

# Econometric analysis of the influence of climate characteristics on the ecological condition of soils and the productivity of agricultural crops

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**Abstract.** An increase in air temperature causes water loss from irrigated areas due to evaporation. Such changes, in turn, increase the water demand of crops. High air temperature accelerates the natural decomposition of organic matter and causes a decrease in soil fertility. Furthermore, the probability of the spread of plant pests and diseases increases. This article presents an econometric analysis of the influence of climate characteristics on the ecological status of soils and the productivity of agricultural crops. The results of econometric modeling show that the constructed models can be used to forecast cotton yield for future periods. In Chimboy district (model 1), the influence of non-saline and weakly saline lands, groundwater level and relative air humidity on productivity was clearly demonstrated.

## 1. Introduction

Global warming and accompanying climatic changes have serious consequences affecting or threatening important social, economic and ecological aspects of the country's life [1, 2]. As observed in all sectors, the development of agriculture depends on climate change, which has a negative impact on land and water resources. Therefore, effective use of land and water resources and their protection, as well as increasing soil fertility in the conditions of climate change, will be the impetus for the future development of agricultural industries and determine the country's prospects [3]. The dependence of agricultural productivity on climate change is largely determined by the geographical location of the area. The impact of climate change is characterized by an increase in the problem of water scarcity in growing crops in arid regions [4-7]. Clearly, an increase in air temperature causes water loss from irrigated areas due to evaporation. Such changes, in turn, increase the water demand of crops. High air temperature accelerates the natural decomposition of organic matter and causes a decrease in soil fertility. Furthermore, the probability of the spread of plant pests and diseases increases [8-10].

In the conditions of global climate change observed in the world, scientific researches are being conducted to prevent the process of salinization occurring in the soil cover and to mitigate its consequences, to take into account natural and climatic conditions in determining the influence of external factors on soil properties. In this regard, the influence of climate characteristics on the ecological condition of soils and the productivity of agricultural crops diagnostic work using econometric modeling methods, special attention is paid to the creation of models of salt tolerance of agricultural crops and soil salinity in order to effectively use saline lands [11, 12]. This, in turn, is of great importance in the correct description of the direction of the processes taking place in the soil and the determination of interrelationships between them, the management of soil processes, the improvement of the condition of saline lands in the conditions of climate change, their rational use, and the development of optimal agro-ameliorative measures aimed at preventing negative factors [13]. At a time when climate characteristics are significantly changing and its impact on the environment is

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increasing. It is important to preserve soil cover and biological diversity from the active influence of various factors, especially the anthropogenic factor [9-11].

In this regard, many scientific research institutes in the world and in our republic are conducting valuable scientific research work on mitigating the consequences of global warming, managing saline soils, and restoring highly saline soils [10-12]. In particular, the development of theoretical foundations and effective methods of combating salinity, the use of modern agro-technologies in the cultivation of agricultural products taking into account the maintenance and increase of soil fertility, the development of biological ways of restoring and increasing soil fertility, and the creation of advanced technologies, the diagnosis of land reclamation of degraded lands such as developing new methods, studying the dynamics of changes in various climatic characteristics of the region due to global warming [2, 3, 4, 6].

Gómez-Limón JA [10] that the hydrological drought risk associated with climate change in the immediate regions also significantly affects the Mediterranean countries. In this regard, issues related to the negative consequences of interruptions in water supply in irrigated agricultural lands, which cause great concern, especially in water supply enterprises, have been researched. Accordingly, a new type of index insurance is proposed to cover the risk of drought-induced water supply interruptions of irrigated agricultural land. The proposed type of index insurance is a promising tool to effectively manage the risk associated with hydrological drought. Eze E. et al [11] studied the risk mitigation issues for local people as a result of reducing the impact of climate change on agricultural crop productivity through the introduction of index insurance. In the research work, agriculture has sought to evaluate the use of crop water requirements in assessing crop productivity. In this regard, they recommended a model for estimating the yield of agricultural crops using the CROPWAT 8.0 program of the Food and Agriculture Organization based on index insurance [4-6].

Regional climate change will lead to an increase in the number of extreme weather events, such as periods of drought and increased summer highs, patterns of water resources formation, and land degradation [1]. In particular, Uzbekistan pays special attention to actions such as protection and rational use of natural resources in the face of climate change. It should be noted here that the main soil resources used in agriculture are limited in terms of area and quality. Obviously, their current condition is certainly alarming, because in the last 30-50 years, the soil has become poor in humus and nutrients, subjected to salinization, water and wind erosion, polluted with heavy metals, fluorides, agrochemicals, etc. Especially in the desert regions, as a result of the increasing risk of negative factors such as drought, desertification and salinity, severe water shortages are observed, as a result of which soil fertility and crop yields decrease. The largest areas facing this problem correspond to the territory of the Republic of Karakalpakstan [5].

## 2. Materials and Method

It is known that the problem of salinity in irrigated lands causes both economic and social consequences at the same time. As a result of salinity, deterioration of all diagnostic indicators determining soil fertility was observed. For example, a decrease in the amount of soil humus, macro and micronutrients, deterioration of agrophysical properties, and a decrease in microbiological and biochemical processes. Aligning this, various measures have been implemented by the State to eliminate the problem of salinity: PD -2731 of the President of the Republic of Uzbekistan dated January 18, 2017 "On the state program for the development of the Aral Bay region in 2017-2021", PF -5065 and 5635 of the President of the Republic of Uzbekistan dated May 31, 2017 and January 17, 2019, "On measures to strengthen control over land protection and rational use, improve geodesy and cartography activities, and regulate state cadastre management" and "Five priority areas of development of the Republic of Uzbekistan in 2017-2021". According to the Decree on the implementation of the Action Strategy in the "Year of Active Investments and Social Development" and other regulatory legal documents related to this activity, the main tasks are to increase and maintain the productivity of irrigated soils in the harsh environmental conditions towards further improvement of targeted measures.

It is known that global climate change is of great importance in the conditions of Uzbekistan, and its manifestation is often associated with human activities aimed at rapid development of land. Therefore, the study of problems related to climate change, that is, its impact on nature and its consequences, requires a comprehensive approach. To date, the environmental condition of natural components, including soils, is strongly observed in the territory of the island. Increased irrigation and saline leaching rates are leading to rising seepage water levels, which in turn are causing further soil salinization. In fact, soil salinity has a negative impact on soil properties and at the same time sharply reduces crop productivity. Therefore, with the increase in soil salinity, its quality also decreases. Therefore, studying the causes of salinization processes that are rapidly occurring not only in our country, but also in various regions of the globe, and developing the theoretical basis of measures aimed at its prevention are very urgent issues.

In this research, lands of varying degrees of salinity distributed in the Chimboy district of the Republic of Karakalpakstan were selected, where all experiments were carried out.

### 3. Results and Discussion

According to the results of a large number of experiments, a significant reduction in the yield of the main agricultural crops was observed even in low salinity lands. The acceleration of this process can make the land unsuitable for agricultural crops, which attracts the attention of many researchers. Soil salinity is largely dependent on crop selection, water management, and agricultural technologies. For example, growing cotton requires more water than growing wheat. In the case of saline soils, this creates a number of difficult situations. Therefore, in order to deeply understand all the processes taking place in desert soils and their relationship with external environmental factors, in order to solve these general problems, it is important to study the factors that cause salinity, as well as the factors that can be negatively affected by the salinization process.

Econometric modeling of the impact of climate change on the productivity of agricultural crops allows to identify “narrow” areas in this field and to make optimal decisions on their elimination. Econometric modeling is one of the areas that can analyze the activity of agricultural industries in our country and develop these industries in the future. Econometric models allow not only to quantitatively analyze the development indicators of the agricultural sector, but also to determine the composition of factors affecting it and the share of each factor [7, 8]. In the case of Amudarya and Chimboy districts of the Republic of Karakalpakstan, the following factors were selected in order to determine the effect of climate change on the productivity of agricultural crops through econometric modeling:

- the resulting factor - productivity of agricultural crops (cotton), ts/ha, (  $Y$  );
- as influencing factors:
  - ✓ non-saline lands, ha ( $X_1$ ),
  - ✓ weakly saline lands, to ( $X_2$ ),
  - ✓ average salinity land ha ( $X_3$ ),
  - ✓ strong and very strong saline lands ( $X_4$ ),
  - ✓ underground water level, meter ( $X_5$ )
  - ✓ credit score of land, score ( $X_6$ ).
  - ✓ average annual air temperature, °C ( $X_7$ )
  - ✓ amount of annual precipitation, mm ( $X_8$ )
  - ✓ average annual temperature of the soil surface, °C ( $X_9$ )
  - ✓ relative air humidity, % ( $X_{10}$ )

First of all, before creating a multi-factor econometric model for cotton productivity in Chimboy district, it is necessary to determine the density of correlation between the factors included in this model. For this, correlation coefficients were calculated between factors (Table 1).

**Table 1.** Matrix of correlation coefficients calculated between cotton yield and factors affecting it in Chimboy district

$\ln(Y)$	$\ln(X_1)$	$\ln(X_2)$	$\ln(X_3)$	$\ln(X_4)$	$\ln(X_5)$	$\ln(X_6)$	$\ln(X_7)$	$\ln(X_8)$	$\ln(X_9)$	$\ln(X_{10})$	
$\ln(Y)$	1										
$\ln(X_1)$	0.6779	1									
$\ln(X_2)$	-0.0908	0.4431	1								
$\ln(X_3)$	0.5852	0.8924	0.5574	1							
$\ln(X_4)$	0.4504	0.7061	0.4042	0.8565	1						
$\ln(X_5)$	-0.5023	-0.1508	0.2779	0.0879	0.2319	1					
$\ln(X_6)$	0.8251	0.8156	-0.0925	0.6351	0.4973	-0.3715	1				
$\ln(X_7)$	0.1373	0.2493	0.2369	0.1998	0.0296	-0.2069	0.0976	1			
$\ln(X_8)$	-0.0798	-0.1933	-0.0719	0.0574	0.0893	0.2507	-0.2604	-0.0567	1		
$\ln(X_9)$	-0.0588	-0.0625	0.1180	-0.1157	-0.2535	-0.2480	-0.1270	0.7930	-0.1966	1	
$\ln(X_{10})$	-0.3119	-0.0473	0.1673	-0.1313	0.0588	-0.0777	-0.2119	-0.1076	0.2056	-0.0999	1

Cotton yield ( $\ln Y$ ) and annual precipitation, mm ( $\ln X_8$ ). A weak positive correlation was found between soil yield ( $\ln Y$ ) and the average annual temperature of the soil surface °C ( $\ln X_9$ ). There was also a weak inverse relationship between soil yield ( $\ln Y$ ) and relative air humidity ( $\ln X_{10}$ ). Correlation coefficients determined between the factors related to Chimboy district show that there is an average correct relationship between cotton yield ( $\ln Y$ ) and non-saline land, ha ( $\ln X_1$ ). There was a weak inverse relationship between cotton yield ( $\ln Y$ ) and weakly saline soils, ga ( $\ln X_2$ ). There is a moderately positive relationship between cotton yield ( $\ln Y$ ) and average salinity of land, ha ( $\ln X_3$ ). A weak positive correlation exists between cotton yield ( $\ln Y$ ) and high and very high salinity soils ( $\ln X_4$ ). It was found that there was an average inverse relationship between soil yield ( $\ln Y$ ) and groundwater level, meters ( $\ln X_5$ ). Furthermore, there was a strong positive association between soil yield ( $\ln Y$ ) and land credit scores, and scores ( $\ln X_6$ ). There was a

weak positive relationship between yield P (lnY) and mean annual air temperature, °C (lnX<sub>7</sub>). A weak inverse relationship was found between P ash yield (lnY) and annual precipitation, mm (lnX<sub>8</sub>). A weak inverse relationship was found between P ash yield (lnY) and the average annual temperature of the soil surface °C (lnX<sub>9</sub>). There was also a weak inverse relationship between soil yield (lnY) and relative air humidity (lnX<sub>10</sub>).

It should also be noted that there was a strong relationship between the pairwise correlations between the factors, which means that there was multicollinearity between the factors. This means that one of these factors should not be included in the constructed econometric model. This problem can be solved by constructing a multifactor econometric model by factors. Now we will create a multi-factor econometric model of cotton productivity in both districts based on the factors mentioned above. According to the Chimboy district, it has the following appearance:

$$Y = -34,803 + 0,313 \cdot \ln X_1 + 0,389 \cdot \ln X_2 - 0,678 \cdot \ln X_3 + 0,475 \cdot \ln X_4 - 0,959 \cdot \ln X_5 + 14,041 \cdot \ln X_6 - 1,071 \cdot \ln X_7 + 0,419 \cdot \ln X_8 + 0,692 \cdot \ln X_9 - 2,723 \cdot X_{10} \quad (1)$$

$$R^2 = 0,8733; F_{\text{account}} = 6,89.$$

Noteworthy, the coefficient of -34.803 in the model indicates the influence of factors were not taken into account. It can be said that planting more cotton per hectare (lnX<sub>1</sub>) on non-saline lands can lead to an average increase in cotton yield (lnY) by 0.313 quantile. Planting cotton more than 1 hectare on weakly saline lands (lnX<sub>2</sub>), it can increase cotton yield (lnY) by 0.389 quantile on average. Planting cotton more than 1 hectare in medium salinity lands (lnX<sub>3</sub>), it can be seen that cotton yield (lnY) can decrease by 0.678 quantile on average. Planting more cotton per hectare (lnX<sub>4</sub>) on strongly and very strongly saline soils can increase cotton yield (lnY) by an average of 0.475 quantile. An average rise of the underground water level by 1 meter (lnX<sub>5</sub>) causes a decrease in cotton yield (lnY) by 0.959 quantile on average. An average increase in land quality scores by one point (lnX<sub>6</sub>) leads to an average increase in cotton yield (lnY) by 14,041 quantile. Average annual air temperature, °C (lnX<sub>7</sub>) increases by 1 degree, causing cotton productivity (lnY) to decrease by 1,071 centners on average. If the amount of annual precipitation, mm (lnX<sub>8</sub>) increases by an average of 1 mm, the yield of cotton (lnY) will increase by an average of 0.419 centners. If the average annual temperature of the soil surface °C (lnX<sub>9</sub>) increases by 1 degree, the yield of cotton (lnY) will increase by 0.692 centners on average. Also, if the relative air humidity (lnX<sub>10</sub>) increases by 1% on average, cotton productivity (lnY) will decrease by 2,723 centners on average.

Furthermore,  $R^2 = 0,8733$  - the coefficient of determination showed that 87.33 percent of cotton productivity in Chimboy district depended on the factors included in the multifactor econometric model. The remaining 12.67 percent was the effect of unaccounted factors (mineral fertilizers, agrotechnology, irrigation regime, cotton variety). It was checked that whether the constructed multifactor econometric model matches the studied process or was statistically significant. Fisher's F-test was used for this. Fisher  $F$  -criterion, it was possible to check the full adequacy of the model: its compatibility with the real economic process [8]:

$$F_{\text{account}} = \frac{R^2(n-m-1)}{(1-R^2)m}, \quad (2)$$

where  $n$  – number of observations ;  
 $m$  – in the model effect doer number of factors ;  
 $R$  – multiple factor correlation coefficient.

The calculated Fisher criterion was compared with its value in the table. Finding the Fisher coefficient in the table row for  $k_1$  and  $k_2$ , it was necessary to define a column:  $k_1 = n - m - 1$  and  $k_2 = m$ . If  $F_{\text{account}} > F_{\text{table}}$  b dies, the constructed econometric model is said to be statistically significant or suitable (adequate) for the process being studied. If  $F_{\text{account}} < F_{\text{table}}$  b dies, the constructed econometric model was said to be statistically insignificant or inappropriate for the process being studied. In this case, a non-linear econometric model was chosen instead of a linear econometric model. (1) for the model  $k_1 = n - m - 1 = 21 - 10 - 1 = 10$  and  $k_2 = 10$  considering that, it can be determined that its value in the table is equal to 2.98. It turned out that it was by district  $F_{\text{account}} > F_{\text{table}}$ , that was  $F_{\text{account}} = 6,89 > F_{\text{table}} = 2,98$ . Therefore, the constructed econometric model was statistically significant, as it directly determines the state of cotton productivity in Chimboy district. In addition, with the help of this model, it was

possible to forecast cotton yield in both districts for future periods. In order to check the complete adequacy of the constructed multifactor econometric model (1), besides, it was checked the reliability of the factors involved in it. For this, Student's  $t$ -test was used and it was calculated using the following formula [7]:

$$t_R = \frac{R\sqrt{n-k-1}}{1-R^2}, \tag{3}$$

where,  $n-k-1$  - the number of degrees of freedom;  
 $t_R$  - compared with the value in the table;  
 $n-2$  with degrees of freedom  $t$  having a distribution

$$t_{a_j} = \frac{a_i}{\sigma_{a_j}}, \tag{4}$$

the reliability of the regression coefficients was checked based on the value. The values of Student's criteria calculated according to the values of regression coefficients in the econometric model constructed for Chimboy district are as follows:

$$\begin{aligned} t_{\ln x_1} &= 0,804 \quad \text{prob} = 0,440; \quad t_{\ln x_2} = 0,536 \quad \text{prob} = 0,604; \quad t_{\ln x_3} = -0,979 \quad \text{prob} = 0,351; \\ t_{\ln x_4} &= 1,644 \quad \text{prob} = 0,131; \quad t_{\ln x_5} = -3,269 \quad \text{prob} = 0,008; \quad t_{\ln x_6} = 0,952 \quad \text{prob} = 0,363; \\ t_{\ln x_7} &= -0,602 \quad \text{prob} = 0,561; \quad t_{\ln x_8} = 1,744 \quad \text{prob} = 0,112 \\ t_{\ln x_9} &= 0,317 \quad \text{prob} = 0,758, \quad t_{\ln x_{10}} = -2,388 \quad \text{prob} = 0,038. \end{aligned}$$

To check the reliability of these calculated parameters, which refer to the Student distribution table. If  $t_{\text{accounted}} > t_{\text{table}}$  it was then the regression coefficients are said to be reliable, otherwise they are said to be unreliable.

According to the Student's distribution table, 95 percent accuracy was equal to  $t_{\text{table}} = 2,0860$ . The factors of underground water level ( $\ln X_5$ ) and relative air humidity ( $\ln X_{10}$ ) in the constructed econometric model (1) meet the requirements (the accuracy probability of these factors  $\alpha = 0,05$  is less than 0.05). All other influencing factors were non-saline land ( $\ln X_1$ ), followed by weakly saline land ( $\ln X_2$ ), moderately saline land ( $\ln X_3$ ), strong and very strong saline land ( $\ln X_4$ ), land credit score, score ( $\ln X_6$ ), average annual air temperature, °C ( $\ln X_7$ ), annual precipitation, mm ( $\ln X_8$ ) and average annual temperature of the soil surface, °C ( $\ln X_9$ ) do not meet the reliability according to Student's  $t$ -test. Because the  $t_{\text{account}} < t_{\text{table}}$  condition was fulfilled and their probability was  $\alpha = 0,05$  greater than 0.05 in

accuracy. It was used the Darbin-Watson (DW) criterion to check the autocorrelation in the residuals of the resulting factor according to the model [3]:

$$DW = \frac{\sum_{t=2}^T (\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^T \varepsilon_t^2} \tag{5}$$

If there was no autocorrelation among the residuals of the resulting factor,  $DW = 2$ , tends to zero in positive autocorrelation  $DW$ , and tends to zero in negative autocorrelation 4 ha. If there is no autocorrelation in the residuals of the resulting factor, then the value of the calculated  $DW$  criterion will be around 2. In the example, the value of the  $DW$  criterion calculated for the Chimboy district was 1.72. This indicates that there is autocorrelation from the resulting factor residuals. Therefore, as a result of the multicollinearity identified in the correlation analysis above, there was not an adequate multifactor econometric model. It was found that it was successively removed the factors from the multifactor econometric model that are insignificant and have multicollinearity between the pairwise correlation coefficients.

It can be seen from the table that the density of correlations between the factors related to Chimbo district was as follows, that was, there was a strong correlation between non-saline lands ( $\ln X_1$ ) and moderately saline lands ( $\ln X_3$ ) (0.8924). There was also a strong correlation (0.7061) between non-saline lands ( $\ln X_1$ ) and strongly and very strongly saline lands ( $\ln X_4$ ). There was a strong correlation (0.8156) between non-saline lands ( $\ln X_1$ ) and land credit scores ( $\ln X_6$ ). There was also a strong correlation (0.8565) between saline lands ( $\ln X_3$ ) and strongly and very strongly saline lands ( $\ln X_4$ ). Also, a strong correlation was found between the average annual air temperature ( $\ln X_7$ ) and the average annual temperature of the soil surface ( $\ln X_9$ ), which was 0.7930 (Table 2).

In this case, in order to eliminate multicollinearity, we consider the correlation density of each of the strongly correlated factors with the resulting factor, that is, cotton yield ( $\ln Y$ ), and if any factor is weakly associated with cotton yield ( $\ln Y$ ), this factor was removed from the multifactor econometric model (1). Strongly and very strongly saline lands ( $\ln X_4$ ), land credit score ( $\ln X_4$ ) and soil surface temperature ( $\ln X_9$ ) have the largest multicollinearity in Chimbo district, and these factors from the multifactor econometric model (1) were extracted. Again, the correlation coefficients between the factors were calculated (Table 2): there were the insignificant strong and very strong salinity land ( $\ln X_4$ ), land credit score ( $\ln X_4$ ) and soil surface temperature ( $\ln X_9$ ) factors from Chimbo district from the multi-factor econometric model: on the one hand keeping the density of connection between the factors and on the other led to elimination of multicollinearity between influencing factors.

**Table 2.** Matrix of correlation coefficients calculated between cotton yield and factors affecting it in Chimbo district

	$\ln(Y)$	$\ln(X_1)$	$\ln(X_2)$	$\ln(X_3)$	$\ln(X_5)$	$\ln(X_7)$	$\ln(X_8)$	$\ln(X_{10})$
$\ln(Y)$	1							
$\ln(X_1)$	0.6780	1						
$\ln(X_2)$	-0.0908	0.4431	1					
$\ln(X_3)$	0.5852	0.8924	0.5574	1				
$\ln(X_5)$	-0.5024	-0.1508	0.2779	0.0879	1			
$\ln(X_7)$	0.1373	0.2493	0.2369	0.1998	-0.2069	1		
$\ln(X_8)$	-0.0799	-0.1933	-0.0719	0.0574	0.2507	-0.0567	1	
$\ln(X_{10})$	-0.3119	-0.0473	0.1673	-0.1313	-0.0777	-0.1076	0.2056	1

A new multifactor econometric model was created. According to the Chimbo district, it had the following appearance:

$$Y = 14,469 + 0,296 \cdot \ln X_1 - 0,571 \cdot \ln X_2 + 0,323 \cdot \ln X_3 - 0,838 \cdot \ln X_5 - 0,735 \cdot \ln X_7 + 0,149 \cdot \ln X_8 - 1,524 \cdot X_{10} \tag{6}$$

$$R^2 = 0,8333; F_{\text{account}} = 9,284; t_{\ln X_1} = 1,212 \text{ prob} = 0,2468; t_{\ln X_2} = -1,623 \text{ prob} = 0,1285, \\ t_{\ln X_3} = 0,861 \text{ prob} = 0,4045, t_{\ln X_5} = -3,247 \text{ prob} = 0,0064, t_{\ln X_7} = -0,754 \text{ prob} = 0,4642, \\ t_{\ln X_8} = 0,8191 \text{ prob} = 0,4275, t_{\ln X_{10}} = -1,8554 \text{ prob} = 0,0863.$$

It was found that the multifactor econometric model (2) obtained for the district was more statistically significant than the model (1), and the parameters of the model were reliable. At the next stage, the insignificant factors of average salinity land  $\ln(X_3)$  was removed, average annual air temperature  $\ln(X_7)$  and average annual temperature of the soil surface  $\ln(X_9)$  from the multifactor econometric model to be built next. After removing the above factors from the multifactor econometric model, the correlation matrix between the factors is shown in Table 3.

**Table 3.** Matrix of correlation coefficients calculated between cotton yield and factors affecting it in Chimbo district

	$\ln(Y)$	$\ln(X_1)$	$\ln(X_2)$	$\ln(X_5)$	$\ln(X_8)$	$\ln(X_{10})$
$\ln(Y)$	1					
$\ln(X_1)$	0.6780	1				
$\ln(X_2)$	-0.0908	0.4431	1			
$\ln(X_5)$	-0.5024	-0.1508	0.2779	1		
$\ln(X_8)$	-0.0799	-0.1933	-0.0719	0.2507	1	
$\ln(X_{10})$	-0.3119	-0.0473	0.1673	-0.0777	0.2056	1

It can be seen that the multicollinearity between the influencing factors was eliminated. It was created a new multifactor econometric model based on the previously mentioned factors. The new multifactor econometric model looks like this:

$$Y = 12,811 + 0,487 \cdot \ln X_1 - 0,497 \cdot \ln X_2 - 0,723 \cdot \ln X_5 + 0,236 \cdot \ln X_8 - 1,745 \cdot X_{10} \tag{7}$$

$$R^2 = 0,8127; F_{\text{account}} = 13,015; t_{\ln x_1} = 5,624 \text{ prob} = 0,0000; t_{\ln x_2} = -1,747 \text{ prob} = 0,1011,$$

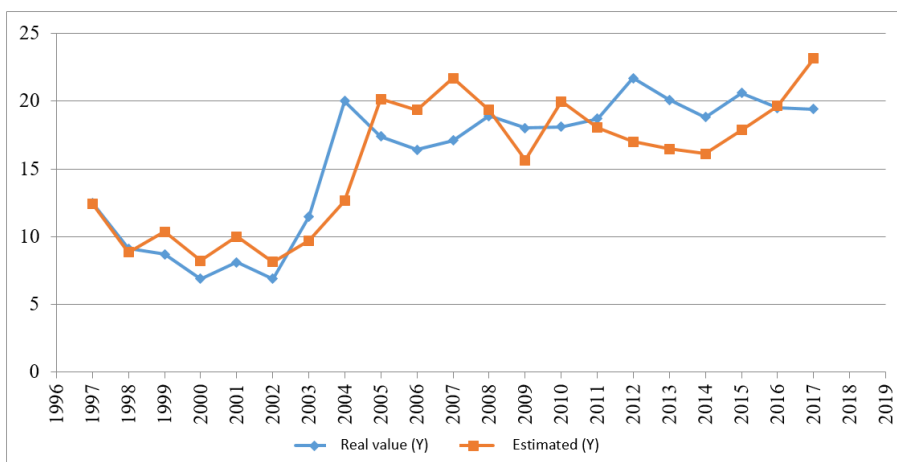
$$t_{\ln x_3} = -3,039 \text{ prob} = 0,0083; t_{\ln x_4} = 1,737 \text{ prob} = 0,1029; t_{\ln x_5} = -2,563 \text{ prob} = 0,0216.$$

The presence of autocorrelation in the residuals according to the multifactor econometric model (3) was created, of which results are presented in Table 4

**Table 4.** Examination of autocorrelation in outcome factor residuals for Chimboy district

Observations	Residuals, ( $e_i$ )	( $e_i - e_{i-1}$ )	( $e_i$ ) <sup>2</sup>
1	0.0 04349		1.8916E-05
2	0.018953	0.00021327	0.00035921
3	-0.17308	0.03687475	0.02995498
4	-0.12378	0.0024302	0.01532099
5	-0.06932	0.0029655	0.00480549
6	-0.15809	0.00787905	0.02499107
7	0.038266	0.03855396	0.00146429
8	0.657792	0.38381223	0.43269006
9	-0.24696	0.81857073	0.06098785
10	-0.20927	0.0014202	0.04379461
11	-0.29192	0.00683149	0.08521989
12	-0.12278	0.02861154	0.0150737
13	0.440953	0.31778955	0.19443977
14	-0.09804	0.29051559	0.00961218
15	0.235469	0.11122959	0.05544578
16	0.143464	0.00846489	0.02058205
17	0.170085	0.00070865	0.02892887
18	0.114599	0.00307871	0.01313287
19	0.093039	0.00046481	0.00865629
20	-0.0069	0.00998864	4.7665E-05
21	-0.4168	0.16801833	0.17372591
<b>Total</b>	<b>0.0</b>	<b>2.23842168</b>	<b>1.21925242</b>

When creating a multi-factor econometric model, we logarithmized their values, taking into account the presence of factors in different measurement units. Now we exponentiate the logarithmic values to get the real values of the factors and we get the real values of the factors. Estimated and actual values of cotton yield in Chimboy district are presented in Figure 1 below.



**Fig. 1.** Values of real and multifactor econometric model (4) of cotton productivity in Chimboy district

It can be seen from the picture that the calculated and actual values of cotton yield in Chimboy districts during 1997-2017 had almost the same values. That was, the differences between them were not so great. So, based on the constructed model, it was possible to forecast the cotton productivity in the districts for future periods. Trend models of non - saline land ( $\ln X_1$ ), underground water level ( $\ln X_5$ ) and relative air humidity ( $\ln X_{10}$ ) factors affecting cotton productivity in Chimboy district by time factor ( $t$ ).

Trend model for non-saline lands:

$$\ln x_1 = 1,1249 + 0,074 \cdot t \quad (8)$$

(0,181) (0,014)

$$R^2 = 0,5799; F_{\text{account}} = 26,231; t_{\ln x_1} = 5,122$$

Trend model for weakly saline soils:

$$\ln x_2 = 2,824 - 0,0014 \cdot t \quad (9)$$

(0,090) (0,0006)

$$R^2 = 0,6914; F_{\text{account}} = 4,23; t_{\ln x_2} = 2,290$$

Groundwater trend model:

$$\ln x_5 = 5,246 - 0,00645 \cdot t \quad (10)$$

(0,097) (0,007)

$$R^2 = 0,7351; F_{\text{account}} = 6,6916; t_{\ln x_3} = -3,67$$

Relative humidity trend model:

$$\ln x_6 = 4,0743 - 0,0025 \cdot t \quad (11)$$

(0,0312) (0,0025)

$$R^2 = 0,7511; F_{\text{account}} = 10,022; t_{\ln x_6} = -3,673$$

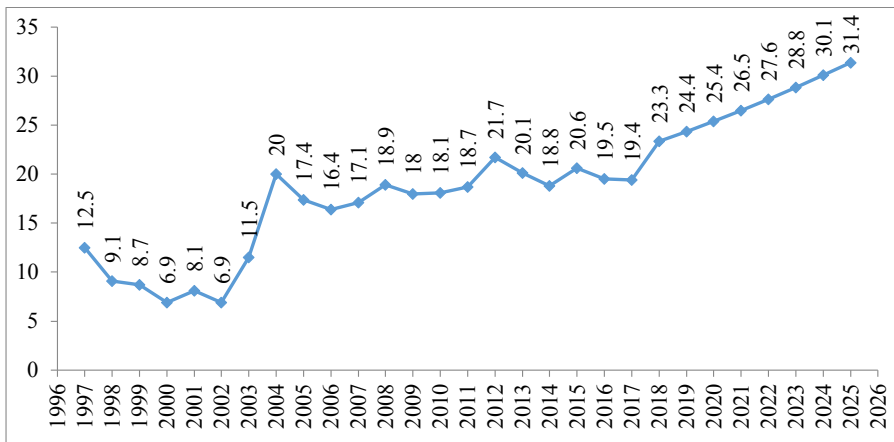


Fig. 2. Dynamics of cotton yield in Chimboy district in 1997-2017 and forecast indicators for 2018-2025

Cotton productivity ( $\ln Y$ ) and non- saline lands, ha ( $\ln X_1$ ), slightly saline lands, ha ( $\ln X_2$ ), groundwater level, m ( $\ln X_5$ ) and relative air humidity ( $\ln X_{10}$ ) were calculated according to trend models. The forecast results of the books are presented in table 4 (logarithmic values are converted to real values by exponentiation). Thus, the constructed models (1, 2) were checked for their compatibility with the studied process (F-criterion), normal distribution, reliability of model parameters (t-criterion) and the presence of autocorrelation in the residuals of the resulting factor (DW). As a result, the constructed model (1, 2) can be used to forecast cotton yield for future periods (Figure 2). Using the table data on the dynamics of the main indicators of cotton productivity in 1997-2017 and forecast indicators in 2018-2025.



#### 4. Conclusions

The density of correlations between the factors related to Chimboy district was as follows, that was, there was a strong correlation between non-saline lands ( $\ln X_1$ ) and moderately saline lands ( $\ln X_3$ ) (0.8924). It was found that the multifactor econometric model (2) obtained for the district was more statistically significant than the model (1), and the parameters of the model were reliable.

As a result of the econometric analysis, it was found that the area of non-saline and weakly saline land, groundwater level, and relative air humidity are important in Chimboy district. This indicates that the area is highly sensitive to climate change. That is, this modeling method requires us to pay particular attention to factors that are weakly related to cotton yield.

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