HINDRANCES AND RESTRICTIONS TO FARMING

V.V. Shabanov and **A.I. Golovanov**
Moscow State University of Environmental Engineering, Moscow, Russia

Keywords: Productivity, environmental factors, quality of land, requirements of plants, need for melioration, hindrances to farming, productivity of agricultural cultures.

Contents

Summary

This article describes the quantitative assessment of productivity of agricultural crops, depending on hindrances and restrictions to farming. A simple mathematical model of the plant-environment system was offered by Prof. V. Shabanov. On the basis of experimental research and theoretical studies, the general dependencies relating environmental conditions and crop productivity were obtained. The parameters of the models are shown to be functions of the different stages of plant development.

The factors influencing productivity of land are considered. These include salinization, sensitivity to erosion, level of drainage, sensitivity to flooding, clogging with stones, overgrowth of scrub, abundance of mounds, and reforestation. Of these, salinization of land is considered in detail. It results in disturbance of the gaseous exchange and oxidation-reduction functions of biota, resulting in reduction of its geo-chemical cycling and purification capacity. Actual dependencies of relative crop capacity $\overline{U_s}$ = Us/Umax are given.

It is shown, that a special program of re-cultivation should be used for each level and type of pollution. Scenarios of decrease, stabilization or increase of the level of pollution, from different sources, are considered.

It is emphasized, that it is necessary to create engineering-ecological systems in terrain with an extreme ecological situation.

1. Quality of lands and productivity.

The factors restricting productivity of soils and plants are as follows:

- excess moisture content in the root layer of the soil;
- poor aeration of the root layer;
- excess acidity;
- poor availability of moisture in the root layer;
- low soil moisture;
- low content of humus and available nutrients;
- thermal regime unfavorable for the crop species;
- salinization of soil;
- pollution;
- unfavorable physical-mechanical properties of soil.

1.1. Change of productivity depending on environmental factors.

Quantitative description of change of productivity, as a dependency on environmental factors, can be described in many ways. The simplest form of mathematical model of a plant-environment system was offered by Prof. V. Shabanov. On the basis of experimental research and theoretical generalization, general dependencies were obtained between environmental conditions and productivity of plants. The different stages of crop production are relevant parameters of these models.

So, for the i-th instant the change of relative productivity S_i depending on environmental conditions (factor φ_j), can be written in the following form:

$$\frac{\mathrm{d}S_i}{d\varphi} = \frac{kS\left(\varphi - \varphi_{opt}\right)}{\left(\varphi + a_1\right)\left(\varphi - a_2\right)} \qquad (1)$$

Where k is a coefficient; φ_{opt} is an optimum value of j-th factor at i-th instant of time; α_1 and α_2 are corresponding functions of minimum and maximum values of factors $\varphi_{\min}$ and $\varphi_{\max}$, at which the plant can exist; and S_i is relative productivity.

The solution of this equation for i-th instant of life of a biological object and for j-th factor at $\varphi_{\min}$ =0 can be written in the form:

$$S(\varphi) = \left(\frac{\varphi}{\varphi_{opt}}\right)^{\gamma\varphi_{opt}} \left(\frac{\varphi_{\max} - \varphi}{\varphi_{\max} - \varphi_{opt}}\right)^{\gamma\left(\varphi_{\max} - \varphi_{opt}\right)} \qquad (2)$$

Presented in graphical form, this function has a dome-shaped form. The “width” of the dome depends on parameter γ, and the position of its maximum depends on the optimum quantity of φ_{opt}, factor which varies in dependence on the kind of plant and its age.

Eqation (2) permits calculation of the boundaries of ecological niches at different levels S. Where there are two factors, such a niche can be contoured by an ellipse, and, where it is three-dimensional, by an ellipsoid.
If we consider water (W) and thermal (t) factors as variables, for a fixed level S=const, the equation will be written in the form:

$$\left(\frac{W-W_0}{\vartheta_w}\right)^2-\frac{2r\left(W-W_0\right)\left(t-t_0\right)}{\vartheta_w\vartheta_t}+\left(\frac{t-t_0}{\vartheta_t}\right)^2=const \qquad (3a)$$

Where W and W_0 are current and average reserves of soil moisture content of, ϑ_w is the norming factor of soil moisture content, t and t_0 are current average temperatures of soil, ϑ_t is the norming factor of temperature, r is quantity, related to the angle of symmetry of axes of ellipses which defines the degree of dependence of one factor on another.

The general view of equations $S(\varphi)$ shows, that, beginning from S < 0.8, there is a sharp decrease of productivity at a small deflection of the value of the factor from the optimum, i.e. beginning from level $S \leq$ 0.8, there is a considerable increase of the absolute value of the derivative.

Averaging values S_i during the vegetation period can be realized on the following relations:

$$\bar{S}(\varphi)=\frac{U_j}{U_{\max}(R)}=\frac{1}{n}\sum_{i=1}^{n}S_i(\varphi) \qquad (3)$$

Where U_j is productivity of the autotrophic link in j-th year; $U_{\max}(R)$ is maximum productivity, which could be obtained under optimum conditions and at maximum (for this region) sum of active radiation of photosynthesis R; $S_i(\varphi)$ is a degree of factor optimality at i-th instant of time; n is the number of registration moments.

Or

$$\bar{S}(\varphi)=\sum\eta_i S_i(\varphi) \qquad (4)$$

Where η_i is the contribution of φ factor at the i-th moment into the final productivity.

Or

$$\bar{S}(\varphi)=\wedge\left(\vee S_i\right) \qquad (5)$$

Where $\wedge$ is operator "AND" of obligatory sequence of advancing through all phases of development, $\vee$ is operator "OR" of advancing through a phase at the optimum moment.

For transition from single-factor relations $S_i(\varphi)$ to multi-factor $S_i^{(z)}(\varphi)$, where z is the number of factors, it is possible to synthesize the impact of all the factors proceeding from "the law of minimum". It can be noted as follows:

$$S_i^{(z_i)}(\varphi) = \sum S_i(\varphi) g(l) \tag{6}$$

Where

$$g(l) = \begin{cases} 0, & \text{At } \varphi = \min_l \\ 1, & \varphi_l \neq \min \end{cases} \tag{7}$$

With allowance for this record, the multi-factor dependence over the period of growth of an autotroph can be written in the form:

$$\overline{S}^z(\varphi) = \sum_{i=1}^{n} \eta_i S_i^{(z_i)}(\varphi) \tag{8}$$

For determination of losses of productivity $\Delta S^{(z)}$ due to temporary non-optimum conditions, it is possible to write expression (8) in the form:

$$\Delta\overline{S}^{(z)} = 1 - \overline{S}^{(z)}(\varphi) \tag{9}$$

The submitted models are one of the optional versions of description of productivity of autotrophs, and in particular, of agricultural plants, as a dependence on conditions of the environment.

On the basis of the indicated dependencies, it is possible to write the expressions for estimation of crop productivity in the form:

$$U = U_{\max}(R)\overline{S} = U_{\max}(R)\sum_{i=1}^{n} \eta^{(\varphi_{\min})} S_i^{(\varphi_{\min})} \tag{10}$$

Where $U_{\max}(R)$ is an estimation of maximum productivity of an autotroph as a function of solar radiation; $\eta^{(\varphi_{\min})}$ is the contribution to productivity of the i-th moment under the minimum factor, and $S_i^{(\varphi_{\min})}$ is the degree of optimality at the i-th moment under the minimum factor.

A similar approach can be used for description of soil biota or biotic of elements of water bodies.

Depending on which factor is limiting, i.e. constraining the growth and development of a plant, the land reclamation technologies can be selected. First of all, the conditions under the first limiting factor are improved, then those under the second factor, etc., and the process continues until crop productivity reaches the necessary level.

Applying optimal hydro-thermal conditions not only for agricultural plants, but for biotic constituents of the soil, it is possible to make up the loss of organic matter in the humus horizon. The humus horizon is the layer of soil with the highest content of organic matter (usually 0-20 cm). Humus is part of the organic matter of soil. The contents of humus in the basic types of soils (according to I.V. Tyurin) varies from 2 to 12%, as follows:

- dernovo-podzolic soil – 2-4%;
- gray forest podzolic soil - 4-6%;
- chernozem: southern - 4-6%, ordinary – 6-8% leached – 7-8 %, potent – 10-12 %;
- dark-chestnut soil – 3-4 %;
- desert soil - 1-2 %;
- red-earth – 5-7%.

Between 600 and 700 kg of humus are mineralized annually per hectare in dernovo-podzolic soils. As for chernozem, the process involves about 1000 kg per hectare. These figures represent 1% and 0.5 % of the total of organic matter, respectively. Mineral compounds of nitrogen are formed in the process of mineralization, and these are accessible to plants. In order to obtain 1 part of nitrogen, it is necessary to mineralize 20 parts of humus.

The role of various elements of nutrition in the life of plants is very important. So, for example, nitrogen is a constituent part of all amino-acids, proteins, nucleic acids, chlorophyll, and other organic compounds in plants. Phosphorus enters the structure of nuclear albumens (nucleoproteins), and potassium promotes progression of carbohydrates from leaves into other parts of plants, and strongly influences the water-filling of vegetative colloids.

If the element of mineral nutrition is a limiting factor, methods of regulation of nutrition mode are applied.

However, the efficiency of use of improved lands can be significantly decreased if there is a danger of soil erosion, if the level of natural land drainage is insufficient, if soil hydraulic properties are unfavorable, if the soils are clogged with stones, if agricultural holdings are overgrown with shrubs, and if agricultural holdings are subject to flooding and inundation (see *Natural Resources and Food and Agriculture*)

-
-
-

Bibliography

Agropromizdat, M., 1990. Irrigation. Directory. Melioration and water economy. *[Reference book for designers, in which all necessary data are represented for substantiation and design of irrigation systems]*.

Averyanov S.F. Struggle with salinization of irrigated areas. M. Kolos, 1978. *[The methods of substantiation and compilation of estimation of water-salt regime of lands for a sufficiently long period]*

Aidarov I.P., Golovanov A.I., Mamaev M.G. El riego. Editorial Mir. Moscu. 1982. *[The data are presented, which allow to determine the necessity of leaching regime, its intensity and the terms of additional feeding of water]*

Hanks, R. J. 1984. Prediction of crop yield and water consumption under saline conditions. Section 8.2, pages 272-283, in Shainberg, I. and J. Shalhevet (ed), Soil Salinity under Irrigation: Processes and Management, Springer-Verlag, Berlin.

Melioration: Encyclopedia and Directory. 1984. Minsk, 567 pgs. *[All issues of reclamation are considered in this encyclopedia]*.

Pereira, L. S., Perrier, A. Ait Kadi, M. and Kabat, P. (eds) 1992. Crop Water Models. Special issue of the ICID Bulletin. 41 (2), 200 pp.

Pereira, L. S. and Allen, R. G. 1998. Crop water requirements. Chapter 1.5.1 of Handbook of Agricultural Engineering, CIGR and ASAE.

Plyusnin I.I.,.Golovanov A.I. Melioration agrology. M., Kolos, 1983. *[The manual for training of engineers hydro-technologists]*.

Rhodes, J. D., A. Kandiah, and A. M. Mashali. 1992. The use of saline waters for crop production. Irrigation and Drainage Paper 48. Food and Agriculture Organization of the United Nations, Rome, 133 pages.

Shabanov V.V. The bio-climatic substantiation of hydro-thermal melioration. L., Gidrometeoizdat, 1973. [*The monograph is devoted to the questions of bioclimatic substantiation of land reclamation which means setting quantitive indices of the gap between crop demands and environment conditions. The developed method of calculation may be used for the purposes of planning and managing land reclamation over vast territories.]*

Biographical Sketch

Shabanov, Vitaliy Vladimirovich, Doctor of Technical Sciences, Professor of the Moscow State University of Environmental Engineering, Academician of the Russian Academy of Agricultural Sciences V.V. Shabanov was born on June 27, 1937, in Moscow, into the family of hydrologist. In 1964, he graduated from the Engineering Department of the All-Union Institute of Extension Education in Agriculture; in 1991, he took the retraining course in Ecology at Moscow State University and got the diploma of Expert in Ecology

His scientific career started in the Yakutian Expedition of the Research Center of Moscow Institute of Hydraulic Engineering and Water Management, where he worked as a laboratory assistant and then junior researcher from 1956 to 1966. In 1966, he headed the works on the creation and maintenance of the automated system of water regulation on reclaimed lands in Byelorussia. From 1972 to 1987, he was the

Head of the Laboratory of the Problems of Regulation of Water, Temperature, and Salt Regimes of Reclaimed Lands; since 1987, he has been a scientific supervisor of this laboratory. From 1981 to 1995, he headed the Chair of Multiple Use and Management of Water Resources. Since 1995, he has been a professor of the Chair of Amelioration and Rehabilitation of Lands of the Moscow State University of Environmental Engineering.

In 1969, V.V. Shabanov defended his Candidate Sci. dissertation on the feasibility of land reclamation measures; his Doctoral dissertation (1992) was devoted to quantitative methods of assessing and regulating the factors controlling crop development under conditions of reclaimed lands.

Scientific interests of Prof. Shabanov are connected with mathematical modeling of economic efficiency and environmental security of land reclamation projects, including the models describing the interaction between plants and environmental factors and the optimization of the use of water resources upon irrigation. His recent works were aimed at assessing changes in potential crop yields under various climatic scenarios and developing the methodology for monetary evaluation of environmental factors for land reclamation projects and optimization of investments.

Professor Shabanov is the author of more than 150 scientific works, including two monographs: "Bioclimatic Factors and Land Reclamation" (Leningrad: Gidrometeoizdat, 1973) and "Water Supply of Spring Wheat and Its Calculation" (Leningrad: Gidrometeoizdat, 1981). He is a co-author of two textbooks on the multiple use of water resources and related issues of environmental protection.