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III. AGROECOLOGY

BASIC NATURAL FACTORS INFLUENCING SUSTAINABLE AGRICULTURE

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Abstract: The development of sustainable agriculture in the European Union is one of the most important strategic objectives of the actual and future Common Agriculture Policy. One way to environmentally use water as a non-renewable natural resource in agriculture is to use information and computer systems to determine the necessary irrigation time and quantity norms to obtain optimal actually possible yields of agricultural crops. At the Institute of Soil Science "N. Pushkarov" an Automated system for prognosis and management of irrigation regime was developed. It is based on the two basic natural factors influencing the agriculture, namely the solar radiation and the soil-physical properties of the soil types. The basic models of dependencies that make up the algorithms of the system are presented. The relationship between energy water potential and yield is considered.

Key words: solar radiation, soil-physical properties, scheduling irrigation

INTRODUCTION

Sustainable agriculture can be understood as an ecosystem approach to agriculture. The goal of sustainable agriculture is to meet society’s food and textile needs in the present without compromising the ability of future generations to meet their own needs. Practitioners of sustainable agriculture seek to integrate three main objectives into their work: a healthy environment, economic profitability, and social and economic equity [26].

The development of sustainable agriculture in the European Union is one of the most important strategic objectives of the actual and future Common Agriculture Policy [12]. In this report several important dimensions are defined and between them are: Irrigation methods, Volume of water used for irrigation and Soil productivity. In some areas sufficient rainfall is available for crop growth, but many other areas require irrigation. For irrigation systems to be sustainable, they require proper management (to avoid Salinization) and must not use more water from their source than is naturally replenishable. Otherwise, the water source effectively becomes a non-renewable resource.

The necessity is recognized that to develop information systems and tools to better inform water management allocation decisions. One way to use water as a sustainable non-renewable natural resource in agriculture is to use information and computer systems to optimize the planning of irrigation infrastructures, such as information systems to support planning decisions in conditions of increasing climate variability; tactical level to determine the optimum distribution of water over a given period (season, year); and at the operational decision-making level, to optimize the water distribution at farm level to determine the required irrigation time and quantity norms to obtain optimal actually possible yields of agricultural crops [19].

The visit of Dr. Howard Haise [13] as FAO Project Consultant at the Institute of Soil Science "N. Pushkarov" stimulated the work in Bulgaria on the establishment of a Programming system for irrigation scheduling using computing equipment. The onset was done by a Wang 700B programmable calculator using the Kansas experience [15]. In the period 1975 - 1978 an analogous package of programs with a number of modifications and additions was developed by A. Sadovski with Extended Basic programming language [8] at the Computing Center of the "N. Pushkarov" Institute for NOVA-ECLIPSE minicomputer. Following the computational experiments and field trials conducted in 1978, it became possible to implement this new System for prognosis and management of irrigation regime (Scheduling irrigation system) [16].

MATERIALS AND METHODS

The main elements of the model in consideration are: Penman's combination equation, the water deficit equation in the active water supply soil layer, the dependence between the potential evapotranspiration and some physical and biological parameters in the soil-plant massif-atmosphere system. The model uses constant (soil-biological) and current (meteorological) information. The description of the model is given in the main publications [17], [18].

Modifications and improvements of the original method have been made, which allow complete automation of the computing process and its application in the conditions of our country. In the application of the decision-making model for management of irrigation regime, meteorological

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information is used, which includes a system of 7 indicators for each day: maximum, minimum and average air temperature, sunshine duration or daily sum of solar radiation, relative air humidity, amount of rainfall and average wind speed. Analyzes of long-term data of these indicators show that they can be grouped into three groups - the first one covers four indicators and can be called "temperature" that is conditioned by sunshine; the second is associated with rainfall and the third is identified with the wind. These indicators account for 92.29% of the total variation [23], [24]. Hence the conclusion that ***the solar radiation is the first basic natural factor affecting agriculture***.

Here we present some essential elements of the system for forecasting and management of irrigation regime. The question of mathematical modeling of the impact of solar radiation on the production process and the formation of crop yields is discussed in detail by Tooming [25]. Radiation is not only a source of energy for photosynthesis and the formation of the water-heat regime of plants, not only its photomorphogenetic regulator, but through the dynamics of the architectonics of sowing and through light adaptation it also affects the dynamics of photosynthesis, the growth of individual plant organs and the formation of crops.

For the first time, the relationship between the total radiation-income during the day Q_s is expressed by the formula

$$Q_s = Q_0(0.25 + 0.75S),$$

where Q_0 is the radiation-income, which corresponds to a perfectly clear day, and S is the time of sunshine expressed in the greatest possible time of sunshine as unit [3].

Because the daily sum of solar radiation is measured with instruments directly in only at a few meteorological stations in the country, it is calculated by algorithm in cal/cm^2, depending on the geographic latitude and the day of the year. The actual fallen radiation R_s is determined by the formula [9], [14]:

$$R_s = (a_s + b_s \frac{n}{N})R_a,$$

where n is the duration of sunshine, N is the duration of the day that is calculated for the selected location by a specific sub-program. The constants are $as = 0.25$ and $bs = 0.5$ respectively. R_a is the maximum solar radiation at atmospheric transparency, equal to one, and is calculated as

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r \left[\omega_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)\right].$$

Here Gsc is solar constant = 0.0820 MJ m^{-2} min$^{-1,}$

d_r is inverse relative distance Earth-Sun

$$d_r = 1 + 0.033\cos(\frac{2\pi}{365}J).$$

The hour angle of the Sun ω_s is given by the equation

$$\omega_s = \arccos\left[-\tan(\varphi)\tan(\delta)\right].$$

φ is the geographic latitude of the point and δ is the declination of the Sun

$$\delta = 0.409\sin(\frac{2\pi}{365}J - 1.39),$$

where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December). It is determined by the given date and month by the following algorithm:

```
INPUT D, M
J = INTEGER (275 M/9 - 30 + D) - 2
IF (M < 3) THEN J = J + 2
IF (leap year and (M > 2)) THEN J = J + 1
OUTPUT J
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The magnitudes d_r, ω_s *and* δ are known from Astronomy [4], [1].

An algorithm for determining dew point temperature is developed, which usually reports either from tables or by a nomogram based on the average temperature and relative humidity of the air. The dew point can be mathematically determined as follow with given:

0°C < T < 60°C
0,01 < R_h < 1,00
0°C < T_d < 50°C

where T is the air temperature [°C], R_h is the relative humidity and T_d is the calculated dew point [°C].

$$T_d = \frac{b\gamma(T, R_h)}{a - \gamma(T, R_h)}$$

with

$$\gamma(T, R_h) = \frac{aT}{b + T} + \ln R_h,$$

where a = 17,27 and b =237,7 [°C]

The maximum error of the calculated dew point temperature is ± 0.4 °C.

The algorithms described above for solar radiation and dew point are included in the programs of the irrigation forecasting and management system.

The second basic natural factor influencing agriculture are the soil-physical properties of the soil type on which the sowing is located. Here it is important to emphasize the significance of the quantities - soil field capacity FC, wilting point WP and soil bulk density BD. From them the lowest value of soil moisture potential can be find, which corresponds to a specific energy level L [7]. This is illustrated with the following data for different soils in Bulgaria.

Let's have the following data from soil profiles:

Table 1. Calcareous chernozem, Lom [7].

Designation of horizon	Genetic horizon capacity (cm)	Thickness of the soil layer		Field Capacity		Wilting Point		Bulk Density	
			(cm)		(%)		(%)		(g/cm3)
A'k	0 - 26	d1	26	Fc1	23.11	Wp1	8.31	Bd1	1.20
A"k	26 - 54	d2	28	Fc2	21.33	Wp2	9.04	Bd2	1.27
A"bk	54 - 78	d3	24	Fc3	20.82	Wp3	9.05	Bd3	1.31
BCk	78 - 108	d4	30	Fc4	20.75	Wp4	8.25	Bd4	1.32
Root inhabitable layer	0 - 108		108		21.48		8.65		1.28

Table 2. Deluvial-meadow soil, G. Lozen [22].

Designation of horizon	Genetic horizon capacity (cm)	Thickness of the soil layer		Field Capacity		Wilting Point		Bulk Density	
			(cm)		(%)		(%)		(g/cm3)
A	0 - 24	d1	24	Fc1	28.82	Wp1	13.98	Bd1	1.28
Af	24 - 46	d2	22	Fc2	26.64	Wp2	15.14	Bd2	1.37
af	46 - 70	d3	24	Fc3	27.65	Wp3	16.22	Bd3	1.41
a(f)	70 - 108	d4	38	Fc4	27.13	Wp4	17.18	Bd4	1.49
Root inhabitable layer	0 - 108		108		27.52		15.84		1.41

For irrigation management purposes it is important to determine the water-physical properties and the available water supply in the root inhabitable layer. This is accomplished through the following steps:

The field capacity, wilting point and bulk density are calculated using the formulas:

$$W_{fc} = \frac{d_1.Fc_1 + d_2.Fc_2 + \ldots + d_n.Fc_n}{d_1 + d_2 + \ldots + d_n},$$

$$W_{wp} = \frac{d_1.Wp_1 + d_2.Wp_2 + \ldots + d_n.Wp_n}{d_1 + d_2 + \ldots + d_n},$$

$$B_d = \frac{d_1.Bd_1 + d_2.Bd_2 + \ldots + d_n.Bd_n}{d_1 + d_2 + \ldots + d_n},$$

where n is the number of the last layer in the root inhabitable zone.

The formulas give following values for calcareous chernozem from the data in Table 1:

$Wfc = 21.48$, $Wwp = 8.65$ and $Bd = 1.28$.

For the deluvial-meadow soil from Table 2 the values are:

$Wfc = 27.52$, $Wwp = 15.84$ and $Bd = 1.41$.

They are needed to determine the volumetric water content at the point of field capacity and wilting point

$$\theta_{fc} = B_d.W_{fc} \quad and \quad \theta_{wp} = B_d.W_{wp}.$$

The available water capacity (AWC) is defined as the range of available water that can be stored in soil and be available for growing crops. The concept, put forward by Veihmeyer and Hendrickson [27], assumed that the water readily available to plants is the difference between water content at field capacity (FC) and permanent wilting point (PWP):

AWC = FC − PWP, which is $\theta_{av} = \theta_{fc} - \theta_{wp}$.

Correspondingly, for both soils, volumetric values and AWC are obtained:

Calcareous chernozem -

$\theta_{fc} = 27.41, \quad \theta_{wp} = 11.03.$ AWC = 16.38.

Deluvial-meadow soil -

$\theta_{fc} = 38.56, \quad \theta_{wp} = 22.19.$ AWC = 16.37.

The measurement of soil water potential is the measurement of the amount of energy available in the soil to do work. It is the amount of energy required for a plant to perform work in order to extract moisture from soil. Using J/kg, the more negative the number then the greater amount of work a plant needs to do in order to extract moisture from soil.

Richards and Weaver [20] found that water content held at potential of −33 J/kg correlates closely with field capacity. It is denoted as $\psi_{fc} = -33$.

Permanent wilting point or permanent wilting percentage is defined as the soil wetness at which a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 h. Veihmeyer and Hendrickson [28] found that it is a constant characteristic of the soil and is independent of environmental conditions. It is usually taken as the water content at −1500 J/kg. The corresponding value is indicated as $\psi_{wp} = -1500$.

In agriculture, it is assumed that -33 J/kg is field capacity (the optimal moisture potential for plants) and permanent wilting point is -1500 J/kg (the point of plant mortality). Importantly, these values of field capacity and wilting point are assumed to be the same for all soil types (in fact field capacity and wilting point does vary depending on the plant species under consideration).

An indicator of the energy levels of soil moisture L is suggested by Christov [7]. Based on it, a classification of these levels is proposed, which is grouped into 9 classes. For its illustration and argumentation data on the average yields of corn grain Y' (kg/dka), obtained at suitable fertilization norms during the period 1982 - 1988 in the soil and climatic conditions of northwestern Bulgaria were used. Dependence is represented by the following equation:

$Y' = 19.214 - 0.516L$, t/ha with correlation coefficient r = 0,973.

Using this equation a simulation study is performed in order to clarify relationships between the water potential ψ_{cr}, the L indicator, the volumetric water content θ_{cr}, the average maximum allowable soil moisture deficit D_n and the yield Y' of grain maize.

θ_{cr} and D_n are calculated from the following equations:

$$\theta_{cr} = \exp\left[\ln(A / abs(\psi_{cr}) / B\right],$$

$$D_n = (\theta_{fc} - \theta_{\min}) / 10,$$

where

$$B = \ln(\psi_{wp} / \psi_{fc}) / \ln(\theta_{fc} / \theta_{wp}),$$

$$\psi_{wp} = -1500, \quad \psi_{fc} = -33,$$

$$A = 1500.\theta_{wp}^{B},$$

$$\theta_{\min} = \exp\left[\ln(A / abs(-33)) / B\right].$$

The results are presented in Table 3.

Table 3. Values of water potential, L indicator of Christov, water content, soil moisture deficit, yield and relative yield decrease.

ψ_{cr} (J/kg)	L ($J^{1/2}/kg^{1/2}$)	θ_{cr} (%)	Dn (mm/cm)	Y' (kg/da)	Y'-Y'max (%)
-33	5	27.41	0.000	1700	0
-50	7	24.83	0.259	1627	4
-100	10	21.04	0.637	1458	14
-150	12	19.10	0.831	1322	22
-200	14	17.84	0.957	1207	28
-300	17	16.19	1.122	1017	40
-400	20	15.12	1.229	861	49
-500	22	14.34	1.307	728	57
-600	24	13.73	1.368	613	63
-700	26	13.23	1.418	512	69
-800	28	12.82	1.459	422	75
-900	30	12.46	1.495	341	79
-1000	31	12.15	1.526	268	84
-1500	38	11.03	1.638	0	100

There is a close functional dependence of the indicator L on the water potential ψ_{cr}, expressed by the equation:

$$L = f(\sqrt{|\psi|}) = a.b^{|\psi|}.|\psi|^{c},$$

where

a = 0.357303, b = 0.979650, c = 1.49001 with correlation coefficient r = 0.9971.

From these results it is evident that the interval of water potential (-33,-100) covers levels of biological optimum; the interval (-100, -400) means a reduction in yield from 15 to 50%; next interval (-400, -900) reduces yield by 60 to 80% of the maximum, and the interval (-900, -1500) practically means no yield.

RESULTS AND DISCUSSION

The application of the developed irrigation management system under real conditions shows a number of advantages. In its use, the potential high-precision evapotranspiration is determined by the selected basic parameters - maximum, mean and minimum air temperature for each day, average relative air humidity, mean wind speed and daylight solar radiation expressed by the duration of the sunshine. The system determines the water deficit for each day and allows calculating exactly how much of the water in each rainfall completes the current soil deficiency, whether the maximum water stock for the soil has been reached and what proportion of the rainfall is not used.

It has been found that under conditions of insufficient productive water stock in the soil for a duration of 3-4 days there are slight but permanent changes in the development of the plants, which lead to irreversible reduction of the yield from them, although the required water supply is then restored [5].

The software package enables us periodically (each 3 days) to carry out up-dating calculations throughout the crop growing season for every field. Calculation schemes of irrigation scheduling are accomplished in chronological sequence during the season in 1994 for maize and cotton grown in the Experimental Field of the Institute at Sindos, Greece [6].

Let's make a comparison with two other well-known irrigation scheduling systems.

The system CropWat is developed by the FAO [9] and there is a new refined version [11]. CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. It can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions. CropWat uses daily, decade or monthly climate data to estimate reference evapotranspiration [2]. If you want to calculate irrigation water requirements for any previous year, then you need to collect the climate data for that year from your nearest meteorological station. If you want to calculate irrigation water requirements for any future time then you need to collect future forecast data. If local climatic data are not available, you can obtain those data for over 5,000 stations worldwide from CLIMWAT. CLIMWAT is a climatic database to be used in combination with the computer program CROPWAT and allows the calculation of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations worldwide [10].

CropWat requires the following soil data: total available soil moisture (mm/meter), maximum rain infiltration rate (mm/day), maximum rooting depth (cm), initial soil moisture depletion (as % TAM), initial available soil moisture (mm/meter). There are several available irrigation timing and irrigation application options. Despite these qualities, it is not suitable for current (operational) management of the irrigation regime.

KanSched is a computer software program that is designed to help monitor the root zone soil profile water balance and schedule irrigation events on a field using evapotranspiration (ET) data [21]. The program can also be used to monitor the soil profile water content of non-irrigated fields. ET-based irrigation scheduling is a tool that can help you determine when and how much irrigation water to apply. The basic process involves using data on crop water use (crop evapotranspiration or ETc), rainfall, and soil water storage to assess when an irrigation event is needed and how much water could be applied.

One of maim advantages of KanSched is that it uses soil data such as - soil type and values for the available soil water holding capacity, the permanent wilting point and the initial soil water availability at the start of the water budget date. Whenever the crop receives rainfall, the value for the appropriate day is entered in KanSched. This value will then be used to calculate your soil's current water content. The disadvantage of the system is the absence of current basic meteorological data when determining the evapotranspiration, the date and the rate of irrigation.

The advantages of the described System for prognosis and management of irrigation regime [16], which is based on the two main natural factors - the solar radiation and the soil-physical properties of the soil types, on which the productive process in agriculture is carried out, are obvious.

CONCLUSION

The advantages of the Bulgarian irrigation management system consist not only in the fact that it uses current meteorological and permanent soil and physical information. It is based on verified meaningful and empirical models that have a solid scientific basis. It enables assessment and operational management of the irrigation regime by defining the expected date and irrigation norm for the particular field of production in agriculture by automating all computational processes.

The application of this system reveals opportunities for a significant increase in productivity, due to the fact that particular weather and soil conditions are taken into account during the vegetation period of the crop. It allows reducing the water consumption for irrigation, to reduce the soil structure destruction during irrigation and to prevent contamination of surface and ground water. It can be seen as an important element of a complex ecologically sustainable agriculture.

Our research, confirmed by many foreign scientists, shows the utmost importance of the two basic natural factors discussed here, which determine the final results in agriculture. Next study should be devoted to the third major natural factor, namely the nutrients content in the soil needed for the growth of plants.

REFERENCES

1. Abalkin V.K. (Ed). Astronomical calendar, The constant part. Nauka, Moscow, 1981, 704 p. (in Russian).

2. Allen R.G., L. Pereira, D. Raes, M. Smith. Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage, p. 56, FAO, Rome 1998.

3. Angstrom A. Solar and terrestrial radiation. Quart J Roy Met Soc.; 1924, 50:121–5.

4. Bonev N., Astronomy, "Nauka i Izkustvo", Sofia, 1953, 412 p. (in Bulgarian)

5. Christov, I., A. Sadovski, Optimal water regime determined by using meteorological, soil-physical and biological information. Hydrol. and Meteor., 1984, XXXIII, № 6, 73-82 (in Bulgarian)

6. Christov, I.D., A.N. Sadovski, A. Panoras, Y. Mavroudis, A. Louisakis, Application of Computer Technology for Crop Irrigation Scheduling to Reduce Negative Impact on Environment, Journal of Balkan Ecology, 1998, 1 (3), 34-40

7. Christov I. Estimation of Agroecosystem Water Status and Formation of Plant Water supply in Soils. "PublishSaiSet-Eco", Sofia, 2004, 216 p. (in Bulgarian)

8. Data General Co. Extended BASIC User's Manual. Southboro, Mass. 1977, 139 p.

9. Doorenbos J., W.O. Pruitt. Guidelines for predicting crop water requirements. Irrig. Drain. Pap. 24, 2nd ed., Food and Agric. Org., Rome, 1977, 156 p.

10. FAOa. CLIMWAT 2.0 for CROPWAT. Rome, 2017. http://www.fao.org/land-water/databases-and-software/climwat-for-cropwat/en/

11. FAOb. CropWat 8. Land & Water, Rome, 2017. http://www.fao.org/land-water/databases-and-software/cropwat/en/

12. Fusco D., P. Giordano, M. Greco, V. Moretti. Sustainable agriculture in EU. A method for a synthetic classification of the NUTS2 AREAS. EAAE 2014 Congress, Ljubljana, Slovenia

13. Haise, H.R., Soil physics (Irrigation). Rept. for N. Poushkarov Inst. Soil Science Project, AGL:DP/BUL/69/506. FAO, Rome, 1973, 37 p.

14. Jensen M., H. Haise. Estimating evapotranspiration from solar radiation. J. Irrig. & Drain. Div., Amer. Soc. Civil Eng., 1963, 96(IR1), 25-38

15. Kincaid D.C. D.F. Heermann. Scheduling Irrigation Using a Programmable Calculator. ARS-USDA, North Central Region. Pub. 1974, ARS-NC-12, 55 p.

16. Krafti G., A. Sadovski, I. Christov, B. Kolev. Prognosis and management of the irrigation regime. Plant Sci., Sofia, 1980, vol. XVII, No. 4, 135-143. (in Bulgarian)

17. Krafti G., I. Christov., A. Sadovski, B. Kolev. Automated system for forecasting of irrigation regime, Rept. Nat. Symposium "Theory and practice of Science and Tech. Forecasting in PRB". SCSTP, STU, Sofia, 1980, p. 65-67. (in Bulgarian)

18. Krafti G., I. Christov, A. Sadovski, B. Kolev. Model for prognosis and management of irrigation regime. Proc. Symp. "Physics - Agric.

Prod.", Sofia, 1980, 306-312. SPhB, 1981. (in Bulgarian)

19. OECD. Sustainable Management of Water Resources in Agriculture. 2010, 122 p.

20. Richards L.A., L.R. Weaver. Moisture retention by some irrigated soils as related to soil moisture tension. J. Agr. Res., 1944, 69, 215–235

21. Rogers D.H., M. Alam. KanSched 2. An ET-Based Irrigation Scheduling Tool, Manual. K-State Research and Extension, October 2006, 17 p.

22. Ruseva S., B. Kolev. Comparative study of methods for establishing the curve of soil moisture retention. Proc. Symp. "Physics - Agric. Prod.", Sofia, 1980, 282-289. SPhB, 1981. (in Bulgarian)

23. Sadovski A. Principal components analysis to determine the basic noncontrolable factors influencing yields. Hydrol. and Meteor., Sofia, 1976, vol. XXV, No. 5. (in Bulgarian)

24. Sadovski A. Experience with environmental statistics in the Bulgarian environmental monitoring system. Statistical J. of UN ECE, Amsterdam, 1989, vol. 6, No. 1, 69-73.

25. Tooming H. Solar radiation and the formation of crops. Gidrometeoizdat, 1977. Leningrad, 200 p. (in Russian)

26. UC Davis. What is sustainable agriculture? Agricultural Sustainability Institute, 2017, http://asi.ucdavis.edu/programs/sarep/about/what-is-sustainable-agriculture

27. Veihmeyer F.J., A.H. Hendrickson. The relation of soil moisture to cultivation and plant growth. Proc. 1st Intern. Congr. Soil Sci.,1927, 3, 498–513.

28. Veihmeyer F.J., A.H. Hendrickson. Methods of measuring field capacity and wilting percentages of soils. Soil sci., 1949, 68, 75–94.

ОСНОВНИ ПРИРОДНИ ФАКТОРИ, ВЛИЯЕЩИ ВЪРХУ ЕКОЛОГОСЪОБРАЗНО УСТОЙЧИВО СЕЛСКО СТОПАНСТВО

Александър Садовски

Резюме: Развитието на устойчивото селско стопанство в Европейския съюз е една от най-важните стратегически цели на настоящата и бъдещата „Обща селскостопанска политика“. Един от начините за екологосъобразно използване на водата като невъзобновим природен ресурс в селското стопанство е използването на информационни и компютърни системи за определяне на необходимите поливни норми по време и количество за получаване на оптимални действително възможни добиви от селскостопанските култури. В Института по почвознание "Н. Пушкаров" е създадена Автоматизирана система за прогнозиране и управление режима на напояване. Тя се базира на двата основни природни фактори, влияещи върху селското стопанство, а именно слънчевата радиация и почвено-физическите свойства на почвените типове. Представени са основните модели на зависимостите, които влизат в състава на алгоритмите на системата. Разглежда се зависимостта между енергийния воден потенциал и добива.

Ключови думи: слънчева радиация, почвено-физически свойства, програмиране на напояването

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