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Impact of climate change on yield production in Algeria: evidence from ARDL empirical approach

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ABSTRACT

This study attempts to assess the impact of climate changes factors, such as average rainfall and average temperature on cereal production in Algeria from 1990 to 2019. We employed the autoregressive distributed lag (ARDL) simulations techniques and Granger causality test to estimate the long and short-term effects of climate change variables. The results showed that the rainfall, agricultural technology, agricultural labour, and cultivation of land enhance cereal output. The long-run ARDL model results provides that the temperature does not impact on cereal productivity. The findings provided by Granger causality tests also suggest that there is a unidirectional relationship between cereal production, climatic variables, and non-climate factors. The ARDL technique provides a better methodology to understanding of the variability of cereal production in Algeria as a result of climate factors.

Keywords: Climate change, Cereal production, ARDL approach, Granger causality, Algeria.

JEL Classification : Q54, Q13, C22

Introduction

In recent years, climate changes have affected considerably temperature, precipitation intensity geographical distribution, drought and flood frequency all over the world (Intergovernmental Panel on Climate Change, IPCC 2007). However, its effects differ from one country to another. Notably, its implications may be more severe for the developing nations and poor individuals IPCC, (2007). In fact, temperature, rainfall changes, winds and floods have all hampered agricultural sector, which is one of the most vulnerable sectors to climate change Aryal, J. P., and Stirling, C. (2019), due to global climate change. Furthermore, the latter influences remarkably the agriculture of increased yield losses, decreased agricultural land area and poor-output production. Furthermore, Dell, M et al., (2008) revealed that bad climate conditions have a detrimental impact on the world's poorest countries. Similarly, numerous research works have been conducted to estimate the effects of climatic variation on the agricultural production. For example, Khan et al., (2018) proved that the annual average temperature has a substantial influence on crop productivity and, due to temperature rise blossoms become sterile, which reduces cereal reproduction. Moreover, it was demonstrated, in some studies (Francesco Bosello et al., (2017)), that the change of climate factors, such as high temperatures and reduced precipitation, have a negative impact on agricultural yields. In another work, James et al., (2012) assessed the impact of climate variations on the economic development in Zambia by focusing on the deterioration of the

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agricultural activities. Indeed, this decrease may cause poverty and prevent economic growth. They argued that the GDP in Zambia falls by 4.3 billion dollars every year, raising the poverty rate in this country. Another empirical study conducted by Howard et al., (2016) revealed that the short-run and long-run changes in precipitation and temperature affect crop productivity. It also demonstrated that global warming has bad effects on the environment and human activities. For example, Zaveri et al., (2019) used a fixed effects technique to examine the implications of climatic changes on India's wheat output. The obtained findings imply that irrigation can help to mitigate the negative repercussions of these variations. The Mediterranean basin, on the other hand, is particularly vulnerable to rising temperatures and decreased rainfall. Algeria is the most affected country in North Africa by these factors Niang et al., (2014). Despite the increasing grain demand due to the high population density, Algerian's agricultural production has shown, in the last decades, high output productivity and crop variability has contributed greatly to Algeria's economic growth. In 2019, it contributed by 12.3 percent of the total GDPs and enhanced the living conditions of around 30 % of the national rural population by creating more employment opportunities, Bessaoudet et al., (2019). Despite the importance of this sector, the Algerian agricultural sector depends on precipitation, as revealed by Schilling et al., (2012). In fact, rainfed land accounts for 50% of the entire area of grain production (Bensemane et al., (2011)). Besides, Zargar et al., (2017) studied the influence of climate change on cereal production in Bordj Bouarreridj, Algeria's neighbor and observed the positive impact of climatic factors on wheat output. Moreover, in their study, Fenni, M., (2013) examined the effect of climate change on Sétif region. The experimental results show that rainfall variation influences positively on cereal output in the Sétif high plains. In the present paper, the impact of climate change on Algerian's cereal production is explored using the Autoregressive Distributed Lag approach. The remaining of the paper is organized as follows. The used data sources and the applied techniques are described in Section 2. Then, empirical findings and discussions are presented in Section 3. Finally, Section 4 shows the obtained findings and some suggestions to stakeholders.

1 Methodology

In the performed analysis employing yearly time series data collected from 1990 to 2019, some variables (e.g., cereal production, agricultural machinery, labor force, average annual temperature, average yearly rainfall,-and land area of cereal cultivation) were investigated. The data utilized in this paper (see Table 1) was gathered from the World Bank Indicator (WDI, 2022).

Table 1: Analysis variables lists

Var-abbreviation	Full form	Units	Data source
Cp	Production of cereals	Thousands of tones	WDI
K	Agricultural machinery	Number of tractors	WDI
L	Labor force	Thousands of persons (Total)	WDI
Temp	Annual temperature	Celsius	WDI
Rain	average	Millimeter	WDI
LCP	Annual precipitation	1000 hectares	WDI
	average		
	Cereal producing area		

1.1 Autoregressive Distributed Lag technique

To explore the role of climatic and non-climatic variables on Algerian's cereal output, the ARDL model introduced by Pesaran et al., (2001) was used. This method permits for levels of interaction to be analyzed the variables at I (0), integrated at I (1) or mutually cointegrated, Pesaran et al., (2001); Keele et DeBoef (2008). The Phillips-Perron test (1988) was also performed to check the stationarity and to guarantee that no variable would be integrated in order 2. The ARDL technique was also applied to verify the short-term and long-term co-integration of the specified variables. Pesaran (1997) suggested the ARDL framework to analyze long-run and short-run connection and compared the obtained results with those provided by earlier techniques such as methods proposed by Engle et Granger (1987) et Johansen et Juselius (1990). The ARDL procedure, which is appropriate for short data sets, reduces endogeneity problems and is designed to get better long-run relationship. Equation 1 written below explains the impact of climate and non-climate factors on cereal output in Algeria:

$$Cp_t = f(K_t, L_t, Temp_t, Rain_t, LCP_t) \quad (1)$$

where CP, K, L, Temp, Rain and LCP represent, respectively, cereal production, agricultural machinery, labor force, average yearly temperature, average annual rainfall, and Area under cereal production, while t denotes the period (1990-2019). All utilized variables were converted into natural log form to obtain intuitive and appropriate findings. Thus, Equation (1) becomes:

$$LnCp_t = \alpha_0 + \alpha_1 LnK_t + \alpha_2 LnL_t + \alpha_3 LnTemp_t + \alpha_4 LnRain_t + \alpha_5 LnLCP_t + \varepsilon_t \quad (2)$$

The ARDL technique, applied to evaluate the interaction of the short run and long run, is presented by Equations 3 and 4.

$$\Delta LnCp_{t-i} = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta LnCp_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LnK_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta LnL_{t-i} + \sum_{i=1}^{q} \alpha_{4i}\, \Delta LnTemp_{t-i} + \sum_{i=1}^{q} \alpha_{5i}\, \Delta LnRain_{t-i} + \sum_{i=1}^{q} \alpha_{6i}\, \Delta LnLCP_{t-i} + \varepsilon_t \quad (3)$$

Furthermore, ECM technique was used in the conducted analysis to assess the short-run interaction between the climate factors. The equation ~~of~~ applied in the ECM model is formulated below:

$$\Delta LnCp_{t-i} = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta LnCp_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LnK_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta LnL_{t-i} + \sum_{i=1}^{q} \alpha_{4i}\, \Delta LnTemp_{t-i} + \sum_{i=1}^{q} \alpha_{5i}\, \Delta LnRain_{t-i} + \sum_{i=1}^{q} \alpha_{6i}\, \Delta LnLCP_{t-i} + \alpha_7 ECT_{t-1} + \varepsilon_t \quad (4)$$

Equations (3) and (4) were employed to evaluate the short-term and long-term relationships between the selected variables of climate change, non-climate changes and cereal production in Algeria. LnCp, LnK, LnL, LnTemp, LnRain and LnLCP stands for the logarithm of cereal production, agricultural machinery, temperature, rainfall and logarithm of area land under cereal production at time t; ECT_{t-1} denotes the ECM's error correction model; Δ represents the first difference; $\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, and\ \alpha_6$ ~~is~~ are the short-run and long-run coefficients~~,~~ while α_7 designates the error correction term coefficient (ECT) and ε_t is the error term.

2 Data analysis

2.1 Unit root tests and descriptive statistics

In this study, descriptive statistics on cereal production (LnCp), agricultural machinery (LnK), labor force (LnL), temperature (LnTemp), rainfall (LnRain) and land area under cereal production (LnLCP) of Algeria between 1990 and 2019 are presented in Table 1. The number of the analyzed observations is 30 (Table 2). In fact, the average cereal production during this period is 14.86 while the annual average rainfall, temperature and the cereal production coefficient of variation are 4.40, 3.14 and 0.04, respectively. On the other hand, the variation of coefficient of temperature and that of the cereal production variables are equal to 0.004 and 0.035, respectively. The diffusion is also small, and the distribution is homogeneous of the last variable. The Philips Perron test was employed to show whether the above-mentioned variables are stationary or not. Table 3 displays the results of the stationarity tests, that agricultural machinery, labor force and temperature used of Algerian agricultural is integrated of order one. However, cereal production, and area under cereal production is stationary at the level which intercept. Therefore, form the obtained results, we may deduce that all used variables are integrated in I (0) and I (1) (M.H. Pesaran et al., (1997, 1999, 2001)).

Table 2: Descriptive statistics results

Variables	LnCp	LnK	LnL	LnTemp	LnRain	LnLCP
Mean	14.865	11.516	14.279	3.143	4.404	14.728
Median	15.057	11.504	14.337	3.144	4.440	14.801
Maximum	15.618	11.629	14.548	3.165	4.642	15.114
Minimum	13.676	11.413	13.955	3.109	4.040	13.872
Std. Dev.	0.539	0.069	0.209	0.013	0.154	0.340
Sum	445.952	345.479	428.394	94.294	132.138	441.867
Observations	30	30	30	30	30	30

Table 3: Unit root tests outcomes

Variables	Phillips – Perron test			
	At levels		At first difference	
	T. statistic	P. value	T. statistic	P. value
LnCp	-4.298 ***	0.002	-15.811 ***	0.000
LnK	-0.353	0.904	-10.898 ***	0.000
LnL	-0.437	0.889	-2.793 *	0.072
LnTemp	-2.518	0.121	-9.999 ***	0.000
LnRain	-5.102 ***	0.000	-24.833 ***	0.000
LnLCP	-5.417 ***	0.000	-8.848 ***	0.000

Note: *; **; * represents the 1 %, 5 %, and 10 % of significance level.**

3. Empirical results and discussion

3.1 Cointegration tests

The findings were described from a cointegration bounds analysis evaluating for variable and the outcomes are revealed in Table 4 bellow. At a 5% significance level, the critical value is 6.422 which is greater than highest bounds limit. It shows that there are long-run interactions between cereal production, area land, labor force, agricultural machinery, temperature, and rainfall. However, in the performed experiments, Johansen and Juselius (1990) co-integration approach was used to show the long-term connection between the variable. Table 5–demonstrates the existence of a long-term equilibrium between all variables utilized in this study. The two obtained co-integration vector levels were validated using trace statistics (10.05).

Table 4: ARDL cointegration results

Function	F-statistic	
F_{LnCp} (LnK, LnL, LnTemp, LnRain, LnCLP)		**6.422**
Bounds tests	I [0]	I [1]
10 %	2.26	3.35
5 %	2.62	3.79
1 %	3.41	4.68
R^2	96.408	
Adj. R^2	93.353	
F-statistic	33.554	

Probability (F statistic)	0.000

The estimated of the impacts of climate change are shown in Table 6. A positive coefficient of 4.539 and a value of probability equal to 0.036 were obtained by using the agricultural machinery exploited for cereal production as a dependent variable. The provided findings prove the existence of positive association between agricultural machinery and the amount of the produced cereal. Moreover, Table 4 shows that a rise by 1 % in the agricultural machinery will lead to a 4.539% increase in cereal production. It is also clear that agricultural machinery has a vital role in enhancing cereal output in Algeria. Additionally, the coefficient of rainfall equal to (1.832)-reveals that a 1% increase in rainfall rises cereal output by 1.823%. This result confirms that obtained by Kumar, P., et al (2021). Furthermore, area land under cereal production showed a significant and positive effect at 1% with a coefficient of (0.798). This conclusion is supported by earlier empirical findings of Chandio, A.A. and al., (2019) and Pickson, R. B., et al., (2020). Furthermore, the present empirical analysis proved a short-terms interaction among the study variables.

Table 5: Johansen cointegration tests

H-No. Of CE(s)	E-value	T. statistic	C. value	P-value
None *	0.745	118.011	103.847	0.004
At most 1 *	0.652	79.741	76.972	0.030
At most 2	0.559	50.143	54.079	0.107
At most 3	0.452	27.182	35.192	0.279
At most 4	0.202	10.301	20.261	0.610
At most 5	0.131	3.962	9.164	0.417
Max-Eigen statistic				
Statistics	0.745	38.270	40.956	0.097
At most 1	0.652	29.598	34.805	0.183
At most 2	0.559	22.960	28.588	0.221
At most 3	0.452	16.880	22.299	0.240
At most 4	0.202	6.339	15.892	0.749
At most 5	0.131	3.962	9.164	0.417

The coefficients of agricultural machinery, labor force and land area under cereal cultivation are equal to 4.485, 1.157 and 1.064 respectively, showing a favorable interaction in the short run with cereal production. The coefficient value of area under cereal production demonstrates a significant and positive influence of climate change on cereals productivity in the short run. In fact, an increase of 1 % in land area leads to a rise of 1.064 % in cereal production. This result was corroborated by Ahmed and Schmitz's (2011); Lobell et al., (2011). Therefore, the estimated findings presented in Table 6 show that the temperature coefficient in short run is equal to (8.186), revealing the positive and significant relation between grain output and temperature. They also demonstrate that a 1% increase in temperature may lead to an 8.186% rise of cereal production. The result is significant at 1% level, which highlights that cereal production and temperature are correlated in Algeria. These findings are consistent with those provided by the analytical study performed by Brown, M. E., Funk, C. C., (2008), Loum, A., and Fogarassy, C. (2015), Praveen and Sharma (2019b).

Table 6: Long- and short-terms outcomes tests

Variables	Coefficient	Std. Error	T. Statistic	Prob
Long-term estimates				
LNK	4.593 **	1.993	2.303	0.036
LNL	0.474	0.511	0.926	0.368
LNTEMP	-1.086	5.415	-0.200	0.843
LNRAIN	1.832 ***	0.585	3.127	0.006
LNLCP	0.798 ***	0.264	3.022	0.008
C	-44.926 **	20.291	-2.214	0.042
Short-run dynamics				
D(LNK)	4.485 **	1.883	2.380	0.031
D (LNK (-1))	3.699 **	1.407	2.629	0.019
D(LNL)	1.157 *	0.573	2.017	0.061
D(LNTEMP)	8.186 ***	2.455	3.334	0.004
D(LNRAIN)	0.222	0.146	1.524	0.148
D(LNLCP)	1.064 ***	0.063	16.742	0.000
CointEq (-1) *	-0.733 ***	0.102	-7.167	0.000
R^2	97.76			
Adj. R^2	96.97			
F-stat	124.789 ***			
Prob. (F-stat)	0.000			
Notes: *** and * show 1% and 10% level of significance, respectively				

As far as the coefficient of labor force is concerned, it is positive and statistically significant at the 10% level, showing that the labor force increases crop yield. This observation means that the augmentation of the labor force by 1%, the cereal production increase by 1.157. Such findings are consistent with provided by the analysis performed by Gul, A., et al., (2022). The climate variable (rainfall) coefficient equal to 0.222 deflects a non-significant negative interaction with cereal production. As a result, we may conclude that there are amounts interaction between the variables. The ARDL approach and error correction model (ECM) can be utilized Pesaran et al., (2001), Keele et Deboef (2008). The outcomes of error correction term are negative and significant impact at 1% (-0.733; 0.000), showing that there is long-run connection from agricultural machinery, labor force, warmth,-and precipitation on cereal. The results of the Granger causality are presented in Table 7. They suggest that there is unidirectional causality between cereal production, climate factors (rainfall and temperature)-and non-climate factors (agricultural machinery, labor force and land area under cereal production). The error correction term of the ECM also reveals long-run effects of adjustment to stability, Granger (1986), Engle and Granger (1987), when cereal production is the regression factor, ECT’s 73.36%, it will return to equilibrium rapidly.

Table 7: Granger causality test results

Estimations	Δ LnCp	Δ LnK	Δ LnL	Δ LnTemp	Δ LnRain	Δ LnLCP
Δ LnCp	--	0.419	0.834	0.589	1.344	1.030
Δ LnK	5.605 *	--	4.175 **	0.565	0.572	2.650 *
Δ LnL	4.416 **	2.629 *	--	0.245	0.249	3.495 **
Δ LnTemp	3.782 **	4.202 **	0.686	--	0.473	2.125
Δ LnRain	3.573 **	0.410	0.412	0.502	--	1.273
Δ LnLCP	2.127	1.151	0.387	0.087	1.445	--

Notes: ** and * show 1% and 10% level of significance, respectively

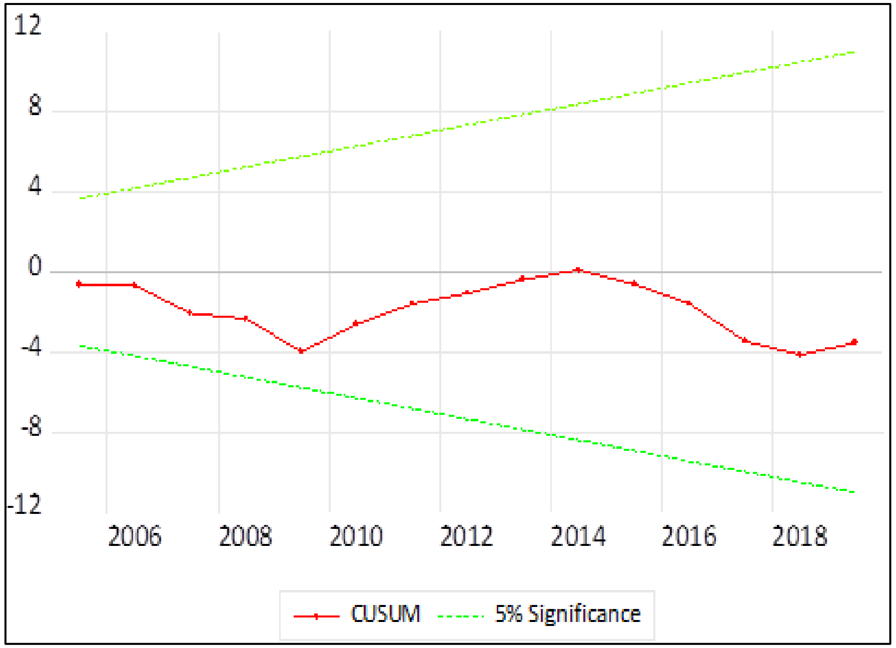
3.2 Residuals and stability tests results

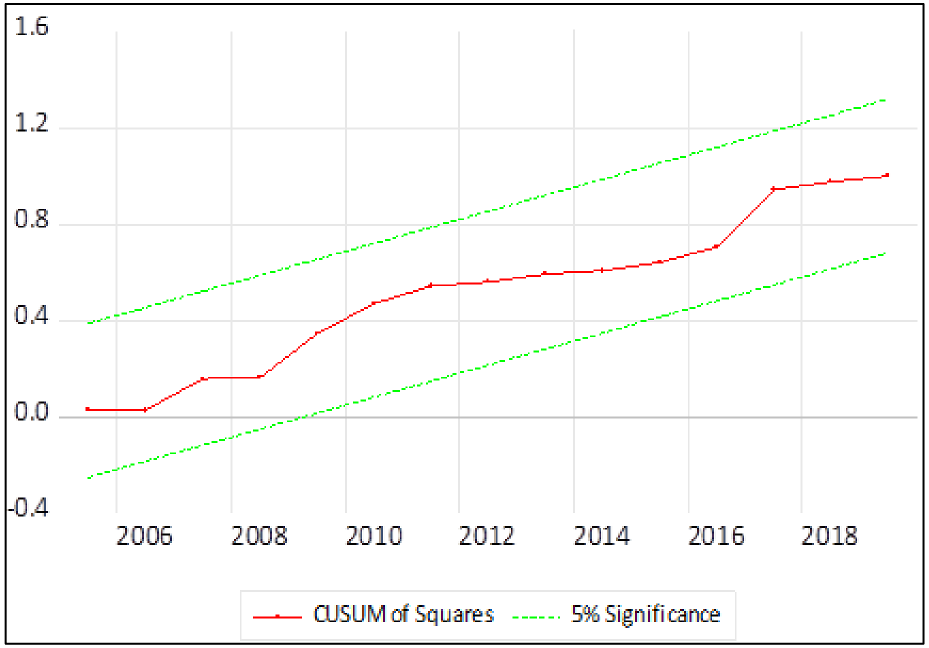
The residual diagnostic test results provided by applying the ARDL model test are shown in Table 8. The Breusch-Pagan-Godfrey heteroskedasticity test suggests that climate and non-climate variables are quantified as explanatory variable, i.e., there are no serial association between the variables and the residuals are normally distributed. Moreover, the CUSUM and CUSUM squares presented in Figure 1 bellow show that the graph lies within the 5% indicating that the model employed in this paper is stable.

Table 8: Residual Diagnostic test results

Diagnostic tests	F-statistics	Probability
Jarque-Berra	0.424	0.808
χ^2 RESET	0.910	0.377
χ^2 SERIAL	0.376	0.828
χ^2 ARCH	1.817	0.177
CUSUM	Stable	
CUSUMSQ	Stable	

Figure 1: CUSUM and CUSUM squares test for stability





4. Conclusion and policy implications

Global warming has recently become a danger that threatens the whole planet and has resulted in several climate changes. The latter affect considerably the developing countries, such as Algeria which is the case study of the present work. This country suffers from bad environmental factors (e.g., temperature rise and rainfall decline) which deteriorated the agricultural production. Given the importance of agriculture in the country's economy and the rural livelihood, climate change adaption appears critical. In this research work, the impact of climate change on grain output was also examined using annual time series data collected from 1990 to 2019. The obtained results reveal that meteorological factors, such as precipitation, temperature, farm machinery, labor-and land area affected crop yields, affect considerably the agricultural production. From the provided results, we may conclude that there is unidirectional relationship between grain production, climatic factors (rainfall and temperature), and non-climatic variables (farm machinery, labor and land area devoted to grain production). In the short term, there is a crucial positive interaction between grain production and temperature. The obtained statistical findings demonstrate that a 1% increase in temperature resulted in an 8.19% rise in grain yield. It was also show that rainfall is an important factor to cereal production. In fact, with an augmentation of 1.823% in cereal crops output, the precipitation rose by 1 %. In the short term, agricultural machinery, labor, and cultivable land will influence positively the Algerian cereal output. Indeed, agricultural machinery enhanced the cereals production by 4.54% during the study period. It was also proven that the increase of the labor force by 1% improved the grain production by 1.18%. As far as the area land under cereal production it affected positively cereal production. In the short run, a 1% rise in land area corresponds to an increase of 1.06 % rise in cereal output. This variable has a long-term favorable influence on productivity. Thus, stakeholders are invited to find solutions to cope with the increasing average temperature to reduce its effect on grain production. In this context, climate mitigation (more precisely greenhouse gas mitigation) is an efficient solution. In addition, stakeholders should encourage the owners of agricultural land, especially on a small scale, to produce cereals. The most important step that must be taken is to introduce a national policy of agricultural support and training of farmers. Second, it would be better to support producers and of provide insurance service for ~~of~~ the agricultural income. Finally, the agricultural activities and commercial exchanges should be regulated and managed adequately.

DECLARATIONS:

Conflict of interest: The authors declare no competing interests.

Consent to participate: Not applicable

Consent to publish: Not applicable

Ethical approval: Not applicable

Data availability: The data will be available on request.

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