FORECASTING WHEAT PRODUCTIVITY IN IRAQ FOR THE PERIOD 2019-2025 USING MARKOV CHAINS

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ABSTRACT

This research was aimed to reveal the level of wheat crop productivity in Iraq by forecasting it using Markov chains for the period 2019-2022 , also exploring ways to improve the productivity of the crop under investigation by studying recent predictive values that are mainly based on previous data not far away. The problem of the study is the low productivity of wheat crop and its failure to achieve levels comparable to global and regional productivity. As long as it represents a permanent problem, this calls for concern that casts a shadow on other aspects such as self-sufficiency in this crop and endangering food security at risk. The results showed a continued decrease in the productivity of the wheat crop due to the superiority of the changes in the area to the changes in production, which are among the most important factors in determining productivity as well as the other factors that surround them, which should be noted. Accordingly, the research recommended the necessity to follow vertical intensification in agriculture, which has proven effective in influencing the productivity of a unit area, in addition to the need for vertical intensification to be compatible with the provision of other factors, namely the provision of improved seeds, highly efficient fertilizers and the necessary pesticides. As well as the need for all of the above to be consistent with the quality and efficiency of management, which plays an effective role in raising productivity. From a statistical point of view, the research recommends adopting the Markov chains method in forecasting because it needs less stringent assumptions than other methods, including a few historical past observations series and fewer statistical tests.

Key words: cereal crops productivity; stochastic processes ; normal distribution test; transitional matrix
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التنبؤ بإنتاجية محصول القمح في العراق للمدة 2019-2025 باستعمال سلاسل ماركوف

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المستخلص

استهدف البحث الكشف عن مستوى انتاجية محصول القمح في العراق من خلال التنبؤ بها باستخدام سلاسل ماركوف للمدة 2019-2025 ،. فضلا عن الكشف عن سبل الارتقاء بالإنتاجية للمحصول قيد البحث عن طريق دراسة القيم التنبؤية الحديثة المعتمدة اساسا على بيانات سابقة ليست بعيدة. تتمثل مشكلة الدراسة في تدني انتاجية محصول القمح وعدم تحقيقها لمستويات تضاهي الانتاجيات العالمية والاقليمية وطالما انها تمثل مشكلة دائمة فان ذلك يستدعي القلق الذي يلقي بظلاله على جوانب اخرى كالاكتفاء الذاتي من هذا المحصول وتعريض الامن الغذائي للخطر فضلا عن ان مفهوم الانتاجية يرتبط بدرجة كبيرة بكفاءة استغلال الموارد المرتبطة بظروف انتاجها الامر الذي يجعل من عملية التنبؤ بالقيم المستقبلية له اهمية بالغة. أظهرت النتائج استمرار انخفاض إنتاجية محصول القمح وكان هذا بسبب تفوق التغيرات في المساحة على التغيرات في الإنتاج واللذين يعدان من اهم العوامل في تحديد الانتاجية فضلا عن العوامل الاخرى التي تحيط بهما والتي ينبغي الاحاطة بها. وتبعا لذلك اوصى البحث بضرورة اتباع التكثيف العمودي في الزراعة الذي اثبت فاعليته في التأثير على إنتاجية وحدة المساحة، فضلاً عن ضرورة ان يتوافق التكثيف العمودي بتوفير العوامل الأخرى وهي توفير البذور المحسنة والاسمدة عالية الكفاءة والمبيدات اللازمة. فضلا عن ضرورة توافق كل ما سبق مع جودة الإدارة وكفاءتها التي تلعب دوراً فعالاً في رفع الإنتاجية. ومن الناحية الاحصائية يوصي البحث باعتماد طريقة سلاسل ماركوف في التنبؤ وذلك لاحتياجها الى فروض اقل صرامة من الطرق الاخرى ومنها سلسلة مشاهدات تاريخية ماضية قليلة واختبارات احصائية اقل.-

الكلمات المفتاحية: انتاجية محاصيل الحبوب، العمليات العشوائية، اختبار التوزيع الطبيعي، المصفوفة الانتقالية
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INTRODUCTION

Prediction studies concerned with searching for a set of indicators related to many aspects, including the agricultural side, which is the scope of our research here, and among these indicators are production, productivity, consumption, area and prices of agricultural crops in an attempt to extrapolate the future in search of numbers that come close to the reality that the researcher hopes to reach and minimize the values of forecasting errors that it should appear in forecasting studies to reach decisions that benefit those in charge of setting agricultural policies in setting their policies for the future based on research by specialists and making the best decisions in this regard. Productivity is one of the important indicators of performance efficiency in the agricultural sector and occupies a distinguished and influential position in the overall economic activities as an important tool in distributing wealth and directing resources, it also means, in general, the efficient use of the available economic resources in the production process, as it is a relationship between inputs and outputs. Therefore, studying the future of agricultural production of agricultural crops through the productivity index will give answers to the reality of efficient use of economic resources. As for choosing the forecasting tool, the method used in the search (Markov chains) does not require many historical data about the phenomenon in question(13), also, this method does not retain from its evolutionary history except the most recent data, i.e. the last known value of the phenomenon, which enables linking future events when predicted by relatively recent past events. The research problem is that the agricultural sector always faces many problems, including the problem of low productivity of most crops, including wheat, which casts a shadow on other aspects such as self-sufficiency and endangering food security at risk, in addition, the productivity of the main crops, including wheat, is closely related to the efficient use of the resources associated with their production conditions, which makes the forecast process important because it enables the development of future plans to meet changes in production. The research assumes that the wheat productivity has decreased despite its improved levels, but it has remained below global averages. The research also assumes that Markov chains are most appropriate in estimating this type of data because they do not need many historical data. The Markov chain method also requires less stringent assumptions and provides more information than other methods such as the regression method. The research aims to reveal the truth about the level of productivity of the wheat crop in Iraq by forecasting it using Markov chains. It also aimed at researching ways to improve the productivity of the wheat by studying recent predictive values that are mainly based on previous data not far in order to reach realistic forecasts that contribute to the formulation of policies related to inventory, distribution and the supply of agricultural products to different regions of the country. The Markov chains methodology has gained the attention of many researchers in forecasting, including (Bualsept 2015) when predicting wheat productivity in Algeria using Markov chains, where his findings on wheat productivity in Algeria in the three years that he predicted indicated that they do not differ much from their actual values, as the relative error in 2013 did not exceed 11.64%, as for the years 2014 and 2015, this error did not exceed the 4% level, this means that the estimated value approaches the actual value of wheat productivity in Algeria by more than 88% in 2013 and more than 96% in the years 2014 and 2015, this clearly indicates the accuracy of this method of analysis(13). (Matis) (1985), pursued Markov chains in predicting crop yields and recommended using this approach because it assumes less stringent assumptions and provides more information than other approaches such as regression (18). While (Jain & Rangana) (15) adopted the Markov chain to predict the revenue of sugar cane and recommended its adoption for its success in predicting the revenue of crops (15). The researchers (Ramasubramanian and Lamohan bahar) (2014) used multiple Markov chain models and simulation of the sugar cane crop and concluded that such models contributed to increasing the prediction time with the same accuracy (23). Other researchers discussed Markov chains in other sectors, including

(Marcos & other) (2013) and (Subedi and other) (2013). Whereas, prediction on agricultural crops was addressed in other ways (28). (Al-Kaabi 2015), and both (Alrasool and Saleem, 2004), used the Holt model and ARIMA and concluded that the productivity estimates for all agricultural crops in Saudi Arabia are efficient and unbiased (9,5,4). As for (Al-Qazzaz 2006), developed sampling methods to predict wheat productivity in Egypt and reached a set of methods that gave estimates of wheat productivity close to reality (8). As for (Kropp, 2007), used the method of modeling crop growth and improving the accuracy and timing of regional crop yield forecasts (17). While (Attia 2009) used the exponential smoothing model on the annual productivity data of sesame and recommended the necessity for attention to forecasting studies because it is possible to develop future plans to face changes in production (12). The researcher (Purana Chandra, 2012) predicted the productivity of agricultural crops in India using ARIMA models and took another approach by linking productivity with multiple factors such as rain, fertilizers, pesticides and subsidies and concluded that these models are important for understanding the factors affecting the productivity of the crops covered in the study(22). As for (K.prabakaran & other, 2013), used the same method of (Purana Chandra, 2012) to predict the areas and production of wheat in India and the results of the research showed that there are increases in areas and production as predicted values(22,16). The researchers (Mox and Hu, 2014) used the photosynthetic coefficient pattern (V cmax) to predict crop yields (19). The researcher (Mubarak 2016) used artificial neural networks models and Box Jenkins models in predicting the productivity of wheat crop in Sudan and concluded that increasing the forecast period in the future makes using artificial networks more accurate than the results of Box Jenkins (6). It should be noted that Markov chains were used in sectors other than the agricultural sector and from these studies were (Rodin, Muhammad, Abu Lebda) (25,20,1). Al-Dami and Al-Hiyali (2017) recommended the necessity of adopting a balanced support policy between production and production requirements in order to achieve improvement in the productivity of the wheat crop, that is, the correct prediction of productivity must be supported by improving both production and area (3). While (Shahid and Al-Badri) (2018) pointed to the need to increase the number of modern technologies and distribute them in a manner compatible with the cultivated area, and this means positively affecting one of the productivity poles, which leads to improvement it (26).

Theoretical framework

The first one to write in this field was the Russian mathematician (Markov), one of his most famous works related to the theory of "stochastic process", and his research is known as the Markov chains. Stochastic Processes, defined a set of random variables {t≥0 X_ (t,)} indicated by time (10). While we mean the random variable as a real function and knowledge in the sample space, and divides into a district and continuous random variable (11). Markov chains were defined by (Zewulf) as a movement from one state to another at a later time(29). If the expectation or probability of this transition is given, then the value of this probability can be used to predict the direction of the change from the first to the second state in the future (29).

Transition probability matrix

The probabilities for movement or moving from one state to another during a certain period of time are called transition probabilities, it is represented by matrix called a transition matrix or Markov matrix (2). The aggregation of transition probabilities can be written in matrix as it follows (14):

$$\mathbf{P}= \begin{array}{c} \\ \mathbf{i=0} \\ \mathbf{i=1} \\ \mathbf{i=2} \\ \\ \end{array} \begin{array}{c} \begin{array}{cccc} \mathbf{j=0} & \mathbf{j=1} & \mathbf{j=2} & \end{array} \\ \begin{pmatrix} P_{00} & P_{01} & P_{02} & \ldots\ldots \\ P_{10} & P_{11} & P_{12} & \ldots\ldots \\ P_{20} & P_{21} & P_{22} & \ldots\ldots \\ . & . & . & \ldots\ldots \\ . & . & . & \ldots\ldots \end{pmatrix} \end{array}$$

This called the transition probability matrix for the Markov chain $\{X_n : n \in T\}$ as the matrix is divided into double rows and columns, meaning that the number of rows and the number of columns are equal. The symbol (i) represents rows, while the symbol (j) represents columns, as for the element (i, j)

whose arrangement is , the probability P_{ij} is the probability that the random process will move from state (i) to state (j) in one step during a specific time period, for example(24):

$$P=\begin{array}{c} \\ S1 \\ S2 \\ S3 \end{array}\begin{array}{c} \begin{array}{ccc} S1 & S2 & S3 \end{array} \\ \begin{pmatrix} 0.5 & 0.1 & 0.7 \\ 0.3 & 0.5 & 0.2 \\ 0.2 & 0.4 & 0.1 \end{pmatrix} \end{array}$$

P_{11}= The probability of remaining in the same state (1) equals 0.5

P_{21}= The probability of moving from state No. (2) to state No. (1) equals 0.3

P_{32}= The probability of moving from state No. (3) to state No. (2) equals 0.4

The following figure shows the probability of moving from one state to another (7):

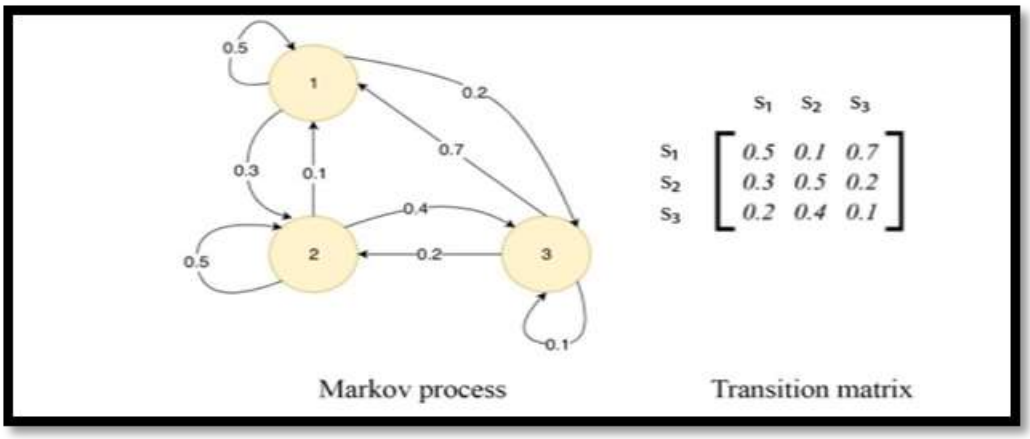

Figure 1. probability of moving from one state to another

MATERIALS AND METHODS

Predicting wheat productivity with Markov chains requires the following steps (27,13):

a- After preparing the data for the phenomenon that we are going to predict its future path, we start dividing it into certain levels, after we subtract the smallest value of the phenomenon R_{Min} from its largest value R_{Max} (Range), then divides the result of the subtraction process by the number of levels previously determined

$$\boldsymbol{outpt = \frac{R_{Max} - R_{Min}}{number\ of\ specific\ states}}$$

Then we create the levels according to the number of specific states, for example if the states are (4):

States	The first limits	The second limits
State1	R_{Min}	$Y_1 = \left(R_{Min} + \frac{Range}{4}\right)$
State2	Y_1	$Y_2 = \left(Y_1 + \frac{Range}{4}\right)$
State3	Y_2	$Y_3 = \left(Y_2 + \frac{Range}{4}\right)$
State4	Y_3	$R_{Max} = \left(Y_3 + \frac{Range}{4}\right)$

b- define the transition matrix, where each element in this matrix expresses the probability of the phenomenon moving from one level to another provided that the sum of each row of the transition matrix is equal to the correct one (for example, if levels are 4):

	S1	S2	S3	S4	Total
S1	P_{11}	P_{12}	P_{13}	P_{14}	1
S2	P_{21}	P_{22}	P_{23}	P_{24}	1
S3	P_{31}	P_{32}	P_{33}	P_{34}	1
S4	P_{41}	P_{42}	P_{43}	P_{44}	1

c- take the average productivity values for each of the four levels:

State1	State2	State3	State4
$\sum Y1/N1$ Number of first state values	$\sum Y2/N2$ Number of second state values	$\sum Y3/N3$ Number of third state values	$\sum Y4/N4$ Number of fourth state values

d- The shape of vector of its elements is according to the number of levels defined by (a) and they are all equal to zero except for an element that is equal to one its location in the line is corresponding to the level in which the last value of the phenomenon is located. (If the last value is located at the fourth level, for example, the vector is written as follows:

State1	State2	State3	State4
0	0	0	1

e- Multiplying this vector by the transition matrix so we get a new vector and we also

multiply this last vector by the transition matrix so we get a new one.

f- Multiplying the vector of the new one by the averages calculated by step (c), and we get the expected value of the phenomenon in the coming year.

g- By repeating the last two steps on the last vector we get the values of the phenomenon in subsequent years.

RESULTS AND DISCUSSION

The research has followed a set of states to reach the predictive values, and one of these states will be chosen based on a set of statistical tests as well as the researcher's experience, which will stand in line with the approved statistical tests. The analysis was done using Microsoft Excel and Minitab programmers, as results were obtained for a set of states for the Markov chain method, and the state was chosen that was able to pass the statistical tests. Table 1 shows the productivity of one dunum of wheat crop during the period 2000-2018.

Table 1. productivity of one donum of wheat crop during the period 2000-2018

Year	Yield Kg donum^{-1}	Year	Yield Kg donum^{-1}
2000	241.5	2010	495.8
2001	425.3	2011	429.3
2002	392.7	2012	442.9
2003	339.8	2013	566.5
2004	297.5	2014	596.3
2005	347.6	2015	649.5
2006	377.6	2016	825.5
2007	350.8	2017	705.4
2008	218.6	2018	690.5
2009	336.7		

Source: Noori, N.S and A.D.K Al-Hiyali (21)

First: Determining the number of states and their distribution(13):

To determine the number of states, data collected for (19) years for the period (2000-2018), where the highest productivity was reached (825.5) and the lowest productivity, which amounted to (218.6), then subtract the two values and the output of the offering was about (606.9), then by dividing the result by (6) The number of possible states represented, the result reached about (101.15), and therefore the distribution of the six states is as follows:

Table 2. Determination of number and distribution of states

states	from	To
State1	218.6	319.75
State2	319.75	420.9
State3	420.9	522.05
State4	522.05	623.2
State5	623.2	724.35
State6	724.35	825.5

Table 3. Distribution of the six states to yield data during the period (2000-2018)

Year	Yield Kg donum^{-1}		States distribution	Year	Yield Kg donum^{-1}		States distribution
2000	241.5	1	State 1	2010	495.8	3	State 3
2001	425.3	3	State 3	2011	429.3	3	State 3
2002	392.7	2	State 2	2012	442.9	3	State 3
2003	339.8	2	State 2	2013	566.5	4	State 4
2004	297.5	1	State 1	2014	596.3	4	State 4
2005	347.6	2	State 2	2015	649.5	5	State 5
2006	377.6	2	State 2	2016	825.5	6	State 6
2007	350.8	2	State 2	2017	705.4	5	State 5
2008	218.6	1	State 1	2018	690.5	5	State 5
2009	336.7	2	State 2				

Max value= 825.5
Min value= 218.6
Range= 606.9

Range/6= 101.15

Second : Calculating the average productivity values in each of the six states The values were collected in each of the six states, and the result divided by the number of values in each state. The average values for each state were as follows:

	State1	State2	State3	State4	State5	State6
Number of states	3	6	4	2	3	1
average	252.53	357.53	448.33	581.4	681.8	825.5

Third: Creating the transition matrix: It is clear from the previous step that the number of values in the first state (3) and the number of values in the second state (6) and the number of values in the third state (4) and the number of values in the fourth state (2) and the number of values in the fifth state (3) and the number of values in the sixth state (1), thus the total values (19) are the number of years, and then the transition matrix is created:

Table 4. Transition matrix

	State1	State2	State3	State4	State5	State6
State1	0	2/3	1/3	0	0	0
State2	2/6	3/6	1/6	0	0	0
State3	0	1/4	2/4	1/4	0	0
State4	0	0	0	1/2	1/2	0
State5	0	0	0	1/3	1/3	1/3
State6	0	0	0	0	1/1	0

Table 5. Transition matrix as percentages

	state1	state2	state3	state4	state5	state6
state1	0	0.67	0.33	0	0	0
state2	0.33	0.50	0.17	0	0	0
state3	0	0.25	0.50	0.25	0	0
state4	0	0	0	0.50	0.50	0
state5	0	0	0	0.33	0.33	0.33
state6	0	0	0	1	0	0

Fourth: vector calculation

The vector is calculated according to the last value, which is the current value, where the value of productivity in (2018) reached a value of (690.5), i.e. it falls in the fifth state, meaning that the vector will be as follows (0,0,0,0,1,0):

State1	State2	State3	State4	State5	State6
0	0	0	0	1	0

Fifth: Multiply the vector by the transition matrix

	state1	state2	state3	state4	state5	state6
state1	0	0.67	0.33	0	0	0
state2	0.33	0.50	0.17	0	0	0
state3	0	0.25	0.50	0.25	0	0
state4	0	0	0	0.50	0.50	0
state5	0	0	0	0.33	0.33	0.33
state6	0	0	0	1	0	0

We get:

0	0	0	0.33	0.33	0.33

After extracting the result, it is multiplied by the average value of the six previously calculated states, which are:

	Stat1	Stat2	Stat3	Stat4	Stat5	Stat6	Total
average	252.53	357.53	448.33	581.4	681.8	825.5	
vector	0	0	0	0.33	0.33	0.33	
result:	0	0	0	191.862	224.994	272.415	
Yield value of 2018							689.3

Referring to the value of productivity in 2018, we find it reached (690.5), which confirms the accuracy of the Markov model in forecasting, and this means that the actual wheat

productivity level differs from its estimated level not exceeding 0.002%, as we find that its estimated value of (689.3) approaches the actual value amounting to (690.5) by 99.8%. Predictive values will continue to be extracted for subsequent years along the same lines. As for the predictive value for 2019, it was as follows:

Productivity for year 2019:

0	**0**	**0**	**0.6039**	**0.2739**	**0.1089**

The last vector is multiplied by transition matrix, we get: Then the above last vector is multiplied by the average values of the six states, as the result is (627.7).

	Stat1	Stat2	Stat3	Stat4	Stat5	Stat6	Total
average	**252.53**	**357.53**	**448.33**	**581.4**	**681.8**	**825.5**	
vector	**0**	**0**	**0**	**0.6039**	**0.2739**	**0.1089**	
Result	**0**	**0**	**0**	**351.10746**	**186.74502**	**89.89695**	
Yield of 2019							**627.7**

By continuously following the same steps for subsequent years, the predictive values were represented in table 6:

Table 6. Predictive values for the period (2019-2025)

Years	Predictive Wheat Yield Kg donum^{-1}
2019	**627.7**
2020	**633.5**
2021	**639.6**
2022	**634.4**
2023	**631.1**
2024	**629.3**
2025	**627.0**

After the previous mathematical steps were applied to predict the rest of the states of other Markov chains and test them based on the (Kolmogorov- Semernov test) (K-S) test. Resorting to the next step, which is to choose the appropriate state, which should meet a set of features, including passing the statistical test(K-S).

Table 7. Results of predicting wheat productivity in Iraq during the period (2019-2025) and according to the states of Markov chains

Years	State 2	State 3	State 4	State 5	State 6
2019	**579.8**	**622.8**	**680.2**	**623.5**	**627.8**
2020	**549.4**	**595.5**	**675.0**	**636.4**	**633.5**
2021	**527.3**	**575.7**	**673.2**	**630.8**	**639.6**
2022	**510.6**	**561.4**	**672.6**	**591.8**	**634.4**
2023	**498.2**	**551.1**	**672.4**	**583.8**	**631.1**
2024	**488.8**	**543.7**	**672.3**	**576.7**	**629.3**
2025	**481.8**	**565.1**	**672.3**	**548.9**	**627.03**
KS	**0.15**	**0.15**	**0.03**	**0.15**	**0.15**

***A state that gives almost equal values of productivity is excluded (for example state 4)**

Table 7 shows the results of the analysis of these cases and the predicted values, which extend to the next 7 years. We notice that all states passed the normal distribution test except the fourth case, that did not pass the test and through the prediction results we find that the fourth case has generated constant predictions of wheat productivity and this cannot be accepted because the productivity results are correlated with production variables and the area that in turn are related to many factors. Hence, the stability of productivity for the coming years requires the stability of all variables, which is something that cannot happen, so this case will be excluded. The research chose the sixth state, as we find that the results of the sixth state were better than its counterparts for other states, because it took the points above into consideration, as the value of the (K-S test) for the sixth state reached about (0.15) which is greater than the level of significance 0.05. (K-S-test) was conducted, which is one of the non-parametric tests of the normal distribution as it tests the null hypothesis that the observations of a given variable follow the normal distribution against the alternative hypothesis that the data are not distributed naturally. As it appears from Figure 3 of the results of the (K-S) test that the value of P-value is greater than 0.15 and is greater than the significance level 0.05, which supports the validity of the assumption that the data follow the normal distribution. It is also clear from the figure that most of the data is located on the straight line and very close to it, which in turn is consistent with the results of

the KS test, which confirms the nature of the data.

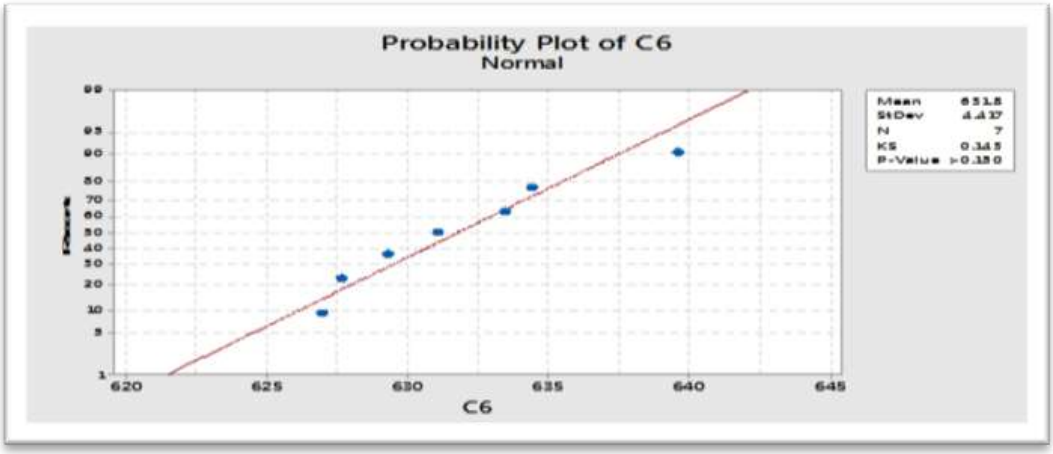

Figure 2. Normal distribution of wheat productivity data during the period (2019-2025) according to the K-S test for the sixth state

It should be noted that the research has made multiple attempts to predict the area and production of the (wheat) crop, depending on the mathematical steps that were explained previously and the (Markovian) state that passes statistical tests will be adopted and explain this state without entering into the details of other states. Table 6 shows that the predicted values started to decrease starting from 2022 and then stabilized at the level of 627.0 in 2025 although all the predicted values were close and the reason for our dependence on these values is that they have given the lowest value of the predictive accuracy scale MSE compared to other states Table 9. Until the interpretation takes its economic extent, the prediction for both area and production has been made, since they represent the polarity of the productivity law per unit area. The reason for this procedure is that prediction of any economic phenomenon cannot be done independently of other phenomena, especially those that relate to the values of the phenomenon being examined, for this reason, the research resorted to making a prediction of the phenomena associated with productivity, namely production and area, in order to achieve one of the most important objectives of the prediction process, which is concerned with finding interdependence, complementarity, and coordination between the parts of the phenomenon for the purpose of achieving appropriate planning, which is one of the goals for which the prediction is conducted. The reason for the decrease recorded by the productivity values from 2022 to 2025 is due to the fact that the changes in the area were greater than the changes in production, which clearly affected the predicted productivity rates, then it recorded a slight increase in the following years and then decreased slightly, here we conclude clearly that the conditions surrounding the wheat crop, especially production, did not allow for a positive effect on the productivity values, while we find that there is an increase in the cultivated areas, which confirms that there is a horizontal expansion at the expense of vertical expansion, which must be available, especially in the case of stunted cultivated areas, which must intensify production within the unit area. The compatibility of the statistical method with the economic logic in interpreting the results should be available, perhaps the evidence indicates that wheat productivity in Iraq was greatly affected by the conditions surrounding the area and production and the factors that affect them. Most studies indicated that area and production are affected by all factors, including environmental conditions such as temperature, humidity, rain, etc., and economic conditions or so-called price factors that play a large role in affecting production and area, which in turn will affect productivity, which is the focus of our research, whereas, the research on the factors affecting productivity is not separate from its counterpart affecting production and area. Depending on the foregoing and as long as productivity here is affected by changes in the area greater than changes in production, this means the need for attention to the area

resource and try to improve it and this is done by focusing on the efficiency of managing this resource and trying to be a method of using it vertically, i.e. intensifying production per unit area. The predicted values of productivity, as previously reported, were influenced by the factors affecting them. Moreover, following up on the plans of the Ministry of Agriculture for the coming years will be dependent on important factors including the water situation and the ministry's expectations of climatic and environmental conditions, in addition to other factors such as price factors. In this regard, according to the report of the Ministry of Agriculture announced for the winter plan for the agricultural season (2018-2019), it mainly relied on irrigation method, as the total cultivated area of the wheat crop reached about 7.2 million donums, and the Ministry supplies farmers with production requirements in accordance with the plan, the above report confirms the fact that if conditions are favorable, all the requirements of the plan in place will be achieved, and therefore this will effect on the productivity whose numbers will increase or decrease depending on the success of the plan.

Table 8. Predicted values for productivity, area and wheat production in Iraq for the period (2019-2025)

	Area/ 1000 donums		Production/ 1000 tons		Productivity/ Kg/donum	
Years	**State 4**	%Δ	**State 3**	%Δ	**State 6**	%Δ
2018	**3153.9**		**2177.9**		**690.5**	
2019	**4807.7**	**52.44**	**2364.0**	**8.54**	**627.7**	**-9.09**
2020	**5049.5**	**5.03**	**2458.6**	**4.00**	**633.5**	**0.92**
2021	**5232.5**	**3.62**	**2513.2**	**2.22**	**639.6**	**0.96**
2022	**5363.6**	**2.51**	**2544.6**	**1.25**	**634.4**	**-0.81**
2023	**5453.3**	**1.67**	**2562.5**	**0.70**	**631.1**	**-0.52**
2024	**5513.5**	**1.10**	**2572.9**	**0.41**	**629.3**	**-0.29**
2025	**5554.1**	**0.74**	**2578.8**	**0.23**	**627.0**	**-0.37**

Table 9. MSE values of time series and predicted values according to the six states

states	State2	State3	State4	State5	State6
MSE	**12530.9**	**10413.1**	**7622.9**	**9880.7**	**8384.2**

***The fourth state was excluded for the previously mentioned reasons**

From the foregoing, the research concluded that the research hypothesis was proven by the continued low productivity of wheat crop and its lack of approach to international rates, where it was found from statistical analysis that the predictive values of the selected state confirmed a significant decrease in the wheat crop. The results of the research also confirmed that the Markov chains do not need old historical data, which did not constitute a major obstacle in the interpretation of the forecast results, as it is recognized that the effect of future values, especially in agriculture, with previous close data, which gives logical explanations of what will happen in the future depending on what happened In recent years nearby, this conclusion is supported by the presence of mathematical models used by researchers in economic analysis for the purpose of interpreting future events. One of the most famous of these models is a dynamic model that is based on the idea that the variable to be estimated is affected by variables for previous years such as $(t_{-1}, t_{-2}, ...)$(Dynamic Nerlove model). The results proved the approximation of the actual values of wheat crop productivity with its estimated values for the following year, and the matter applied to the convergence of these results for subsequent years with previous years, which confirms the high accuracy of Markov chains, in addition to the fact that these chains are affected by their impact in recent years, positively to obtain these results, meaning that what happened in the recent past had the most impact in the near future. Therefore, the lack of local data for the accuracy required to carry out economic and statistical analysis alike casts a shadow over the choice of the appropriate method of

analysis, since Markov chains (the method used exclusively) do not need much data to predict, the research recommends the need to follow this method for suitability to analyze data that lacks accuracy in some of its observations. The research also recommends the necessity to follow the vertical intensification in agriculture, which has proven effective in influencing the productivity of the unit area. This is evident from the experiences of developed countries that have made great strides in this field. In addition to the need for vertical condensation to be compatible with the provision of other factors, namely the provision of improved seeds, high-efficiency fertilizers and the necessary pesticides. Moreover, all this is consistent with the quality and efficiency of management, which plays an effective role in raising productivity. And as far as the matter relates to appropriate statistical analysis, the research recommends paying attention to the statistical aspect and choosing the appropriate statistical tools because access to valid quantitative models and forecasts is very important because it relates to providing correct recommendations to public and agricultural policy makers in particular and enables them to make correct decisions away from wrong guesses, therefore, the correct forecasts of the reality of the wheat crop will have the greatest impact on the safety of the agricultural plan for this crop, and consequently, the agricultural plan is consistent with the plans in other sectors. As well as the need for full coordination between what is planned for the cultivation of wheat crop with the plans of the Ministry of Agriculture that are developed depending on the water plans and natural conditions that the ministry takes into account. In addition to directing attention to the areas of concentration in this crop, as it represents the areas of supply and distribution of this crop, with attention directed towards the areas of concentration in relation to providing advisory agriculture requirements while addressing the problems that these areas are exposed to exclusively. To show the effectiveness of the statistical method used in this research (Markov chains), the research recommends the necessity of making statistical comparisons of predictive values extracted in this way with their counterparts at the other end to judge the quality of this method from others.

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