ORIGINAL ARTICLE

ECONOMETRIC ANALYSIS FOR MANAGING THE EFFICIENCY OF WATER CONSUMPTION IN AGRICULTURE IN THE REGIONS OF UZBEKISTAN

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| Received June 29, 2023 | | Accepted July 05, 2023 | | Published July 10, 2023 | | ID Article | Normatovich-Ref2-6-16ajiras290623 |

ABSTRACT

Introduction: The efficient management of water consumption in agriculture is essential for sustainable water resource utilization. This study focuses on developing mathematical models to assess the socio-economic efficiency of water consumption in agricultural practices in Uzbekistan, considering regional characteristics. The objective is to derive indicators for effective water consumption management and analyze causal relationships between these indicators. **Objective**: The objective of this study is to build and test mathematical models using open data from official statistics to evaluate the socio-economic efficiency of water consumption in agriculture in Uzbekistan. Additionally, this research aims to develop indicators for water consumption management, taking into account regional characteristics. **Results**: The findings of this study suggest that analyzing causal relationships and considering the "lagging influence" of indicators in econometric models is crucial. To address this, the indicators were examined using both "current" values and values with lags of 1-2 years. Furthermore, several measures can be implemented to address water consumption and promote efficient use of water resources in the agricultural sector. These measures include: Implementation of a water pricing system: Introduce a tiered pricing structure that charges users based on their water consumption. This system can incentivize users to be mindful of their water usage and promote water conservation. Promotion of water-saving technologies: Encourage the adoption of water-saving technologies, such as drip irrigation systems and water-efficient devices. These technologies have the potential to significantly reduce water consumption in agriculture. Encouragement of water conservation practices: Promote practices like rainwater harvesting and greywater recycling to reduce reliance on freshwater sources and minimize overall water consumption. Investment in water infrastructure: Allocate resources to develop and maintain water treatment plants and distribution systems. This investment can help reduce water losses due to leakage and enhance overall water use efficiency. Public education: Raise awareness among the population about the importance of water conservation and efficient water use. Encourage individuals to adopt responsible water management practices. **Conclusion**: In conclusion, this study highlights the significance of analyzing causal relationships and considering lagging influence in econometric models when evaluating indicators of water consumption management. Implementing measures such as a water pricing system, promoting water-saving technologies, encouraging water conservation practices, investing in water infrastructure, and conducting public education campaigns can contribute to effective water resource management and sustainable agricultural practices..

Keywords: *management, socio-economic efficiency of water consumption, agriculture, water management.*

1. INTRODUCTION

The Concept for the Development of Water Resources in the Republic of Uzbekistan for 2020-2030 [1] emphasizes the importance of expanding the use of water-saving irrigation technologies and enhancing water use efficiency as key priorities. It also highlights the need for state support and incentives to encourage agricultural producers to adopt water-saving methods and technologies [1]. To ensure the effective implementation of the Concept, it is crucial to address methodological and information-algorithmic challenges related to continuous monitoring of target indicators. These indicators reflect the utilization of the substantial potential for improving water supply to farmers and enhancing the efficiency and productivity of water use at the agricultural holdings level [1]. In order to evaluate the significance of developing quantitative research methods for assessing water consumption efficiency in Uzbekistan's agriculture, considering regional variations, a comprehensive analysis of scientific and practical works in this specific area was conducted. This analysis aimed to provide a foundation for the development of robust and scientifically sound methodologies for studying water consumption efficiency in agriculture in Uzbekistan.

The task of developing and analyzing indicators of water consumption in agriculture, which are systematically linked to corresponding indicators of water consumption in other sectors and the overall economy, has been addressed by several studies [4,5,6,810]. Additionally, indicators of socio-economic efficiency have been considered. This task was discussed during the 24th session of the FAO on "Water Resources Management for Agriculture and Food security" (Rome, 29.09 – 03.10.2014), where it was acknowledged that agriculture, accounting for approximately 70% of total water consumption, is increasingly demanding its share of water resources to ensure food production and food security. However, the rationality of water use in agriculture is being scrutinized [2].

The literature review presented in this study reveals a limited representation of an important area of quantitative research that requires further development in terms of methodology and data availability. Specifically, there is a need for the creation of modeling and analysis tools based on open data sources to understand the macroeconomic response to changes in water consumption in agriculture [7].

This direction is very relevant for the Republic of Uzbekistan and the regions in connection with the above Concept for the Development of the Water Resources of the Republic of Uzbekistan for 2020-2030, the task of constantly monitoring the achievement of the main target indicators for improving the efficiency of the use of water resources.
On the other hand, the presented review of the works makes it possible to take into account their individual aspects in the formation of the purpose and objectives of this study.

To achieve the goal of the study, the following tasks were solved:

Creation of an information array based on official statistics of Uzbekistan, including spatial and dynamic characteristics of water consumption, as well as indicators of economic growth of the economy as a whole and agricultural production. Performing statistical cluster analysis in order to identify homogeneous groups of regions of the Republic of Uzbekistan in terms of water consumption and economic growth in the economy and the agricultural sector. Carrying out a quantitative "causal" analysis in order to identify and assess the direction of the relationship between indicators of the dynamics of water consumption in agriculture and indicators of economic growth, assess the specifics of these relationships for individual regions and regional clusters. Performance management indicators for water consumption, taking into account regional features of the "response" of the economic system to the use of water in agricultural production.

2. MATERIALS and ETHODS

2.1 Study Design

This study adopts a quantitative research approach to examine the relationship between water consumption in agriculture and economic growth indicators in the Republic of Uzbekistan.
Data Collection:

Official statistical data will be collected from reliable sources, including government reports, agricultural databases, and economic indicators. The data will cover a specific time period to capture the relevant trends and patterns.

Variables:

Dependent Variable: Economic growth indicators (e.g., GDP, agricultural production)
Independent Variable: Water consumption in agriculture.

2.2 Data Analysis

Creation of an information array: Compile and organize the collected data, including spatial and temporal dimensions of water consumption and economic growth indicators.

Descriptive analysis: Calculate summary statistics and examine the distribution of variables.

Statistical cluster analysis: Employ cluster analysis techniques to identify homogeneous groups of regions based on water consumption and economic growth patterns.

Quantitative "causal" analysis: Conduct regression analysis or other appropriate methods to determine the relationship between water consumption in agriculture and economic growth, considering the specific characteristics of different regions and clusters.

2.3 Ethical Considerations:

Ensure the confidentiality and anonymity of collected data and comply with ethical guidelines regarding data usage and research integrity.

2.4 Limitations:

Acknowledge potential limitations of the study, such as data availability, quality, and the complexity of capturing all factors influencing economic growth in the analysis.

2.4 Statistical Software:

Utilize statistical software (e.g., SPSS, R, STATA) to perform data analysis and generate meaningful results.
Interpretation of Results:

Analyze the findings in relation to the research objectives and discuss the implications for water resource management, agricultural practices, and economic policies.

3. RESULTS AND DISCUSSION

According to the Law of the Republic of Uzbekistan "On official statistics" (2021), state statistical bodies are obligated to provide statistical data to public authorities and integrate with information systems of state and economic administration bodies, as well as local executive authorities, to conduct statistical observations and analyze official statistical data [11].

The presented indicators enable the construction of a hypothetical directed graph illustrating the information links (Figure 1). The graph shows both direct (solid arrows) and indirect (dashed arrows) mutual influences between indicators representing water consumption in the overall economy and agriculture, as well as corresponding indicators of economic growth. The objectives of this study included statistically assessing the directions and strengths of connections within the graph based on the generated data array for Uzbekistan's regions. Additionally, the study

aimed to evaluate the economic growth response of regions to changes in agricultural production (Δ_(2 (t))) due to variations in water consumption in agriculture (Δ_(1 (t))) [9].

The presented graph also reveals the bidirectional nature of the cause-and-effect relationships among the considered indicators, represented by the two-way arrows in the figure. Consequently, the study addressed the issue of determining the priority direction of the causal relationship between the indicators in order to include them in the model. The resulting values serve as response indicators (and) of Δ_(1 (t))economic Δ_(1 (t))growth and the growth of agricultural production in response to the dynamics of water consumption in agriculture (indicated by unidirectional arrows in Figure 1).

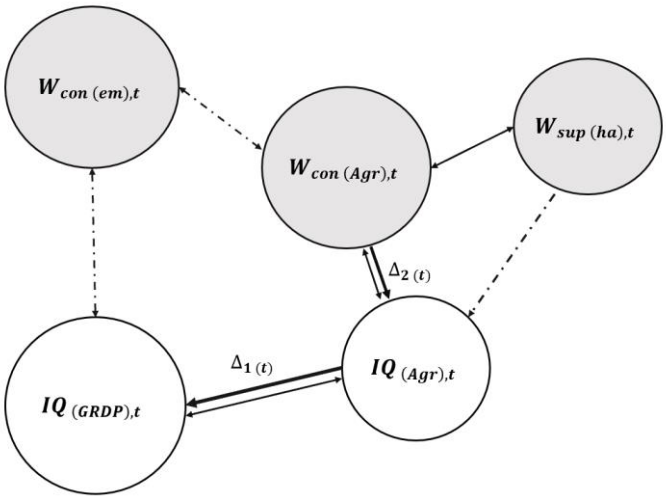

Figure 1: Fig.1. Graph of links (hypothetical) of indicators of official statistics characterizing the efficiency of water consumption in agriculture of the regions of the Republic of Uzbekistan.

The available information for the study allowed us to conduct a cluster analysis, which involved delimiting the study period (2015 and 2022) and the "post-COVID" period (2020 and 2021). Hierarchical cluster analysis was performed using Ward's method and the "Euclidean" distance estimation metric to compare population units.

Based on the data presented in Table 1, it is evident that the cluster composition has changed over the years under consideration. To investigate the time lags and their impact on the analysis of causal relationships between indicators, it is important to assess the extent of divergence in cluster composition within specific intervals. This assessment will enable us to determine the time interval with the most significant change in cluster composition and subsequently estimate the relationships between indicators over that particular time interval.
Table 1 presents two-input contingency tables containing the results of the distribution of regions in two clusters in the compared years (2023 and 2015 and 2022 and 2021).

Table 1: Assessing the contingency of the results of clustering the regions of the Republic of Uzbekistan in terms of the efficiency of water consumption in agriculture:

(a) 2015 – 2023

2015 / 2022	Cluster 1	Cluster 2	Total
Cluster 1	6	1	7
Cluster 2	3	3	6
Total	9	4	13

(b) 2021 – 2023

Evaluate the similarity between two cluster partitions, the Fowlkes - Mallows index can be used . index) [12].

The assessment of this index (FM) was carried out according to the method described in the Internet resource "Quality Assessment in the Clustering Problem" [13]. The following values were used:

TP is the number of elements belonging to the same cluster in both years (in the first case: 2015 and 2022);

FP is the number of elements belonging to the same cluster in the base year (2015) but to different clusters in the compared year (2022);

FN is the number of elements belonging to the same cluster in the compared year (2022) but to different clusters in the base year (2015).

FM index is calculated using the formula:

$$FM = \sqrt{\frac{TP}{TP+FP} * \frac{TP}{TP+FN}}. \quad (2)$$

According to Table 2 (a), the value of the FM index was 0.43, and according to the data of the same table, but point (b), it was 0.35.

A higher index value means greater similarity between the clustering of regions in the indicated years.
It can be concluded that in the last years of the " post-COVID " period, an increase in "territorial stratification", i.e. in this study, the differentiation of regions in terms of the efficiency of water consumption in agriculture was significantly more intense than in the previous eight-year period.

The assessment of the closeness of the relationship of systemically related indicators should be supplemented by an analysis of their orientation, which allows for each pair of interrelated variables to establish a variable - "cause" and a variable - "consequence".
The solution to this problem is possible using the Granger causality test (Granger Causality test)
Table 3. Assessment of the directions of causal relationships between the indicators " Growth rates of agricultural production by regions, in comparable prices, as a percentage of the previous year ($IQ_{(Agr),t}$)" and " Growth rates of gross domestic (regional) product, in comparable prices, in percent to the previous year ($IQ_{(GRDP),t}$)" according to the Granger method [8].

No.	Territory	Economic growth is the "cause"; the growth of agriculture is a "consequence". PKC values	Agricultural growth is the "cause"; economic growth is a "consequence". PKC values	The relationship between economic growth and agricultural growth is reciprocal in the current period. PKC values
1	The Republic of Uzbekistan	0.429	-	0.409
2	Republic of Karakalpakstan	-	-	0.799
3	Andijan region	0.371	-	0.404
4	Bukhara region	-	-	0.882
5	Jizzakh region	-	0.433	0.602
6	Kashkadarya region	-	0.531	0.404
7	Navoi region	-	-	-
8	Namangan region	0.591	-	0.691
9	Samarkand region	0.561	-	0.664
10	Surkhandarya region	0.373	-	0.637
11	Syrdarya region	-	-	0.608
12	Tashkent region	-	-	-
13	Fergana region	-	-	0.559
14	Khorezm region	0.434	-	0.583

Note: paired correlation coefficients (PKC) are given. Significant by Student's t -test.

Generalization of the results of the assessment of paired correlation coefficients between indicators of economic growth ($IQ_{(GRDP),t}$) and agricultural production growth ($IQ_{(Agr),t}$) for 2005-2021. Taking into account the lags of lagging influence, leads to the conclusion that the territories under consideration have a different type of causal dependence of the indicated growth parameters:

(1) The growth of the economy as a whole and the growth of agricultural production have a significant statistical relationship only in the current year, that is, the "instantaneous" Granger relationship described above is manifested. These are the regions: the Republic of Karakalpakstan, Syrdarya, Bukhara and Fergana regions.
(2) The growth of the economy as a whole is the "cause" of the growth in the results of agricultural production. This is evidenced by a statistically significant close correlation between the growth of GRP, taking into account the annual lag of the lagging effect, and the growth of agricultural production in the current year. This type of relationship manifested itself in the Republic of Uzbekistan as a whole, as well as in Andijan, Namangan, Samarkand, Surkhandarya, Khorezm regions.
(3) The growth of agricultural production is the "cause" of the growth of the economy as a whole. In this case, the closest correlation appears between the growth of agricultural production in the previous year and the growth of the economy in the current year. This type of causal relationship is typical for Jizzakh and Kashkadarya regions.
(4) For two regions (Navoi and Tashkent regions), a statistically significant relationship between the growth of GRP and the growth of agricultural production was not revealed either in the current assessment or taking into account lagging impact lags. The indicated types of causal relationship and the corresponding estimates of the type of economy by region of the Republic of Uzbekistan are presented in Figure 2.

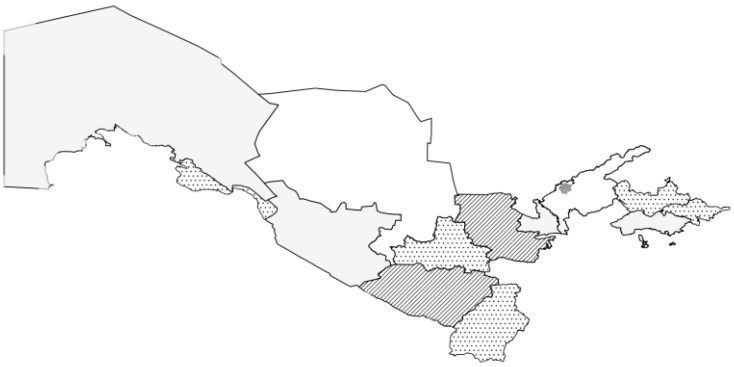

Figure 2: Table presents the types of regions according to the characteristics of causal relationships of economic growth and agricultural production growth, established on the basis of the Granger test according to the data of the Republic of Uzbekistan for 2005-2021

Designations:

The growth of the economy as a whole predetermines the growth of agricultural production.
The type of economy is "more" industrial .

The growth of agriculture predetermines the growth of the economy.
The type of economy is "more" agrarian.

The growth of the economy as a whole and the growth of agricultural production are interconnected "at the same time", the relationship has no sign of causality.
The type of economy is balanced.

There was no significant statistical relationship between economic growth and agricultural production growth.
The type of economy is unbalanced.

In accordance with the results of the analysis of the directions and strength of causal relationships, it was found that in the Kashkadarya region, the growth of agriculture to the greatest extent determines the growth of the economy (Fig. 3).

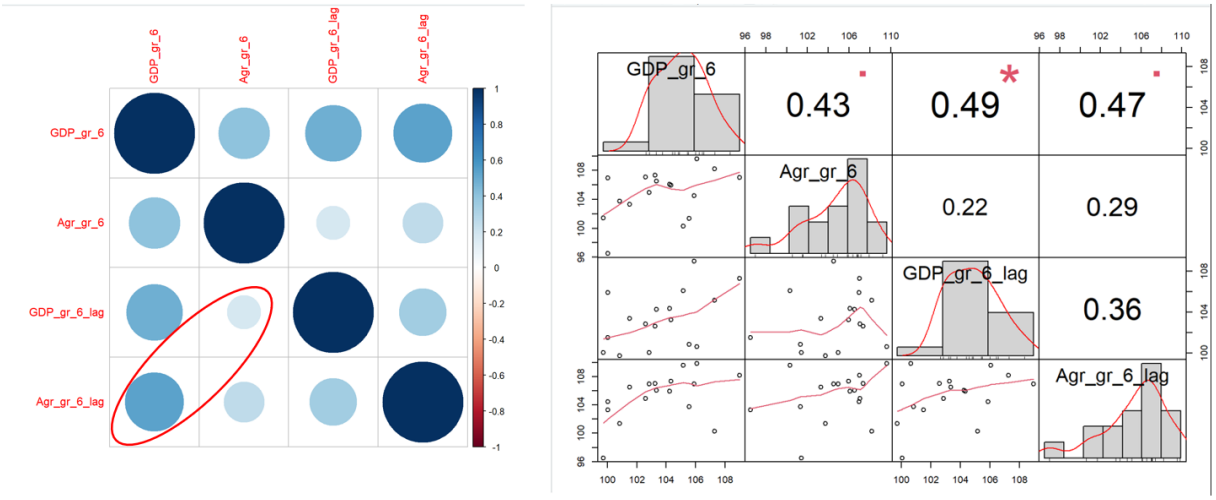

Figure 3 : Figure presents the statistical characteristics of the directions of the causal relationship between the indicators of economic growth and the growth of agricultural production in the Kashkadarya region, 2005-2021
Note 1. The following designations are used in Figure 3:

GDP _ gr _6 and GDP _ gr _6_ lag - respectively, the indicators "Growth rates of gross domestic (regional) product, in comparable prices, as a percentage of the previous year " in the current year and taking into account the annual lag. Number 6 corresponds to the number of this region in Table 3.

Agr _ gr _6 and Agr _ gr _6_ lag - respectively, indicators " Growth rates of agricultural production, in comparable prices, as a percentage of the previous year " in the current year and taking into account the annual lag.

Note 2. On the left is a graphical representation of the paired correlation coefficients; on the right are histograms of the distribution of the indicated variables.

Figure 3 shows the strongest effect of "causation" of economic growth due to the growth of agriculture revealed in Kashkadarya region. This effect is a manifestation of the agrarian type of economy, which, as shown by calculations for two regions of Uzbekistan (Kashkadarya and Jizzakh regions), which are geographically close to each other. In Fig. 3 (left), this effect is underlined by an oval to compare the values of paired correlation coefficients when using the Granger causality method and supplemented by the possibility of comparing the histograms of the distribution of indicators GDP_gr_6 and Agr_gr_6_lag located at the extreme points of the diagonal (right side of Fig. 3). Both distributions have a left-sided asymmetry.

For the agrarian-type economy, as well as for the other selected types of the regional economy of Uzbekistan ("industrial", "balanced", "unbalanced", see Fig. 2), it is theoretically and practically significant to solve the issue of developing indicators for managing the efficiency of water consumption in agriculture. This is due both to the above estimates of the causal relationship between economic growth and agricultural growth, and the high share of agricultural production in the volume of gross regional product. According to the Agency of Statistics under the President of the Republic of Uzbekistan, " In January-September 2022, the share of agriculture, forestry and fisheries in the GDP of the Republic of Uzbekistan amounted to 24.8%. The largest shares of agriculture, forestry and fisheries in the sectoral structure of GRP are in Jizzakh (49.7%) and Surkhandarya (46.9%) regions. The smallest shares of agriculture, forestry and fisheries were noted in Navoi (13.3%) and Tashkent (21.7%) regions.

4. CONCLUSION

Taking into consideration this conclusion, in order to analyze the causal relationships of the indicators being examined and account for the effect of "lagging influence" in econometric models, the indicators were used with both "current" values and values with lags of 1-2 years.

Here are some measures that can be implemented to address water consumption and promote efficient use of water resources:

- Implementation of a water pricing system: Introduce a pricing system that charges users based on their water consumption, preferably with a tiered structure where higher levels of consumption incur higher costs. This can incentivize users to be more mindful of their water usage.
- Promotion of water-saving technologies: Encourage the adoption and use of water-saving technologies such as drip irrigation systems and water-efficient devices. These technologies can significantly reduce water consumption in various sectors.
- Encourage water conservation practices: Promote water conservation practices like rainwater harvesting and greywater recycling. These initiatives can help reduce reliance on freshwater sources and minimize overall water consumption.
- Investment in water infrastructure: Allocate resources to invest in water infrastructure, including the development and maintenance of water treatment plants and distribution systems. This investment can help reduce water losses due to leakage and enhance overall water use efficiency.
- Public education: Educate the population about the importance of water conservation and the need for efficient water use. Raise awareness about water-saving habits and encourage individuals to adopt responsible water management practices.

By implementing these measures, it is possible to reduce water consumption, improve water resource management, and ensure the sustainable use of this valuable natural resource.

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Cite this article: AKHMEDOV SAYFULLO NORMATOVICH. ECONOMETRIC ANALYSIS FOR MANAGING THE EFFICIENCY OF WATER CONSUMPTION IN AGRICULTURE IN THE REGIONS OF UZBEKISTAN. *Am. J. innov. res. appl. sci.* 2023; 17(1): 15-24.