DOI: https://doi.org/10.31073/mivg202401-384
Available at (PDF): https://mivg.iwpim.com.ua/index.php/mivg/article/view/384

UDC 633.854.54;633.854

FEATURES OF FORMING WATER AVAILABILITY FOR WINTER WHEAT IN THE SOUTH OF UKRAINE

R.V. Saidak[1], Ph.D. in Agricultural Sciences, P.V. Pysarenko[2], Dr. of Agricultural Sciences, V.V. Knysh[3], Yu.O. Tarariko[4], Dr. of Agricultural Sciences, Yu.V. Soroka[5], Ph.D. in Agricultural Sciences, Z.V. Shcherbyna[6], Ph.D. in Agricultural Sciences

[1.] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine, https://orcid.org/0000-0002-0213-0496; e-mail: saidak_r@ukr.net;
[2.] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine, https://orcid.org/0000-0002-2104-2301; email: pavel_pisarenko74@ukr.net;
[3.] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine, https://orcid.org/0000-0002-3220-9883; e-mail: iwpim27@gmail.com;
[4.] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine, https://orcid.org/0000-0001-8475-240X; e-mail: urtar@bigmir.net;
[5.] Institute of Water Problems and Land Reclamation of NAAS, Kyiv, 03022, Ukraine, https://orcid.org/0000-0001-6228-4131; e-mail: agroresurs@bigmir.net;
[6.] Breeding and Genetic Institute, National Center of Seed Science and Variety Investigation of NAAS, Odessa, 65036, Ukraine, https://orcid.org/0000-0002-4630-8372; email: zoyasgi09@ukr.net

Abstract. *The article examines the importance of considering several factors affecting the soil water regime in the context of developing models for forecasting productive soil moisture reserves. It was established that the main factors, such as the type of soil, its density, and mechanical composition, remain constant in different soil and climatic regions of Ukraine. The second group of factors, such as air temperature, precipitation, and soil moisture, are subject to changes throughout the growing season and even over short periods. Therefore, the dynamics of soil moisture as a function of the main variables, such as average air temperature and precipitation, was considered using calculations. Initial moisture reserves are used in the calculations for more accurate forecasting of moisture reserves at the end of a specified period. Hydrothermal conditions considered as predictors in the regression equation are also used. The reliability of the conducted research is confirmed by the analysis of independent input and output information from the Kherson weather station in the period from 2018 to 2021 regarding the actual reserves of productive moisture in the soil at a depth of 0–20,0–50 and 0–100 cm.*

The average error between actual and calculated data did not exceed +13,5 %. It confirms the reliability and precision of the conducted research making it the basis for further analyses and conclusions. The conclusions noted the need for accurately determining soil moisture to effectively manage agrometeorological conditions and optimize crop yield. The authors believe that the research work presented in this article can significantly contribute to developing modern approaches to water availability in agriculture and agrometeorology. That will contribute to the gradual and improved development of soil moisture forecasting methodology, which is key to ensuring sustainable and productive development in agriculture.

Key words: *soil water regime, forecasting of moisture reserves, modeling, influencing factors, hydrothermal conditions, productivity, agriculture, climate change*

Relevance of research. In modern conditions of climate change, in particular global and regional warming, there is a change in the ratio between the physical evaporation of moisture from the soil and its direct use by plants. The rate of moisture absorption by plants also changes with increasing temperature. These potential changes in water consumption need to be quantified, considering the influence of all factors that form the basis of precision agriculture. To determine the mechanism of forming the dynamics of water availability for crops during the growing season, it is necessary to take into account the variable nature of hydrothermal conditions and the potential plant productivity, which is proposed to be done using ground and remote monitoring data. It is possible to predict changes in moisture reserves for the decade by the forecast of air temperature and amount of precipitation when using developed models and having information about the actual or determined reserves of productive moisture at the beginning of the decade.

Analysis of recent research and publications. Global climate change has different manifestations in different regions of the world, and its impact on the environment and socio-economic development is becoming more and more noticeable and is one of the pressing problems of our time. Assessing the impact of this change on all aspects of human life plays an important role in the fundamental science of the 21st century as well as in global economics and politics. One of the main consequences of climate change is a change in the hydrological regime, the amount and quality of water resources, which affects various areas of the economy, especially agriculture.

In modern conditions, the lack of water availability becomes one of the main limiting factors for the sustainable development of agriculture. For this reason, attention to the problem of water management in agriculture is growing. Over the past decades, many studies have been devoted to this topic, which resulted in a significant increase in publication activity. For example, during 1993–2017, the number of publications on this topic increased 67 times. In [1], the impact of climate change on available water resources in agriculture was investigated, given global trends and perspectives. The authors analyzed changes in the precipitation regime, distribution, and water availability for irrigation and production. An assessment of changes in the hydrological regime in agricultural areas under various climate change scenarios was also carried out [2].

Scientists have analyzed changes in river flow, groundwater levels, and water demand for various crops. The review study [3] considered the modeling of the impact of climate change on plant water demand and irrigation needs. Scientists have analyzed changes in water availability for various crops and irrigation requirements depending on climatic conditions. It was established that if water availability decreases in the future, soils with high water-holding capacity will be preferable for use to reduce the impact of drought on crop productivity. In works [4, 5], the authors investigated the vulnerability of the main field crops to climate change. They analyzed the impact of climate change on yields, drought risks, and other factors affecting production sustainability and assessed the impact of climate change on countries' adaptation strategies.

Ukrainian scientists have made databases for assessing [6] and rational use of agricultural resource potential of areas, analyzed the impact of global and regional climate change on increasing evaporation and moisture deficit, as well as on decreasing precipitation in the Southern Steppe subzone [7]. Four basic models of climate change are commonly used now. Summarizing the above and conducting our research will not only contribute to the development of scientific approaches to the problem of water availability of main field crops (in our case, it is winter wheat) but will also make it possible to develop specific practical recommendations and innovative solutions for farmers and agricultural enterprises to effectively cope with the challenges, posed by climate change.

The purpose of the research is to study the features and establish the dependencies between the dynamics of water availability of winter wheat and the hydrothermal conditions of the growing season in the South of Ukraine.

Research materials and methods. The research was conducted at the Institute of Water Problems and Land Reclamation of the NAAS by processing the data from long-term field experiments, weather forecasts, data from the Hydrometeorological Center, and further processing of the obtained information using automation tools.

Research results and their discussion. Environmental constraints on water, temperature, and energy balance are known as key factors that can vary independently in time and space. Studies by many scientists show that these factors have complex spatial and temporal relationships, which are important to be considered when analyzing ecological systems. Spatial co-variances, such as relationships between air temperature, atmospheric humidity, and soil moisture, indicate the effect of landscape structures on climatic conditions. Changes in the landscape can affect the distribution and availability of water, as well as air temperature and other environmental parameters. Time co-variance is also a significant factor, especially regarding climate change. Correlated daily or seasonal fluctuations in air temperature and atmospheric humidity indicate changes in climatic conditions over time [8].

Global climate change generates joint trends in changing air temperature and water availability that have been manifested over many years [9]. That can have serious consequences for ecological systems, in particular for resources distribution. Simultaneous changes in precipitation, water availability, and environmental humidity can amplify or weaken the effects of climate change depending on the patterns of changes in the hydration state of organisms. That indicates the importance of carefully investigating the changes in air temperature and environmental water availability for understanding ecological processes in a changing climate environment. In arid regions in particular in the South of Ukraine, the spatial-temporal distribution and availability of water resources are studied at different levels (local, regional, and global) [10, 11]. These studies identify vulnerable to water scarcity areas and develop ecosystem management strategies. They are a key tool for the development of effective water management policies and adaptation to climate change [12].

In crop cultivation water availability is a key factor. It directly affects the yield and determines the cultivation technology. Most agricultural producers pay attention to the average amount of precipitation, but it is also important to consider its distribution during plant development [13, 14]. It is important to determine the soil moisture in the early spring period at the initial stages of plant growth to prevent material and yield losses due to the moisture lack [15, 16].

The main factors affecting moisture dynamics were considered when developing models for forecasting productive moisture reserves. They include soil type, density, and mechanical composition, which almost do not change over a long period and practically remain constant in each soil and climate region. The second group of factors, on the contrary, changes significantly both during the entire vegetation period (growth phases, plant height, and stem density) and short periods: months, decades, and days (air temperature, precipitation, soil moisture, etc.). Moisture consumption for evaporation from the soil surface increases with the rise of temperature, which is accompanied by a decrease in air humidity [17]. Plant transpiration also significantly affects the intensity of total evaporation depending on soil moisture [18].

When developing models for forecasting moisture reserves at the end of any period (a decade, one or two months), it is necessary to consider the initial moisture reserves in the soil layer as a predictor for the regression equation at the time of making the forecast (*Wn*) [19, 20]. Other independent variables in the equation are indicators of hydrothermal conditions, such as average air temperature (Tn) and precipitation (*Rn*). Therefore, the change in moisture in the soil layer over a certain (n-th) period (ΔWn) is a function (*F*) of the following main variables:

$$\Delta Wi = F(\Delta Wi, ti, Ri, P, S),$$

where *P* is a soil type and its mechanical composition; *S* is a condition of crop sowing area (phase of plant development, height and density of stems).

Due to the stability of soil type and its mechanical composition, which change little over time but significantly vary within the territories, it is possible to include them in forecasting models of moisture reserves. That can be done by developing separate models for regions with similar or predominant soil characteristics, typical for steppe, forest-steppe, and steppe soil zones. Due to the different water-physical properties of these soils, the formation of moisture reserves in their layers is not the same. Also, the hydrothermal regime formed in these regions affects the dynamics of moisture reserves differently. The change in the reserves of productive moisture per decade (ΔWi) in the 0–20, 0–50, and 0–100 cm soil layers under winter wheat is determined by the algorithm:

$$\Delta Wi = a + bW\text{н}i + cti + dRi,$$

where *Wi* is the initial moisture reserves at the beginning of the *i-th* decade; ti, *Ri* is the average air temperature and amount of precipitation per decade; *a, b, c, d* are multiple regression coefficients that differ depending on the natural and climatic conditions, soil layer, month and decade for which the change in moisture reserves is calculated.

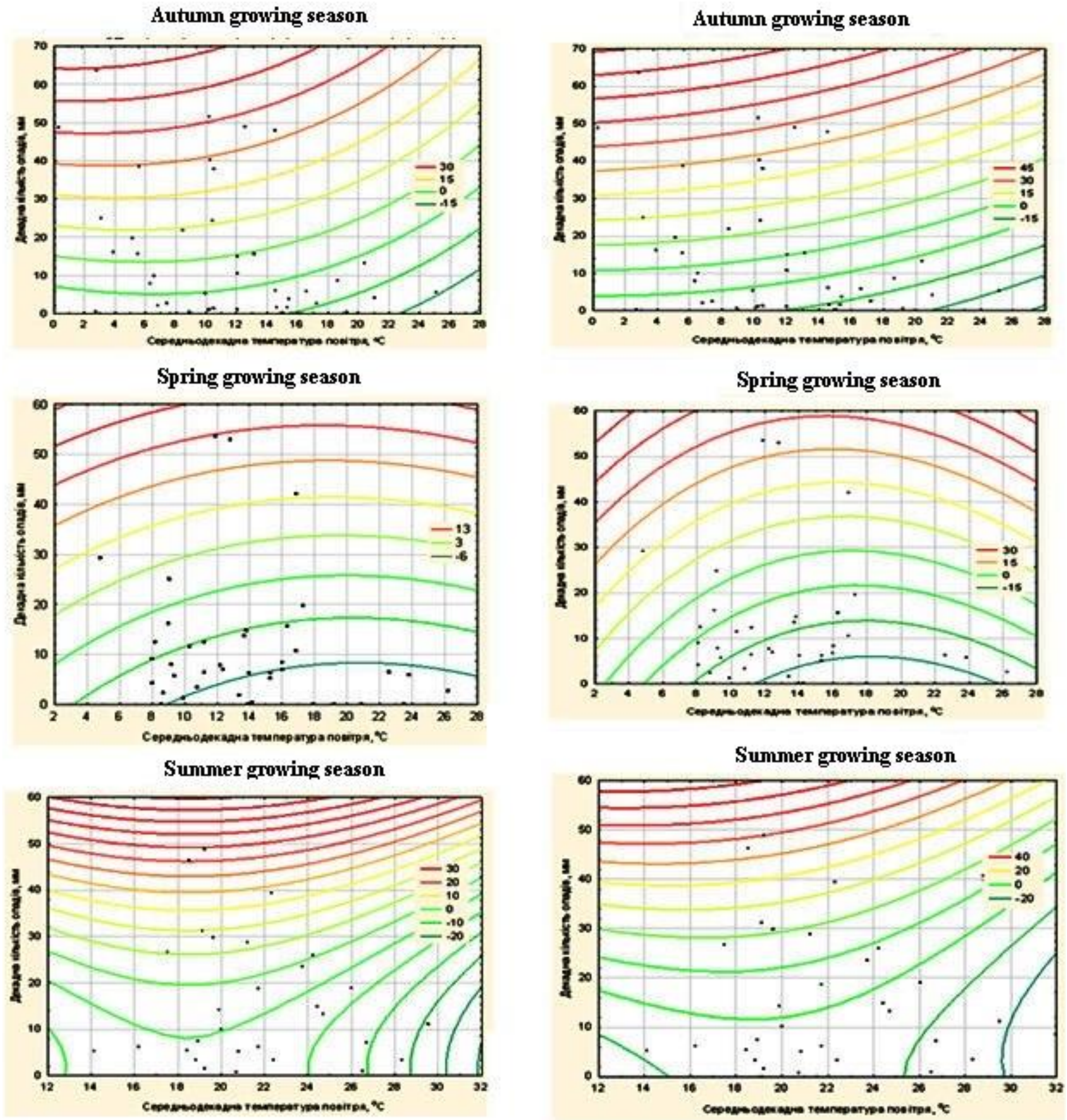
The results of the author's verification show that their reliability in the vast majority exceeds 80 %. Quantitative dependencies and models of hydrothermal indicators' influence on moisture reserves in soil layers 0–20, 0–50, and 0–100 cm were investigated per decade. Average decadal air temperature and decadal precipitation were used as input variables. The dynamics of soil moisture reserves (ΔWn) was estimated as the difference between the values of the current decade (*Wn*) and the previous one (*Wn–1*):

$$\Delta \text{Wn} = \text{Wn} - \text{Wn}-1$$

The determination coefficient (*R2*) of the established mechanism, depending on the estimated soil layer and the crop growing season, ranges from 0,82 to 0,94.

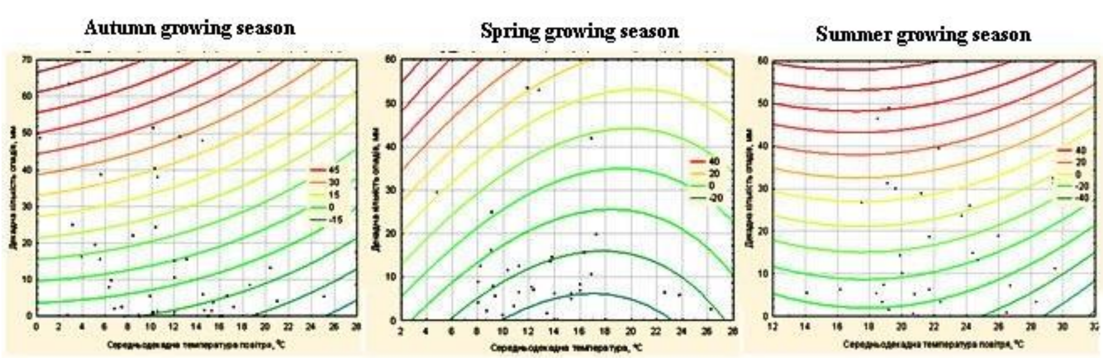
Graphical models for evaluating the dynamics of soil moisture reserves under winter wheat were investigated on soil layers 0–20, 0–50 and 0–100 cm (Fig. 1).

The results of the analysis of independent input and output information regarding the actual reserves of productive moisture in the soil at a depth of 0–20 and 0–100 cm for the period from 2018 to 2021, using the data from a weather station located in the city of Kherson, confirmed the high reliability of the developed models (Figure 2). Figure 2 illustrates the results of verification of the models used to forecast changes in productive moisture reserves in the soil under winter wheat in the period from 2018 to 2021, according to the data of the Kherson weather station.



0–20 cm 0–50 cm

Fig. 1. Graphical models for evaluating the dynamics of soil moisture reserves under winter wheat in the 0–20, 0–50, and 0–100 cm soil layer



0–100 cm

Fig. 2. Results of verifying models of changes in productive moisture reserves in the soil under winter wheat (Kherson meteorological station, 2018–2021)

The obtained results allow us to conclude that it is possible to determine the expected changes in soil moisture reserves during the decade, based on the analysis of actual and simulated data, given the forecast air temperature and the expected amount of precipitation. This approach enables users to calculate expected moisture reserves at the end of a specified period, given a reliable meteorological forecast. When having actual data on soil moisture reserves at the beginning of calculations, the calculation process remains unchanged, and the actual values of moisture reserves are taken as the basic values. This approach increases the accuracy and reliability of soil moisture forecasts and is important for agricultural resource management and decision-making in agriculture.

Conclusions. It was established that the correlation analysis of hydrometeorological factors affecting the formation of soil moisture reserves shows a significant influence of initial moisture reserves on their amount in subsequent periods (correlation coefficient varies from 0,45 to 0,84). The dependence of soil moisture reserves on air temperature is averagely significant, and the general trend shows a decrease in the direct influence of the temperature regime with an increase in the depth of the calculated soil layer.

The investigated dependences and models of the dynamics of water availability for winter wheat in the south of Ukraine, considering the condition of crop sowing area and hydrothermal conditions of the growing season in the soil layers 0–20, 0–50 and 0–100 cm per a decade, have a determination coefficient (*R2*) ranging from 0,82 to 0,94. Verification of the accuracy of the above models when using independent data for 2017–2020 proved their reliability. The average error between actual and calculated data did not exceed +13,5 %.

References

1. Smith, M., & Jones, A. (2020). Impact of Climate Change on Agricultural Water Resources: A Global Perspective. *Agricultural Water Management*, 241, 106393.

2. Garcia, R., & Nguyen, T. (2019). Assessment of Hydrological Changes in Agricultural Areas under Climate Change Scenarios. *Journal of Hydrology*, 573, 608–620.

3. Wang, L., & Zhang, H. (2018). Modeling the Impacts of Climate Change on Crop Water Requirements and Irrigation Demands: A Review. *Agricultural Water Management*, 213, 1–12.

4. Sharma, A., & Singh, B. (2017). Assessing the Vulnerability of Agricultural Systems to Climate Change: A Review. *Agricultural Systems*, 151, 86–104.

5. Olesen, J., & Bindi, M. (2002). Consequences of Climate Change for European Agricultural Productivity, Land Use and Policy. *European Journal of Agronomy*, 16 (4), 239–262.

6. Tarariko, Iu.O., Saidak, R.V., & Soroka, Yu.V. (2019). Pidsumky ta perspektyvy doslidzhen z otsinky ta ratsionalnoho vykorystannia ahroresursnoho potentsialu silskohospodarskykh terytorii. [Results and Prospects of Research on the Assessment and Rational Use of Agricultural Resource Potential of Agricultural Areas]. *Melioratsiia i vodne hospodarstvo*, 2, 186–198 [in Ukrainian].

7. Holoborodko, S.P., & Dymov, O.M. (2019). Hlobalna zmina klimatu: prychyny vynyknennia ta naslidky dlia silskohospodarskoho vyrobnytstva Pivdennoho Stepu. [Global climate change: causes and consequences for agricultural production in the Southern Steppe]. *Melioratsiia i vodne hospodarstvo*, 1, 88–98 [in Ukrainian].

8. Owen Smith, N., & Goodall, V. (2014). Coping with savanna seasonality: Comparative daily activity patterns of African ungulates as revealed by GPS telemetry. *Journal of Zoology*, 293, 181–191. 10.1111/jzo.12132.

9. Kelley, C.P., Mohtadi, S., Cane, M.A., Seager, R., & Kushnir, Y. (2015). Climate change in the Fertile Crescent and implications of the recent Syrian drought. *Proceedings of the National Academy of Sciences*, 112, 3241–3246. 10.1073/pnas.1421533112.

10. Nickel, S., Schröder, W. Fuzzy modelling and mapping soil moisture for observed periods and climate scenarios. An alternative for dynamic modelling at the national and regional scale? *Ann. For. Sci.*, 74, 71.

11. IPCC. (2007). Climate Change 2007: Synthesis Report. An Assessment of Intergovernmental Panel on Climate Change. Geneva, Switzerland. Retrieved from: http://ipcc.ch/index.html.

12. Goubanova, K., L. Li. (2007). Extremes in temperatures and precipitation around the Mediterranean basin in an ensemble of future climate scenario simulations Glob. *Planet. Change*, 57, 27–42.

13. Planton, S., Deque, M., Douville, H., Spagnolli B. (2005). Impact du réchauffement climatique sur le cycle hydrologique C. R. Geoscience, 337, 193–202.

14. Diodato, N. (2004). Local models for rainstorm induced hazard analysis on Mediterranean river torrential geomorphological systems Nat. *Haz. Earth Syst. Sci.*, 4 (0), 389–397.

15. Booij, M.J. (2005). Impact of climate change on river flooding assessed with different spatial model resolution. *Journal of Hydrology*, 303 (1–4),176.

16. Treut, H.Le, Gastineau, G., Li., L. (2008). Uncertainties attached to global or local climate changes C. R. Geoscience, 340 , 584–590.

17. Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO. *Irrigation and drainage paper*, 56 (300), 6541. FAO, Rome.

18. Zhovtonoh, O.I. et al. (2015). Metodychni rekomendatsii z planuvannia zroshennia na terytoriiakh z urakhuvanniam klimatu ta modelei ahrarnoho vyrobnytstva. [Methodological recommendations for planning irrigation in the territories taking into account climate and agricultural production models]. Kyiv: Ahrarna nauka [in Ukrainian].

19. Data on soil condition. (2024). Glosis. Retrieved from: http://54.229.242.119/GSOCmap/

20. Romashchenko, M.I., Kovalchuk, V.P., Tarariko, Yu.O., Soroka, Yu.V., Krucheniuk, A.V., & Demchuk O.S. (2016). Systema informatsiinoho zabezpechennia ahrarnoho vyrobnytstva cherez merezhu internet. [Information support system for agricultural production via the Internet]. *Melioratsiia i vodne hospodarstvo*, 104, 87–92 [in Ukrainian].

УДК 633.854.54;633.854

ОСОБЛИВОСТІ ФОРМУВАННЯ ВОЛОГОЗАБЕЗПЕЧЕННЯ ПШЕНИЦІ ОЗИМОЇ НА ПІВДНІ УКРАЇНИ

Р.В. Сайдак[3], канд. с.-г. наук, П.В. Писаренко[2], докт. с.-г. наук, В.В. Книш[3], Ю.О. Тараріко[4], докт. с.-г. наук, Ю.В. Сорока[5], канд. с.-г. наук, З.В. Щербина[6], канд. с.-г. наук

[1.] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна;
https://orcid.org/0000-0002-0213-0496; e-mail: saidak_r@ukr.net;
[2.] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна
https://orcid.org/0000-0002-2104-2301; email pavel_pisarenko74@ukr.net;
[3.] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна;
https://orcid.org/0000-0002-3220-9883; e-mail: iwpim27@gmail.com;
[4.] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна
https://orcid.org/0000-0001-8475-240X; e-mail: urtar@bigmir.net;
[5.] Інститут водних проблем і меліорації НААН, 03022, м. Київ, Україна
https://orcid.org/0000-0001-6228-4131; e-mail: agroresurs@bigmir.net;
[6.] Селекційно-генетичний інститут – Національний центр насіннєзнавства та сортовивчення НААН,
65036б, м. Одеса, Україна, https://orcid.org/0000-0002-4630-8372; email: zoyasgi09@ukr.net;

Анотація. *У статті досліджується важливість урахування низки факторів, які впливають на водний режим ґрунту у контексті розробки моделей для прогнозування запасів продуктивної вологи в ґрунті. Встановлено, що основні фактори, такі як тип ґрунту, його щільність та механічний склад, залишаються сталими у різних ґрунтово-кліматичних регіонах України. Друга група факторів, таких як температура повітря, опади та вологість ґрунту, піддаються змінам упродовж вегетаційного періоду та навіть коротких проміжків часу. Тому подальшими обчисленнями враховано динаміку вологості ґрунту як функцію основних змінних, таких як середня температура повітря та кількість опадів. Для більш точного прогнозування запасів вологи на кінець визначеного періоду використовують початкові запаси вологи, а також гідротермічні умови, розглянуті як предиктори у рівнянні регресії. Достовірність проведених досліджень підтверджується аналізом незалежної вхідної та вихідної інформації з метеостанції м. Херсон у період з 2018 по 2021 рр. щодо фактичних запасів продуктивної вологи в ґрунті на глибині 0–20, 0–50 та 0–100 см. Середня похибка між фактичними та розрахунковими даними не перевищувала +13,5 %. Це підтверджує надійність та прецизійність проведеного дослідження, роблячи його основою для подальших аналізів і висновків. У висновках відзначено необхідність точного визначення вологості ґрунту з метою ефективного управління агрометеорологічними умовами та оптимізації врожайності сільськогосподарських культур. Автори підкреслюють, що науково-дослідна робота, яка лягла в основу цієї статті, здатна зробити вагомий внесок у розвиток сучасних підходів до вологозабезпечення у галузі сільського господарства та агрометеорології. Це сприятиме поступовому та вдосконаленому розвитку методології прогнозування вологості ґрунту, що є ключовим для забезпечення стійкого та продуктивного розвитку сільського господарства.*

Ключові слова: *водний режим ґрунту, прогнозування вологозапасів, моделювання, фактори впливу, гідротермічні умови, врожайність, сільське господарство, зміна клімату*