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EXPERIENCE IN ELABORATING THE NATIONAL SYSTEM FOR ESTIMATING THE LAND SUITABILITY

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Under discussion is the FAO algorithm modified to estimate the suitability of lands and soils for agricultural purposes using the definite LUI index (land unit index). The latter is calculated by rating of soil indices taken into complete account and accepted by FAO, USDA (USA) and the Ministry of Agriculture in the Russian Federation. The algorithm and proposed computer programs of interactive expert systems ((ADAPTER, LAND, PLANT) are universal and make it possible to use the indices for solving a number of intricate tasks in off-line regime.

Keywords: estimate of land suitability, indices for estimating the lands

INTRODUCTION

The materials containing information and the data about the soils and soil cover are found to be a basis for inventory of agricultural lands in the country. The regulations accepted by the cadastre survey aimed at estimating the quality of lands is a part of the agricultural land register. The characteristics of soils and soil cover status, the fertility of soils and their degradation resistance should be considered as the most important indices for evaluating a number of soil properties and composition. Not the crop yield but the soils and the soil cover status serve as an indicator and criterion of the land fertility [15].

The regional approach is required to use the indices of soil bonitet, the content of humus and nutrient elements in soils, standards of their suitability for agricultural crops. It means that only the natural-agricultural regionalization should be broadly used with a view of improving the specialization of agricultural production and rational crop allocation[1] in particular.

An ecological aspect of land use is especially important not only from the viewpoint of dangerous technogenic pollution, the sanitary state, etc. The adaptive-landscape technologies should be elaborated to promote the rational use of the soil cover and in the end the long-term economic effect.

It is necessary to estimate the status of soils and soil cover for purposes of regular monitoring over the agricultural lands and their transformation at the territory of farms with different property forms.

THE DATA ABOUT SOILS, INFORMATION

The results of soil studies associated with great effort, labor and economic expenditures should be written in documents, unified and included into the databases and specific GIS open to general use. The experience in elaborating the GIS-technologies has being gained in the country and abroad for more than 30 years. There is a huge volume of data about the soils assimilated in numerous publications, archive materials, databases and different-scaled soil maps. Several maps have been digitized to be an information basis for different GIS now. Before 1988 the total territory of Russia has been mapped at a scale of 1:25 000 and a third part of the territory – at 1:10 000 scale. The means of today's informatics are applicable in soil science for a long period of time [14].

In Internet there is information on soils accounting for hundreds thousand pages (Fig.1A). Even 1% of these data about the required soil indices and those indicating their literature sources give an idea of soils and soil cover at the given territory. The fragment in Fig.1Б shows not only an amount of pages but also the available middle-scale soil maps [17]. The most important characteristics of large-scale soil maps have

[1] One should ascertain that the qualitative assessment of lands has been so far carried out insufficiently. The principle is prevailing to assess the lands not from the viewpoint of the agricultural production and soil fertility but in view of their suitability for the non-agricultural purposes and proximity to the administrative center. By this reason, the price of lands covered by chernozems in Voronezh region seems to be cheaper than that of podzolic soils near Moscow.

A

GOOGLE: *почвы Ленинградской области*

- ***Ленинградская область*** — Википедия
- Даринский А. В. ***Почвы*** // География ***Ленинградской области***. — Санкт-Петербург: Глагол, 2001. — С. 35-39. — ISBN 5-88729-025-0; ↑ Карта растительности **...**
- Природа - История - Население - Экономика
- *ru.wikipedia.org/.../Ленинградская_**область*** - Сохранено в кэше - Похожие
- ***Ленинградская область*** - общая характеристика
- ***Ленинградская область***. На сайте КТМЗ & ARATclub. **...** (леса с преобладанием ели) растут обычно на глинистых и суглинистых, реже- на супесчаных ***почвах***. **...** *ktmz.boom.ru/library/.../index.html* - Сохранено в кэше - Похожие
- Карта ***Ленинградской области***: химическое загрязнение ***почвы*** и воды
- Химическое загрязнение ***почв Ленинградской области*** формируется за счет эмиссий от промышленных объектов, выбросов автотранспорта и размещения отходов **...** *www.cottagesspb.ru/.../tehnogennye/* - Сохранено в кэше - Похожие
- ***Почва*** и почвенные ресурсы
- В данном ресурсе представлены изображения территории в

B

ФРАГМЕНТ ИНТЕРНЕТ-ДАННЫХ

№ Субъект федерации	Площадь (км²)	Население	ИНТЕРНЕТ тыс.стр.	Карты
01 Адыгея	7.600	447.000	292	
03 Башкортост	.143.600	4.103.000	350	1988
05 Дагестан	50.300	2.584.000	575	
06 Ингушетия	4.000	469.000	487	
08 Калмыкия	76.100	292.000	310	
43 Калужская	29.900	1.041.000	4 28	1985
546 Костромская	60.100	738.000	336	
48 Курская	29.800	1.236.000	407	1961,1985
49 Ленинградская	84.000	1.671.000	658	
50 Липецкая	24.100	1.213.000	304	
52 Московская	46.000	6.627.000	2000	1956,1985

Fig. 1. Fragments of pages in Internet to find the data about the soils: A – fragment of the answer; B – report of subjects in the Russian Federation.

to be the detail description of the soil profile location as well as morphological and analytical descriptions. However, one should take notice of the fact that the major data obtained earlier have no coordinates of soil profiles and describes only their location in a number of zonal soils. It is necessary to stress that the soil data are represented by quite different indices characterizing the properties of soils, their composition and conditions for the soil formation. The position of soils recognized at taxonomic levels is also different. In view of this, the unification of soil indices is required to provide their comparability and general interpretation. Nominal, ordinal and arithmetical scales for the obtained data have a varying set of permissible arithmetical operations and methods for their processing [10].

Taking into complete account the demands accepted by State system of standard reference data it seems reasonable to differentiate the soil data according to their truth and accuracy. In the 1980s the V.V. Dokuchaev Soil Science Institute was a leading center in studying the physical-chemical properties of soils. Numerous publications, reference books and reviews made a contribution to operative use of the unified information on the results of soil studies including the standards of soil samples.

The reliable level of data is an important factor responsible for the results of any work. In this context the reference information should be classified as standard, recommended and information one.

The standard reference data include digital values of physical constants, properties of soils studied on the basis of a comprehensive analysis and estimation of reliable results and adopted by State Standard agency. It is advisable to continue the experience gained by the Dokuchaev Soil Science Institute in the formation of standard soil samples.

The recommended reference data include values of physical constants and properties obtained by estimating errors in measuring results. These parameters should be also adopted by State Standard agency. As an example one should mention "Soil Classification and Diagnostics" (1977) and the materials of the land management containing the soil data.

The information reference data contain the whole complex of data about the nomenclature, properties and parameters of the soil quality in a definite period of time. This is the author's studies, personal and corporative databases.

The creation of the soil-ecological database is advisable with the due account of the above differentiation in order to avoid the huge amount of data, the lack of agreement between the classifiers and facet classifications. The main data, information and knowledge may be expressed through the following formula:

Data =*is*=>information=*es*=>knowledge, where the data are represented as primary measurements (including information characteristics), *is* – information system or recommended data and *es* – expert system, declarative and procedure knowledge. The first data are able to answer the questions – *who? what?*, the second data – *how?* It is expedient to consider them as standard reference data.

The characteristics of the soils and soil cover status, the fertility of soils and their degradation resistance are the complex indices substantiating the values of a number of soil properties and composition. By this reason, the information and especially the knowledge is usually represented by empirical or determining formulae and criteria. As an example one should indicate the soil bonitet generalized several soil properties and crop demands; as a verbal information is the soil classification containing the data about the soil taxa. The regional approach is required for indices of soil bonitet, the content of humus and nutrient elements, standards of their suitability for agricultural crops used in instructions to the cadastre survey. For instance, the humus content equaled to 2.5% is very low for chernozems, it is an average value for soddy-podzolic soils and rather high for light-chestnut soils. In view of this, the soil regionalization with the due account of specific soil indices may help to create a soil database.

The organizational aspects have something in common to geographical peculiarities of soils and soil cover. The organization of soil monitoring should be differentiated at federal, regional and local levels. Such differentiation is associated with the types of reference data: information – at local level, recommended data – at regional level and standard data – at federal level. The levels in the soil information are differentiated in the same way [4].

Objective natural (environmental) and organizational aspects determining the demands to represent the data about soils and soil cover may be added by the existing specialization of the agricultural production at a vast territory of the country and diverse forms of land property.

ABOUT THE SOIL-ECOLOGICAL DATABASE

The monitoring of agricultural lands includes the control over the changes in the soil fertility and factors responsible for determining these changes. This is the control over anthropogenic and economic effects on the land productivity. It is worth emphasizing that the crop yield depends on many conditions that can be frequently accidental and independent, for instance – the drought, harmful insects, plant diseases, the seed material of low quality, inappropriate technologies, etc. The properties and composition of soils enable foretell adverse processes leading to degradation of soils, decreasing their productivity or deteriorating the quality of agricultural production.

The structure of the soil-ecological database being corresponded to applied goals of the land monitoring is complicated to a lesser extent as compared to that used for scientific research. It is meant to solve those problems that cannot be formalized without strict algorithms. There exists an experience in elaborating prototypes of expert systems that may serve as a key for the soil-ecological database.

For purposes of soil monitoring a conceptual model of the soil-ecological database has to include cartographic and attributive components, declarative (normative) and procedure knowledge. This database is regarded to temporal systems, i.e. the time is also a parameter taking into consideration. The temporary lag of remote and terrestrial surveys is determined by organizational-technical conditions for the soil register. However, the changes in soil indices prove to be specific. The soil properties have the different characteristic time being distinguished into conservative (soil-memory: texture, the total composition, etc.) and dynamic (soil-moment: porosity, acidity, content of nutrient elements, etc.). The meteorologists recognize as possible the climate changes that are fixed after 30 years, but the short-term changes are considered as weather variations. As regards the soils it is impossible to adhere to such a position. The temporary interval can be different for definite crops and levels of the database organization including local, regional and federal ones.

The important stage is the choice of informative soil-ecological indices so vital for decision-making. The available approaches to integral indices of the soil fertility are beneath criticism [20]. The values of the correction coefficient have no scientific grounds, the depth of the organogenic horizon, the humus content in the topsoil, a share of physical clay, water pH are not sufficient for an integral index. In the USA the soil classification (Soil Taxonomy) is a standard and every soil taxon has a set of diagnostic indices. However, “Soil Classification and Diagnostics” (1977) in the former USSR is rather freely interpreted and there is no guarantee that the given soil has been correctly recognized and named.

The classification is an information system of many objects. The conception of the information base for the classification makes it possible to elaborate an exhaustive soil classification [19, 10]. As a normative block (declarative knowledge) of soils in the country's agricultural zone may serve an expert system of soil classification and diagnostics MERON [16, 4]. This system gives not only the information but also determines the similarity of new descriptions with standards. The attributive content and program of MERON being renewed may be a bearer of standard reference data at all the levels of the database organization.

The soil classification published in 2004 can serve as a basis for standard reference data (standards, typical soil samples, etc.). They are combined with MERON system into the united information system INFOSOIL. Thus, there are possibilities for creating a unified block of classification and description of soils in the soil register permitting to identify new soil descriptions according to their similarity and to consider them as standards in the information system.

The formalized classification of the soil cover structures simplifies the inclusion of the factor responsible for the land fertility into the database of their register (Fig. 2) [1].

Taking into consideration a number of gradations at taxonomic level in the classification of soil cover structures we have the following classification units:

Category x formation x ranks x forms = N:

for microstructures = $2 \times 2 \times 20 \times 3 = 240$

for mesostructures = $3 \times 3 \times 20 \times 12 = 1440$

in total – 1680.

Thus, the diversity of the soil cover structures includes 1680 units. A combination of gradations according to taxonomic levels will serve as a key for the soil cover structure.

Every gradation can have a great number of families and subfamilies differed by composition of soils and their share in the soil complex. To generalize qualitatively the indices for the soil cover structure an algorithm has been elaborated with the due account of soil properties and the contour forms in the soil combination.

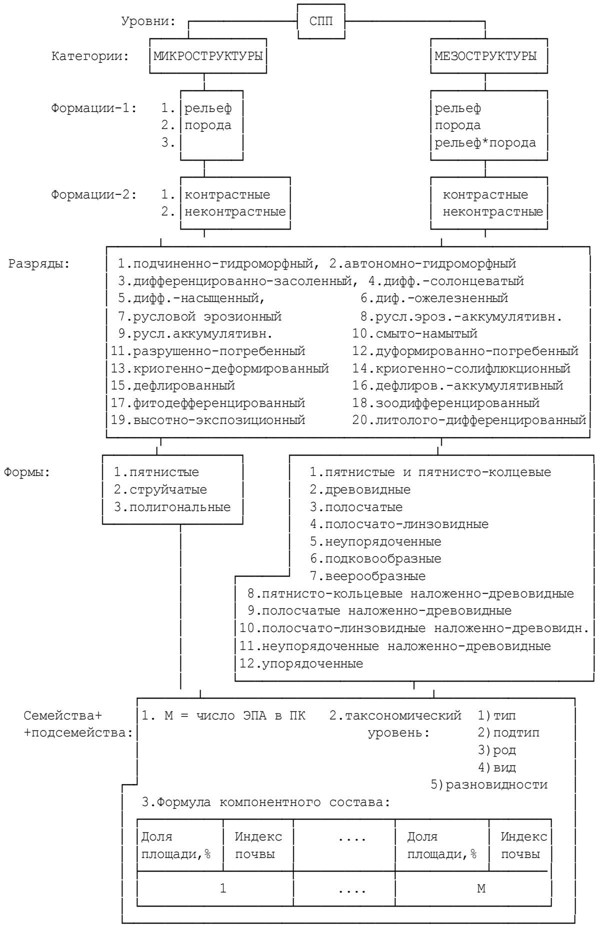

Fig. 2. Classification of soil cover.

Assessment of land suitability for agricultural crops. An expert system LAND intended for estimating the land suitability for agricul tural crops has to serve as a functional key for the database of procedure knowledge [16]. The history of studies with the aim to give a quantitative assessment of the land suitability is rather short. At the same time, they are urgently required for cadastre estimation, for determination of the agricultural area structure, for crop allocation, etc.

Table 1. Ratings and limitations in land use

Code	Limitation level	Rating, %
0	Absent	100–98
1	Weak	97–85
2	Middle	84–60
3	Strong	59–45
4	Very strong	44–0

Such an assessment can be carried out at the level of field, farm or region and determined by the whole complex of soil indices to answer concrete purposes. Under use is an index based upon the soil indices to assess the land suitability [2, 5, 6, 17]. The rating of such indices to detect the suitability or some limitations in land use is conducted in an expert way on the basis of experience gained in the country and abroad (Table 1).

Kinds of integral indices for the land productivity

1. Karmanov I.I. (1990): a soil-ecological index
2. Grinchenko T.A., Egorshin A.A. (1985):
   $Y_i = \exp(-k^*/(X_i - A_i)/(A_i\text{-}B_i)/^{h,}\}$,

where X_i – initial index; A_i – optimum; B_i – the most worse value; k = 5, h = 3 – taken for definite conditions; $X_i > A_i Y_i = 1$.

The combined index of the land quality is

$$P = [Y_i Y_2 \ldots Y_m]^{1/m}$$

3. Linkes (1985) – index of active limiting factor

$$LFA = [(Z_i Z_2 \ldots Z_m)^{(m-2)}/10]^{1/2}$$

4. Magazinshchikov T.P. (1987) an index of total land productivity (P)

$$P = L\ T\ N\ S\ O\ A\ M\ D\ H,$$

where L – rating of the soil depth, T – soil texture, N – base saturation; S – salinity degree; O – humus content; A – cation exchange and character of clay minerals; M – parent material; D – drainability degree; H – moistening degree.

The land productivity is assessed by P value: 100–65 – very high; 64–45 – high; 34–20 – middle; 19–8 – low and 70 – very low.

5. FAO (1976): LUI = 100 ($RiR2 \ldots Ri$), where LUI – land unit index, %; R_i – rating of t-index
6. GIS ADAPTER (1996)

$$LUI = 100\ [(R_i R_2 \ldots R_i)]^{1/t}$$

The assessment of the land suitability for agricultural areas and/or crops taking into account the LUI index is conducted according to the following classes:

Class 1 – (LUI>75%) – suitable lands with the slightly expressed limitation at the 3/4 territory;

Class 2 – (74–50%) – moderately suitable lands with limitation at the 2/3 territory;

Class 3 – (50–25%) – weakly suitable lands with limitation at the 2/3 territory and only one index of severe limitation;

Class 4 – (<25%) – unsuitable lands, their use needs additional measures to be improved. It can be divided into two subclasses. (4a) – practically unsuitable lands with severe limitations at the 2/3 territory but such limitations can be removed and (4b) – unsuitable lands with severe limitations that cannot be removed at all.

When assessing the category of the land suitability it is necessary to take indices affecting the rational use of lands for agricultural purposes (land under crop, hay land, pasture). Among them are relief elements, declivity, drainage and moistening degree, the groundwater depth, land cultivation, erosion, the thickness of the soil profile, texture, the content of stones, carbonates, soil gleying, etc. Special studies or expert estimates are required to determine ratings of indices depending on their significance for the given territory. The totality of such ratings serves as a normative base. In our case the FAO, USD and GIS-Pa recommendations are used and demonstrated in Table 2.

The described approach is illustrated by the dialogic expert system LAND and its realization ADAPTER [16]. The indices with corresponding gradations are shown on the monitor; every gradation has an interval of ratings that can be changed by user in the interactive regime. Having chosen the rating it is possible to obtain expert characteristics of the contour containing a list of indices, their rating, the value of LUI and its interpretation, i.e. the category of land suitability. In the course of calculations the rating can be corrected.

The results can be also represented in cartograms based upon a soil map of the given territory. The color of every contour corresponds to the category of the land suitability.

Table 2. Ratings of soil properties

№	Gradation	Estimate, %
	Relief	
1	Watershed	85–98
2	Slope < 2	98–100
3	Slope 2–5	85–98
4	Central flood plain	60–85
5	Flood plain near the channel	45–60
6	Plain	85–98
	Contour	
1	ESA	85–98
2	Weak contour	85–98
3	Middle contour	60–85
4	Strong contour	45–60
	Cultivation	
1	Uncultivated	45–60
2	Weakly cultivated	60–85
3	Cuultivated	85–98
4	Deeply cultivated	98–100
5	Cultural	98–100
	Drainability	
1	Excessive	60–85
2	Normal	98–100
3	Middle	85–98
4	Weakly expressed	45–60
5	Very weakly expressed	< 45
	Moistening	
1	Weak (dry)	60–85
2	Normal	98–100
3	Episodic overmoistening	85–98
4	Periodical overmoistening	45–60
5	Constant overmoistening	< 45
	Soil compaction	
1	Compact	< 45
2	Weakly expressed	60–85
3	Absent	85–98
	Groundwater depth,m	
1	> 3	98–100 (>60)[*]
2	1.2–3	85–98 (45–60)
3	0.5–1.2	85–98 (< 45)
4	< 0.5	45–60 (< 45)

№	Gradation	Estimate, %
	Erosion danger	
1	No	89–100
2	Weak	85–98
3	Middle	60–85
4	Strong	45–60
5	Very strong	< 45
	Erosion degree	
1	No	98–100
2	Weak	85–98
3	Middle	60–85
4	Strong	45–60
5	Very strong	< 45
	Declinity	
1	< 1	98–100
2	1–3	85–98
3	3–8	60–85
4	8–30	45–60
5	> 30	< 45
	Soil depth, cm	
1	> 200	98–100 (98–100)[**]
2	100–200	85–98 (98–100)
3	50–100	60–85 (85–98)
4	30–50	45–60 (60–85)
5	< 30	< 45 (45–60)
	Texture	
1	Clay	85–98 (60–85)[***]
2	Heavy loam	98–100 (85–98)
3	Middle loam	90–98 (60–85)
4	Light loam	85–90 (60–85)
	Content of stones, m_3/ha	
1	No	98–100
2	< 50 (slight)	85–89
3	50–100	60–85
4	100–200 (strong)	45–60
5	> 200 very strong	< 45
	Content of carbonates	
1	< 25 (no)	95–100
2	25–50 (present)	85–95

№	Gradation	Estimate, %
	Salinity,	
1	Nonsaline	98–100, 85–98, 60–85****
2	Slightly saline	85–98, 60–85, 60–85
3	Moderately saline	60–85, 60–85, 45–60
4	Strongly saline	45–60, 45–60, < 45
5	Very strong saline	45–60, < 45, < 45
	Gleying	
1	No	98–100
2	Slightly gleyed	85–98
3	Gleyic	60–85
4	Gley	45–60
5	Gley	< 45

* In brackets – the saline groundwater depth.
** In brackets – values for a compacted (loose) rock.
***In brackets – the content of skeleton <25% (>25).
****It is shown for the content of Na =5–10, 10–15, >15%.

Table 3. Expert characteristics of the object

No.	Index	Estimate, %
1	Relief	85
2	Cultivation degree	88
3	Drainability	99
4	Moistening	98
5	Ground water	100
6	Erosion	85
7	Erosion degree	85
8	Declinity	65
9	Soil depth	85
10	Texture	85

In total:

Category	Land suitability	Index
1	For the area under crop	87

What is to do? 1 – correction of rating 2 – in conclusion

If LUI <50%, there is a list of limiting factors, i.e. indices which have minimal values of rating:

Category	Land suitability	Index
3	For pasture	43

What is to do? 1–correction of rating 2 – in conclusion

Limiting factors	Rating, %
Contour	20
Drainability	20
Erosion degree	20

The obtained results are presented in a table, where the contour, rating intervals and interpretation of the estimate are given.

No. contour	Rating	Interpretation
0	<25	Unsuitable
1	50–25	Suitable for pasture
2	51–75	Suitable as hay lands
3	76–100	Suitable as the area under crop

Assessment of land suitability for agricultural crops. When assessing the land suitability for any agricultural crop it is reasonable to define the similarity between the crop demands and the indices characterizing the given agricultural area. Every agricultural crop makes definite demands to the soil. A set of such indices – *m* is shown as *Zj*, where *j=1…m* – the number (No.) and amount of indices. For every contour there is a set of indices – *m*, their total amount is given in a table of objects – *Xij* where *i* = 1,…,*n* of areas and *j* = 1…*m* of indices. The matrix of observations has *n* lines what agrees with the amount of contours and *m* columns according to the amount of indices. To assess the land suitability for agricultural crops the following indices should be taken into consideration: the air and soil temperature, the physiologically active radiation, the Ivanov's moistening coefficient, the water supply, the soil depth, the bulk density, the content of physical clay, salt pH, the content of available N, P, K.

There exists an expert system for assessing the soil suitability for agricultural crops "PLANT".

The minimal average difference between the soil properties and crop demands means the best land suitability:

$$d = 1/m \sum_{j=i}^{m} [(X_j - X_{ij})/(X_{maxj} - X_{maxj})]^2.$$

It is evident that for such calculations the computer must keep the description of land contours to assess the land suitability, the description of several real soils, their averaged or modal characteristics, holotypes – the most typical soils. This is illustrated by Fig. 3.

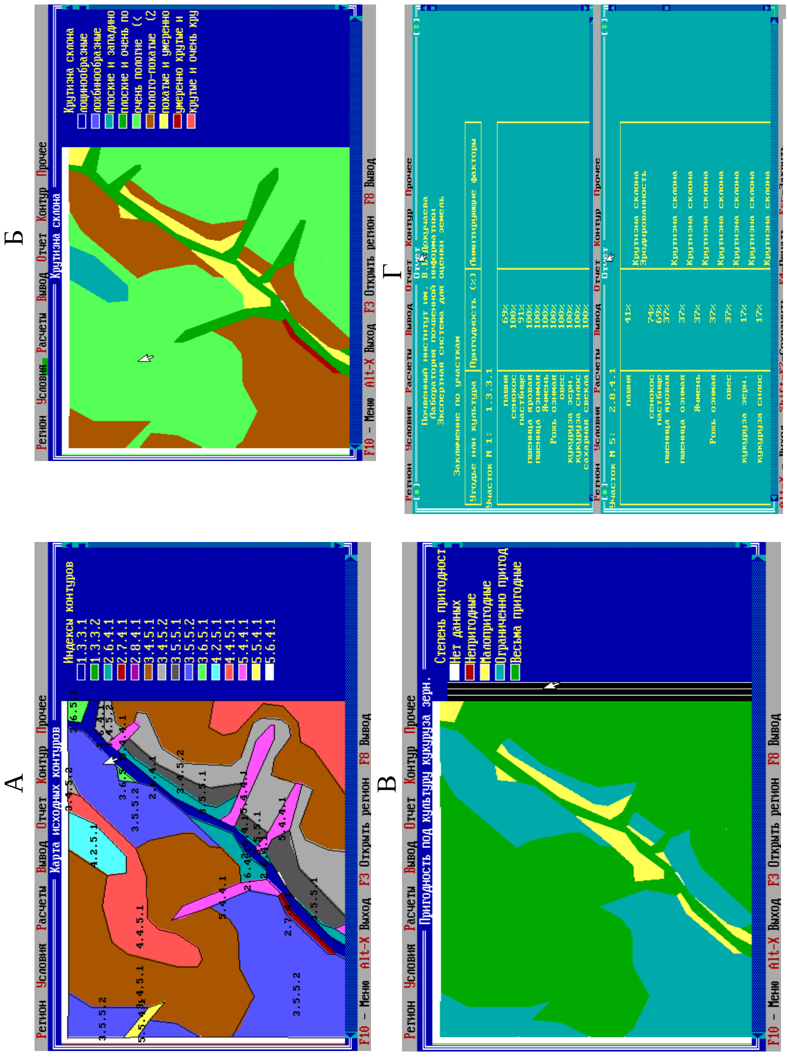

Fig. 3. Fragment of the estimation of the land suitability for crops by PLANT module: А – plan of agricultural land; Б –slope steepness; В – land suitability for maize; Г – report on estimations according to contours of the initial map.

CONCLUSIONS

The program-information modules of the soil-ecological block in the agricultural land register is considered. These means allow unifying the soil diagnostics without using the author's and regional subjectivity in the soil composition and properties. Analogous unified approaches are offered for assessing the erosion danger and preventive technologies to cultivate agricultural crops [12]. Under discussion is also the mechanism responsible for the classification in soil science [13]. To assess the soil suitability for agricultural areas and crops, there is no necessity to use the variation coefficients; quantitative indices of soil fertility and international calculation methods are offered as integral indices of the fertility.

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