Climate Induced Soil Deterioration and Methods for Mitigation

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Summary

According to prognoses milder winters with more precipitation, warmer and dry summers, and extreme fluctuations in the precipitation and temperature should be expected in the Pannonian region from the 2nd decade of the 21st century. The first aim of this study was to discuss the predicted climate phenomena endangering regional soils and deploying methods of measures in the alleviation. Examples of soils deterioration to be typical in seasons and confirmation that tillage should be an important tool realising soil preservation solutions in the practice are presented. Considering the predicted climate extremes most of classical beliefs are to be supervised. The effects of the rain stress e.g. washing dust and clay colloids down, surface siltation, soil settlement, extension of the existing compact layer and deteriorating crumb fraction in regional soils are demonstrated. Negative impacts of the drought stress on soils are also presented, among others, soil desiccation, unutilised water below serious pan layers, crumb reduction and increased dust and crust formation. The first evidence of the investigation is that climate will be more incalculable in the next decades, and for this reason applying mitigation methods is really urgent. The second evidence refers to the soil tillage which could take part in the degree of climate induced damages through soil condition modification.

Key words

climate risk, rain stress, drought stress, soil deterioration, Pannonian region

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Introduction

The Pannonian region is Europe's largest intermountain basin formed through geomorphic inversion during the Miocene, by the rising of the Carpathians and the subsiding of the areas in between and finally by the drying out of the Pliocene's Pannonian sea. The basin is dominated by the combined effects of oceanic, Mediterranean and continental climates and, by virtue of its nature as a basin, it is exposed to climate extremes (Varga-Haszonits, 2003). Groundwater surging up to the surface from lower layers cannot be held back, while, if the groundwater table sinks deeper down, drought is to be faced. Practical experience leads to the conclusion that any attempt of regulating groundwater was practically doomed to failure (Várallyay, 2013). Research findings show that agricultural activities have contributed to climate change and at the same time climate extremes having adverse impacts on agriculture (Jolánkai et al., 2013). Prior to the IPCC Third assessment Report (2001) and following the publication of the Report, detailed regional and sub-regional climate scenarios, including the Pannonian basin (Bartholy and Pongrácz, 2007; Harnos, 2008), were also published and analysed. Over the last three decades climate change has already had a marked influence on the biological systems in the world (Harnos, 2008). As Szalai and Lakatos (2013) noted, the tendencies in the precipitation sums, the number of precipitation events with threshold values, especially the more intense rains, shows tendencies having serious effects on the available water amount and the surface water balance. In the years of the last decade there were particular weather patterns in the region, as 2010 was a year of extreme amounts of rains, while 2011 and 2012 saw extremely dry. Weather extremes were also in the last two years. The weather extremes took their toll on arable soils. Garamvölgyi and Hufnagel (2013) outlined that agricultural site factors, including water balance of the soils, will also be altered. Soil is an environmental element labelled by a variable state and quality, renewed or degraded (Várallyay, 2011). The effects of the rain stress e.g. leaching dust and clay colloids, surface siltation, soil settlement, the expansion of the existing compact layer and the diminishing in the crumb fraction, cause physical deterioration in arable soils (Bottlik et al., 2014). Whereas, consequences of the heat stress also endanger the soils quality through over drying, great water deficit, crumb degradation, surface crusting and cracking (Kalmár et al., 2013). Tillage is one of the management variables that may improve, maintain or deteriorate soil quality, and through the long-term impact that becomes a key factor of the soil vulnerability to the climate phenomena. Few of the papers mentioned have answered the basic question of soil tillage role in the regional climate damage mitigation solutions. Therefore the combined aims of this study are: (i) discussing the predicted climate consequences endangering regional soils quality; (ii) presenting examples of soils deterioration to be typical in extreme rainy and dry seasons; (iii) confirming that tillage could be one of the tools for soil preservation solutions.

Materials and methods

According to the scenarios for the second part of the 21st century, climate models concerning the Pannonian region predict the expected changes (Bartholy et al., 2004). Most of the analysed factors e.g. amount, frequency and intensity of the precipitation, annual and monthly temperature, seasonal warming, frequency of the flooding and drought, will indisputably impact agricultural production. Considering the agricultural activity in the region, four main climate induced risk factors can be formulated from the optimistic and the pessimistic scenarios that are milder winters with more precipitation, warmer and dry summers, extreme fluctuations in the annual distribution of the total precipitation and increased numbers of windy and stormy incidences. The factors and the possible measures are discussed in this paper. Impacts of climate phenomena on soils were studied in a long-term trial conducted in a Cernic Chernozem soil (WRB, 2006) and in the monitored area with similar type of soil. The experimental field belongs to the Experimental and Training Farm of the Szent István University, near the town Hatvan (47°41'N, 19°36'E, 136 m a.s.l.). The research site is flat and the soil presents a clay loam texture and a moderate sensitivity to settling (Bottlik et al., 2014). The experiment was of the single-factor type, in random stripe arrangement in four replications (Sváb, 1981), in which five methods of tillage management were applied (Birkás et al., 2013): direct drilling (DD), disking (15 cm, D), cultivator use (22 cm, C), ploughing and levelling (32-33 cm, P), and loosening (40 cm, L). From these and from the additional area two main variants were selected: preserved (P) and degraded (D) soil condition with clean (bare, B) and covered (C) surface sub-variants (PB, PC, DB, DC). Ratio of the cover in the trial was 0% and 45%. The size of each plot was 185 × 13 m. Places for measurements were pointed in each strip with an area of 8 m x 4 m.

The measurements were taken and evaluated in accordance with the applicable standards (Csorba et al., 2011; Sváb, 1981; Soil Sampling Protocol, JRC, 2010), and taking conventional recommendations also into account (Dvoracsek, 1957). The last five years' precipitation figures differed from the annual mean (580 mm) that are significant deficits (283, 286 mm) in dry years of 2011 and 2012, and excess amount (371 mm) in a rainy year of 2010. The last 2013 year also proved to be extreme that is a precipitation surplus (100 mm) was measured in the first half of year, and a dry period dominated the second half of the year, including winter.

The data were statistically analysed to determine the significance of the treatments on the measured parameters. ANOVA was performed at a 0.05 level of significance to determine whether the treatments were different. Increasing in penetration resistance at three selected layers of soil was analysed by the series of experiments with one way grouping. For analysis of the parallel effect of the soil and the season on soil crumbling an analysis with two independent variables (Sváb, 1981) was used. Correlations between the individual data were controlled using Microsoft Excel (Gödöllő, Hungary).

Results and discussion

The predicted climate consequences endangering regional soils quality

The soil moisture storage capacity should be maintained and increased in order to cope with winters of abundant precipitation (Várallyay, 2011). More water can accumulate in soils of which the state is suitable for water infiltration. Precipitation form can mostly be rain, and with lower occurrence can be snow, however extremes in the amount and in the distribution can also be expected. Birkás et al. (1989) cited classic authors that suggested leaving the tilled soil surface in cloddy state to catch more snow. This proposal has also come under criticism in the new climate situation, due to the large surface that is really acting in direction of water wasting during and after snow melting. Moreover, the frequency of winds and wind induced water loss in winter result with the growing need for moisture preservation, which may turn attention to the application of surface levelling at primary tillage (Kalmár et al., 2011). Uncertainty of the amount and form of precipitation in winter necessitates the preservation of moisture that remained in soil after previous crop harvest for the better performance of the next, spring-sown crop. For this reason, the importance of water conserving soil management in and out of the growing season is already growing in importance (Birkás, 2011). Mild weather in autumn to be found more frequent nowadays and due to this, harvest of the crops ranking among the long growing season (e.g. maize) is also delayed. Primary tillage for the next crop is also coming later, when the soil moisture content has already exceeded the optimum. Performing any tillage operation in wet soil would probably cause structural damage, such as smearing and pan compaction (Bottlik et al., 2014). Whatever the tool being used, primary tillage should be aimed at helping rainwater infiltration and at minimising the loss of water outside the growing season (Shen et al., 2012), except in heavy soils with poor internal drainage. A soil, that contains no compacted layers and that can take in and store water, should be created. A deeper (about 40-45 cm) root zone may increase the chances of minimising yield losses during a dry summer season. This root zone depth can be created by tillage or that can also be maintained by soil preserving farming methods (Birkás, 2011).

Frost impacts may occur less frequently or only exceptionally (Varga-Haszonits, 2003). Soils that have become damaged and with degraded structure will suffer from the repeated frosts. Frost-dusts formed by freezing present small particles in size are exposed to rain splashing or can be blown with strong winds. Covering the soil surface with field residues will therefore become even more important in fields of degraded and light soils (Birkás et al., 2013). Clod forming is mostly originated from plough performing at low moisture content and from breaking compacted layers. Moreover, the clumps larger than 30 cm cannot soak up the water and become friable. Preserving the soil structure, avoiding the application of tillage leading to clod and dust forming, rationalizing the soil disturbance and extending the period during which the soil is covered (even after sowing) will be indispensable (Kalmár et al., 2013; Várallyay, 2013).

The frequency of hot and dry summers will affect crops growing seasons and yields (Bartholy et al., 2004). Even winter crops can suffer from hot and dry weather in the period of grain filling. Summer crops of longer growing seasons may suffer stress-induced ripening. The summer is really critical period of moisture loss at disturbed soils (Várallyay, 2013). Conventional tillage systems that result in increased soil moisture loss by leaving the field without surface press after ploughing or subsoiling should be replaced by moisture and carbon conserving techniques (Birkás et al., 2013). Shallow primary tillage may have to be applied before sowing in late summer or during the autumn owing to the ever-increasing energy prices, while a deeper root zone should be more efficacious in the mitigation of the climate-induced damages. The increasingly extreme distribution of summer rains and the higher intensity of heavy rains call for laying increasing emphasis on maintaining the soils' water intake capacity and for avoiding, at the same time, the desiccation and pulverisation of the soil surface (Tesfuhuney et al., 2013). Weeds and volunteers water consumption will also draw more attention to the control. There are quite a number of highly drought-tolerant weed species, and some of them even favour hot and dry weather and their seeds ripen even more quickly under such weather conditions. This will necessitate forcing weed seedlings to emerge so that they can be exterminated more effectively.

Soils deterioration expected in the extreme seasons

Climate changes and their consequences results in significant alterations in soil conditions. Results of the soil monitoring in and out of the experimental plots showed six types of the rain stress phenomena. The dust, formed in the surface due to the periodic frost or soil disturbance can seriously be silted. Later on, water logging develops in the soil surface where siltation has already occurred. Water stagnation can also be found in soil, above the pan layer which has formed below the regular depth of tillage. Due to the repeated rainfall a loosened soil has altered to the over consolidated state. The former dusts transport into the soil, at least to the nearest pan, and extend the former compacted layer. Crumb formation has continuously declined in a rainy season. When soil surface dries, e.g. between two rainy period, strong crust has formed in the surface that was previously deteriorated by siltation.

The cyclic freezing and thawing in winter, and the parallel drying and wetting causes substantial soil structure disruption in the soil surface, especially if soil organic matter content is low. Further factors that are water soaking to the surface from the deeper layer, the frost induced soil volume increase and the soil slumping during frost melting contribute to the disintegration of the soil structure (Dagesse, 2013). The frost induced soil breaking can unambiguously be found in the upper side of the large clods in ploughed soils. The thickness of the pulverised layer was found between 10-15 mm in dry winter periods, and 16-22 mm when amount of winter precipitation showed the seasonal average. At this time amount of the pulverised particles were also higher. This frost induced dust can be removed by early spring winds. Besides, periodic rains of end-winter can seriously affect silting of the larger part of the frost induced dusty surface. In the experimental plots five variants were selected where different sized soil particle dominated (at least 80% in a unit area). A significant decrease of the silted area occurred parallel with particle size increase (Figure 1). The correlation between the data was close ($P < 0.001$), our formula gave a 98.9% explanation for the particle size impact on the occurrence of the siltation. Dominance of the smaller (< 2.0 mm) particles in the soil surface has indisputably been contributing to the higher soil siltation. This fact calls attention to the negative effect of the frost induced soil pulverisation. The dusts in the process of siltation block the porosities of the soil and water infiltration (Wu and Fan, 2002), and thus may contribute to the water stagnation in

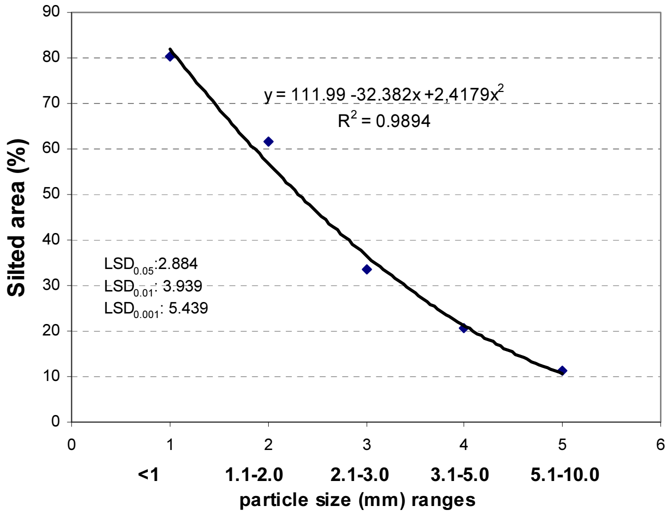

Figure 1. Relation between soil particle size and ratio of silted area (at 0.295 g g^{-1} soil moisture content, March, 2013)

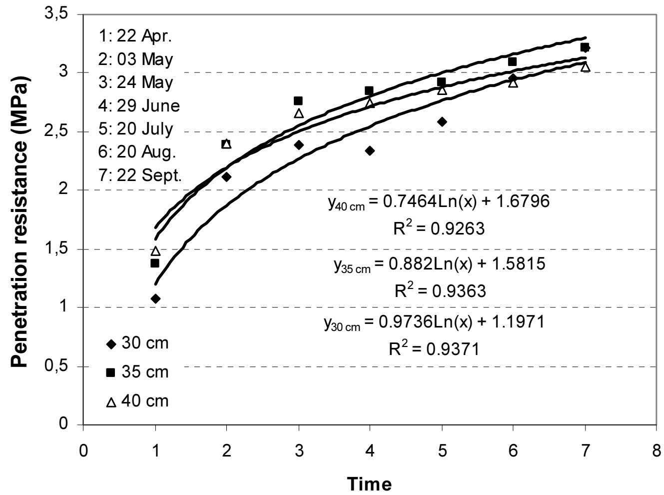

Figure 3. Changing in penetration resistance values in three affected layers of a ploughed soil, in a rainy season (seasonal average of soil moisture content: 0.245 g g^{-1})

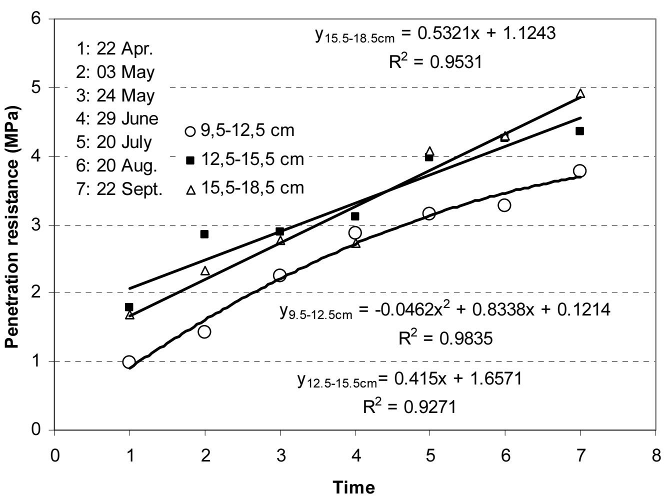

Figure 2. Changing in penetration resistance values in three affected layers of a disk tilled soil, in a rainy season (seasonal average of soil moisture content: 0.245 g g^{-1})

the soil surface. In case of the greater particles (5.1-10.0 mm in diameter) dominance the soil deterioration has remained at a tolerable level.

Recalling to the paper from Bottlik et al. (2014), in which ratio of silted area variants were ranked, and concluded that when degree of the referred area is surpassed of 51% that is considered to be serious. As they found, siltation at the covered surface and the preserved soil proved to be negligible.

The dust formation is considered to be the negative phenomenon, regardless of what was the primary reason of the damage, e.g. climate and/or pulverising tillage. Wu and Fan (2002) observed that precipitation can wash down a large amount of finer particles from the air onto and into the surface. As we noted above, the dusts are often transported into the soil, at least to the nearest pan layer. The proportion of dust in the surface layer is continuously decreasing during the rainy season (2010), while it is increasing below the disk tilled and ploughed layer. Three seriously affected layers were found both in disk tilled and in ploughed soils (Figure 2 and 3).

Penetration resistance values – at similar soil water content that is at 0.245 g g^{-1} – have continuously increased in the referred layers due to the dust sedimentation and adjoining to the former compact layer. Increasing ratios of the penetration resistance were significant ($LSD_{0.05}$: 0.593 at disked and 0.339 at ploughed soil, $P < 0.01$ and 0.001) referring the three selected layers.

The correlations between the data were close, and our formula gave explanations between 92.7 and 98.3% for the compaction extension in the disked soil, and between 92.6 and 93.7% in the ploughed soil. As a result of the dust sedimentation the undisturbed zone soil became more compacted, therefore, the compaction zone was extended, particularly towards the soil surface. In a rainy year (2010) extension of the pan compaction was observed both in disk tilled and ploughed soil, at same (0.245 g g^{-1}) soil moisture content. Penetration resistance of the whole upper 50 cm layer has increased from April to September by 2 MPa both in the two tillage variants. The highest increase of the penetration resistance for the layer between 10 and 20 cm was detected at disking variant *(*Figure 4), while it was found at the depth of 25-35 cm in the ploughed variant (Figure 5).

Water stagnation above the disk and plough pan was also proved both in the rainy year of 2010 and in the same way in the rainy spring in 2013. Soil settling has become a typical phenomenon in the regional soils in the first half of year 2013. But, as Bottlik et al. (2014) noted, it strongly depended on the soil quality, mainly on physical and biological condition. They measured a quite intensive settling effect on degraded soils and on soils having bare (uncovered) surface.

In spring 2013 crusts have been formed both in soils to be unsown and in the row spacing of the winter and spring crops. Crust development follows several stages under the effects of cumulated rainfall and this phenomenon has followed with

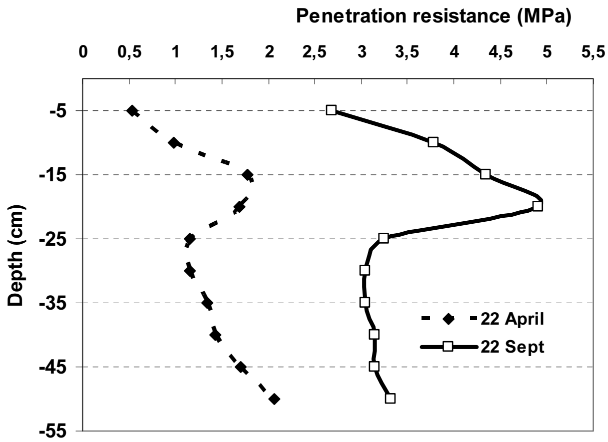

Figure 4. Extension of the former compacted layer in a disk tilled soil in a rainy season

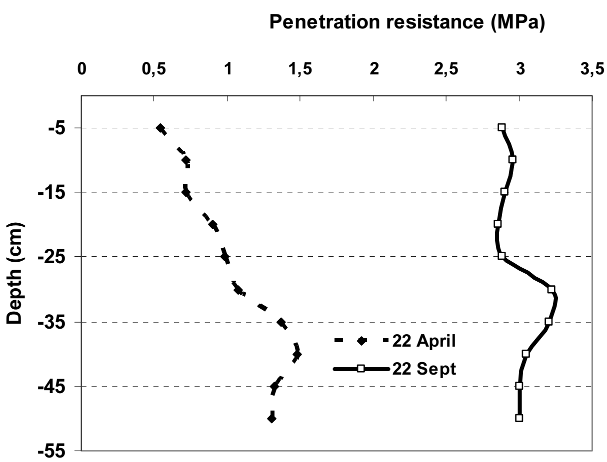

Figure 5. Extension of the former compacted layer in a ploughed soil in a rainy season

appropriate attention in the international research (e.g. Fang et al., 2007; Badorreck et al., 2013). To crust formation in the silted surface considering the frequency was payed more attention because no similar serious damages occurred in the last decades. By assessing the crust thickness at different soil quality and surface state (Figure 6) a low degree of the damage was stated at preserved soil variant (PC, DC), mainly when surface was adequately (by 45%) covered by stubble residues. The statistical analysis showed significant effects ($P < 0.01$) for the soil quality and surface cover on the crust thickness. In addition, interaction between the factors had also a significant effect ($P < 0.01$) on the crust thickness.

The surface cover had greater effect (by 32.6%) on the preserved soil (PC) in the decrease of the crust thickness than on degraded soil (DC). The crust formation was stronger in a bare surface and for this reason, the difference between better (PB) and degraded (DB) soil remained quite low (11.9%). The crust was deepest at the second measuring time (on April 10). This finding was attributed to the period when a dry and warm weather succeeded a term characterized by strong rains. Skidmore and Layton (1992) noted that the high amount of fine particles in soil play a very important role in the process of the formation and remaining of crusts.

Six main types of combined heat and drought stress phenomena were observed in and out of the experimental plots. Soil desiccation has ensued from time to time when lack of precipitation became more severe. Limited water transport and greater drought stress were found in soils deteriorated by compacted pan. However, unutilised water was measured below the serious pan layers. Ratio of crumb has gradually reduced in bare, heat-affected soils, and simultaneously increased the proportion of the dust. When rainy period has stopped, crusts were formed in the surface which was previously deteriorated by siltation. Number of earthworms has also been reduced in warmed and poorly structured soils (Birkás et al., 2010).

The annual precipitation may cover the water requirements of the crops even for adequate yield levels. Under Pannonian conditions a considerable part of the precipitation is lost by surface runoff, downward filtration and evaporation (Várallyay, 2013). Moreover, the infiltration is often limited by the impermeable soil layer(s) occurred near to the soil surface (disk pan) or below the regular depth of ploughing (plough pan). Soil desiccation during warm summers is a usual phenomenon in this region (Pospišil et al., 2011). However, water loss from soils during colder periods is found as a relatively new challenge. Considering the possibility of dry weather in the spring, the conventional soil preparation requires an evaluation by a new aspect. According to the National Meteorology Service (OMSZ) the actual soil water deficit in the

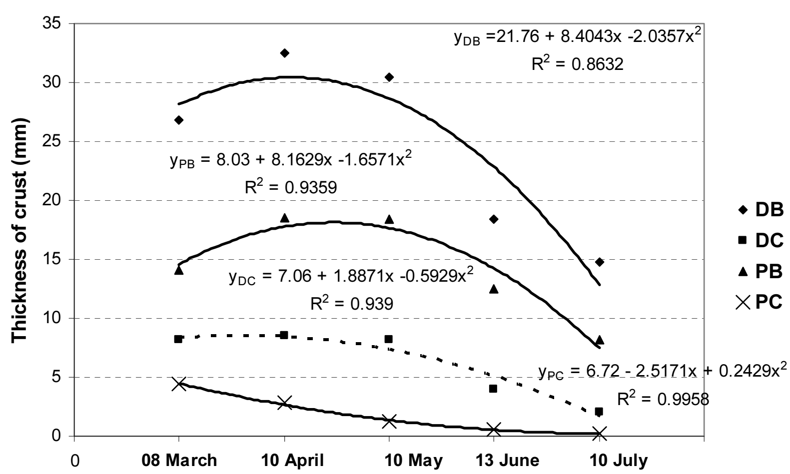

Figure 6. Changing in crust thickness at different soil quality in a rainy season (2013). **Legend:** DB: degraded soil, bare surface; DC: degraded soil, covered surface, PB: preserved soil, bare surface, PC: preserved soil, covered surface. Ratio of the cover: 45%.

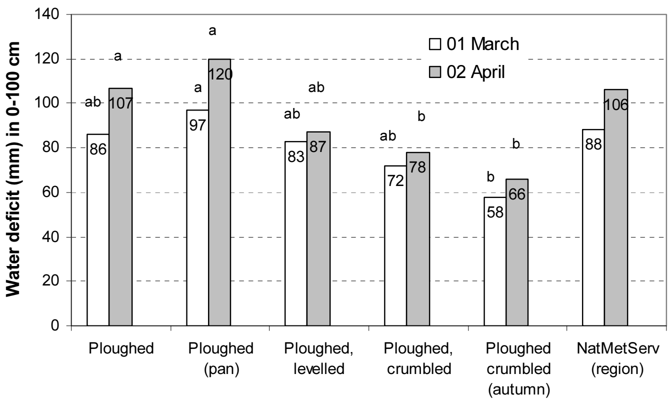

Figure 7. Water deficit in ploughed soils prepared by different methods in spring, 2012; Columns with different letters indicate significant differences at $P < 0.05$; $LSD_{0.05}$: 27.25

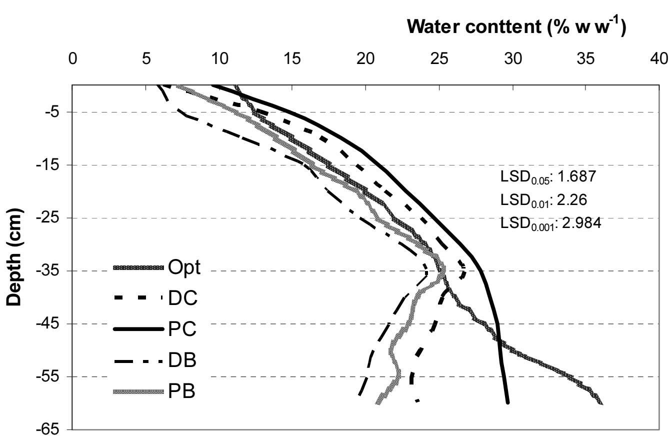

Figure 8. Optimal and actual water content, to a depth of 0-65 cm layer at the end of an extreme season at different soil quality (2013). **Legend:** DC: degraded soil, covered surface, PC: preserved soil, covered surface. DB: degraded soil, bare surface; PB: preserved soil, bare surface; Ratio of the cover: 45%

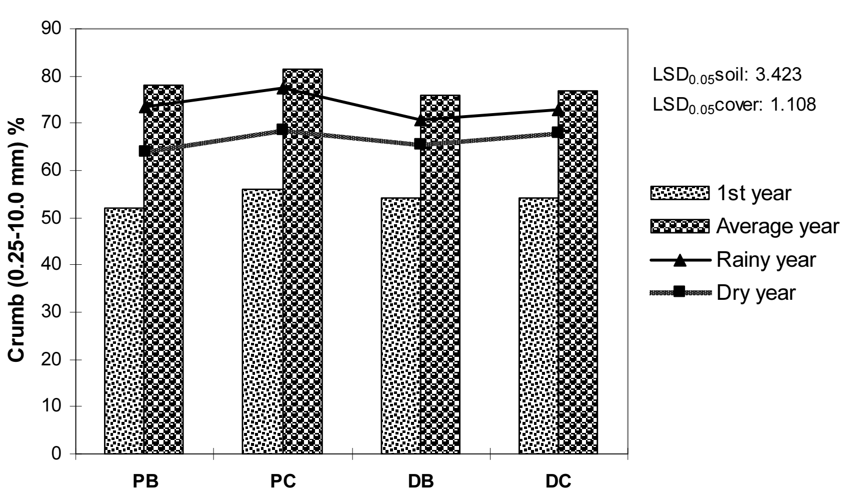

Figure 9. Ratio of crumbs at four soil quality state at the beginning, in average, in wet and in dry years. **Legend:** DC: degraded soil, covered surface, PC: preserved soil, covered surface, DB: degraded soil, bare surface; PB: preserved soil, bare surface; Ratio of the cover: 45%

sub-region of Hatvan showed 68-115 mm in March 2012 and decreased slightly to 68-110 mm till April. The highest water deficit (97 mm in March, 120 mm in April) was recorded in a ploughed variant that was deteriorated by a hard pan (Figure 7).

Cause of the poorer soil water content can be explained with the lower water storage and with higher water loss. Confidence intervals of the difference (that is h_1 and h_2 = 79.20 ± 18.40) can be interpreted for the given soil situation. Ratio of water deficit in March was: minimum 60.8 and maximum of 97.6 mm, and in April minimum 64.5 and maximum 118.7 mm, at similar dry period by a 0.05 level of significance. The water deficits (mm) early in the season were as follows in downward tendency: Ploughed, pan (120) > Ploughed (104) > Ploughed, spring levelling (87) > Ploughed, spring crumbling (78) > Ploughed, autumnal crumbling > (66). These soil variants, due to different moisture content, had differently suffered from the drought that stricken the region in year 2012.

Deficiencies in water content of soils are real risk in the dry periods, as it was found in the autumn of 2013. There were differences between soil state and quality variants. According to Keller et al. (2007) there is a water content of soil at which the amount of aggregates produced is the largest, and, conversely, the amount of clods is the smallest. The optimal water content for tillage was determined in relation to the volumetric water content at the lower plastic limit of the soil (Csorba et al., 2011). In addition, the maximum of crumb ratio and soil friability was also taken into account. At the end of the growing season, soil water content of the two variants (PC and DC) was surpassed the optimal level in the upper layers (Figure 8). The average water content was significantly lower ($P < 0.001$) in the DB and PB variants. We may suppose that the plough pan layer, which occurred at the depth of 28-30 cm (DC, DB), has retained some water above the pan zone. Though, the moisture that has trapped below the pan zone can not be used to alleviate dry condition of the top layer. In spite of the classic belief, presence of the pan compaction can not be adaptable to the water conservation.

The influence of climatic change on soil structure (e.g. type, spatial arrangement and stability of soil aggregates) is a more complex process with numerous direct and indirect impacts (Várallyay, 2007). The proportion of crumbs and particularly water resistant crumbs is an important indicator of land use and tillage (Dvoracsek, 1957). At the beginning of the experiment the crumb fraction (0.25-10 mm) made up 54% of the soil. Ratio of crumbs on the average of the four treatments in optimal year reached 78%, in wet year 74%, and in dry year dropped to 66.5% (Figure 9).

The statistical analysis showed significant ($P < 0.01$) effects for the surface cover on crumb ratio, however, the quality of soil, which is preserved or degraded, had minimal effect. In addition, the interaction between soil quality and cover had a significant effect on the crumb formation. A 45% cover ratio is considered to be a medium level, but at the same time it can mitigate both rain and heat stress. A degraded soil quality coupled with bare surface has indisputably increased soil sensitivity to the various climate stresses. In semi-arid regions wetting and drying cycles are essential factors for soil aggregation (Bodner et al., 2013). This positive phenomenon played an important role in the revival of the earthworm activity that was fairly poor during the preceding extreme periods. We may outline findings from Birkás et al. (2010) that the climate change is having both positive and negative impacts on earthworm activity.

Role of soil tillage in climate damage mitigation

The mitigation solutions presented in this sub-chapter are based on long-term research and regional cooperation (Birkás and Mesic, 2012). For future agricultural development in the region and under new climate conditions, we will need strong professional competence in order to elaborate the adaptable mitigation techniques. There are two important facts that we will have to face with in future research programs. The first is that climate will more incalculable in the next decades, and for this reason all research projects that are targeting mitigation can not be delayed. The second fact is that soil tillage predominantly influences soil condition and it can influence alleviation of negative consequences of climate induced damages. Water surplus in soils originates from high amount of precipitation coupling unpredictable distribution and temporal variability.

The most important measure is to take into account the prevention steps before the predicted damages become more serious in our soils. Creating and maintaining soil condition suitable for water surplus intake is important. Preventing unfavourable changes in soils surface that are pulverisation, silting, and crust forming require the revision and neglect of the overrated practice e.g. sowing into dust. Avoiding clod formation as the preceding phase of the pulverisation has also great significance and new view of the practice e.g. tilling the soil at workable state, and neglecting tillage tools creating clods. Preventing pan compaction occurrence and aggravation is worthy of attention e.g. omitting to use tools creating pans in wet soils, and knowing that dispersed soil fractions may transport to the nearest compacted layer and promote its extension. In other words in soil where is no pan, there is no dust filter. Avoiding crust forming and crust thickening in soil surface requires increasing soil resistance with long-term OM recycling and surface covering. A moderated swelling and shrinking process can really achieved by limiting surface silting and short time drying by surface cover (at least by 50%). We may note that the natural induced water logging can be managed by hydro-ameliorative interventions. However, any farming induced water stagnation is to be prevented by regular subsoiling. In our region a great challenge should also be using a soil condition maintaining tillage in wet condition that is cultivating wet soils by moderated damages that are easily curable in the next season.

A dry soil condition gives good chances to improve soil physical defects formed by inadequate tillage interventions in wet period. Mitigation tillage technique adaptable to the droughty seasons is closely connected with solutions that are suitable to the wet condition. Creating and/or maintaining a loosened state in soil improves water infiltration to the soil, and in the same way promotes water transport from the deeper layers to the root zone. Maintaining and improving water retention ability of soil is primarily required, however fulfilling this goal supposes organic matter conservation in long-term. Shaping a water retaining surface is also recommended since reducing water loss can really be expected mainly in the critical periods. Surface cover should be one of the most important soil and water conservation technique e.g. it contributes to the reduction of clod and dust formation and alleviation of the siltation and crusting. Organic matter conservation, through OM recycling and carbon preserving tillage, will be more appreciated. Ratio of the required cover depends on the soil circumstances although that may presumably varied between 30-60%. E.g. reducing soil warming in summer supposes applying a higher cover ratio. Avoiding dust formation in ploughed soil surface in winter (as frost effect) should also be primary requirement. Considering this, classic ideas and beliefs may also be weighed.

Conclusions

Climate change may have negative impact on soil quality in the Pannonian region. The existing land use and soil tillage systems are often based on the classic – and outdated – beliefs. Soils will really be exposed to the climate stresses. Vulnerability of soils has already become an acute problem for agricultural and environmental sustainability, and it will be even more complex problem in future decades.

The predicted milder winters with more precipitation give chance for more water storage if the soil moisture intake capacity is maintained and improved by adaptable tillage. Any tillage intervention should be aimed at helping rainwater infiltration and at minimising the loss of water in and outside the growing season.

A relatively new challenge is the water loss from soils during colder periods, which call attention to form water preserving surface before soil wintering.

Considering the possibility of dry and hot summers, the conventional soil preparation requires an evaluation by a new aspect. Rationalising soil disturbance and extending the period during which the soil is covered will be indispensable if damage by winds and storms is to be alleviated.

A water managing tillage is to be combined with the organic matter conservation including OM recycling and carbon preserving solutions.

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