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The Prediction of Tea Production Using Dynamic Rolling Update Grey Model: A Case Study of China

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Abstract

China is one of the world's largest tea-producing countries, and its production fluctuations affect the international market and domestic economic stability. Existing research often uses limited predictive models at the local scale and lacks systematic national analysis. This study evaluated five models—autoregressive integrated moving average model (ARIMA), grey model (GM (1,1)), Markov chain grey model (Markov-GM (1,1,)), particle swarm optimization Markov chain grey model (PSO-Markov-GM), and dynamic rolling update grey model (DRUGM (1,1))—using three stages of annual tea production data from China (2004-2023). The results indicate that DRUGM (1,1) has the lowest prediction error, demonstrating superior ability to capture production trends. The dynamic update mechanism of this model enhances its adaptability, providing an efficient and scalable framework for predicting the production level of tea and other crops. Accurate predictions are crucial for improving agricultural planning, optimizing resource allocation, and providing information for trade policy design. This study provides practical tools for sustainable agricultural decision-making, helping to strengthen rural economic stability and resilient food systems.

Keywords: Tea production prediction, grey model, dynamic rolling update, Markov chain model, particle swarm optimization

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1 Introduction

China's history of tea production spans more than 4000 years. China is also an important promoter of global tea culture and industry development. As the world's largest tea producer, China's annual output has accounted for over 45% of the global total for several consecutive years (https://www.fao.org/faostat/en/#data). Meanwhile, the annual variation in the rate of tea production in China is as high as 6.8% (https://data.stats.gov.cn), representing significant fluctuations, far higher than those for grain crops. This volatility is a consequence of the lack of high-precision prediction mechanisms, and may lead to a market supply–demand imbalance, reduced incomes for tea farmers, and weaker export performance. These fluctuations also diminish the effectiveness of policy subsidies and contribute to instability in social employment. Therefore, it is necessary to establish a scientific and dynamic tea production forecasting system. This could provide a foundation for improved government decision-making and market regulation.

2 Literature Review

Deng (1982) proposed grey theory in the 1980s to address the issue of "small information and small samples". Many fields have adopted GM $(1, 1)$, including manufacturing (Chang et al., 2015), transportation (Xie et al., 2020), health (Gao et al., 2020), energy (Yuan et al., 2016), and transportation (Liu et al., 2021).

Some scholars have conducted further research on GM $(1, 1)$ based on different application scenarios and problem characteristics. For example, Jia et al. (2020) introduced Markov-GM to reduce errors in coal consumption prediction. Markov-GM has also produced reliable results in other fields, such as electricity production (Elgharbi et al., 2019), ground monitoring (Yuan et al., 2021), traffic accidents (Jin et al., 2020), and the economy (Qiu et al., 2023). In Markov-GM, scholars have generally divided state intervals using empirical judgment rather than, a unified standard. Some scholars use optimization algorithms to solve this issue. Zheng et al. (2021) optimized the non-linear components of NGBM $(1, 1)$ through the PSO algorithm, finding that it proved effective in improving prediction performance. Several researchers have developed rolling-based grey forecasting models, utilizing new information to improve modeling accuracy. Zhou et al. (2021) proposed GRPM $(1, 1)$ for predicting carbon dioxide emissions in China. To bridge this gap, this research seeks to develop and evaluate an accurate predic-tive model for tea production in China. Using annual tea production data from the past twenty years in China, we conducted a systematic performance comparison of five prediction models: ARIMA, GM $(1, 1)$, Markov-GM $(1, 1)$, PSO-Markov-GM, and DRUGM $(1, 1)$.

3 Results

The results show that DRUGM $(1, 1)$ performs well in predicting tea production at both national and provincial levels in China. PSO-Markov-GM $(1, 1)$ has certain advantages over DRUGM $(1, 1)$ in short-term predictions, but its error in the testing stage tends to increase, indicating that it has limited applicability in long-term prediction. GM $(1, 1)$ and Markov-GM $(1, 1)$ are more effective at capturing overall trends, but their performance in dealing with short-term fluctuations and structural changes is poor. Although ARIMA has outstanding fitting performance during the training phase, it exhibits strong instability

during years of anomalous production.

This study further demonstrates that DRUGM $(1,1)$ is superior in overall predictive performance, with its low error rate and high stability indicating that the model maintains good adaptability in response to data fluctuations and trend changes. DRUGM $(1,1)$ combines rolling data updates with dynamic error correc-tion mechanisms. Not only can it reduce the impact of outdated information, but it can also iteratively adjust deviations when new data are available, enabling it to maintain higher stability and accuracy in the event of sudden fluctuations or trend changes. DRUGM $(1,1)$ effectively reduces prediction bias through dynamic updating and correction mechanisms, allowing superior performance in long-term trend prediction.

4 Conclusions

This study analyzed the data for Chinese tea production and evaluated the predictive performance of five models—ARIMA, GM $(1,1)$, Markov-GM $(1,1)$, PSO-Markov-GM $(1,1)$, and DRUGM $(1,1)$—using four performance indicators (APE, MAPE, RMSE, and MAE). The results indicate that DRUGM $(1,1)$ consistently achieved the lowest prediction error across all datasets, demonstrating the best fit with historical data. Integrating the dynamic rolling update process into the GM $(1,1)$ framework improves accuracy while maintaining the simplicity of the model.

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