INTRODUCTION

The climate and its changes both in central Europe and worldwide are gradually becoming a topic of interest to the general public. The shares of the civilization factors involved and the natural climatic variability have not been fully resolved. The available data suggest that in previous centuries, the Bohemian countries also experienced periods of extreme droughts (Brázdil et al. 2015, Beranová et al. 2018). These dry episodes resulted in poorer quality of life of the inhabitants, extensive losses of crops leading to a significant increase of prices of food, and necessity to adopt the emergency measures to eliminate the impacts of the extreme droughts. The analyses of trends in the development of temperature and humidity characteristics from the past years document a gradual elevation of the temperature at our territory, fluctuations in precipitation sums, and deepening the soil moisture deficit (Rožnovský, 2019). The prospective climatic scenarios presenting the potential consequences of the climate change for the years 2050 and 2100 in the Czech Republic show the possible impacts of these continuing trends in the climate development (Trnka et al. 2018).

The prospects of climate change in the central European region for the 21st century, which signal a risk of long-lasting and more intensive episodes of drought, namely in the period of April-September, show the expectations of essential adverse impacts on the spheres of agriculture, forestry, as well as water management (Naveen et al. 2007, Trnka et al. 2016).

The extent of agricultural drought consequences is growing not only due to the unfavourable development of climate conditions, but also in association with the degradation of agricultural land and loss of its surface area. Agricultural land comprises about 53.5% of the Czech Republic (CR) territory, 38% of which consists of arable
land (20% of the CR territory). An additional 34% of the CR territory is represented by woodlands (Janků, 2016). Absorption of precipitation water by soil and its subsequent retention in the soil environment is one of important extra-production functions of agricultural land, particularly with regard to reducing the consequences of drought and flash floods (Humann, M et al. 2011, Geroy et al. 2011).

The landscape character and use also play some role in the climate variability. During the 20th century, the Czech landscape underwent dramatic changes associated with the manner of management of agricultural and forest land and with dynamic development (Sklenička et al. 2004, 2014). The increasing temperatures and growing frequency of dry periods are greatly enhanced by agricultural management on large blocks of arable land sown with monocultures (Kiryluk, 2016). In addition, the soil is threatened by a number of degradation processes. The most important risk is erosion by water, which threatens about 60% of land (approximately 12% of which is already degraded), 14% is at risk of erosion by wind; other degradation processes include compaction, lack of organic matter, and soil acidification (SOWACGIS).

The change of this alarming state is possible only by modifying the manner of land management, which is particularly relevant regarding agricultural subjects. Agriculture, as a tool for maintenance of the quality and quantity of water and land condition, can employ additional anti-erosion measures, i.e. introduction of novel land-protecting technologies and support of application of complex land adaptations (Vitikainen, 2014). Adaptations of the structure of land blocks should contribute to increasing the water retention capacity of the landscape and decrease the risk of erosion, or optionally allow the construction of water management facilities. During zone planning, emphasis is placed among other factors on increasing the coefficient of ecologic stability, in association with the adaptation to the climate change.

This study was aimed at finding the differences in the water retention capacity of various land types – permanent grass cover and arable land – in the experimental areas: Hustopeče/Starovice and Němčice, located in the South Moravian region, territory at the highest risk of climate change impacts, i.e. increasing temperatures and agricultural drought.

**METHODOLOGY AND DATA**

**Model locality Micmanice**

In order to simulate natural rain and measure the speed and amount of infiltrated water, including surface runoff, we used an adapted portable rainfall simulator – infiltrometer of the US Geology Service (Mc QUEEN, 1963, Janeček 1989). In our project, the device for capturing the surface suspension has been rearranged. In the original simulator, the surface suspension was aspirated, while after adaptation, the suspension freely flowed to the collecting vessel (Fig. 1).

This type of rainfall simulator met the requirements of usability under the field conditions, i.e., low demands on material technical support (the locality has no access to water and energy supplies) as well as relatively easy installation, operation and transport.

This apparatus consists of: a spray head (dripper), a holding tank with a regulator, a stand with anti-wind protection, and an overflow device for collecting surface runoff. Distilled water is used to simulate the rainfall. The volume of water in the tank (ca 20 l) is sufficient to create a sum of rainfall of 120 mm. Drops fall to the collecting area from the height of 1.6 m inside an organic glass column. A metal ring in the form of a reversed truncated cone of 200 mm inner diameter is used to delineate the collecting area. At the soil surface level, this ring contains a hole (outlet) by which the suspension of eroded soil flows to a graduated cylinder. The simulator was used at two experimental localities, both on a permanent grass cover and on arable land. We investigated the following data: duration of precipitation, total sum of precipitation, total intensity of precipitation, total infiltration, total infiltration intensity, mean infiltration intensity, infiltration coefficient, total surface runoff, total intensity of surface runoff, mean intensity of surface runoff, and runoff coefficient.

**Characteristics of study localities**

The Hustopeče/Starovice area (Fig. 2) is part of a small agricultural catchment with a distinct talweg ended by a dry reservoir with an outlet to the Starovice Brook at the border of a built-in area. According to the overall climate
character, Hustopeče with its surroundings belongs to the natural region of Hustopeče Highlands with favourable climatic conditions. The geomorphological unit makes a part of a warm region, warm and dry district with moderate winters and relatively short sunlight. The mean annual temperature is 9.2°C. The mean precipitation reaches 563 mm per year with a maximum in July and minimum in February.

Representation of soil types in the studied locality (experimental area):
- Modal chernozem (CEm)
- Washed-off modal chernozem (CEm)

The Němčice study area (Fig. 3) is located in the catchment of the Němčice Brook and climatically belongs to a moderately warm region, moderately humid district. The mean annual temperature fluctuates around 6°C; the mean annual sum of precipitation reaches 652 mm. The relief of the experimental catchment forms moderately broken, long gentle slopes of the Drahanské Highlands. The water divide at the highest point crosses the altitude of 656 m; the catchment closure is situated at the altitude of 556 m and the mean catchment altitude is 606 m.

RESULTS

Field surveys were always conducted in the spring and autumn seasons (before and after the crop growth). During the project, 24 simulated rainfall processes were conducted by a field rain simulator and the results of the experiments on permanent grassland and arable land were compared. An example of determining the quantities above is presented in table 1 and in Figs. 4 to 6.

On the basis of the measurement results of the ratio of simulated precipitation and runoff for all the investigated years, the infiltration and runoff coefficients were established. The infiltration coefficient (ratio of the infiltrated amount of precipitation to the precipitation volume) for all investigated localities and land types as an indicator of the soil infiltration capacity is presented in Figures 7 and 8. The overall evaluation of the infiltration capacity based on all measurements is presented in Figure 9.

The results of the experiments showed higher infiltration capacity of permanent grass covers compared to arable land by 34.5%, while the permanent grass cover infiltration capacity on cambisols exceeded that of arable land by 35.2% and that on chernozems by 33.8%. These findings correlate with those by Van Dijk et al. (1996),
who tested the infiltration capacity of grass strips with the width of 1.4–5.0 and 10 m. These strips were capable of infiltrating precipitation and retaining the erosion washout sediment to the extent of 50% to 90%. The infiltration coefficient of arable land on chernozems was 52% and on cambisols 57%. However, the infiltration rate is dependent on the soil condition (Otalvaro et al.)
2016), amount of organic matter (Minasny et al. 2017, Hollis et al. 1977), manner of cultivating crops, and agro-technical operations (Kintl et al. 2018, Manojlović et al. 2008). These findings are also documented by the results of the experiments performed in our model localities; e.g., in the Hustopeče/Starovice locality, on September 11th, 2019 the infiltration experiments were conducted.
Table 1. Rated for rainfall simulation

|                              |        |        |        |        |
|------------------------------|--------|--------|--------|--------|
| Duration of sim. precipitation: | 35.0   | [min]  | duration |        |
| Total sum of sim. precipitation: | 79.1   | [mm]   | height   |        |
| Total precipitation intensity:  | 2.3     | [mm/min] | intensity |        |
| Mean precipitation intensity:   | 2.2     | [mm/min] | intensity |        |
| Total sum of infiltration:      | 691.7   | [ml]   | volume   |        |
| Total infiltration intensity:    | 0.7     | [mm/min] | intensity |        |
| Mean infiltration intensity:     | 1.0     | [mm/min] | intensity |        |
| Infiltration coefficient:       | 30.9    | [%]    | ratio    |        |
| Total surface runoff:           | 1550.0  | [ml]   | volume   |        |
| Total intensity of surface runoff: | 1.6    | [mm/min] | intensity |        |
| Mean intensity of surface runoff: | 1.2    | [mm/min] | intensity |        |
| Runoff coefficient:             | 69.1    | [%]    | ratio    |        |

Fig. 4. Time course of precipitation, runoff and infiltration values

Fig. 5. Time course of the precipitation, runoff and infiltration intensity

Fig. 6. Time course of the runoff and infiltration coefficients
directly after loosening the soil by stubble-tillage and the infiltration coefficient was higher than that of the permanent grass cover. The differences in the infiltration capacity of arable land at both localities are also influenced by the cultivated crops – the locality of Hustopeče/Starovice is mainly occupied by broadcast crops (Zea mays), the manner of cultivation and treatment of which has negative impacts on the surface runoff. The Němčice locality is sown exclusively by narrow-row crops (cereals, fodder crops), which provide good coverage and contribute to higher water retention capacity of the land.

**CONCLUSIONS**

Our experiments have shown the effects of permanent grass cover on increasing the water retention capacity of soil. The average infiltration coefficient (ratio of the infiltrated amount of precipitation to the precipitation volume) was 1.7-fold higher than at permanent grass cover (further referred to PGC) than at arable land. When comparing the median infiltration coefficients (PGC = 48.51%, arable land = 86.03%), the infiltration coefficient at PGC is again higher, by 37.51%. The minimum infiltration values also
confirm the higher values of the infiltration coefficient at PGC (PGC = 63.70%, arable land = 14%).

These data should be taken into account when designing the measures of agricultural management aimed at enhancing the water retention capacity of soil. A significant role may be played by grassed soaking strips, grassed talwegs, and grassing of sloped positions.

A land block of 100 ha surface was used as arable land until 2015. Gradually, a grassed talweg of 5.4 ha surface area and grassed soaking strips of total surface area of 2.2 ha have been implemented, as introduced in Fig.9. In total, a surface area of 7.6 ha has been grassed. The infiltration coefficient at arable land is 51.8%, i.e., 48.2% of the precipitation volume runs off from the land block. The infiltration coefficient at PGC is 85.7%, i.e., only 14.3% of the precipitation volume is not captured by the cover. It means that before grassing, almost half of the precipitation ran off from the surface area of 100 ha. After grassing, the loss of arable land represented 7.6% and the potential retention of the entire area increased by 2.6%. The application of grassing also plays a non-negligible role as a guideline for the manner of land management and as a transformation space and barrier to the surface runoff.

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**References**

1. Beranová, R. and Kyselý, J. 2018. Trends of precipitation characteristics in the Czech Republic over 1961–2012, their spatial patterns and links to temperature and the North Atlantic Oscillation. International Journal of Climatology, 38: e 596–e606.
2. Brázdíl, R., Trnka, M., Mikšovský, J., Řezničková, L. and Dobrovolný, P. 2015. Spring-summer droughts in the Czech Land in 1805–2012 and their forcings. International Journal of Climatology, 35(7): 1405–1421.
3. Geroy, I.J., Gribb, M.M., Marshall, H.P., Chandler, D.G., Benner, S.G., McNamara J.P. 2011. Aspect influences on soil water retention and storage. Hydrological Processes – Wiley Online Library
4. Hümann ,M., Schüler, G., Müller, CH., Schneider, R., Ohst, M., Caspari, T. 2011. Identification of runoff processes – The impact of different forest types and soil properties on runoff formation and floods. Journal of Hydrology, 409(3–4), 9, 637–649
5. Hollis, J. M., Jones, R. J. A. and Palmer, R. C. 1977. The effects of organic matter and particle size on the
water-retention properties of some soils in the West Midlands of England. Geoderma, 17(3): 225–238.

6. Janeček, M. 1989. Portable rainfall simulator – infiltrometer. Meliorace, 25(1): 7–17 (in Czech)

7. Janků J., Sekáč P., Baráková J., Kozák J. (2016): An analysis of land in terms of protection of farmland. Soil and Water Research, 11: 20–28.

8. Kintl, A., Elbl, J., Lošák, T., Vaverková, M. D. and Nedělník, J. 2018. Mixed intercropping of wheat and white clover to enhance the sustainability of the conventional cropping system: effects on biomass production and leaching of mineral nitrogen. Sustainability, 10(10): 3367–3380

9. Kiryluk, A. 2016. Changes in Technologies Soil and Plant Cultivation in the Province Podlaskie and Their Impact on Environment. Ekonomia I Srodowisko-Economics and Environment. 2(57), 287–301

10. Manojlović, M., Aćin, V. and Šeremešić, S. 2008. Long-term effects of agronomic practices on the soil organic carbon sequestration in Chernozem. Archives of Agronomy and Soil Science, 54(4): 353–367

11. MC Queen, I. S. 1963. Development of a Hand Portable Rainfall-Simulator Infiltrrometer. Geol. Surv. Circ. 482, Washington, D.C.

12. Minasny, B. and Mcbratney, A. B. 2018. Limited effect of organic matter on soil available water capacity. European Journal of Soil Science, 69(1): 39–47.

13. Naveen, K. et al. (2007) Impacts of climate change on agriculture. Outlook on Agriculture, 36(2), 109–118.

14. Otalvaro, I. F., Neto, M. P. C., Delage, P. and Caicedo, B. 2016. Relationship between soil structure and water retention properties in a residual compacted soil. Engineering Geology, 205: 73–80

15. Rožnovský, J., Střeštík, J. 2019. Dynamics and trends of air temperature in the territory of the Czech Republic. Úroda (Harvest). 67(12), 65–71. (in Czech)

16. Sklenička, P., Šimová, P., Hrdinová, K., Šálek, M. 2014. Changing rural landscapes along the border of Austria and the Czech Republic between 1952 and 2009: Roles of political, socioeconomic and environmental factors. Applied Geography. 47, 89–98

17. Sklenička, P., Cerný Pixova, K. 2004. Importance of spatial heterogeneity to landscape planning and management. Ekologia (Bratislava), 23(1), 310–319

18. SOWACGIS https://geoportal.vumop.cz/

19. Trnka, M., Semerádová, D., Novotný, I., Dumbrovský, M., Drbal, M. K., Pavlík, F., Vopavril, J., Štěpánková, P., Vizina, A., Balek, J., Hlavinka, J., Bartošová, L., Žalud, Z. 2016. Assessing the combined hazards of drought, soil erosion and local flooding on agricultural land: a Czech case study. Climate Research, 70: 231–249.

20. Trnka M., Hayes A., Jurečka F., Bartošová L., Brázdił R., Brown J., Camarero J., Cudlin P., Dobrovolný P., Eitzinger J., Feng S., Finnessey T., Gregorič G., Havlík P., Hain C., Holman I., Johnson D., Kersebaum K., Charpentier Ljungvist F., Luterbacher J., Micale F., Hartl-Meier C., Možný M., Nejedlík P., Olesen J., Ruiz-Ramos M., Rötter R., Senay G., Vicente-Serrano S., Svoboda M., Susnik A., Tadesse T., Vizina A., Wardlow B., Žalud Z., Büngen U. 2018. Priority questions in multidisciplinary drought research. Climate Research, 75, 241–260

21. Van Dijk, M., Kwaad, F. J. P. M., Klapwijk, M. 1996. Retention of water and sediment by grass strips. Hydrological Processes, 10(8).

22. Vitikainen, A. 2014. An Overview of Land Consolidation in Europe. Nordic Journal of Surveying and Real Estate Research, 1(1).