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ENSURING SUSTAINABLE WATER SUPPLY OF FOREST PLANTATIONS ON INTRAZONAL GLEYIC KASTANOZEMS OF THE NORTHERN CASPIAN SEA REGION

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Abstract. Groundwater level, mineralisation and gradients were studied under different types of soils occupied by virgin field and forest vegetation to substantiate the possibility of creating sustainable forest stands. Summarised were the results of studying the characteristics of water cycle on saline haplic kastanozems and sodic solonetz soils, as well as on desalinated gleyic kastanozems. Vertical multidirectional moisture exchange with the underlying sandy horizon along local meso-depressions of the relief (depressions with meadow-chestnut soils) was demonstrated: descending during infiltration of thaw water and ascending as a result of an updraft by massive forest plantations. Explored has been the possibility of creating hydrologically neutral sustainable small groves and narrow shelter belts in the depressions, their water supply ensured by infiltrating thaw water, which has been historically irretrievably lost to groundwater outflow through the underlying sandy horizon.

Keywords: *arid region, meso-depressions, fresh water lens, forest plantations, water exchange, underlying sandy horizon*

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Much attention has been paid to the study of the peculiarities of dynamic phenomena in water flows in arid regions, their modeling and forecasting under the influence of climate change and agricultural load, including agroforestry reclamation (Sokolova et al, 2001; Sophocleous, 2002; Kollet, Maxwell, 2006; Fleckenstein et al., 2010; Zhou, Li, 2011; Bradford et al., 2014; Kolesnikov, 2019; Gleeson et al., 2020; Shein et al., 2021; Quichimbo et al., 2021).

In this regard, it should be noted that in the originally treeless arid territories, for example, in the Caspian Lowland, the cultivation of long-lived forest plantations is extremely difficult due to permanent water deficit, because trees and shrubs need much more moisture than native herbaceous plants, which can end their seasonal development under soil drought already in the middle of the growing season, while woody vegetation should function until autumn. Therefore, closed stands can grow here only when groundwater is available, as spring soil moisture recharge is completely insufficient for their full life activity (Rode and Pol'skii 1963; Olovyannikova, 1966, 1976; Sapanov et al., 2010)

Mechanisms of water and salt movement in soil-soils of the Caspian Sea were studied in detail in agroforestry systems of the Dzhanybek station of the Institute of Forest of the Russian Academy of Sciences, which is located in the semi-desert between the Volga and Ural rivers (49.3980^{O}N, 46.7960^{O}E). Over a 70-year period of research, seminal papers have been published, presenting, for example: moisture accumulation of soils of solonetz complex due to redistribution of atmospheric precipitation over the territory in the process of snow transport and surface runoff of melt water; water-physical soil constants and their intervals; types of soil water regime and ranges of active moisture on virgin lands and in agroforestry systems; evapotranspiration of ecosystems, including from groundwater (Moseson, 1955; Raspopov, 1956; Rode, Pol'skii, 1961, 1963; Kissis, Pol'skii, 1963; Bolshakov, 1964; Bazykina, 1974; Sizemskaya, 2013).

It was shown that local micro- and meso-zonings of relief (hollows, large hollows) with meadow-chestnut soils and fresh lenses at a depth of 5.5—7.0 м. However, even here, gradual salinization of these lenses and death of stands is always observed during establishment of multi-row closed forest crops (Olovyannikova, Lindeman, 2000; Sapanov, 2005).

In this connection, the issues of revealing the mechanism of secondary salinization of fresh lenses in meadow-chestnut soils and the possibility of their preservation by creation of special types of forest plantations are interesting. For example, for a long time it was assumed that on large padins the increase of salinity under massive plantations occurs by lateral underflow of saline groundwater from under adjacent light-chestnut soils. To exclude this process and to replace it, it was suggested to create stands not only at some distance from the edge of the paddy, but also with leaving 1/3...1/5 of the paddy under virgin vegetation or even "perpetual fallow" (Kovda, 1950; Raspopov, 1956; Rode, Pol'skii, 1963; Karandina, Erpert, 1972; Senkevich, Olovyannikova, 1996)

However, the freshwater lens under multi-row stands still started salinization after ~ 25-year period of their cultivation. Only in the early 1980s G. P. Maksymyuk suggested that under high-transpiration stands secondary salinization occurs due to vertical rise of saline water from the underlying horizon. This process was further confirmed by other scientists (Olovyannikova, Lindeman, 2000; Sapanov, 2003, 2005). Therefore, it was necessary to clarify the presence of an interlayer water table between the heavy loam and the underlying sandy horizon, and, in its absence, to identify the peculiarities of involvement of the underlying layer in water rotation.

The aim of this work is to show the general scenario of the water cycle in a forest-agrarian landscape taking into account the complexity of soil cover and diversity of plant ecosystems, with the definition of mechanisms of water flow under all types of soils, including in closed depressions of relief, to identify the possibility of creating in them ecologically safe stands with sustainable hydrological regime of freshwater lenses use.

OBJECTS AND METHODOLOGY

The studies were conducted at the sites of the Dzhanybek station. The studied area, the former Caspian Sea bed, is a closed system in hydrological terms and represents a tectonic depression, the upper part of which is composed of sandy-clay sediments of the Quaternary transgressions of the Caspian Sea (Table 1). The territory has an insignificant slope (0.1 ‰) towards the sea. The relief is flat-wavy, with flat depressions — padins and limans (Kovda, 1950; Rode and Pol'skii, 1961).

The main soil cover is represented by a three-member solonetz complex, the formation of which is due to the microrelief with a height difference of several tens of centimeters: Solonchak solonts with desert grass communities are developed on upland areas, light-chestnut solonetz soils with semi-desert communities are developed on slopes, in closed micro-depressions (so-called "hollows") — dark-colored chernozem-like (meadow-chestnut) soils with grass-grass steppe communities. The soil types alternate every few meters. The territory also contains saucer-shaped mesoponisations (large padins) with depth up to2 м and area from 1 to100 га, which occupy about 10—12 % of its total area. Meadow-chestnut soils with steppe vegetation are also developed in the padins. In some areas in the general soil cover, meso- and micro-declines in total can occupy up to 30 % of the area (Kamenetskaya, 1952; Rode, Pol'skii, 1961, 1963; Konyushkova, Kozlov, 2010)

Ground waters have a general level and are in the state of dynamic equilibrium at the depth of 5.5—7.0 м. Under virgin solonets they are saline up to 10 g/l, under light chestnut soils — up to 5—6 g/l, their composition is sodium chloride-sulfate. Under meadow-chestnut soils there is desalinized lens of hydrocarbonate-calcium composition and salinity less than 1.0 g/l, which is as if pressed into saline waters. Constant different salinization of groundwater under different types of soils, absence of hydrographic network and general gradient on the plain territory indicates its drainlessness (Rode, Pol'skii, 1963).

Groundwater regime and salinity in the freshwater lens were studied in the virgin pasture, in the arboretum of the Dzhanybek station, in small adult multi-row forests, in narrow 2—3-row forest belts, as well as in separate clumps. The forest plantations under consideration are represented by oak (*Quercus robur* L.), squat elm (*Ulmus pumila* L.), Pennsylvania ash (*Fraxinus pennsylvanica* Marsh.), various species of poplars (*Populus*) and other tree and shrub species.

In several permanent observation wells under different landscape elements, the groundwater table (GWT) was measured every decade for many years with clappers with an accuracy of ±1 см. Temporary observation wells were also installed in forest crops of different species composition. All wells were leveled relative to each other. The total annual GSS value was determined in wells located in the saline solonchak and calculated as the arithmetic mean of monthly values. Changes in groundwater salinity were determined by chemical analysis of autumn samples (Vorobieva, 1998). Archival data of the Saratov hydrogeological expedition of the Nizhnevolzhsky geological department of the RSFSR Ministry of Geology were used.

Table 1. Granulometric composition and salinization of soils under light chestnut soils adjacent to the big padina*

Depth, m	Power, м	Amount of salts, g/100 g dry soil	Note
0—15	15	0.998	Heavy loam, from10 м light, viscous
15—19	4	0.074	Quartz, fine-grained, clayey sand
19—21	2	0.087	Light, sandy, compacted clay
21—37	16	0.082	Fine sand, quartz sand
37—40	3	0.204	Clay dense, weakly micaceous
40—45	5	0.046	Fine sand, quartz sand
45—80	35	0.284	Clay with sprinkles of sand, dense
80—92	12	0.184	Clay sand
92—100	8	0.335	Clay is dense

* Note. Data were provided by G. P. Maksymyuk (cited in Sapanov, 2003, p. 24).

RESULTS AND DISCUSSION

Studies of the Dzhanybek station revealed the main features of the water cycle in virgin landscapes of the Caspian Lowland, where only precipitation is an input part of the water balance. Over a 70-year period, the average amount of precipitation is291 мм. The cold period of the year accounts for135 мм (with an amplitude of 150—498 мм), while the monthly norm is 18—25 мм. The main part of this moisture is redistributed over the area and deposited in the soil. The warm period accounts for156 мм (with an amplitude of 44—354 мм), with a monthly norm of 22—33 мм. This moisture is immediately involved in evapotranspiration of terrestrial ecosystems. Evapotranspiration in the warm season (April-September) is many times higher than precipitation, reaching a maximum in July –1018 мм (Sapanov, 2021).

Autumn-winter precipitation as a result of uneven snow distribution and periodic surface runoff of melt water over micro- and mesorelief elements form different spring moisture reserves on different soil types and partially recharge groundwater. In virgin solonchak solonts spring moisture reserves are almost half as much as precipitation during the cold period of the year (~80 мм), in light chestnut soils correspond to them (~144 mm), and in meadow-chestnut soils exceed them more than twice (~332 мм). Annually, this moisture on all types of soils is spent on evapotranspiration of plant communities. In addition, the average discharge from groundwater on all types of soils is considered to be about 30 mm/year, mainly due to physical evaporation (efflux) from the surface of the capillary rim, only on meadow-chestnut soils it is somewhat higher due to desiccation of some species of deep-rooted grasses (Rode and Pol'skii, 1963; Olovyannikova, 1966).

Water inflow to groundwater is carried out through troughs and padins (according to G. N. Vysotsky (1960), the “potuscular type” of water regime is observed when infiltration waters are interlocked with a freshwater lens during through-wetting with the formation of a temporary water dome, which, then settling, replenishes these lenses and participates in the general hydrostatic rise of the groundwater table (Raspopov, 1956; Rode and Pol'skii, 1963).

General dynamic phenomena in groundwater occur due to meltwater infiltration and seasonal evapotranspiration of plant ecosystems. In other years, early spring complete wetting of soil with recharge of freshwater lenses may not be observed. The resulting value of the water balance of the territory is the average annual groundwater table, which is regulated by the ratio of its inflow and outflow parts. In general, the annual groundwater table rises in the territory in humidified years, and falls in dry years. The most indicative is the rapid rise of groundwater table by more than 2 m in 1980—1994, which, incidentally, coincided with the rise of water level in the Caspian Sea and a small lake Chelkar. Since the middle of the twentieth century, the lowest groundwater table has been noted in1976 г. (7.2 m), the highest — in1995 г. (4.4 m). The state of dynamic equilibrium of groundwater table in virgin landscapes is mainly caused by climatic changes in the natural environment (Sokolova et al., 2001; Sapanov, 2007, 2021).

Another thing is transformation of soil-hydrological situation under the influence of agroforestry reclamation, when water and salt flows change not only in speed, but also in direction. For example, due to amelioration and additional snow accumulation in forest belts, solonchak solonets and light chestnut soils become permeable, which causes periodic complete wetting of aeration zone and washing of upper horizons from easily soluble salts, as a result of which the lower part of profile and groundwater become even more saline and therefore still remain inaccessible for plants. At the same time, evapotranspiration costs from the aeration zone increase on these soil types to 181 mm and 227 mm respectively. Expenditures from groundwater on ameliorated solonets and light chestnut soils remain the same (physical evaporation in vapor form), while on meadow-chestnut soils there is a significant change in the mechanisms of moisture expenditure from groundwater due to increased desiccation by woody-shrub vegetation (Bazykina, 1974; Olovyannikova, 1996; Sizemskaya, 2013).

Formation of soil hydrological regime in the troughs. The area of troughs varies significantly (from several tens to hundreds of square meters). The amount of water deposited in virgin depressions due to surface inflow depends on their capacity and catchment area, as well as additional snow accumulation. A distinctive feature of these depressions is their shallow depth, so under periodic surface inflow they can maximally hold about 300—500 mm of water. Depressions are filled with water quite often: during heavy rains, winter thaws, spring snowmelt. Infiltration of this water into the soil leads to extinguishing of the entire moisture deficit in the aeration zone and periodic formation of a water dome (Rode and Pol'skii, 1963).

Further mechanism of water flows formation in the dome is not sufficiently studied. It is believed that its gradual disappearance is related to physical indentation into the freshwater lens, due to which, in fact, they are formed. However, there are works that indicate the possibility of their some spreading under the adjacent light chestnut soils. In any case, infiltration domes participate in spring rise of the total water mirror in the whole landscape without noticeable change in the architecture of salt state of all types of soils. It is this condition that indicates the process of preferential dome indentation into groundwater with subsequent hydrostatic correction of its level in the whole virgin landscape.

The virgin freshwater lenses in troughs are often saline, apparently due to the excess of the flow part of the water balance over the inflow part (Rode and Pol'skii, 1963; Sizemskaya and Bychkov, 2005). The close location of saline water in a particular depression can be judged, for example, by the rapid increase in salinity almost from the surface of the water mirror when drilling a well with gradual withdrawal of mixed water (Table 2).

Table 2. Change in groundwater salinity under virgin trough with increasing well depth (groundwater table) 5.2 m

Well depth, m	Amount of salts, g/l	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+
		mmol-eq./L						
5.5	1.677	0	5.6	7.6	11.8	9.5	3.8	11.7
6.8	2.510	0	4.2	14.0	21.0	16.5	9.5	13.2
7.4	3.060	0	4.6	16.4	26.5	16.5	11.0	20.0
8.0	4.102	0	4.4	19.4	39.0	17.5	11.0	34.3

This circumstance indicates their low capacity and lack of significant water exchange with the underlying sandy horizon.

In hollows used for planting closed forest crops, the freshwater lens disappears even faster and is not restored due to increased desucc tive discharge from its capillary fringe. Even the infiltration water domes constantly appearing here at the expense of better snow retention and surface runoff of melt water during thaws do not help to restore the lens. In other words, in hollows all infiltration water entering the soil is always completely spent on evapotranspiration of forest plantations, as their root systems occupy the entire volume of the aeration zone of the soil profile up to the capillary border. Many species of planted trees and shrubs in the process of growth and development quite adapt to the dynamics of annual soil moisture reserves and can function for quite a long time (Olovyannikova, 1976; Sapanov, 2003; Kolesnikov, 2019). That is why the peculiar colony-western landscape at the Dzhanybek station has been preserved without agrotechnical and silvicultural care for more than 70 years.

Formation of soil hydrological regime in padins. Under virgin large padins the hydrological regime of freshwater lenses differs significantly from the scenario of water flows in the hollows. Padins are filled only as a result of periodic surface spring meltwater inflow with the formation of short-lived lakes (3—10 days) with a depth of 50—100 sm. Such surface runoff of melt water into the padins occurs every few years due to rapid snowmelt when constant daily air temperatures above 0 °C are established for several days against the background of frozen soil, which prevents in situ moisture absorption. Infiltration of this water into the soil leads to the formation of a water dome. It has been estimated that with1000 mm additional infiltration moisture, the water dome can emerge to the soil surface at an initial water level in the freshwater lens of about7 m. Later, as a result of evapotranspiration of plant communities and hydrostatic equalization of the total groundwater mirror, these domes disappear (Rode, Pol'skii, 1963; Bazykina, Maksimyuk, 1978).

The question of the capacity of the freshwater lens itself in the padins is of interest. According to data of Saratov hydrogeological expedition, in virgin padina chemical analysis of selected samples from piezometric wells, filters of which are located at the depth of 9—12 m from soil surface in heavy loam, reveals the presence of fresh lens with total mineralization 0.2—0.4 g/l, while water from underlying sandy interlayer horizon with filters at the depth of 15.2—17.3 m shows mineralization 0.5—2.5 g/l. In addition, a sharp decrease of soil salinity in the underlying sandy horizon under saline light-chestnut soils near the padina was revealed (see Table 1), which apparently indicates the desalinizing effect of the underlying interstratum horizon by infiltration waters under their horizontal outflow.

As we can see, the thesis about the transit of infiltration water under virgin paddies to the interlayer horizon of light mechanical composition through a long-existing freshwater lens in heavy loam seems quite probable, but difficult to prove. In case of existence of this mechanism on a treeless plain terrain, such horizontal outflow along the underlying horizon having high moisture conductivity will cause hydrostatic rise and equalization of the general groundwater mirror under all types of soils. The presence of such a process implies some accumulation of fresh infiltration water in the underlying sandy horizon, and the resulting value is the total groundwater rise in the whole landscape.

Evapotranspiration discharge of grass ecosystems in summer period causes reverse water flow with uneven sinking of groundwater table under different types of soils. At the same time, in virgin padins, water lowering causes the formation of a depression funnel, the bottom of which is located below the total groundwater table, which indicates not only the outflow, but also the desucc tion of steppe grass species from the capillary fringe of the freshwater lens (Fig. 1). At the same time, the substituting underflow into this depression can obviously originate from the underlying sandy interbed horizon.

The scenario presented here reveals for the first time the peculiarities of the natural water cycle in the virgin plain treeless territory with the involvement of the underlying horizon in the hydrostatic correction of the total water mirror; however, it has a number of assumptions, so it cannot be considered as reliably proven, although it fully explains the diversity and persistence of groundwater mineralization under different types of soils against the background of the potuscular water supply and its annual dynamics.

Reliable evidence of water exchange between heavy loam and underlying sandy horizon became possible with the appearance of artificial forest ecosystems, which began to be cultivated here since the middle of the twentieth century. The existing diversity of forest crops in terms of assortment,

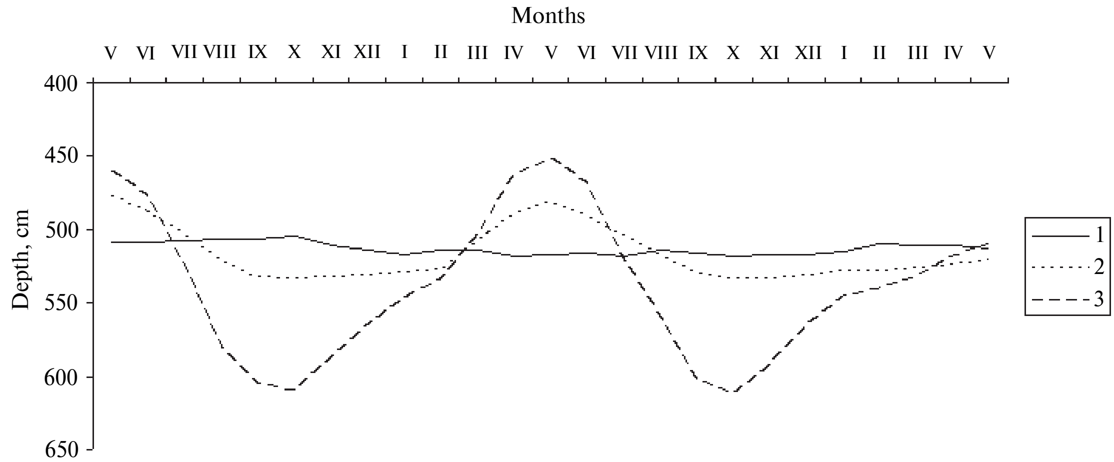

Fig. 1. Seasonal dynamics of groundwater table over a three-year period on solonchak solonetz with virgin desert vegetation (1) and on meadow-chestnut soil of two large padins with virgin steppe and woody-shrub vegetation, (2) and (3), respectively.

planting methods and placement on padins allows revealing some mechanisms of water movement in saturated soils.

Peculiarities of soil and hydrological conditions in afforested large padins. Since 1951, at the Dzhanybek station, various forest plantations have been established in padins. The most interesting are multi-row forests in which in the period from 22 to 27 years the freshwater lens begins to gradually salinate, especially under stands of petiole oak and squat elm, which have a two-tier root system: their first tier is located in the upper soil horizon of spring water accumulation, the second — in the capillary border of the freshwater lens. Strong desucc tive discharge from the capillary fringe causes the formation of a seasonal bowl-shaped depression funnel in the freshwater lens up to2.5 m under such stands (Olovyannikova, 1977, 1996; Sapanov, 2000).

The most difficult was the calculation of desucc tion from groundwater because of the constant substituting underflow into this depression, which is difficult to determine correctly. At the stationary site, the underflow rate was taken into account by two methods (using different specific water yield coefficients). According to the first method, the underflow was determined by the rate of fall water level rise after the cessation of vegetation of plants, and according to the second method, in addition to this, the rate of night level recovery after daytime stand transpiration was also taken into account. Using these methods, it was calculated that annual desucc tion from the freshwater lens in oak and elm is more than 450 mm/year, and the total evapotranspiration rate approaches evapotranspiration (Kissis, 1963; Olovyannikova, 1977; Sapanov, 2003; Kolesnikov, 2019). Under such desucc tion of plantations, the entire freshwater lens stock, which is about3600 мм freshwater in the heavy loam horizon, should be used up within 8 years. In reality, obviously, due to different reasons: gradual increase in leaf mass over a long period of time and periodic replenishment of the freshwater lens by infiltration water, its exhaustion starts from the age of 25 years, which is registered by a sharp increase in its mineralization, which then stabilizes at the level of 6—7 g/l (Fig. 2).

This is due to the fact that it is under such salinization that stand decay starts. For example, single specimens of oak in the middle part of multi-row forest massif begin to die, regardless of tree development ranks after groundwater salinity reaches about 3 g/l. Later, as secondary sulfate-chloride-calcium salinization of the lens increases to 4.0—6.5 g/l, complete decay of the oak stand due to water deficit is observed here, as trees stop consuming it. Similar secondary salinization of the freshwater lens, accompanied by the death of oak, elm and poplar trees, is observed in other padins (Olovyannikova, Lindeman, 2000; Sapanov, 2005). The level of salinization of the freshwater lens after the decay of the planted stand does not decrease with time, due to the persistence of high desiccation by spontaneously appearing undergrowth of self-seeding species of other trees and shrubs. In other words, in the presence of tree and shrub vegetation, freshwater lens recovery does not occur.

It is this process of freshwater lens depletion in the middle part of the forest massifs that suggested the mechanism of replacement of desucc tively expended moisture by upward underflow from the underlying sandy horizon (Sapanov, 2000, 2003). In particular, this is indicated by the depressive funnel bottom with a slope of only 0.23±0.1 degrees (Table 3), as well as by the unchanged preservation of fresh water in he lens under the virgin paddy around the forest massif and even under the edge rows of trees (Table 4).

The lenticular zone in the lens beneath the plantation no more than 8—10 m wide remains desalinated for a long time, apparently due to lateral freshwater inflow from beneath

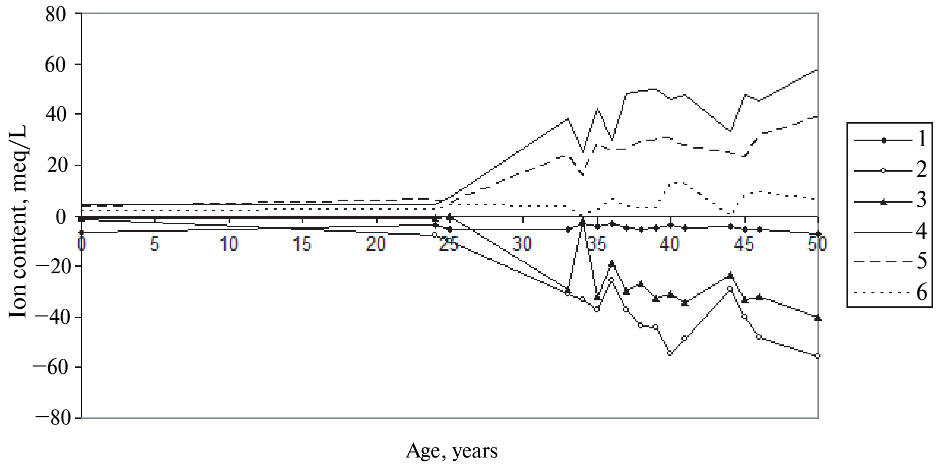

Fig. 2. Dynamics of secondary salinization of freshwater lens under oak crops in padina. Ions: 1 — HCO_3^-; 2 — CI^-; 3 — SO_4^{2-}; 4 — Ca^{2+}; 5 — Mg^{2+}; 6 — Na^+ (cited in Sapanov, 2003, with addition).

Table 3. Highest gradients in water levels in the freshwater lens within the 35-year-old oak plantation and in the edge zone

Plot	Time of year	Slope of groundwater table, deg	Standard deviation
Inside the plantation	spring	0.23	0.1
	summer	0.32	0.1
Downdraft	spring	3.43	2.5
	summer	21.2	2.1

Table 4. Autumn salinity and groundwater composition along the profile: virgin solonchak solonetz — virgin light chestnut soil — virgin meadow-chestnut soil of big padina — forest massif with width100 m of 35-years old crops of oak cherry — 36-years old crops of soft hawthorn (*Crataegus submollis* Sarg.).

No.	The sum of the salts, g/l	mmol-eq./L						
		CO_3^{2-}	HCO_3^-	CI^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+
Solonchak solonets (50 m from padina)								
1	9.09	0	6.8	76	62	29.6	21.7	93.5
Light chestnut soil (on the slope of the padina)								
2	6.07	0	4.7	2.2	81.5	20.5	16.5	51.4
The virgin eastern part of the padina (16 m from the crop edge)								
3	0.84	0	6.2	4.6	1.4	4.7	3.7	3.8
The virgin eastern part of the padina (5 m from the edge of the forest)								
4	0.90	0	6.6	2.3	3.9	6.3	4.2	2.3
Eastern forest canopy 1 stand row								
5	0.91	0	7.2	3.8	1.9	6.3	2.6	4
Forest stand area (2 m from 1 row)								
6	1.01	0	5	9.7	1.4	8.9	5.3	1.,9
Forest stand area (4 m from 1 row)								
7	1.13	0	4.2	14.3	1.4	11.1	3.6	1.3
Forest stand area (8 m from 1 row)								
8	1.30	0	4.2	18.1	0.5	13.2	9.4	0.2
Middle part of the stand (50 m from the eastern edge)								
9	4.89	0	5	41.4	34.5	52.2	27.8	3.4
Middle part of the stand (25 m from the western edge)								
10	4.94	0.6	4.8	32.4	42.8	40.4	25.3	14.3
Western forest canopy 1 stand row								
11	1.23	0	5.6	12.8	1.9	11.1	8.4	0.8
Hawthorn crops								
12	1.42	1.4	5.5	16.4	1.3	7.7	6.5	9

the adjacent part of the padina along the slope of more than 21^0 clearly expressed here (Table 3 and Table 4).

Therefore, the trees here continue to remain healthy. However, if the stand is located close to the edge of the paddy, the edge trees also die due to lateral inflow of saline water from under the adjacent light chestnut soil (Sapanov, 2003).

The freshwater lens is not salinized at all when planting narrow forest belts on the paddy, even when using highly transpiring species, for example, of squat elm. In the elm two-row 70-year-old plantation the salt concentration does not exceed 0.880 g/l. As we can see, in the edge rows of massive stands and in narrow forest belts, desucc tive discharge from the capillary border of freshwater lens is obviously dampened by lateral water inflow from under the adjacent virgin part of the paddy. In turn, on virgin land, the freshwater lens is periodically replenished by infiltrating meltwater, which is usually irretrievably lost as outflow along the underlying sandy horizon. It is the interception of this freshwater that provides the rationale for the establishment of ecologically neutral stands in relation to freshwater lenses. This practical result can only be achieved by establishing narrow forest belts or small clumps of forests evenly spaced away from the edge of the padinas. Existing single 100-year-old healthy specimens of petiole oak and a clump of smooth elm (*Ulmus laevis* Pall.) in the padins near the station confirm this thesis.

The study and long-term monitoring of water-salt regime of all types of soils in the plain Caspian area in virgin and afforested condition earlier allowed us to propose similar variants of afforestation establishment (Sapanov, 2003), but the analysis carried out here revealed the whole scenario of water movement in the landscape, including perpendicular vertical water exchange with the underlying sandy horizon along the closed local depressions of relief (large padins). This significantly details and deepens our understanding of the water cycle in the semi-desert of the Northern Caspian Sea, and also makes it possible to create sustainable forest crops with hydrologically sustainable regime of water consumption through the use of irretrievably lost infiltration water.

CONCLUSION

Soil hydrology was investigated in agroforestry systems of Dzhanybek station, which is located on heavy loamy complex soils of the Northern Caspian Sea area, in order to optimize silviculture.

It is shown that in this area the participation of groundwater in moisture cycle under different types of soils is very different. The role of saline water in vegetation evapotranspiration on solonchak solonts and light-chestnut soils located on upland areas is quite insignificant, since its discharge is mainly in the form of physical evaporation.

The role of water from freshwater lenses of local relief depressions (hollows and large hollows) with meadow-chestnut soils is quite large and varies significantly depending on their areas. In small hollows, where this lens is initially low-powered and unstable, forest plantations completely exhaust it. Preservation of stands here depends on the degree of additional moisture accumulation by the entire soil-soil strata due to frequent snow collection and winter-spring surface inflow of melt water.

The virgin large padins are filled with melt water only periodically every few years; infiltration of this moisture replenishes freshwater lenses and is consumed by horizontal outflow along the underlying sandy horizon, causing a simultaneous, hydrostatically driven, seasonal vertical rise in the water table beneath saline soil types.

In afforested padins under massive forest plantations, desucc tive flow prevails in the freshwater lens, which causes its depletion in the period from 22 to 27 years to the level critical for trees. This is due to the fact that annual water replacement in the middle part of the stand is due to hydrostatic vertical upward flow of moisture from the underlying sandy horizon into the depressional funnel bottom in the lens. In pubescent rows, as well as in narrow forest belts and under separate small clumps, such replacement is carried out due to lateral freshwater inflow from under the virgin part of the paddy along a noticeable slope of the depression funnel.

The conducted studies reveal for the first time a general scenario of climatogenic dynamic-equilibrium standing water table on complex soil types of the Northern Caspian Sea under the participation in the moisture cycle of the sandy underlying horizon under local mesoponifications of the relief (large padins) and reveal the possibility of creating small-scale sustainable forest plantations with ecologically sustainable hydrological regime, under which desucc tive discharge from freshwater lenses will be replaced by infiltration water irretrievably lost to in-soil outflow.

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