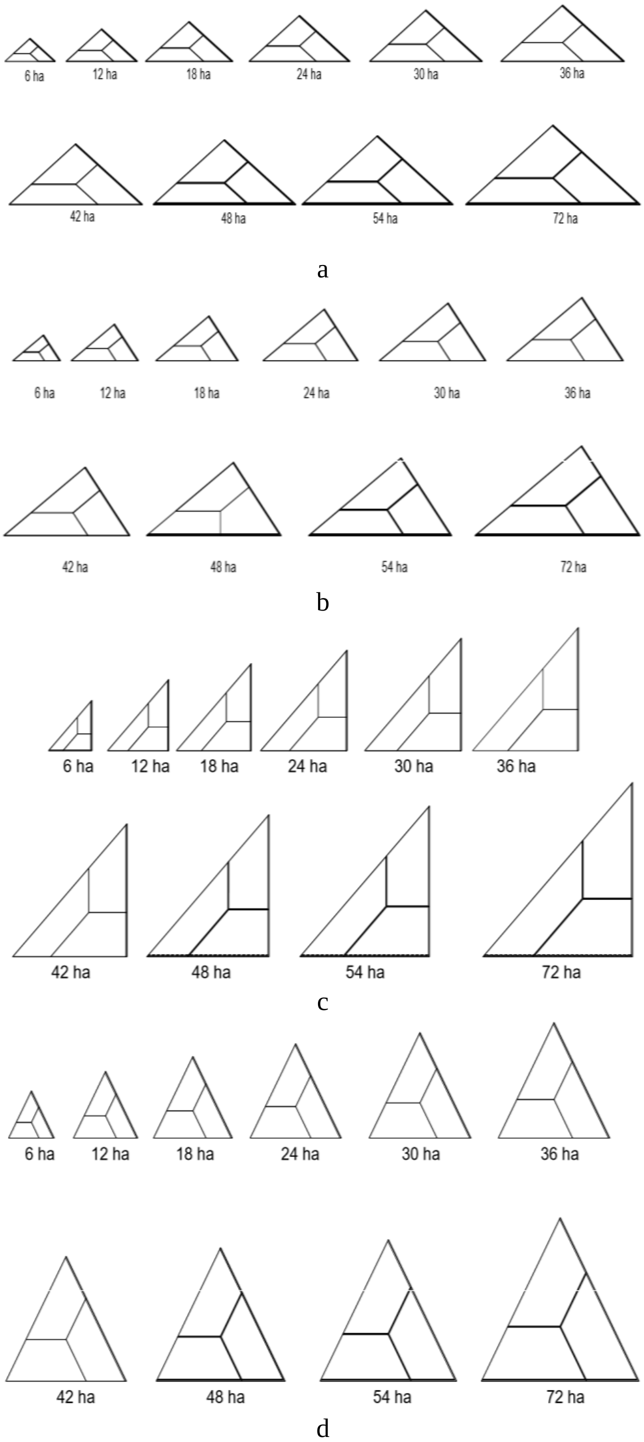

Fig. 2: Triangular shape land plots schemes: a) isosceles; b) scalene; c) rectangular; d) equilateral

Division on trapezoidal lines crossing through center of masses and parallel to triangular site sides is envisaged in order to improve spatial-geometric characteristics of such land plots and ensure their rational use. To create favorable microclimatic conditions, to protect land from degradation processes, and to form ecological territory framework within boundaries of obtained sites, field-protective shelterbelts system will be foreseen if necessary. Also, within plots boundaries, placement of field roads is provided, which will optimize their territory use.

Ecological and economic indicators used for cumulative analysis of design decisions regarding land plots division of triangular form on trapeze can be reduced to following groups: capital expenditures; annual expenses; given costs, additional products cost, etc.

Capital expenditures for shelterbelts establishment (*K*) are calculated by multiplying projected shelterbelts area (*P*) for the cost of creating 1 ha of a shelterbelt (*c*):

$$K = P \cdot c, \quad (1)$$

where K – capital expenditures;
P – projected shelterbelts area;
c – cost of creating 1 ha of a shelterbelt.

Annual expenses for shelterbelts creation include: loss of income from the area occupied by shelterbelts and field roads; cost of idle race and reversals mechanized cultivation, working within specific workspaces; additional transportation costs; additional losses in mechanized works from increasing the working slope; depreciation deductions from capital costs for the shelterbelts creation. Calculations of each of the group parameters for design decisions variants are carried out.

Unprofitability (*d*), from the area occupied by shelterbelts (P_{shb}), by field roads (P_{fr}) is determined by the formula 2:

$$d = (P_{shb} + P_{fr}) + (aN - E), \quad (2)$$

where a – grain crops quantity that could be obtained from unit area before shelterbelts and field roads design;
N – cost per unit of crop production (grain crops), UAH;
E – cost of seeds and other useful works that would be carried out on the arable land before designing shelterbelts and field roads, UAH.

The cost of idle race and reversals are determined by using special graphs for each working area and are substituted in the formula 3:

$$\varphi = \sum_{i=1}^{n} Pi \cdot Xi, \quad (3)$$

where P – workspace area, ha;
X – cost of the idle race and reversals in longitudinal and transverse works, UAH;
n – workspaces number.

The transportation cost of additional products obtained from the arable land protected area (*C*) was defined by multiplying production volume (*Q*) for the transportation cost of 1 ton of cargo, taking into account the weighted average distance (*S*).

$$C = Q \cdot S, \quad (4)$$

where C – expenses for additional products transportation, UAH;
Q – volume of additional production, t;
S – transportation cost of 1 t of cargo in a calculated average weighted distance from industrial (economic) center to land mass, UAH [12].

The depreciation allocations value (*A*) is determined according to the relevant norms of deductions from capital expenditures (*K*) by the formula (5):

$$A = K \cdot \eta, \quad (5)$$

where A – depreciation allocations, UAH;
K – capital expenditures, UAH;
η – normative coefficient (for calculations accepted 6%).

An important economic indicator that characterizes the capital expenditures efficiency for creation of shelterbelts is the payback period, which is calculated by the formula 6:

$$N = Q \cdot \sqrt{10(1 + \frac{4K}{d} + (1 + \frac{2q}{d}),} \quad (6)$$

where N – payback period of capital expenditures, UAH;
K – capital expenditures for shelterbelts creation, UAH;
Q – zonal coefficient (values are taken from 0.7 to 2 depending on the composition of plantations of their growth rate, etc., in forest-steppe areas – 0.7 – 1.5; – in the steppe areas – 1-2; (lower values are taken for strips with fast growing trees of rocks);
d – net additional profit, UAH;
q – cost due to which net additional profit was received (annual net profit and additional products cost), UAH.
The resulted expenses indicator is calculated by the formula 7, for the aggregate capital and annual expenditure the efficiency characteristics:

$$R = K \cdot C_n + E \qquad (7)$$

where R – amount of resulted expenses, UAH;
K – capital expenditures for shelterbelts creation, UAH;
C_n – cost efficiency normative coefficient (0.08 – 0.20);
E – annual expenses, UAH.
The results of calculations are presented in the graph form of annual net profit (ths. UAH), resulted expenses (ths. UAH) and capital expenditures payback period (years) from the land area (ha).
Similarly, parameters graphs are constructed for each triangles form.
As a result, the optimal area for splitting into workspaces in the trapezoidal form for each of the triangles is compared and established.
Correlation-regression analysis between areas of land plots and ecological and economic their use consequences (Fig. 3 – 6) showed strong functional relationship between investigated features ($0.73 \leq R^2 \leq 0.95$). In analyzing these graphs (Fig. 3 – 6), power polynomials described by equations were used to establish trends and describe functional dependence between land area and annual profit size, reduced costs and payback period.
For example, for variant with land plot in rectangular triangle form (Fig. 3), functional relationship is described by following equations:

- for annual profit

$$y = 3E\text{-}05x4\text{-}0.0048x3 + 0.2042x2\text{-}1.9466x + 9.5688 \qquad (8)$$

(coefficient of determination $R^2 = 0.9535$)

- for cost recovery

$$y = -1E\text{-}05x^4 - 3E\text{-}05x^3 + 0.1347x^2 - 6.3526x + 89.279 \qquad (9)$$

(coefficient of determination $R^2 = 0.8183$)

- for payback period

$$y = -3E\text{-}05x4 + 0.0049x3\text{-}0.2063x2 + 3.4131x\text{-}9.5881. \qquad (10)$$

(coefficient of determination $R^2 = 0.9517$)

Similarly, power polynomials were created to characterize functional interdependence of quantities investigated for other triangles types (Fig. 5 – 6).
In the example graph (Fig. 3) of functional interdependencies for a rectangular triangle, we will analyze results obtained. Thus, according to research, given costs increase not evenly, in triangular sections with an area of up to 42 ha they increase in proportion to the area, and then there is sharp jump due to necessity of designing shelterbelts along boundaries of trapezoidal form. Thus, workspace area has increased 12 times, and costs are almost 9. The graph shows (Fig. 3) dividing land in rectangular triangles form with an area up to 8 hectares on trapezoid is economically not feasible. In this case, the costs are higher than annual net profit. The payback expense reaches its maximum and is 59 years in this division.

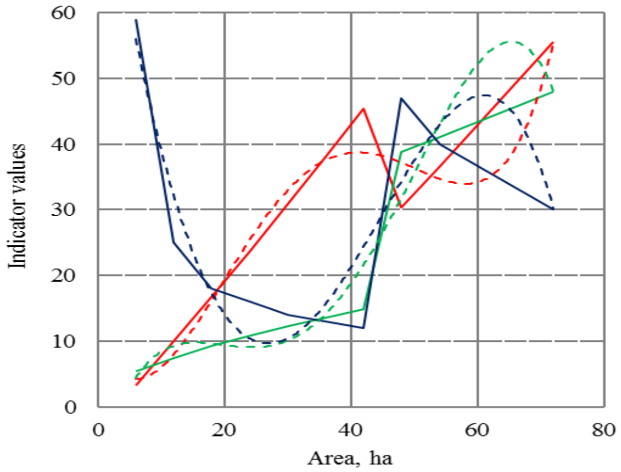

Fig. 3. Graphs of annual net profit (ths. UAH), resulted expenses (ths. UAH) and the payback period of capital expenditures (years) from the land plot area (ha) for rectangular triangles

Land plots triangular from of area from 8.0 to 18.0 ha divided into trapezoids is not appropriate.

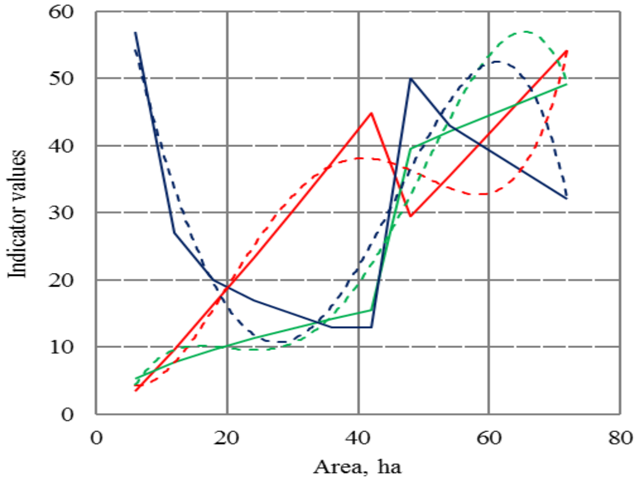

Fig. 4. Graphs of annual net profit (ths. UAH), resulted expenses (ths. UAH) and the payback period of capital expenditures (years) from the land plot area (ha) for equilateral triangles

But at this point there is noticeably rapid decline in the payback of more than 2 times – up to 25 years. In this case, net profit is three times (from $ 120 to $ 350), and the costs are increased by one and a half times (from $ 192 to $ 278).

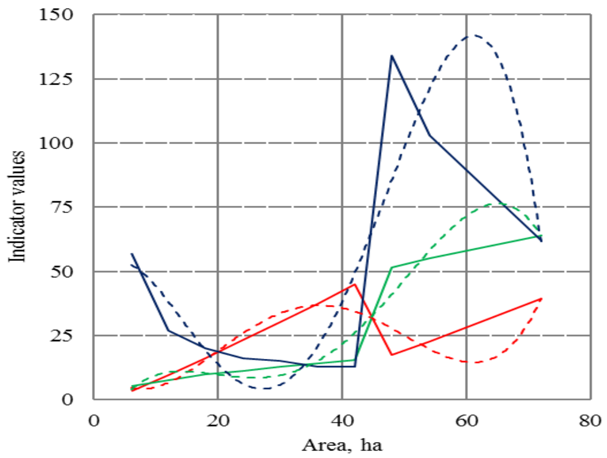

Fig. 5. Graphs of annual net profit (ths. UAH), resulted expenses (ths. UAH) and the payback period of capital expenditures (years) from the land plot area (ha) for isosceles triangles

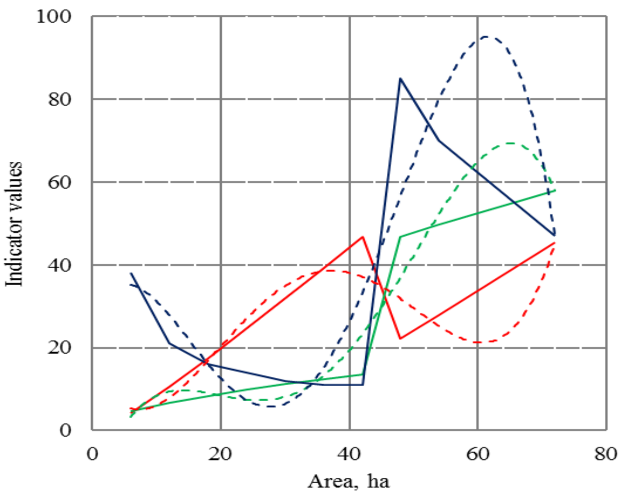

Fig. 6. Graphs of annual net profit (ths. UAH), resulted expenses (ths. UAH) and the payback period of capital expenditures (years) from the land plot area (ha) for scalene triangles

At this interval, land use process is not unprofitable, but efficiency gains are too weak.

For triangular areas, starting with an area of 18.0 ha, it is expedient to perform division into workspaces in trapezoidal forms form. In this case, resulted expenses are almost twice less than the annual profit. The payback for this gap is still high at around 18 years, but there is dynamics to reduce this term. Analyzing the graph (Fig. 2), we can note that the best option for division into workspaces in the trapezoid form is an interval from 40.0 to 42.0 ha. At this interval, the protective effect of the shelterbelt reaches its maximum, while profits loss from the area occupied by shelterbelts is minimal.

The ecological effect, in this case, is expressed in terms of economic, namely additional product creation (grain yield growth) at rate of 3.5 c/ha. Length ratio and width of working areas are approaching optimal, thus not creating additional costs for cost of idle race and reversals. Thus, triangular plots area has increased by 7 times (from 6.0 ha to 42.0 ha), and costs of idle race and reversals are three times (from $ 64 to $ 198). The interval from 42.0 to 62.0 ha according to graph (Fig. 2) is critical.

The main reason for such decline is a necessity for designing, within workspaces boundaries, in trapezoidal form field-protective forest belts, to create favorable microclimatic conditions on plot territory. Again, there is a high payback period, which is about 47 years, due to significant increase in capital expenditures for forest belts creation. At the same time, depreciation costs for planting are growing and profit (4 times) from the area occupied by forest stands substantially increases. Starting from the area of 62.0 hectares, and then the annual net profit prevails over resulted expenses.

Shelterbelts protective action ecological and economic effect is still in process of reaching its maximum, but this is enough to cover losses from the area occupied by shelterbelts. At this stage, a decrease in payback period can be observed, but it still will not reach its minimum as in range of 40.0 to 42.0 ha. Consequently, the land plot in the rectangular triangle form makes sense to divide into workspaces in trapezium form from 18.0 ha, and variants of division in the range from 40.0 to 42.0 hectares are optimal.

It is impossible to achieve such a level of ecological and economic effect when dividing land plots of larger area triangular form.

In this case, it is necessary to consider other variants of design decisions, for example, with the allocation one large plot in trapezoid form and carry out small plots grassing on the periphery. Similarly, we analyze other charts (Fig. 5 – 6), where there is a similar situation with triangular land plots.

The results of performed researches are reduced to Table 1.

Table 1: Evaluating feasibility of dividing triangles different types areas into trapezoidal form workspaces

Form of a triangle	Intervals square (ha)			
	Economically unprofitable (loss-making) division	Low-efficiency division	Feasible division	Optimal division
Rectangular	0.0 - 8.0 42.0 - 62.0	8.0 - 18.0 62.0 - 72.0	18.0 - 40.0	40.0 - 42.0
Equilateral	0 - 8.0 42.0 - 64.0	8.0 - 20.0 64.0 - 72.0	20.0 - 36.0	36.0 - 42.0
Isosceles	0 - 10.0 42.0 - 72.0	10.0 - 20.0	20.0 - 36.0	36.0 - 42.0
Scalene	0 - 7.0 42.0 - 72.0	7.0 - 17.0	17.0 - 35.0	35.0 - 42.0

As research result, it was established (Table 1) that for division of triangular form area is optimal in range from 36.0 to 42.0 ha; for rectangular triangle – 40.0 – 42.0 ha, and for scalene – 35.0 – 42.0 ha.

It is advisable to carry out division for triangular plots in the range 20.0 – 35.0 ha, with the widest interval of area have plots in rectangular triangle form 18.0 – 40.0 hectares, and the smallest interval of land plots in equilateral and isosceles triangles form 20.0 – 36.0 ha.

The land plots division in triangles form in range of 8.0 – 18.0 ha and for certain types of triangles 64.0 – 72.0 ha can be considered as ineffective. At the same time, for the rectangular triangle form land plots, the widest range is 8.0 – 18.0 ha and 62.0 – 72.0 ha, and for the regions in isosceles and scalene triangles form 10.0 – 20, 0 ha and 7.0 – 17.0 ha respectively. In other cases, the triangular form land plots division on trapeze is considered inappropriate.

For all triangles types, the reason is the same: effect of dividing workspaces and, if necessary, field defences creation has not yet reached its maximum, and environmental benefits that we can express due to economic indicators are not able to cover costs of measures envisaged.

4. Conclusion

First of all, a stable landscape frame should be created from the territory organization elements of long-term effect (shelterbelts, anti-erosion elements, etc.) when developing land management projects.

Thus, in order to create conditions for rational use of triangular form land plots, it makes sense to divide them into trapezium at an area of 36.0 to 42.0 ha; for a plot in rectangular triangle form the interval is 40.0 – 42.0 ha, and for plot in scalene triangle form 35.0 – 42.0 ha.

Division of triangles in the range of 8.0 – 18.0 ha and for some types of triangles 64.0 – 72.0 ha can be considered ineffective.

At the same time, the rectangular triangle has the widest range of 8.0 – 18.0 ha and 62.0 – 72.0 ha, and an isosceles and scalene triangle of 10.0 – 20.0 ha and 7.0 – 17.0 ha, respectively.

In other cases, trapezoid separation is economically unprofitable.

The reason for unprofitableness is that maximum effect from division into workspaces and field protection plants creation has not been achieved, because the environmental benefits, which were expressed in terms of economic indicators, are not able to cover costs.

Land organization without formation of an environmentally stable frame is permissible for plots, which is not appropriate to divide into work areas in trapezoidal form.

In other cases, triangular form land plots division on trapeze is considered inappropriate. The obtained results can be used as recommendations in land management projects development on territories spatial development, territory organization, rational use and land protection organization, creating conditions for economically feasible, environmentally safe and socially oriented.

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