Ecological and economic significance of the Middle Don sand arenas

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Abstract. The research purpose is a comprehensive assessment of the Middle part of the Don river sand massifs soil and hydrological conditions. The research objects are the sandy massifs of the Middle Don on an area of 527 thousand hectares. The sand arenas water balance dynamics for the period from November to March and for the period from April to October has been revealed. It has been established that atmospheric precipitation is the main source of river water supply. The basis of river systems flood filling are clay soils that form an intra-soil runoff. The low water period level is supported by sandy soils. A decrease in the density of plant formations contributes to an increase in groundwater supply. The total underground runoff reaches 599 million m^3 from the sandy massifs of the Middle Don. The volume and dynamics of the moisture movement in the soil depend on the system of sandy areas use. Therefore, the load on sandy arenas should be regulated. Pasture farming should remain the dominant form of sand use. An effective method of sandy arenas afforestation is the planting of pine plantations according to the savanna type.

1 Introduction

The rational use of fresh water resources for economic purposes is based primarily on information about their availability and qualitative characteristics against the background of a reduction in the number of river basins that contribute to the surface and subsurface runoff formation [1, 2]

Sandy massifs are capable of desalinating the river systems of large rivers. On the Don sand massifs, which cover an area of 1 million hectares, fresh and ultra-fresh water comes from the sands all year round and increases the flow rate of rivers. The volume of such runoff depends on the sand arenas development methods. At the same time, an integrated approach is needed to consider issues of environmental aspects and spatial distribution of land [3]. The main reason for the negative agroecological changes is the abnormal economic load affecting the water balance elements ratio in the regions where this activity was carried out. This affects the spatial and temporal features of the water resources distribution. The choice of sandy massifs agricultural development should be based on such indicators as climatic and soil conditions, water availability, biological productivity, etc. [4-

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7]. The combination of different crops cultivation methods makes it possible to optimize the water supply of agrocenoses and increase productive moisture reserves [8-12].

The search for optimal ways of sandy lands introduction to economic turnover, which began at the end of the XIX century, led to the development of water-regime research in our country. The water regime of the Don region sands was studied by V.A. Dubyansky (1949), S.S. Sobolev (1939), A.G. Gael (1952), A. S. Manaenkov (2018) [13]. General changes in water reserves in the sands of the Don basin were studied by V.V. Mironov (1970), A.E. Ivanov, I.S. Matyuk (1955) without dividing them into water balance separate elements. The features of the water regime of the steppe zone sandy lands, which are occupied by dry pine forests, were characterized by N.A. Voronkov (1963) and P.M. Svetlishchev (1964) [14].

However, the water resources formation assessment and the water balance dynamics on this territory is still relevant and occupies an important place in the management of water systems, protection of water from depletion and pollution as well as runoff regulation and territorial redistribution.

The purpose of the research is a comprehensive assessment of the Middle part of the Don river sand massifs soil and hydrological conditions.

2 Materials and methods

The research objects were the sand massifs of the Middle Don. The research was carried out on 527 thousand hectares' area. The largest areas are occupied by turf-steppe soils (300 thousand hectares). Primitive soils are spread over an area of 116 thousand hectares, chernozem – like - on 79 thousand hectares, soils of ancient watercourses – on 32 thousand hectares.

For determining the volume of water intake from the sand massifs, information was collected with the following indicators: precipitation, areas of sandy lands with a division into the main types according to the degree of overgrowth, water-physical properties and economic use, water regime of the main sands types, water balance of sands, groundwater slopes, water migration routes, water quality, examples of desalination river waters, etc. issues. A significant amount of information was obtained on the basis of literary summaries and author's research, which has been going on for more than 20 years.

Precipitation values were taken from the weather stations of the Near-Don region. Runoff from agricultural fields to sandy massifs was determined by cartograms [15]. Satellite images were used to determine the types of sands and the areas occupied by them.

The results of regular observations of the humidity of the sands in various areas were used for determining the types of water regime [16]. In the same time, hydrological constants and physical indicators were determined.

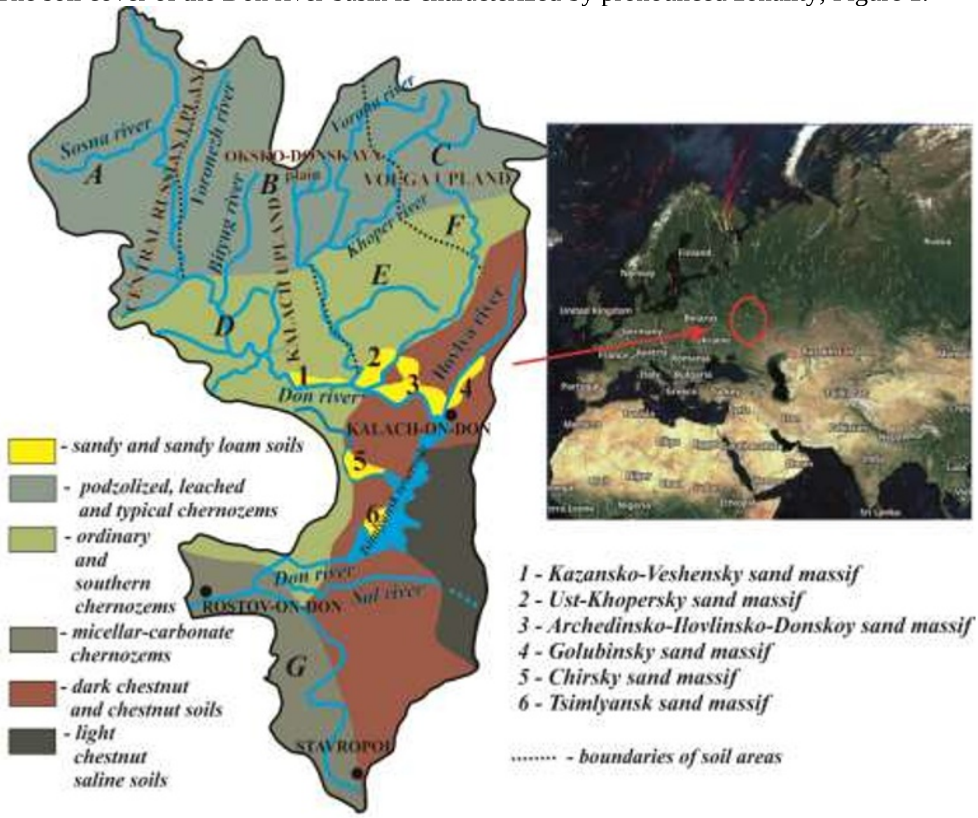
The water balance is calculated based on the following indicators: precipitation, transpiration, evaporation, outflow of moisture into groundwater. The calculations are based on the methods of A. A. Rode (1952), N. F. Kulik (1979), S. V. Astapov (1959).

The groundwater of sandy massifs (depth of occurrence, quality, slopes) was studied by drilling on the routes of leveling courses, point drilling and the method of triangular polygons.

Agricultural and forest lands as well as the state of vegetation have been studied in detail. The possibility of groundwater contamination by various objects (livestock farms, railway stations, landfills) was determined to a small extent.

3 Results and discussion

The soil cover of the Don river basin is characterized by pronounced zonality, Figure 1.



A – podzolized, leached and typical medium-humus thick black soils of gray forest soils of the Central Russian Upland; ***B*** – typical obese black soils of the Oka-Don lowland; ***C*** – typical obese and leached obese black soils of the Volga upland; ***D*** – the dismembered area of ordinary medium-humus medium-thick black soils and southern low-humus medium-thick and low-power black soils of the Don-Chirsky and Don-Khopersky watersheds; ***E*** – undulating-plain region of ordinary and southern black soils of the Khoper-Medveditsky interfluve; ***F***– the area of ordinary and southern black soils of the Caspian upland; ***G*** – the area of micellar- and deep-micellar-carbonate low- and medium-humus thick black soils of the lower reaches of the Don basin.

Fig. 1. Sandy massifs of the Middle part of the Don river

Most of the chernozems, gray forest and chestnut soils varieties are quite well structured and differ in a large content of water-bearing aggregates. In this regard, surface runoff in the summer period can be formed only when heavy rains fall, the intensity of which exceeds the absorption capacity of the soil (the exception are solonetzes and saline soils).

During the cold period (CP) in the Middle Don basin falls 160 mm of precipitation, during the warm period (WP) – 220 mm. 24 mm is spent on physical evaporation in the cold period, 110 mm in the warm period. On chernozem-like soils water does not move to groundwater, on turf-steppe soils the runoff is 93 mm, on primitive soils 113 mm moves to groundwater during the cold period, Table 1.

In the warm season transpiration by plants, depending on the phytomass, on primitive soils is 73 mm, on turf-steppe soils – 113 mm, on chernozems – 246 mm, on soils of ancient watercourses – 306 mm. The total underground flow from the sandy massifs of the Middle Don is 599 million m^3.

Table 1. The water balance dynamics on the Middle Don sand arenas for the period from November to March (CP) and for the period from April to October (WP)

Soils	Transpiration, mm		Dynamics of moisture in the soil, mm		Runoff to ground water, mm		Runoff, million m^3
	CP	WP	CP	WP	CP	WP	
Turf-steppe	0	133	+43	-43	93	46	417
Primitive	0	73	+23	-23	113	60	201
Chernozem-like	0	246	+136	-136	0	0	0
Soils of ancient watercourses	0	306	+26	-26	110	-170	-19
						Total	599

The depth of groundwater occurrence, the moisture capacity of soils, as well as vegetation cover have a great influence on the water regime formation. Clay soils that form an intra-soil runoff are the basis of river systems flood filling. Water level in the low water period is supported by sandy soils. With an increase in the density of the herbaceous and shrubby vegetation layer and with the appearance of forest communities on the sands, there is a decrease in the nutrition of river systems and greater desiccation of soils. Reducing the plant formations density increases the nutrition of groundwater.

The underground flow rate dynamics has a seasonal cyclical character, which is associated with fluctuations in the annual amount of precipitation. However, comparing the results of the previous years' work by other authors, it can be noted that there is a clear decrease in gravitational runoff because of water intake for transpiration due to the sandy lands intensive self-overgrowth in the study area [14].

The volume and dynamics of moisture movement in the soil also depend on the sandy territories using system. The load on sandy lands should be regulated. Orchards, vineyards, melon crops, forest lands are profitable on sandy lands, especially when groundwater is close. But the main agricultural industry is livestock breeding with summer bases for fattening currently and should remain in the future, which allows reducing the steppe fire hazard and increasing the filling of groundwater.

Natural forest vegetation within the research region is confined to places of possible additional water supply due to groundwater, surface runoff or along riverbeds. Hanging birch, aspen, willows, black alder, petiolate oak are dominated in species composition. Pine is introduced into the culture and dominates the area. The forest cover of the territory is 15-18%. Individual sandy massifs are forested by 30%. The forest on the sands performs primarily protective functions, and also gives wood. However, forest formations consume moisture and especially ground water more than grasses. Therefore, an increase in forest cover will lead to runoff decrease. In this situation, it is necessary to reach the optimum. We recommend soils of ancient watercourses and areas directly adjacent to them with a ground water level of 1.5-2 m, as well as on turf-steppe soils with a shallow ground water level for plantations. The total percentage of forest cover for the Near-Don sands should not exceed the existing one, which is sufficient for reliable anti-deflationary protection. A further increase in forest cover may lead to a decrease in the supply of fresh water to the Don River and its tributaries as well as to springs and groundwater

Hilly sands are effectively afforested by planting pine plantations according to the savanna type. This technology has been successfully worked out by the authors in the "Lysaya Gora" natural boundary (Volgograd), Figure 2. A good planting material is a standard 2-year-old seedling, which takes root well when planted in spring. When forming a hole for planting with the removal of weeds, chemical treatment with the "Roundup" herbicide was carried out.

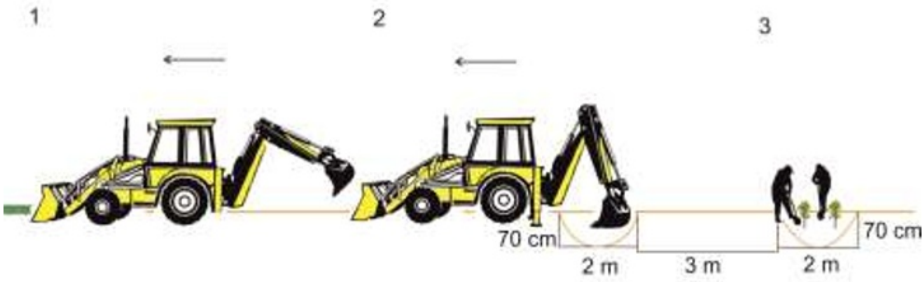


Fig. 2. Scheme of planting pine plantations by type of savanna in the tract "Lysaya Gora" Volgograd

With appropriate pre-planting soil preparation, timely agrotechnical care and chemical treatment, the survival rate of seedlings can achieve good results (up to 100%). Such plantings contribute to the accumulation of horizontal precipitation (hydrometeors), which improves their water supply.

4 Conclusion

The analysis of the obtained materials made it possible to evaluate sand massifs as a source of water supply for river systems and to determine the fundamental provisions in their economic use.

From the sand massifs of the Middle Don, the total underground runoff reaches 599 million m^3. The water coming from the sands desalinates the river system of the Don. In the low water period, the share of fresh waters from sandy massifs in the total volume of river waters is 22%.

The load on the sand arenas should be regulated. To ensure deflationary protection and preserve the recreational attractiveness of landscapes, the most productive forest phytocenoses should occupy 15-20% of the area. An increase in forest cover leads to a decrease in the flow of fresh water into rivers. The accumulation of horizontal precipitation on hilly sands contributes to the planting of pine plantations by savanna type. Pasture farming should remain the dominant form of sand use, which allows reducing the steppe fire hazard. To prevent pollution of the waters coming from the sands into the Don River, sand massifs should be kept clean.

The work was carried out within the framework of State Task No. 122020100450-9 "Development of a new methodology for optimal management of biological resources in agricultural landscapes of the arid zone of the Russian Federation using system-dynamic modeling of soil-hydrological processes, a comprehensive assessment of the impact of climatic changes and anthropogenic loads on agrobiological potential and forest conditions".

References

1. Zh.A. Baialieva, N.E. Mamatov, T.B. Askaraliev, K.E. Omurzakov, B.O. Askaraliev, Vestnik of the Kyrgyz National Agrarian University K.I. Scriabin, **2**(53), 127-131

(2020)

2. A.S Voronin, A.V. Komolkin, D.A. Markelov, in: Materials of the 17th International School-Conference, march 29 – april 03, 2020, Saint Petersburg, Russia, 138-139 (2020)
3. K.N. Kulik, A.S. Rulev, A.N. Sazhin, Russian Meteorology and Hydrology, **43(**9), 607-612 (2018) DOI: 10.3103/S1068373918090078
4. V.V. Borodychev, A.K. Kulik, N.F. Kulik, in: Proceedings of the Nizhnevolzhsky agrouniversitetskiy complex: Science and higher professional education, **3**(51), 26-34 (2018)
5. J. Huang, Earth-Science Reviews, **208**, 103-295 (2020)
6. A.N. Salugin, A.K. Kulik, M.V. Vlasenko, Russian agricultural science, **1**, 21-24 (2017)
7. Yu.A. Trapeznikov, G. Zhang, Natural and technical sciences, **3**(47), 179-185 (2010)
8. N.V. Solomatin, Yu.M. Nesterenko, in: Proceedings of the Orenburg State Agrarian University, **5**(79), 33-36 (2019)
9. A.I. Belyaev, K.N. Kulik, A.S. Manaenkov et.al., *Methodological recommendations on phytomeliorative reconstruction of degraded and desolate pastures of the Russian federation with innovative environmentally safe resource-saving technologies*, 68 (Volgograd, 2021)
10. A.L. Ivanov, A.G. Bolotov, R.V. Desyatkin et.al., *Land use in Russia in the context of global climate change and unprecedented socio-economic challenges: the state of the soil (land) cover, trends of change, degradation, accounting methodology, forecasts,* 100 (Moscow, 2022) DOI: 10.52479/978-5-6047604-3-7
11. V.V. Melikhov, K.N. Kulik, Irrigated agriculture, **1**, 6-7 (2020)
12. K.N. Kulik, A.L. Ivanov, A.S. Rulev et.al., *Strategy for the development of protective afforestation in the Russian Federation for the period up to 2025*, 36 (Volgograd, 2018)
13. A.S. Manaenkov, *Forest reclamation of arid zone arenas*, 428 (Volgograd, 2018)
14. N.F. Kulik, *Water regime of arid zone sands*, 280 (Leningrad, 1979)
15. A.T. Barabanov, *Agroforestry in soil protection agriculture*, 156 (Volgograd, 1993)
16. A.K. Kulik, R.N. Balkushkin, Arid Ecosyst., **12**, 374–381 (2022). https://doi.org/10.1134/S2079096122040102