

Statistical Aspects for Evaluation of The Efficiency of Water Consumption in Agriculture

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Abstract- In this paper has been proposed methods have been tested on statistical data on the regions of the Republic of Uzbekistan for a long period, which makes it possible to take into account the specifics of the stages of world economic cycles in the studied relationship of indicators.

Keywords: Agricultural production, irrigation, melioration, water consumption, growth, cluster analysis, time intervals, statistics.

1. INTRODUCTION

The economy of Uzbekistan in general, and one of its leading industries in particular, is characterized by a high dependence on water resources and a shortage of local fresh water resources. According to the conclusions presented in the World Bank report, “If current trends in water usage and population growth continue, Uzbekistan will reach water scarcity levels by 2030. In addition, climate change is having an adverse impact on the regime of formation, volume and quality of water resources in the region” [1].

According to the level of groundwater mineralization, a number of territories are classified as “mainly saline”, in some areas there is a “secondary salinization” of lands by 45.7 percent” [2]. For the purpose of stable water supply of the population and all industries of the economy of the Republic of Uzbekistan in 2020-030, improving the ameliorative state of irrigated lands, widely introducing market principles, mechanisms and digital technologies in the water sector, ensuring the reliable operation of water facilities, as well as increasing the efficiency of the use of land and water resources, was developed and approved by the Decree of the President “Concept for the development of the water sector of the Republic of Uzbekistan for 2020-2030” [2]. The main recommendations of this Concept include "the development of guidelines for design, introduction and application of water-saving irrigation technologies, as well as criteria for evaluating the effectiveness of their use [2].

2. LITERATURE REVIEW

Estimation of the water use efficiency at the farm level has been a challenge, because it is not easy to measure crop evapotranspiration. The gravimetric method, which involves taking soil samples to determine moisture content by weighing the wet and then the dry soil, and to estimate the specific gravity for each sample at various places on a plot, are very difficult and expensive. Due to the spatial variability of soil, it requires taking several samples from each plot of each crop which would involve many people to do this task.

The use of lysimeters is another method that requires the construction of these devices which is usually done in research institutions, but its use is not possible in every crop or plot of interest. Turbulent flow measure devices (Eddy Correlation) are also used, but the cost is high and is generally used to calibrate other more simplistic methods.

There are several empirical or semi-empirical methods that have been used to estimate water use of crops for many years, among them, the method of Thornthwaite, Blaney and Criddle, Penman-Monteith, which generally attempt to estimate the potential or reference evapotranspiration, which measures the evapotranspiration demand by climatic factors. On the other hand, the crop evapotranspiration is generally very variable since it depends on the crop vegetative development, on the spatial variability of soil, on water stress in the plant and many other factors whose variability is difficult to assess. Currently available automatic weather stations can be used to estimate the reference evapotranspiration by the Penman-Monteith equation, with software that is installed in the automatic weather station [5].

As mentioned before, the crop evapotranspiration is highly variable and it is usually estimated, affecting the reference evapotranspiration by a dimensionless factor called crop coefficient (K_c) [5]. The crop coefficient

changes according to the crop development. Interestingly, this factor can be estimated based on a vegetation index called NDVI, which can be obtained using satellite images. In this regard, it should be noted that compared with METRIC, a model developed by the University of Idaho, the method described in this article is easier to develop and gives similar results in the estimation of the water use efficiency when used properly [6].

3. ANALYSIS AND RESULTS

The development of methods for regulating the water supply of sectors of the economy (and agriculture in particular) requires mathematical and statistical research on long-term spatial and temporal data. Combining technological and economic information of water consumption. However, scientific publications in this area are very limited. As an example of two research approaches, two papers based on the application of statistical methods are presented below. Each of these studies presents methodologies. requiring meaningful reinforcement: the first - in the spatial and technological aspect, and the second (having a spatially technological orientation) - vice versa. in the economic aspect [1].

The study was carried out according to the data of the regions of the Republic of Uzbekistan for years with a five-year interval: 2005, 2010, 2015, 2020, and 2021 was included in the calculations to compare the pre- and post-COVID situation. Cluster analysis was carried out according to indicators characterizing the intensity of water consumption in sectors of the economy per one employed person, the intensity of obtaining (transferring) water and industrial consumption in agriculture (per 1 ha), as well as the growth of agricultural production - the main sector of water consumption [3].

The inclusion of the latter indicator in the cluster analysis made it possible to assess the structural and dynamic changes in the characteristics of industrial water consumption in relation to the effectiveness of agricultural production.

The following indicators were used in the study:

- The volume of water annually received in the sectors of the economy, m3 per 1 employed person (Vz_{05}, \dots, Vz_{21})
- Growth rates of agricultural production by regions, % ($Gr_{AG_{05}}, \dots, Gr_{AG_{21}}$)
- Water transfer, m3/ha ($Vper_{ga_{05}}, \dots, Vper_{ga_{21}}$)
- The volume of water consumed per 1 hectare in the regions, thousand m3 per 1 ha ($PotrV_{ga_{05}}, \dots, PotrV_{ga_{21}}$).

At the first stage of the study, based on the results of cluster analysis (Ward method), it was found (Table 1) that in the regions included in the cluster with higher growth rates of agricultural production, the relative values of water supply, water disposal and water consumption per 1 ha are higher. In the covid (2020) year, the situation reversed: the regional cluster with higher values of the considered irrigation indicators lagged behind in the growth rates of agricultural production. this indicates that non-technological (market) factors had a more significant impact in the crisis year. In the post-COVID year (2021), the situation returned to pre-crisis. However, a significant difference in indicators of water availability and water consumption by regional clusters did not provide the pre-crisis effect of the difference in the growth rates of agricultural production. The elasticity of agricultural production growth in terms of interrelated indicators of water availability and water consumption returned to positive values, but remained significantly lower than in the pre-coronavirus period.

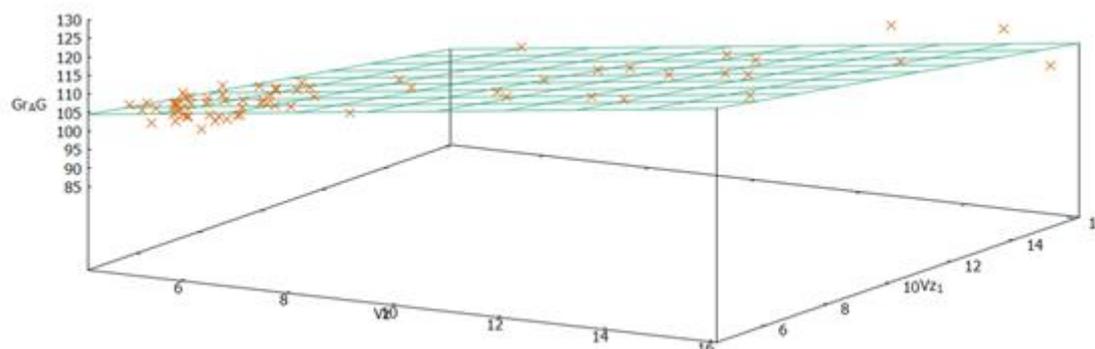


Fig.1. Graphical representation of a panel regression model that characterizes the impact of water consumption (taking into account the annual lag) on the growth of agricultural production (Cluster of 3 regions of the Republic of Uzbekistan).

Model 1 (cluster 1)

$$\text{Gr_AG}(1) = 107.67 + 0.996 * \text{Vz_1} - 0.691 * \text{Vper_ga_1}$$

Model 2 (cluster 2)

$$\text{Gr_AG}(2) = 109.89 - 1.14 * \text{Vz} + 2.52 * \text{Vz_1} + 0.987 * \text{Vper_1} - 2.01 * \text{Vper_ga_1}$$

Model 3 (cluster 3)

$$\text{Gr_AG}(3) = 101.37 + 1.868 * \text{Vz} - 1.254 * \text{Vz_1}$$

Designations of indicators of models are given above. The sign (_1) indicates that the indicator is included in the model with a one-year lag [4].

The explanatory properties of the obtained models are very high (more than 80%). The quality of the models is also confirmed by the distribution of residuals close to the normal distribution law (Fig. 3).

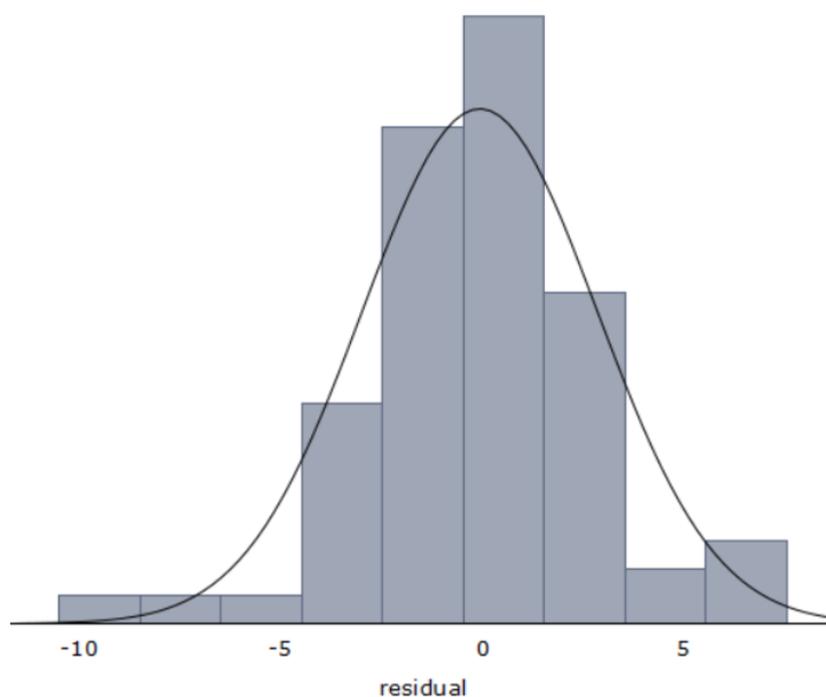


Fig. 2. Distribution of residuals of the panel regression model characterizing the impact of water consumption on the growth of agricultural production (Cluster 3).

4. CONCLUSIONS

From the content of the models, we can conclude that indicators for assessing the response of agricultural production growth should be not only (and not so much) water consumption per 1 ha of crops (as suggested in the above works), but the interdependence of technological indicators of irrigation, their intensity per 1 ha and 1 worker, as well as the cyclicity of influence, as indicated by the signs of the model parameters at the current and lag values of the variables. When developing management indicators for the efficiency of water consumption in agriculture, it is also necessary to consider the spatial specificity of the identified statistical patterns.

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