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APPLICATION OF BIG DATA TECHNOLOGIES TO ASSESS THE NATURAL MOISTURE OF THE TERRITORY

A.I. Pavlova

Due to the sharp changes in climatic conditions in Western Siberia, the most pressing problem is food security associated with forecasting crop yields. There is a need to estimate the natural wetness of the area on the basis of agroclimatic indicators, among which the sum of active air temperatures and precipitation is currently the most widely used.

Background. *However, for a comprehensive assessment of the wetness of the territory, it is necessary to take into account the climate energy resources associated with evaporation of different time resolutions (day, decades, months, vegetation period, year). The initial meteorological parameters are described in the form of poorly structured information of a large volume. Therefore, various technologies and algorithms of machine processing are used in the work.*

Purpose. *The application of big data technologies to assess the natural moisture of the territory*

Materials and methods. *With the help of the high-level Python programming language and engineering libraries, a comprehensive assessment of the territory was carried out using the example of Mirny of the Kochenevsky District of the Novosibirsk Region in the context of long-term average data and two years 2019 and 2020. That the use of machine processing technologies related to NoSQL data requests, creation of data set and big data slices allows to store and process meteorological parameters using cloud services of different time resolution. This makes it possible to significantly reduce the time for a comprehensive assessment of the territory according to agroclimatic parameters. As a result of the work, precipitation distribution, temperature, relative air humidity, evaporability, humidification coefficients (Ivanov-Vysotsky and Selyaninov hydrothermal coefficient) were obtained.*

Results. *The paper proposes to use technologies of big data processing using Python, including pre-processing of poorly structured hydrometeorological data,* *execution of NoSQL queries, compilation of summary reports on agroclimatic parameters. Pre-processing consists of processing hourly meteorological data, filling gaps in the data, making slices in big data to process multi-temporal queries (day, month, growing season, year). By the example of Mirny farm in Kochenevsky district of Novosibirsk region (Russian Federation), big data processing was performed to calculate agroclimatic parameters to assess the natural moisture content of the area and yield forecasting.*

Conclusion. *The practical significance of the work is as follows:*

- *the application of big data processing technologies has significantly reduced the time for the labor-intensive process of assessing agrometeorological parameters;*
- *obtained aggregated meteorological parameters of different temporal resolution (hours, days, decades, months) allowed us to identify a strong variability of agroclimatic conditions for the territory of Mirny farm Kochenevsky district, located in the forest-steppe zone of Western Siberia;*
- *perform an integral assessment of agroclimatic conditions by calculating the integral indices of moisture, climate continentality, and agroclimatic potential.*

Keywords: *climatic conditions; moisturizing; machine learning algorithms; machine learning model; forest-steppe zone; yield forecasting; moisture supply of the territory*

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Научная статья | Водный режим почвы

ПРИМЕНЕНИЕ ТЕХНОЛОГИЙ БОЛЬШИХ ДАННЫХ ДЛЯ ОЦЕНКИ ЕСТЕСТВЕННОЙ ВЛАЖНОСТИ ТЕРРИТОРИИ

А.И. Павлова

В связи с резким изменением климатических условий в Западной Сибири наиболее актуальной проблемой является продовольственная безопасность, связанная с прогнозированием урожайности сельскохозяйственных культур. Возникает необходимость оценки естественной увлажненности территории *на основе агроклиматических показателей, среди которых в настоящее время наиболее широко используется сумма активных температур воздуха и осадков.*

Обоснование. *Однако для комплексной оценки увлажненности территории необходимо учитывать климатические энергетические ресурсы, связанные с испарением различного временного разрешения (сутки, декады, месяцы, вегетационный период, год). Исходные метеорологические параметры описываются в виде плохо структурированной информации большого объема. Поэтому в работе используются различные технологии и алгоритмы машинной обработки.*

Цель работы. *Применение технологий больших данных для оценки естественного увлажнения территории.*

Материалы и методы. *С помощью языка программирования высокого уровня Python и инженерных библиотек была проведена комплексная оценка территории на примере г. Мирный Коченевского района Новосибирской области в разрезе средних многолетних данных и двух лет 2019 и 2020 гг. Что использование технологий машинной обработки запросов к данным NoSQL, создание набора данных и срезов больших данных позволяет хранить и обрабатывать метеорологические параметры с использованием облачных сервисов различного временного разрешения. Это дает возможность значительно сократить время на комплексную оценку территории по агроклиматическим параметрам. В результате работы получено распределение осадков, температура, относительная влажность воздуха, испаряемость, коэффициенты увлажнения (гидротермический коэффициент Иванова-Высоцкого и Селянинова).*

Результаты. *В работе предлагается использовать технологии обработки больших данных с использованием Python, включая предобработку слабоструктурированных гидрометеорологических данных, выполнение NoSQL запросов, составление сводных отчетов по агроклиматическим параметрам. Предварительная обработка заключается в обработке почасовых метеорологических данных, заполнении пробелов в данных, создании срезов в больших данных для обработки разновременных запросов (день, месяц, вегетационный период, год). На примере хозяйства «Мирный» Коченевского района Новосибирской области (Российская Федерация) была проведена обработка больших данных для расчета агроклиматических параметров с целью оценки естественной влагообеспеченности территории и прогнозирования урожайности.*

Заключение. *Практическая значимость работы заключается в следующем:*

- *применение технологий обработки больших данных позволило значительно сократить время на трудоемкий процесс оценки агрометеорологических параметров;*

- *полученные агрегированные метеорологические параметры различного временного разрешения (часы, дни, декады, месяцы) позволили выявить сильную изменчивость агроклиматических условий для территории хутора Мирный Коченевского района, расположенного в лесостепной зоне Западной Сибири;*
- *провести интегральную оценку агроклиматических условий путем расчета интегральных индексов увлажнения, континентальности климата и агроклиматического потенциала.*

Ключевые слова: *климатические условия; увлажнение; алгоритмы машинного обучения; модель машинного обучения; лесостепная зона; прогнозирование урожайности; влагообеспечение территории*

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Introduction

Good spatial planning is essential to implementing ecological-landscape approaches. An adaptive-landscape farming systems are being developed for the rational use of agricultural land in Russia. The basic of such systems are the results of agro-ecological evaluation of land. It is necessary to perform a comprehensive assessment of the territory by climatic, geomorphological, soil, and economic conditions. The application of geographic information systems (GIS) allows us to systematize a variety of information in spatial databases. Climatic factors play the most important role in shaping crop productivity. Currently relevant research in the field of automated data analysis for assessing the state, monitoring agricultural land and crop productivity management [5, 11, 15]. Application of geoinformation technologies allows to systematize various information in cartographic and attributive databases, facilitates the solution of the problem of integrated assessment of the territory [7, 14, 17-20].

In the domestic literature there are often works devoted to the calculation of the average annual agrometeorological parameters. However, due to the sharp fluctuations of weather conditions, the calculation of agrometeorological parameters for individual periods of the growing season during the year is most relevant. In the domestic literature there are articles devoted to the problem of forming databases of meteorological parameters of different temporal resolution.

Scientific novelty of the work consists in the application of technologies for processing poorly structured meteorological data. The big data processing technologies used in the work are related to statistical analysis of the data, identification and filling in the missing values, taking into account the average value for the day, conversion of symbolic data into a numeric form, structuring the original information and recording it in a compact SQLite database. The novelty of the research is in the application of NoSQL queries to large meteorological data, allowing the formation of the result in the form of tables and summary reports with different time intervals [24-25]. This is of practical importance for calculating not only the average annual values, but also the actual agrometeorological parameters for individual periods of crop vegetation [2, 12, 13].

A large number of works devoted to the creation of spatial geodatabases (geodatabases) have been published. The practical implementation of such geodatabases is often associated with the geographic data set of the ArcGIS geographic information system. Geographic datasets, in turn, consist of spatial objects united by thematic content. The objects belonging to the same class are characterized by a certain geometric data type, coordinate system and map projection. From this point of view, the spatial database acts as a physical repository of diverse information [16].

In our opinion, the development of spatial databases for agricultural land assessment requires a multidimensional approach.

Such an approach can be realized by applying:

- modern Internet technologies, cloud technologies of data storage and access;
- technologies of big data processing;
- use of Geographic Information System (GIS) for spatial reference of objects and creation of information models.

Currently, there are challenges in developing a spatial data infrastructure for comprehensive agricultural land assessment.

Despite the various functionality of GIS, work on the creation of applied agronomic GIS is still relevant [21-23, 26]. In particular, agroclimatic assessment of territory resources and soil-ecological assessment is carried out on the basis of multi-year statistical hydrometeorological parameters [4, 6, 12, 13]. When predicting and managing the productivity of cereals, it is necessary to operate not only with the average long-term information of the heat and moisture supply of the growing period, but also with their change during the current year by decades, months, vegetation periods. In the conditions of the sharply continental climate of Western Siberia, uneven precipitation in certain periods of vegetation has a significant impact on the level of productivity of grain crops.

The purpose of the studies is to assess the wetness of the territory (Mirny in the Kochenevsky district of the Novosibirsk region) using Big Data technologies.

The tasks of the work are to select agroclimatic parameters for assessing the wetness of the territory; initial data collection and systematization; processing of current and archived meteorological data using big data technologies.

Data processing technologies based on data mining are becoming increasingly common. Among such methods regression, decision trees, deep neural networks, genetic algorithms are most widely used. Big data technologies are available to a wide range of people thanks to the Python language. The object-oriented programming language Python is characterized by the compactness of the program code and the presence of engineering libraries.

Materials and Methods

Agroclimatic indicators affecting plant growth and development, and, consequently, the value of yields, were used to estimate the moisture content of the area. The sum of active air temperatures above 10°C was used as an indicator of heat supply of the territory and biological needs of crops. This sum of average daily air temperatures determines the duration of the growing season of the leading crops. Precipitation, air humidity, evaporation, as well as coefficient by N.N. Ivanov (Ky) [4] and hydrothermal coefficient (HC) by G.T. Selyaninov [12] were used as indicators of humidity. To fully assess the energy resources of climate and agroclimatic conditions of crop cultivation, the climate continental coefficient (Cc) and agroclimatic potential (AP) were calculated [3, 6].

In determining evaporability, equations of water and heat balances are used, as well as empirical relationships of evaporability with air temperature and air humidity deficit. The humidification coefficient was determined by the formula of G. N. Vysotsky – N. N. Ivanov [4]:

$$K_y = R/E, \quad (1)$$

where R – rainfall, mm; E – evaporability, mm.

In the conducted studies, evaporability was calculated according to the formula of N.N. Ivanov, according to which monthly indicators of relative humidity and air temperature are taken into account:

$$E_м = 0{,}0018 \cdot (25 + T)^2 \cdot (100 - \alpha), \quad (2)$$

where $E_м$ – monthly evaporability in mm; T – average monthly air temperature in °C; α – average monthly relative air humidity as a percentage.

Evaporability per decade in mm was calculated using the formula of N.N. Ivanov:

$$E_д = 0{,}061 \cdot (25 + t)^2 \cdot (1 - 0{,}01\beta), \quad (3)$$

where $E_д$ – evaporability per decade in mm; t – average air temperature in ° C per decade; β - relative air humidity per decade,%.

The value of continental climate is influenced by the geographical features of the territory, as well as the air temperature of the warmest month and the coldest month. The climate continental coefficient (C_c) was calculated according to the formula [6]:

$$C_c = \frac{360(t_{\max} - t_{\min})}{\varphi + 10}, \quad (4)$$

where $t_{\max}$ – the average monthly temperature of the warmest month; $t_{\min}$ – the average monthly temperature of the coldest month; φ – the latitude, degrees.

For a generalized assessment, the agroclimatic potential is calculated

$$AP = \frac{\sum t > 10(K_y - P)}{C_c + 100}, \quad (5)$$

where – sum of active air temperatures above 10°C;

K_y – precipitation-evaporation ratio;

P – correction for humidification factor.

To assess the hydrothermal conditions of wheat cultivation, an integral humidification indicator was used in the work – a hydrothermal coefficient (HC) determined by the formula of G.T. Selyaninov in the form of a ratio of the sum of precipitation for a certain period multiplied by 10 to the sum of active air temperatures above 10°C for the same period:

$$HC = \frac{R \cdot 10}{\sum t > 10}, \quad (6)$$

where R – the amount of precipitation, mm; At the same time humidification excess for HC is more than 1.3; optimal with HC from 1 to 1.3; insufficient for HC less than 1; weak – HC less than 0.5 [12].

Results

In order to increase the efficiency of calculations of agroclimatic parameters, an information model has been developed. This model is necessary in the future for the practical implementation of agronomic geographic information systems.

For calculations, daily data of hydrometeorological parameters obtained at meteorological sensors of weather stations are used. Fig. 1 shows the initial data of the meteorological station Obskaya, located in the Novosibirsk region and having the number according to the generally accepted international system 29635.

Местное время	T	Po	P	U	DD	Ff	ff10	VV	Td	RRR	tR	sss
16.12.2020 19:00	-12.4	766.0	778.3	83	Ветер, дующий с юго-юго	5		4.0	-14.7	0.2	12	
16.12.2020 10:00	-15.6	766.9	779.3	90	Штиль, безветрие	0		10.0	-16.9			
16.12.2020 07:00	-14.4	766.2	778.5	89	Ветер, дующий с юго-зап	1		4.0	-15.9	1	12	28
16.12.2020 01:00	-12.7	764.5	776.7	89	Ветер, дующий с юго-зап	2		4.0	-14.1			
15.12.2020 22:00	-12.3	763.1	775.3	87	Ветер, дующий с юго-зап	2		4.0	-14.0			
15.12.2020 19:00	-11.9	762.1	774.3	88	Ветер, дующий с западо-	2		4.0	-13.5	0.3	12	
15.12.2020 16:00	-11.9	760.6	772.7	87	Ветер, дующий с юго-зап	3		4.0	-13.6			
15.12.2020 13:00	-9.6	759.3	771.2	91	Ветер, дующий с юго-зап	4		4.0	-10.8			
15.12.2020 10:00	-8.7	758.8	770.8	92	Ветер, дующий с юго-зап	3		10.0	-9.8			
15.12.2020 07:00	-9.5	758.6	770.5	86	Ветер, дующий с юго-зап	4		20.0	-11.4	1	12	24
15.12.2020 04:00	-10.1	758.5	770.5	85	Ветер, дующий с западо-	3		20.0	-12.2			
15.12.2020 01:00	-8.6	758.2	770.1	86	Ветер, дующий с юго-зап	4		20.0	-10.6			
14.12.2020 22:00	-8.4	758.8	770.6	93	Ветер, дующий с юго-юго	7	11	4.0	-9.3			
14.12.2020 19:00	-9.1	759.7	771.6	87	Ветер, дующий с юго-юго	8		20.0	-10.9	0.2	12	
14.12.2020 16:00	-11.9	761.2	773.3	88	Ветер, дующий с юго-юго	2		10.0	-13.5			
14.12.2020 13:00	-12.0	762.1	774.1	85	Ветер, дующий с юго-юго	5		20.0	-14.1			
14.12.2020 10:00	-11.9	762.3	774.4	85	Ветер, дующий с юго-юго	5		20.0	-13.9			
14.12.2020 07:00	-11.6	762.4	774.4	85	Ветер, дующий с юго-зап	3		10.0	-13.6	0.2	12	23
14.12.2020 04:00	-12.2	762.1	774.3	85	Ветер, дующий с юго-зап	2		20.0	-14.2			
14.12.2020 01:00	-12.5	762.0	774.1	85	Ветер, дующий с западо-	2		10.0	-14.5			
13.12.2020 22:00	-12.3	761.3	773.4	81	Ветер, дующий с юго-зап	2		20.0	-14.9			
13.12.2020 19:00	-11.6	760.9	773.0	79	Ветер, дующий с западо-	2		20.0	-14.5	0.4	12	
13.12.2020 16:00	-11.1	760.4	772.4	87	Ветер, дующий с юго-зап	2		4.0	-12.9			
13.12.2020 13:00	-11.8	760.8	772.9	82	Ветер, дующий с юго-юго	7		20.0	-14.3			
13.12.2020 10:00	-12.8	761.1	773.2	85	Ветер, дующий с юга	7		20.0	-14.8			
13.12.2020 07:00	-12.5	761.4	773.5	86	Ветер, дующий с юго-юго	7		10.0	-14.4	Следы ос	12	23
13.12.2020 04:00	-11.7	761.9	774.0	86	Ветер, дующий с юго-юго	5		10.0	-13.6			
13.12.2020 01:00	-10.6	762.3	774.3	87	Ветер, дующий с юго-юго	5		10.0	-12.4			
12.12.2020 22:00	-10.2	762.9	774.9	86	Ветер, дующий с юго-юго	5		20.0	-12.1			
12.12.2020 19:00	-9.8	763.1	775.1	86	Ветер, дующий с юго-юго	5		20.0	-11.8	0.3	12	
12.12.2020 16:00	-10.2	763.0	775.1	88	Ветер, дующий с юга	3		10.0	-11.9			
12.12.2020 13:00	-10.8	763.5	775.6	90	Ветер, дующий с юга	5		2.0	-12.2			
12.12.2020 10:00	-11.1	763.9	776.0	87	Ветер, дующий с юго-юго	7		10.0	-12.8			
12.12.2020 07:00	-11.2	763.9	776.0	90	Ветер, дующий с юга	5		4.0	-12.6	0.2	12	23
12.12.2020 04:00	-10.8	764.5	776.6	83	Ветер, дующий с юга	6		10.0	-13.1			

Fig. 1. Baseline meteorological data used to estimate humidification.
Source: *https://rp5.ru/*

Initial meteorological data are characterized by poor structuring, large volume, complexity of processing in a traditional way, for example, using mathematical calculations using Microsoft Excel. For example, in the absence of precipitation, various types of data are used: numerical (in the presence of precipitation), as well as symbolic (in the presence of traces of precipitation or their absence). In this regard, a program was developed in the Python programming language. Python language allows you to develop full-featured programs with a graphical interface, as well as perform data processing online using frameworks. In practice, various frameworks are used: Google Colab, PyTorch, Veles (Samsung), Apache Spark Mllib, Apache Mahout, Apache Singa, Caffe 2, Microsoft Azure ML Studio, Microsoft Congnitive Toolkit, Amazon Machine Learning, Brainstorm, Marvin, Neon.

This allowed us to analyze wetting conditions using the example of the Mirny land use located in Kochenevsky district of Novosibirsk region (81.9591°, 54.8962°, 82.2747° eastern longitude, 55.0092° north latitude, Russia). The study area belongs to the central forest-steppe Priobsky agro-landscape region. Geomorphologically, this area belongs to the high structural geomorphological relief surface [1,8,9,10] with prevailing elevations from 175 to 210 m above sea level. The Priobskoe plateau is located in the south-eastern part of the Ob-Irtysh interfluves and occupies most of the Novosibirsk region. The Priobskoe plateau is bounded by the Salair ridge in the north, the Biye-Chumyshskaya Upland in the south, the Kulundinskaya alluvial plain in the southwest and the Barabinskaya lowland in the west. During the Paleogene there was a gradual sinking of the Priobskoe plateau with a gradual accumulation of thick layers of sedimentary rocks. The modern relief was formed in the Lower and Middle Quaternary period and is associated with erosion processes. Later in the Upper Quaternary, a young erosional relief developed on the Priobskoe plateau [1, 8-10].

The soil cover is diverse. Automorphic, hydromorphic and semi-hydromorphic soils are widespread. Automorphic soils with common and leached chernozem are found on the tops of hills. The slopes of the uvals are occupied by meadow-chernozem and dark grey forest soils. The lower parts of slopes are mainly covered with meadow-chernozem soils. Meadow soils, as well as soil complexes with salts, meadow-marsh humus, meadow solonchaks and meadow-marsh marshes are widespread among the massifs of black earth soils. The most depressed areas in the relief are occupied by meadow-marshy humus, marshy soils. In the depressions, marshy soils can be found under woody vegetation.

Meteorological parameters of 2019 and 2020 were used for processing (more than 8000 lines in the dataset) (Table 1). The following techniques of big data processing are used in the work, involving mathematical operations of sorting, coding, construction of data slices, and aggregation. The process of enlargement or aggregation serves in the work to reduce dimensionality and better represent the results of moisture estimation. Aggregation procedures were used to systematically describe precipitation, air temperature, relative humidity, and evaporation with different temporal resolution: by decades, months, vegetation periods (May-June, May-July, May-August) and annual average.

Table 1.

Agroclimatic conditions of growing season humidification for grain crops cultivation

Indicator	month	2019 year	2020 year
Precipitation, mm	May	28	44
	June	17	32
	Jule	94	75
	August	20	49
Sum of active air temperatures above 10 degrees Celsius	May	372	569
	June	571	576
	Jule	699	716
	August	705	688

In general, the hydrothermal conditions of the growing season in 2019 for wheat growth on the territory of Mirny in the Kochenevsky district were insufficient and assigned to the dry agriculture zone (HC = 0,68). The hydrothermal conditions of the growing season in the current 2020 for wheat growth were also insufficient and classified as an arid zone of agriculture (*HC* = 0,78). The results of the assessment of natural humidification in 2019 and this year showed that the studied area belongs to the zone of moderately insufficient and unstable humidification. Humidification ratios were 0,40 (2019) and 0,58 (2020).

The results showed that the agroclimatic conditions for wheat cultivation in the current year were more favorable, in comparison with 2019. The humidification indicator for the vegetation period (Vysotsky-Ivanov humidification coefficient) and the hydrothermal coefficient (G.T. Selyaninov) exceed the values of last year.

In general, the values of soil and environmental indices in 2019 are less by an average of 30 points, which is explained by a decrease in agroclimatic potential (*AP* = 6,55). Agroclimatic conditions in 2020 were more favorable for wheat cultivation, compared to 2019. The climate continental coefficient was 185, which is significantly less than the average long-term value (C_c = 364). Agroclimatic potential is higher by 3,65 compared to last year.

Discussion

In the course of the research, the moisture content of the farm located in the forest-steppe zone of Western Siberia was assessed. In the cultivation of grain crops climate is the most important factor. The results of the work showed the possibilities of quantitative assessment of agroclimatic parameters with different temporal resolution.

The use of big data processing technologies to assess the moisture content of the territory allows one hand to process poorly structured data without the use of standard data query languages. This significantly speeds up the analysis process. On the other hand, use of programming language Python and engineering libraries is aimed at possibility of fast conversion of the processed data in different formats. So our developed program allows to save data in Excel, pdf, csv formats and present it as a table of modern DBMS SQLite. This is aimed at expanding the possibilities of displaying spatial data for geographic information systems.

However, for crop yield prediction, the results of evaluation of topography, soils and environmental factors related to plant requirements are needed. Therefore, further research is aimed at an integrated approach in the assessment of agroclimatic, geomorphological and soil conditions of the territory for the prediction of grain crop yields.

In the course of the research, the moisture content of the farm located in the forest-steppe zone of Western Siberia was assessed. In the cultivation of grain crops climate is the most important factor. The results of the work showed the possibilities of quantitative assessment of agroclimatic parameters with different temporal resolution.

The use of big data processing technologies to assess the moisture content of the territory allows one hand to process poorly structured data without the use of standard data query languages. This significantly speeds up the analysis process. On the other hand, use of programming language Python and engineering libraries is aimed at possibility of fast conversion of the processed data in different formats. So our developed program allows to save data in Excel, pdf, csv formats and present it as a table of modern DBMS SQLite. This is aimed at expanding the possibilities of displaying spatial data for geographic information systems.

However, for crop yield prediction, the results of evaluation of topography, soils and environmental factors related to plant requirements are needed. Therefore, further research is aimed at an integrated approach in the assessment of agroclimatic, geomorphological and soil conditions of the territory for the prediction of grain crop yields.

Conclusion

The practical significance of the work is as follows:

- the application of big data processing technologies has significantly reduced the time for the labor-intensive process of assessing agrometeorological parameters;
- obtained aggregated meteorological parameters of different temporal resolution (hours, days, decades, months) allowed us to identify a strong variability of agroclimatic conditions for the territory of Mirny farm Kochenevsky district, located in the forest-steppe zone of Western Siberia;
- perform an integral assessment of agroclimatic conditions by calculating the integral indices of moisture, climate continentality, and agroclimatic potential.

In general, the obtained results of the assessment of humidification of the territory of the farm Mirny Kochenevsky district 2019 and 2020 characterize a significant variability of agroclimatic conditions for the cultivation of grain crops. Uneven distribution of the main environmental factors of heat and moisture during the growing season of crops has a significant impact on the value of agroclimatic potential.

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