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## ESTIMATION OF THE MOISTURE TURNOVER IN THE VICINITY OF MOSCOW

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Observations for 25 years at the Sobakino agrometeorological station led to the setting up of a scheme for the local moisture distribution in the Moscow area. The agrometeorological station at Sobakino is found 30 kilometers southwest of Moscow in a fairly flat location. About 40 percent of the total area of the vicinity of the meteorological station is under a forest; the soils are heavy — namely, podzolic clays. Meteorological observations began in 1915. For working-up purposes observations from 1915-1941 were taken. In addition the field station for more than ten years carried out observations at an additional station in the locality for the purpose of studying the run-off located within a kilometer from the field station. The region of the run-off was found within 300 meters of the border of the large solid mass of forest in an area of a few thousand hectares. The scheme of water turnover was calculated from the formula:

precipitation + condensation = evaporation + run-off + filtration.

Observations on precipitation were carried out both at the main field base and at the run-off area.

The results showed that the total quantity of precipitation in the warm time of the year (April-October) was 384 millimeters. The mean results obtained over 10 years by parallel observations at the main field station and at the run-off area gave satisfactory agreement: at the former, 378 millimeters; at the latter, 384 millimeters. Thus agreement is pretty good. We take as the precipitation the round figure of 380 millimeters.

Measurement of the snow precipitation gave different results. The field station for the winter months (November-March) found 89 millimeters, the run-off where the rain gage (protected and guarded with nickel-iron) stood near the border -- 138 millimeters.

In order to determine which of these magnitudes was more accurate a supplementary study was carried out in the park of the agrometeorological station on a large glade of oval form (the large dimension ~~the transverse one~~ was about 80 meters and the small one about 30 meters) surrounded by high (20-25 meters) trees of various species (greenwoods and conifers). Therefore, even in the most powerful wind there were observed in the glade no drifts or drifting snow at all. In the times of snowstorms it was possible to see how snowflakes spinning on high, on reaching the level of the crests of the trees, fell quietly and tranquilly to earth. The snow fell in an even layer, on the whole glade. In the midst of this glade in the winter of 1927-28 there was set up a rain gage with a nickel iron fence of the usual height of 2 meters, above the earth. Parallel measurements from December-March gave 43 millimeters in the field and 79 millimeters in the park. Thus the rain gage in the park gave 184 percent of the snow precipitation measured by a rain gage in the field. Assuming the figure measured in the park as the real quantity of precipitated snow which fell we obtain from the above computation for the cold season normal amount of winter precipitation, the figure of 165 millimeters.

The snow gage survey gives also a close value for the winter precipitation. The average of a series of annual snow-gage surveys on the experimental field gave at the end of March a value of about 116 millimeters (varying between the limits of 102-188 millimeters). The evaporation at the surface of the snow according to Wild came to 59 millimeters, up to the present time. The sum of these magnitudes

(116 + 59 = 175 millimeters) gives a value close to the above-mentioned quantity of winter precipitation measured by the rain gage. When we round off these figures we obtain as the normal amount of winter precipitation 170 millimeters, and as the total precipitation we obtain 380 + 170 = 550 millimeters.

In addition to precipitation incoming forms of water distribution are manifested directly by condensation of water vapor in the form of surface or subsurface dew. If it is difficult to calculate the amount of winter precipitation that falls, it is still more difficult to calculate the amount of moisture condensing directly.

Let us first analyze the case of condensation on soil and plants. As is well known, the temperature of the surface of the soil and plants differs from the temperature of the surrounding air. On sunny days they are higher as a result of the sun's radiation; on a clear night they are lower as a result of emission. When the night-time relative humidity of the air reaches the dew point at the temperature of the soil surface or of the plants, dew forms on them. Yet the temperatures of the soil and of various plants are different as a result of the different emission in dependence on color, the character of the surface, the heat capacities and the orientation. Therefore, the amount of dew on them will also be different. To calculate the total amount of dew by the usual gravimetric method is not possible. The best of these methods -- the hygroscopic plates of Leick -- also is inadequate. Painted in various colors -- brown, green, yellow -- they give various amounts of precipitated dew. A more objective method is found in the calculation of the decrease of specific humidity of the air in the surface layer during the night hours, as shown by us in a special way.(1)

Let us analyze the final results. The recurrence of dew which we had was very great. The ordinary meteorological observations, especially by the old instructions, did not yield the total dew formed and dried up between the hours of 21 and 7 or between the hours of 1 and 7. The partition "drososcope" of Kariozopolis (1) which recorded all the rain gave materially great repetition. Parallel observations by us for the two years 1939 and 1940 gave by the drososcope 167 percent of the usually visually recorded dew. The mean quantity of dew by visual observations over 25 years from April to November was 86. The actual figure with corrections must be 146. By the observations of the Leick dew measurement at night a mean of 0.14 millimeters of dew was formed. In all for summer about 20 millimeters were formed. This value in my opinion is exaggerated.

Let us turn to soil dew. The change of soil moisture over the course of a summer day -- lowered in the afternoon hours and increased in the night hours -- is an irrefutable fact. But as to whether it proceeds at the expense of condensation as A. F. Lebedev figures or at the expense of the absorption phenomenon, as P. I. Koloskov maintains, is a debatable point. We propose that when the moisture in the soil is less hygroscopic both processes are possible and when the moisture is more highly hygroscopic then the condensation process must operate. Absorption would contradict the whole idea of maximum hygroscopicity. No matter how that would be, still the amount of the supply of moisture in the soil in addition to precipitation is not open to doubt. To determine the amount of condensation accurately is possible only by observation of soil moisture at every layer. We regard with suspicion the usual method of calculating soil dew by weighing in the evening and in the morning a glass full of soil placed in a depression in the earth. Unfortunately the determination of soil moisture by the drilling method is very difficult and a systematic investigation by it is not possible. With students from MGMI* I carried out systematic observations on soil moisture in a half-meter layer over the course of a day and a half during every two hours with a 5-fold frequency. They revealed that at night moisture only penetrated the surface of a 10-centimeter layer and did not sink deeper. The size of the supply is small and in the summer months perceptible amounts are not formed. *(Note: MGMI is Moscow State [illegible])

It is not thus in the winter. Every winter after the ground freezes the supplies of moisture in it grow all the time. Since it is not possible for moisture from precipitation (snow, frost) to penetrate, then the amount of it may change only due to condensation. During the remoistening, absorption is scarcely possible. Six-year observation on winter corn and crops gave as an average in November a supply of water in the half-meter layer of 166 millimeters, and in March of 216 millimeters. The difference of 50 millimeters; the absolute amount of moisture for some reason has not been calculated. If the difference in the supply is taken between the first 10 days of November and the last 10 days of March, then it is even greater -- 77 millimeters. But this value is less reliable due to the possibility of penetration into the soil of the liquid precipitate at the start and end of winter. More reliable is the amount taken for the last 10 days of November to the second 10 days of March, inclusively -- 42 millimeters.

| | |
|---|---|
| Atmospheric precipitation in the summer | 380 millimeters |
| Atmospheric precipitation in the winter | 170 millimeters |
| Dew | 20 millimeters |
| Winter condensation | 42 millimeters |
| | 612 millimeters |

Let us turn to the calculated part of the balance: evaporation, run-off, filtration.

Evaporation was observed with surface water, ice, snow, and with soil, both bare and covered with vegetation. Systematic observation was carried out the whole 25 years only on evaporated water and snow by the Wild apparatus. The observations on the Wild apparatus were censured without cause. It is undoubtedly necessary to vindicate them everywhere. Basically it is best to use them in a uniform apparatus and conditions of the same type under which they work with great simplicity and convenience of observation. The apparatuses are found at all stations at one condition of height, ventilation, and are protected from the sun. A small mass of water in the cup guaranteed rapid perception of the temperature of the surrounding air. The eternally perplexing question comes in for this -- at which temperature whould the calculation of the moisture deficit be made -- water or air temperature. Careful maintenance of the apparatus -- lubrication of the bearing parts, fineness of the prism, maintenance of the urosine water filling always carefully watched -- guarantees uniformity and accuracy of results. Undoubtedly, of course, it is true that the displayed Wild apparatus does not give the actual amount of vaporization in the reservoirs. But the work of the Yershovski Reservoir showed the constancy of the rewetting coefficients, and according to Pozdnishev it comes to 84 percent.(3)

Our comparison of the given Wild apparatus with the given soil evaporator at definite conditions also gave stable rewetting coefficients.

According to Wild, evaporation with surface waters during April-October came to 574 millimeters, with surface snow during November-March

59 millimeters, with surface ice about 20 percent less than with snow. Apparently the roughness of the surface and the porosity of the snow are determining.

It is considerably more difficult to determine evaporation with surface soil, both with bare and with vegetation-covered soil.

Observation on evaporation with soil was not carried out systematically by us since the vaporization of different systems was investigated: Pikachev, Popov, Pikachev with a humidified system, and Dorant. There was calculated also the evaporation for a change in the reserve of water in the soil and a dropping precipitation. In the special form selected by us for the conditions of operation of this apparatus, we here only indicate that for climatological purposes the observations of the Popov apparatus alone may be used. All the others are exclusively for special agrometeorological purposes.

The Popov evaporator with 2-3 time repetition gives an accuracy of the order of 5 percent. Evaporation in the lysimetric position of the apparatus is less than in the evaporometric one. It is necessary to take the average of the results in both positions. A Check shown in the observation of the change of the water reserve in the soil gives completely agreeing results.

Unfortunately the Popov apparatus operated only a few years and gave the following amounts of evaporation:

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|---|---|
| 1935 sod, June — October | 320 millimeters |
| 1937 fallow field, June-September | 227 millimeters |
| 1937 oats, June-September | 247 millimeters (after harvest of oats, crops) |
| 1938 fallow field, June-August | 108 millimeters |
| 1939 fallow field, June-August | 88 millimeters |

The following amounts of vaporization (in millimeters) give a more continuous observation on the moisture of the soil and the precipitation in the field:

SUPPLY OF WATER IN A HALF-METER LAYER OF SOIL

| | Decade III April | Decade III September | Difference | Precipitation May-September | Evaporation |
|---|---|---|---|---|---|
| Fallow | 156 | 153 | 3 | | 310 |
| Rye | 177 | 131 | 46 | 307 | 353 |
| Oats | 166 | 126 | 40 | | 347 |

In the given quantities the vaporization did not enter in April (from the descent of snow till the first determination of soil moisture) and in October; therefore, for them it is necessary to make an addition. Evaporation for the rewetted soil as shown by our observations departed little from the evaporation of water in the Wild apparatus. Snow on the average stood at 10 for April; for two decades of April there evaporated, according to Wild, about 40 millimeters and in October about 35 millimieters. To the sum of these quantities (75 millimeters) there follows the addition of the above-mentioned amounts of evaporation, i.e., evaporation with fallow, and winter corn comes to 385 millimeters, with a field of rye and after plowing to 428 millimeters, with an oat field and with winter corn to 422 millimeters.

Evaporation in the sod gives a special observation on the soil moisture conducted at the meteorological station. Since in the years 1935-1941 at the beginning of springtime, after the way the snow stood and the cracks on drilling did not overflow with water, tests of moisture were carried out at the meteorological station with 5-fold frequency repetition. In late Autumn when the weather was freezing, tests were carried out anew. The region of the meteorological station is level, and without drainage. The surface of the soil is well sodded; since 1919 it has not been worked up.

The observations gave the amount of evaporation with sod as a mean of 366 millimeters (varying from 303 to 440 millimeters).

Observations on the run-off were carried out over a course of 10 years on the special region.

In brief the following principal conclusions are drawn: The principal run-off proceeds in the spring due to the thaw water. Summer run-off is small. The amount of run-off is governed by the slope and character of the surface soil (sod, plowed land, crop land). The run-off of thaw water with waste land at a slope of 23 thousandths came to 44 millimeters; with plowed land, 60 millimeters. The summer run-off with waste land came to 7 millimeters; with plowed land, 35 millimeters. In annual results the run-off was 51 millimeters for waste land and 95 millimeters for plowed (crop) land. The run-off in the woodland was not observed.

The last form of water discharge is filtration. The fundamental lysimetric observations were made by the section of soil science under the direction of Professors Gemerling and Kochinsky. In various years three stations have worked with lysimetric apparatus, without disturbing the soil structure under various soil science-genetic countours. Unfortunately these observations thus far have not been made public and it is necessary to be limited only to our personal impressions. Filtration in the summer was very insignificant and was observed only in the upper contours. In the spring it was much larger and all the lysimeters worked to a depth of 2 meters. Our observations on filtration with the aid of the lysimeter evaporator of Popov and Dorant also showed extremely low filtration in the summer just after very heavy rains.

For the determination of filtration of thaw water we attempted to proceed by an indirect method. We measured at a flat place on a plowed field the supply of water in a meter layer for a determined wetness of the soil during a snow fall and some weeks after. Adding the amount of precipitation at this time and calculating the evaporation we must get as the residue the filtration through the meter layer.

The run-off we calculate at a level place is negligible. Observations in 1940 gave the following:

The supply of water in a meter layer of soil:

Initial 19/IV* 384 millimeters (*Note: "19/IV" stands for 19 April)

Final 30/V 324 millimeters

Precipitation for 19-30/IV

Discharged 38 millimeters

Evaporation 23 millimeters

384 − 324 + 38 − 23 = 75 millimeters

Filtration is 75 millimeters.

Analogous calculation for 1940 gave:

Filtration for 19/IV to 29/IV 1 millimeter

Filtration for 19/IV to 9/V 1 millimeter

As we see, the results agreed.

The range of calculated quantities is very large and the average of them is scarcely reliable. But we had no other data.

We come to a discharge balance (in millimeters):

VAPORIZATION

| | Run-Off | Winter | Summer | Filtration | Total |
|---|---|---|---|---|---|
| Sod | 57 | 59 | 366 | 33? | 513 |
| Fallow field | 95 | 59 | 385 | 33? | 572 |
| Rye | 95 | 59 | 430 | 33? | 617 |
| Oats | 95 | 59 | 420 | 33? | 607 |

It is undoubtedly necessary to add the sod filtration since run-off is small with it and obviously due to the amount of filtration. We calculate it as greater by the amount of decrease of run-off with sod, i.e., by 95 − 57 = 38 millimeters. Then the filtration of thaw water in sod will be 33 + 38 = 71 millimeters. The total discharge with sod is 551 millimeters.

We come to a balance (in millimeters):

| | Fallow | Rye | Oats | Sod |
|---|---|---|---|---|
| | Charge | | | |
| Precipitation | 550 | 550 | 550 | 550 |
| Dew | 20(?) | 20(?) | 20(?) | 20(?) |
| Winter Condensation | 42 | 42 | 42 | 42(?) |
| Total | 612 | 612 | 612 | 612 |
| | Discharge | | | |
| Vaporization | 444 | 489 | 479 | 425 |
| Run-off | 95 | 95 | 95 | 57 |
| Filtration | 33 | 33 | 33 | 71 |
| Total | 572 | 617 | 607 | 553 |

As we see the balance for rye and oat fields agreed well; for fallow and sod they disagreed primarily by 10 percent decrease of discharge as compared to charge. More likely are shifts in the determined filtration (diminished in the fallow field) and in the dew (additive).

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