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THE MODELING OF THE AGRO-CLIMATIC RESOURCES INFLUENCED ON THE FORMATION OF THE CROP PRODUCTIVITY

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ABSTRACT

The research is to develop model for regional agro-climatic resources, affected on the crop productivity, on the basic of the concept of maximum plant productivity. The results of the modeling of yield formation and the methods of the microclimatic variability assessment for climatic elements in the hilly relief are performed.

Keywords: ***Modeling, agro-climatic resources, plant capacity in production process, agro-ecological category of productivity, ontogenetic curve of photosynthesis, soil fertility***

1. INTRODUCTION

To take into account effects of climate on agricultural production efficiency the determination of regional agro-climatic resources, realized by its agro-climatic zoning, should be done.

One of the general conditions of good agricultural practice is the most rational and complete use of climate resources. Thereby the study of climatic security for the crops yield formation taking into the account the features of regional microclimate has great scientific and practical meaning.

2. LITERATURE REVIEV

Taking in to the impact of climate change on agricultural production efficiency, the main thing is to determine agro-climatic resources of the territory, which is realized by means of their agroclimatic zoning.

There are quite a number of works (Azzi, 1959, Dimitrenko, 1975, Koloskov, 1953), in which an attempt to evaluate agro-climatic resources with physical-statistical models of the formation of crop yields was made.

One of the fundamental directions of estimation of agroclimatic resources is the one developed in the works of Korovin, 1981, Abramov, 1987, Dyubin 1993, Korneev, 1993, Korneeva, 1993, connected with the solution of the task of the agroclimatic characteristics of crops in connection with the selection and sufficient placing of crops.

To estimate the potential productivity of crops Heino Tooming (Tooming, 1984; Sepp, Tooming, 1991) has proposed a method of “standard crop”, which is the logical conclusion from the principle of maximum plant productivity.

Basing on the development and deepening of the well-known concept in plant ecology, the plant grows and develops normally only when its life cycle coincide with favorable environmental conditions, and the latter have stochastic nature. Zhukov (1989, 1998) formulated a new direction in the direction in agroclimatic resources estimation of - creation complex models of pattern recognition «climate-crop» that allow to keep a record of agro-climatic resources of the territory by identifying the risk and losses of particular crop due to unfavorable weather conditions. The studies of Zoidze (1998) for agricultural appraisal of the climate are also made within the specified direction.

International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

Sirotenko (2000) established the information system «climate – harvest», based on the use of dynamic models of the production process of plants, which has been successfully used to estimate the impact of possible climate change on agricultural productivity in Russia.

3. THEORETICAL CONTEXT

The basic model for evaluation of agro-climatic resources has a block structure and contains of 6 blocks:

- the input information;
- indicators of solar radiation and moisture-temperature regime with exposure of a field;
- functions of influence of the development phase and meteorological factors on the production process of plants;
- soil fertility and plant mineral nutrition availability;
- agro-ecological categories of yields;
- general estimating characteristics.

Look more closely to these blocks.

Block of input information contains data of standard meteorological and agro-meteorological observations and includes all the necessary characteristics to perform the calculations. The information is divided into 3 groups:

1. The reserves of productive moisture in the soil, the average per decade air temperature, the average per decade amount of sunshine hours , the amount of precipitation per decade, the average per decade deficit of humidity, the amount of days in the decade;
2. The doses of application of nitrogen, phosphorus and potassium fertilizers, optimal doses of fertilizers, the doses of application of organic fertilizers and its optimal dose, the year of application of organic fertilizers, soil site class rating;
3. The exposure and steepness of a slope, which the field is located, the characteristic of the slope type and the field location on the slope.

Block of parameters of solar radiation and moisture-temperature regime with exposure of a field. The total solar radiation intensity can be calculated by the formula of S.I. Sivkov (Sivkov, 1961):

$$Q_o^j = 12.66\,(SS^j)^{1.31} + 315\,(A^j + B^j)^{2.1}, \qquad (1)$$

where Q_o – total solar radiation arriving on a horizontal surface, kcal/cm^2 per day;
SS – the average per decade the number of hours of sunshine;
j – the number of the decade;
A и B – interim characteristics, which are calculated according to latitude and declination of the Sun.

The temperature on the slope can be defined as:

$$T_{Seks}^{\ j} = k_{eks}^{\ T(j)}\, T_S^j, \qquad (2)$$

where T_{Seks} – the average per decade air temperature on the slope, °C;
k^T_{eks} – factor for recalculation of air temperature on the slope, relative unit;
T_S – the average per decade air temperature on a horizontal surface, °C.
To calculate the volatility E_0 we can use the method of A.M. Alpatiev (Alpatiev, 1954):

$$E_o^{\ j} = 0.65\, DWW^j\, dv^j\, 0.75, \qquad (3)$$

where DWW – the average per decade deficits of humidity;
dv – number of days in the decade.

The total evaporation may be expressed by the method of S.I. Kharchenko (Kharchenko, 1968):

$$E_{eks}^j = \frac{2W_{eks}^j + O_{S_{eks}}^j + P_{norm}^j}{1 + \dfrac{2W_{HB}}{E_{Oeks}^j}} \qquad (4)$$

where E_{eks} – the total evaporation on the slope;
P_{norm} – the norm of vegetation irrigation;
W_{fc} – the field capacity in 0-100 cm soil layer;
O_{Seks} – the amount of precipitation per decade with accounting of the slope steepness;
W_{eks} – the reserves of productive moisture in 0-100 cm soil layer.

Block of functions of influence of the development phase and meteorological factors on the production process of plants. The basis of the plant production process is photosynthesis. Its intensity is caused by the phase of the plant development as well as the environmental conditions. To calculate the ontogenetic curve of photosynthesis may be modeled through the following form

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$$\alpha_{Ph}^{j} = \exp\cdot\left[-a_{Ph}\cdot\left(\frac{TS_2-\Sigma t_1}{10}\right)^2\right], \qquad (5)$$

where α_{Ph} – the ontogenetic curve of photosynthesis, relative unit;
$\sum t_1$ – the sum of effective air temperatures from germination, at which there is the maximum rate of photosynthesis of plants,°C;
TS_2 – the sum of effective temperatures,°C.

The function of influence of moisture availability of crops was considered as a combination of the two functions. Taken into account the function of influence of soil moisture on plant productivity (according to the actual water reserves) and the ratio of total evaporation of crops to volatility with the exposure and steepness of slopes:

$$FW = \left(\gamma_{Ph}^{j}\cdot\frac{E_{eks}^{j}}{E_{0eks}}\right)^{0.5}, \qquad (6)$$

where FW – the relative moisture content of crops.

Block of soil fertility and plant mineral nutrition availability. Soil fertility characterized by the content of humus in it, which depends on the degree of the influence of soil erosion.

$$\mathrm{Gum}_{eks} = k^{G}_{er}\,\mathrm{Gum}, \qquad (7)$$

$$F_{G_{um}} = \frac{G_{um_{eks}}}{G_{um_{opt}}}, \qquad (8)$$

where Gum – the amount of humus in the soil, %;
Gum_{eks} – the amount of humus in the soil on the slopes with the erosion, %;
k^{G}_{er} – function of influence of soil erosion on the presence of humus, relative unit;
Gum_{opt} – the optimal for culture (crop) amount of humus in the soil, %.

The function of influence the amount of humus in the soil can be defined by the formula of A.S. Obraztsov (Obraztsov, 1990) for the calculation of security of mineral nutrition elements

$$FW_{G_{um}} = (F_{G_{um}})^{1.35}\exp[1.1\,(1-F_{G_{um}}), \qquad (9)$$

where FW_{Gum} – the function of influence of humus in the soil on the yield formation.

The generalized function influence of soil fertility and introduction of mineral and organic fertilizers can be calculate on the principle the Liebig

$$FW_{ef}^{j} = \min\left\{FW_{O_{rg}}^{j}, FW_{N}^{j}, FW_{P}^{j}, FW_{K}^{j}\right\}, \qquad (10)$$

where FW_{ef} – influence function of effective crop fertility, relative unit.

Block agro-ecological categories of yield. The value of different agro-ecological categories of productivity, concerning about our modifications and also with the involvement of more complete information should be defined.

Increment of potential yield per decade was determined according to the intensity of photosynthetically active radiation (PAR) and biological characteristics of the culture to reflect changes in the ability of plants to photosynthesis during the growing season:

$$\frac{\Delta PY^{j}}{\Delta t} = \alpha_{Ph}^{j}\,\frac{\eta\cdot Q_{PAR}^{j}\cdot k_{eks}^{Q^{J}}\cdot d\nu^{j}}{q} \qquad (11)$$

where $\frac{\Delta PY}{\Delta t}$ – the growth of the potential yield per decade;
Q_{PAR} – intensity of PAR;
k^{Q}_{eks} – factor for converting the average for the decade of the total solar radiation to the horizontal surface for slopes with the varying steepness and exposure;
q – calorific value.

The growth in meteorologically possible yield is the increase of potential productivity, which is limited to effect of moisture-temperature regime:

$$\frac{\Delta MPY^{j}}{\Delta t} = \frac{\Delta PY^{j}}{\Delta t}\cdot FTW_2, \qquad (12)$$

where $\frac{\Delta MPY}{\Delta t}$ – the growth in meteorologically possible yield;
FTW_2 – generalized function of the influence of

moisture-temperature regime with correction to the various extreme conditions, the function is defined on the principle of Liebig considering the influence of air temperature and moisture conditions on the production process.

Formation of indeed possible yield is limited by the level of natural soil fertility:

$$\frac{\Delta IPY^j}{\Delta t} = \frac{\Delta MPY^j}{\Delta t} \cdot B_{syc} \cdot F_{G_{um}}, \quad (13)$$

where $\frac{\Delta IPY}{\Delta t}$ – the growth of indeed possible yield;
B_{syc} – score of soil yield class.

Getting the level of economic yield is limited to the current level of farming and efficiency of mineral and organic fertilizers' introduction:

$$\frac{\Delta PY^j}{\Delta t} = \frac{\Delta IPY^j}{\Delta t} \cdot k_{farm} \cdot FW_{ef}^j \quad (14)$$

where $\frac{\Delta УП}{\Delta t}$ – the growth of the production yield;
k_{farm} – the factor, which characterizes the level of farming and economic activities;
FW_{ef} – the function of the efficiency of organic and mineral fertilizers' introduction depending on the moisture availability during the vegetation decades.

The different agro-ecological categories of yield can be calculated:

$$PCY = PCY_o\, K_{ec}\, 1.14\ 0.1, \quad (15)$$

where PCY_o – potential crop yield (with a standard grain moisture = 14 %), t/ha;
K_{ec} – the total mass of grain crops in the yield, relative unit.

The meteorologically possible yield, indeed possible yield and yield in production may be defined similarly.

4. MATERIALS AND METHODS

The main purpose of the research is to develop the basic model for assessment of agro-climatic resources, which are influenced on the crop productivity, based on Tooming's concept of the plant maximum productivity, results of modeling of the crop formation obtained in (Polevoy, 1983, 1988), as well as scientific statements about the variability of climatic elements in a hilly relief formulated in (Romanova, 1977).

5. CONCLUSIONS

Equations (1) – (15) allow to identify the agro-ecological categories of productivity of the different crops in the various relief parts formed under the influence of soil and climatic conditions and microclimate features of a region.

Inclusion into the model parameters, which characterize the definite requirements of different crops and its groups to the external environment, is helped to carry out the extensive researches on the assessment of the influence of the agro-climatic conditions to the various crops productivity.

Based on the proposed model the agro-climatic productivity zoning for winter wheat (Vitchenko, 1983; Hajiyev, 1997), rye (Vitchenko, 1983), spring barley (Vitchenko, 1983), maize [8], potatoes [3], flax [3], considering microclimatic features of the territories in different soil and climatic conditions and evaluation of growth of natural vegetation and desertification [6] was made.

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International Journal of Research In Earth & Environmental Sciences

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