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Modeling soil water fluxes in two arable Chernozems with different depth to carbonates after fifty years under bare fallow and under corn

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Arable Chernozems of the East European Plain were studied in Voronezh region (51°36' N, 38°58' E, 180–185 m AMSL). The studied soils were formed on calcareous loess-like loam parent material in well-drained position with groundwater level at 8–10 m depth. The mean annual air temperature at the site is 6.9 °C, mean annual precipitation is 587 mm. The weather conditions are highly variable: the extreme values of monthly precipitation registered in June were 7 (in 1960) and 219 mm (in 1988); the extreme daily value of precipitation was 95 mm (in 1988); the extreme air temperatures registered in June were –1.6 and 38.9 °C.

The first experimental plot was under corn monocrop and another one was under bare fallow for 50 years. The depth to the top of the carbonate horizon was 1.4-1.6 m under corn and 0.8 m under bare fallow. We supposed that this difference in carbonate depths is due to carbonate accumulation in the upper soil layers under bare fallow and that it can be explained by the repeating upward water fluxes, which are much greater under bare fallow than those under corn. To test this hypothesis a series of simulations was carried out using the Hydrus-1D modeling environment.

Simulation of soil hydrology was performed for the vegetation period. The depth of modeled soil profile was 2 m. Sand, silt and clay contents were about 20, 40 and 40 % and were similar for both plots. The lower boundary condition was free drainage. Monthly precipitation was set equal to (1) long-term average norm, (2) half-norm, (3) two norms and (4) three norms. The monthly distribution of precipitation was either (a) two rainy days at the beginning of each month followed by 28-days dry period or (b) one rainy day at the beginning of each decade followed by 9-days dry period. Evapotranspiration during dry periods was estimated using the standardized FAO56 Penman – Monteith model. Simulations were performed for each combination of (1)–(4) and (a)–(b) conditions and for the real-time weather data.

The two plots differed in profile moisture distribution in all simulation series. The moisture content in the upper 0–0.5 m layer was higher under corn and the moisture content at the 0.5 m depth and deeper was significantly higher under bare fallow. The repeating upward fluxes of soil water were obtained only for the plot under bare fallow. The thickness of the soil layer with downward and upward fluxes increased with monthly precipitation. This result indicates the particular role of the years with extra precipitation in the process of carbonate accumulation within the upper part of the soil profile under bare fallow.