Assessment of irrecoverable retention of liquid atmospheric precipitation by meadow grass stands of the Middle Urals

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Abstract. The process of retaining precipitation by grass vegetation is important in the processes of moisture circulation in forest landscapes. At the same time, there is an erroneous opinion that grasses are not able to retain a significant amount of rain moisture, which further forms the river flow. For this reason, the question remains poorly understood. In turn, grass stands are able to retain rainfall on their leaves in whole or in part. It depends on the duration and intensity of the rain. The leaves of grass stands have a specific morphology and are arranged more vertically than the leaves of woody plants; therefore, moisture on the leaves of grasses is held in film and drip forms (in woody plants - only in drip). When droplets roll down the stem, water is trapped in bowl-shaped recesses or funnels of grass leaves. The article discusses the relationship of precipitation and vegetation. The authors conducted field experiments on the retention of rainfall by grasses that grow in the landscapes of the Middle Urals. The experiments consisted of artificial sprinkling of grass samples and their subsequent weighing (weight experiments). In the course of the experiments, the connections were developed for the retention capacity of rain deposited on the leaves of species of grass vegetation with the leaf surface area of grass stands and their green mass. The magnitude of the loss of rainfall on grass stands is comparable with the magnitude of the rainfall of individual rains. According to the results of the experiment, it was found that under the forest canopy, the interception of precipitation is 0.1–0.2 mm, in the clearings – 1–2 mm, in the clearings – 2–4 mm. The results can be used to assess the actual rainfall to the surface of the soil and to calculate the change in the discharge of water from rain floods on rivers as a result of forest successions.

1. Introduction

In modern hydrologic and ecological studies, there has been a strong opinion that grass stands retain a negligible amount of precipitation. That is why the role of grass stands in the process of a forest water cycle is often neglected. During forest succession and the replacement of forests with grass vegetation, rainfall infiltration into soils may be less than it was in forest landscapes, which affects the hydrological regime of rivers in the forest zone.

The present study aims to determine the values of irrecoverable rainfall retention on the leaf surface of grass stands during individual rains in the period of maximum growth of the green mass of meadows.
2. Coverage of studies

In foreign literature, there is evidence to indicate a wide range of values of grass stand capacity, depending on the type of vegetation and its density. As G. W. Lall notes [9; 14] that tall grass retains up to 84% of precipitation if rainfall intensity is 3.2 mm per 30 min and 47% if it is 25.4 mm [7].

Significant water retention capacity of grass stands is predetermined by high values of leaf area index (LAI, ha/ha) exceeding these values for tree stands. A special calculation of the leaf area of grass stands was carried out at the water-balance station near Moscow [6]. When grass stands are as high as 15-20 cm, the leaf area reaches 15-20 m² per 1 m² of the surface. Grass communities distributed in different climatic conditions have higher leaf indices than forest stands.

3. Materials and methods

Experimental work was carried out on the following species of grasses distributed in forest catchments of the Middle Urals: fibrous wheatgrass (Elymus fibrosus), rhizomatous sedge (Carex rhizina), nettle (deaf and dioecious) (Lamium album L, Urtica dioica L.), Cock’s-foot (Dactylis glomerata L.), dandelion (Taraxacum officinale Wigg.), common wormwood (Artemisia vulgaris L.), and coltsfoot (Tussilago farfasa L.).

All grasses growing on representative plots of 40×40 cm were cut off at the root and the number of plants and leaves on each of them were counted manually. Moreover, the number of leaves from which a random sample was formed (20-30 leaves) and the geometric dimensions of each leaf plate in the sample were determined. Statistical parameters such as average (normal) leaf area, characteristics of LAI variability (coefficient of variation) and bias (asymmetry coefficient) were calculated as well (table 1). In order to determine the capacity of water retention on the leaf plates, cut plants were artificially sprinkled using the unit designed and assembled by the authors (water is sprayed through the holes in 6 aluminium tubes arranged in parallel). The technique is described in detail in [2; 8-9].

Plants were fixed vertically in a metal grid. Using a weight method, both the total green mass before sprinkling and the maximum green mass during the sprinkling were determined. The difference in mass corresponds to the maximum water retention capacity.

Table 1. Statistical parameters of the sizes of leaf plates of the analysed grass stands

| Name of grass stand             | Statistical parameters of leaf surface area, m² |
|---------------------------------|-----------------------------------------------|
| Orchard grass (Dactylis glomerata L.) | 0.0011 0.18 0.54 |
| Taraxacum officinale (Taraxacum officinale Wigg.) | 0.0044 0.06 -0.31 |
| Sagebrush (Artemisia vulgaris L.)    | 0.0017 0.45 0.43 |
| Common bull’s-foot (Tussilago farfasa L.) | 0.0095 0.35 -0.27 |

4. Results and discussion

The most important result of the experimental work performed is to obtain actual data on the capacity of rainfall retention on the leaf surface of the analysed grass stands. The empirical data were interpreted in the form of dependences of maximum water retention capacity on the amount of green mass or leaf surface area (figure).

Expressed in terms of precipitation layer, the highest values of water retention are typical for rhizomatous sedge (Carex rhizina) which is 7.9 mm, followed by fibrous bromegrass (Elymus fibrosus) and nettle (deaf and dioecious) (Lamium album L. and Urtica dioica L.) with 2.5 mm and 1.1 mm respectively. For other analysed grass stands, retention values are less than 0.5 mm. Thus, the retention values are significantly less than the precipitation layer intercepted by deciduous and coniferous stands [2; 8-9]. At the same time, the layer of precipitation consumed for wetting the grass stands is comparable with the amount of precipitation for individual rains, so it cannot be neglected when calculating flood runoff.
Since hydrological calculations require the understanding of the spatial distribution of rainfall losses over sufficiently large areas (ranging from 0.1 to 200 km²), there have been attempts to estimate the values of green mass of meadows during its maximum growth.

The dependence of pasture productivity on the tree canopy density is shown in Table 2. To determine the dry phytomass by the grass green mass, we used the following coefficients [1]: 3-4 for forest hayfields, 4-4.5 for flooded lowland meadows, and 2.5-3 for dry meadows.

Under the forest canopy, the values of rainfall interception are insignificant, which is not more than 0.1-0.2 mm. In clearings, the layer of intercepted precipitation reaches 1-2 mm, and in logging areas, it accounts for 2-4 mm. Similar values for water retention by grasses were obtained by V. P. Lokhov: cut meadow grasses retain 1.4 mm of water all at once, whereas green mosses and lichens retain 9.8 mm and 4.5 mm respectively [3].

5. Conclusion
The above data indicate that the precipitation retention by grass stands is, on average, slightly less than that by forest stands. If a layer of rainfall is 10 mm, then with the retention capacity of the vegetation cover of 1 mm, 9 mm of precipitation will pass through it. When the rate of rainfalls is up to 1 mm at intervals sufficient to dry the wet leaves, no precipitation will pass through. Since most species of vegetation cover have a retention capacity of at least 1 mm, it can be assumed that almost all precipitation of up to 1 mm is intercepted by them. On average 25% of such precipitation is observed during a year in all zones of Russia. The incoming part of the water balance of forest soils turns out to be greater than that of soils of non-forested areas.

Acknowledgment
The study was funded by the Russian Foundation for Basic Research within the framework of scientific project No. 20-05-00448.

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