Analysis of humidity in the territory of Central Siberia in order to optimize the types of hydromelioration measures

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Abstract. An important element in the hydromelioration development of the territory is the identification of the conditions of the territory moisture. The degree of moisture of the territory is the importance of the soil layer. In turn, the moisture content of the soil is determined not only by the amount of precipitation, but also by various types of melioration work, as well as morphological features of the surface. The value of the soil layer moisture is a determining factor in choosing the agro-industrial focus of agricultural lands or their ecological state. In this paper, the analysis of the moisture content of the territory of Central Siberia is carried out based on a joint consideration of the elements of water and heat balances. The choice of the type of hydromelioration measures aimed at both improving the ecological state and for the integrated development of natural resources depends on the degree of moisture of the active layer of soil. Based on the analysis of water availability of the territories of Central Siberia, the values of soil moisture for different intervals, as well as the soil moisture of the growing season in years characteristic of water availability, are determined.

1 Introduction

In connection with the intensive economic development of the northern countries, the expansion of cultivated areas, and water management construction, the problems of studying the patterns of formation of the water balance of individual regions and the accurate accounting of water resources in the developed territories are becoming increasingly important. The discrepancy between the available water resources and the volumes of water consumption can lead to a change in the established water balance of the territories over a long period, which ultimately affects the water supply or, otherwise, the overmoistening of the soils.

The most optimal solution for influencing the soil moisture is to carry out hydromelioration work, influencing the water-physical properties of the soils. The main objective of hydromelioration measures is to create optimal conditions for the moisture content of the soils [1] by redistributing moisture over time for the purpose of rational use of water and land resources.

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The need for certain types of hydromelioration and the choice of the necessary methods for their implementation largely depend on natural conditions. The primary role in such a choice is played by the conditions of natural moisture supply. Therefore, the first step in establishing hydromelioration modes is the determination of the quantitative characteristics of these conditions. An important indicator of the possible use of the territory is the natural moisture content of the territory. Moisture supply determines the development of a particular type of development of production forces [2] or the development of the direction of the agro-industrial complex. The level of moisture, in most cases, is the determining factor in the need to apply hydromelioration measures.

In this regard, the study of the humidity of the territory is a priority area in the development of the territory and expansion of production, which is becoming relevant at the stage of modern development of the state.

The degree of humidity of the territories is mainly determined by the amount of atmospheric humidity and the provision of solar radiation in the process of heat and moisture exchange [3]. At the same time, anthropogenic activity has a significant impact on the amount of humidity. Human efforts to improve living conditions in every possible way can lead to a significant change in the conditions for the formation of surface runoff, which can negatively affect the environmental situation of the surrounding natural landscape.

Excessive human activity contrary to the moisture supply conditions established over many years can lead to both soil drying and over-wetting with the corresponding consequences. Therefore, the requirements for maintaining the ecological balance of soil moisture [4] during the development of territories must be met in strict accordance.

An important element of the rational use of water resources is a comprehensive assessment of the dynamics of water balance elements and soil moisture deficiencies in the conditions of the heterogeneity of the territory of Central Siberia. The results of such assessments, together with heat and energy supply, are an indicator of the current state of the territory, taking into account the climate change conditions observed over the past decades.

Due to the extremely uneven distribution of water resources across the territory under consideration, as well as in time (during the year by seasons, as well as over a long-term period), there is a need for a comprehensive and complex analysis of the natural situation in order to determine the direction and extent of hydromelioration and planned scientifically substantiated artificial change of natural conditions. This can be done confidently and accurately only on the basis of a broad generalization of the conditions of moisture and heat supply, carried out in the form of mass calculations and maps of isolines of balance elements and other characteristics, as well as a scheme of hydrological and climatic zoning of the territory [5].

The materials for the study were hydrometeorological data from meteorological stations. The method of analysis, calculation and generalization was the method of hydrological and climatic calculations developed by Professor V.S. Mezentsev (1957). The essence of this method is in the joint consideration of the heat and water balance of any land area, and the main advantage is in the unity and interrelation of all equations that form the system, therefore, in the unity of the approach to determining the calculation elements. This makes it possible to indirectly judge the accuracy of the obtained results of those elements that cannot be measured, based on a comparison of the elements associated with them, such that can be compared with the measured values.

2 Materials and methods

The study of water balance and natural moisture of Central Siberia was carried out in close connection with the thermal resources of the climate based on the method of hydrological and climatic calculations.

The maximum possible evaporation value was adopted as an equivalent of the thermal resources of the climate, the numerical value of which is determined by the positive flows of the radiation balance, turbulent heat exchange and heat exchange in the soil, directed to the daytime surface of the active layer [6].

The territory of Central Siberia occupies a significant part of all of Siberia. The great distance from the Atlantic Ocean, the closure from the Pacific Ocean and from the south by highlands and the openness from the Arctic Ocean predetermined the harsh, sharply continental climate of the territory. A longer cold period, compared to a warm period, does not allow solar radiation to warm the soil layers, and therefore permafrost is widespread everywhere, especially in the north of the territory.

The degree of continentality increases from west to east. Within the territory under consideration, several soil and vegetation zones are distinguished [7]: the arctic desert zone, the tundra zone, the forest-tundra zone, the taiga zone and the zone of grass forests and island forest-steppe. Such a diversity of soil and vegetation zones predetermines the possibilities of using the territory under consideration [8].

The study of soil moisture conditions based on observations is currently very limited in general, and for Central Siberia in particular, since stationary observations are extremely insufficient. The available materials can only characterize the territory used in agricultural production, which is an insignificant part of the territory under consideration.

The harsh climate of Central Siberia, especially the vast areas of impassable forests of the taiga zone, have caused the sparse population, and, consequently, the poor study of this territory. Very little information on soil moisture observations, with the exception of materials from periodic expeditionary studies. Due to the diverse characteristics of natural landscapes with a large species composition of vegetation and water-physical properties of soils [9], great difficulties arise in zoning the territory according to the features of soil moisture. All this affects the accuracy of calculations when determining soil moisture. In this regard, the lower limit of the permissible measurement error does not decrease below 15% of the average moisture reserves.

Forest taiga soils with shallow permafrost are characterized by increased moisture up to the full moisture capacity [8] of the lower boundary of the active layer (60-100 cm) at the end of summer and beginning of autumn. Studying the water regime of soils in the southern part of Central Siberia, it can be established that the highest moisture content in the upper meter layer is observed immediately after snowmelt.

The calculation method for determining soil moisture has its advantages in that it reflects the average state of soil moisture in large areas [9]. In this sense, the calculated moisture content is more representative than that measured at many points in the area.

When determining soil moisture, the following soil-hydrological constants are used: total moisture capacity (TMC), capillary moisture capacity (CMC), minimum moisture capacity (MMC), capillary break moisture (CBM), wilting point moisture (WM), maximum hygroscopicity (MH), maximum adsorption moisture capacity (MAC).

With an increase in soil moisture and TER, total evaporation increases, and the increase in soil moisture depends on the degree of its saturation. In turn, the degree of soil saturation over a period of time, at the beginning and at the end of the calculation period W_1 and W_2, is different. In this regard, to calculate the water characteristics of soils for a time interval, it is necessary to know the average soil moisture for this interval. Depending on the water-

physical characteristics of the soil, the following expression can be used to determine the moisture for the middle of the time interval under study:

$$W_{cp} = \frac{W_1 + r \cdot W_2}{r + 1}, \tag{1}$$

Where r is a parameter depending on the water-physical properties of the soil.

For convenience of calculations, it is more appropriate to operate with relative moisture content using as an indicator the ratio of soil moisture W in to the soil constant for moisture - the least moisture capacity W_{MMC} $V = \frac{W}{W_{MMC}}$, then, accordingly, V_{TMC}, V_{CMC}, $V_{MMC}=1$, V_{CBM}, V_{WM}, V_{MH}, then we obtain,

$$Wcp = Vcp \cdot W_{MMC} \tag{2}$$

$$Vcp = \frac{V_1 + r \cdot V_2}{r + 1} \tag{3}$$

The arithmetic mean of equation (3), under the condition of equality of the parameter r = 1, we obtain

$$Wcp = \frac{W_1 + W_2}{2} \tag{4}$$

Or in relative values (as a fraction of W_{MMC})

$$Vcp = \frac{V_1 + V_2}{2} \tag{5}$$

The value of W_{cp} in the range from 0.4 W to 1.2 W can be determined by the ratio

$$Wcp = W_1 \left(\frac{W_2}{W_1} \right)^{1/r} \quad \text{or} \quad Vcp = V_1 \left(\frac{V_2}{V_1} \right)^{1/r} \tag{6}$$

By solving equations (3), (5) and (6) for V_{cp}, the soil moisture content at the end of the calculation period V_2 is easily determined:

$$V_2 = \frac{(r + 1) \cdot V_{cp} - V_1}{r} \tag{7}$$

$$V_2 = 2V_{cp} - V_1 \tag{8}$$

$$V_2 = V \left(\frac{V_{cp}}{V_1} \right)^r \tag{9}$$

To perform calculations of water balance elements by the hydrological-climatic method, data from standard observations of meteorological stations and posts on the atmospheric

precipitation regime were used, taking into account local features of the catchment area. Based on this, private methods were developed that take into account the diverse nature of the morphological features of the structure of the surface of the basin.

3 Results

Calculations of soil moisture (Table 1) are made according to climate data using a system of equations. All calculations are made in fractions of the least moisture capacity W_{MMC}. The intra-annual soil moisture regime is characterized by average monthly values given for a number of stations in the territory under consideration.

Table 1. Average soil moisture in fractions of the least moisture capacity.

Station	Warm period of the year							Cold season of the year
	IV	V	VI	VII	VIII	IX	X	
Chelyuskin, m.			1.50	1.36	1.26	1.23		1.40
Dixon, Fr.			1.45	1.30	1.17	1.13		1.32
Saskylakh			1.24	1.08	0.98	0.98		1.15
Volochanka			1.52	1.27	1.09	1.07		1.34
Olenek			1.26	1.09	1.00	1.00		1.18
Igarka			1.87	1.49	1.22	1.20		1.64
Turukhansk		1.91	1.69	1.36	1.14	1.12		1.55
Tura		1.30	1.18	1.02	0.91	0.90		1.12
Erbogachen		1.33	1.17	0.97	0.87	0.85		1.12
Vanavara		1.55	1.34	1.09	0.94	0.93		1.27
Yeniseisk	1.61	1.48	1.28	1.05	0.90	0.88	0.95	1.33
Krasnoyarsk	1.20	1.13	1.01	0.90	0.87	0.87	0.92	1.09

As follows from the table, the moisture content of the active soil layer is characterized by a spring maximum and a minimum at the end of summer and beginning of autumn. In the taiga zone and in the far North, even in the summer months, the soil contains more moisture than the minimum moisture capacity, with the exception of the eastern regions, where by the end of summer the soil dries to the level of the minimum moisture capacity, and south of the Arctic Circle - below the level of the minimum moisture capacity.

A characteristic feature of the forest and forest-steppe zones is an increase in soil moisture [9], often exceeding the minimum moisture capacity. A further decrease in soil moisture continues with the onset of summer, reaching its minimum at the end of summer, but the soil moisture does not decrease below the moisture level of the rupture of capillary bonds.

Table 2 shows the calculated values of water-physical constants in fractions of the minimum moisture capacity for soils of different mechanical compositions at n = 2.5 (a parameter depending on the physical and geographical characteristics of the soil)

Table 2. Water-physical constants in fractions of the least moisture capacity.

Water-physical constants	Parameter r			
	1.25	1.50	1.75	2.00
V_{MH}	0.14	0.26	0.33	0.38
V_{WM}	0.21	0.39	0.49	0.56
V_{CBM}	0.41	0.55	0.64	0.70
V_{MMC}	1.00	1.00	1.00	1.00
V_{CMC}	1.78	1.61	1.50	1.42
V_{TMC}	3.50	2.84	2.44	2.19

4 Discussion

The table shows that the soil moisture corresponding to V_{CBM} varies depending on the mechanical composition from 0.41 to 0.70, while according to the calculations, in the southern regions of the grass forest zone and the island forest-steppe, the active soil layer dries out to a level of 0.8 W_{MMC} by the end of summer.

Analyzing the nature of the distribution of average values of the moisture content of the meter-thick soil layer during the growing season, it can be noted that the taiga zone is the most humid (V> 1.20). Optimal conditions for water supply and aeration of the root system of plants are observed to the south of the southern boundary of the taiga zone, where the isoline V = 1.0 passes.

Based on the calculation results, the numerical values of the average moisture content of the active soil layer during the vegetation period in average and typical years were determined for a sample number of stations in the study area.

Analyzing the data in Table 3, it is possible to trace the dynamics of the average soil moisture content during the vegetation period in a multi-year plan.

Table 3. Average soil moisture during the growing season in shares of the lowest moisture capacity in average and typical years with a provision of 20%.

Station	$V = W/ W_{MMC}$		
	Dry year	**Average year**	**Wet year**
Turukhansk	1.37	1.52	1.64
Tura	1.04	1.10	1.17
Erbogachen	1.02	1.08	1.10
Podkamennaya Tunguska	1.33	1.44	1.56
Vanavara	1.16	1.23	1.30
Yeniseisk	1.10	1.18	1.26
Kezhma	1.01	1.07	1.14
Tyukhtet	1.03	1.08	1.13
Krasnoyarsk	0.94	0.98	1.03
Kansk	0.88	0.91	0.97

In a dry year in the taiga zone, the average moisture content of the active soil layer during the growing season decreases compared to the average annual level to 1.10-1.20, and only in the Yenisei Ridge Mountains is it quite high (V = 1.50 or more), but in the grass forest zone and the island forest-steppe, the active soil layer dries out to 0.9 or less.

In a wet year in the taiga zone, the average soil moisture content during the growing season increases to 1.60, in the Yenisei Ridge Mountains to 1.90, and in the grass forest zone it reaches the level of the lowest moisture capacity.

In order to track the dynamics in the active soil layer profile, calculations were made to determine it in the 0-20 cm layer for the agricultural territory and in the 0-50 cm layer for the entire study area.

5 Conclusion

Analysis of these calculations shows that the moisture content of the upper soil layer (up to 20 cm) is directly dependent on the season. The highest moisture content values, up to the state of over-moistening, are observed in the spring, while in most cases the moisture level exceeds the capillary moisture capacity. The lowest moisture content occurs in the summer, when the soil moisture deficit is observed below the VRK.

The main factor in the formation of soil moisture resources is latitudinal zonality, which is explained by the intensity of changes in physical and geographical factors associated with the influx of solar energy and the variability of total evaporation within the territory of Central Siberia.

The presented analysis of water and heat balance elements and quantitative characteristics of natural soil moisture and heat supply conditions, based on hydrological and climatic calculations, allows us to develop recommendations for their further use. Of particular interest for the development of the national economy of the country is the development of natural resources of Central Siberia, as well as types of agricultural development of the territory.

An important result of the study of the moisture content of the territory is the possibility of using them in the geoecological assessment of landscape complexes, determining the technology capacity and establishing the regulatory framework for the technogenic load on the elements of the ecological environment of the studied territory.

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