Features of water regime changes of steppe chernozem in the South-East of Central Chernozem zone in modern conditions

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Abstract. The article presents an analysis of the elements of the water regime of the steppe chernozems of the Stone Steppe of the Central Chernozem Region in the conditions of the dry period from the end of 2019 to the autumn of 2020. The objects of the study were: the mowed fallow land plowing in 1882, the old-growth forest strip of 1903 planting and arable land adjacent to fallow plots. The soil-hydrological constants were calculated (total water capacity, lowest field capacity, permanent wilting point) both in the time interval and down the soil profile to a depth of 2 m. The reserves of productive moisture during the growing season were also studied. The maximum values of productive moisture content was reached on the mowed fallow sites by the beginning of February, the minimum in the forest belt areas, the arable land plots had an intermediate value. By the middle of the growing season (June), 2020, the moisture reserves in the soils of the forest strip, fallow and arable land were 127, 123 and 109 mm, respectively, in the meter thickness. The highest amount of productive moisture in the upper soil horizon (0-20 cm) is observed under the forest belt – 39 mm. However, moisture content under the fallow land in the upper horizon had decreased to rate of the dead moisture reserve by early August. Similar values were found in soil under the forest belt and arable land. Otherwise, moisture profile was formed in underlying carbonate horizons. The forest belt soils in insufficient atmospheric moisture conditions in 2020 were more dried out than soil of fallow and arable land. The estimation was given for nature of soil profile changes of soil moisture profile due to influence of forest belt. The data of productive moisture reserves in soil at different distances from the forest belt were presented. In the meter layer at the edge of the forest belt, moisture reserves were at the level of 94.0 mm, sharply decreasing to 60.3 mm at a distance of 25 m from the forest strip, with a gradual decrease to 34 mm at a distance of 125 m. The results of observations showed a clear downward trend of productive moisture content due to distance from the old-growth forest belt.

1. Introduction

Weather conditions were a powerful factor determining the nature of changes in individual components moisture content of modern agroforestry landscapes. A common pattern was a rather significant change in individual components that characterize the air temperature regime and atmospheric humidification.

An important component of agricultural landscapes structure was steppe fallow areas with rich grassy cover, which had the maximum ecological stability, soil and water protection value [1]. As a result of plowing steppe soils the existing ecosystems has been changed. With a low agronomic culture, there is primarily a hydrological degradation of soils and a decrease in soil fertility [2].
Considering a number of works devoted to the study of the hydrological profile of chernozems [3, 4], it can be concluded that it varies depending on the type of soil.

Therefore, research of steppe and forest-steppe chernozem properties transformation in the Central Chernozem region remains very relevant [5]. Forest belt served as a powerful factor that changed the direction of natural soil-forming processes of the original steppe soils. It is necessary to assess its impact on the water content on the whole territory and directly under the forest cenosis. It is necessary to analyze the direction of changes in moisture regime of steppe chernozem and spatial parameters in the zone of forest belts influence.

2. Materials and methods
Studies, observations and analyses were conducted in the Laboratory of Agri-soil Science of the FGBSI “Voronezh FASC named after V.V. Dokuchaev”. The objects were the areas adjacent to each other: fallow land, old-growth forest belt No. 40 planting in 1903 and arable land near the forest belt. Soil moisture was determined by the thermostatic-weight method (sampling to 2 m depth every 10 cm). Volumetric water content and productive moisture reserves were determined by calculation. To assess the change in the nature of soil profile moisture content in space under the influence of forest belt, an area survey was conducted with the overlay of a grid of drilling wells with a cell size of 25 by 50 m.

3. Results and Discussion
The analysis in the nature of soil moisture profile changes was considerably interesting under conditions of autumn 2019 and the first half of 2020 with extremely soft and snowless winter. During the winter period of 2020 due to lack of soil freezing and above-zero temperatures, there was a gradual replenishment of moisture to a greater extent in the upper horizons. The content of productive moisture reached maximum values in the fallow land plots in early February: in the 0-20 cm layer – 44 mm, 0-100 cm – 131 mm and 0-200 cm – 214 mm. Under the forest belt the content of productive moisture during this observation period was minimal – 50 mm, 128 mm and 188 mm, respectively. The arable land site occupied an intermediate position – 36.0, 133.0 and 212.0 mm.

By the beginning of spring field work, the nature of moisture has changed. The leading position in terms of productive moisture reserves was taken by the fallow land soils– 43 mm (0-20 cm); 213 mm (0-100 cm) and 396 mm (0-200 cm). Under the forest belt these values were respectively 51.0 (close to the February figures); 187.0 and 275 mm. There was shown a gradual significant increase in moisture content of the first meter layer. The moisture reserves in upper arable layer (0-20 cm) in the arable area in early period of the field season were lower only on 27 mm than the fallow land and the forest belt. Similar small reserves was characterised for one meter soil layer (154 mm) and entire 0-200 cm horizon (292 mm).

Availability of soil moisture was quite high by the middle of growing season (June) 2020. Precipitation at a low temperature conditions contributed to the preservation and balanced use of soil moisture. The highest amount of productive moisture in the upper soil horizon (0-20 cm) was under the forest belt – 39 mm, the minimum in the arable land plots – only 18 mm. The fallow land samples had the intermediate value (23 mm). At the same time, very close numbers were typical for the one meter depth – 127, 123 and 109 mm, respectively.

The lack of precipitation during the summer period with an increased temperature conditions led to desiccation and a shortage of moisture. The moisture deposit had decreased close to the dead moisture reserve in soil under the mowing fallow in early August. The entire 200-centimeter layer of soil was characterized by a complete lack of available moisture. The similar situation was in soil under the arable land and the forest belt. Replenishment of soil moisture began only in early September. Moreover, the nature of moisture significantly differed. The presence of soil moisture in the arable land was only below 100 cm up to 200 cm – 42 mm. There was no productive moisture in the upper 0-100 cm soil horizon. A significant amount of available moisture was in the forest belt soils. There was 26 mm of available moisture in the 0-100 cm horizon to compare to the fallow land plots at a
significantly lower amount of 17 mm. However, with depth the nature of moisture availability was changed and priority went to the fallow land soils. Under the forest belt the productive moisture deposit was 105 mm against 67 mm under the fallow land site.

Dry weather conditions with a small amount of precipitation in the second half of the summer term in 2020, as well as in autumn, led to a significant drying up of chernozems soil profile. The highest content of available moisture was in the forest cenosis despite of a generally low content of productive moisture in mid-September. In the upper soil layer (0-20 cm) the amount of productive moisture was at 13.5 mm gradually increasing to 29.9 mm in 0-50 cm layer of soil. The water regime in the fallow and the arable land plots was quite different. The upper layer of chernozem under the fallow vegetation was moistened significantly lower at about 2.0 mm of available moisture and 8.0 mm in the 0-50 cm layer. The most critical deposit of moisture was in the arable land samples. There was no productive moisture in the arable horizon and only in deeper horizons the value gradually rising to 5.3 mm (layer from 20 to 50 cm).

Further discussion will consider the features of the water regime under such components of modern agricultural landscapes as mown fallow land, arable land and forest belt. In the dry conditions of 2019-2020 the highest moisture deposit was in soil profile of the mowed fallow land immediately after snowmelt (figure 1).

The greatest moisture content in early spring was in 2020 due to gradual ingress of moisture into soil during entire cold period. However, the upper soil horizons (arable land) didn’t contain gravitational moisture. Moistening at the level of the lowest field capacity of soil ($LFC$) was below the depth of 30 cm (figure 1). Moreover, this period was longer – until mid-July due to the weather conditions in 2020. The greatest desiccation these years was in the soil upper horizons. By the end of August, soil moisture of the arable horizon was at permanent wilting point level (PWP).

![Figure 1. Moisture categories for fallow land, 2020.](image)

Soil moisture regime was completely different on arable land. Observations showed that soil moisture reached the values of the lowest field capacity ($LFC$) in early spring, in the sub-arable horizon, soil moisture increased to the category between the lowest and total water capacity ($LFC$-$TWC$) (figure 2). This period was maintained almost until the beginning of sowing. With agricultural plants development during the growing season there was a gradual desiccation to critical values. By
harvesting and in the following period, soil moisture reduced to values below the lowest field capacity, in the arable horizon moisture content dropped to permanent wilting point level (PWP). Soil moisture decreased to zero, below of permanent wilting point (PWP) due to lack of precipitation in the autumn 2020.

Figure 2. Categories of moisture for arable land, 2020.

Special moisture regime was formed directly under the investigated forest belt. Throughout the year, soil moisture was below the lowest field capacity level (PWP-LFC) (figure 3). Only at the beginning of spring, the upper soil horizon had fragmentary higher moisture content below than the lowest field capacity level (LFC). The forest belt soils under insufficient atmospheric moisture conditions were more dried up to compare to the fallow and arable land soils. Tree species due to powerful root system dry out the soil profile to several meters.

Figure 3. Moisture categories in the soil of forest belt No. 40, 2020.
The data on plant available water reserves at various distances from the forest belt were presented to estimate the influence on the nature of soil profile moisture content changes. The results were obtained in the third decade of June. This period was the most significant impact for grain formation of main agricultural crops.

The results showed that the arable plots of watershed components of landscape near the forest belt were characterized by a higher degree of moisture content. There was a clear downward trend of productive moisture content with the distance from the forest belt (figure 4).

![Figure 4: Deposit of productive moisture depending on the distance from the forest belt No. 40 according to soil horizons, mm.](image)

Moisture deposit in the meter layer on the edge of the forest belt were at 94.0 mm level, on the 25 m distance sharply decreased to 60.3 mm with a gradual decline to 34 mm at 125 m distance. Plough root-inhabited layer (0-20 cm) has had the same formation direction of moisture reserves. Moisture reserves decreased from 17.0 mm (the edge of the forest belt) to 7.0 mm at the maximum distance from the forest belt (125 m).

The moisture profile in the underlying carbonate horizons was formed quite differently. It was determined by the nature of land use and growing vegetation. On arable land with agricultural crops, with a relatively short growing period, moisture consumption was mainly from the upper root-inhabited soil horizons (up to 50 cm). The fallow land and especially forest belt soils has had moisture consumption from deeper soil horizons. The amount of available moisture under the fallow land vegetation was 16.8 mm in 50-100 cm layer, the forest belt-30.2 mm at the beginning of autumn (September). While on the arable land plots was higher - 49.2 mm.

More significant differences were characterized to 100 to 200 cm underlying soil horizon. Reserve of available moisture in arable land soils was 97.9 mm. Mowed fallow land had 66.1 mm. The minimum value was typical for chernozem soils under tree cover – only 49.7 mm.

4. Conclusion
Water regime of steppe chernozem in the conditions of 2020 had its own features. Content of available moisture reached the maximum values on the fallow land plots; the minimum in the forest sites, the arable land samples occupied an intermediate value at early February. By the middle of the growing season (June) 2020 soil moisture availability was quite high. The highest amount of productive moisture in the upper soil horizon (0-20 cm) was under the forest belt. The lack of precipitation during the summer period with an increased temperature conditions led to desiccation and a shortage of moisture. Moisture content of the fallow land plots had decreased to the dead moisture deposit by early August.
Similar values were found in soils under the forest belt and the arable land. Moisture profile in the underlying carbonate horizons was formed quite differently. On arable land with agricultural crops, with a relatively short growing period, moisture consumption was mainly from the upper root-inhabited soil horizons (up to 50 cm). The fallow land and especially forest belt soils had moisture consumption from deeper soil horizons. In insufficient atmospheric moisture conditions in autumn Chernozems directly under tree cover suffer from desiccation more. However, forest belt had a positive influence to adjacent arable land areas. Forest belt contributed to a better moisture supply of cultivated agricultural crops and increased yield. Productive moisture content had a clear downward trend with increasing distance from the forest belt.

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