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Remote-Geoeconomic Estimation of Agricultural Land Potential of the South of Russia

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Abstract: Problems of geo-economic research methodology application while fulfilling agrarian potential remote estimation are considered in the paper. Methods for geo-economic estimation of agro-ecological potential of soils in the South of Russia with the uses of air-space photography are given. The technologies use satellite images contain a lot of information about the soil state with indicating the precise geographic coordinates. Introduction of the equation of humus content changes (determined by space photography), to the geo-economic model of agricultural lands estimation, provides the possibility of the remote monitoring of soil cost.

Key words: Remote · Geo-economic · Estimation · Agricultural · Land · Potential · Soils · Air-space photography

INTRODUCTION

In the process of agrarian nature management, there arises the necessity to develop measures on the conservation and restoration of nature potential of the South of Russia. In this connection, the main tasks are the natural resources rational use substantiation, land protection measures development, geo-economic estimation of natural resources and ecology-economic estimation of applied agro-technologies efficiency.

Geo-economically oriented nature management and environment conservation have to determine the content and potential of economic system functioning and also to become a real criterion of contemporary economic efficiency [1].

Geo-economic estimation of lands is an important tool for grounding economic expediency and kinds of natural management on an examined territory. For all this, sustainable production of farm produce depends, first of all, on agriculture efficiency increase and is achieved by means of controlling influences on the functioning of its concrete systems.

The adoption of agriculture-landscape systems stimulates farm products production adaptation to various elements of an agro-landscape, farming forms and material resources. Technological decisions are taken on the basis of newest achievements of science and techniques in response to the solution of ecological problems of agricultural production and resource-saving.

According to the data of the State (national) report "About condition and use of the Russian Federation (RF) lands in 2003" [2], only for 12 years since 1991 till 2003 arable land area has reduced by 8.8 million ha and sowing area – by 33.2 million ha.

Soil fertility has declined by 30-60% due to water erosion on arable land. Area of ravines is more than 900 thousand ha, ravine-forming paces total 10-15 thousand ha per year. More than 30% of arable lands are exposed to intensive blowing with the carrying-out of fine earth amounting to 10-17 t/ha per year. Water- and wind-erosion products carrying out not only impoverishes soil, but pollutes surface water springs.

Results of agricultural lands fertility monitoring reveal technological degradation because of agricultural lands agrochemical characteristics deterioration. Large part of yield in contemporary extensive farming forms owing to the soil fertility mobilization without compensation of nutritional elements carrying out with the yield which leads to negative balance of nutritional substances and humus losses.

At present time, noticeable increase of an area of over-moistened, swamped and acidic soils, soils with a poor content of phosphorous and exposed to drought, erosion and deflation, an influence of other negative processes. An absence of systematic monitoring of agricultural lands quality state does not permit to analyze and regulate these processes. Therefore, the switch-over from the 5-year to annual inspection of agricultural lands quality state is necessary.

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The conservation and broadened reproduction of soil fertility are possible only under using scientifically grounded precise (coordinate) farming systems at each farm. Such systems are reliable means for ensuring sustainable agriculture and natural resources conservation. Agricultural systems must be constructed in such a way that humus reproduction in soils and the main nutrition substances content should not require special expenditures, but should be a consequence of measures aimed at the increase of agricultural ecosystems productivity and soils protection from different kinds of degradation.

Soil fertility is a base of farms economic prosperity. Therefore, soil state remote estimation in contemporary conditions is seemed to be economically stipulated basis for the development of measures on its potential conservation and extension.

MATERIALS AND METHODS

A system of the estimation of only one function of soils – their placing locality – has been developed in Russia and is actively used in economic practice [3].

In connection with it, soil indices are not used while estimating this component of soil resources and a value of lands (and, correspondingly, the choice of an economically optimum category of use) is determined on a basis of benefits (renter profit, market cost, economic expenses, public significance) being acquired from placing those or others economic or nature objects (housing, industrial, forest, water etc.). But for agricultural soils, fertility is the most important parameter which is taken now into account only when calculating soils value as a fertility integral index – relative magnitude of a soil properties and indications combined influence on productivity (cropping capacity) of agricultural lands with given soil cover, being measured by estimate scale marks (in a range from 0 to 100) [4].

The methods of the state cadastral estimation of agricultural lands are used in the Russian Federation on a level of subjects. The estimation is made with a method of the rated rent income capitalization. To fulfill these calculations initial information is used such as: main crops real yield capacity for many years, productivity of pastures, of perennial plantations and prices of agricultural produce realization, estimate expenditures for growing main crops, a sowing areas structure in a subject of RF. The cadastral estimation results in basic indices of 1 ha agricultural lands cadastral cost in the subjects of RF.

The method of a separate land site estimation according to a tariff for 1 mark of zonal soils estimate scale, developed by the Soil Institute named after V.V. Dokuchaev, is used while observing the condition of a soil cover (with a help of soil-ecological index calculation for the period from one round of observation to another) and to estimate the positive or negative change of fertility in money as a result of human production activity. Two principle components lay in the method base: soil-ecological index – a estimate scale mark, reflecting a level of soil fertility taking into account concrete conditions and an estimated site soil type tariff category.

The soil-ecological index calculation is based on soil-agrochemical investigations results and climate conditions of a region. An index magnitude is the product of the soil, agrochemical and climatic indices which calculation is made with the help of coefficients reflecting an influence of either indices on a soil fertility level.

An area unit income divided by an index rate gives 1 mark tariff expressed in cadastral prices.

However, such an estimation method is expensive one and demands conducting additional field, cartographic and laboratory research.

Taking into account the aforesaid, it is possible to note that soil fertility losses are mostly connected with a humus waste. Therefore, humus content may appear as an economic criterion serving for the soil cast determination.

RESULTS AND DISCUSSION

Humus content in soil, being an indication of ecological condition, can be reliably defined by space-photographs, it gives a possibility to pass on the ecology-economic monitoring of soils in agro-landscapes. The possibility to connect space-photography materials of soil with its humus content [5], also data on soils characteristics, ensure the soils cost estimation and on this basis – the determination of a damage from degradation or profits from melioration measures.

The calculation of a value of soil humus is made by expenditures for its replacing with organic fertilizers [6]. If organic fertilizers cost is known, it is possible to count the cost of humus in soil. In our case, 1000 rubles per 1 ton (year 2007) can be assumed as a basis price of organic fertilizers [7].

The humus cost calculation method use allows defining the cost of soil in a landscape by humus content. In spite of this the basis cost of one ton of humus C_{BH}:

$$C_{BH} = C_{OM}/K_S \quad (1)$$

Where: C_{OM} - market cost of 1 t organic fertilizer; K_S - coefficient of substitution (humification).

According to given materials, a coefficient of substitution K_S for horned cattle (HC) manure is equal to 0.25.

Humus cost on 1 ha of plough land is defined by the cost of organic fertilizer required to substitute available in soil humus.

Taking into account that the weight of 1 ha plough land G_P is defined by a formula:

$$G_P = 10000 \cdot b \cdot \gamma, \text{ t} \quad (2)$$

Where: b – tillable horizon depth, m; γ – specific mass of soil, t/m^3 and knowing humus relative content in soil H, it is possible to define humus mass G_H on 1 ha of plough land by a formula:

$$G_H = H \cdot G_P, \text{ t} \quad (3)$$

The substituting organic fertilizer amount G_{OFsub} is defined by a formula:

$$G_{OFsub} = G_H / K_S, \text{ t} \quad (4)$$

The cost of substituting organic fertilizer C_{OFsub} on 1 ha of plough land is defined as

$$C_{OFsub} = P_{OF} \cdot G_{OFsub} \quad (5)$$

Where: P_{OF} – price of 1 t organic fertilizer.

The cost of humus on 1 ha of plough land C_{Hha} is equal to substituting organic fertilizer cost C_{OFsub}.

An example of the calculation of humus cost on 1 ha is given in Table 1. The calculation reflects an alteration of 1 ha agricultural land cost in the modeling version when changing humus content (1 - humus content in ploughing horizon of agricultural lands is 2.7%, 2 - humus content in ploughing horizon of agricultural lands is 2.8%).

The state of soils can be defined by air-space monitoring on the basis of developed method for determining humus content in soil.

A formula for determining 1 ha soil cost C_{SH} taking into account humus content according to space photography is as follows:

$$C_{SH} = 10000 \cdot K_{ST} \cdot e^{-0.0276f} \cdot b \cdot \gamma \cdot P_{OF} / K_S \quad (6)$$

Where: K_{ST} – coefficient of soil type; f – phototone of an open soil (ploughland) surface image.

The proposed method realization is presented in Tables 2, 3. Ploughland degradation thematic maps created as the monitoring result give a possibility both to define areas of sites with different humus content at a test polygon and to determine the cost of contained here humus.

Proposed approach allows conducting the permanent monitoring of ploughland aimed at its cost estimation, calculation of means necessary for its fertility well-timed restoration.

The cost of soils on sites of the examined field with corresponding levels of degradation is given in Table 3.

The definition of the degradation level, magnitude and place of degraded areas location permits to create a space-photo-map of humus distribution over a field. It has a great significance both for ascertaining ecological state and defining the humus supplying cost.

On the base of the considered method use, it has been defined that humus content changes from 0.85 to 4.34%. The lesser value corresponds to the washed off sites of the field with a 2-3 º slope. Sites having the greatest humus content are on more gentle sloping plots of the field and in depressions.

Table 1: Cost of 1 ha agricultural lands depending on humus content.

No.	Parameter	Version 1	Version 2
1.	Chestnut soil density in ploughing horizon, t/m^3	1.2	1.2
2.	Ploughing horizon depth, m	0.2	0.2
3.	Mass of 1 ha soil ploughing horizon, t	2400	2400
4.	Humus content in ploughing horizon, %	2.7	2.8
5.	Mass of humus in ploughing horizon on 1 ha, t	64.8	67.2
6.	Coefficient of substitution (humification) for HC manure	0.25	0.25
7.	HC manure quantity substituting soil humus, t	259.2	268.8
8.	Market cost of 1t HC manure, rubles	1000	1000
9.	Cost of humus on 1 ha, rubles	259200	268800

Table 2: Estimation of degradation level at test polygon sites.

Level of degradation	Average phototone	Amount of pixels	Areas ratio, %	K_{ST}	Humus, %	Area, ha
Normal	93.42	104443	26.59	57.4	4.36	37.12
Risk	101.59	128406	32.69	57.4	3.48	45.64
Crisis	109.59	128406	32.69	57.4	2.77	45.86
Disaster	152.58	30918	7.87	57.4	0.85	10.99
Total		392784	100			139.61

Table 3: Cost of soils on various degradation level sites.

Degradation level	Area, ha	Cost of 1 ha, rubles	Cost of soils, rubles
Norm	37.12	418560	15536947
Risk	45.64	334080	15247411
Crisis	45.86	265920	12195091
Disaster	10.99	81600	896784
Total	139.61		43876234

CONCLUSIONS

Remote-geoeconomic estimation of the soils agricultural potential is the methodological basis for the development of new technologies for their conservation and recovery. These technologies use satellite images contain a lot of information about the soil state with indicating the precise geographic coordinates. The studies found a correlation between the content of soil humus and the amount of phototone image of arable land on the satellite images developed the equation that defines this relationship. It is determined that regularities for different soils types remain constant, with changing coefficients. It should be noted that the equation is developed for soils located in the air-dry condition. In this regard, the satellite imagery must be taken, when the weather is dry. When the humidity changes it is necessary to use additional components in the equation. With the introduction of the equations in the model it geo-economic valuation of agricultural land there is a possibility of carrying out this assessment by imageries.

The applications of the proposed method using aerial mapping and monitoring to assess the content of humus in the soil gives the opportunity to obtain data on the distribution of degraded sites over the agricultural area (plantation, a farm field and others), to assess the damage from the reduction of fertility and to determine the necessary costs for restoration of fertility not approximately, on the whole, but exactly at each site in accordance with the level of its degradation. The economic effect of the application of the proposed method consist not only in quick and accurate assessment of the value of soils on the agricultural lands, but also in reduction of the amount of field work.

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