Water resources of a steppe zone of the Southern Urals, formation and use

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Abstract. The formation of water resources in the anthropogenically altered steppe zone of the Southern Urals is considered. Under conditions of arid climate, precipitation is aimed at increasing moisture reserves in arable land, reducing water flow. Soil moisture is spent mainly for evaporation. In the Orenburg region, it is necessary to develop a system for the integrated use of water resources, to increase the efficiency of using flood water by building reservoirs and ponds.

1. Introduction
The main territory of the Southern Urals is occupied by steppes. Their most important feature is the lack of precipitation relative to evaporation, which causes aridity of the climate and the formation of drought-resistant steppe vegetation, making the steppe the main element of the landscape [1, 2]. Water has become a factor determining the direction and speed of the occurring of many processes in the nature of the Southern Urals. The lack of water resources leads to the formation of adapted biogeological systems, the specifics of nature management and nature protection, which differ from excessively and sufficiently moist areas.

Half of the steppes of the Southern Urals are plowed up, while the other is being mown and intensively grazed. As a result, the biosphere, natural systems and river flow regimes have changed, a different environment has been formed. Under conditions of low availability of water resources, according to the law of minimum [3], water has become a system-forming component of nature, economic and social development, and the ecological condition of the man-nature system depends on the efficiency of its use. The nature of the Southern Urals and its water resources are overloaded with anthropogenic impact. As a result, they are transformed and degraded. J.E. Hansen, A.A. Lacis [4], J.F. Mitchell [5] and Danilov-Danilyan, Losev [6] say that the global sustainability threshold is exceeded. V.G. Gorshkov [7] and C. Lorius [8] point out the need to find ways to create optimal living conditions for people. According to C. Lasch [9], the improvement of their life is possible only by the efforts of mankind, otherwise this task is unsolvable.

The paper considers the possibilities of efficient use of water resources in natural and anthropogenically altered natural systems of low-water regions.

2. Materials and methods
We study the water resources of the steppes of the Southern Urals in natural and changed by economic activity conditions. With the settlement of its territory by man and the transition to cattle
breeding, and especially to agriculture, anthropogenic influences have an ever-increasing impact on natural waters. Currently, they have changed the main draining factors on its watersheds. The basis of the research methodology is the principle of comprehensive study of the main components of nature with the release of a system-forming component. In the Southern Urals, water resources, which are its main component [1, 2], were studied by the water balance method. To assess the effectiveness of the total impact of precipitation and heat supply on biogeosystems and the formation of water resources, the most appropriate is the coefficient of moisture (Kuv), which is the ratio of precipitation (P) to evaporation (Eo) and calculated by the formula A.R. Konstantinov [10] 

\[ Kuv = \frac{P}{Eo} \]

The steppes of the Southern Urals with \( Kuv < 1 \) are water-deficient, the direction and types of development of their nature are determined by water resources. Grasses, forest and the soil-forming process lack moisture during almost the entire vegetation period with relatively excessive provision of heat. As a result, drought-resistant biocenoses are formed in the natural steppe, adapted to water restrictions, but demanding to heat. In connection with a decrease in nutrition, groundwaters go down to greater depths, providing an increase in soil and ground aeration. This leads to the predominance of oxidative processes in them and the accumulation of salts.

Water availability should be considered in relation to specific territories. For small areas, when determining the provision of heat, not only solar insolation, but also the direction of the slope, the absolute elevation and albedo of the surface are of essential importance. For large areas (river basins or their parts), the importance of local factors decreases due to their averaging.

The water resources of the water-deficient steppe zone of the Southern Urals are considered in comparison with sufficiently and excessively wet areas. The influence of the level of provision with water and heat resources on the formation of bioresources and geochemical processes in natural areas is revealed. The results of the study are aimed at improving the efficiency of water use in the society and economy of the steppe Southern Urals.

3. Results

Natural waters are formed as a result of the complex interaction of precipitation with a specific ground surface, living matter of the subsoil and the atmosphere. These natural processes in nature are influenced by an anthropogenic factor that displaces the dynamic equilibrium in nature in one direction or another, and even replaces some processes with others. But the anthropogenic factor also acts in the conditions of the existing water supply of the territories.

The Southern Urals has a high level of development of industry and agriculture and, therefore, is experiencing a double press of anthropogenic impact on nature: the impact of industrial zones that cause cities occupying about 2% of its territory and agricultural land use on 90% of its territory. With relatively smaller agricultural impacts per unit of area, based on the entire area, they significantly exceed the industrial ones. In the southern Urals, agricultural land use has changed water-physical properties and soil quality, which has changed the balance of natural waters [1]. The increasing human alienation of organic matter from the closed steppe system led first to a decrease in the capacity of the turf, then to the soil layer and humus in it, to an increase in the surface runoff of thawed and storm water. The deterioration of the water supply of the steppe vegetation accelerated the further degradation of the steppe, turning it into a trampled unproductive steppe. The data from table 1 confirm a significant deterioration in the filtration properties of the trampled virgin soil. Similar results were obtained by A.M. Green, S.V. Bass and G.V. Nazarov [11], and by other researchers [12, 13] on ordinary heavy loamy black soil in the Stone Steppe.

In the arid zones climatic conditions the agricultural land use systems are focused on increasing the moisture reserves in fields, hayfields and pastures due to water flow. The moisture accumulated on them is spent on evaporation, replenishing its amount in the atmosphere. With a limited moisture capacity of the atmosphere, moisture falls in the form of additional precipitation, increasing the small water cycle on the continent, increasing the efficiency of its use.
The ratio of the expenditure parts of the water balance in the catchment area of the river is significantly influenced by the filtration properties of the earth's surface. They determine how much water that has entered the earth's surface will go to soil moisture, to filter into groundwater and to surface runoff to the hydrographic network. Our studies of the formation and use of atmospheric precipitation near the city of Orenburg showed that on arable land on elevations of relief with large reserves of snow (120 mm) and a significant flow of water from them (28 mm on average), it was little beyond the arable land (on average 2.3 mm) and did not go beyond the layer of moisture consumption by vegetation, not feeding groundwater, partially draining, it accumulated in closed deepenings. The melt water accumulated in them saturated the active layer of the aeration zone, from which it was consumed by plants (1.5 m on average). One part was spent on groundwater supply, and not absorbed water, overflowing the deepening flowed down the slope into the hydrographic network.

### Table 1. Filtration properties of the southern loamy black soils on arable lands of the Southern Cis-Urals.

| Agricultural lands         | Indicator | Time from the beginning of flooding t, min | Filtration ratio, mm/min | Volume weight in a layer of 20 cm, g/cm³ |
|----------------------------|-----------|-------------------------------------------|--------------------------|----------------------------------------|
| Trampled virgin land       | Absorption rate, mm/min | 1,5, 1,3, 1,2, 1,0, 0,8 | 0,8 | 1,20 |
|                           | Absorption during t, mm | 3, 7, 25, 47, 64 |                         |                                        |
| Non-movable virgin land    | Absorption rate, mm/min | 10, 5, 1,05, 2,0, 1,8 | 1,8 | 1,05 |
|                           | Absorption during t, mm | 20, 35, 75, 117, 153 |                         |                                        |
| Arable land                | Absorption rate, mm/min | 6, 3,5, 2,2, 1,9, 1,7 | 1,7 | 1,05 |
|                           | Absorption during t, mm | 12, 23, 58, 97, 132 |                         |                                        |
| Forest floor belt          | Absorption rate, mm/min | 20, 8, 3,8, 3,2, 2,9 | 2,8 | 0,93 |
|                           | Absorption during t, mm | 40, 64, 132, 199, 258 |                         |                                        |

On arable land in deepening occupying 11% of the studied slope, an average of 270 mm was consumed for nutrition, which is 29 mm per total area. On the trampled virgin soil with average snow reserves on the slope of 134 mm and runoff of melt water from the relief elevations of 78 mm, their runoff from the total area of the slope was 41 mm. It took an average of only 17 mm to groundwater. On non-trampled virgin soils with average snow reserves of 180 mm and runoff from heights of snowmelt waters of 53-mm, the total runoff from the slope was 8 mm. Only 361 mm went to groundwater from the deepening, and related to its entire area it was 50 mm.

Comparison of water balances on rippling, trampled, and non-trampled virgin land during snow melting shows that the condition of the earth's surface significantly affects surface and underground runoff. Before the period of intensive development of cattle breeding and before the development of virgin lands in the Southern Urals, a large amount of melt water infiltration ensured the low-water
full-flowing of the rivers on non-trampled lands. With the increase of livestock population, virgin lands lost a significant part of the turf, the soil surface was compacted. As a result, the infiltration of melt waters decreased, the low-flow runoff decreased accordingly, and the floods increased. Plowing virgin lands, and especially the transition to winter plowing led to a general reduction in the share of melt water in rivers.

The study of the water balance in the watersheds of the Southern Urals showed that on all types of land there are both evaporative and infiltration types of water exchange. The first is associated with elevations, and the second relates to the closed deepening of the relief. By interacting, they form a spotty variety of vegetation, soil and many other components of nature, uneven supply of groundwater over the area.

Changes in the relation between different types of land in a catchment with different filtration properties of the surface change the values of its water balance components. With increasing or decreasing the filtration supply of groundwater, respectively, taking into account the time of their flow, the river flow changes. Table 2 shows water balance of a small river in the Southern Urals region, depending on the proportion of arable land in the catchment area and the intensity of their use.

Table 2. Water balance in the catchment of the river Samara (S = 1340 km²) depending on the share of arable land by periods of agricultural activity in 1936-2010*.

| Period in agriculture | Share of arable land in the catchment% | Share of rippling in the catchment% | Annual precipitation, mm | Winter precipitation, mm | Evaporation mm/year | Runoff mm | River flow, mm/year | Runoff coefficient |
|-----------------------|----------------------------------------|-------------------------------------|--------------------------|--------------------------|-------------------|-----------|-------------------|------------------|
| 1936-1954, I extensive land use | 25 | 10 | 336 | 114 | 246 | 65 | 90 | 0.57 |
| 1955-1990, II intensive land use | 64 | 45 | 390 | 144 | 298 | 44 | 88 | 0.30 |
| 1991-2010, III Multiple land use | 55 | 21 | 416 | 160 | 270 | 75 | 146 | 0.47 |
| Difference II- I | 39 | 35 | 54 | 30 | 52 | -21 | -2 | -0.27 |
| Difference III- I | 30 | 11 | 80 | 46 | 24 | -10 | 56 | -0.10 |
| Difference III-II | -9 | -24 | 26 | 16 | -28 | 31 | 58 | 0.17 |

* Data on precipitation, runoff coefficient and river runoff are calculated from the materials of the Hydrometeorological Service [14, 15]; information on the plowed watersheds and the share of digging taken from the materials of statistical offices.

The analysis shows that in 1936-1954 with extensive land use with 25% of arable land and 10% of the rippling on the studied catchment area, 57% of winter precipitation went to surface runoff forming floods, and the annual river flow per catchment area was 90 mm. Total evaporation was 246 mm / year.

During the period of intensive land use in 1955-1990. with 64% of arable land and 45% of the rippling on the catchment area, increasing moisture reserves in the active layer of the aeration zone by 40-60 mm, the coefficient of surface runoff decreased to 0.30, and the river flow only by 2 mm / year, which is within measurements, but evaporation increased to 298 mm / year.

In the period of the destruction of the state-collective-collective land use system and the formation of a multi-structured system in 1991-2010. on the catchment area, the use of arable land has decreased to 55% and that of rippling to 21%. As a result, the runoff coefficient increased to 0.47
with a decrease in evaporation from the catchment by 28 mm/year and an increase in the flood and annual river runoff.

With an increase in total evaporation of 52 mm with intensive land use, the annual amount of precipitation also increased by 54 mm compared with the period before the development of virgin lands. During the restructuring of the land tenure system in agriculture (1991-2010), a significant part of arable land was not sown, which reduced moisture reserves in the fields and evaporation from them. Respectively, precipitation decreased, but flood flow increased by 58 mm.

In the Orenburg region, which occupies the main part of the Southern Urals, water is a backbone component of nature. The importance of water resources increases with its increasing scarcity. The coefficient of moisture in the region is 0.4-0.6. As a result, the yield of grain crops is low. Low water in the low season has a negative impact on the quality of life of the population, water-intensive production does not develop.

In the water balance of the region territory, incoming items make up an average of 44 km³ per year, including 41 km³ of precipitation in the region and 3.5 km³ inflow of river water from the outside. 80% of all incoming water resources are spent for evaporation. 20% of the precipitation fall on the river runoff, of which four fifths fall on the flood, mainly discharged from the region without prior use for its needs, often causing damage in river valleys. At the same time, less than 5% of the flood flow is regulated in the region, which is less than in the neighboring regions.

The total amount of surface water resources formed from river runoff and accumulated water reserves in reservoirs and ponds in the Orenburg region is 18.5 km³, which is 149 mm per region. In neighboring areas with a similar climate in the Saratov and Samara regions, the total amount of water resources per area is 17 times larger. As a result, in the worst conditions of water availability, the population density in Orenburg is 16.4 people/km², which is 1.5 times less than in Saratov and 3.6 times less than in Samara regions. In areas with worse conditions, the young working-age population migrates to a greater extent beyond its limits. The efficiency of precipitation use in crop production is low in the region. The cultivation of grain crops consumes only 35-40% of its annual amount, providing crops average yield of 1.1 t/ha, which is almost 1.6 times lower than the average yield in the country.

Under the prevailing conditions in Orenburg, it is necessary to develop a system for the integrated use of water resources. In plant growing, it is possible to increase the efficiency of using precipitation up to 50-55% by introducing late-autumn planting of spring grain crops, which yielded in our production experiments 1.5-2 times higher yields than that on the adjacent fields of spring sowing with a loss of 80-100 mm of moisture with fields for unproductive physical evaporation.

To increase the efficiency of the use of flood waters in the region, it is necessary to intensify the construction of reservoirs and ponds. As a result, the destructive floods will decrease and the low-flow runoff will increase without significant losses in the average annual river runoff. They will allow optimizing the anthropogenically disturbed runoff of rivers in the interests of the modern biosphere, population and economy of the Orenburg region.

Reservoirs and ponds should be built on small rivers near the settlements of promising development, improving recreational conditions for them. In strategic terms, they will become the centers of gravity of the population from neighboring unpromising villages. In growing settlements, it will be cost-effective to create a modern production structure and socio-cultural base for a comfortable life of the population. In rural areas they will be agro towns.

4. Discussion
In the Southern Urals, development of a system for the integrated use of water resources is needed. In plant growing, it is possible to increase the efficiency of using precipitation from 35-40% to 50-55%. To increase the efficiency of use of flood waters in the region, it is necessary to intensify the construction of reservoirs and ponds. They optimize the disturbed runoff of rivers in the interests of the modern biosphere, population and economy of the region.
5. Conclusion
In the arid conditions of the Southern Urals, water resources are a backbone component of nature, society and the economy, determining their level of development.

Agricultural activities, which occupy 90% of the watersheds, have a significant impact on the filtration properties of the earth's surface, changing the ratio of the expenditure and income items of their water balance.

The current anthropogenically altered river runoff must be regulated by reservoirs and ponds in the interests of nature, society and the economy.

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