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METHODOLOGY FOR EVALUATION AND CATEGORIZATION OF AGRICULTURAL LAND WITH CULTIVATED SOILS IN BULGARIA

A B S T R A C T

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I. INTRODUCTION

Modern research (Fig. 1) shows that compared to the background of the Earth's water surface (75% of the planet's surface), about 12% of the land due to climatic relief, soil and other reasons is inhospitable to life and civilized habitation (deserts, glaciers, mountains, etc.). Human civilization has used about 10% for construction (including lands with extremely unfavorable for agriculture soils). Only about 3% of the remaining land is appropriate for active agriculture.

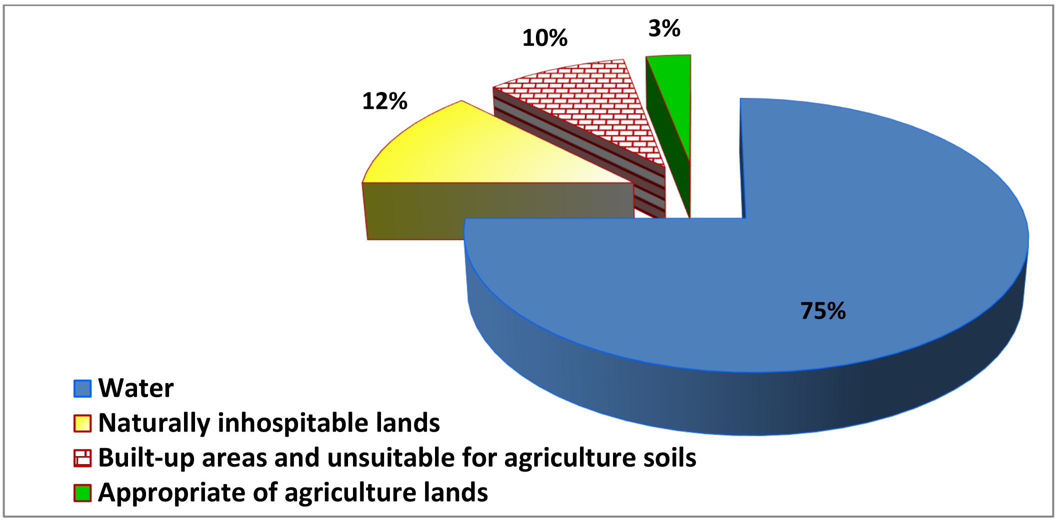

Fig 1. Allocation of resources according to land surface

Over the past few years, there has been a steady decline in arable and non-arable land, which is directly related to the intensive development of society and industry.

Today, per capita in the world there are about 0.30 ha, and in our country - 0.52 ha of arable land. Among other negative factors (erosion, salinization, acidification, etc.), a relatively large share in terms of the reduction of arable land is attributed to lands expropriated and disturbed by the mining and processing industries. If the process of land disturbance continues, in the near future each person will have only about 0.1 - 0.2 ha of arable land.

The following crises and conflicts are emerging, which in many aspects are related to the development of the agricultural sector:

- Climate (environmental) crisis.
- Crisis in food and fodder production.
- Energy crisis.
- Conflict between food and bioenergy.

The crisis with natural resources is characterized by declining biodiversity, deteriorating soil fertility due to degradation processes, declining water resources, declining soil resources, etc.

The destruction and pollution of soils is the result of a number of natural and anthropogenic processes, the most important of which are: soil erosion, soil compaction, disturbance and covering (sealing) of soils, soil pollution and disturbances caused by the mining and processing industries.

The development of deposits (mining) is carried out by several main methods:

1. Classic open method - by building quarries and mines (Fig. 2). This method leads to the destruction of large areas necessary for the placement of internal and external embankments.

Fig 2. Classic open mining method

2. The classical underground method (Fig. 3) is divided into two types: a) developing vertical mine developments (shafts) reaching the level of the ore deposit; b) laying out horizontal mine developments (tunnels) to reach the ore deposit. The changes in the environment accompanying the underground method of development are mainly related to the deposition of the sterile rocks and geological materials brought to the surface and the construction of mine yards and technological developments on the surface of the mine.

Fig 3. Underground mining method

3. Geotechnological method - passing acid drillings to the level of the ore deposits (Fig. 4). Treatment of the ore with a solution of sulfuric acid and extraction of this enriched solution to the surface. This method causes particularly large

disturbances and changes in the landscape and soil layer on the territory of the sites – mechanical violation of the integrity of the soil and exposure to the chemical effects of the used solutions, which leads to complete destruction of their humus horizon and pollution of the surface layer with radioactive materials.

Fig 4. Geotechnological mining of uranium

4. Tailing ponds and landfills (Fig. 5) are specific sites built during the processing and enrichment of ore, which are located in natural depressions of the terrain and take up large areas. They are characterized by destroying the soil layer and polluting the surrounding areas under the influence of wind erosion.

Fig 5. Landfills for quicklime and coal ash

5. A large portion of the lands on the territory of the country is damaged and destroyed (Fig. 6) during the construction of linear sites (highways, roads and railways; pipelines, power lines, lifts, etc.).

Fig 6. Disturbances of the soil layer due to the construction of highways and pipelines

Everything shown so far defines the theoretical scenarios in the field of soil reclamation and their practical application as particularly necessary and timely activities.

Reclamation is a long and complex process. It includes a variety of techniques that return the site the closest possible to its natural form, then it can be used for recreation, sports, tourism, agriculture, forestry and other purposes. It takes place on the basis of a prepared in advance, agreed and approved project, which is an integral part of the process for the site development and includes the following stages:

1. Establishing the nature and extent of the disturbance. there are three main categories of sites based on the extent of disturbance - physically disturbed, chemically polluted and an intermediate category, combining the previous two. These groups consist of diverse sites formed as a result of various industrial processes – depositions of industrial waste, quarries and embankments from open pit mining, collapses due to underground mining, ash dumps (ash dumps near thermal power plants), landfills, lands polluted with various harmful substances, etc.
2. Presence, quantity, quality (or the lack of) of deposited humus material before the disturbance of the soil layer.
3. **Technical reclamation**. During this stage, the terrain is cleaned and prepared; loading and transportation of land masses according to their intended purpose; leveling and shaping the terrain in its final form, adding soil improvers, retrieving, transporting and spreading the humus layer;

construction of temporary and permanent roads, construction of anti-erosion and hydro-ameliorative facilities; shaping of water areas.

4. The technical reclamation is followed by biological reclamation, when the land is reclamated for agricultural use, a number of agrotechnical, agrochemical, technological and meliorative activities are planned over a 5 year span after the technical reclamation in order to restore the productivity of the reclaimed areas. If the terrain is recultivated for forestry use, forestry, agrochemical, technological and meliorative activities are carried out to create forest plantations composed of trees and shrubs during the first 3 years after the implementation of technical reclamation and afforestation.
5. Performing **bioremediation** on contaminated terrains. The natural ability of plants and soil microorganisms to reduce, remove and transform (ie biodegrade) toxic substances in the soil into non-toxic or less toxic ones is applied.
6. In recent decades, there has been an alarming trend of a negative balance of humus as a result of reclamation. For this reason, a new approach has been developed - **humus-free reclamation**.

For the recultivated soils intended to be added back to the pool of agricultural lands, there should be a final 7th stage "**grading and categorization**", but at the moment this stage has not been developed. Therefore, our current research is focused in this particular area.

II. GOALS AND TASKS

The conducted preliminary research and experiments show that the adopted and widely applied in our country "Methodology for use and development of the cadastre of agricultural lands in Republic of Bulgaria" (E. Petrov & co, 1988), is not applicable for lands with reclaimed soils. A new, original study is required, the results of which should be aligned with those of the cited methodology if possible. That is why the goal of the dissertation is:

Development of a Methodology for grading and categorization of lands with recultivated soils intended to be added back to the pool of agricultural lands in Bulgaria

In order to accomplish the above-mentioned task, the following problems have to be solved:

1. To choose the appropriate methods part of the research.
2. To compile a set of land characteristics (soil, under soil, agroclimatic) based on which the assessment of lands with reclaimed soils will be performed.
3. To compile algorithms (quality scales and equations) for grading and categorization of agricultural lands with reclaimed soils and to recommend a model for aligning them with the results of assessments of lands with undisturbed soils.

4. To develop software in Ms Excel, which operates based on the new methodology.
5. To test out the obtained results and conclusions, if possible on at least 2 sites with lands with reclaimed soils intended for agricultural use.

III. BIBLIOGRAPHY REVIEW

Based on the methodological nature of the research and the specific objectives, an extensive literature review was made, focused on two main areas:

a) Publications related to the methods and techniques for grading and categorization of agricultural land adopted in our country and the FAO recommendations in this regard;

b) Publications related to the requirements and the course of work regarding soil reclamation intended for future agricultural production.

III.1. Theory and practice in Bulgaria

History shows that scientific achievements in the field of relative evaluation (grading and categorization) of agricultural lands and their application in practice in our country can be traced back to 1962.

A critical analysis of the achievements in terms of first establishment, improvement and the need of further development of the "Methodology for the introduction of a cadastre of agricultural land in the Republic of Bulgaria" has been prepared.

Based on the research of the literature sources concerning the grading of agricultural lands in our country, it is concluded that during the entire historical period of research in this field there was a lack of fundamental philosophy for the development of this scientific branch.

III.2. FAO recommendations

Researchers from the International Food and Agricultural Organization (FAO) recommend classifications based on valuations for different types of land uses.

The FAO system pays attention to distinguishing between quantitative and qualitative classifications, as well as between current and potential land suitability.

For each specific case, according to the type of the studied land use, it is recommended to work with differently selected types of assessment, approaches and methods.

III.3. Reclamation of soils for agricultural use

This section of the literature review is devoted to:

- the types of disturbance of lands and soils caused by different types of industrial, mining, processing and construction activities;

- the methods for conducting technical reclamation of the disturbed and polluted lands;

- the classification of the geological and soil materials according to their suitability for undergoing technical and biological reclamation;

- technological solutions for biological restoration of the fertility of technically reclaimed lands and soils.

The main conclusion from this section, which relate to our research are the following:

- the literature examines in detail the negative impacts of the various industrial activities on soils;

- a number of technologies have been developed for technical and biological restoration of the fertility of the disturbed and polluted lands and soils;

- in order for the reclaimed lands to be added back to the pool of arable lands of the country it is necessary to categorize them, ie to assess their fertility.

IV. MATERIALS AND METHODS

Based on the goals of the research and the tasks laid out for achieving those goals, the following can be summarized:

1. The research is methodological. It is a system for current and potential relative valuation (grading) of lands with reclaimed soils, intended for being used in agricultural production, reaching a final (cumulative) valuation and classification of general suitability of land use.
2. Apart from being a fundamental setting, it is also intended to serve agricultural practices intended to be applied in our environment at public and private levels - agricultural policy, development of national and externally focused agricultural strategy, crop zoning, regulation of market relations, agricultural production. It can function on large scales (M 1: 5000; 1: 10000 and 1: 25000).
3. The developed system shall adhere to the limitation methods recommended by the FAO and in particular to those taking into account the number and extent of existing restrictions for a given set of land characteristics.
4. The application of the recommended methodology goes through three main stages – collecting the required initial input data of land characteristics, individual assessments of the characteristics according to the developed grading scales, summarizing and final classification of the evaluated land.

V. RESULTS AND DISCUSSION

V.1. Collection and processing of the initial input data

During the selection of the functional characteristics of lands, we considered the following major principles for development of systems for relative valuation (grading), applied both in Bulgaria, as well as in other world leading schools (mostly the recommendations by FAO, which are widely used applied in the EU).

The required initial input data is in fact numerical values of the land characteristics selected for participation in the assessment. Those have been systematically sorted for work during their initial input in Table 1 below.

Table 1. Selected appropriate for work land characteristics and their indices

Land Characteristics	**Unit**	**Index**
1. Agroclimatic:		
1.1 Active temperature sum during the period with average daily air temperatures of $t^0 > 10\ ^0C$	^0C	L^{TS}
1.2. Balance of natural atmospheric humidity for the period June - August	mm	L^{WB} ↑
2. Relief and stoniness of the soil:		
2.1. Predominant slopes	%	L^{SL} ↑
2.2. Stoniness of the plowing soil layer	volume %	L^{ST} ↑
3. Drainage conditions:		
3.1. Textural differentiation of the soil profile	coefficient	L^{TD}
3.2. Groundwater level	cm	L^{GWT} ↑
4. Soil fertility:		
4.1. Mechanical composition of the soil	phys. clay %	L^{TX}
4.2. Root environment (depth of root barrier)	cm	L^{RS}
4.3. Soil acidity (pH measured in water suspension)	pH в H_2O	L^{PH} ↑
4.4. Organic matter content in arable land (humus)	%	L^{HC} ↑
5. Salinity and / or alkalinity of the soil:	%	L^{SAAL} ↑
5.1. Contents of water-soluble salts	%	L^{SA} ↑
5.2. Exchangeable sodium content	%	L^{AL} ↑
6. Soil contamination with heavy metals and toxic elements	%	L^{CO} ↑
Note: Symbol „↑“ is used to mark the anthropogenically correctable to a different degree restriction values of the characteristics.		

Before starting the data collection and any site assessment activities, the valuator should be aware of the following important issues:

First: To review both the documents and on site that the reclamation activities have been completed to their full extent and the land is intended for agricultural use.

Second: To make sure that all necessary data can be obtained via officially certified for such research institutions (the National Institut of Meteorology and Hydrology, the Institute of Soil Science, the Agricultural academy, etc.).

Third: To take into account that at least three evaluations are upcoming according to the current methodology:

- First one - immediately after the completion of reclamation. It does not take into account possible anthropogenic improvements.
- At the same time, a parallel assessment of the undisturbed soil surrounding the reclaimed terrain. This is necessary for a comparative input into the existing categorization of agricultural land in our country.
- After 10 years of land use - a second monitoring assessment of land with reclaimed soil, taking into account possible improvements.

Soil samples from reclaimed areas are taken in accordance with the procedure established for large-scale soil mapping (if necessary, even using a denser network), and from undisturbed soil in a circle around the site by creating as large as possible buffer zone (> 50 - 100 m).

Before moving on to the description of the developed quality scales, it is necessary to clarify some details about the method we have chosen - "Limitation method taking into account the number and degree of restrictions".

Experts in the field of rating usually prefer using a "parametric" approach. However, our long practical experience has shown that for lands with reclaimed (new, anthropogenically restored) soils, this otherwise very precise approach gives inadequate results. Perhaps, after decades of land use, it could be applied successfully.

The "simple limitation method" is popularly called by some authors the "shot barrel method", i.e. the capacity of the vessel is determined by the lowest hole it has and it will store liquid only up to there - in other words, the greatest limit is decisive for the overall assessment.

The "limitation method, taking into account the number and degree of restrictions" in this case turned out to be the most appropriate - firstly, because the research deals with "general suitability" of land for agricultural practices and secondly - it starts from quantitative values and results can be compared to those of the parametric assessments.

V.2. Rating scales for assessment of the agroclimatic characteristics

Total sum of the active temperature

This characteristic was chosen, because it actually determines the beginning and ending of the active vegetation (length of the vegetation period) of the agricultural plants.

At $\Sigma T^0 > 10^0C$ lower than 1600 ^0C the conditions are basically not appropriate for agricultural activities in terms of crop production. The higher this sum is, the wider range of crops can be grown. The diversity expands not only with more warm-loving plants, but also with their different varieties (hybrids) – very early, early, semi-early, semi-late, late and very late.

Table 2. shows Rating scale 1 for assessment of the sum of the active temperature.

Tabe 2. Assessment of the sum of the active temperature

Rating scale 1.	
$\Sigma T^0 > 10^0C$	Levels of restriction L^{TS}
> 3600	$L^{TS}{}_0$
3600 ÷ 3100	$L^{TS}{}_1$
3100 ÷ 2600	$L^{TS}{}_2$
2600 ÷ 1900	$L^{TS}{}_3$
< 1900	$L^{TS}{}_4$
The levels cannot be adjusted	

Conditions of natural atmosphere humidity

This characteristic represents the balance between the average precipitation „p" and the evaporation „E" (evapotranspiration) for the months June, July and August ($p - E_{(VI-VIII)}$) expressed in millimeters. It was chosen as particularly indicative for assessment of the balance of atmospheric humidity, under conditions without irrigation, during a very important period of vegetation for an extremely large number of agricultural crops. The Main Rating Scale 2a. is shown in Table 3a.

The characteristic is relates to the specific climatic conditions of the country, which are characterized by a negative balance (deficit). The balance is positive only in the mountains. The higher the values of this deficit, ie. the closer to 0, the more favorable the conditions are for agricultural plants and vice versa.

The rating scale 2a. is used in this format during the first assessment of lands with reclaimed soil and the undisturbed comparison sample nearby.

Table 3a. Assessment of the natural atmospheric humidity

Rating scale 2a.	
p–E $_{(VI\text{-}VIII)}$ mm	Levels of restriction L^{WB}
> -100	$L^{WB}{}_0$
-100 ÷ -200	$L^{WB}{}_1$
-200 ÷ -300	$L^{WB}{}_2$
-300 ÷ -400	$L^{WB}{}_3$
< -400	$L^{WB}{}_4$
The levels can be adjusted	

In case of existing conditions for irrigated agriculture, when conducting the second and latter assessments, the levels of restrictions should be adjusted according to the availability of water for irrigation purposes, expressed in perecentage from 0 – 100, at 25% intervals. (Table 3b.).

Table 3b. Adjustments in the assessment of the natural atmospheric humidity due to existing conditions for irrigation

Rating scale 2b.						
	Adjustments according to the availability of water for irrigation (%)					
	p–E $_{(VI\text{-}VIII)}$ mm	0	25	50	75	100
Levels of restriction L^{WB}	> -100	$L^{WB}{}_0$	$L^{WB}{}_0$	$L^{WB}{}_0$	$L^{WB}{}_0$	$L^{WB}{}_0$
	-100 ÷ -200	$L^{WB}{}_1$	$L^{WB}{}_0$	$L^{WB}{}_0$	$L^{WB}{}_0$	$L^{WB}{}_0$
	-200 ÷ -300	$L^{WB}{}_2$	$L^{WB}{}_1$	$L^{WB}{}_0$	$L^{WB}{}_0$	$L^{WB}{}_0$
	-300 ÷ -400	$L^{WB}{}_3$	$L^{WB}{}_2$	$L^{WB}{}_1$	$L^{WB}{}_0$	$L^{WB}{}_0$
	< -400	$L^{WB}{}_4$	$L^{WB}{}_3$	$L^{WB}{}_2$	$L^{WB}{}_1$	$L^{WB}{}_0$

V.3. Rating scales for assessment of the relief and stoniness of the soils

The features of the topographical relief and the stoniness of the arable layer of the soil are assessed according to the degrees of suitability for mechanized tillage.

Predominant Slopes

For assessments of this, certain standards are established based on international experience. First is the level of agricultural technology, for which the methodology is intended. If it is high, the degree of the slopes, the susceptibility of the terrain to leveling, terracing, the provision of machinery and funding are taken into account. The boundaries in the grading scales are quite strict and mostly technologically oriented. If the assessments will be made at lower levels of agricultural technology, then they are more relaxed, often diffused, depending on the selected agricultural plants, and taking into account the requirements the assessment.

When assessing the specifics of both aspects, it is necessary to take into account the risks of existing or potential soil erosion.

Regarding grading methods applied for intensive agriculture, depending on the type of land use, FAO recommends optimal limits of up to 8% slopes, and restrictive limits of up to 30%, suggesting that anything above these limits makes tillage of the land either impossible or inefficient.

The algorithms for estimating the predominant slopes are shown in Table 4a. and 4b.

Table 4a. Assessment of the predominant slopes

Rating scale 3a.	
Predominating slopes %	Levels of restriction L^{SL}
< 2 or terraced	$L^{SL}{}_0$
2 ÷ 8	$L^{SL}{}_1$
8 ÷ 16	$L^{SL}{}_2$
16 ÷ 30	$L^{SL}{}_3$
> 30	$L^{SL}{}_4$
The levels can be adjusted	

Table 4b. Adjustments in the assessment of the predominant slopes, according to the present conditions for leveling (terracing)

Grading scale 3b.						
Levels of restriction L^{SL}	Adjustments according to the present conditions for leveling (%)					
	Slopes %	0	25	50	75	100
	< 2 or terraced	$L^{SL}{}_0$	$L^{SL}{}_0$	$L^{SL}{}_0$	$L^{SL}{}_0$	$L^{SL}{}_0$
	2 ÷ 8	$L^{SL}{}_1$	$L^{SL}{}_0$	$L^{SL}{}_0$	$L^{SL}{}_0$	$L^{SL}{}_0$
	8 ÷ 16	$L^{SL}{}_2$	$L^{SL}{}_1$	$L^{SL}{}_0$	$L^{SL}{}_0$	$L^{SL}{}_0$
	16 ÷ 30	$L^{SL}{}_3$	$L^{SL}{}_2$	$L^{SL}{}_1$	$L^{SL}{}_0$	$L^{SL}{}_0$
	>30	$L^{SL}{}_4$	$L^{SL}{}_3$	$L^{SL}{}_2$	$L^{SL}{}_1$	$L^{SL}{}_0$

Stoniness of the plowing soil layer

Stony soils with content and size of stones and gravel up to certain limits do not interfere with agro-technical activities, but hinder the development of some plants (especially in the initial stages). In other cases (vineyards for white table wines) such conditions are desirable, etc.

When the content of stones is high (mostly in the arable layer) or they are very large in size, tillage is difficult, in some cases impossible and / or economically unprofitable.

When compiling algorithms for rating, the above must be taken into account and the approach must always be specific.

There are different classifications for stoniness of soils according to the volume of the contents of gravel and stones in the soil layer, their size, the depth of positioning, etc. The content percentage (volume %) of stones and gravel in the arable layer (the top 35 - 36 cm from the surface) of the soils is most often taken into account. Table 5 presents the classification that is widely used in Bulgaria for grading assessments. This is the classification that was kept in mind, while composing Rating Scales 4a and 4b of Tables 6a and 6b.

Data on the stoniness of the soil is collected by the so-called "meter method". Depending on the size of the assessed land with recultivated soil, data about the stoniness of the arable layer is collected by dividing the plot into a rectangular network. The data is processed statistically for the whole area.

Table 5. Level of stoniness of the soils (E. Petrov and Co., 1988)

Level of stoniness	Contents of stones and gravel in the arable layer (volume %)
Not stony	0
Low stoniness	0 ÷ 10
Medium stoniness	10 ÷ 20
Highly stony	20 ÷ 40
Extremely stony	> 40

Table 6a. Assessment of the stoniness of the arable layer

Rating Scales 4a.	
Stones and gravel volume %	Levels of restriction L^{ST}
< 5	L^{ST}_0
5 ÷ 15	L^{ST}_1
15 ÷ 30	L^{ST}_2
30 ÷ 40	L^{ST}_3
> 40	L^{ST}_4
Levels can be adjusted	

Table 6b.

Adjustments to the assessment of the stoniness of soils under the existing conditions for cleaning the arable land from stones and gravel

Rating Scale 4b.						
Levels of restriction L^{ST}	Adjustments according to existing conditions for cleaning (%)					
	Stoniness %	0	25	50	75	100
	< 5	L^{ST}_0	L^{ST}_0	L^{ST}_0	L^{ST}_0	L^{ST}_0
	5 ÷ 15	L^{ST}_1	L^{ST}_0	L^{ST}_0	L^{ST}_0	L^{ST}_0
	15 ÷ 30	L^{ST}_2	L^{ST}_1	L^{ST}_0	L^{ST}_0	L^{ST}_0
	30 ÷ 40	L^{ST}_3	L^{ST}_2	L^{ST}_1	L^{ST}_0	L^{ST}_0
	>40	L^{ST}_4	L^{ST}_3	L^{ST}_2	L^{ST}_1	L^{ST}_0

V.4. Rating Scales for assessment of drainage conditions

Textural differentiation of the soil profile

The sudden texture differentiation of the soil profile and precipitation conditions determine the surface and intra-profile over-humidifying.

The quantitative-textural differentiation of the profile is calculated as a ratio of the clay content (usually this means the physical clay - particles <0.01 mm) in the heaviest subsurface and lightest surface soil horizon or layer.

Table 7 shows the developed Rating Scale 5 for assessment of texture differentiation.

Table 7. Assessment of texture differentiation of the soil profile

Rating Scale 5.	
Texture coefficient	Levels of restriction L^{TD}
< 1.3	$L^{TD}{}_0$
1.3 ÷ 1.5	$L^{TD}{}_1$
1.5 ÷ 2.0	$L^{TD}{}_2$
2.0 ÷ 2.5	$L^{TD}{}_3$
> 2.5	$L^{TD}{}_4$
The levels cannot be adjusted	

Groundwater level

The high level of groundwater determines the degree of soil swamping - a phenomenon hindering the development of almost all crops. The levels of restrictions (from 0 to 4) to a large extent take into account the conditions for naturally occurring drainage in case of fluctuation of the groundwater level and possibilities for technical implementation. Tables 8a and 8b demonstrate the scales developed for evaluation of this characteristic.

Table 8a. Valuation of the groundwater level

Rating Scale 6a.	
Groundwater level cm	Levels of restriction L^{GWT}
> 300	$L^{GWT}{}_0$
300 ÷ 200	$L^{GWT}{}_1$
200 ÷ 100	$L^{GWT}{}_2$
100 ÷ 50	$L^{GWT}{}_3$
< 50	$L^{GWT}{}_4$
The levels cannot be adjusted	

Table 8b. Adjustments in the valuation of the groundwater level

Rating Scale 6b.						
	Adjustments according to the present conditions for draining activities (%)					
Levels of restriction L^{GWT}	Level of underground water cm	0	25	50	75	100
	> 300	$L^{GWT}{}_0$	$L^{GWT}{}_0$	$L^{GWT}{}_0$	$L^{GWT}{}_0$	$L^{GWT}{}_0$
	300 ÷ 200	$L^{GWT}{}_1$	$L^{GWT}{}_0$	$L^{GWT}{}_0$	$L^{GWT}{}_0$	$L^{GWT}{}_0$
	200 ÷ 100	$L^{GWT}{}_2$	$L^{GWT}{}_1$	$L^{GWT}{}_0$	$L^{GWT}{}_0$	$L^{GWT}{}_0$
	100 ÷ 50	$L^{GWT}{}_3$	$L^{GWT}{}_2$	$L^{GWT}{}_1$	$L^{GWT}{}_0$	$L^{GWT}{}_0$
	< 50	$L^{GWT}{}_4$	$L^{GWT}{}_3$	$L^{GWT}{}_2$	$L^{GWT}{}_1$	$L^{GWT}{}_0$

V.5. Rating scales for assessing soil fertility

Mechanical composition of the soil

The water-physical, mechanical, many of the chemical properties, their air regime, etc. depend on the values of the mechanical composition of the soil. That is why this characteristic is perhaps the most important for the evaluation of agricultural land.

The development of algorithms for assessment of the mechanical composition is a very difficult task. The difficulties stem from the fact that its behavior under different conditions of natural humidity in combination with the content of organic matter is quite dynamic. For example, a slightly sandy-clay mechanical composition (physical clay 20-30%) for many crops when grown in conditions without irrigation is indicated as not so favorable. However, if the area in which this soil is located is moist and it is well cultivated, with a humus content (over 3%), then the situation is quite different.

Moisture storage would be higher, and by adding a better structure, better air regime compared to more clayey soils, the estimates should be adjusted accordingly to higher values. On the contrary, soils with a heavier (clayey) mechanical composition (around and above 75% physical clay) should be assessed more favorable on this indicator in relatively arid areas (moisture retention with predominant clay content is better). However, there are risks of over-humidification in humid climates, and accordingly there the assessments must take this into account.

Due to these reasons, when developing algorithms for assessing the mechanical composition of the soil, despite the latter being treated as a soil characteristic (and not as a quality) of agricultural land, the rating scales need to be adjusted according to the local humidity conditions.

Because the assessment is made according to the specific needs of the plants and more precisely the conditions in the root zone, the arithmetic averaging cannot be used for an adequate assessment. The so-called "weight factors" or "depth adjustments of the indices" can be used as described in a research by C. Sys, E. Van Ranst, J. Debaveye, 1991.

Table 9 presents the developed rating scale for assessment of the characteristic “mechanical composition of the soil”.

Table 9. Evaluation of the mechanical composition of the soil profile

Rating Scale 7.	
Physical Clay %	Level of restrictions L^{TX}
< 10	$L^{TX}{}_4$
10 ÷ 20	$L^{TX}{}_3$
20 ÷ 30	$L^{TX}{}_2$
30 ÷ 45	$L^{TX}{}_1$
45 ÷ 60	$L^{TX}{}_0$
60 ÷ 75	$L^{TX}{}_1$
> 75	$L^{TX}{}_2$
The levels cannot be adjusted	

Root space

When planting agricultural plants, horizontally certain distances and configurations are technologically observed. Vertically, however, what concerns depth, things do not depend on man. The root space is actually the distance from the surface of the soil to a barrier, insurmountable for the roots. This could be a shallowly located solid rock (a so called "D" horizon), extremely strong clay horizon, compacted deposit materials, etc., through which the roots do not grow. The Evaluation Scale 8, which evaluates this characteristic, is shown in Table 10.

Table 10 Evaluation of the root space

Evaluation Scale 8	
Depth to the root barrier cm	Limitation levels L^{RS}
> 130	L^{RS}_0
130 ÷ 100	L^{RS}_1
100 ÷ 80	L^{RS}_2
80 ÷ 50	L^{RS}_3
< 50	L^{RS}_4
Levels cannot be adjusted	

Soil reaction

The soil reaction (pH) represents a negative decimal logarithm of the concentration (activity) of hydrogen cations (H+). There are two methods used for its determination - in a 1: 2.5 aqueous soil suspension (pH in H2O) or in saline suspension (potassium chloride - pH in KCl).

The composition, properties and fertility of the soil depend to a large extent on this soil characteristic. Highly acidic and highly alkaline soils without meliorations are unsuitable for growing crops.

In the Evaluation studies in our country the scale for pH determined in water is used. It is wider and implies greater precision in handling. However, if such data are not available and the reaction is measured in potassium chloride, it is possible to estimate what the values would be in an aqueous suspension as follows:

For pH values (in KCl) ≤ 5.0 pH (H_2O) = pH (KCl) + 0.8
For pH values (in KCl) > 5.0 pH (H_2O) = pH (KCl) + 0.6

The Evaluation Scale 9a (Table 11a) is used to assess soil reaction and is oriented to the requirements of a large number of agricultural crops. The alkaline pH spectrum measured in aqueous suspension above 8.6 excludes the characteristic from the estimates. This is done for the reason that "soil salinity and/or alkalinity" is evaluated as a separate characteristic.

Table 11a Assessment of soil reaction

Evaluation Scale 9a	
Soil reaction – pH in H_2O	Limitation levels L^{PH}
< 5.0	L^{PH}_4
5.0 ÷ 6.0	L^{PH}_3
6.0 ÷ 6.5	L^{PH}_2
6.5 ÷ 7.3	L^{PH}_0
7.3 ÷ 8.6	L^{PH}_1
> 8.6	not assessed
Levels cannot be adjusted	

When funding and technological support are available, the soil reaction limitation levels are surmountable to a large extent. In Table 11b, Evaluation Scale 9b is shown, which is used to adjust the assessments.

Table 11b Adjustments to the assessment of the soil reaction

Evaluation Scale 9b						
	Adjustments according to the availability of means for corrections of pH (%)					
	pH в H_2O	0	25	50	75	100
Limitation levels L^{PH}	< 5.0	L^{PH}_4	L^{PH}_3	L^{PH}_2	L^{PH}_1	L^{PH}_0
	5.0 ÷ 6.0	L^{PH}_3	L^{PH}_2	L^{PH}_1	L^{PH}_0	L^{PH}_0
	6.0 ÷ 6.5	L^{PH}_2	L^{PH}_1	L^{PH}_0	L^{PH}_0	L^{PH}_0
	6.5 ÷ 7.3	L^{PH}_0	L^{PH}_0	L^{PH}_0	L^{PH}_0	L^{PH}_0
	7.3 ÷ 8.6	L^{PH}_1	L^{PH}_0	L^{PH}_0	L^{PH}_0	L^{PH}_0
	> 8.6	-	-	-	-	-

Organic matter content in arable land (humus)

The content of humus in the surface genetic horizon, accumulative sediment or artificially laid layer of soil determines to a very large extent its composition, properties and fertility. Depending on the humus content, under our natural conditions, soils can be classified into 6 classes (Table 12).

Table 12 Classification of Bulgarian soils according to their humus content (according to M. Penkov, 1995)

Classes		Humus content (%)
1.	Deficient in humus	< 1
2.	Slightly humic	1 ÷ 2
3.	Moderately humic	2 ÷ 3
4.	Rich in humus	3 ÷ 4
5.	Very rich in humus	4 ÷ 5
6.	Abundantly stocked with humus	> 5

The amount of humus in our soils is decreasing, which is the result of: the removal of organic matter with the production; erosion processes; stubble burning; poor use of organic fertilizers; application of very high doses of mineral fertilizers, etc.

The amount of humus is of great importance in land evaluation. All other things being equal, humus-rich soils are always more fertile. Low humus contents in soils can be compensated to varying degrees by appropriate fertilization systems, technologically appropriate crop rotations, etc.

In Tables 13a and 13b Evaluation Scales 10a and 10b are shown, developed for the relative assessment of the characteristic "humus content" for agricultural land with recultivated soils.

Table 13a Assessment of humus content

Evaluation Scale 10a	
Humus content %	Limitation levels L^{HC}
> 3.0	$L^{HC}{}_0$
3.0 ÷ 2.5	$L^{HC}{}_1$
2.5 ÷ 2.0	$L^{HC}{}_2$
2.0 ÷ 1.0	$L^{HC}{}_3$
< 1.0	$L^{HC}{}_4$
Levels cannot be adjusted	

Table 13b Adjustments in the assessment of humus content

Evaluation Scale 10b						
	Adjustments according to existing conditions for improvement (%)					
	Humus content %	0	25	50	75	100
Limitation levels L^{HC}	> 3.0	L^{HC}_0	L^{HC}_0	L^{HC}_0	L^{HC}_0	L^{HC}_0
	3.0 ÷ 2.5	L^{HC}_1	L^{HC}_0	L^{HC}_0	L^{HC}_0	L^{HC}_0
	2.5 ÷ 2.0	L^{HC}_2	L^{HC}_1	L^{HC}_0	L^{HC}_0	L^{HC}_0
	2.0 ÷ 1.0	L^{HC}_3	L^{HC}_2	L^{HC}_1	L^{HC}_0	L^{HC}_0
	< 1.0	L^{HC}_4	L^{HC}_3	L^{HC}_2	L^{HC}_1	L^{HC}_0

V.6 Evaluatio Scales for assessing the salinity and / or alkalinity of soils

Salinization is one particularly unfavourable phenomenon for agricultural practice, which is mainly characteristic of arid and semiarid regions. This is a process in which water-soluble salts (chlorides, sulphates, and ordinary soda), toxic to the agricultural plants, as well as exchange sodium, accumulate in the soil.

When the soils contain more than 1% of water-soluble salts that are toxic to agricultural plants, they are conventionally called Solonchaks. When the exchange sodium accumulates in the soil profile above 20% of the sorption capacity (T), the so called alkaline soils - Solonets are formed (Table 14). Due to the specific conditions in Bulgaria, soils of the mixed type of salinity Solonchaks-Solonets and Solonets-Solonchaks predominate.

Table 14 Classification by soil salinity, used in the adopted methodology for work on the cadastre of agricultural lands in Bulgaria (E. Petrov et al., 1988)

Water soluble salts (%)	Exchange Na (%)	Degrees of salinity
< 0.3	< 5	Non-saline
0.3 ÷ 0.5	5 ÷ 10	Slightly saline
0.5 ÷ 0.8	10 ÷ 15	Moderately saline
0.8 ÷ 1.0	15 ÷ 20	Highly saline
> 1.0	< 20	Solonchaks
< 1.0	> 20	Solonets

Saline soils in our country are of great interest because they occupy some of the most flat terrains (plains, valleys, terraces), very suitable for mechanized agriculture, and are located near natural water sources, so their irrigation is much easier to realize and more economical. For these reasons, at first glance, especially if the salts are not on the surface, these lands may seem attractive for agricultural use.

Solonchaks and Solonets (as well as soils with mixed type of salinization) are characterized by very low fertility and require large investments for melioration activities, which are not always justified. Agricultural crops, traditional for Bulgaria, have an extremely wide range of sensitivity to soil salinization.

Based on the above, Evaluation Scale 11a was developed for soil salinity assessment (Table 15a). What is special about it, is that 2 parallel evaluations are performed - one according to the concentration of water-soluble salts and a second one for alkaline salinity /according to the concentration of exchange sodium (Na) in the sorption capacity (T)/.

The overall assessment is considered this one, which takes into account more restrictive conditions. Thus, the most representative estimate is found for pure and mixed types of salinization (Solonchak, Solonets, Solonchak-Solonets, Solonets-Solonchak).

Table 15a Assessment of soil salinity and / or alkalinity

Evaluation Scale 11a			
Water soluble salts (%)	L^{SA}	Exchange Na (% of T)	L^{AL}
< 0.3	L^{SA}_0	< 5	L^{AL}_0
0.3 ÷ 0.5	L^{SA}_1	5 ÷ 10	L^{AL}_1
0.5 ÷ 0.8	L^{SA}_2	10 ÷ 15	L^{AL}_2
0.8 ÷ 1.0	L^{SA}_3	15 ÷ 20	L^{AL}_3
> 1.0	L^{SA}_4	> 20	L^{AL}_4
Final assessment L^{SAAL} = the more restrictive of L^{SA} and L^{AL}			
Levels can be adjusted			

As the problems with soil salinization are, to a different extent, anthropogenically surmountable, Evaluation Scale 11b has been developed (Table 15b), which offers different degrees in the adjustment of the assessments.

The evaluation scales for assessing this characteristic have been developed according to the requirements of a relatively large number of agricultural plants, but with varying degrees of unfavourable assessments, growers must keep in mind that, as already mentioned, that there are crops with different tolerance to salinization. According to literature data (M. Penkov, 1995), some of them can be grouped into 4 groups (Table 16).

Table 15b Adjustments in the assessment of soil salinity and / or alkalinity

Evaluation Scale 11b						
	Adjustments according to existing conditions for improvement (%)					
	Assessment as per Evaluation Scale 11a	0	25	50	75	100
Limitation levels L^{SAAL}	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0
	L^{SAAL}_1	L^{SAAL}_1	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0
	L^{SAAL}_2	L^{SAAL}_2	L^{SAAL}_1	L^{SAAL}_0	L^{SAAL}_0	L^{SAAL}_0
	L^{SAAL}_3	L^{SAAL}_3	L^{SAAL}_2	L^{SAAL}_1	L^{SAAL}_0	L^{SAAL}_0
	L^{SAAL}_4	L^{SAAL}_4	L^{SAAL}_3	L^{SAAL}_2	L^{SAAL}_1	L^{SAAL}_0

Table 16 Salt resistance of agricultural crops (according to M. Penkov, 1995)

Highly sensitive (< 0.25 % salts)	Poorly salt-resistant (0.25 ÷ 0.50 % salts)	Moderately salt-resistant (0.50 ÷ 1.00 % salts)	Salt-resistant (> 1.0 % salts)
Red clover	Caster-oil plant	Sudan grass	Common wormwood
White clover	Sunflower	Alfalfa (Lucerne)	Tamarix
Peas	Corn	Rice	Tropis
Soy	Flax	Sorghum	
Green beans	Oats	Millet	
Beans	Rye	Wheat	
Celery	Carrots	Barley	
Radishes	Sugar corn	Cotton	
Cucumbers	Lettuce	Sugar beet	
Berries	Cauliflower	Rapeseed	
Melons	Pepper	Tomatoes	
Pumpkins	Spinach	Potatoes	
Peaches	Vine	Salad beets	
Apricots		Asparagus	
Almonds		Cabbage	
Plums		Sainfoin (Esparzeta)	
Apples		Onions	
Pears			

V.7 Evaluation scales for assessment of soil contamination with heavy metals and toxic elements

Contamination of soils with heavy metals and toxic elements is a dangerous adverse phenomenon, most often caused by certain types of anthropogenic activity in the fields of industry, agriculture, household, etc. It can be a direct or indirect consequence of these human activities. Except as a local problem, it is increasingly emerging as a global one and the inclusion of indicators of soil contamination (as well as of air and water, if necessary) in the assessment of agricultural land is becoming increasingly urgent.

The peculiarities of parameterizing indicators of this type is that they are most often associated with certain mandatory hygiene standards (for the environment, plant and animal products, etc.), legally adopted at national and international level. Often these are not one-time acts.

For the purposes of this study, we focused on the regulatory framework set out in Ordinance No. 3 (MoEW, 2008) “Standards for permissible content of harmful substances in soils”.

In practice, soil contamination with several soil contaminants is often observed. The developed methodology envisages work with one of them, the so-called "Leading Soil Pollutant" - this SP, whose Measured Concentration (let's call it MCSP) exceeds at most the corresponding Precautionary Concentration (PC). To determine the Degree of Soil Contamination (DSC) with individual SPs, we propose an algorithm shown below in Equation 1.

$$DSC_x = 100(MSCP_x - PC_x)/(MPC_x - PC_x) \qquad (1)$$

Where:

DSC_x - Degree of Soil Contamination with SP_x (%).

$MCSP_x$ - Measured Concentration of SP_x (mg/kg).

PC_x - Precautionary Concentration of SP_x (mg/kg).

MPC_x - Maximum Permissible Concentration of SP_x (mg/kg).

In fact, with the help of the developed Equation 1 the Degree of Soil Contamination (DSC) is determined, expressed as a percentage between the fixed Precautionary Concentration of the pollutant (PC which, for our purposes, we accept as the limitation level $L^{CO}{}_0$) and its Maximum Permissible Concentration (MPC - accepted as the maximum limitation level $L^{CO}{}_4$). Therefore, at DSC values ≤ 0 it is assumed that the assessed land has no limitations regarding soil contamination, and when DSC values are ≥ 100, i.e. exceed the Maximum Permissible Concentration, the most restrictive assessment of level 4 shall be assigned.

Ordinance No. 3 (MoEW, 2008) lists a total of 40 soil contaminants (9 for heavy metals and metalloids and 31 for persistent organic pollutants and petroleum products. Not all of the latter (with few exceptions) apply to agricultural land. However, in order to perform a precise assessment, it is necessary, starting from the pre-cultivation condition of the soil, to take samples, perform analyses, process the results according to Equation 1 for each potential pollutant and on this basis determine the leading one.

In Table 17a the developed scale for up-to-date assessment of the characteristics (Evaluation Scale 12a) of agricultural lands "soil contamination with heavy metals, metalloids, organic pollutants and petroleum products" is shown. When working with it, it is necessary to perform a number of analytical definitions to identify the "Leading Pollutant".

In many cases, although expensive, remediation of such soils is economically justified. In Table 17b Evaluation Scale 12b has been developed, which can be used for potential assessment of agricultural land with recultivated soils.

Table 17a Assessment of soil contamination

Evaluation Scale 12a	
DSC Leading Pollutant %	Limitation levels L^{CO}
< 0	L^{CO}_0
0 ÷ 30	L^{CO}_1
30 ÷ 65	L^{CO}_2
65 ÷ 100	L^{CO}_3
>100	L^{CO}_4
Levels can be adjusted	

Table 17b Adjustments in the assessment of soil contamination under existing remediation conditions

Evaluation Scale 12b						
Limitation levels L^{CO}	Adjustments according to existing conditions for remediation (%)					
	DSC Leading Pollutant %	0	25	50	75	100
	< 0	L^{CO}_0	L^{CO}_0	L^{CO}_0	L^{CO}_0	L^{CO}_0
	0 ÷ 30	L^{CO}_1	L^{CO}_0	L^{CO}_0	L^{CO}_0	L^{CO}_0
	30 ÷ 65	L^{CO}_2	L^{CO}_1	L^{CO}_0	L^{CO}_0	L^{CO}_0
	65 ÷ 100	L^{CO}_3	L^{CO}_2	L^{CO}_1	L^{CO}_0	L^{CO}_0
	>100	L^{CO}_4	L^{CO}_3	L^{CO}_2	L^{CO}_1	L^{CO}_0

V.8 Algorithms for general assessment and categorization of lands with recultivated soils

We adopt the recommendations of the FAO and the experience in Western Europe and offer a modified version of the limitation methods for our conditions by taking into account the number and severity of limitations in the complex assessment of agricultural land, set out below.

The results of the categorization of lands are harmonized with the "Methodology for work on the cadastre of agricultural lands" (E. Petrov et al., 1988), which is currently valid in our country.

Workflow

1. For each individual object of assessment, a database of primary data is compiled, which contains:
2.

<u>Administrative data</u>

- Land as per UCATTU /Unified classifier of administrative-territorial and territorial units/ ....
- Locality ....
- Recultivated site ....
- Area (decares) ....
- Assessment ordered by ....
- Assessment performed by ....

<u>Agro-climatic data</u>

- Σ T^0C for the period with average daily temperatures > 10 ^0C ....
- Average monthly precipitation amounts (mm) June ..... July ...... August ....
- Average relative air humidity (%) June ..... July ...... August ....
- Average monthly air temperature (^0C) June ..... July ...... August ....
- Calculated Evapotranspiration (Evaporation E mm) ....
- Calculated Atmospheric Humidity Balance (B mm) ....
- Indicate Irrigation Availability (% 0; 25; 50; 75 or 100) ....

<u>Data on the topography and stoniness of the soils</u>

- Predominant slope incline (%) ....
- Possibilities for slope adjustments (% 0; 25; 50; 75 or 100) ....
- Stoniness of the arable layer of soil (%) ....
- Possibilities for stoniness corrections (% 0; 25; 50; 75 or 100) ....

<u>Data on drainage conditions</u>

- Texture coefficient ....
- Groundwater level (cm) ....

- Existing drainage possibilities (% 0; 25; 50; 75 or 100) ....

Data on soil fertility

- Mechanical composition (physical clay - particles <0.01 mm %) ....
- Root space (depth to root barrier cm) ....
- Soil reaction (pH measured in aqueous suspension) ....
- Possibilities for pH adjustments (% 0; 25; 50; 75 or 100) ....
- Content of humus (according to Tyurin %) ....
- Possible nutrition regimen adjustments (% 0; 25; 50; 75 or 100) ....

Data on soil salinity and / or alkalinity

- Concentration of water-soluble salts (%) ......
- Concentration of exchange Na (% of T) ......
- Possible adjustments for salinity / alkalinity (% 0; 25; 50; 75 or 100) ......

Data on soil contamination with heavy metals and toxic elements

Pollutants	SP_x[1]	$MCSP_x$ (mg/kg)[2]	PC_x (mg/kg)[3]	MPC_x (mg/kg)[4]	DSC_x (%)[5]
• Pollutant 1	....	....	....	....	....
• Pollutant 2	....	....	....	....	....
• Pollutant 3	....	....	....	....	....

.... to 40 (as per Ordinance No. 3., MoEW, 2008) ....

- Leading SP [........] DSC_x (%)[5] of Leading Pollutant = [..............]

Legend:

[1] SP_x Identified Soil Pollutants (As; Cd; Cu ....).
[2] $MCSP_x$ (mg/kg) Measured Concentration of Soil Pollutant.
[3] PC_x (mg/kg) Precautionary Concentration of Soil Pollutant.
[4] MPC_x (mg/kg) Maximum Permissible Concentrations of Soil Pollutant.
[5] DSC_x (%) Degree of Soil Contamination (as per Equation 6).

3. After compiling the primary database for the object of assessment, the degrees of limitations (L_0 to L_4) are determined for each land characteristic separately through the developed Credit Rating Scales (Sections V.2; V.3; V.4; V.5; V.6; V.7). As can be seen from the scales, two parallel assessments are possible:

- Current - it does not take into account possible adjustments.
- Potential - taking into account possible adjustments.

4. A comprehensive assessment and classification according to the "general suitability for agriculture" of the assessed lands with recultivated soils is performed using the algorithms given in Table 18a below. Depending on which individual assessments we work with, this table also allows two final classifications - current and potential.

Table 18a Comprehensive assessment of agricultural land with recultivated soils and final classification according to general suitability for agriculture

Classes		Units	Criteria
			Land units that:
S_1	Very good lands	(1)	have no limitations
		(2)	or have up to 5 limitations of level L_1
			Land units that:
S_2	Good lands	(1)	have more than 5 limitations of level L_1
		(2)	or have up to 4 limitations of level L_2
			Land units that:
S_3	Moderately good lands	(1)	have more than 4 limitations of level L_2
		(2)	or have up to 3 limitations of level L_3
			Land units that:
N_1	Bad lands	(1)	have more than 3 limitations of level L_3
		(2)	or have up to 1 limitation of level L_4
			Land units that:
N_2	Unsuitable lands	(1)	have more than 4 limitations of level L_3
		(2)	or have more than 1 limitation of level L_4

5. If necessary, the classification results can be adapted to ones obtained by a parametric assessment method (Table 18b).

Table 18b Adaptation of the results of the evaluations obtained by the proposed limitation method to those expected by the parametric method

Classes		Units	Land categories	Evaluation scores
S_1	Very good lands	(1)	I	> 90
		(2)	II	80 ÷ 90
S_2	Good lands	(1)	III	70 ÷ 80
		(2)	IV	60 ÷ 70
S_3	Moderately good lands	(1)	V	50 ÷ 60
		(2)	VI	40 ÷ 50
N_1	Bad lands	(1)	VII	30 ÷ 40
		(2)	VIII	20 ÷ 30
N_2	Unsuitable lands	(1)	IX	10 ÷ 20
		(2)	X	< 10

V.9 Software for practical work with the methodology

The general preconditions that we have set for the software development are:

1. To be implemented in a generally accessible environment, convenient for work even by non-specialists.

2. To use the full set of data provided in the methodology and at the same time to give results from both the individual assessments and the general evaluation and categorization in both aspects - current and potential assessment.

3. To perform a summary final evaluation of the assessed sites in classes and units (according to the recommendations of the FAO) and indicate harmonization with the categorization and parametric scores laid down in the adopted in our country "Methodology for work on the cadastre of agricultural land" (E. Petrov et al., 1988).

4. To provide a printed output, which at the same time to serve as an official document of the assessed land.

The software (Figure 7) is a file-programme implemented in an MsWindows environment (Microsoft Office 10).

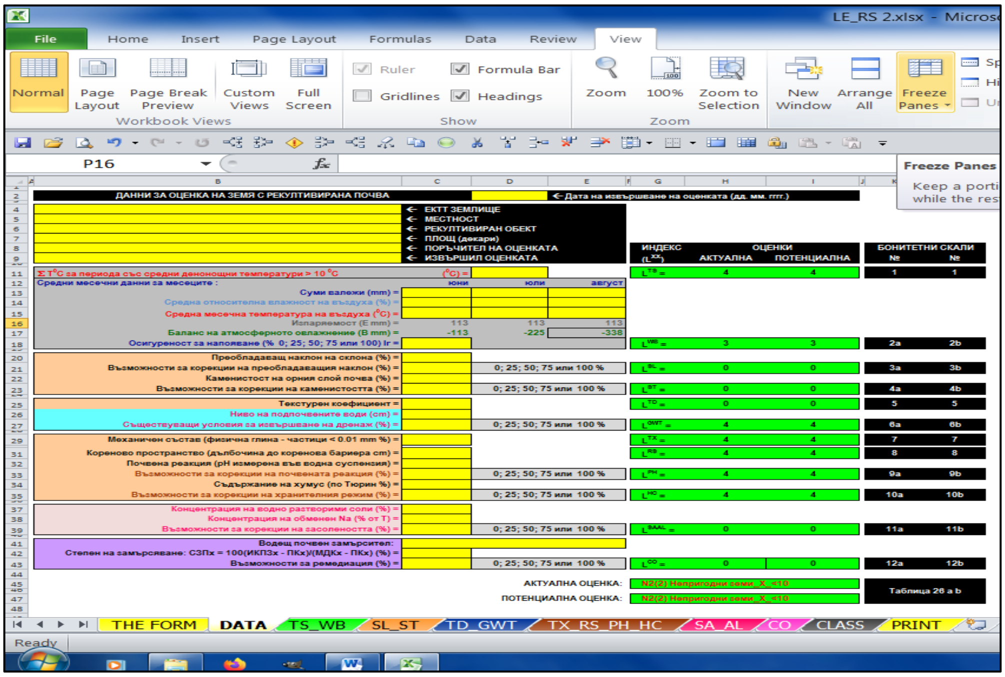

Figure 7 Main working screen of the software for evaluation assessment and categorization of agricultural lands with recultivated soils

For implementation, the functions built into Excel 10 are used. Below we provide a brief description of the 10 worksheets:

Worksheet THE_FORM It is a form that can be printed out and is used for preliminary collection of primary data.

Worksheet DATA This is the main worksheet the evaluator works with. The left part of the screen (yellow cells) is reserved for data entry (pre-collected data from THE_FORM form is entered). The peculiarity here is that the characteristic "Balance of atmospheric humidity for the period June - August" is calculated automatically from the entered primary data for temperature, relative humidity and precipitation.

In the middle columns (cells on a green background), with the entry of the data, the individual assessments of the particular characteristics (current and potential) automatically appear.

When all the data are entered, at the bottom of the screen (again on a green background, but in red font) the final results of the assessments are demonstrated - classification and categorization (current and potential) of the assessed agricultural land with recultivated soil.

The rightmost columns of cells (on a black background with a white font) serve to guide the evaluator-operator on which evaluation scale of the developed methodology the assessments are assigned.

Only cells with a yellow background are available for entries to the evaluator.

Worksheet TS_WB assigns the limitation levels for the agro-climatic characteristics according to the Evaluation scales 1; 2a; 2b.

Worksheet SL_ST assigns the limitation levels for topography and stoniness of the soils according to Evaluation scales 3a; 3b; 4a; 4b.

Worksheet TD_GWT assigns the limitation levels for drainage conditions according to Evaluation scales 5; 6a; 6b.

Worksheet TX_RS_PH_HC assigns the limitation levels for soil fertility according to Evaluation scales 7; 8; 9a; 9b; 10a; 10b.

Worksheet SA_AL assigns the limitation levels for the salinity and / or alkalinity of soils according to Evaluation scales 11a; 11b.

Worksheet CO assigns the limitation levels for soil contamination with heavy metals and toxic elements according to Evaluation scales 12a; 12b.

Worksheet CLASS (Figure 8) On this worksheet, the software reads the individual assessments obtained and compares them as set out in Tables 18a and 18b and performs final evaluation and classification as follows:

1. Five classes of general land suitability for agriculture (C_1; C_2; C_3; H_1 and H_2 in accordance with the FAO recommendations) are obtained, each class having

two units, indicated by Arabic numerals in brackets - "(1)"and" (2)".

2. The resulting classification is harmonized with the land categorization carried out by possible parametric methods, indicating the categories (indicated by Roman numerals) and the limits of evaluation scores.

The final formulation looks like this:

Class (unit) Usability_Category_Score from - to

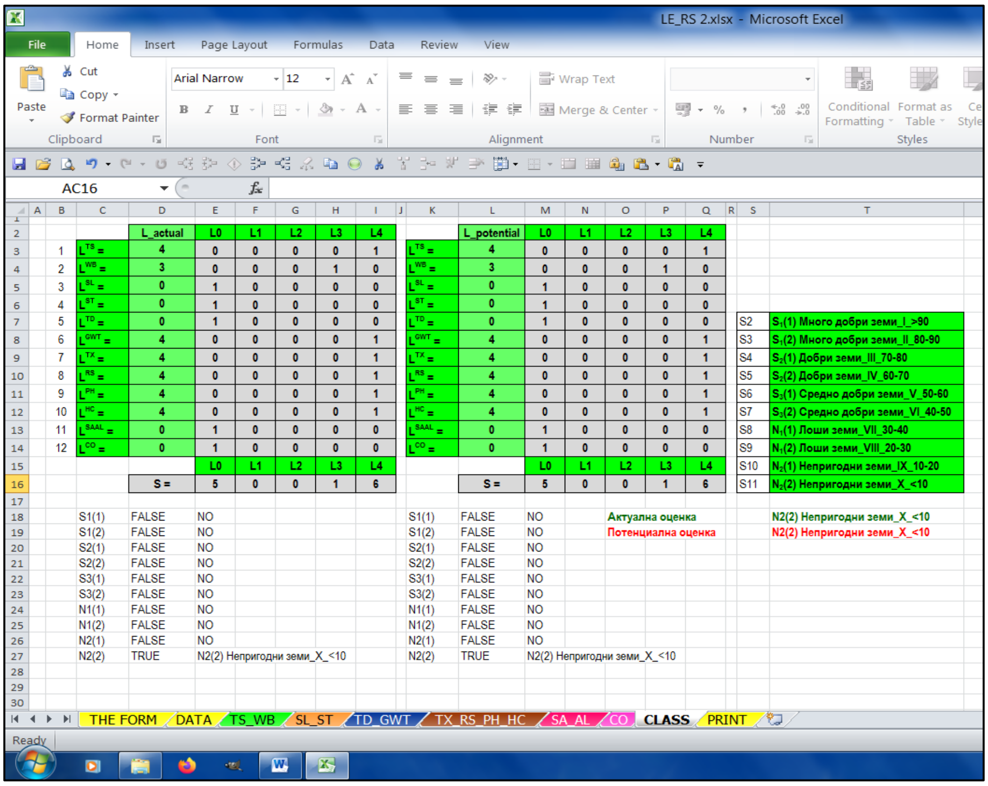

Figure 8 Worksheet CLASS

The cited worksheets use the logical functions built into Excel 2010 - "IF", "AND", "OR", etc. These worksheets are available to the user only as a screen demonstration (they are locked - the evaluator cannot make changes in them). For this reason, as shown in Figure 9, in the working version of the software they are hidden (with the command "Hide"). The operator can always view them (with the "Unhide" command), but cannot change anything on them. The same figure shows the three available worksheets (THE_FORM, DATA and PRINT) that the operator actually works with.

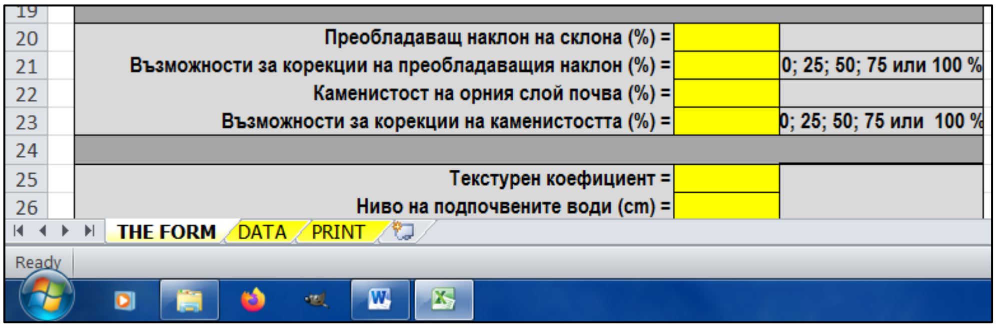

Figure 9 User-friendly worksheets in the main screen

Worksheet PRINT (Figure 10) It is used to print the obtained results. The print output is designed as a document in A4 paper format with the possibility of entering remarks (handwritten after printing) and certification by the signature of the evaluator.

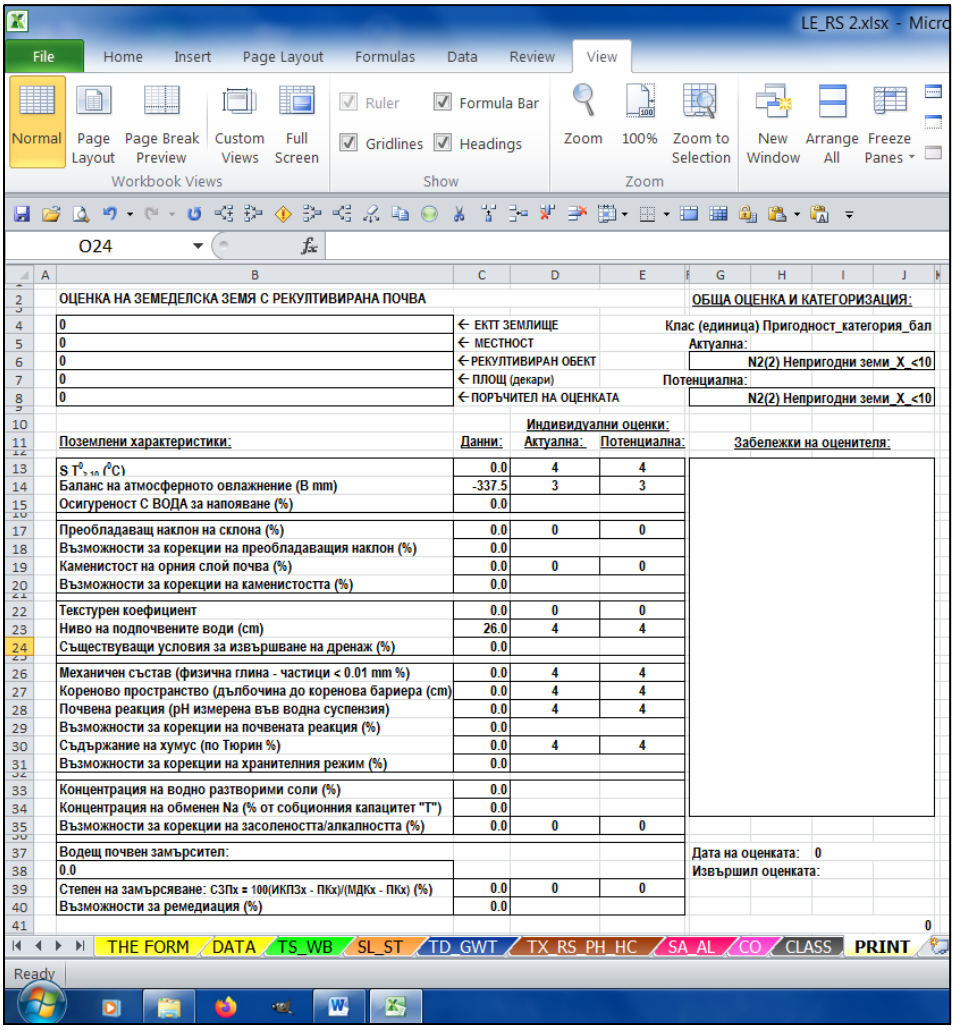

Figure 10 Worksheet PRINT

VI. Conclusions

Bulgarian agricultural science and practice need a methodology for relative assessment of soils after their recultivation. This methodology must take into account the latest scientific researches in Europe and at the same time be in line with the recommendations of the Food and Agriculture Organization (FAO). In addition, it is imperative that the final classification results set out in it be largely comparable to the parametric approach already used in practice.

The developed "Methodology for evaluation and categorization of agricultural land with recultivated soils in Bulgaria" is characterized by:

1. It is an original, newly developed system for relative assessment and classification of recultivated soils entered in the agricultural fund.
2. The chosen integrated "Method of limitations taking into account their number and severity" is recommended by the FAO, but is not applied in Bulgaria.
3. The approaches used provide an assessment of the "general suitability of the land for agricultural use" against the requirements of an extremely wide range of agricultural crops, which has not been assessed so far in our country.
4. The proposed assessment is based on 13 land characteristics, grouped into 6 large groups: <u>(1) Agro-climatic</u> – active temperature amount for the period with average daily air temperatures $t^0 > 10\ ^0C$ and balance of natural atmospheric humidity for the period June-August; <u>(2) Topography and stoniness of the soils</u> – predominant slope incline and stoniness of the arable layer of soil; <u>(3) Drainage conditions</u> – textural differentiation of the soil profile and groundwater level; <u>(4) Soil fertility</u> – mechanical composition of the soil (soil texture, weighted average depth), root space (depth to root barrier), soil reaction (pH measured in aqueous suspension) and organic matter content in arable land (humus); <u>(5) Salinity and / or alkalinity of the soil</u> – content of water-soluble salts and / or content of exchange sodium and <u>(6) Soil contamination</u> – with heavy metals and toxic elements according to current regulations in the country. This set of characteristics implies the most comprehensive relative assessment of the agricultural suitability of the assessed land, while excluding overlapping of individual assessments for the individual land characteristics.

5. The limitations for each characteristic are evaluated on a 5-point scale - L_0 there are no limitations; L_1 minor and slight limitations; L_2 moderate limitations; L_3 there are strict limitations and L_4 there are very strict limitations.

6. In the "Methodology for evaluation and categorization of agricultural land with recultivated soils in Bulgaria", it is envisaged to carry out "actual" and "potential" land evaluation in parallel. The actual assessment answers the question "What is the overall suitability of the land being assessed at the time of the assessment under certain levels of agricultural technics and technologies?". The potential assessment answers the question "What would be the overall suitability of the land being assessed after applying additional options (on a 5-point percentage scale - 0, 25, 50, 75 and 100 %) in order to overcome existing limitations - irrigation, levelling, terracing, soil improvement, drainage, special fertilization schemes, remediation, special agricultural technics and crop rotations, etc.?".

7. The developed final classification scale of the assessed lands is uniform for the actual and potential assessment (Table 27a). In it the lands are divided into 5 classes: S_1 - Very good lands; S_2 - Good lands; S_3 - Moderately good lands; N_1 - Bad lands and N_2 - Unsuitable lands. According to the number and degree of limitations in each of these classes two units are separated /S_1 (1), S_1 (2), S_2 (1), S_2 (2) ... N_2 (1), N_2 (2)/.

8. A scale for comparison of the obtained final results with those after a possible parametric assessment, which is currently performed routinely in Bulgaria on all other agricultural lands, is given. The adaptation scale (comparison of the limiting technique, recommended in the research, with a possible parametric one) is shown in Table 27b. With its help, the "classes" and "units" are translated into the well-known and widely used in practice scale for parametric assessment in "categories" and "evaluation scores". This scale is also aimed at both current and potential relative assessment.

9. The practical use of the methodology is facilitated by the created application for relative assessment of recultivated and / or remediated soils. The application is part of the widely used and accessible MS Office software and in the presence of a correctly collected database of primary data can be used successfully by administrators, land users, landowners, etc.

10. It is recommended that the first assessments be carried out immediately after recultivation, when the soils are handed over for agricultural use. Appendices 1 and 2 give two such examples of recultivation of an ash dump and a saturation field in the land of the town of Gorna Oryahovitsa. The examples are a simplified variant, compared to the possibilities of the methodology, because the sites are in close proximity, i.e. the agro-climatic conditions are the same, the materials used in the reclamation are identical and there is no soil contamination (need for remediation). Comparing the assessments of the surrounding lands with undisturbed soils with those in the recultivated sites, it can be seen that the recultivation was carried out extremely successfully and the quality of anthropogenically created soils fully corresponds to the agro-landscape. These first assessments must be required and reported at the state level in order to create a database of recultivated soils, like the one that exists for the natural ones. Evaluations are also important for direct producers as a technological reference point in their activity.

After a period of time, but not shorter than 5 years and not longer than 10 years, it is advisable to perform another assessment. It is in the interest of landowners to see how soil characteristics change and, in the event of unfavourable values, to consider changing plant technology.

11. What has been achieved in this research can be applied in the following areas:

- ✓ In scientific terms - as a methodology in similar researches, in geographical, environmental and soil studies, training of students, farmers, etc.
- ✓ For working out policies in agriculture, strategies, development programs, etc.
- ✓ In the regional administrations related to agricultural production, absorption of funds, change of land use, etc.
- ✓ In the market environment - this will be useful for organizations and individuals engaged in trade in agricultural land and its products.
- ✓ It is useful for direct agricultural producers when targeting their production specialization.
- ✓ In cases of recultivation of municipal landfills for non-hazardous waste.

VII. Scientific and scientific-applied contributions

As a result of the developed "Methodology for evaluation and categorization of agricultural land with recultivated soils in Bulgaria", the following scientific and scientific-applied contributions can be formulated:

1. Theoretically and practically, a pioneering system for evaluation and categorization of lands with recultivated soils, intended for plant production, has been developed. It aims at a "general assessment of land suitability" (not for a limited set of crops).
2. In the "Methodology" are set two parallel lines - for current and potential (at different levels of investment) relative assessments of the objects of research.
3. For the first time in Bulgaria the more complete version of the "Land Evaluation Limitations Method" recommended by the FAO ("Method of limitations by taking into account their number and weight") has been adapted for work.
4. A set of 13 land characteristics has been compiled, systematized in 6 groups (Table 1), which should be included in the relative assessment. The set is especially important for the adequacy of the assessments. Thus, the possibility of underestimation and / or overlapping (double and triple evaluation) of the individual characteristics is excluded to the maximum extent.
5. Twelve 5-grade evaluation scales have been developed for individual up-to-date assessments of the land characteristics (Tables with numbers 2; 3a; 4a; 6a; 7; 8a; 9; 10; 11a; 13a; 15a and 17a).
6. Eight 5-grade evaluation scales have been developed for individual potential assessments of land characteristics (Tables with numbers 3b; 4b; 6b; 8b; 11b; 13b; 15b and 17b).
7. Adapted and recommended for work is a method for weighing the average data of soil texture (mechanical composition) in the root layer.
8. Equation (Equation 1) has been developed for determining the degree of soil contamination with heavy metals and toxic elements and determining the leading pollutant with which the methodology works.
9. A unified final classification scheme has been developed regarding the general agricultural suitability (current and potential) of the assessed agricultural lands (Table 18a).
10. A scheme has been developed for adapting the results of the evaluations obtained by the proposed limitation method to those expected by the parametric method (Table 18b).
11. Software has been developed for practical work with the achievements in the methodology.

The experimentation of the results proved that the newly developed "Methodology for evaluation and categorization of agricultural land with recultivated soils in Bulgaria" has achieved its objectives, operates adequately and can be applied in practice.