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INTEGRAL ESTIMATE OF TERRESTRIAL COMPARTMENT CONDITION IN MANAGEMENT OF BIOTECHNOSPHERE OF RURAL AND URBAN AREAS.

Ivaschuk O. A. , Polschykov K. A., Lazarev S. A., Ivaschuk O. D., Fedorov V. I.
Belgorod State University, 85, Pobedy St., Belgorod, 308015, Russia.

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Abstract

The method for integral estimate of current and forecast condition of soils in rural and urban areas is considered in the article. Appropriate situational models are developed to implement this method on the basis of fuzzy logic and GIS-technologies.

The work is carried out in the frame of the completion of state tasks in the sphere of scientific activities within Project № 671 "Development of intellectual technologies of monitoring and forecasting ecotechnology-related risks and management of technosphere safety of the territories" (Customer –Ministry of education and science of the Russian Federation)

Keywords: Situational modelling, environment, integral estimate and forecast, linguistic variable, fuzzy logic.

Introduction.

Today one of the most important and rapidly growing sectors of the Russian economy is construction, as well as the corresponding non-manufacturing component - housing and communal services, the condition of which largely determines the level of economic development of regions and affects the general employment. Due to the influence of the expansion and densification on modern urbanized and suburbanized territories anthropogenic transformation of the biosphere is constantly going on. Rural and urban areas should be paid special attention, because their natural environment quality affects the residents' health and vital activities greatly. One of the important components of the biosphere in rural and urban areas is a terrestrial compartment. Contaminants entering the soil can be spread through the soil profile and accumulate in high concentrations in the upper horizons. These processes affect both the possibility of agricultural crops being mown and the contamination of contacting media (water, air) significantly affecting the people's health and vital activities. [1] In connection with the foregoing there arises the problem of adaptive and effective management of the terrestrial compartment quality of rural and urban areas. At the same time in order to improve the efficiency of information support of this process it is necessary to carry out the integral assessment of the soils conditions of rural and urban areas.

The main part.

The analysis, the results of which are provided in the articles [2,3], showed that the soils condition is described by a large number of different parameters. An integrated approach is required for the soils quality effective control. Meanwhile, until recently none of the existing ecological systems and monitoring services was focused on an integral assessment of soil condition of rural and urban areas, as well as information support of integral environmental goals.

There are no measuring devices that can provide an accurate integral estimate of the soil condition as a characteristic of the aggregate condition of its components. Such an estimate can only be carried out qualitatively and expressed with the use of a natural language and linguistic variable taking values in the form of "favorable", "unfavorable", "satisfactory", "unsatisfactory", etc. [4-8]

While applying an integral approach at the initial stage it will be enough for the decision makers (DM), who make decisions about the need for soils condition control, to obtain such a qualitative assessment as:

Soil condition is "unfavorable".

This is an analogue of an alarm lamp. At this level a decision maker does not know the cause or the level of negative changes exactly, but he has a signal that it is necessary to generate management scenarios.

On the basis of the foregoing the soils condition, which already exists or is forecast, when the settings of the biotechnosphere change, is described by the linguistic variable "Soils conditions", provided in the form:

$$\{SoilSt, T, SS, G, H\}, \qquad (1)$$

where SoilSt is the name of the variable [3], T is a basic term set, SS is a set of quantitative characteristics, on the basis of which it is possible to determine the membership of the values of SoilSt as ones within the range of T; G – a set of syntactic rules for the formation of new values SoilSt, wch are not included in the basic term set (e.g. "very poor", "more or less favorable"); H –mathematical rules that allow you to convert a new name formed by G into a fuzzy variable, namely, specify the type of the membership function. The dimensions of the basic term set determine the selected accuracy of the estimate. The minimum accuracy of an integral qualitative estimate of soils conditions on rural and urban areas is determined by two basic terms: T_1 = 'favorable' T' = 'unfavorable'. The total number of terms in the basic set for sufficient differentiation of estimate is defined to be equal to 4:

$$T = \{T_1, T'\} = \{T_1, T_2, T_3, T_4\}, \qquad (2)$$

– T_2 = "moderately hazardous". This estimate is provided in several cases:

- when the chemical composition of the soil allows its use for growing any crops on the condition the quality of crops is checked and has little impact on the health of the population living in the area;

- when the chemical composition of the soil limits its use to cultivation of a number of agricultural crops and has no effect on the health of the population living in the area.

– T_3 = "highly hazardous ". This estimate is provided in case if both characteristics are combined: the chemical composition of the soil limits its use to the cultivation of a number of agricultural crops and it has no significant impact on the health of the population living in the area;

– T_4 = "extremely hazardous". This estimate is provided in case if the soil is unsuitable for growing crops and has a significant impact on the health of the population living in the area.

For the formation of the above detailed differentiation of the term-sets (2) we used the method of expert estimations in the form of individual questionnaires and interviews conducted with the anonymity of the experts' answers in relation to each other in order to eliminate the influence of conformism, as well as with the quantitative estimate of the coherence of the experts' judgments.

The analysis shows that SoilSt is a composite linguistic variable, respectively, the process of classification of soils conditions in rural-urban areas and detalization of the basic term-sets are associated with the analysis of the interaction of the parts included in SoilSt:

$$SoilSt = (SoilSt_{CX}, SoilSt_{3}), \quad (3)$$

where $SoilSt_{CX}$ – a linguistic variable characterizing the soils condition in rural-urban areas from the perspective of the influence of the chemical composition on the soil's suitability for agricultural needs; $SoilSt_3$ – one characterizing the rural-urban soils condition from the perspective of the effect of the chemical composition on the residents' health.

Moreover, further detalization of the introduced variables is necessary:

$$SoilSt_{CX} = (SoilSt_{CX1}, SoilSt_{CX2}, \ldots, SoilSt_{CXi}, \ldots, SoilSt_{CXI}),\ i = \overline{1, I},$$
$$SoilSt_{3} = (SoilSt_{31}, SoilSt_{32}, \ldots, SoilSt_{3j}, \ldots, SoilSt_{3J}),\ j = \overline{1, J}, \quad (4)$$

During the detalization of $SoilSt_{CX}$ parameters it is necessary to meet the following requirements:

– the choice of those components of the soil that are most vulnerable to the negative impacts on the territory under consideration;

– the choice of those parameters that reflect the behavior of chemical contaminants and (or) physical types of pollution, which cause the greatest danger because of the large volumes of their discharge, toxic properties, characteristics of transferability, ability to accumulate and resistance to decay, as quality indices.

During the detalization of $SoilSt_З$ parameters of the urban agglomeration territory it is necessary to comply with the following requirements:

– the choice of those parameters of the soils in rural and urban areas, which have a significant impact on the residents' health;

– the choice of those parameters, which are really manageable, as indices.

Similar to (1) let us introduce the description of linguistic variables $SoilSt_{CX}$ and $SoilSt_З$:

$$\{ SoilSt_{CX}, T_{ПС}, SS_{CX}, G_{CX}, H_{CX}\}, \quad (5)$$
$$\{ SoilSt_З, T_З, SS_З, G_З, H_З\}.$$

where T_{CX} and $T_З$ – basic term sets, which specify the values of linguistic variables $SoilSt_{CX}$ and $SoilSt_З$, respectively; T_{CX} – a fuzzy variable within numeric set SS_{CX}, the elements of which are considered to be the soils conditions parameters that characterize its suitability for agricultural use; $T_З$ – within $SS_З$, the elements of which are considered to be the soils conditions parameters that characterize its impact on the residents' health. The minimum accuracy of the estimate is determined by two main terms:

$$T_{CX1} = «favorable», \; T_{З1} = «favorable»,$$

$$T'_{CX} = «unfavorable», \; T'З = «unfavorable»,$$

As a result, the classification of SoilSt is divided into the analysis of the interaction of a number of parts that will be included in the composition of the linguistic variable "Soils conditions" that will allow forming the dependence of the result on the combinations of elements of this variable (synthesizing the result).

In order to define the introduced multivariate dependencies we build the corresponding sets of conditional rules of inference "if "set of conditions", then " inference". It is a set of predicate rules of the type, for example, SolidSt [9]:

if ($SoilSt_{CX}$ is T_{CX1}) and ($SoilSt_З$ is $T_{З1}$)

or ($SoilSt_{CX}$ is T_{CXn}) and ($SoilSt_З$ is $T_{Зm}$)

… (6)

then SoilSt is T_l,

where T_{CXn} ($n = \overline{1,N}$) and T_{3m} ($n = \overline{1,M}$) – fuzzy terms, which are used to estimate linguistic variables $SoilSt_{CX}$ and $SoilSt_3$ respectively, $T_{CXn} \in T_{CX}$, $T_{3m} \in T_3$; SoilSt = T_l ($l = \overline{1,L}$) – values obtained on the basis of the rules of fuzzy inference. Since linguistic variables $SoilSt_{CX}$ and $SoilSt_3$ are also composite, a conditional set of rules is built for them in similar way (6). Each numerical value of sets SS_{CX}, SS_3 (experimentally measured or forecast with application of specially developed mathematical models) corresponds to the degree of membership of the value to term T_{CXn} or T_{3m} according to the membership functions $\mu_{T_{CXn}}$and $\mu_{T_{3m}}$ specified in certain way. The rules' inferences about the membership of the established (or forecast) environmental situation to a certain term T_l are also made according to the specified membership functions $\mu_{T_1}, \mu_{T_2}, \ldots, \mu_{T_L}$

In this work the degree of membership to a particular level of the rating scale: SS = {1,2,3,4,5} is defined as the resulting estimate of the soils condition in the area under study (values SoilSt). The numerical expression of the degree of membership, as it is outlined above, is represented by the value of the membership function. When building membership functions $\mu_{T_{CXn}}$, $\mu_{T_{3m}}$ and μ_{T_l}, it is necessary to use the experts' general knowledge and experience in the subject area, data of official statistics and specially organized monitoring, as well as the results of their scientific analysis and regulatory documents (Sanitary Rules and Regulations, etc.). On this basis the type and parameters of the corresponding membership functions were determined. For example: the modal value of a triangular membership function is defined by expert knowledge about the value, which is the most typical for this linguistic variable; the linear portion of a trapezoidal membership function is determined by the values, which equally influence the formation of a given situation; the Gaussian membership function can be rationally applied if it is doubtful to attribute a specific value to a specific group that is one of the groups, which the linguistic variable is divided into. In order to make inference on the basis of fuzzy logic different algorithms can be used: Mamdani, Tsukamoto, Sugeno, Larsen, which are based on four basic steps: introduction of fuzziness; inference; composition; reduction to accuracy [10]. The algorithm of integral estimate of rural and urban soils is presented in figure 1.

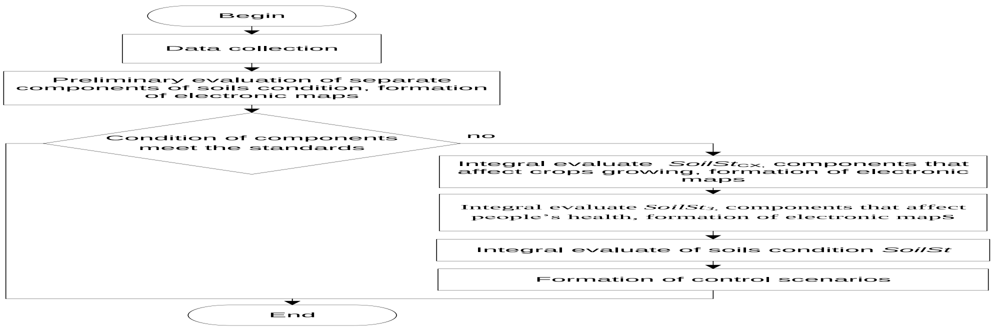

Figure 1 - Algorithm of integral evaluate of soils condition in rural and urban areas.

It should be noted that provision of ecological information that is obtained through instrumental monitoring and computer modeling (for decision makers, as well as the media and great masses of population) is directly related to visualisation and spatial data analysis. The most optimal is the use of geoinformation technologies (GIS-technologies) due to the fact that the results of environmental monitoring are always geo-referenced [11]. In this work we propose formation of GIS layers for the development of electronic maps reflecting an integral estimate of the soil condition in the considered urban-rural areas: both current and forecast (subject to changes of the weather conditions and implementation of various management scenarios). Electronic maps for the area under consideration, which reflect its soils condition (with specific parameters of external influences including background pollution) meeting the requirements of Sanitary Rules and Regulations are computer models of favorable condition of soils. Allocation of the areas, in which there are deviations from "favorable" of different levels, i.e. appearance of such characteristics as "moderately hazardous", "highly hazardous" or "extremely dangerous" on the electronic maps are computer models of unfavorable environmental situation. More detailed computer models correspond to each such model.

Conclusion.

We developed a method of situational modeling and models of its implementation. These are the models of integral estimate of current and forecast conditions of terrestrial compartment in rural and urban areas, which provide the opportunity for effective functioning of the intelligent management system to control biotechnosphere in these areas. The situational models are based on the use of linguistic variables and fuzzy logic; they allow evaluating the dynamics of soil conditions depending on the change of the aggregate condition of its main components. The result the integral model evaluation is represented in a qualitative form with assignation of a certain rating (with some degree of membership); the result is also displayed on the electronic map.

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