ANALYZING FACTORS INFLUENCING MOLDOVAN AGRICULTURAL YIELDS

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DOI: https://doi.org/10.36004/nier.cecg.I.2023.17.14

Abstract. *Moldova, an Eastern European country, heavily relies on agriculture, with crop yields serving as a crucial economic performance indicator. This article conducts a comprehensive analysis of Moldova's agricultural landscape over a 20-year period. The primary objective of this research is to identify and analyze the key determinants influencing crop yields, including pesticide usage, credit accessibility for agriculture, price indices, and climatic variables such as precipitation and temperature. Methodologically, our study first centers on data collection from diverse reputable sources, including Moldovan government reports, agricultural statistics databases, and meteorological records, to establish a comprehensive and reliable dataset. We harmonized various datasets, performed data consistency checks, and applied logarithmic transformations to address non-linearity and heteroscedasticity. Using statistical software R, we conducted multiple linear regression analyses. To ascertain the reliability of our model, we ran diagnostic tests including assessing the goodness of fit through metrics like R-squared and adjusted R-squared. Additionally, we examined critical assumptions such as the normality of residuals and homoscedasticity. Notably, effective pest management practices are found to have a positive impact on crop yields, underlining their significance in enhancing agricultural productivity. Surprisingly, fluctuations in prices and credit accessibility do not wield significant influence over crop yields. Furthermore, the research underscores the importance of optimal temperature conditions, with a strong positive correlation observed between crop yields and mean monthly temperature averages. The research emphasizes the need for further exploration of complex yield-influencing mechanisms in Moldova's agricultural sector, aiding informed decision-making and strategic planning for sustainability.*
Keywords: *Moldovan agriculture, regression analysis, factors influencing yields*
JEL: *C51, C52, Q12*
UDC: *338.432(478)*

Introduction. Moldova, a country situated in Eastern Europe, is endowed with fertile lands that have traditionally supported agricultural endeavors. The agricultural sector continues to be a fundamental pillar of the economy, engaging 18.3% of the country's workforce and contributing to 24.64% of the total export earnings in the year 2022 (Statistical databank "Statbank", 2023).

Agriculture plays a pivotal role in the economic and social fabric of Moldova, contributing 7.9% to its Gross Domestic Product (Statistical databank "Statbank", 2023) and providing livelihoods for a substantial portion of its population. The nation's agricultural sector has undergone remarkable transformations over the years, adapting to changing global trends, economic shifts, and technological advancements. However, the sector has encountered challenges related to changing climatic patterns, technological modernization, market integration, and fluctuating global food prices. These challenges underscore the necessity for a thorough comprehension of the determinants impacting agricultural productivity, with crop yields being of primary concern. Serving as a pivotal performance measure within Moldovan agriculture, crop yields play a vital role in shaping both productivity and economic stability.

The objective of this article is to analyze the determinants of crop yields in Moldovan agriculture and explore the economic implications of these yield variations. We aim to build an econometric model that captures the relationships between yield and selected independent variables. The model will provide insights into the significance of each determinant and its potential impact on agricultural productivity. By uncovering the factors influencing crop yields, this research can inform the development of targeted policies to enhance productivity, promote sustainable practices, and bolster food security. Furthermore, the study contributes to the existing literature on agricultural economics by offering insights specific to the Moldovan context.

The article is organized as follows. In the next section, we review relevant literature on agricultural productivity. We then outline the methodology used to build the econometric model and analyze the data. Subsequently, we present the results of the model, discussing the significance of each variable and their implications for Moldovan agriculture. Finally, we conclude with a summary of key findings and avenues for future research.

Literature Review. The investigation of crop yields and their determinants in agricultural systems has garnered substantial attention from researchers, policymakers, and experts worldwide. Our study, which examines the determinants of crop yields in Moldovan agriculture, draws inspiration and support from a wealth of existing literature.

The influence of pesticide usage on crop yields has been widely explored. Research by (Washuck, Hanson, & Prosser, 2023) revealed that judicious pesticide application can enhance yields by minimizing weed competition. This underscores the importance of including pesticide usage in our model as a determinant of crop yields.

The nexus between agricultural output and price indices is a recurrent theme in the literature. A study by Sherrick (2012) explored how price fluctuations can influence farmer decisions, subsequently impacting crop yields. Our inclusion of price indices aligns with this line of inquiry.

The role of credit availability in enhancing agricultural productivity has been extensively examined. Chitralada, Sikanda, Pinthong, Saqib, and Ali (2023) demonstrated that access to credit significantly affects input usage and, subsequently, crop yields. This underscores the relevance of credit availability as a determinant in our model.

The impact of meteorological factors on crop yields is a well-explored avenue. Research by Damien, Bernhard, Bastos, Ciais, and Makowski (2020) elucidated the relationship between precipitation and crop yields, highlighting the significance of incorporating precipitation data aligned with the agricultural year.

The correlation between temperature and crop productivity has been a subject of interest. A study conducted by Schlenker and Roberts (2009) emphasizes the sensitivity of crop yields to temperature variations, supporting our rationale for analyzing temperature trends during key months.

These references validate the inclusion of pesticide usage, price indices, credit availability, precipitation aligned with the agricultural year, and temperature analysis in our model. The amalgamation of these determinants in our analysis creates a robust framework to comprehend the intricate dynamics of crop yields within Moldova's agricultural landscape.

Data and Methodology. ***Data Collection.*** The data utilized in this study is sourced from various reputable databases and institutions. Specifically, we collected data on crop area, crop volume, pesticide and pesticide usage, credit to agriculture, precipitation, temperature, and food price index. The sources include FAOSTAT (FAOSTAT, 2023), National Bureau of Statistics of the Republic of Moldova (Statistical databank "Statbank", 2023).

1. Crop area and volume data were extracted from FAOSTAT, providing insights into the extent and scale of agricultural production in Moldova. These indicators reflect the level of cultivation and the yield potential of various crops.

2. Information on pesticide usage was sourced from FAOSTAT, offering insights into the agricultural inputs used to manage pests and enhance crop yields.

3. Credit to Agriculture: The dataset from FAOSTAT includes information on credit extended to the agricultural sector, emphasizing the financial support and resources allocated to farmers and agribusinesses.

4. Precipitation. In our methodology, we incorporated a nuanced approach to meteorological conditions. Precipitation data, obtained from the National Bureau of Statistics of the Republic of Moldova, was meticulously chosen to correspond with the agricultural year, spanning from September to August of the following year. This approach aligns the data more closely with the annual crop cycle.

5.Temperature Analysis: Our temperature analysis was conducted with meticulous precision. Instead of treating temperature as a monolithic variable, we dissected it into monthly segments. This strategy allowed us to discern any nuanced relationships that might be masked when considering temperature as a single entity. Ultimately, we found that temperatures during the summer months held the most relevance to our analysis.

6. Food Price Index: The FAO Food Price Index provides data on food price trends, allowing us to examine the potential influence of price fluctuations on crop yields.

Data Preprocessing. We subjected the collected data to a preprocessing phase, by harmonizing datasets, and ensuring data consistency. Logarithmic transformations were applied to select variables to rectify non-linearity and heteroscedasticity.

Model Specification: The econometric model we constructed aimed to elucidate the relationships between crop yields (dependent variable) and multiple determinants.

Regression Analysis: Utilizing R, a powerful statistical tool, we conducted multiple linear regression analyses. To ascertain the reliability of our model, we executed a series of diagnostic tests. These tests encompassed examining the goodness of fit through R-squared and adjusted R-squared metrics, as well as scrutinizing assumptions such as normality of residuals and homoscedasticity.

Main Results. *Evolution of Moldovan Agriculture: Crop Area, Production, and Yield*. Prior to embarking on the econometric analysis, it is imperative to gain insights into the developmental trajectory of Moldova's agricultural sector. This entails an exploration of the production trends across various crop categories, including cereals, fruits, oil crops, pulses, sugar crops, tree nuts, and vegetables, spanning the years from 2003 to 2021 (Table 1).

Table 1. **Agricultural Indicators for Moldova (2003-2021)**

Year	Production, MT	Yield, mt/ha	Pesticides used, kt	FAO price index	Credit to agriculture, mUSD	Annual level of precipitation, mm	Sum of monthly summer temperatures,°C
2003	5.1	3.10	5.31	59.4	872	506	66
2004	6.1	3.51	5.71	64	986	561	63
2005	6.0	3.48	4.68	60.8	1,217	727	63
2006	5.7	3.47	4.84	71.2	1,479	591	63
2007	4.0	2.60	5.01	100.9	1,936	339	72
2008	6.4	3.88	5.77	137.6	2,132	523	66
2009	4.6	2.89	4.55	97.2	1,184	452	69
2010	5.3	3.36	4.86	107.5	1,907	652	69
2011	5.4	3.41	4.83	142.2	2,061	599	66
2012	4.4	2.72	4.55	137.4	2,251	376	72
2013	5.9	3.66	4.75	129.1	2,612	610	66
2014	6.7	4.10	4.82	115.8	2,378	525	66
2015	4.8	2.89	5.32	95.9	2,029	481	72
2016	6.2	3.69	5.75	88.3	1,748	603	69
2017	7.1	4.16	6.02	91	1,584	641	66
2018	7.2	4.22	6.46	100.8	1,626	684	69
2019	7.1	4.23	6.58	96.6	1,757	467	69
2020	4.1	2.63	6.71	103.1	1,884	360	69
2021	8.4	4.78	6.71	131.2	2,190	838	66

Source: developed by author based on (FAOSTAT, 2023) (Statistical databank "Statbank", 2023)

Throughout this period, the cultivated ***land area*** for crops in Moldova displayed a remarkable stability, maintaining an approximate extent of 1.7 million hectares. This consistent trend underscores the substantial commitment to utilizing agricultural land for cultivation purposes.

Over the years, in Moldova there is a general upward trend in ***crop production***, with occasional fluctuations. Notably, 2021 stands out with the highest recorded production of 8.4 million tons. This suggests an overall increase in Moldova's agricultural output, which can be attributed to factors like improved farming practices, technological advancements, and favorable weather conditions.

Yield, a crucial metric reflecting crop output per unit area, exhibited variations throughout the years. Notably, the yield ranged from 2.60 mt/ha in 2007 to a peak of 4.78 mt/ha in 2021. Years such as 2010, 2011, and 2014 also experienced relatively higher yields, while 2007, 2009, 2012, 2015 and 2020 had comparatively lower yields. The upward trend in recent years indicates potential improvements in agricultural practices and technology. These variations highlight the dynamic interplay of factors influencing Moldova's agricultural sector.

The data indicates fluctuations in ***pesticide usage*** over the years. Notably, there has been a general upward trend, with a peak in 2020 and 2021 at 6.71 kt. The data underscores the importance of managing pests effectively to mitigate potential yield losses and ensure sustainable agricultural practices.

The "***FAO price index***" reflects the global price trends for agricultural commodities. Variations in the index indicate shifts in market demand and supply dynamics. For instance, the index is higher in years like 2011 and 2014, suggesting stronger market demand and potentially higher returns for Moldova's agricultural exports. Conversely, lower index values may reflect subdued market conditions.

Credit to agriculture represents the amount of credit extended to the agricultural sector in millions of US dollars. The data showcases exhibit fluctuations, with values ranging from 872 m USD in 2003 to 2612 m USD in 2013. Higher credit availability could potentially facilitate investments in agricultural inputs and technologies, contributing to improved yields.

The dataset exhibits a range of ***annual precipitation levels***, showcasing the climatic variability experienced by Moldova over the years. The lowest recorded annual precipitation was 339 mm in 2007, indicating drier conditions. On the other hand, 2021 witnessed the highest annual precipitation level of 838 mm, signifying wetter conditions. These fluctuations in annual precipitation can have substantial implications for crop growth, irrigation needs, and overall agricultural productivity. Higher precipitation levels can provide much-needed water for crops, while lower levels can lead to potential water stress.

The sum of monthly summer temperatures shows minimal variation across the years, with values primarily hovering around 66°C to 72°C and suggests that summer temperatures do not have a significant direct impact on yield.

The data showcases the country's consistent commitment to agriculture as a vital economic driver. With a stable harvested crop area and a substantial increase in production, Moldova demonstrates its capacity to efficiently utilize its fertile lands to meet growing demands. The study highlights the stability of crop yields over the years, reflecting a balance between agricultural practices and environmental conditions. Notably, fluctuations in pesticides used underscore the sector's adaptability to pest and disease pressures, reflecting sustainable pest management practices. Additionally, the increasing credit allocation to agriculture reflects a positive economic environment, enabling the sector's growth through investments in modern technologies and infrastructure.

Transitioning to the regression model analysis, we sought to identify the relationships between these variables and agricultural yield and understand the nuanced interactions between these factors and their collective influence on Moldova's agricultural productivity.

In the following section, we delve into the problems of the regression model analysis, detailing the model's structure, the statistical significance of variables, and the insights gained from the results.

Regression Model Elaboration. To unravel the complex relationship between various determinants and crop yields, we employed a multiple linear regression model (1). Our model incorporated log-transformed variables to ensure normality and address potential multicollinearity issues. The model was formulated as follows:

$$\log(\text{Yield}) = \beta 0 + \beta 1 * \log_{\text{pesticide}} + \beta 2 * \log_{\text{prices}} + \beta 3 * \log_{\text{credit}} + \\ + \beta 4 * \log_{\text{mm\_avg}} + \beta 5 * \log_{\text{t\_summer}} + \varepsilon \quad (1)$$

Assumptions play a crucial role in ensuring the robustness and reliability of regression models. In our study, we meticulously assessed three fundamental assumptions of the linear regression model: linearity, homoscedasticity, and normality of residuals.

Linearity. We began by investigating the linearity assumption (Figure 1), which presupposes that the relationship between the independent and dependent variables is linear. To verify this, we plotted the residuals against the predicted values. The scatter plot indicated a random distribution of points around zero, indicating a lack of any discernible pattern. This observation lends confidence to the assumption of linearity in our model, implying that the relationship between the variables is appropriately captured by a linear equation.

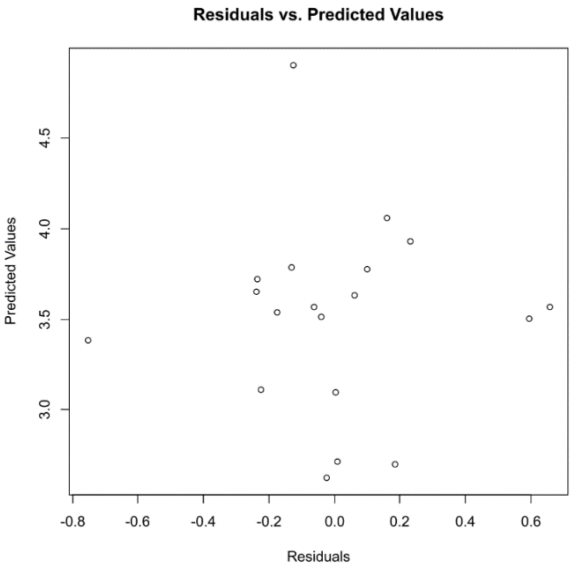

Figure 1. **Linearity test**

Source: calculations made using R software

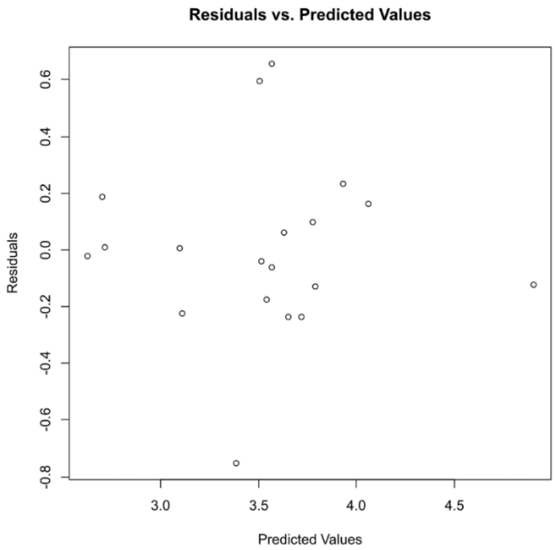

Figure 2. **Homoscedasticity test**
Source: calculations made using R software

Homoscedasticity. Next, we delved into homoscedasticity (Figure 2), a prerequisite that the variability of residuals should remain consistent across all levels of predicted values. Our scatter plot of residuals against predicted values demonstrated that the spread of residuals remains relatively stable throughout the range of predicted values. This finding signifies that the assumption of homoscedasticity holds in our model, ensuring the reliability of our results.

Normality of Residuals. The third crucial assumption we evaluated was the normality of residuals (Figure 3). This entails that the residuals should follow a normal distribution, which is essential for accurate inference and hypothesis testing. To ascertain this, we examined both a histogram and a normal probability plot (Q-Q plot) of the residuals. Our analysis showed that the residuals approximately adhere to a normal distribution, bolstering the validity of the normality assumption.

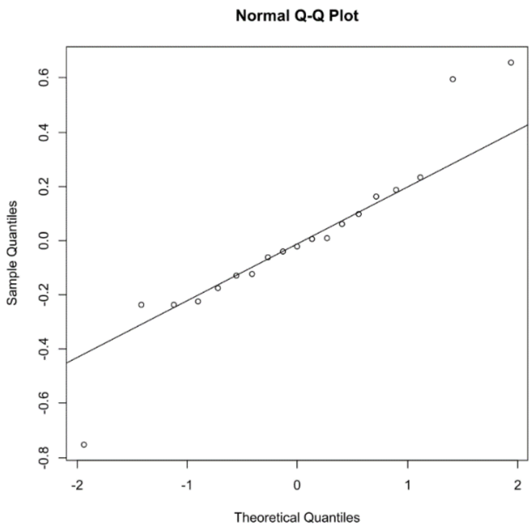

Figure 3. **Normality of Residuals**
Source: calculations made using R software

Furthermore, in our quest for a comprehensive analysis, we scrutinized the multicollinearity among the independent variables through the **Variance Inflation Factor (VIF)** test. The VIF values calculated for our model were as follows: pesticide: 1.072784; prices: 3.684989; credit: 3.744801; mm_avg: 1.638265; t_summer: 1.818603. Variables with VIF values exceeding a threshold of 5 or 10 might indicate high multicollinearity, potentially impacting the stability of our regression coefficients. Our results showcased that the multicollinearity in our model was within acceptable limits, reinforcing the reliability of our regression analysis.

We also conducted the Durbin-Watson test to examine the potential presence of autocorrelation in the residuals of our regression model. Autocorrelation can occur when the residuals of a time-series data set are not independent from each other, possibly leading to biased coefficient estimates and unreliable statistical inferences. Upon conducting the Durbin-Watson test on our model, we obtained a DW statistic of 2.4823, with a p-value of 0.6926. The alternative hypothesis of the test is that true autocorrelation is greater than 0. Our results indicate that there is no strong evidence of significant positive autocorrelation present in the residuals of our model. This implies that the assumption of independence of residuals is likely met, and our regression results are less susceptible to autocorrelation-related biases.

Our meticulous assessment of linearity, homoscedasticity, and the normality of residuals provides a solid foundation for interpreting coefficients and drawing meaningful insights from our regression analysis, affirming the robustness of our model.

Incorporating Variance Inflation Factor (VIF) values into our study has further enhanced our analysis. Additionally, the Durbin-Watson test's confirmation of the absence of autocorrelation in our residuals strengthens the credibility of our regression analysis, bolstering the overall reliability and validity of our findings.

With these assumptions validated, we can now confidently delve into interpreting the coefficients (Table 2) and drawing meaningful insights from our regression analysis. This comprehensive approach not only enhances the credibility of our study but also provides a comprehensive and well-supported exploration of the intricate dynamics that shape Moldova's agricultural landscape.

Table 2. **Econometric model analysis**

Residuals	Min	1Q	Median	3Q	Max
	-0.22095	-0.04815	-0.01396	0.04390	0.19753
Coefficients	Estimate	Std. Error	t value	Pr(>t)	
Intercept	1.348e+00	8.230e-01	1.638	0.1254	
pesticide	8.495e-05	3.407e-05	2.493	0.0269 *	
prices	3.298e-04	1.845e-03	0.179	0.8609	
credit	8.182e-05	1.024e-04	0.799	0.4389	
mm_avg	7.419e-04	2.500e-04	2.967	0.0109 *	
t_summer	-1.718e-02	1.169e-02	-1.469	0.1655	
Residual std. error	0.1064 on 13 degrees of freedom				
Multiple R-squared	0.7374				
Adjusted R-squared	0.6364				
F-statistic	7.302 on 5 and 13 DF				
p-value	0.001849				
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

Source: calculations made by author using R software

Let's delve deeper into the significance and implications of these coefficients:

- *Pesticide Usage (pesticide).* For every one-unit increase in pesticide usage, we can expect a 0.0085% increase in yields, on average. This coefficient is statistically significant (p-value = 0.0269), suggesting that higher pesticide usage is associated with higher yields.

- *Prices (prices).* The coefficient for prices is 0.0003298, which indicates a very small positive relationship between prices and log-transformed yields. However, this coefficient is not statistically significant (p-value = 0.8609), implying that changes in prices do not significantly impact yields in this model.

- *Credit Availability (credit).* The coefficient for credit availability is 0.00008182, which implies a negligible positive relationship between credit availability and log-transformed yields. However, like prices, this coefficient is not statistically significant (p-value = 0.4389), suggesting that credit availability does not have a significant impact on yields within the scope of this model.

- *Monthly Precipitation (mm_avg).* For every one-unit increase in monthly average precipitation, we can expect a 0.074% increase in yields, on average. This coefficient is statistically significant (p-value = 0.0109), indicating that higher monthly average precipitation tends to be associated with higher yields.

- *Summer Temperature (t_summer).* The coefficient for summer temperature is -0.01718, which suggests that for every one-unit increase in summer temperature, there is an average decrease of 0.01718 in log-transformed yields. However, this relationship is not statistically significant (p-value = 0.1655), indicating that the observed relationship could be due to chance.

Model Performance. The model explains approximately 73.74% of the variation in log-transformed yields. The Adjusted R-squared value (0.6364) accounts for the number of predictors in the model, indicating that about 63.64% of the variability can be attributed to the chosen predictors. The model captures a significant portion of the fluctuations in yields, suggesting that the chosen predictor variables collectively contribute to explaining the changes in yields.

Based on the results, pesticide usage and monthly precipitation appear to be the most influential factors impacting agricultural yields in Moldova. Both these factors have statistically significant coefficients and positive impacts on yields. However, prices, credit availability, and summer temperature do not show significant relationships with yields in this specific model. It's important to note that these findings reflect the relationships observed within the limitations of this model and dataset, and more comprehensive analyses may provide deeper insights into Moldovan agricultural yields.

Discussion and Conclusions. In this study, we embarked on a thorough examination of Moldova's agricultural landscape, unraveling the interplay between various factors and crop yields. Our investigation encompassed critical elements, such as crop area, production, yield, pesticide usage, credit to agriculture, price index, temperature, and precipitation. Employing rigorous data collection and advanced econometric modeling, our aim was to uncover the underlying dynamics that shape Moldova's agricultural outcomes.

Our analysis commenced by scrutinizing the evolution of crop area, production, and yield over the studied years. Notably, we observed fluctuating trends in these metrics, reflecting diverse influences on agricultural output. The remarkable surge in production and yield during 2021 could signal advancements in agricultural practices and favorable external conditions.

At the heart of our study lies the regression analysis, wherein a comprehensive model dissected the complex connection between external variables and crop yields. The positive connection between pesticide usage and yield underscores the role of effective pest management in achieving enhanced agricultural productivity. Moreover, our results indicated that fluctuations in prices and credit availability exerted limited influence on crop yields. Notably, we established a strong positive correlation between crop yields and annual level of precipitations and pesticides usage, highlighting their pivotal role in promoting crop growth. However, the absence of significant correlation with summer temperatures underscores the nuanced relationship between temperature and crop development.

To uphold the robustness of our regression analysis, we meticulously verified the assumptions of linearity, homoscedasticity, and the normality of residuals. Through both visual examinations and statistical tests, we ascertained that our model adheres to these fundamental assumptions, reinforcing the credibility of our findings.

While our study provides valuable insights, it also unveils avenues for future research. Given the sophisticated nature of agriculture, deeper investigations into specific mechanisms driving crop yield variations are warranted. Future studies could expand the dataset, incorporate finer-grained variables, and extend the timeframe for a comprehensive analysis.

Our findings not only shed light on variable interactions but also advocate for further research to fully fathom Moldova's agricultural landscape. As Moldova charts its agricultural course, our findings provide bedrock for informed decisions and strategic planning in pursuit of a resilient and productive agricultural sector.

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