Youth Corner

The Hungarian Journal of Hydrology is committed to fostering the next generation of professionals. As part of this mission, the Youth Corner's pages provide high school students with the opportunity to present their research. We encourage our readers to welcome and support their study with respect. This study was prepared for the Hungarian competition of the Stockholm Junior Water Prize in 2024.

Improving the water retention properties of our soils

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Abstract
Changes in weather patterns over recent decades have had a significant impact on agricultural production. Due to changes in the distribution of precipitation extremes and an increase in the frequency and length of drought periods the loss of soil moisture is increasing. By studying soil samples collected in Szekszárd (Hungary), the area around our residence, by designing soil mixtures and analysing them, we would like to draw conclusions and make suggestions for improving soil water management. Our hypothesis is that the water management of soils can be improved by the application of soil improvers, which could have a significant positive impact on the water balance of Hungary. Changes in climatic elements started with an analysis of 40 years of meteorological data from the area where we live. Soil samples, soil mixtures and soil amendments (perlite, alginate, zeolite, compost, peat, cattle manure) were analysed for texture, water retention capacity, humus content and pH, and finally, our soil samples, our nine soil mixtures and the two soil samples treated with soil cover were tested for water retention capacity by growing wheat in 120 pots under the same conditions for 13 weeks. The soils tested are silt, silty loam soils, with soil amendments mainly enhancing the sand fraction. The water retention capacity improved with the amendments; the humus content increased more significantly with organic amendments. The pH of the soil mixtures shifted the soil samples towards the alkaline direction. Soil mixtures and soils treated with soil cover were able to retain water to a greater extent than the soil sample.

Keywords
Soil, water retention, soil test, soil moisture retention.

Talajaink vízmegtartó tulajdonságainak javítása

Kivonat
Az éghajlat változásai az elmúlt évtizedekben jelentős hatást gyakoroltak a mezőgazdasági termelésre. A csapadék eloszlásának szélsőségessé válása, az aszályos időszakok gyakoriságának és hosszának növekedése csökkentik talajaink nedvességtartalmát. A lakóhelyünk környékén (Szekszárd, Magyarország) gyűjtött talajminták tanulmányozásával, talajkeverékek létrehozásával, elemzésével szeretnénk következtetéseket levonni, javaslatokat tenni a talajvízháztartás javítására. Hipotézisünk az, hogy a talajok vízgazdálkodása javítható talajjavító anyagok alkalmazásával, ami jelentős mértékben javíthatná a magyarországi talajok vízháztartását. Az éghajlati elemek változását a lakóhelyünkről származó, 40 évet felölelő meteorológiai adatok elemzésével kezdtük. A talajminták, talajkeverékek és talajjavító anyagok (perlit, alginit, zeolit, komposzt, tőzeg, szarvasmarha trágya) textúráját, víztartó kapacitását, humusztartalmát és pH-értékét vizsgáltuk, majd a talajmintánk, talajkeverékeink és fedéssel javított talajunk víztartó képességét vizsgáltuk úgy, hogy búzát ültettünk 120 cserépben és azonos körülmények között 13 hétig neveltük. A vizsgált talajok iszapos, iszapos vályogtalajok, melyekben a talajmódosítások főként a homokfrakciót növelik. A vízvisszatartó képesség a módosításokkal javult, a humusztartalom jelentősebben nőtt a szerves talajjavító anyagokkal. A talajkeverékek pH-ja a lúgos irány felé terelte a talajmintákat. A talajkeverékek és a talajtakaróval kezelt talajok a talajmintánál nagyobb mértékben voltak képesek visszatartani a vizet.

Kulcsszavak
Talaj, vízvisszatartás, talajvizsgálat, talajnedvesség-megtartás.

Introduction
Soil moisture retention is on a negative trend across Europe and the world. Eastern Europe has experienced the most severe decline, while Northern European countries have suffered the least soil water loss over the last nearly forty years. Soil moisture levels are decreasing also in Hungary, especially in the spring and summer, posing difficulties to agricultural production. In a study by ELTE researchers, several options are proposed to tackle the problem, one of which is to shift arable cultivation from drought-prone regions to less drought-prone ones. To solve the problem locally, they suggest leaving more ponds, mulching or replacing the missing water with surface water (*Pinke et al. 2022*).

In Hungary, the number of extreme precipitation events and the length of consecutive dry periods have increased over the last 30 years. Based on the past decades, it is not impossible for a summer to be without precipitation for up to half a month, but the number of extreme precipitation events in the summer is also increasing. In Budapest, too, the distribution of precipitation is becoming more extreme, leading to more frequent flash floods, basement collapses and can also hamper transport due to overloading of the sewer network. In rural areas, the extreme distribution of precipitation in agricultural areas poses difficulties to crop production, as our soils dry out quickly and cannot store rainfall for long periods. Most of our soils cannot suddenly absorb the large amounts of rain that do fall, and the rivers drain the water out of the country. 95% of Hungary's surface water comes from abroad, imported by rivers, when the volume of incoming water is compared to the total river runoff. According to data from 1961-1990, an average of 112 km^3 of water arrives from abroad, 6 km3 is domestic runoff and 117 km^3 leaves the country, i.e. our water retention is low (*Somlyódy 2011*). Long periods of drought occurred in the last century, too, i.e. drought can be considered as a characteristic of Hungary's climate, but the summers are getting hotter and intense heat waves are increasing the drought risk (*Szentes 2022*). The damage could be reduced by retaining inland water and abandoning farming in the most vulnerable areas, but this would also reduce our productivity. In the case of drought, the solution is a combination of water recharge, increasing the amount of water infiltrating into the soil and adaptation. The problems of territorial water management can be solved by considering flooding, inland water, and drought together (*Somlyódy 2011*). Soil water absorption and drainage is a complex process in which processes of different directions and magnitudes take place. The soil itself is a passive water source, only able to provide the plant with what it can store from precipitation or absorb from groundwater. Because the distribution of precipitation is uneven, the soil must have the ability to retain water against gravity, but not to such an extent that the plant cannot take it up. The ideal soil composition for most plants is 50% sand, loam and clay, 25% water, 25% air (*Kocsis 2012*). To help solve these problems, we came up with the theme of our project at the end of September 2022, with the aim to propose ways to increase the water retention capacity of our soils. Our aim is to help agricultural crop production and thus a more economical food supply for the country. We have also sought the views of farmers' experts on the extreme weather, who have confirmed the above facts, and local news portals increasingly publish reports on the subject. Our aim is to detect the problem locally by analysing meteorological data and to suggest ways of increasing water retention capacity by examining the properties of the soils in our environment. Our hypothesis is that the soil improvers that can be formed in the country can increase the water retention capacity of our soils to such an extent that our water balance would move towards equilibrium or even shift to be positive and our agricultural production would become more reliable by maintaining soil moisture.

MATERIAL AND METHOD

The meteorological statements were prepared from the data of the Tolna County Government Office *(Tolna County Government Office 2024),* and that of the agro-meteorologist László Kővári from the last forty years (1977-2021). Our aim is to verify the national trends locally (*Kővári 2024*).

Analysis of meteorological data

- For the calculation of the standardized precipitation anomaly index, we determined the mean and standard deviation of precipitation for the period 1977-2021 for each month separately. We then subtracted the mean from the rainfall totals for each month of each year and divided by the standard deviation.

- We examined the number of different precipitation events (0-0.99 mm, 1-4.99 mm, 5-9.99 mm, 10-19.99 mm and 20 mm<) in Szekszárd between 1977 and 2021, broken down by year. We grouped the different rainfall events in each year and then examined the extent to which their number changed over time.

- We determined the amount of precipitation in mm that fell during the extreme rainfall events (20 mm<) in each year and then used the trend line to determine the direction of change.

Soil sampling

The soil samples were collected according to the *MSZ 21470 regulation* from seven different locations: from Decs, Koty, Solt, Hidas, Sióagárd, Fadd, Szekszárd. Samples were taken from the top 30 cm of the soil from several locations within the designated area and then mixed to create the soil sample. The samples were placed in tightly sealable containers and labelled according to their place of origin. Our aim was to learn about the soils in the surrounding areas.

Soil tests

Soil texture analysis

Soil texture analysis was carried out in the laboratory of the Institute of Geography of the University of Pécs, where the samples were dried for 24 hours at 105 ºC using a drying oven. Afterwards, 50 grams of soil samples were weighed and treated with 10% hydrochloric acid and 35% hydrogen peroxide to decompose the aggregates. Finally, the soil samples were placed in distilled water and textured using a Malvern hydro2000M machine. The water is passed through the machine's channel, where it illuminates the soil particles, and the laser can create an accurate image of the size of the soil particles. The values obtained were categorised into clay, silt, sand and then plotted using a soil texture triangle diagram to show the results. The same analysis was carried out with soil mixtures and soil amendments where necessary.

Analysis of humus content

The soil samples were left to dry for 2 weeks, then their humus content was tested in the laboratory of the Institute of Geography of the University of Pécs. The test was performed using the chromic acid method: 1 g of soil sample was weighed into a test tube and then 10 ml of 5% $K_2Cr_2O_7$ solution was added. After 10 minutes of shaking and resting, 20 ml H_2SO_4 was added to the samples. After cooling, the samples were made up to 100 ml with distilled water and left to stand for 16 hours. Subsequently, the determination of the humic matter was performed by spectrophotometry using a Bichrom Libra S-12 spectrophotometer. To use this instrument, a standard must first be set up, for which a glucose solution was used. All soil samples and soil mixtures were placed in the machine, which provided as a result the organic matter content of the soils based on colour.

Permeability test

Soil samples (7), soil mixtures (9) and soil amendments (7) were weighed out as samples of 20-25 grams into special plastic cylinders with a thin dense woven gauze at the bottom, which was fixed with a rubber band (*Figure 1*). The gauze ensured the free flow of water and the retention of the soil samples in the tube. The cylinders were then placed in a water bath at room temperature and allowed to stand in the water for one hour. After this, the water was left in the cylinders for 3 hours and we put the samples in a sand bath. The sand bed ensured the loss of excess water from the samples. After three hours, 25-gram samples by weight were taken from each tube and dried in a drying oven at 105 ºC for 24 hours to constant weight in specially designed annealing crucibles. After drying, the annealing crucibles were placed in a desiccator containing anhydrous calcium chloride until they cooled. After cooling, the crucibles containing the dried soil samples were weighed on an analytical balance. The weighing procedure is shown in the *Figure 1*:

$$WHC = \frac{Mn - Msz}{Msz} * 100 \tag{1}$$

where: WHC: water holding capacity of the soil sample (%), Mn: the exact mass of the wet soil sample taken from the cylinder (g), Msz: the mass of the sample dried to constant mass at 105 ºC for 24 hours (g) (*Kirchkeszner 2017*).

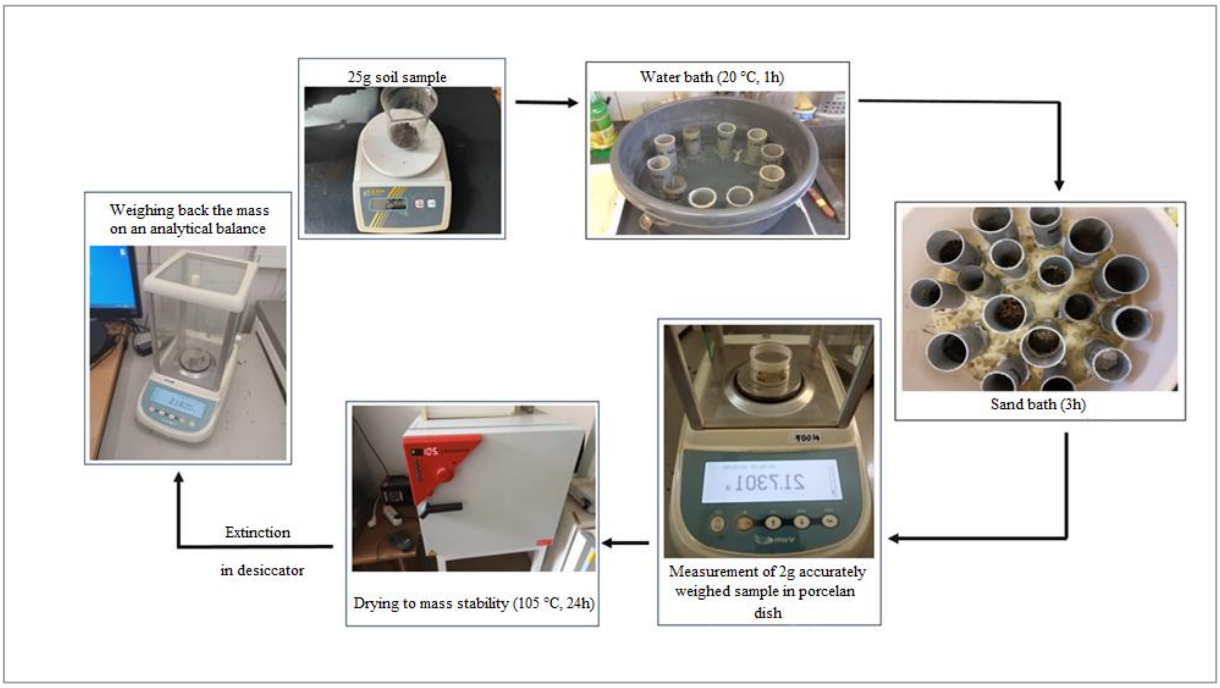

Figure 1. Determining the water-holding capacity of soils
1. ábra. Talajok víztartó kapacitásának meghatározása

PH measurement

Soil pH was measured using a 100-ml sample of the soil texture analysis water. A vwr MU 6100H digital machine was used for the tests, which gives a measurement accurate to two decimal places. In its operation it uses an electrode which is placed in the sample to be measured. Our aim is to get an idea of the pH influence of soil improvers.

Laboratory testing of the water retention capacity of soil mixtures

After testing the soils, the Szekszárd soil sample was selected because it was the easiest to bring large quantities of it to the high school laboratory. We wanted to increase the water retention capacity of the soil by using different materials: compost, perlite, cattle pellets, mulch, peat, alginate, clay pellets and zeolite (*Table 1*).

Table 1. Mixing ratio of soil mixtures
1. táblázat. Talajkeverékek keverési aránya

	Soil collected from the Szekszárd area		Alginitic soil mixture		Zeolitic soil mixture		Perlite soil mixture		Matured cattle manure soil compost		Beef pellet soil mix		Composted soil mix		Peaty soil mix		Base mix containing zeolite, alginate, perlite		Large mix containing peat, cattle manure, perlite, compost, zeolite, alginate	
	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g
Soil	100	1 400	80	1 120	80	1 120	75	1 050	80	1 120	80	1 120	70	980	70	980	55	770	35	490
Alginate	-	-	20	280	-	-	-	-	-	-	-	-	-	-	-	-	15	210	5	70
Zeolite	-	-	-	-	20	230	-	-	-	-	-	-	-	-	-	-	15	173	5	58
Perlite	-	-	-	-	-	-	25	40	-	-	-	-	-	-	-	-	15	24	10	16
Matured beef manure	-	-	-	-	-	-	-	-	20	180	-	-	-	-	-	-	-	-	15	135
Beef pellets	-	-	-	-	-	-	-	-	-	-	20	180	-	-	-	-	-	-	-	-
Compost	-	-	-	-	-	-	-	-	-	-	-	-	30	220	-	-	-	-	10	73
Peat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	90	-	-	15	45
Total	100	1 400	100	1 400	100	1 350	100	10 90	100	1 300	100	1 300	100	1 200	100	1 070	100	1 177	100	887

The soil amendments were weighed on a laboratory balance and 10 pots of each sample were mixed. A total of 12 samples were created and tested. One sample remained 100% Szekszárd soil sample, seven samples were mixed with one type of material in the range of 20-30%. In two samples (mulch, clay ball), we placed the water retention material on the soil surface, and in two cases (base and large mix) we used several soil amendments to make up the mix. In the case of the large mixture, only 35% of the original Szekszárd soil sample remained. The pots filled with the different soil mixtures had different weights, as the percentage by volume of each material was considered when the mixtures were made up, so that the pots were filled with the mixtures in all cases. We used the same 2 litre plastic pots and placed the same underlay under them. In the room where they were placed, they received diffused light, they were not exposed to direct sunlight, they were uniformly affected by air movement, i.e. the 120 pots were equally affected by the weather elements (*Figure 1*). In each planting medium, 25 seeds of Triticum aestivum wheat were planted (*Photo 1.*). The seeds were scattered in the centre of the pot and planted 1 cm deep, and then the soil mixes were watered uniformly with 2 decilitres of water. The mulch and clay balls were placed on top of the soil after germination and sprouting at a rate of 20%. The aim was to test water retention by growing the plants under uniform watering and environmental conditions until their root systems were developed and then to stop watering uniformly to simulate long periods of drought in summer. This allowed us to test the ability of a given soil mix to retain water and keep the plant alive. After the last watering, we sampled each soil mixture once a week to measure the amount of water retained. About 15 grams of soil was weighed out of the sample when wet and placed on a watch glass. The weight of the watch glass was recorded beforehand. The sample was dried for two weeks and weighed again on an analytical balance. The measurements were carried out for 13 weeks. The moisture content was calculated using the following *(2)* formula:

$$\mathrm{Tn\%} = \frac{(\mathrm{Tn}-\mathrm{O})-(\mathrm{Tsz}-\mathrm{O})}{\mathrm{Tn}} * 100 \qquad (2)$$

where: Tn%: soil moisture percentage, Tn: mass of wet soil, O: mass of watch glass and Tsz: mass of dried soil (*Stefanovits et al. 1999*).

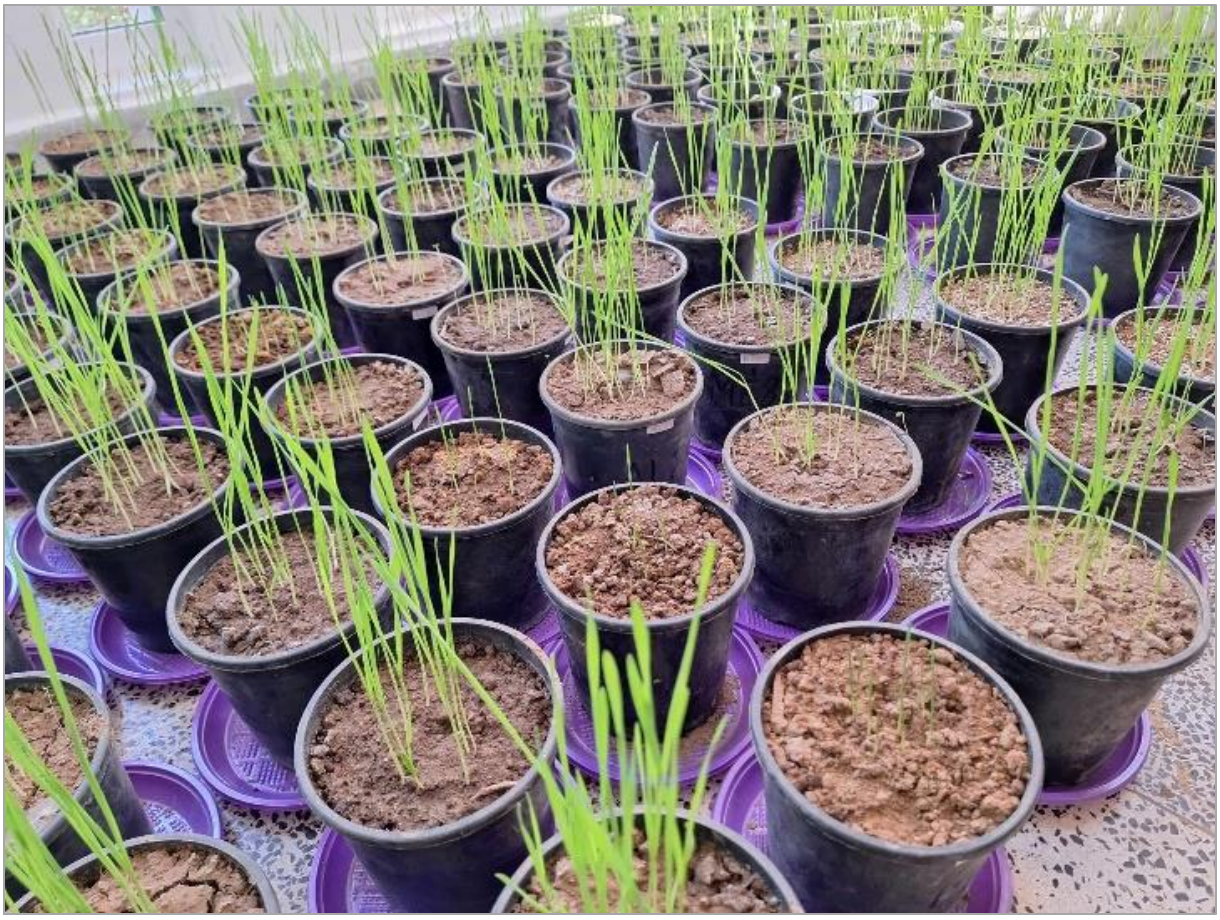

Photo 1. The 120 pots of wheat growing in 12 soil mixes (Photo by Z. Barocsai)
1 kép. A 120 cserép búza növekedése a 12 talajkeverékben (Fotó: Barocsai Z.)

PRESENTATION OF SOIL IMPROVERS

All our soil improvers are available in Hungary. They can be divided into two groups, organic and inorganic. Our organic materials are peat, cattle manure, cattle manure granules and compost. Inorganic materials: alginates, perlite, zeolite. Soil cover materials: mulch, clay pebbles. The map on *Figure 2* shows the soil improvers sites in Hungary.

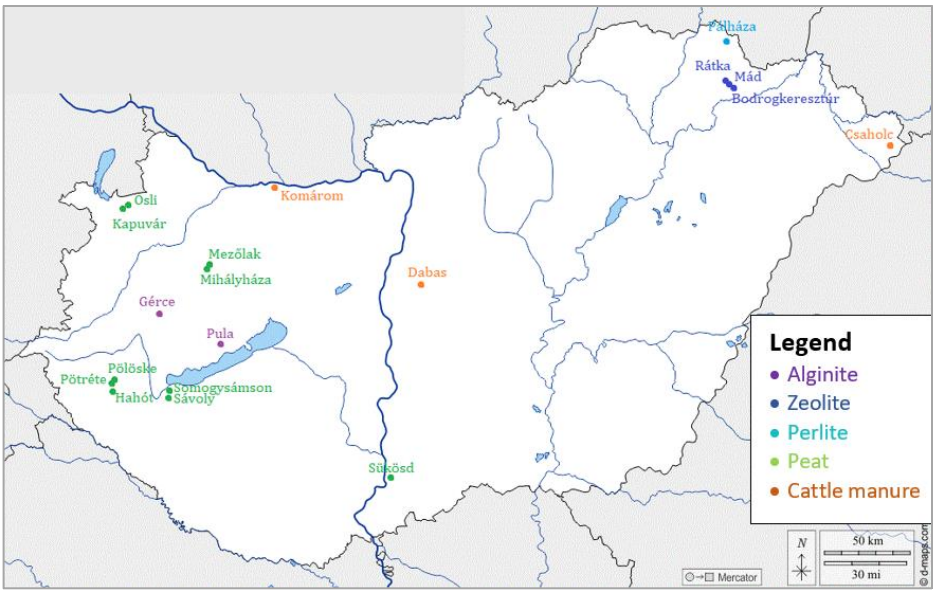

Figure 2. Soil improvers sites in Hungary [edited by B. Sánta and M. Frei based on Barkóczi and Szakál (2007), Dömsödi (2023), Kádár (2002), Hannus (2012)]
2. ábra. Talaj javító anyagok lelőhelyei Magyarországon [(szerkesztette: Sánta B. és Frei M., Barkóczi and Szakál (2007), Dömsödi (2023), Kádár (2002), Hannus (2012) alapján]

RESULTS

The analysis of the meteorological data

The evolution of the standardised precipitation index (*Figure 3*) shows that the distribution of precipitation between years has become increasingly extreme in recent decades.

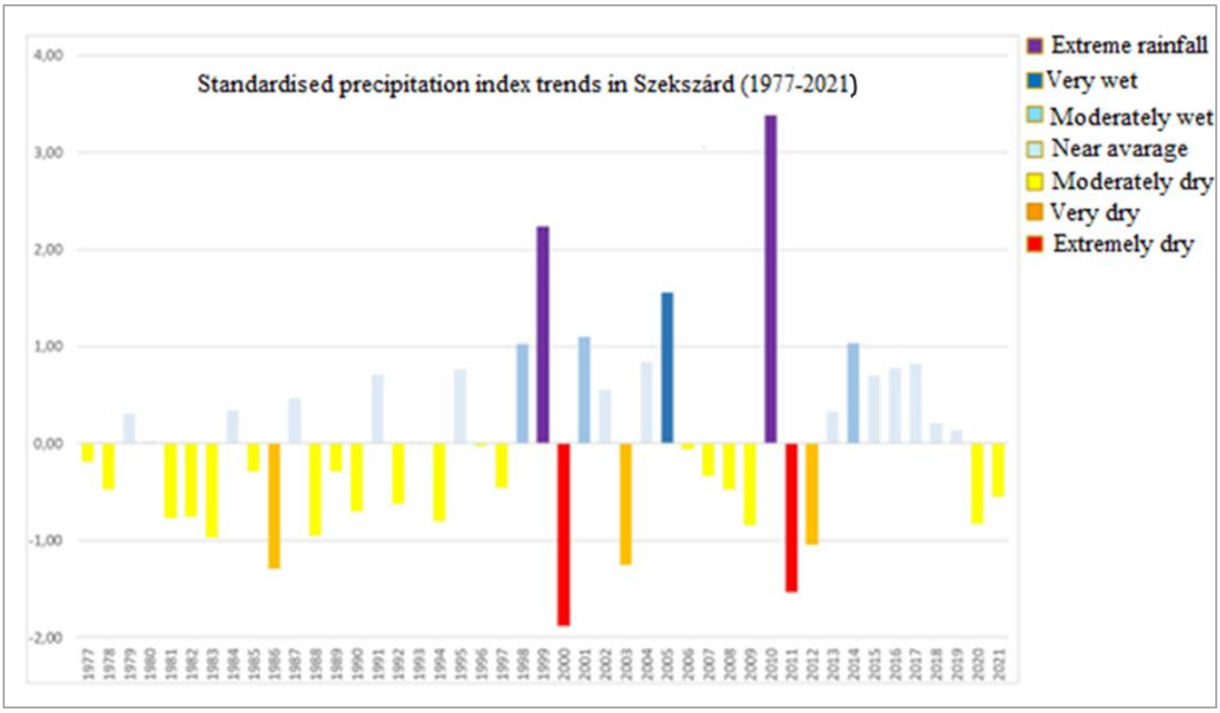

Figure 3. Evolution of the standardised precipitation index in Szekszárd (Hungary) (1977-2021)
3. ábra. A standardizált csapadékindex alakulása Szekszárdon (1977-2021)

As we move towards the present day, we are more and more likely to see years with extreme rainfall and years with extreme drought, even in succession. However, the area around Szekszárd would basically fall into the category between 1 and -1 (moderately dry-average-moderately wet) according to the national records.

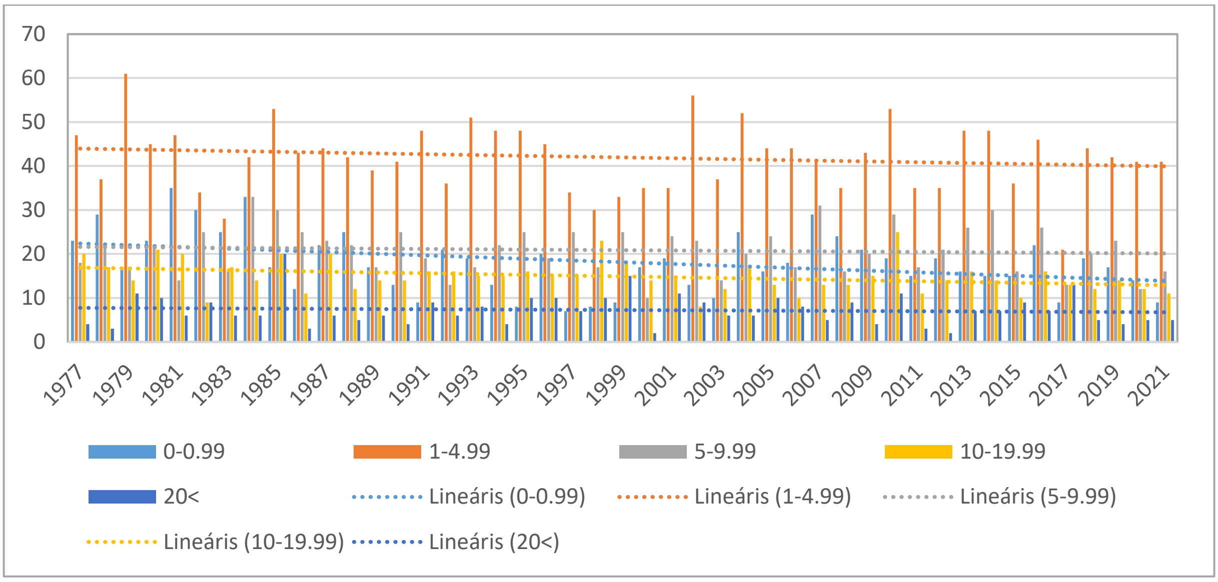

Figure 4. Number of different rainfall events in Szekszárd (1977-2021)
4. ábra. Különböző csapadékesemények száma Szekszárdon (1977-2021)

Looking at the different precipitation events (*Figure 4.*), we can see that the occurrence of precipitation types of below extreme precipitation has decreased in recent decades, while that of extreme precipitation has stagnated. Overall, this means that the same amount of precipitation falls but in fewer days whereas less rainfall, i.e. longer droughts and more frequent heavy rainfall events occur. Soils dry out for longer periods and the rainfall that does fall suddenly runs off, meaning that the soil may not be able to absorb the same amount of water as 40 years ago.

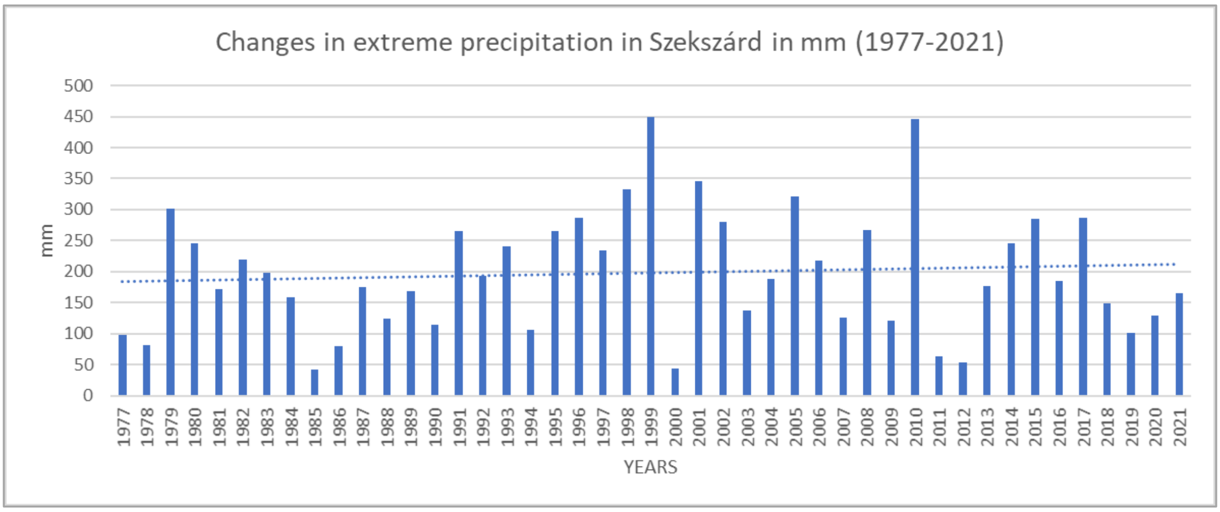

Figure 5. Variation of extreme precipitation in Szekszárd in mm
5. ábra. Az extrém csapadék változása Szekszárdon mm-ben

The amount of water falling as a result of extreme rainfall events is shown in *Figure 5*, which clearly shows an increase. These processes also result in flash floods, which further erode and erode the soil and cause a significant amount of water to run off the area. In sloping areas, it becomes even more difficult to retain rainwater in the soil.

Soil texture analysis

The soil samples clearly fall into the silt, silty loam category (*Figure 6*), which is typical of the loamy soils found in our area. Their water retention capacity is not bad, higher than that of sandy soils, but due to the relatively small space between the soil grains, their permeability is lower than in the case of sandy soils. As a result, these soils are less able to infiltrate sudden heavy rainfall and can store less water in the long term. After creating the soil mixtures, we also examined their grain composition and basically found that the texture of the soil was shifted towards the sand fraction, i.e. the silt and sand fraction started to balance out, but the silt fraction still remained the more. We believe that this has increased the permeability of the soil, meaning that vertical downward seepage may be greater in the event of an extreme rainfall event, but it has not lost any of its water retention capacity due to the water retention properties of the added materials.

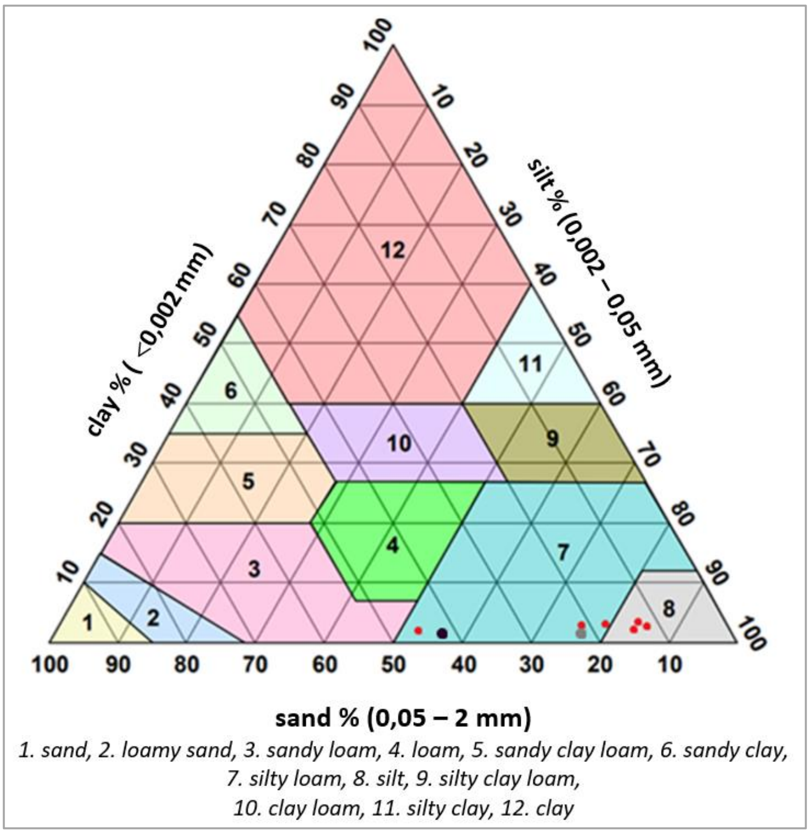

Figure 6. Determination of physical soil types of the tested soils (red: tested soils; grey: average of tested soils; black: average of tested soils with amendment) [Edited by B. Sánta and M. Frei, based on Füleky (2011)]
6. ábra. A vizsgált talajok fizikai talajtípusainak meghatározása (piros: vizsgált talajok; szürke: a vizsgált talajok átlaga; fekete: a vizsgált talajok átlaga módosítással) [Szerkesztő: Sánta B. és Frei M., Füleky (2011) alapján]

Analysis of humus content

The humus content of the tested soil samples (*Figure 7*) ranges widely, as low, medium and high humus content values were found. The highest humus content was found in the Szekszárd sample, the lowest in the Hidas sample. The average of the 7 samples was 3.07%. The large variation may be due to different farming practices, the use or absence of manure or fertiliser and different levels of soil erosion.

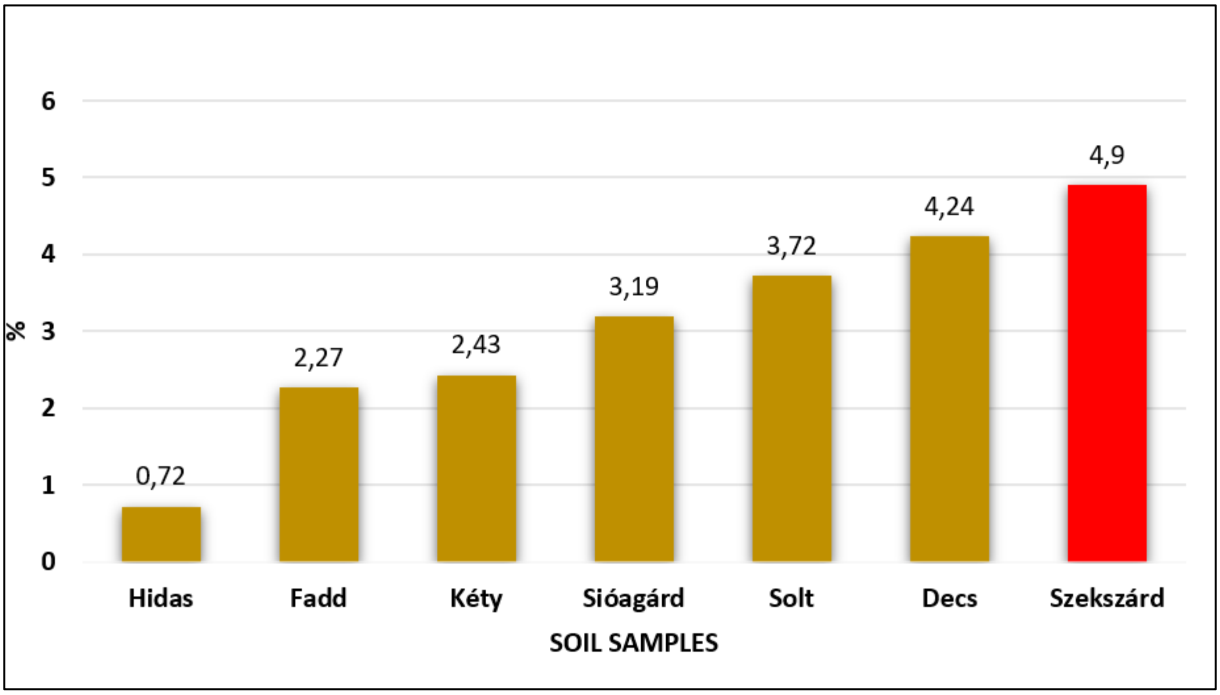

Figure 7. Humic matter content in soil samples in %
7. ábra. A talajminták humusztartalma %-ban

For the humus content of the soil mixtures, all but the base mixture (alginitic-zeolitic-pearlitic) showed an improvement (*Figure 8.*). No significant differences were expected for these soil amendments compared to the selected Szekszárd soil sample, as their organic matter content is either not significant or there is not any. The difference is not significant for the perlite and alginate soil mixes, but significant for the zeolitic mix. In the latter case the high value is due to the high phosphorus and potassium content of zeolite. The mixture with cattle pellets also does not show a significant increase, as confirmed by testing the mixture with wheat, where germination and growth were slower than in the other mixtures. At the end of the range are the peat, matured cattle manure and compost mixtures, which are not surprisingly placed as they have a significant organic matter content. The sample with the name "large mix" contains only 35% of the original soil, so the significant increase in humus content is not a coincidence.

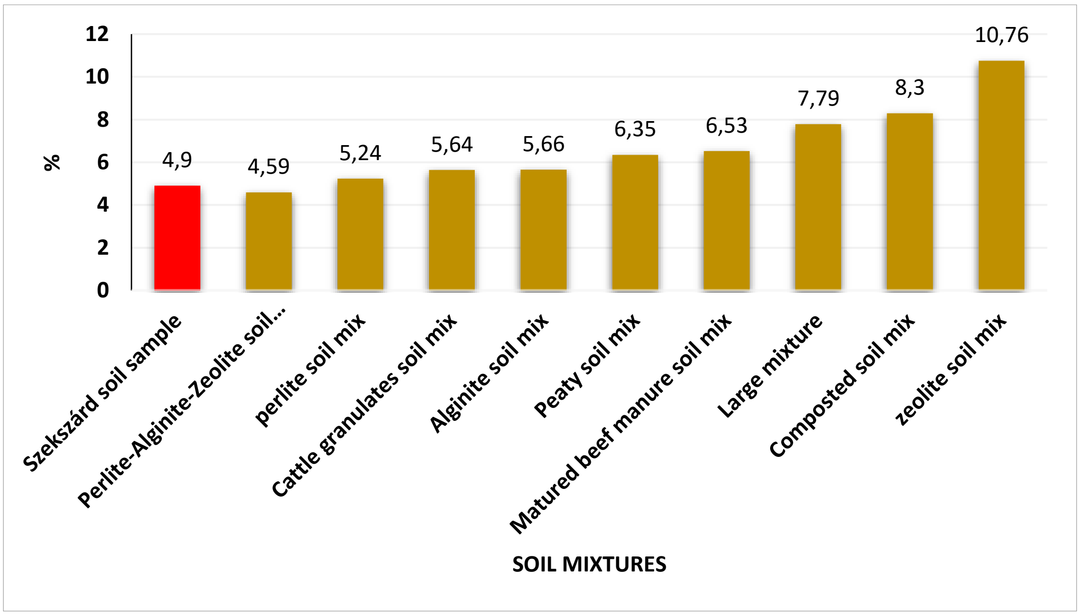

Figure 8. Humus content of soil mixtures in %
8. ábra. Talajkeverékek humusztartalma %-ban

Water retention capacity test

The water retention capacity of the soils tested (*Figure 9*) shows an average value of 28%. Of these, the sample taken in Szekszárd was the highest with a value of 43%. Together with the samples, potting soil was also tested, with a water retention capacity of 101%. Overall, the water retention capacity of the surrounding soils, which are mainly loess and floodplain soils, is not high. Most of our lowlands are also covered by loess soils and floodplain soils, which means that their water retention capacity may be similar. In our sandy areas (e.g. Nyírség, Kiskunság) the value may be even lower, as the coarser grain fraction has better permeability but lower water retention capacity. In the case of clay soils, the water retention capacity may be higher, but the permeability is lower, which makes it less effective in retaining the less frequent rainfall.

For the soil mixtures (*Figure 10*), the water retention increased except for zeolite. Nevertheless, zeolite may be suitable for soil improvement, but it had a negative effect mainly on sandy soils and on silty loam soils. The most significant increase in water retention was for the large mix, which contained 65% water retention enhancers. The peat and compost mixtures with high organic matter content also showed an outlier. Again, there was little variation in the cattle manure sample, so it not only does not add enough to the soil to increase humus content but also does not improve water retention. In general, it can be concluded that organic soil amendments contributed more to water retention and inorganic amendments contributed less.

The soil conditioners (*Figure 11*) alone confirmed the values in the previous diagram. Zeolite is weak while peat has a high water retention capacity.

PH measurement results

It is important to note that our crop and most of the crops we grow are most profitable in slightly acidic, neutral (pH 6-7) soils. When pH is shifted to extremes, either directly or indirectly, but always adversely, it will affect plant growth. Of the soil samples tested (*Figure 12*), one was in the slightly acidic range, one in the neutral range, and the others in the slightly alkaline range. The Szekszárd soil was a fortunate choice as its pH is in the ideal range for crop production. A pH value between 6 and 7 is where the uptake of most nutrients is close to the maximum. Changes in chemistry directly affect the solubility of nutrients.

Soil pH is basically in the neutral to slightly alkaline category and would shift even more towards alkaline with the use of soil amendments (*Figure 13*). The shift is not significant, the soil mixtures are still in the neutral to slightly alkaline category, which does not significantly affect the uptake of nutrients by the plant, but it is worth measuring when they are applied to get an indication of the extent of the shift.

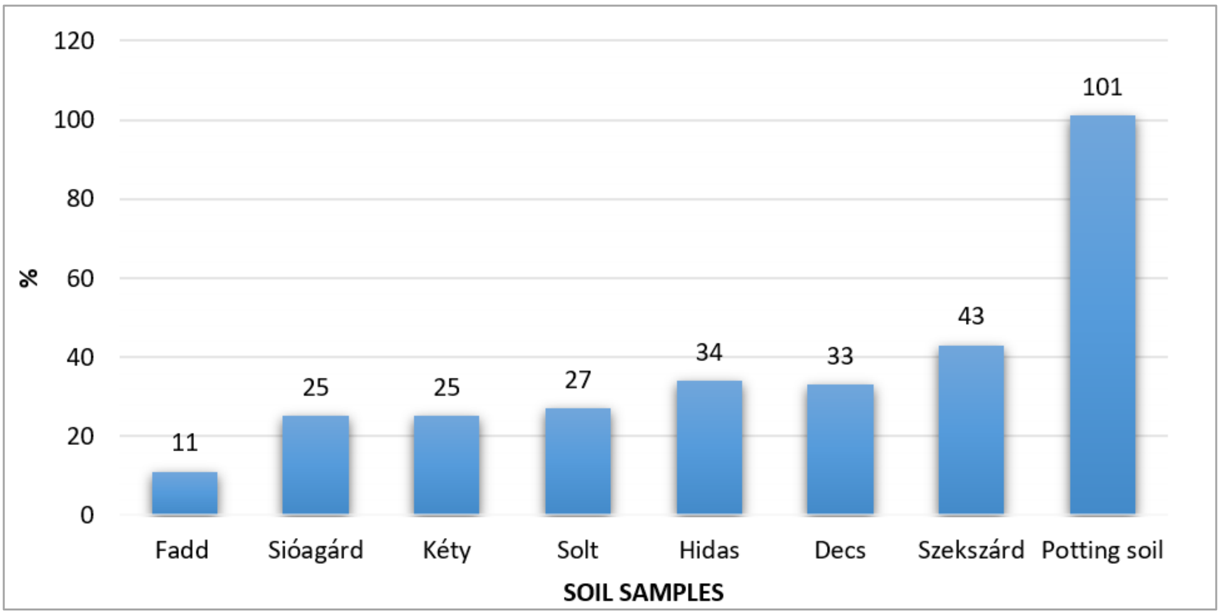

Figure 9. Soil water-retention capacity in %
9. ábra. Talaj vízmegtartó kapacitása %-ban

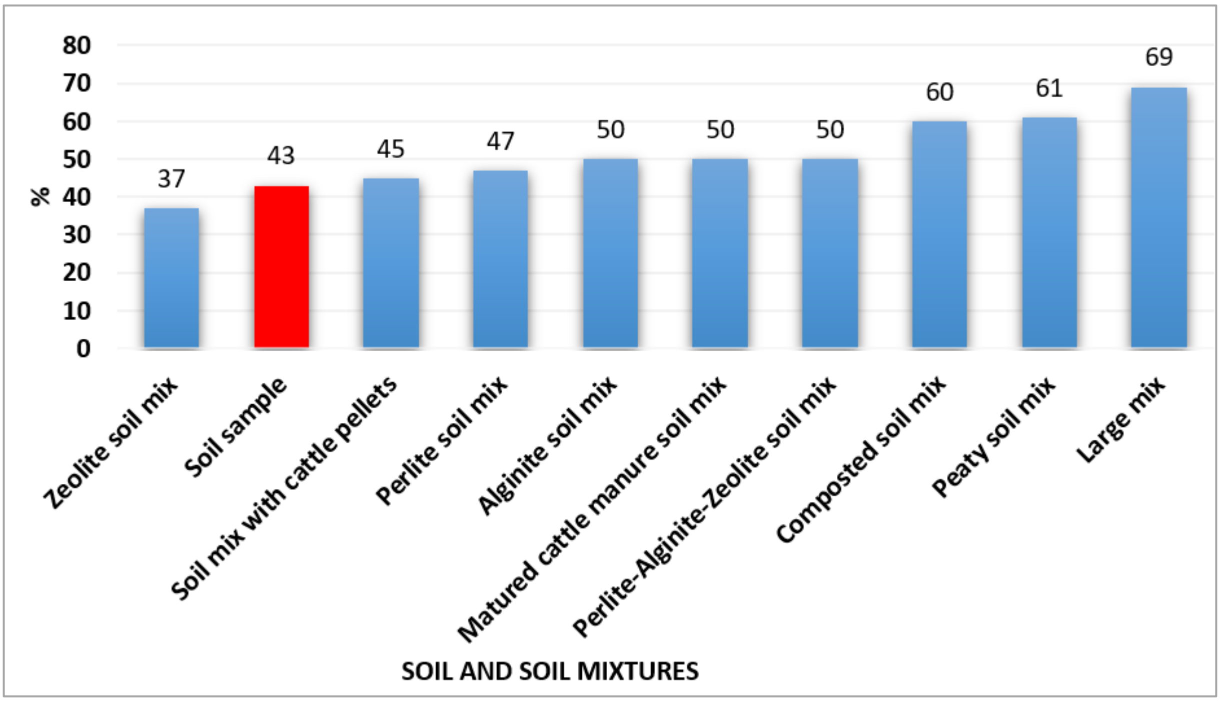

Figure 10. Water retention capacity of soil and soil mixtures in %
10. ábra. Talaj és talajkeverékek vízmegtartó kapacitása %-ban

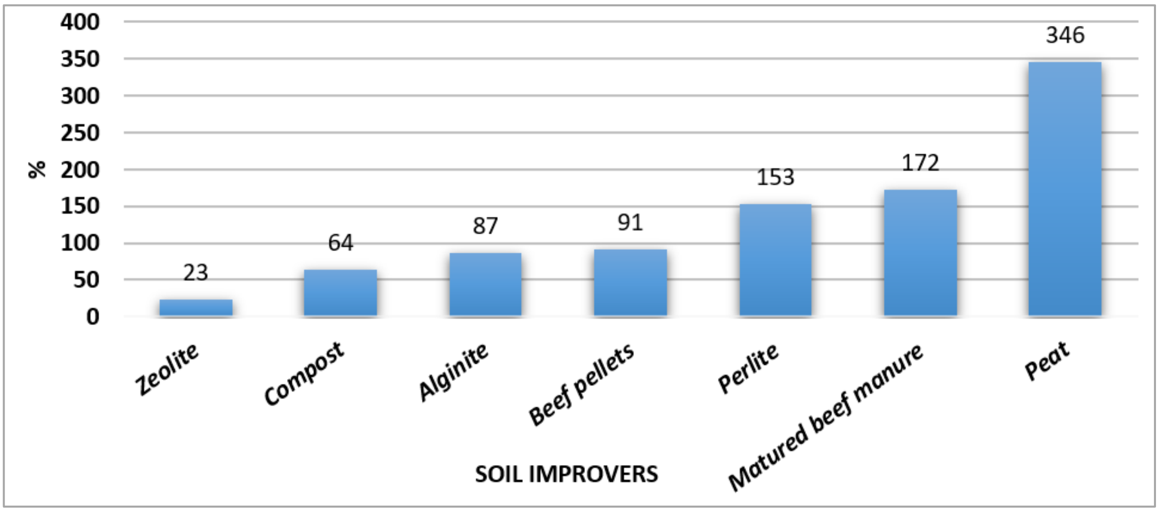

Figure 11. Water retention capacity of soil improvers in %
11. ábra. Talajjavító anyagok vízmegtartó kapacitása %-ban

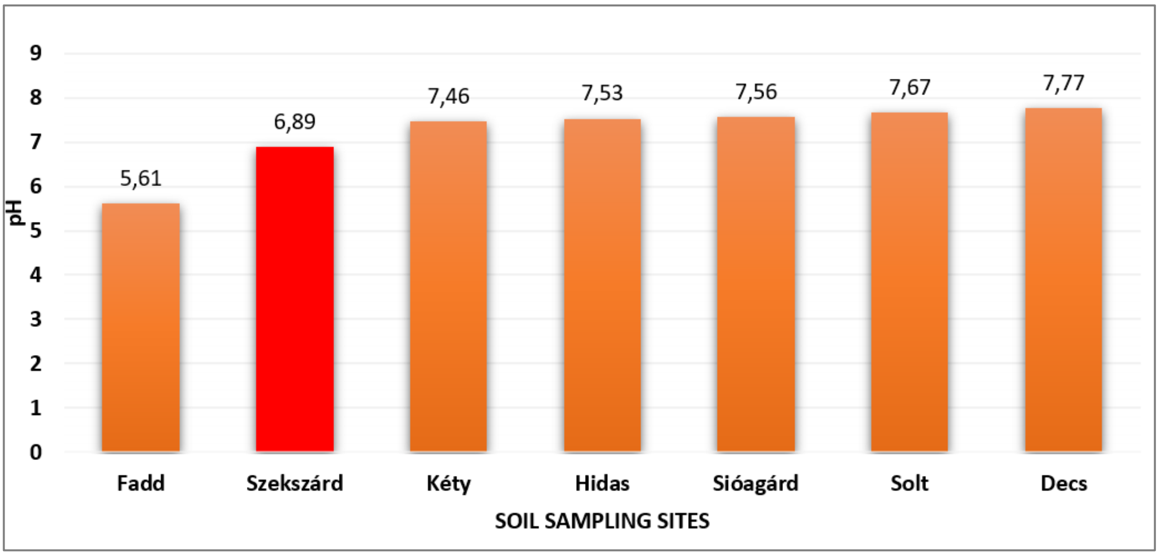

Figure 12. pH of soils around Szekszárd (0-30 cm)
12. ábra. Szekszárd környéki talajok pH-ja (0-30 cm)

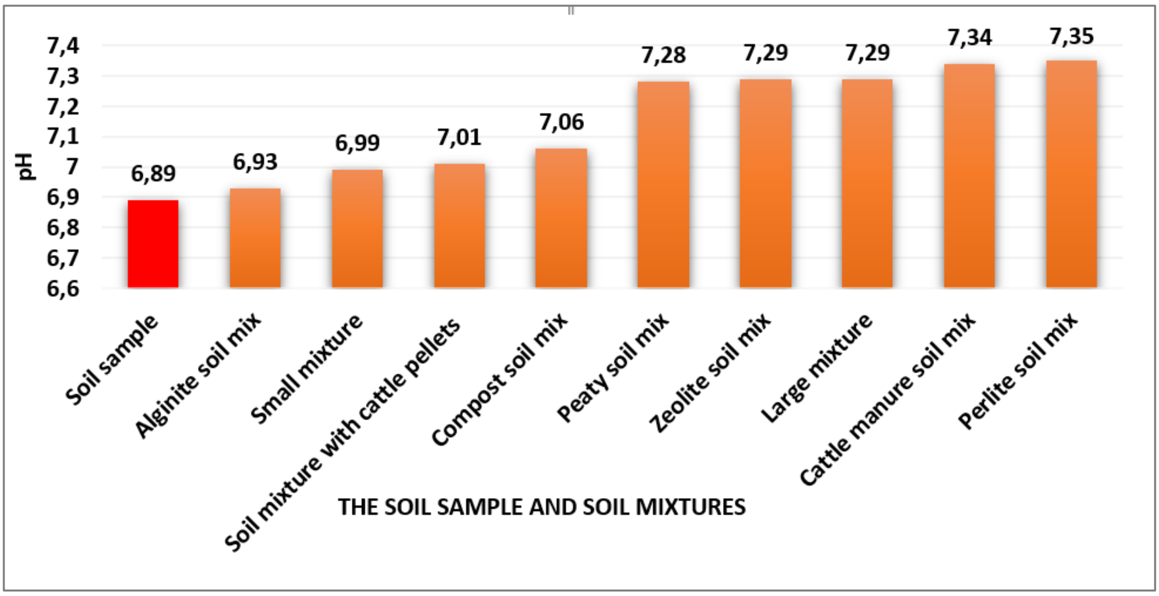

Figure 13. pH value of soil samples and soil mixtures
13. ábra. Talajminták és talajkeverékek pH értéke

LABORATORY TEST RESULTS FOR WATER RETENTION IN SOIL MIXTURES

The results of the test (*Figure 4*) showed (*Figure 14*) that soil collected from the Szekszárd area had the poorest water retention. It was characterised by a water retention of less than 10% throughout the period under study, decreasing to less than 5% from the 3rd to 4th week. At this value, all soil mixtures had a higher water retention. During the first 4 weeks they ranged between 10-30%, except for the large mixture (containing peat, cattle manure, perlite, compost, zeolite, alginate) as it only dropped from an initial value above 50% to below 30% after week 6 (*Photo 2*).

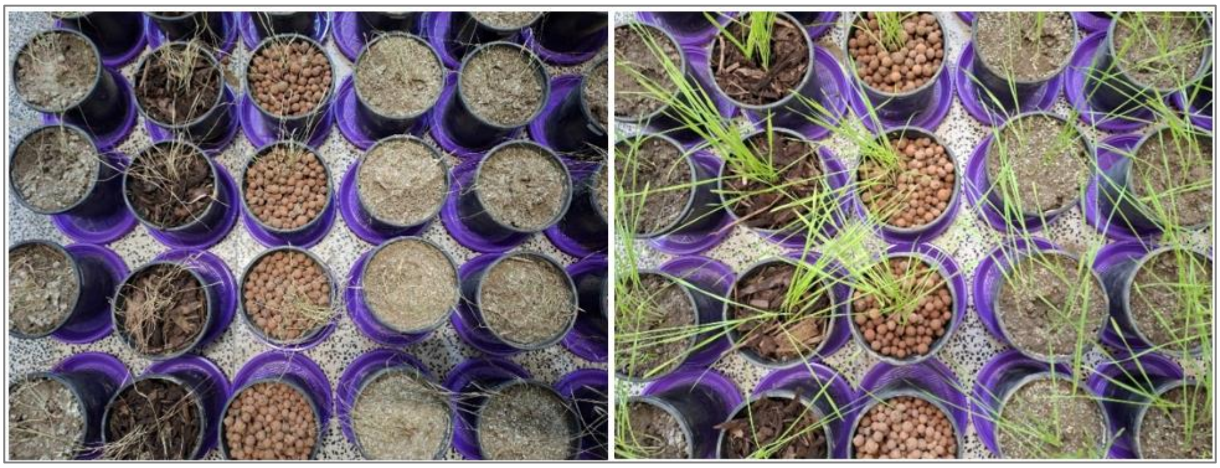

Photo 2. Soil mixtures at the beginning of the study (right) and after 6 weeks (left)
2. kép. Talajkeverékek a vizsgálat kezdetekor (jobbra) és 6 hét után (balra)

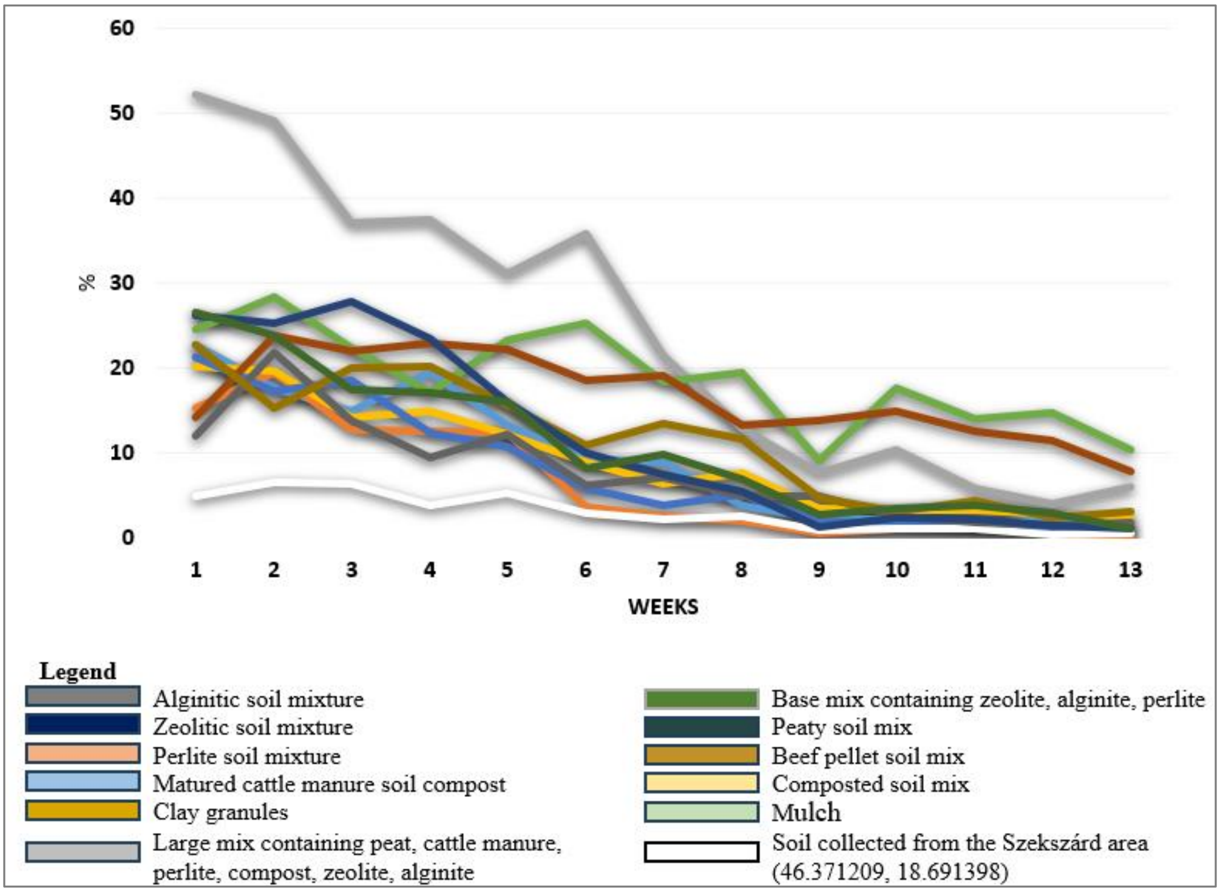

Figure 14. Laboratory testing of water retention capacity of soil mixtures
14. ábra. A talajkeverékek vízvisszatartásának laboratóriumi vizsgálata

Samples improved with soil cover (mulch, clay granules) also gave highly good results. Even after the 5th week, the soil water content was still above 20%, while the other samples apparently started to decline. Soils treated with soil cover were still retaining water significantly better at week 13. At week 6, the water retention of one of the soil mixtures (perlite) dropped down to the level of our soil sample for the first time, but from week 10 onwards none of the soil mixtures showed a significantly large difference from the soil sample. The wheat plants were gradually dying with water deprivation. Slightly earlier in the soils of poorer water retention capacity. In conclusion, our soil mixtures show on average higher results than our soil sample even after 7 weeks of drying, which means that we could retain significant amounts of water in the soil for several weeks or months during long summer droughts. If soil cover were applied in combination with mixtures, even better results could be achieved.

SUMMARY, CONCLUSIONS

We have succeeded in carrying out our planned studies. The analysis of meteorological data has confirmed the global and national trends of increasing extremes in the distribution of precipitation, i.e. less frequent but with an increase in extreme precipitation. The study revealed that the soils collected and tested in the wider area of our residence are classified as silty loam soils, silt loam soils, by texture. They are quite diverse in terms of humus content, due to different farming practices, the use or absence of manure or fertilisers and different levels of soil erosion. Soil pH is generally in the neutral to slightly alkaline category and would shift further towards alkaline with the use of soil amendments. They have a medium water retention capacity, and a lower permeability compared to a sandy soil, but they can retain more water. The use of soil amendments increases the sand fraction in their texture, which increases water permeability, but does not reduce water retention due to the water retention capacity of the materials. Laboratory testing of the soil amendments has confirmed our previous measurements, and we have been able to demonstrate that their application could retain significant amounts of water in our soils over the long term. Our country receives 112 km^3 of water per year from rivers coming from across the border, plus 6 km^3 of runoff from within the country. A bigger problem is that we have 117 km^3 of runoff, meaning we can retain relatively little and use only 1 km^3. In Hungary, a large part of the agricultural areas is characterised by loess soils like those around where we live or by sandy soils with poorer water management (Nyírség, Kiskunság). If we look at our samples, we find an average water retention of 43%. If 20% of the soil is supplemented with better water retaining materials, the water retention improves significantly. We have calculated 20% because that is what is usually recommended when soil amendments are applied. These soil amendments alone, on average, have a water retention capacity of 150%. Overall, we calculated that the water retention capacity of the soil would increase from 43% to 64.4% in this case. We have calculated that an area of 1 km^2 would retain 0.000172 km^3 of water, which means that for every 10 000 km^2 of area, this would be 1.72 km^3 of water. If the top 40 cm is upgraded with one of these materials and the upgraded value is used, this is 2.56 km^3 of water. This means that we can retain 0.86 km^3 of water per 10 000 km^2. Hungary's arable land use is about 55% of the country (agroinform.hu), or 51166.5 km^2. In total, we could retain 4.2 km^3 more water in this area than without the soil amendment. This would still not put us on a positive water balance, but it would move the country's water balance in a positive direction compared to the current one. If a smaller area or a less efficient increase in water retention capacity is expected, this value would decrease, but it would improve the water balance. So, this alone is not enough to solve the agricultural problems caused by climate change, but it could make a significant contribution. The construction of reservoirs and the use of additional irrigation could significantly improve or even turn positive the water balance of our country.

In the case of soil samples collected around Szekszárd, Hungary, soil samples, soil mixtures and soil amendments (perlite, alginate, zeolite, compost, peat, cattle manure) were analysed for texture, water retention capacity, humus content and pH, and finally, our soil samples, our nine soil mixtures and the two soil samples treated with soil cover were tested for water retention capacity by growing wheat in 120 pots under the same conditions for 13 weeks. The soils tested are silt, silty loam soils, with soil amendments mainly enhancing the sand fraction. The water retention capacity improved with the amendments; the humus content increased more significantly with organic amendments. The pH of the soil mixtures shifted the soil samples towards the alkaline direction. Soil mixtures and soils treated with soil cover were able to retain water to a greater extent than the soil sample.

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ZOLTÁN BAROCSAI I graduated from the Eszterházy Károly University (Eger, 2004) and the University of Pécs (Pécs, 2007) with a degree in geography and history. Currently I teach at the Béla I. High School in Szekszárd. I attach great importance to helping my students who want to do research in natural sciences. I have been conducting investigations with my students in the field of hydrology for more than ten years. Our research has been successful in national and international competitions and conferences.

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