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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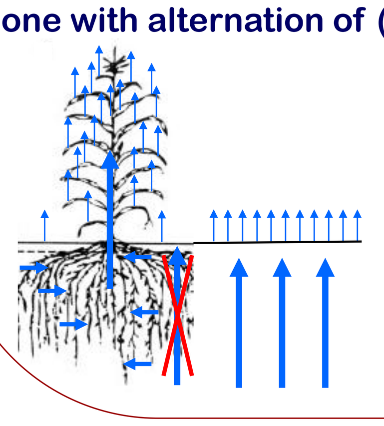
Summary

The studied chernozems were formed on calcareous loess-like loam parent material in well-drained position. After 50 years under bare fallow (1st plot) and under corn monocrop (2nd plot) the depths to the top of the carbonate horizon at these two plots became different.

The weather conditions during this period were 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.

We supposed that the observed 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 Hydrus-1D software.

Simulation of soil hydrology was performed for the vegetation period. Sand, silt and clay contents were similar for both plots. The lower boundary condition was free drainage. The upper boundary condition was time-variable one with alternation of (short) rainy and (long) dry periods.



The two plots differed in vertical water fluxes in all simulation series. The repeating upward fluxes 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.

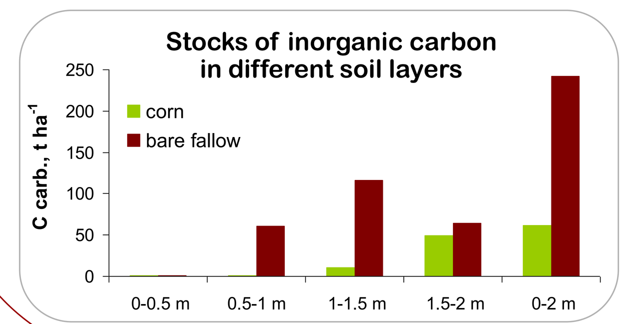
Objects

Arable Chernozems of the East European Plain were studied in Voronezh region (51 36' N, 38 58' E, 180–185 m AMSL).

Under bare fallow

Under corn

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 0.8 m under bare fallow and 1.4–1.6 m under corn.



The stocks of inorganic carbon in the two-meter layer were 240 t ha^{-1} under bare fallow and 60 t ha^{-1} under corn. Under bare fallow considerable amount of inorganic carbon (about 50 t ha^{-1}) was stored in 50–100 cm layer.

Methods

Potential evapotranspiration rate

Evapotranspiration during dry periods was estimated using the standardized FAO56 Penman – Monteith model. The effect of the climate on crop water requirements was given by the reference evapotranspiration ET_o and the effect of the crop by the crop coefficient K_c

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

(after Allen et al., 1998)

Main equations

(after van Genuchten, 1980)

$$q = K \frac{dP}{dz}$$

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \frac{1}{\left[1 + (\alpha P)^n\right]^m}, \quad m = 1 - \frac{1}{n}$$

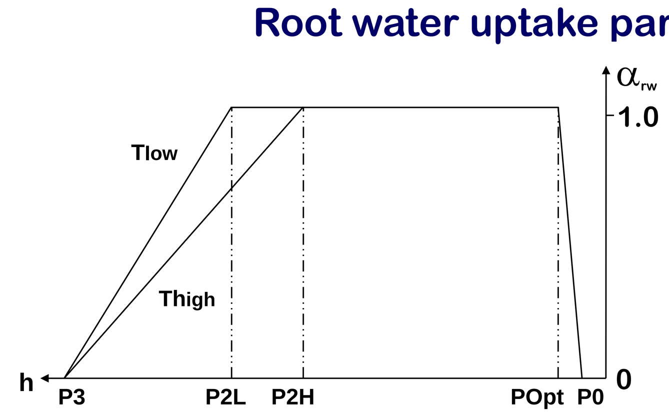
$$K = K_s S_e^{1/2} [1 - (1 - S_e^{1/m})^m]^2$$

Water flow parameters

Sand, Silt, Clay, ρ_b, θ at 33 kPa, θ at 1500 kPa → Rosetta Lite v.1.1 → θ_r, θ_s, α, n, K_s

HYDRUS-1D

Root water uptake parameters

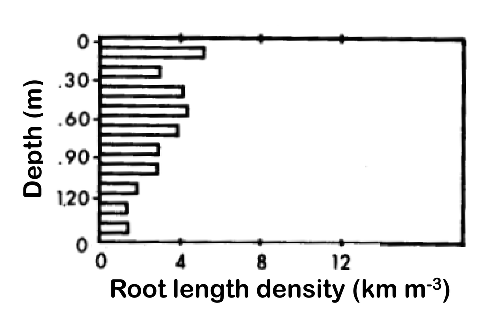


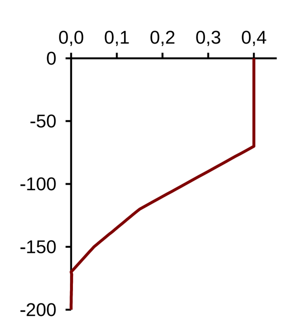
Reduction coefficient for root water uptake α_{rw} as function of soil water pressure head P and potential transpiration rate T_p (after Feddes et al., 1978)

Feddes' parameters for corn (after Wesseling, 1991):

- P0 = –15 cm
- POpt = –30 cm
- P2H = –325 cm
- P2L = –600 cm
- P3 = –8000 cm
- r2H = 0.5 cm day^{-1}
- r2L = 0.1 cm day^{-1}

Root distribution





(after Newell, Wilhelm, 1987)

Simulation series

I. Monthly precipitation:
(1) long-term average norm, (2) half-norm, (3) two norms, (4) three norms.

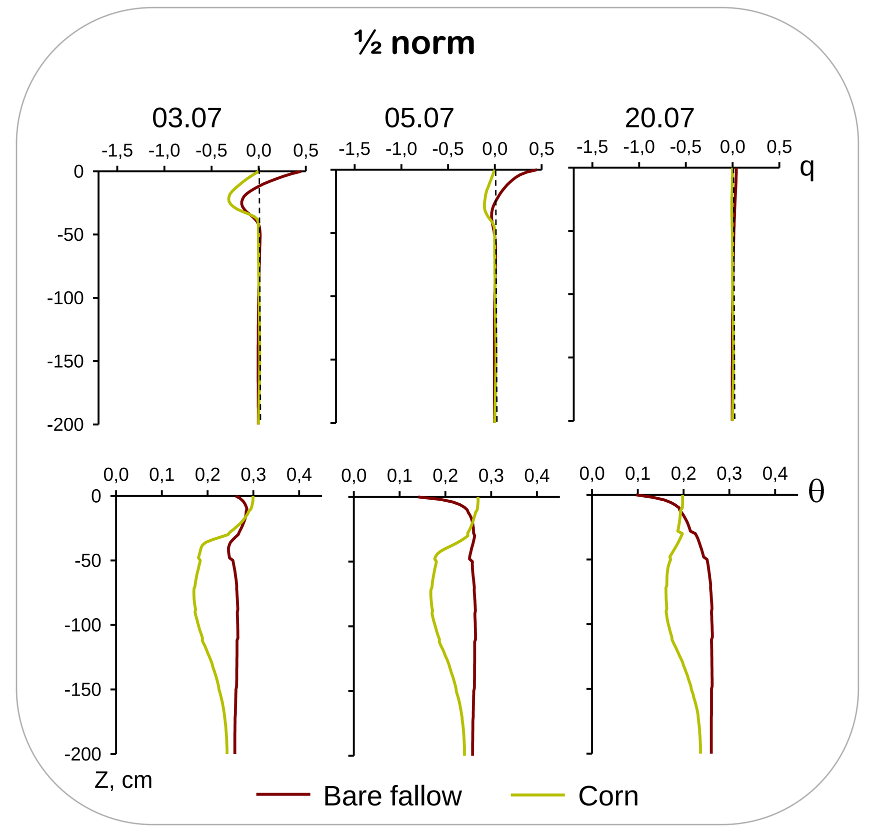
II. Monthly distribution of precipitation:
(a) two rainy days at the beginning of each month followed by 28-days dry period;
(b) one rainy day at the beginning of each decade followed by 9-days dry period.

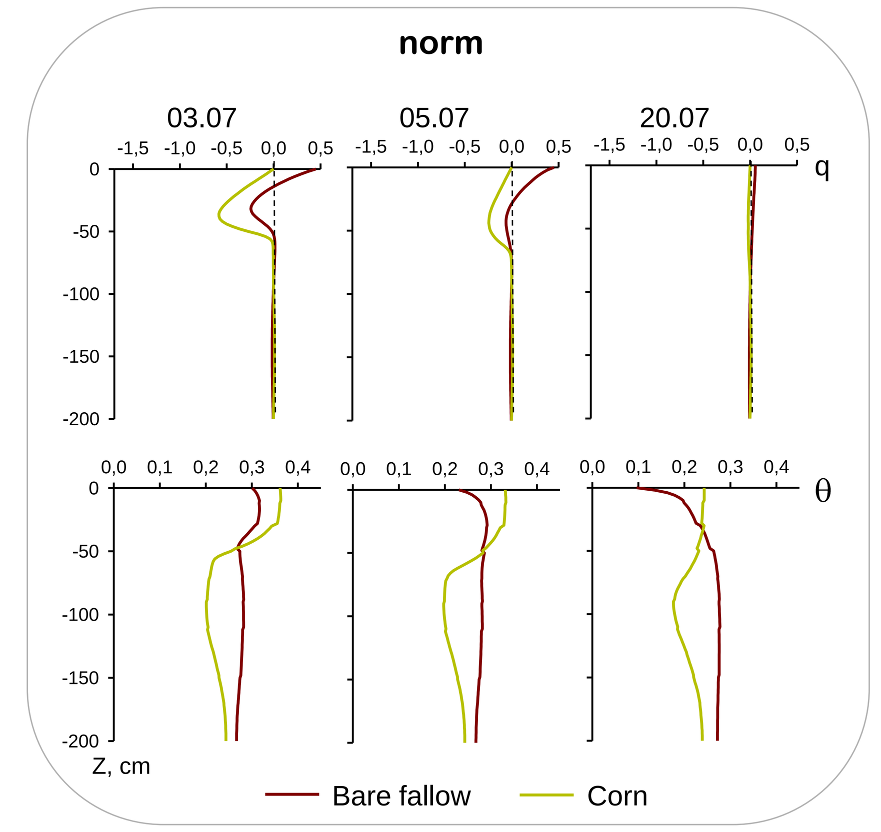
Simulations were performed for two plots for each combination of (1)–(4) and (a)–(b) conditions.

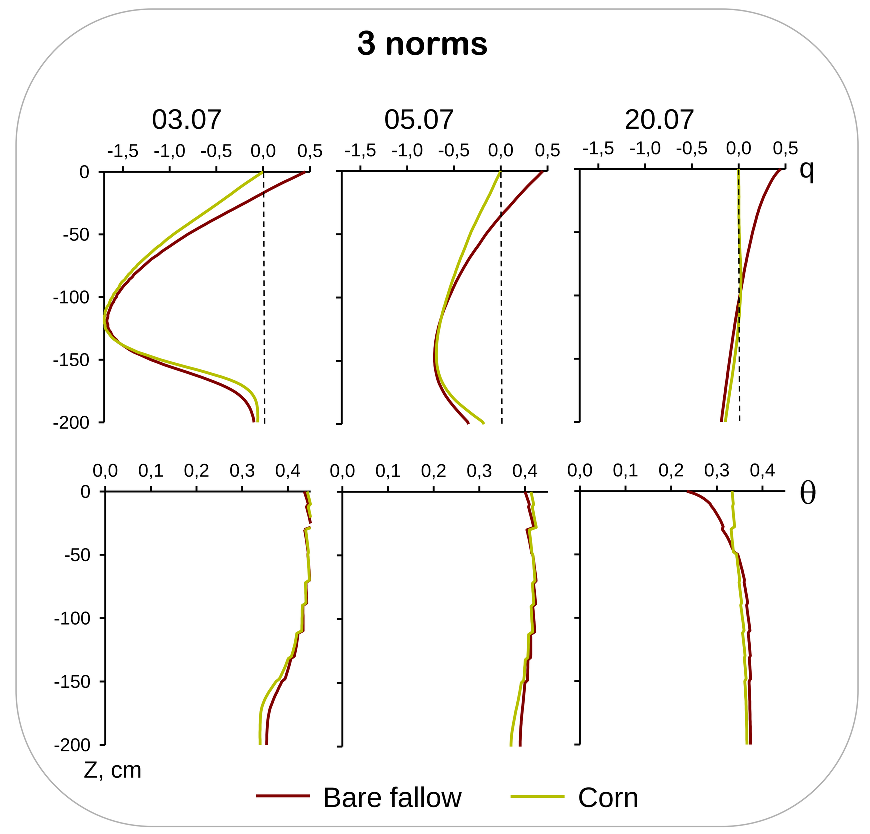
Results

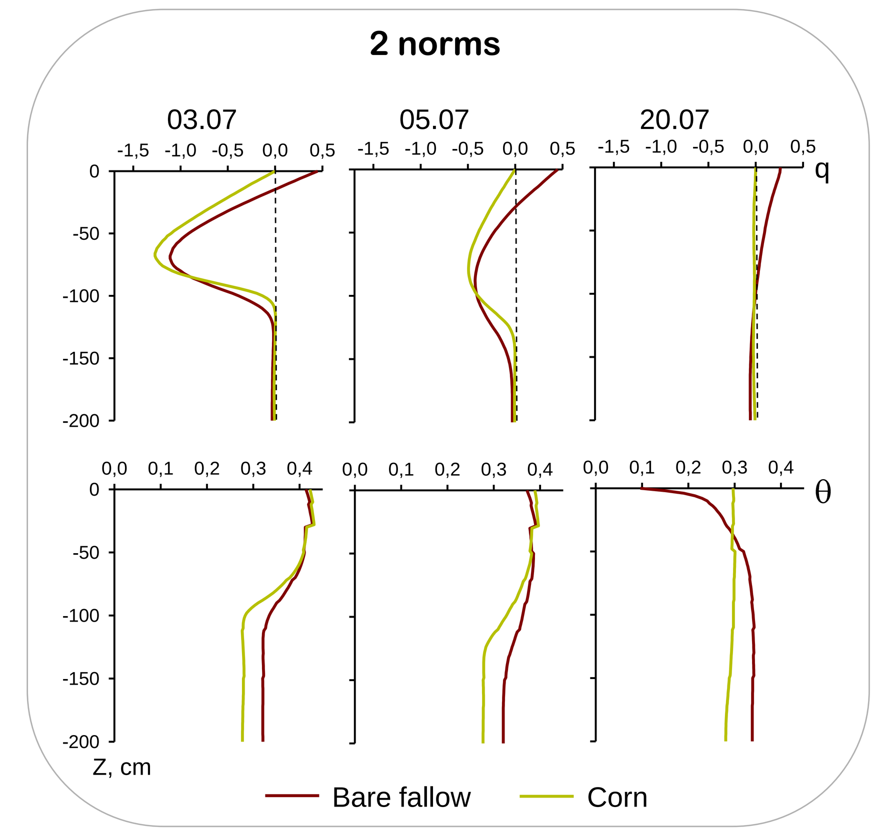
Simulated water fluxes* (q, cm day^{-1}) and water contents (θ, cm^{3}cm^{-3})

Two rainy days at the beginning of each month

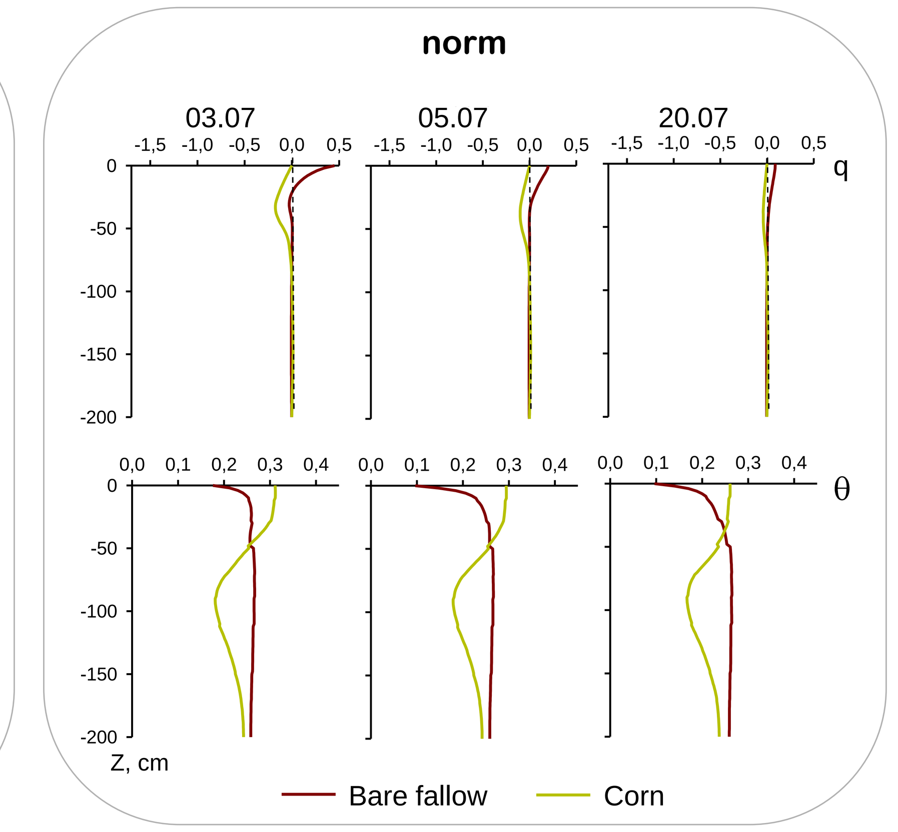


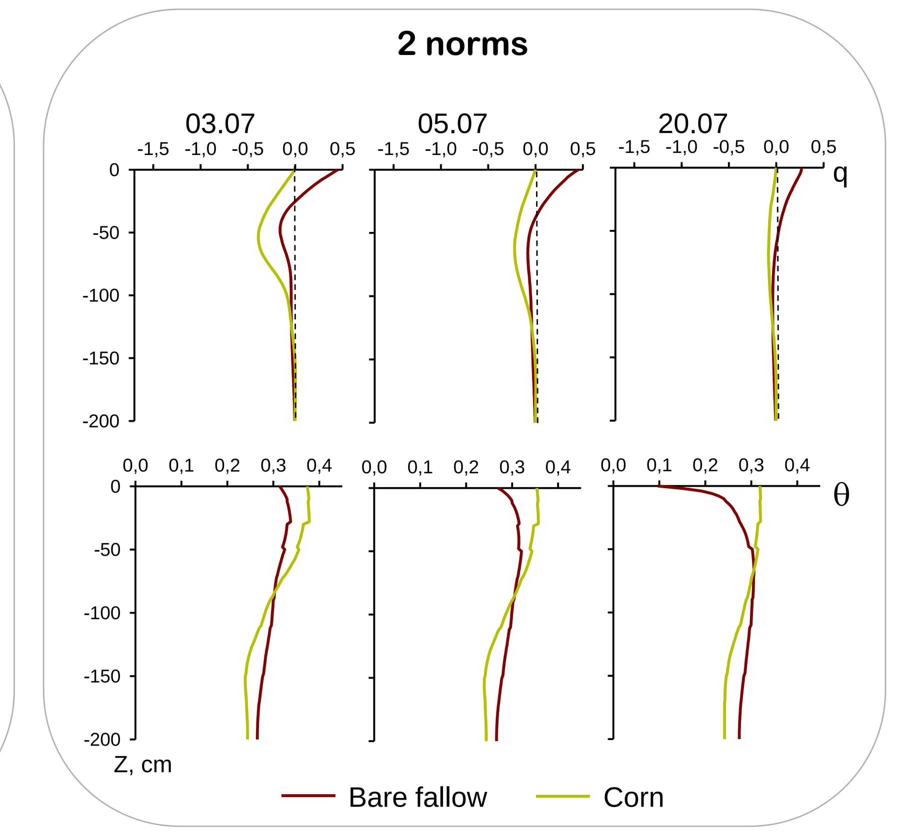






One rainy day at the beginning of each decade





*The upward fluxes are positive, the downward fluxes are negative

Soil properties and water flow parameters

Depth, cm	Sand/silt/clay, %	ρ_b, g cm^{-3}	θ_r, cm^{3}cm^{-3}	θ_s, cm^{3}cm^{-3}	α, cm^{-1}	n	K_s, cm day^{-1}
0-10	19 / 41 / 40	1.10	0.0682	0.5127	0.0093	1.4028	38.61
11-30	19 / 41 / 40	1.16	0.0685	0.4985	0.0082	1.4185	30.73
31-50	21 / 40 / 39	1.22	0.0733	0.4899	0.0106	1.3609	25.58
51-70	20 / 39 / 41	1.28	0.0752	0.4816	0.0093	1.3581	19.50
71-90	26 / 32 / 42	1.34	0.0717	0.4681	0.0083	1.3578	17.32
91-110	29 / 29 / 42	1.39	0.0691	0.4561	0.0075	1.3597	14.11
110-130	19 / 42 / 39	1.45	0.0696	0.4416	0.0066	1.3691	7.18
131-150	24 / 36 / 40	1.49	0.0665	0.4321	0.0060	1.3684	6.12
151-170	21 / 42 / 37	1.52	0.0660	0.4247	0.0057	1.3697	4.38
171-200	25 / 36 / 39	1.52	0.0648	0.4246	0.0057	1.3691	4.81

Upper boundary conditions

	May	June	July	August	September
Air temperature, °C	14.8	18.5	20.5	19.2	13.3
Monthly precipitation, mm	46	74	62	54	61
ET_0, mm day^{-1}	3.42	3.75	3.92	3.60	2.39
PET for corn, mm day^{-1}	4.10	4.50	4.71	4.32	2.86
Potential transpiration for bare fallow, mm day^{-1}	3.93	4.31	4.51	4.14	2.74

Acknowledgements

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