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THE CONTRIBUTION OF ROMANIAN AGRICULTURE TO GLOBAL WARMING AND THE IMPACT OF CLIMATE CHANGE ON VEGETABLE CROPS

Mariana Sandu[1], Amalia Gianina Strateanu[1], Lavinia Udrea[2]
[1]Romanian Academy, Center for Studies and Researchers of Agroforestry Biodiversity, Calea 13 Septembrie, no. 13, 5th district, Bucharest, Romania
E-mail: marianasandu47@gmail.com, strateanuamalia.research@gmail.com
[2]Valahia University of Targoviste, 13, Sinaia Alley, Targoviste, Romania
E-mail: lavinia.udrea@valahia.ro

Abstract

Climate change represents the most serious threat to the environment, with negative effects on agricultural productivity, both in the vegetable and livestock sectors.
The article proposes an analysis of the agricultural sector in Romania from the perspective of the contribution to global warming and the impact of climate change on the plant sector. Data from the National Institute of Statistics, the Ministry of Agriculture and Rural Development, the National Meteorological Agency, the European Union and the European Environment Agency were used for the analysis. The analyzed data show that Romania's agriculture is not intensive in terms of greenhouse gas emissions, the type of emissions being related to the way of soil management within the agricultural holdings, the number of animals in the holdings and the use of biomass in agricultural practices.
Given that Romania's agriculture is dependent on climatic conditions, food security and the well-being of the population largely depends on how farmers, especially those with subsistence farms, will adapt to climate change. Reducing the risks and effects of global warming requires an integrated strategy that includes climate change adaptation measures, complemented by climate change mitigation measures.

Keywords: climate change, emissions, risks, agricultural holdings, food security

1. INTRODUCTION

Globally, climate change is the most serious environmental challenge with economic and social implications. In 1992, at the United Nations Framework Convention on Climate Change it has been established that climate change is attributed, directly or indirectly, to human activity that alters the composition of the atmosphere, generating direct effects on the Earth's temperature.
The IPCC report on climate change and land (IPCC, 2021 [7]), highlights that, during the period 1850-2015, there was an increase in the global average temperature of the air at ground level (+1,53^0 C) greater than the increase in the average temperature of the land surface (+0.87^0 C). The increase in global temperature has led to changes in climatic zones, namely an increase in areas where the dry climate predominates and a decrease in areas with a polar climate, with a direct effect on the structure, composition and functioning of terrestrial ecosystems.
On the other hand, global warming has increased the frequency and intensity of extreme weather and climate phenomena. Recent events show an increase in the frequency, intensity and duration of heat waves and droughts, with direct impacts on ecosystems and food security.
The concentrations of greenhouse gases (GHG) generated by ecosystem and anthropogenic processes are responsible for these global climate changes, emissions that have continuously increased in the last 60 years. If we refer to the net anthropogenic emissions generated by agriculture, forestry and land use in the period 2007-2016, they represented approximately 23% of global anthropogenic GHG emissions (Tubiello, F.N., 2019 [7]). It should be noted that most of the processes of the agro-food system lead to the production of GHG and other indirect emissions (aerosols), the exceptions being some agricultural practices (such as certain agroforestry systems) that can have a net carbon sequestration effect, especially if they are used for the rehabilitation of degraded lands.
Globally, GHG emissions from the food system (from production to consumption, including processing, transport and packaging) vary significantly between different activities in the food chain (Tubiello et al., 2021 [5]) estimated the total GHG emissions generated by food systems, in 2018, at approximately 16,059 million tons of carbon dioxide equivalent (Mt CO_2eq), an increase of 71% compared to 1990. The data presented by the author show an increase of approximately 35% of GHG emissions generated in the pre- and post-production phases, an increase that can be attributed to the increase in production due to consumption requirements.
Agriculture is one of the sectors of the economy strongly affected by climate change, but at the same time, agriculture contributes directly and indirectly to GHG emissions, through significant emissions of carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (N_2O). In IPCC reports, anthropogenic GHG emissions (estimated at 21% of total global emissions) are attributed to agriculture, forestry and land use and are caused by deforestation, crop production, animal production and nutrient management (IPCC, 2021 [7]).
Due to its dependence on climatic conditions, agriculture is the most exposed to climate change. Climate change affects the agricultural sectors in different ways that vary

by region and the frequency and intensity of weather-related events.
Subsistence agriculture is the most affected by climate change due to its low adaptive capacity, which leads to an increase in the risk of famine. (FAO, 2020 [8])
Regarding the impact of climate change on agriculture, most studies highlight the negative effects related to the quantitative aspect and the geographical distribution of agricultural production (Porter et al., 2014 [2]). Variability of production, changes in the seasonal structure of production, possible increased costs for farmers, are consequences of climate change that have negative effects on consumers (Smith et al., 2013 [3], Tirado MC. et al., 2010 [4]).
Estimates of changes in crop yields due to climate change throughout the 21st century provide evidence that crop yields are expected to decline precisely in food insecure areas (IPCC, 2021 [7]).
On the other hand, climate change affects the livestock sector both directly and indirectly, their effects can be grouped into: effects on animal health; on reproductive performance; on production performance (milk, meat, eggs); on animal production systems (Nardone et. al, 2010 [1]).
At the same time, agricultural sectors have a great potential for mitigation and adaptation to climate change, namely the possibility of reducing GHG emissions and adjusting natural or human systems in response to climate change.

2. MATERIALS AND METHODS

The paper analyzes the data related to greenhouse gas (GHG) emissions from Romanian agriculture and those related to the results obtained in the vegetable sector.
The aim of the paper is to provide a picture of how agriculture contributes to global warming and the impact of climate change on the plant sector.
The evolution of ecological agriculture as a method of agricultural production with a limited impact on the environment is also analyzed.
In this sense, a series of scientific papers with relevant results in the field of climate change and special reports on global climate change developed by international bodies, namely the Intergovernmental Panel on Climate Change of the United Nations and the Food and Agriculture Organization of United Nations.
The analysis carried out is based on data from the National Institute of Statistics, the Ministry of Agriculture and Rural Development, the National Meteorological Agency, the European Union and the European Environment Agency which have been systematized, processed and presented in the paper in synthetic form.
In order to highlight the evolution of the studied indicators (GHG emissions, animal density, chemical and natural fertilizers used, cultivated areas, productions obtained) the data are illustrated in graphs and extensively interpreted in the paper.
The analysis ends with the conclusions that underline some aspects related to the topic addressed.

3. RESULTS AND DISCUSSIONS

3.1. Climate changes in Romania

Romania has a temperate-continental climate with oceanic influences in the western part, Mediterranean in the southwest and continental in the northeastern part of the country.
According to the data of the National Meteorological Agency (NMA 2020 [9]), from a meteorological point of view the average annual temperature at the level of the country registered an increase compared to the climatological norm of the period 1981 – 2010 (Table 1). Thus, in a top of the warmest years from the period 1961-2020, 2019 and 2020 are at the top with average annual temperatures of 11.0^0 C and 10.8^0 C, increases of 1.9ºC and 1.7ºC respectively compared to the climatological normal of the period 1981-2010.

Table 1. Top of the warmest years in Romania, for the period 1961-2020

Year	Average annual temperature (^{0}C)	Deviation from the climatological norm (1981 – 2010) (^{0}C)
2019	11,0	1,9
2020	10,8	1,7
2015	10,6	1,5
2007, 2018	10,5	1,4
2014	10,4	1,2
1994, 2009	10,2	1,1
2000, 2008, 2012, 2013, 2016	10,1	1,0
2002, 2017	10,0	0,9
1990, 1999	9,7	0,5
1966, 2010	9,6	0,5

Source: **NMA – Annual Report 2020 (based on data from 129 weather stations)** [9]

Regarding precipitation, compared to the median of the standard reference interval (1981-2010), the annual amount of precipitation in 2020 was 45% lower in the south, east and west of the country, in most areas the rainfall regime was deficient and very deficient (NMA – Annual Report 2020 [9]).
In the first months of 2020, most of Romania's territory was affected by the lack of precipitation (between 20% and 99%), with strong pedological drought recorded in the area of Muntenia and Dobrogea. NMA speaks of 2020 as the driest agricultural year in history, given that the pedological drought affected different regions of the country with different degrees of intensity (moderate, strong and extreme) for both the autumn wheat and corn crops unirrigated. Regarding changes in the climatic patterns in Romania, the forecasts indicate, for the next 50-100 years, a significant change in the temperate-continental climate of the country, respectively a progressive increase in the average annual air temperature, mainly in the summer seasons and winter, growth similar to that anticipated for Europe.

Regarding the level of precipitation, the total amount of precipitation varies greatly between the northern and southern parts of the country.
On the other hand, the scenarios indicate a continued reduction in annual precipitation by 10-20% by the end of the century. It is also expected that the rainfall pattern will change, becoming more difficult to forecast due to the higher frequency of short, intense and localized rains (NMA, 2020 [9]).
Regarding the level of precipitation, for the period 2090-2099, over 90% of the climate models forecast pronounced droughts during the summer, especially in the South and South-East of Romania. For the winter precipitation level, the deviations from the recorded levels are smaller.

3.2. The contribution of Romanian agriculture to climate change

According to the data of the National Institute of Statistics (NIS), the total volume of GHG emissions from Romania in 2019 was 96,839 thousand tons CO_2 equivalent, 26% lower compared to the total volume in 2008 of 130,913 thousand tons CO_2 equivalent.
From the NIS data, for the period 2008-2019, we note that the most important reductions in total GHG emissions were recorded by the manufacturing industry (-29%) and the energy production and supply industry (- 46.9%) due to the removal from the production of some intensively polluting units (Table 2).
If we analyze the data for the year 2019, regarding GHG emissions at an intersectoral level, the largest contribution is made by the processing industry with 24,798 thousand tons of CO_2eq, respectively 25.60% of the total GHG emissions.
The production and supply of energy contributes with 22,395 thousand tons of CO_2eq (23.12%), emissions from agriculture, forestry and fishing with 20,838 thousand tons of CO_2eq (21.52%), the extractive industry with 24,798 thousand tons of CO_2eq (5.90%) while waste management contributes approximately 6.87% to the total GHG emissions, respectively 6,945 thousand tons of CO_2eq (table 2).
Regarding the evolution of the total volume of GHGs from Romanian agriculture, in the period 2008-2019, GHG emissions registered a slight decrease of approximately 1%, a decrease that can be attributed to the transformations that took place in agriculture during this period.
GHG emissions from agriculture arise from the use of agricultural practices that, in the end, can lead to the mineralization of organic carbon in the soil and its emission in the form of CO_2 into the atmosphere.
Here we mainly refer to the emission of methane (CH_4), nitrogen oxide (N_2O) and carbon dioxide (CO_2).

Table 2. GHG emissions from Romania, by economic sector (thousand tons of CO_2eq)

	2008	2019	Variation 2019/2008
TOTAL emissions of which:	130,913	96,839	-26%
Agriculture, forestry and fisheries	21,011	20,838	-0.9%
Extractive industry	9,171	5,723	-37,6%
Manufacturing industry	34,921	24,798	-29%
Energy production and supply	42,137	22,395	-46.9%
Water distribution and waste management	6,915	6,945	+0.4%
Construction	4,617	3,644	-21.1%
Trade	1,568	1,673	+6.7%
Transport and storage	6,915	6,753	-2.3%
Other economic activities	3,658	4,070	+11,3%

Source: **NIS – Tempo online**

Figure 1 shows the evolution of total GHG emissions from Romanian agriculture, respectively the sum of emissions from enteric fermentation of ruminants, manure management, rice cultivation, land exploitation, land use change and forestry, cultivated land and pastures.
According to European Environment Agency (EEA) data, in the period 1990-2019, total GHG emissions from Romanian agriculture decreased by over 63%, from a total of 32,421 thousand tons of CO_2eq in 1990 to a total of 11,955 thousand tons of CO_2eq in 2019, a decrease that can be attributed to the changes that took place in agriculture, both in the plant and livestock sectors.

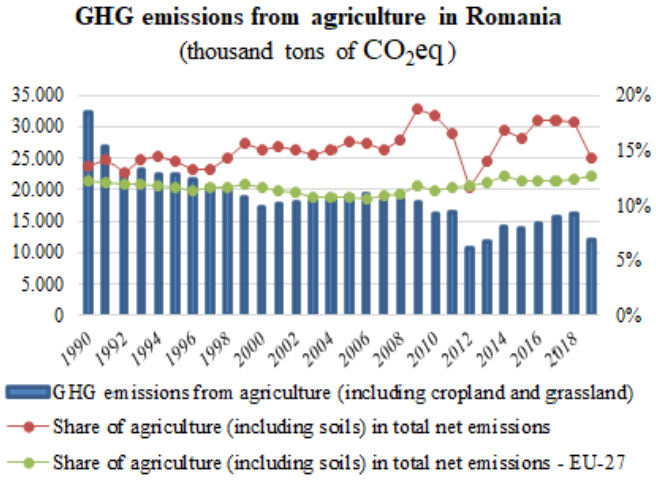


Figure 1. Evolution of GHG emissions from Romanian agriculture, in the period 1990-2019
***Source*: EEA**

The most significant decrease in total GHG emissions was recorded in the period 1990-2010, when total GHG emissions were halved. In the period 2010-2019, total GHG emissions decreased by approximately 26%, from 16,172 thousand tons of CO2 eq in 2010 to a total of 11,955 thousand tons of CO2 eq in 2019.
The total emissions generated by agriculture in Romania, in 2019, represented approximately 13% of the total GHG emissions in the European Union.
Agriculture is one of the important emitters of ammonia (NH_3) through emissions from animal husbandry and the use of inorganic nitrogen fertilizers.
If we analyze the evolution of NH_3 emissions from Romanian agriculture in the period 1990-2019 (Figure 2), from the EEA data we find that total emissions decreased during the analyzed period by 53.4%, from a total of 341 thousand tons of NH_3 in 1990 to 159 thousand tons of NH_3 in 2019. This decrease in total NH_3 emissions can be attributed to the decrease in total livestock numbers and the total amount of chemical fertilizers used in agriculture.

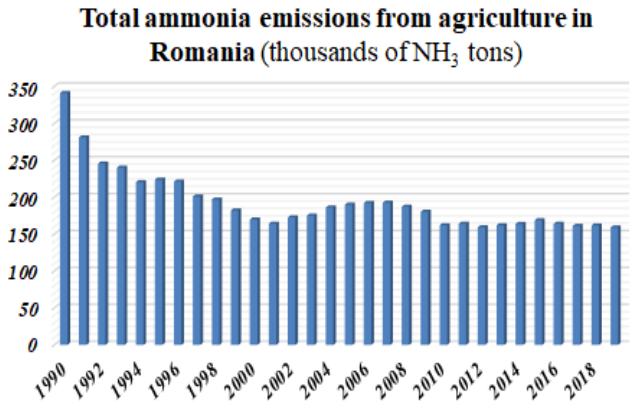


Figure 2. Evolution of total ammonia emissions from Romanian agriculture, in the period 1990-2018
Source: **EEA**

Livestock contribute to climate change through GHG emissions from manure production. The decrease in the total number of animals in Romania is also reflected in terms of the density of animals on the used agricultural surface, an indicator that shows the pressure of animal breeding on the environment.
From the NIS data, regarding the evolution of the number and density of livestock units in Romania, we note that the density of animals decreased from 0.5 LSU per ha of agricultural area used in 2005 to 0.4 LSU per ha of agricultural area used in 2016, given that the number of animal husbandry units decreased by 27% in the period 2005-2016 (from 6,602,750 LSU in 2005 to 4,828,780 LSU in 2016 (Figure 3).
A higher density of animals per hectare of used agricultural area translates into a higher amount of manure available per ha. In fact, the impact of animal husbandry on the environment depends not only on the number and density of animals per hectare of agricultural area used, but also on the agricultural technologies used.

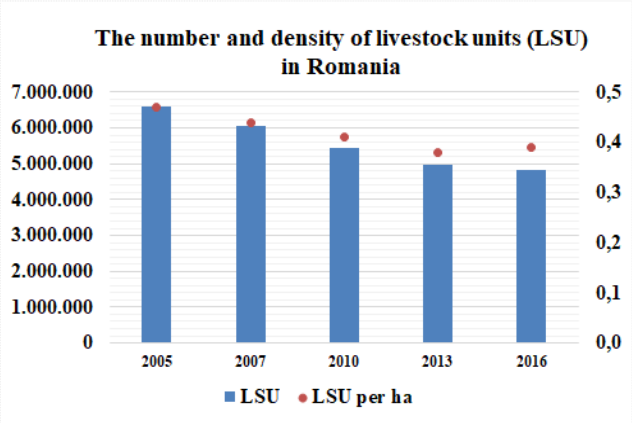


Figure 3. Evolution of the number and density of animals in Romania*
* reference unit = 1LSU (grazing equivalent of an adult dairy cow producing 3000 l of milk / year)
Source: **Eurostat**

If we analyze the NIS data on the use of the total amounts of chemical and natural fertilizers used in agriculture, in the period 1990-2021 (Figure 4), we observe a decrease in the total amount of chemical fertilizers by 16.4% (nitrogen-based fertilizers -17.4 %, those based on phosphorus -15.1% and those based on potassium -11.7%) and a decrease in the total amount of natural fertilizers by 32.5%.

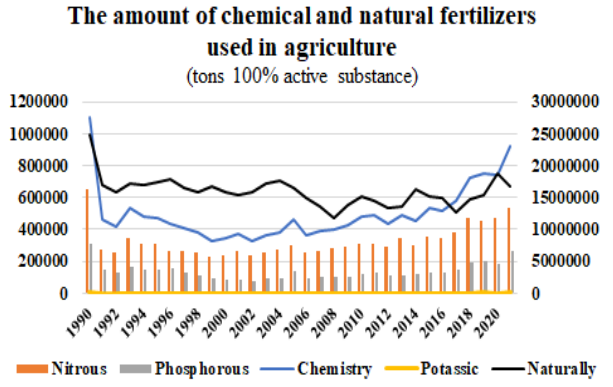


Figure 4. Evolution of the total amount of chemical and natural fertilizers used in agriculture in Romania, in the period 1990-2021
Source: **NIS – Tempo Online**

3.3 The impact of drought on the vegetable sector

The consequences of climate change on agriculture in Romania are visible and are associated with long periods of drought that affect vegetable crops.
Table 3 shows the evolution of the cultivated areas and the productions obtained in some of them during the period 2015-2021.
From the data presented in the table, it can be seen that in 2020 (the year in which there was a strong pedological drought) the productions obtained were lower.
From the NIS data regarding the results obtained in the vegetable sector, it can be observed that the extreme pedological drought of 2020 affected large areas of land

with an impact on the total production obtained in all categories of cereals and oleaginous plants.
Thus, in 2020 compared to 2019, the total cultivated area was slightly lower (2.34 million ha in 2020 compared to 5.56 million ha in 2019) and the total grain production obtained was 44% lower (approximately 17 million tons in 2020 compared to 30.41 million tons in 2019). In the cultivation of oleaginous plants (sunflower, rapeseed and soybean), the total production decreased by 42% (2.78 million tons in 2020 compared to 4.8 million tons in 2019) against the background of the decrease of the total cultivated area by 4.45% (1.72 million ha in 2020 compared to 1.8 million ha in 2019) and the decrease in yield per hectare by 60% (2662 kg/ha in 2019 and only 1065 kg/ha in 2020).

Table 3. Evolution of areas and productions of some vegetable crops in the period 2015-2021

		2015	2016	2017	2018	2019	2020	2021
Cereals	thousand ha	5468	5487	5192	5257	5569	5338	5352
	thousand tons	19333	21765	27139	31553	30412	18154	27791
Maize	thousand ha	2605	2581	2402	2440	2679	2678	2549
	thousand tons	9021	10746	14326	18664	17432	10097	14827
Sunflower	thousand ha	1012	1040	998	1007	1283	1143	1124
	thousand tons	1786	2032	2913	3063	3569	2123	2844
Rape	thousand ha	368	456	598	633	353	363	446
	thousand tons	919	1293	1673	1611	798	780	1375

Source: **NIS-Tempo Online**

The vegetable sector was strongly affected by the drought in 2022 as well. Thus, according to the data of the Ministry of Agriculture and Rural Development (MARD), regarding the evaluation of the effects of the drought, until 01.10.2022 the pedological drought affected vegetable crops in 34 counties of the country.
The total area affected was 413,145 hectares, of which: 206,794 hectares cultivated with wheat and triticale, 74,973 hectares with corn, 37,539 hectares with sunflowers, 33,250 hectares with barley, sorghum, oats, rye, 31,714 hectares with rapeseed, 8,987 hectares with other crops, 7,652 hectares with fodder plants, 5,213 hectares with soybeans and 870 hectares with peas.

3.4. Ecological agriculture in Romania

Organic farming is known as the method of agricultural production with a limited impact on the environment.
Organic agriculture in Romania has seen an upward evolution encouraged both by the behavior of consumers towards healthy products and by the advantages regarding subsidies and the sale price (higher than those of conventional agriculture).
In Romania, the agricultural area used in the ecological system increased year by year, reaching 471,928 hectares in 2020, which represents only 3% of the total agricultural area of the country, almost three times lower than the European average of 9% of the agricultural area used (Figure 5).

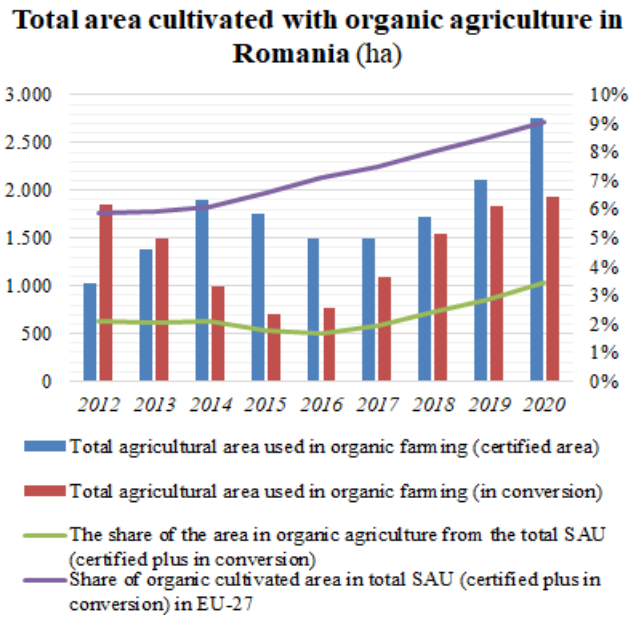


Figure 5. Evolution of the area with ecological agriculture in Romania
Source: **Eurostat**

Regarding the evolution of the number of economic operators registered in organic agriculture in Romania (producers, traders, processors), according to MARD data, in the period 2010-2021 the number of economic operators increased approximately four times, from 3,155 economic operators in 2010 to 12,231 in 2021.
If we analyze the MARD data regarding the evolution of the total area registered in organic agriculture in Romania, we notice that in the period 2010-2021 the total area registered increased from 182.7 thousand ha in 2010 to 580.8 thousand ha in 2021.
On the other hand, the data on the evolution of ecologically certified animal flocks show that in the period 2010-2021 the number of ecologically certified animals registered significant increases in certain species of animals. Thus, in the cattle species, the total number of certified animals increased from 5,358 in 2010 to 23,339 in 2021, with dairy cows representing approximately 64% of all certified cattle in 2021. Similar increases were recorded in the total number of organically certified laying hens which reached 186,699 heads in 2021 compared to 21,580 heads in 2010.
In the other animal species, the number of ecologically certified animals decreased in the period 2010-2021. Thus, the total number of ecologically certified sheep decreased by 26.7%, that of goats by 1.2% and that of horses by over 80%. The pig species is almost non-existent in terms of the number of organically certified animals, the whole sector being affected by African swine fever, instead significant increases have been recorded in the number of organically certified bee families.

4. CONCLUSIONS

Romania's agriculture is not intensive in terms of GHG emissions, the type of emissions being related to the way of soil management within the agricultural holdings, the number of animals in the holdings and the use of biomass in agricultural practices.

As a whole, the agricultural sector is extremely vulnerable to the impact of climate change and the risk is not distributed equally across the country. There are regional differences in terms of drought, torrential rains but also the vulnerabilities, resilience and adaptability of rural communities to climate change.

Given that agriculture in Romania is dependent on climatic conditions, food security and the well-being of the population largely depend on how farmers, especially those with subsistence farms, will adapt to climate change.

The impact of climate change on the productivity of agricultural sectors has negative effects from an economic and social point of view and leads to reduced incomes both at the household and country level, with implications for food security.

In order to reduce the effects of global warming, adaptation measures complemented by climate change mitigation measures are needed.

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