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WATER BALANCE OF FORESTS IN A SOUTHEAST PART OF MOUNTAIN CRIMEA

The aim of the research was to study of water balance of the forests in the south-eastern part of the mountainous Crimea, located on the border of their natural occurrence areal;

The following tasks were specified :

1. to establish the structure of water balance in various forest ecosystems, differing in steepnes and arrangement of slopes, amount and nature of atmospheric precipitation, nature of underlay soils and rock;

2. to analyze the relation of phytogeometry of forest ecosystems with the components of water balance;

Novelty and importance of the proposed task: on the territory of about 100-130 thousand hectares Crimean forests grow under insufficient moisture conditions, on the border of their natural occurrence areal. That is why any changes in their growth conditions, connected with both natural and human factors, can violate the established conditions.

In the south-eastern part of the mountainous Crimea the majority of forests have ecotonic nature. Oak forests of the 3, 4, 5 bonitet classes prevail there. The forests are mainly of a verdure type. To a considerable degree their productivity is connected with the correlation of heat and moisture. Another important factor is the following: a long period (2-3 centuries) of human influence, including chopping, soil and grass trampling, fires, disarrangement of biogeocenotic interactions and growth of susceptibility to pests.

Processes of the Crimean forests degradation result not only from human, but also from natural factors. Location of the forests in extreme conditions doesn't provide for the possibility of natural regeneration by seeds because of moisture deficiency during the period of seeds sprouting and appearance of shoots. Slow growth and these conditions hinder their shoots regeneration, and in many communities dry tops and root systems dying-off can be observed. Further degradation of the Crimean forests is also preconditioned by a recurrent total damage of leaves and young plants by entomofauna, rodents and hares; seeds and shoots are eaten up by other animals (Polyakov, 1980; Mishnev, 1986).

The south-eastern part of the mountainous Crimea was chosen for the present research because of the following reasons:

1. This area has sites and stations where observations of forest cover, as well as of various landscape and geophysical characteristics take place.

2. In this part marginal effects are especially significant and this fact is important for studying forests growth processes under unfavourabe conditions.

The south-eastern mountainous Crimea is characterized by various landscapes. In the axial part of the mountains at a height of 700-900 m rock oak and beech forests can be found. Lower they are substituted by oak forests. From a height of 300-400 m the latter are substituted by shiblyak and steppe ecosystems. However, it is only a general background picture of ecosystems spatial distribution. It is distorted to a certain extent by local humidification and temperature conditions. The greater part of the observations was carried out within the borders of the Kara-Dag nature reserve, founded in 1979. On the rest of the territory forests belong to the first group where industrial felling is prohibited and only maintenance chopping takes place. The forests in this area perform recreational and regenerating functions.

The research is based on the observations which have been carried out at the Kara-Dag landscape-ecological stationary since 1993, at the Kara-Dag hydrometeorological observatory, at the Voronskiy stationary, at several dozens of semi-stations where monitoring of exogenous geodynamic processes is conducted.

Main experimental area is situated on the sloping (10-15^0), average height 185 m above sea-level. Structural soil is brown and small carbonate. Structure of phytocoenosis: downy-oak forest with Cornelian-cherry-trees, bonytet – 4. Vertical structure phytocoenosis which is researching, may have some layers: wood layer of underwood, grassy and layer of forest bedding.

The height of wood layer contains 10-12 m (average height of wood layer 8-9 m). It is downy oak and also field maple, tall ash-tree. Power of tree-top of wood layer 4-7 m (the height of low border treetop 3-4 m). The distance between trees is 2.5 – 4 m. According tree we can say the following valuation survey data: common close 0.7 – 0.8; the average height 8 m, the average diameter on the level of chest 20-22,8 cm, the composition of trees is 244 downy oak, 23- field maple, 4 tall ash-tree.

Underwood is clear and contains in common from cornelian-cherry-trees as usual, haw-throns, morose common. The height of underwood from 1 till 4 m, the close is not the same in the borders of the part of area and in average contains 0,3 – 0,4. Undergrowth (H – 0,5 – 1 m) is seldom, there are maples, ash-trees, ash-thorns, oaks practically is not noticed. Grassy layer is seldom and it is not the similar, designed cover in average contains 20% (H_{av}) - 15 sm.

The grassy layer is more expressed in the places where the forest is not so closed (in forest window) and also at the border of the forest.

On the surface of soil is the stratum from deciduous leaves in average 2-3 cm, but in microlowerings till 5-6 cm.

Horizontal structure of forest phytocoenosis is not the similar. There are some smaller elements of differentiation – parcells.

The most vegetation species appear from the second ten days period of April till June, the least from the second ten days period of August till second ten days period of October.

The curve spreads along the leaf surface of oak trunk in phytocoenosis discovers in the main layer the top 6.5 m for the low and top parts is disappeared, the most of new sprouts are at the top of crowns space. The curve spreads of non leaf surface of oak trunk underlines the main feature which practically is l_1. At the height 3 – 3.5 m is the second less expression , which coincide with the place where trunks and branches begin instead in the middle and the top parts of the crown.

Thus, we have obtained enough data giving representative information concerning water and heat conditions of the forests in this area.

Observations of the water balance components

The system of observations included: 1.Atmospheric precipitation; 2. Evaporation monitoring by microevaporators; 3. Monitoring of the run-off from tree crowns; 4. Monitoring of the run-off from tree trunks; 5. Monitoring of ground humidity under the trees; 6. Monitoring of the run-off from the ground on an open site; 7. Monitoring of the Surju-Kaja southern spring flow rate; 8. Monitoring of the underground waters level in the Kara-Dag valley.

Atmospheric precipitation

Atmospheric precipitation monitoring was conducted at the background station Verkhnije Trassy by an ordinary precipitation measuring device, as well as by the devices for precipitation measuring in the form of glasses. Measurements, obtained at the Kara-Dag meteorological station were also used. When active observations of water balance components were taking place (August - November, 2000), precipitation was very scarce. In September-October, when there were leaves on the trees, precipitation was 14,2 mm, and in November there was no precipitation at all.

At the Kara-Dag meteostation (40 m above sea level) atmospheric precipitation is 410 mm a year. A background monitoring station is situated not far from mount Svjataja, 250 m above sea level. The quantity of atmospheric precipitation rises there up to 550-570 mm a year. Evaporation is 850 mm a year. Thus, the Vysotsky-Ivanov humidification index is equal to 0,66. Such climatic humidification corresponds to the conditions of a southern forest-steppe region. Formation of forest phytocenoses here is probably connected with north-eastern orientation of the slope and this fact determines lesser heating. It means that real humidification is higher in comparison with background climatic one.

With magnification of hight above sea level the annual amount of a rainfall will increase by 60 millimeters on everyone 100 meters.

Evaporation

The background evaporation is equal 400-500 mms per one year. To carry our monitoring of evaporation from the ground compact evaporators - empty steel cylinders, wall thickness - 2 mm, diameter - 80 mm, height - 200 mm - were installed under the forest canopy.

Run-off from tree crowns

The quantity of liquid atmospheric precipitation intercepted by trees was established by precipitation measuring devices according to the difference between the precipitation falling out above the forest or over open spaces and permeating under the forest canopy. One part of the intercepted precipitation is spent on evaporation, another part runs off the crowns, and the third - from tree trunks on the ground. Observations of the run-off from the crown of a typical tree in the oak forest at the "Verkhnije Trassy" station took place in September-November, 2000. During three months, and they turned out to be very dry, atmospheric precipitation didn't permeate under the tree crowns. For obtaining generalized data, we used the results of the observations, which took place in the 80s and 90s, as well as data by some other authors (Vis, 1986).

It was found out that interception depends on the area of leaves and needles. The more closed plant canopy is, the more precipitation is retained, evaporated and doesn't participate in the run-off formation. Casual observations, which were conducted at other times, showed that during a cold season a coniferous forest retains more atmospheric precipitation than a leaf forest. Leaf trees have maximal interception during their vegetation period and minimal interception during their intervegetation period. It depends on the species, age and closeness of the forest.

Precipitation which has permeated through the forest canopy, reaches the ground in a transformed form. Transformed drops are bigger than rain drops, but they fall from a lesser height and don't manage to gain ultimate steady speed

It was experimentally established that drops, fallen from oak trees from a height of 15 m are 2,5 times bigger than rain drops. Their mass turned to be by an order of magnitude greater, calculated falling rate by 61% greater, kinetic energy by a factor of 31 greater than the same parameters of heavy shower drops (Roschkovan, 1981).

The run-off from trunks is lesser than the run-off from leaves, and looks like a stream. Theoretically it will be greater during the same rain in those trees which concentrate the run-off from the branches on the trunk and have a smooth rind. In the trees with a rough rind the run-off is redistributed along numerous lengthwise furrows.

The run-off can concentrate on the ground surface near the trunk base and cause soil erosion.

Monitoring of the run-off from tree trunks

Atmospheric precipitation water, running of a trunk, is intercepted by a tightly fastened metal groove and is extended into a measuring reservoir. The quantity of atmospheric precipitation permeated under the forest canopy and rolled from the trees along the trunks, surface run-off and soil erosion depend on the form, density and height of the crowns, leaves, skeleton brunches and trunks morphology, structure of the root system, capacity and moisture content of the forest underlay, presence of an underbrush, grass cover, moss and lichen. More detailed data concerning intercepted atmospheric precipitation by tree crowns is given in some publications (Landscape-geophysical conditions, 2001;).

On the average, annually pine forests intercept 13-25%, oak forests - 8-42%, beech forests - 4-8% of fallen precipitation.

Calculations show that during the vegetation period about 65-72% of the fallen atmospheric precipitation can permeate under the crown of an oak, growing in a mountain lower height belt. Annually it makes up 75-80% of the fallen atmospheric precipitation.

Run-off from the ground surface under the forest

Water of atmospheric precipitation, permeated through the forest canopy and run off the trunks, can cause a surface slope run-off. But, as a rule, under the forest there is a forest underlay, which is water-proof and has good moisture capacity. It is capable of absorbing water quickly, taking a surface run-off to an underground one, restraining evaporation and soil erosion. The underlay absorbs water many times better, than its dry mass. It retains 4-20 mm and even more, depending on its thickness and other factors.

In September-November, 2000, when observations were taking place at the "Verkhnije Trassy" station, a surface run-off under the forest was not formed because of insignificant atmospheric precipitation. On gentle underlayed slopes, such as the run-off site, it can form only during a period of heavy showers, continuous rains and melting of a thick snow cover, but it happens very seldom and not even every year. More often the run-off is caused by summer showers of extreme character. Formation of destructive high-floods in the gorges and valleys of the forest belt of the Crimean mountains is connected with such showers.

The heavy shower of 09.06.1998 above the water-collecting crater of the Voron River valley lasted for almost two hours and pored about 80,2 mm of liquid precipitation. It caused formation of a surface run-off and a destructive high-flood, with flow rate of 78 m/sec within the Voron River banks. Precipitation, permeated under the forest canopy, washed away only steep river-bed slopes which were not covered by an underlay.

Run-off from the ground surface on open sites

Regular monitoring of the surface and underground run-off was carried out at the landscape-ecological station during the period of 1995-2000, and at the "Verkhnije Trassy" station observation of the run-off from open slopes was conducted in September-November, 2000. Besides, short-time observations of the peculiarities of run-off formation in forest landscapes of other parts of the Crimean mountains were performed.

For the surface run-off monitoring a run-off site was used. The monitoring was conducted after a run-off-forming precipitation fall by a standard procedure (Instructions..., 1975; Recommended methodology..., 1975; Hydrological..., 1987).

In 1996 two minor run-off sites ROS-1 and ROS-2 were constructed on the territory of the landscape-ecological station, on the slopes well-bedded with turf. These sites are the main part of the obsevation system, carried out at the landscape-ecological station.

From 01.07.1996 to 01.12.2000 a surface run-off on the run-off site ROS-1 was formed only once, and on the run-off site ROS-3 - four times. All the cases at the ROS-3 occurred in August and September 1996, when after a long dry period atmospheric precipitation reached 94,0 and 191,4 mm. It exceeds an average monthly norm by 4 and 6 times. During this very wet period daily precipitation 5 times exceeded 20,0 mm and reached 42,7 mm.

In all cases liquid and solid run-off from the slopes was insignificant - correspondingly from 0,09 to 0,33 l/m^2 and from 0,14 to 0,28 g/m^2 during one case of a run-off.

In all cases the run-off from the ROS-3 was connected with heavy showers with capacity of 40,6 mm /10.8/, 42,7 mm /4.9/, 27,5 mm /11.9/ and 23,0 mm /24.9/, their average intensity was from 0,09 to 0,40 mm/min. In some periods intensity of these showers was considerably greater.

In the period of rains in August-September 1996 the run-off site ROS-1, which is located nearby in similar conditions, but on a short slope, surrounded by old oaks, didn't give any run-off. It was registered only at the beginning of January during melting of snow which had fallen previously and had been redistributed by wind. The snow could be blown away from the slope with the ROS-3 and could accumulate on the slope with the ROS-1, could evaporate from the southern slope, where the ROS-1 is located.

Since that time and to present a surface run-off on the run-off sites of Kara-Dag hasn't been noticed, though during the last 4 years liquid precipitation was about 20,0 mm per day. Five rains /20,0-50,5 mm/ out of the above mentioned ones had average intensity of 0,09-0,11 mm/min., and one shower falling on 23.07.1997 during 26 minutes had average intensity of 1,01 mm/min. These rains, similar to the run-off-forming precipitation of 1996, didn't give any run-off.

A thick grass cover intercepts 42-100% of single liquid precipitation with the amount less than 5-10 mm and 14-25% with the amount of 15-20 mm and more.It is possible to come to the conclusion that during dry years the surface run-off from slopes well-bedded with turf is formed when the amount of heavy showers exceeds 20 mm with average intensity of 0,09 mm/min., fallen on previously dampened soil, and during humid years it is intercepted by a higher and thicker grass cover and can be formed under more intense and plentiful precipitation (more than 33,4-44,1 mm and average intensity more than 0,10-0,11 mm/min.).

Spring flow rate

The Surju-Kaja southern spring was chosen for regular observations. It is located not far from the landscape-ecological station on one of the slopes of the Kara-Dag gorge.

Underground waters level in the gorge

Monitoring of underground waters conditions were conducted in an old well, located at the bottom of the gorge, at a distance of 0,3 km from the landscape-ecological station. The well is dug in contemporary 5m thick proluvial sand-and-gravel sediments. During the observation the level variation amplitude reached 3,68 m. The level lowered to 4,80 m and rose to 1,12 m below the gorge bottom.

In accordance with the observation results average monthly and annual values of the underground waters level were calculated /Diagram 10/. The diagram shows that the level was very low in 1995-1996 and high in 1997-1998, and it was average in 1999-2000. The variations of underground waters level in the gorge show that

at the beginning of the vegetation period during humid years these waters can be reached by the plants with root systems penetrating at a depth of no less than 1,5-2 m, and in summer and autumn at a depth no less than 2,5-3,0 m. During dry years underground waters can be used by trees whose roots penetrate at a depth no less than 4-5 m below the surface.

The results of the observations are described in the book Landscape-geophysical conditions.., 2001.

General conclusions on water balance

Observations and data obtained by other authors show that about 75-80% of annual precipitation and 65-72% of precipitation fallen during the period when there are leaves on the trees can penetrate through tree crowns of a closed oak forest. Out of precipitation intercepted during a year about 3-5% can run off down tree trunks on the ground.

Research by I.P.Ved (1970) proves that balance studies should include horizontal precipitation - fog condensation, drizzle, sleet, etc. Their quantity in the Crimean mountains reaches 20-25% of the annual precipitation layer. They compensate for the losses on interception. The amount of horizontal precipitation is higher in forests and lower in open spaces. They play an important role in vital activity of plants without a deep root system in dry seasons.

In sparse growths of trees, where there is no forest underlay and a grass cover is very thin, transformed rain drops, falling from the crowns, water streams, running down from the trunks, are capable of causing a trickling and streamline erosion under the trees canopy.

In closed forests with a good forest underlay a surface run-off occurs only during heavy showers. When extreme precipitation of rare recurrence takes place in gorges and valleys covered with forests, then destructive high-floods and mountain torrents spring up too. It usually happens once or twice in a century.

A surface run-off from water-collectors well-bedded with turf, covered with forests and sparse growths of trees is formed very seldom. During 6 years of observation, when typical (in terms of amount and intensity) atmospheric precipitation fell out and there were no extreme showers, a local run-off from the slopes was registered only during the most humid months of 1996, and there was no run-off in the gorges at all. During the last 10 years it took place, perhaps, only in September 1991 when an extreme rain (in terms of precipitation amount) fell out. The rare occurrence of a surface run-off indicates that precipitation is transferred into an underground run-off and a considerable loss of precipitation and evaporation takes place.

Springs don't play any significant role in the replenishment of underground waters and in the life of plant communities.

Underground waters concentrate at the bottoms of large gorges and valleys. The depth of an underground waters layer varies depending on the amount of precipitation. During the main part of the vegetation period, when all plants especially need water, underground waters are located deeply under the surface and are accessible only for the plants with deep root systems.

The given data and some quantitative characteristics are indicative of very complicated water supply conditions in which living organisms find themselves living in the sparse growths of trees and oak forests of the Crimea.

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