THE TREND ANALYSE OF WATER STORAGE AND PHYSICAL PROPERTIES IN PROFILE OF HEAVY SOILS

TRENDOVÁ ANALÝZA ZÁSOBY VODY A FYZIKÁLNYCH VLASTNOSTÍ V PROFILE ŤAŽKÝCH PÔD

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The aim of this contribution was to show the development trends of water soil storage and selected physical properties of heavy soils of the East Slovak Lowland. Conventional tillage and no-tillage practise of soils were observed. Field observations took place between 1998 and 2007 in Milhostov, where heavy Gleyic Fluvisol (FM_G) is localised.

Soil samples for the determination of water storage were taken from profile 0.0–0.3 m, respectively 0.0–0.8 m from both tillage variants. Soil samples for determination of bulk density and maximum capillary capacity were taken during spring time from topsoil at a depth of 0.0–0.3 m. From the point of view of meteorological factors vegetation seasons of the experimental years were valued by the sum of precipitation, average air temperature and hydrothermic coefficient of Seljaninov. By using these characteristics from the point of view of the sum of precipitation vegetation seasons for the years 1998–2007 are possible to characterise as very dry till extremely humid. By average air temperature, except in 2007, vegetation seasons of other observed years were valued as normal. At valuation by hydrothermic coefficient of Seljaninov, all vegetation seasons had sufficiency of moisture, with the exception of 1999. The effect of soil tillage system on soil water storage, bulk density and maximum capillary capacity was valued by regression analyse and trend analyse by method of linear regression.

Statistically significant dependence (r = 0.61–0.71) between average soil water storage during vegetation season and hydrothermic coefficient of Seljaninov was noted. For conditions of the East Slovak Lowland increasing of boundary value of this coefficient between sufficiency and insufficiency of moisture on 1.25 will be necessary.

Effect of soil tillage systems, so conventional tillage and no-tillage, on higher shown characteristics of Gleyic Fluvisol was not statistically significant. Similarly, the dependence of bulk density and maximum capillary capacity on the sum of precipitation in the winter period was statistically non-significant. On the other hand statistically significant dependence was found between the actual volume of soil moisture and bulk density, respectively, and maximum capillary capacity. The highest correlation coefficient (r = 0.90) was determined for the relation of bulk density and maximum capillary capacity.

By trend analyse of linear regression between 1998 and 2007 for Gleyic Fluvisol in the central part of the East Slovak Lowland favourable changes of observed parameters were noted. The increase of average soil water storage, and the decrease of bulk density values and the increased values of maximum capillary capacity were ascertained.

Key words: soil water storage, physical soil properties, heavy soil, soil tillage system, trend analyse

There is a phenomenon on the Earth taking place, of global environmental change, for example climatic change, loss of the atmospheric ozone, air contamination, loss of biodiversity, soil degradation, limitation of water sources and the weather contamination of oceans [23]. Intensive effect on water storage in soil and hydrophysical soil properties is assumed mainly on account of climate change.

The main part of the results of climate

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change effect on agricultural land and agricultural production in the Slovak Republic was obtained by the using of regional modifications of models of common circulation of atmosphere (CCCM, GISS). Effects of climate change on water storage in these models is quantified on base of change of the average month air temperature and month sum of precipitation. Usually the participation of groundwater is not taken into consideration [16, 6, 24].

Water storage in the aeration zone of soil (no-saturated area of soil) is the amount of water in soil between soil surface and level of groundwater. Water flow between these two boundaries is dependant upon additional meteorological conditions as well as from the physical properties of soil [22, 20, 24].

Amount of soil water, which on concrete stand in definite part of vegetation is available for agricultural plants, is possible to number for example by empirical equations, which deliver in relation between rainfall and potential evapotranspiration [3]. At the agronomical regionalisation of Slovakia for this aim Kurpelová et al. [in 3] used hydrothermic coefficient of Seljaninov.

Tillage of soil is a basic element of the technological systems of agricultural plant cultivation on arable land. The development of agricultural opinions on the importance of soil tillage are changed, by ecologists mainly conventional tillage of soil is the main form of ecological disturbance of agro-ecosystems [15].

In permanently sustainable cultivated systems, protective systems of soil tillage have a very important role. Although the effect of these technologies caused tendencies of making worse the physical and hydrophysical properties of soil mainly at no-tillage systems in comparison to conventional systems, but these changes will not be significant [8, 14]. For heavy soils of the East Slovak Lowland at no-tillage systems in comparison with conventional tillage Kotorová [12], Mati, Kotorová [18], Kotorová, Mati [13] found out higher values of bulk density.

One from methods for quantification of climate change effect to selected elements and components of soil water regime is its direct monitoring. Obtained time sequences of due data are further undergone trend analysis, from which prognoses pro futuro are made [23].

The aim of this paper is to evaluate the development trends of water storage and selected physical properties of heavy soils at its conventional tillage and no-tillage.

Table 1

Characteristic of vegetation season by sum of precipitation and average air temperature [% DN] (in Ivančo et al., 2004)

% DN*	< 60	60–79	80–89	90–110	111–120	121–140	> 140
By sum of precipitation By average air temperature	extremely dry extremely chill	very dry very chill	dry chill	normal normal	humid chill	very humid very warm	extremely humid extremely warm

*Long-time normal

Table 2

Characteristic of vegetation season by Seljaninov hydrothermic coefficient (H_K)

Hydrothermic coefficient	H_K < 0.3	0.3< H_K <0.5	0.5< H_K <1.0	H_K = 1.0	1.0< H_K <2.0	H_K > 2.0
Characteristic of season	catastrophic dry	dry	deficiency of moisture	precipitation equal evaporation	sufficiency of moisture	excess of moisture

MATERIAL AND METHOD

Between 1998 and 2007 at the experimental place of Slovak Agricultural Research Centre – Institute of Agroecology Michalovce a field experiment took place on heavy Gleyic Fluvisol. The effect of various tillage of soil on water storage and soil properties was researched. The experimental site is located at Milhostov, on the East Slovak Lowland near the city of Trebišov with latitude 48° 40' N, longitude 21° 44' E, altitude 101 m. The long-term mean yearly precipitation shows 559 mm, during vegetation season 348 mm, the mean annual temperature is 8.9°C, during vegetation season 16.0°C [7, 19].

Field stationary treatment consisted of ten plots. Crop rotation for the 1st experimental plot, where research of soil water storage and changes of soil properties was realised, was as follows: clover-grass mixtures 2nd crop year – clover-grass mixtures 3rd crop year – grain maize – faba bean – winter wheat – soya bean – winter wheat – grain maize – spring barley – soya bean.

Soil on the experimental plot with content of 47.75% of clayey particles (< 0.01 mm) is classified by N o v á k scale [25] as clay-loamy soil. In topsoil average contents of individual groups of particles were determined as follows: 26.53% of clay, 21.22% of fine and medium dust, 29.96% of coarse dust, 20.50% of fine sand, 1.79% of medium sand.

In field experiment two tillage technologies – conventional tillage (CT) with ploughing and direct sowing without ploughing (NT) – were examined. The conventional tillage system consisted of current agro-technical operations: stubble ploughing, mean ploughing, smoothing, harrowing and sowing. At no-tillage system direct sowing without ploughing by sowing machine Great Plains was used.

Volume soil moisture, respectively water storage in soil profile was determined from disturbed soil samples taken during the vegetation season in 2-weeks intervals in depth 0.0–0.8 m from each 0.1 m with three replications. Gravimetric method [1] was used at it.

Selected physical properties of Gleyic Fluvisol were determined from undisturbed soil samples taken once a year during spring (14-day after sowing of spring crops). Topsoil was sampled in cylinders of 100 cm^3 in depth 0.0–0.3 m with four replications. Soil bulk density (r_d, kg m^{-3}) and maximum capillary capacity (Q_{MKK}, %) were determined by methods published in [11].

The daily sum of precipitation and average air temperatures were taken from the meteorological station of the Slovak Hydrometeorological Institute, in Milhostov. For valuation of vegetation season by sum of precipitation and average air temperature scale shown in Table 1 [9] was used.

Hydrothermic coefficient of Seljaninov, as an

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Evaluation of meteorological factors of vegetation seasons of observed years

Year	Sum of precipitation [mm]	% DN*	Characteristic of vegetation season	Average air temperature [°C]	% DN*	Characteristic of vegetation season	Hydrothermic coefficient of Seljaninov	Characteristic of vegetation season
1998	536	154.0	extremely humid	16.5	103.1	normal	1.78	sufficiency of moisture
1999	260	74.7	very dry	17.6	110.0	normal	0.88	deficiency of moisture
2000	418	120.1	very humid	17.3	108.1	normal	1.36	sufficiency of moisture
2001	439	126.1	very humid	16.5	103.1	normal	1.45	sufficiency of moisture
2002	401	115.2	humid	17.6	110.0	normal	1.25	sufficiency of moisture
2003	315	90.5	normal	17.6	110.0	normal	1.01	sufficiency of moisture
2004	458	131.6	very humid	16.1	100.6	normal	1.51	sufficiency of moisture
2005	484	139.1	very humid	16.7	104.4	normal	1.61	sufficiency of moisture
2006	402	115.5	humid	17.1	106.9	normal	1.32	sufficiency of moisture
2007	328	94.3	normal	17.9	111.9	warm	1.10	sufficiency of moisture

* Long-time normal

integrated indicator of rain and temperature situation, was used. For evaluation of weather conditions of vegetation seasons by this coefficient a scale [10] presented in Table 2 was used.

Obtained data was tested by statistical methods, from which regression analysis and trend analysis by linear regression method were used.

RESULTS AND DISCUSSION

The East Slovak Lowland is a special land complex with the unique status of hydrosphere, including water in the zone of aeration. Rainfall, together with air temperature are basic factors, which indicate the character of landscape, its vegetation cover, water situation in the country and development of agriculture, too. Abbreviated characteristics of these factors for vegetation seasons of valued years is presented here. Numerical valuation of these parameters is shown in Table 3.

Using the parameters from Table 1 from the point of view of sum of precipitation vegetation seasons are evaluated as very dry to extremely humid. Mostly vegetation seasons of observed years were characterised as humid to very humid. The sum of precipitation during vegetation season between 1998 and 2007 reached 74.7–154.0% of long-time normal.

From the point of view of average air temperature vegetation seasons, except in 2007, are valued as normal and average air temperature was on level 103.1–110.0% of long-time normal. The vegetation season in 2007 was valued as warm with average air temperature on level 111.9% of long-time normal.

As an integrated indicator of hydrothermic situations the hydrothermic coefficient of Seljaninov was used. For conditions with sufficiency of moisture values of hydrothermic coefficient in range 1.0–2.0 are characterized. Values of hydrothermic coefficient in range 0.5–1.0 characterise deficiency of moisture. With exception of vegetation season in 1999 which

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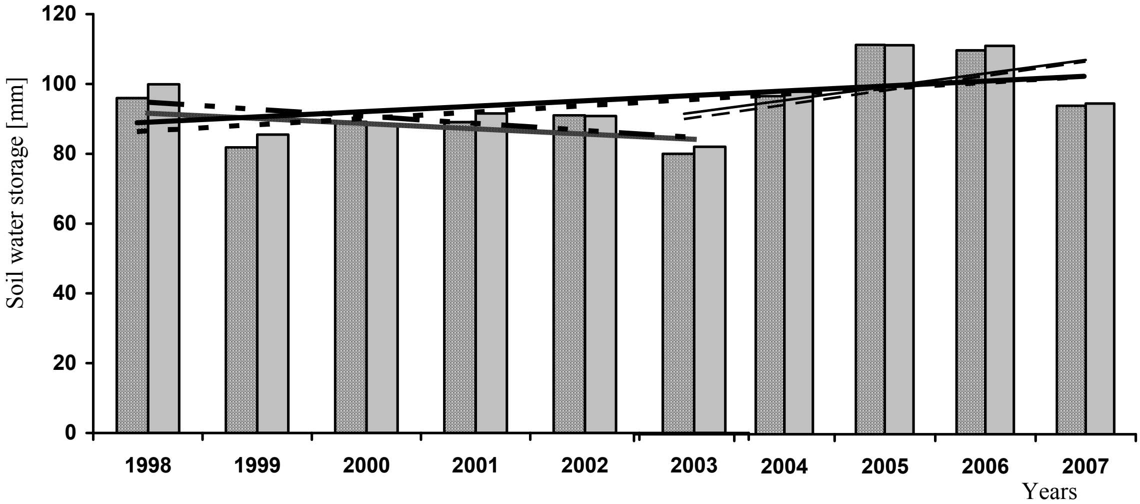
Average soil water storage and selected physical characteristics of Gleyic Fluvisol

Parameter of soil	Soil tillage	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	$\bar{x}$Y
W_F [mm] 0.0–0.3 m	CT	95.97	81.83	89.15	89.10	90.97	79.98	96.87	111.50	109.92	94.11	93.94
	NT	99.92	85.48	88.43	91.52	90.84	81.97	98.09	111.36	111.18	94.71	95.35
	$\bar{x}$T	97.95	83.66	88.79	90.31	90.91	80.98	97.48	111.43	110.55	94.41	94.65
	% W_{ZD}	96.86	82.73	87.80	89.30	89.89	80.08	96.39	110.18	109.31	93.36	93.59
W_F [mm] 0.0–0.8 m	CT	266.65	226.40	237.27	250.87	248.79	212.04	256.50	298.89	289.96	238.26	252.56
	NT	274.22	229.51	236.28	256.75	245.94	215.54	254.99	298.27	296.63	233.97	254.21
	$\bar{x}$T	250.44	227.96	236.78	253.81	247.37	213.79	255.75	298.58	293.30	236.12	253.39
	% W_{ZD}	98.96	90.08	93.56	100.29	97.75	84.48	101.06	117.98	116.13	93.30	100.13
r_d [kg m^{-3}]	CT	1514	1515	1377	1599	1576	1569	1259	1453	1475	1529	1487
	NT	1524	1525	1417	1609	1572	1568	1296	1497	1423	1521	1495
	$\bar{x}$T	1519	1520	1397	1604	1574	1569	1278	1475	1449	1525	1491
Q_{MKK} [%]	CT	37.87	37.53	40.75	33.95	34.74	31.86	45.66	35.83	40.50	35.38	37.41
	NT	37.45	37.62	41.62	30.09	33.76	27.74	46.55	36.73	41.40	35.65	36.86
	$\bar{x}$T	37.66	37.58	41.19	32.02	34.25	29.80	46.11	36.28	40.95	35.52	37.13

CT – conventional tillage
NT – no-tillage
W_F – average soil water storage
W_{ZD} – point of decreased availability
r_d – bulk density
Q_{MKK} – maximum capillary capacity
$\bar{x}$T – average for tillage systems
$\bar{x}$Y – average for years

Soil profile 0.0 – 0.3 m

$y_{CT(98\text{-}07)} = 1.8422x + 83.808$	$y_{CT(98\text{-}03)} = -1.5023x + 93.091$	$y_{CT(03\text{-}07)} = 4.131x + 86.083$
$y_{NT(98\text{-}07)} = 1.5667x + 86.733$	$y_{NT(98\text{-}03)} = -2.0166x + 96.751$	$y_{NT(03\text{-}07)} = 3.857x + 87.891$



Soil profile 0.0 – 0.8 m

$y_{CT(98\text{-}07)} = 2.8948x + 236.64$	$y_{CT(98\text{-}03)} = -5.4937x + 259.56$	$y_{CT(03\text{-}07)} = 8.59x + 233.36$
$y_{NT(98\text{-}07)} = 2.3143x + 241.48$	$y_{NT(98\text{-}03)} = -6.3897x + 265.4$	$y_{NT(03\text{-}07)} = 7.85x + 236.33$

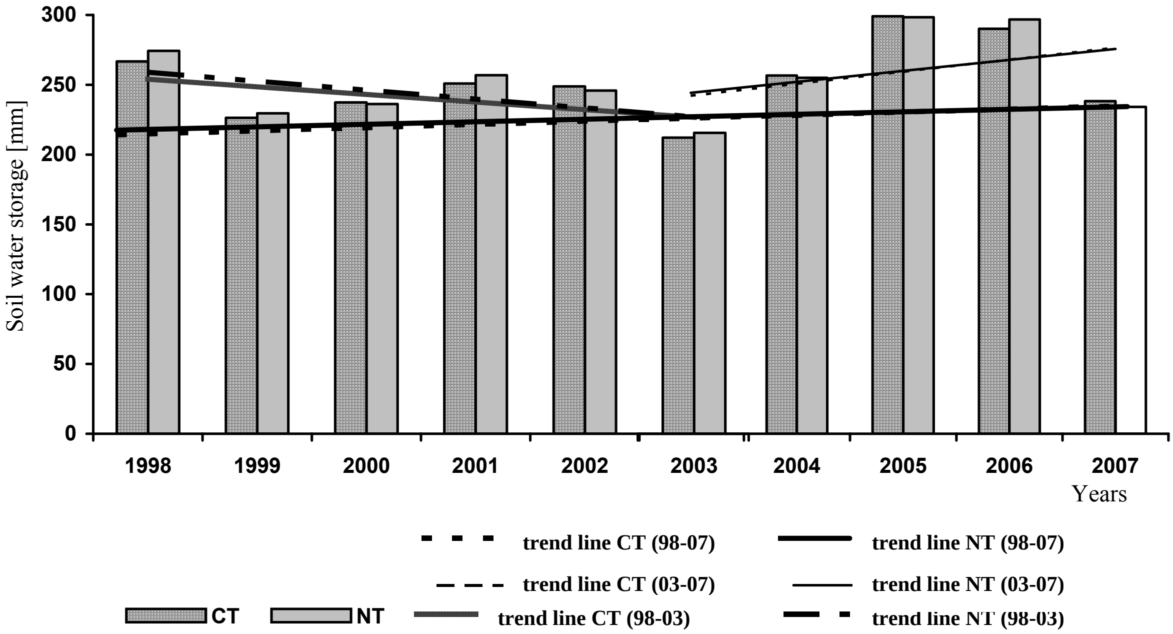


Fig. 1. Trend development of soil water storage on heavy soils of the East Slovak Lowland

had a deficiency of moisture, in the other years vegetation seasons had a sufficiency of moisture.

Effect of tillage systems on soil water storage was valued from point of view of average air temperature in vegetation season ($W_{Ø}$). From Table 4 influenced equalisation of average values for all observed years, in individual years and in valued soil profile 0.0–0.3 m, respectively 0.0–0.8 m, too. Maximum differences between tillage variants of soil were 3.95 mm in profile 0.0–0.3 m, respectively 7.57 mm in profile 0.0–0.8 mm. Tillage systems had not statistically significant effect on average water storage.

The disposal of water storage in soil for plant cover is evaluated by the characteristic state of retention (content of water) in soil, so-called soil hydrologic coefficients. In spite of that, these coefficients are not physically defined with adequate accuracy and clarity, the characterised moment moisture status of soil [1, 21]. From the point of view of the limited effect of deficiency of soil water on physiological processes of plant cover it is point of decreased availability on level of value pF = 3.3.

Between average soil water storage during vegetation season and hydrothermic coefficient of Seljaninov a statistically significant dependence was noted in soil profile 0.0–0.8 m (r = 0.71) and also in profile 0.0–0.3 m (r = 0.61). From the comparison of evaluation of sufficiency of soil moisture for plant cover by hydrothermic coefficient (Table 3) with soil water storage in soil profile 0.0–0.8 m on level of point of decreased availability (Table 4) resulted, that the boundary between deficiency and sufficiency of soil water for plants value of hydrothermic coefficient of Seljaninov H_K = 1.25 is better than value H_K = 1.0. On discrepancy of valuation of soil moisture regime by comparison of water content in soil and by hydrothermic coefficient pointed also Š ú t o r et al. [21].

By the time it was introduced, that between average soil water storage in vegetation season and hydrothermic coefficient of Seljaninov statistically significant dependence was determined. Monitoring of water storages in soil and complicated numerical simulation show possibility of using of hydrothermic coefficient of Seljaninov as simplified criterion of region aridity at eventual adjustment of boundary values of this coefficient.

One from the possibilities of quantification of natural conditions (for example climatic change) or anthropogenic activity (soil tillage technology) on water storage in aeration zone of soil is trend analyse of its course obtained

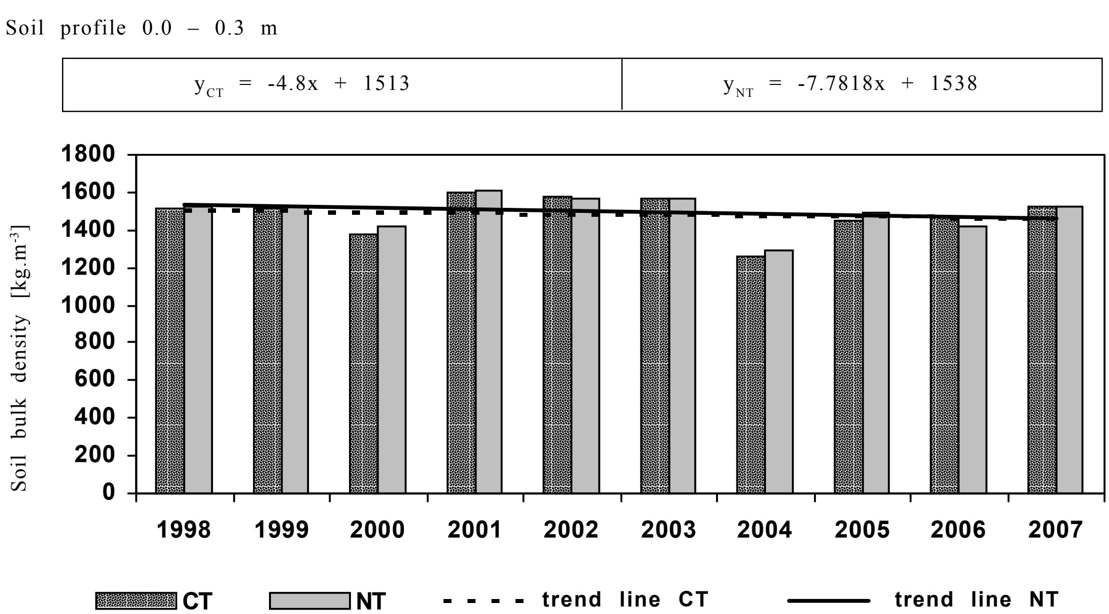


Fig. 2. Trend of bulk density development of Gleyic Fluvisol

from direct monitoring. In this contribution a 10-years sequence of water storage in soil is estimated. For air temperature or rainfall for all area of Slovakia sequences of 100-years observations exist. Some trends indicate a higher presented sequence of water storage in soil, although it is relatively short.

Average water storage in soil profiles 0.0–0.3 m, let us say 0.0–0.8 m and its development trend are shown on Fig. 1. A moderately increased trend between 1998 and 2007 two significantly various periods of years 1998–2003 and 2003–2007 are clear. In the period 1998 to 2007 an increased trend of soil water storage was at conventional tillage 1.84, respectively 2.89 mm year^{-1} and at no-tillage system it was 1.57, respectively 2.31 mm year^{-1}. Results of the development trend may be subjectively distorted by the selection of valued period and trend lines for years 1998–2003, respectively 2003–2007 it show. In 1998 to 2003 a distinctly decreasing trend of development of average soil water storage was determined and decreasing of water storage was ascertained about 1.50–6.39 mm per year out of soil tillage. On the other hand in years 2003–2007 soil water storage was increased about 3.86–8.59 mm per year. This fact point at requirement of long-time observations of soil water storage thus it is for example at sum of precipitation, respectively air temperatures for which reference periods are minimum 20 till 30-years.

Soil bulk density is a basic physical property of soil. Values of bulk density are changed in time and in depth of soil profile in dependence on content of soil water, agrotechnical and others operations. In observed experimental period years 1998–2007 at conventional tillage values of bulk density were in range 1 259–1 599 kg m^{-3} (Table 4) and on no-tillage variant it was 1 296–1 609 kg m^{-3}. From presented results influenced in average for 10-years observed period higher bulk density was found on no-tillage variant (Δ CT – NT = 8 kg m^{-3}), but this difference was statistically no-significant. But D a m et al. [2], L e d v i n a et al. [17], G l a b, K u l i g [5], whether E l d e r, L a l [4] for no-tillage systems introduce more favourable values.

Maximum capillary capacity is hydrophysical parameter, which is connected mainly with water storage in soil and heterogeneity of soil profile from point of view of clay particles content. In our field experiment values of maximum capillary capacity were on variant with conventional tillage in interval 31.86–45.66% and on no-tillage variant in interval 27.74–46.55%. In average but maximum capillary capacity was not significantly

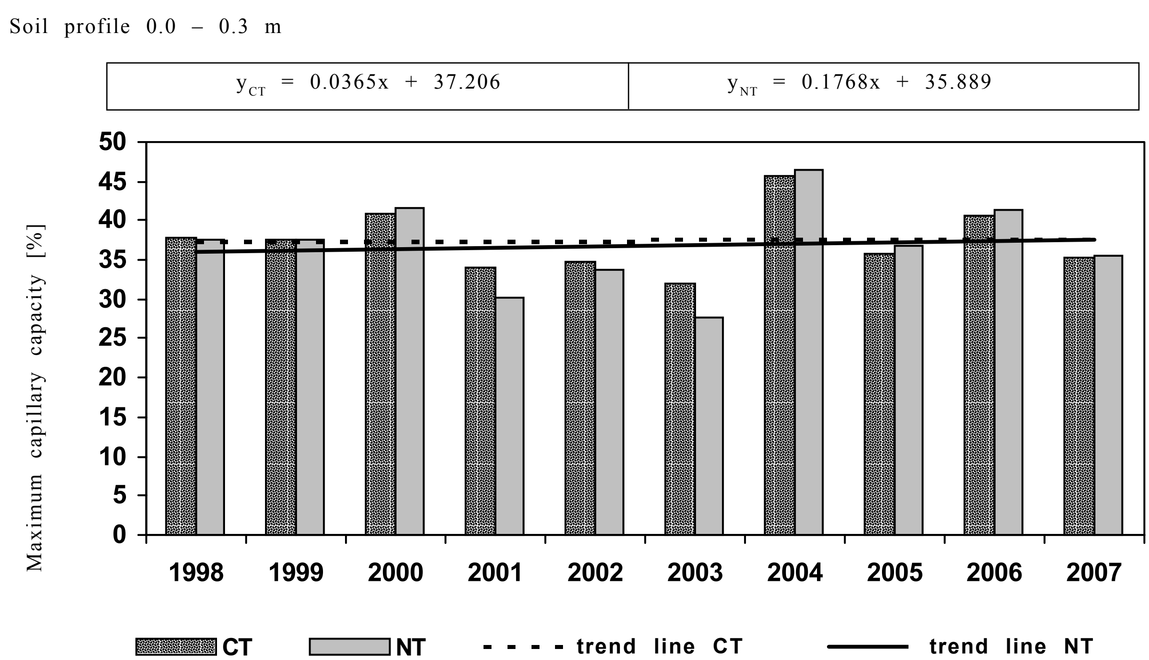


Fig. 3. Trend of maximum capillary capacity development of Gleyic Fluvisol

higher on variant with conventional tillage (D CT – NT = 0.55 %) in comparison with no-tillage variant.

From regression analysis for dependence of bulk density and maximum capillary porosity on sum of precipitation in winter period (October – March) showed that these aren't statistically significant (r = 0.22, respectively 0.19). Relatively large ranges of values of both soil parameters connect with actual soil moisture, when the value of correlation coefficient at bulk density is r = 0.52 and at maximum capillary capacity, r = 0.65. Still stronger regression relation is between single values of bulk density and maximum capillary capacity, when correlation coefficient has value r = 0.90. These facts connect with volume changes of heavy soils in dependence from changes of moisture. Š ú t o r et al. [24] published, that at content of particles of 1st fraction (< 0.001 mm) 28.07% caused volume changes of soil on level 18.77%. Range of volume changes on the East Slovak Lowland is from 4.65% (content 9.80% particles with diameter < 0.001 mm) to 38.92% (content 72.22% particles with diameter < 0.001 mm).

Trend analyse at both soil parameters indicate moderate amelioration its values (Fig. 2 and 3). During the 10-years period, values of bulk density were decreased at conventional tillage about 48 kg m^{-3} and at no-tillage system it was even about 78 kg m^{-3}. Values of maximum capillary capacity were increased at conventional tillage about 0.4% and at no-tillage system about 1.8%.

CONCLUSION

The effect of observed soil tillage systems, that conventional tillage and no-tillage, from the point of view of soil water storage, bulk density and maximum capillary capacity was statistically no-significant.

Between average soil water storage during vegetation season and hydrothermic coefficient of Seljaninov statistically significant dependence was determined. For conditions of the East Slovak Lowland requirement to increase boundary value of this coefficient between sufficiency and deficiency of moisture on 1.25 is shown.

Trend analyse for years 1998–2007 at using systems of husbandry in field stationary treatments of SARC – Institute of Agroecology Michalovce pointed at moderately trend of average soil water storage, on decreasing of bulk density values and increasing of values of maximum capillary capacity.

Statistically significant dependence soil bulk density and maximum capillary capacity on actual volume moisture of soil was determined. Statistically the most significant regression relation (r = 0.90) was noted between values of bulk density and maximum capillary capacity.

Responding to expected or yet applied climate change it is needed to deepen knowledge from water management and dynamics of soil water storage also by its direct monitoring. These findings are namely no-alternative inputs for using and verification of mathematical models in branch of hydrology of regional areas.

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SÚHRN

V príspevku je zhodnotený vplyv konvenčného obrábania pôdy a bezorbového systému na zásobu pôdnej vody, objemovú hmotnosť redukovanú a maximálnu kapilárnu kapacitu fluvizeme glejovej na Východoslovenskej nížine v rokoch 1998–2007.

Vplyv spôsobov obrábania pôdy na zásobu pôdnej vody sa hodnotil z pohľadu jej priemernej hodnoty za vegetačné obdobie v pôdnom profile 0,0–0,3 m, resp. 0,0–0,8 m. Objemová hmotnosť redukovaná a maximálna kapilárna kapacita bola stanovená v jarnom období z ornice v hĺbke 0,0–0,3 m. Z hľadiska meteorologických prvkov boli zhodnotené vegetačné obdobia podľa zrážkového úhrnu, priemernej teploty vzduchu a hydrotermického koeficientu Seljaninova. Regresnou analýzou a trendovou analýzou metódou lineárnej regresie bol zhodnotený vplyv spôsobu obrábania pôdy na zásobu pôdnej vody, objemovú hmotnosť redukovanú a maximálnu kapilárnu kapacitu.

Štatisticky významná závislosť (r = 0,61–0,71) bola zaznamenaná medzi priemernou zásobou pôdnej vody vo vegetačnom období a hydrotermickým koeficientom Seljaninova. V podmienkach Východoslovenskej nížiny sa ukazuje potreba zvýšiť jeho hraničnú hodnotu medzi dostatkom a nedostatkom vlahy na 1,25.

Vplyv sledovaných spôsobov obrábania pôdy, teda konvenčnej agrotechniky a bezorbového systému, na vyššie uvedené charakteristiky fluvizeme glejovej nebol štatisticky významný. Podobne aj závislosť objemovej hmotnosti redukovanej a maximálnej kapilárnej kapacity na úhrne zrážok v zimnom období nebola štatisticky významná.

Naopak štatisticky významná závislosť sa zistila medzi momentálnou objemovou vlhkosťou pôdy a objemovou hmotnosťou redukovanou, resp. maximálnou kapilárnou kapacitou. Najvyšší korelačný koeficient (r = 0,90) bol zaznamenaný medzi hodnotou objemovej hmotnosti redukovanej a maximálnej kapilárnej kapacity.

Trendovou analýzou metódou lineárnej regresie boli v rokoch 1998–2007 na fluvizemi glejovej v centrálnej časti Východoslovenskej nížiny zaznamenané priaznivé relácie zmien sledovaných charakteristík, teda zvýšenie priemerných zásob pôdnej vody, zníženie hodnôt objemovej hmotnosti redukovanej a zvýšenie hodnôt maximálnej kapilárnej kapacity.

Kľúčové slová: zásoba vody v pôde, fyzikálne vlastnosti pôdy, ťažká pôda, spôsob obrábania, trendová analýza