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A Comparison of GM (1,1) and GVM (1,1) for Forecasting Wheat Production in Iraq

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Abstract: Time series forecasting, a statistical method, entails analyzing preceding data patterns to predict future values. It is extensively utilized in a wide variety of fields. This lookup conducts a comparative assessment of the Grey Model GM(1,1) and the Grey Verhulst Model GVM(1,1) to forecast wheat production in Iraq from 2025 to 2035. The goal of this learn about is to decide the most appropriate mannequin and habits a comparative analysis of the proposed models GM(1,1) and GVM(1,1) for predicting wheat production in Iraq in the future. The information spans from 2014 to 2024, comprising eleven years, and was as soon as offered from the "International Production Assessment Division (IPAD)" website. Different metrics such as mean absolute percentage error (MAPE) and the mean squared error (MSE) use in order to consider how suitable this two models perform. Applying both GM(1,1) and GVM(1,1). The effects indicates experimental results that verify the GM(1,1) mannequin as best-matching with least MAPE (15.673205528%) and decrease MSE than GVM(1,1). This suggests that GM(1,1) model is better in forecasting wheat production for Iraq as compared to GVM (1,1). As result, GM(1,1) is mainly encouraged for bettering the forecast of wheat production in Iraq in the path of 2025 _ 2035.

Keywords: Time series, Grey Model, Grey Verhulst Model .

مقارنة بين GM (١،١) و GVM (١،١) لتوقع إنتاج القمح في العراق

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المستخلص: التنبؤ بالسلاسل الزمنية هو أسلوب إحصائي يتضمن تحليل الأنماط السابقة للبيانات للتنبؤ بالقيم المستقبلية. يُستخدم هذا الأسلوب على نطاق واسع في العديد من المجالات. تجري هذه الدراسة تقييمًا مقارنًا بين

نموذج جري GM(١,١) ونموذج جري فيرهلست GVM(١,١) للتنبؤ بإنتاج القمح في العراق من عام ٢٠٢٥ إلى ٢٠٣٥. تهدف هذه الدراسة إلى تحديد النموذج الأكثر ملاءمة وإجراء تحليل مقارن للنموذجين المقترحين GM(١,١) وGVM(١,١) للتنبؤ بإنتاج القمح في العراق في المستقبل. تمتد البيانات من عام ٢٠١٤ إلى ٢٠٢٤، وتشمل ١١ عامًا، وقد تم الحصول عليها من موقع "قسم تقييم الإنتاج الدولي (IPAD)". يتم استخدام مقاييس مختلفة مثل متوسط النسبة المطلقة للخطأ (MAPE) ومتوسط الخطأ التربيعي (MSE) لتقييم مدى جودة أداء النموذجين. تظهر النتائج التجريبية أن نموذج GM(١,١) هو الأنسب، حيث سجل أقل MAPE بنسبة (١٥,٦٧٣٢٠٥٥٢٨٪) وأقل MSE مقارنةً بنموذج GVM(١,١). تشير هذه النتائج إلى أن نموذج GM(١,١) أفضل في التنبؤ بإنتاج القمح في العراق مقارنةً بنموذج GVM(١,١). وبالتالي، يُوصى بنموذج GM(١,١) بشكل أساسي لتحسين توقعات إنتاج القمح في العراق للفترة من ٢٠٢٥ إلى ٢٠٣٥.

الكلمات المفتاحية: السلاسل الزمنية، نموذج Grey، نموذج Grey Verhulst

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Introduction

An critical analytical tool used in many domains, such as meteorology, finance, economics, and agriculture, is time sequence forecasting. It entails estimating future values using historical data. In order to forecast wheat manufacturing in Iraq, time collection forecasting is used in this study. The Grey Model (GM(1,1)) and the Grey Verhulst Model (GVM(1,1)) are the two fashions that are compared for performance.

In Iraq, wheat is a staple crop that is fundamental to the country's financial system and meals security. Policymakers and farmers can make better selections about planting schedules, aid allocation, and import-export strategies with the resource of accurate wheat production forecasts. Reliable forecasting models are critical for danger mitigation and maintaining a steady food furnish in mild of the difficulties introduced with the aid of local weather change, transferring market prices, and unstable political environments. Based on the supposition that historical patterns will persist into the future, time collection forecasting fashions use historical information factors to predict future values. Many models, from straightforward linear models to difficult computing device mastering algorithms, have been developed for this purpose. Grey models have received recognition among them because of their potential to deal with frequent troubles in agricultural data, such as small sample sizes and incomplete information.

The Model Grey Deng Julong created the famous GM(1,1) forecasting model in the Eighties for the Grey device theory. This model works particularly nicely in structures where the data is ambiguous, imprecise, or lacking. In order to get estimated values, the GM(1,1) model requires creating a sequence from the original data, building a first-order differential equation, and solving it. Due to its ease of use and efficiency, it is a broadly used method for forecasting in a variety of industries, including agriculture

Furthermore, the GM(1,1) model is accelerated upon by using the GVM(1,1) model, which carries the logistic extend curve to accommodate constructions with constraints or saturation. This mannequin is especially really useful for datasets containing time-varying make bigger rates, like these from natural systems or market-limited monetary processes. In conditions where the linear assumptions of the GM(1,1) model are now not met, the GVM(1,1) mannequin can produce predictions that are greater correct.

1st: Literature Review

Grey fashions have been utilized to agricultural forecasting in a range of studies. Wang et al. (2015), for example, established how desirable the GM(1,1) model forecasts crop yields in China and how well it can take care of incomplete statistics and small sample sizes. Similar to this, Zhang et al. (2017) validated the superiority of the GVM(1,1) model over the GM(1,1) mannequin in situations involving non-linear growth patterns by way of way of viable of making use of it to predict fishery production.

Previous lookup have centred on precise aspects of agricultural forecasting in the context of Iraq. While Ahmed et al. (2019) regarded into the have an impact on of local weather exchange on crop yields, Al-Rawi and Al-Hadithi (2016) investigated the use of ARIMA fashions for predicting wheat production. The favor for this look up is highlighted thru the paucity of studies evaluating the accuracy of Grey fashions in predicting wheat manufacturing in Iraq.

The efficacy of the GM(1, 1) and Single Exponential Smoothing (SES) in predicting Iraq's corn manufacturing from 2022 to 2030 is in contrast by using Ahmed, D. H., et al. (2023). The researchers examined nineteen time intervals the utilization of statistics from the "Index Mundi-Iraq Corn Production" website, spanning the years 2003 to 2021, in order to discover inclinations pinnacle notch for these models. The study's important intention was as soon as to study how properly the SES and GM (1, 1) fashions expected maize production. The findings proven that a smoothing constant (a) of 0.04 used to be the best parameter for SES, producing MAPE and MSE values of 27.78% and 226,507.92, respectively. The GM (1, 1) model, on the unique hand, had higher accuracy, with MAPE and MSE values of 26.43% and 141,381.94, appropriately. These penalties show off that the GM(1,1) mannequin performs greater than SES in predicting Iraqi corn manufacturing due to the truth it generates smaller error values. This emphasises the magnitude of deciding on the acceptable fashions relying on the residences of the statistics and the needs of the forecast.

2nd: Objective of the research

The goal of this research is to decide which of the two encouraged fashions the GM(1,1) and the GVM(1,1) is great perfect for predicting wheat manufacturing in Iraq. Iraq's wheat production for the years 2025 to 2035 will be estimated the use of the mannequin that is deemed most suitable. Numerous metrics, together with endorse squared error (MSE) and imply absolute share error (MAPE), will be used to check the two models' performance. The mannequin with the high-quality ordinary performance will be chosen to forecast Iraq's wheat production between 2025 and 2035.

3rd: Materials and Methods

Data classification techniques are widely used in statistical methods. A approach for projecting future values, forecasting relies upon on applicable historical and present day data. It consists of each qualitative and quantitative strategies as its necessary approaches. When historic statistics is unavailable, qualitative strategies which depend on intuition are generally employed, whereas quantitative strategies make use of prior facts to facilitate mathematical computations. Iraq's wheat production records from 2014 to 2024 were sourced from the International Production Assessment Division (IPAD) website. The wheat production in Iraq used to be forecasted for the years 2025 to 2035 the usage of the GM (1,1) and GVM (1,1) models.

4th: Forecasting Models

Deng's 1988 introduction of Grey System Theory addresses systems with missing data, or "grey systems," like these with ambiguous operational procedures, behavioural documentation, and unclear structures. The human body, agriculture, and the economy are a few examples. The theory seeks to foster interdisciplinary cooperation throughout a range of fields by means of bridging the hole between the social and natural sciences. Grey System Theory has verified to be enduringly sizable when you consider that its inception, mainly in China, where it is drastically mentioned and utilised in fields which includes geography, agriculture, ecology, economics, meteorology, medicine, and industry.

In Grey System Theory, the GM (m, n) mannequin where m is the order of the difference equation and n is the range of variables is used to predict future outputs with a excessive diploma of accuracy, even in the absence of a complete mathematical mannequin of the system. The GM (1, 1) model is extensively used for predictions and stands out in unique for its computational efficiency. First-order differential equations are used in this mannequin to fit the statistics generated by using the Accumulation Generating Operation (AGO).

The GM (1,1) model's strength is its capability for particular prediction-making with sparse documents and its high computational efficiency. The contemporary search for affords an overview of the GM (1,1) and GVM (1,1) models, imparting greater complete details as follows:

5th:

1- GM(1,1)

The GM (1, 1), which denotes the use of a single variable within the model, is often used as the gray prediction model. There are six steps in the GM (1,1) calculation process, which are as follows:

Step 1 : $X^{(0)}$ gives the non-negative original sequence data.

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\} \qquad , n \geq 4 \qquad (1)$$

Step 2: A one-time accumulated generating operation (1-AGO) is used to create $X^{(1)}$from the non-negative original sequence data $X^{(0)}$. This process is represented as

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)\} \qquad (2)$$

Where:

$$x^{(1)}(1) = \mathrm{x}^{(0)}(1) \text{ and } \mathrm{X}^{(1)}(\mathrm{k}) = \sum_{j=1}^{k} \mathrm{x}^{(0)} \ (\mathrm{k} = 1,2, \dots, \mathrm{n})$$

Step 3: Utilizing the mean generating operation (MGO), ascertain the background value z.

$$z^{(1)}(k) = 0.5\, x^{(1)}(k+1) + 0.5\, x^{(1)}(k) \qquad k = 2,3, \qquad (3)$$

Step 4: A sequence that is constantly rising is the outcome of 1-AGO, and it resembles the solution curve of a first-order linear differential equation. As a result, the 1-AGO data is roughly represented by the solution curve of the following differential equation.:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b \qquad (4)$$

The parameters a and b are referred to as the development coefficient and grey input, respectively. $\mathrm{x}^{(1)}(1) = \mathrm{x}^{(0)}(1)$represents the corresponding initial condition

Step 5: One can compute the parameters a and b through the OLS

$$\binom{a}{b} = (\beta^T \beta)^{-1} \beta^T Y_n \qquad (5)$$

$$\beta = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \\ -z^{(1)}(n) & 1 \end{bmatrix} \text{ and } Y_n = [x^{(0)}(2), x^{(0)}(3), \dots, x^{(0)}(n)]^T$$

where β and Y_n are defined as follows:

Finding the specific solution requires solving Eq. (5) together with the initial condition.

$$\hat{x}^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-ak} + \frac{b}{a} \quad k = 1,2,3, \dots \dots \qquad (6)$$

Step 6: By applying the inverse accumulated generating operation (I-AGO) to x $\hat{x}^{(1)}(k)$, it is possible to approximate the anticipated data of $\hat{x}^{(0)}(k)$in the following manner:

$$\hat{x}^{(0)}(k+1) = (1 - e^{-a}) \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-ak} \qquad (7)$$

Or $$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \qquad (8)$$

2- GVM (1,1)

The GVM forecasts the use of first-order discrete equations for small-sample information with the aid of combining Grey System Theory with the Verhulst model. This is how the GVM formula seems:

Step 1: Considering the original sequence data $X^{(0)}$that is non-negative

$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\}, \quad n \geq 4$ (10)

Step 2: Utilizing the non-negative original sequence data $X^{(0)}$, $X^{(1)}$ is constructed through the 1-AGO process, represented as

$X^{(1)} = \left(x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \dots, x^{(1)}(n)\right)$ (11)

$x^{(1)} = \sum_{i=1}^{k} x^{(0)}(1) \quad k = 1,2,3, \dots, n$

Where: $X^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(1) \quad k = 1,2,3, \dots, n$

Step 3: Using MGO to calculate a background value z:

$z^{(1)}(k) = 0.5x^{(1)}(k+1) + 0.5x^{(1)}(k) \quad k = 2,3, \dots$ (12)

The form of the GVM is as follows:

$\frac{dx^{(1)}}{dt} + ax^{(1)} = bx^{(1)^2}$

where a is the development coefficient and b is the grey action.

Step 4 : The formula for $\hat{a} = [a, b]^T$by applying the function as follows, can be managed with the least squares method: $\hat{a} = [a, b]^T$. The General Motors (1,1) power model's is

$\binom{a}{b} = (\beta^T \beta)^{-1} \beta^T Y_n$ (13)

where B and Y_n are defined as follows:

$$\beta = \begin{bmatrix} -z^{(1)}(2) & (z^{(1)}(2))^2 \\ -z^{(1)}(3) & (z^{(1)}(3))^2 \\ \vdots & \cdots \\ -z^{(1)}(n) & (z^{(1)}(n))^2 \end{bmatrix} \text{ and } Y_n = [x^{(0)}(2), x^{(0)}(3), \dots, x^{(0)}(n)]^T$$

The value obtained is $x^{(1)}(0)$. The time response equation of the GVM is as follows following the solution of the differential equation mentioned above::

$\hat{x}^{(1)}(k+1) = \frac{ax^{(1)}(0)}{bx^{(1)}(0) + \left(a - bx^{(1)}(0)\right)e^{ak}} \quad k = 0,1,2, \dots n$ (14)

Step 5 : Following is the grey Verhulst prediction model of X(0) that results.

$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \quad k = 1,2,3, \dots$ (15)

6th: Evaluate Precision of forecasting Models

1- Mean Absolute Percentage Error (MAPE)

The usual performance and accuracy of the advised model are evaluated the usage of a vary of statistical tests and metrics, such as the Mean Absolute Percentage Error (MAPE). The MAPE index was once once used in this research about to verify the forecasting technique's overall performance and dependability.

$MAPE = \frac{1}{n} \sum_{i=1}^{n} |PE_k| * 100\% = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)} \right| * 100\%$ (16)

2- Mean Square Error (MSE)

Another approach to decide forecasting accuracy is Mean Square Error (MSE). Compiling the squared forecast blunders for every period and dividing the end result by using the complete volume of forecast intervals is the process. The following requirements are used to determine how advantageous a forecasting approach is:

$$MSE = \frac{1}{n}\sum_{i=2}^{n}(error)^2 = \frac{1}{n}\sum_{i=2}^{n} e_t{}^2 = \frac{1}{n}\sum_{i=2}^{n}\left(x^{(0)}(k) - \hat{x}^{(0)}(k)\right)^2 \qquad (17)$$

Where:

$x^{(0)}(k)$: Actual demand $\qquad$ $\hat{x}^{(0)}(k)$: Forecast demand

n: Specified number of time period, $\qquad$ e_t: $x^{(0)}(k) - \hat{x}^{(0)}(k)$

7th: Application

1- Introduction

In order to forecast wheat production in Iraq from 2025 to 2035, this find out about compares the GM (1,1) and the GVM (1,1). This dataset used to be obtained from the "International Production Assessment Division (IPAD)" internet net web page and covers the duration from 2014 to 2024, or 11 years. Then, from 2025 to 2035, wheat manufacturing in Iraq is expected the use of the GM(1,1) and GVM (1,1) models.

2- Variable of this Study

The wheat production data from 2014 to 2024 was used to create the GM (1,1) and the GVM (1,1). The table below shows the data.

Table (1): demonstrations the wheat production in Iraq, from 2014 to 2024

Years	2014	2015	2016	2017	2018	2019
Production (1000 Tons)	3500	4410	4225	4000	3000	4800
Years	2020	2021	2022	2023	2024	
Production (1000 Tons)	4635	3500	3200	5200	5700	

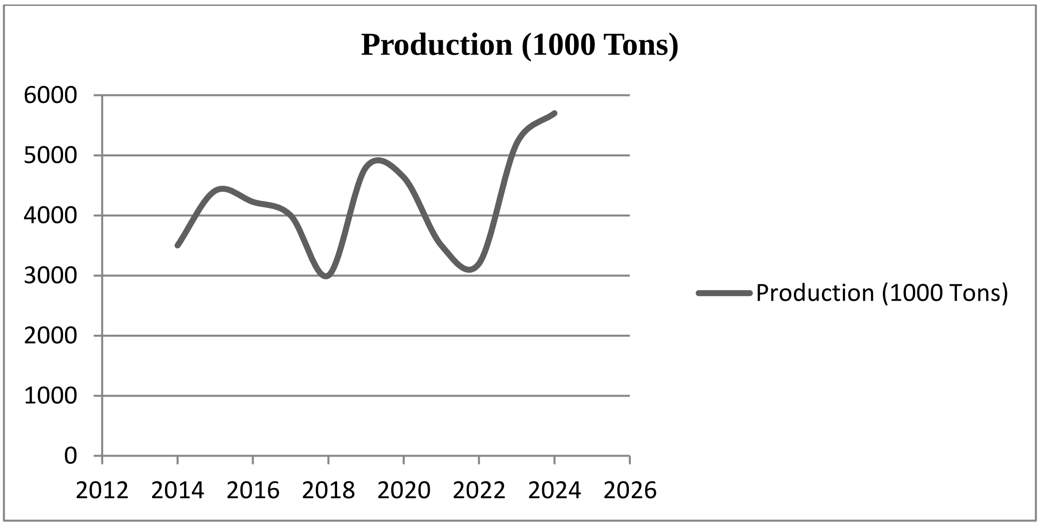

Fig. (1): Plot the wheat production in Iraq from (11) years

Figure 1 of the wheat production chart illustrates how the data demonstrates compliance between the 2014 and 2024 time periods.

3- Results and Discussions

This find out about analysed forecast effects to observe their variability in order to determine the gorgeous forecasting model for projecting wheat production in Iraq from 2025 to 2035. The mannequin parameters had been computed the usage of Microsoft Excel. Excel used to be customary for its giant range of matrix formulas, which made calculations like inverses of extra than one matrices and different calculations easier. The precision cost index and absolute proportion error were two of the metrics used in the find out about to reflect on consideration on the forecasting model's accuracy.

A. Results of GM (1,1)

The GM (1,1) model's parameters have been estimated using the Ordinary Least Squares (OLS) method as follows: The slope (b) is 3679.934342, and the intercept (a) is -0.024413767. The GM (1,1) model produces a MSE of 540456.509 and a MAPE of 15.673205528% which was shows in the table 2.

Table (2): Results of the GM (1,1) model.

Years	Data	Predictive value	Error	Percentage Error (PE%)	$(\text{Error})^2$
2014	3500	3500.0000	0	0.000	0
2015	4410	3811.7225	598.2775433	13.5664	357936.0189
2016	4225	3905.9262	319.0737825	7.5520	101808.0787
2017	4000	4002.4582	-2.458151223	0.0615	6.042507433
2018	3000	4101.3758	-1101.375797	36.7125	1213028.646
2019	4800	4202.7381	597.261885	12.4430	356721.7593
2020	4635	4306.6055	328.3944758	7.0851	107842.9317
2021	3500	4413.0399	-913.0399359	26.0869	833641.9245
2022	3200	4522.105	-1322.104791	41.3158	1747961.079
2023	5200	4633.865	566.1348999	10.8872	320508.7249
2024	5700	4748.387	951.612522	16.6950	905566.392

B. Results of GVM (1,1)

The GVM (1,1) model's parameters, obtained through the least squares solution, are as follows: a=-0.309921695 and b=-0.000005. The data suggests that the GVM (1,1) model has a MSE of 2667775.897 and a MAPE of 31.5206% from the table 3.

Table (3): Results of the GVM (1,1) model.

Years	Data	Predictive value	Error	Percentage Error (PE%)	$(\text{Error})^2$
2014	3500	3500	0	0.0000	0
2015	4410	1178.5760	3231.423956	73.2749	10442100.78
2016	4225	1534.6504	2690.349563	63.6769	7237980.77
2017	4000	1968.5479	2031.452069	50.7863	4126797.51
2018	3000	2477.0950	522.9049578	17.4302	273429.5949
2019	4800	3042.7817	1757.218322	36.6087	3087816.231
2020	4635	3628.8973	1006.102741	21.7066	1012242.726
2021	3500	4178.5630	-678.562993	19.3875	460447.7354
2022	3200	4621.2929	-1421.292902	44.4154	2020073.513
2023	5200	4888.427551	311.5724486	5.9918	97077.39072
2024	5700	4933.469757	766.5302433	13.4479	587568.6139

Table (4): Represents the accuracy of models

Criteria	GM(1,1)	GVM(1,1)
MAPE (%)	15.673205528	31.5206
MSE	540456.509	2667775.897

In Table (4), the GM(1,1) and GVM(1,1) models' MAPE% and MSE are documented. In particular, a 15.673205528% MAPE and 540456.509 MSE are displayed in the GM(1,1) model. Based on these metrics, which exhibit decrease MAPE and MSE values, the GM(1,1) model is greater correct than the GVM(1,1) model. Thus, the study about suggests that future estimates of wheat production in Iraq be made using the GM(1,1) model, based on these results. Table (5) consists of the estimated values for the years 2025 through 2035

Table (5): Forecasting Wheat Production in Iraq using the GM(1,1) Model

Years	2025	2026	2027	2028	2029	2030
Forecasting value	4865.740	4985.993	5109.218	5235.488	5364.880	5497.468
Years	2031	2032	2033	2024	2035	
Forecasting value	5633.334	5772.557	5915.222	6061.412	6211.215	

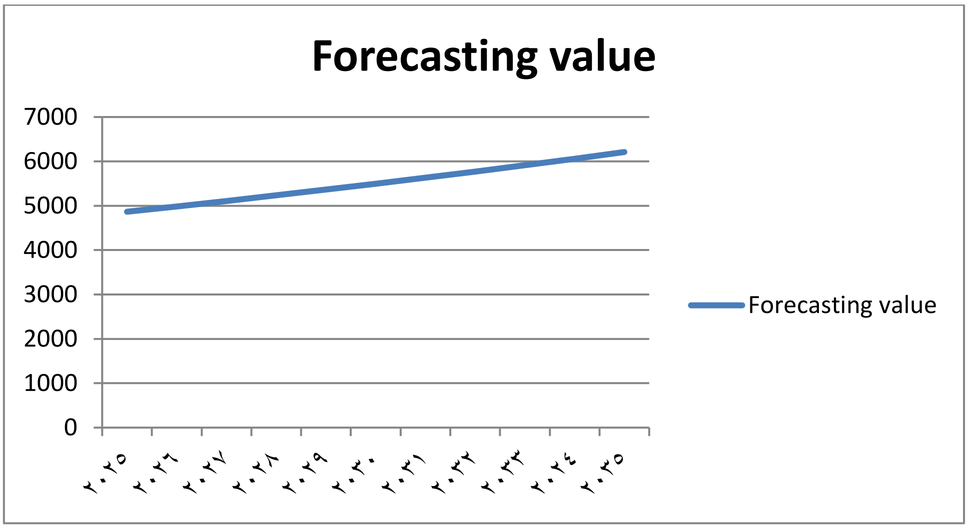

Fig. (2): Plot the forecasting wheat production in Iraq

8th Discussion

The GM(1,1) and GVM(1,1) fashions are in distinction in this locate out about to predict Iraq's wheat production from 2025 to 2035. The contrast is based totally on MSE and MAPE, with the cause of figuring out the most environment friendly technique for predicting Iraq's wheat output. Greater accuracy in forecasting future values is indicated through lower MAPE and MSE values.

It is determined that the splendid model to forecast Iraq's wheat production is the GM(1,1) model. The GM(1,1) model has the lowest MAPE and MSE values when in contrast to the GVM(1,1) model, which leads to this conclusion. In particular, the GVM(1,1) model's MAPE and MSE are 31.5206% and 2,667,775.897, respectively. The GM(1,1) model, on the exceptional hand, has an MSE of 540,456.509 and a MAPE of 15.6732%. Because the GM(1,1) model has lower MAPE and MSE values than the GVM(1,1) model, it can be concluded that it is the most brilliant strategy primarily based absolutely on the typical performance metric of MAPE.

These findings have good sized implications for Iraqi agricultural coverage and planning. Planning for meals security, allocating resources, and retaining monetary stability can all advantage from correct wheat manufacturing forecasts. For these involved in the agriculture industry, the GM(1,1) mannequin is a greater dependable device due to its diminished error rates.

All matters considered; the distinction amply illustrates how well the GM (1,1) mannequin predicts Iraq's wheat production. In order to make bigger the GM (1,1) model's predictive accuracy even more, future lookup may want to seem into applying these fashions to exceptional vegetation or geographical areas.

9th Conclusion and Recommendation

In this study, we learn about how well grey forecasting fashions predict Iraq's wheat production. The effectiveness of two grey forecasting models the GM(1,1) and GVM(1,1) models in predicting wheat production in Iraq was examined. The find out about discovered that, in phrases of MAPE% and MSE, the GM(1,1) mannequin is the first-class mannequin for predicting wheat production in Iraq. The MAPE and MSE of the GVM(1,1) model, which have been recorded at 31.5206% and 2,667,775.897, respectively, are drastically increased than these of the GM(1,1) model, which verified an MSE of 540,456.509 and a MAPE of 15.6732%. With decrease MAPE and MSE values than the GVM(1,1) model, this suggests that the GM(1,1) model is a extra correct technique.
The consequences of this find out about assist the use of the GM(1,1) model for wheat manufacturing prediction due to the fact it affords a forecast that is more correct than the GVM(1,1) model. To further enhance forecasting accuracy, it is advised that future research practice and evaluate the Grey model with different models, such as the Fourier Grey mannequin and the wavelet Grey model.

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