NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 43, 2026
www.incda-fundulea.ro; doi.org/10.59665/rar4342 First Online: April, 2026. DII 2067-5720 RAR 2026-68

Studies on Improving the Water-Holding Capacity and Wind Erosion Resistance of Arenosols through Clay Addition and Organic Fertilizer

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ABSTRACT

Modifications in climatic parameters, expressed regionally through increased frequency and duration of drought periods in areas dominated by Arenosols, have directed soil-forming processes toward aridization and desertification. The research, conducted between 2021 and 2025, aimed to enhance the water retention capacity and wind erosion stability of Mollic Arenosols through the application of clay and organic fertilizers. An experimental field was established in 2021 in the locality of Șimian (47°28′41″N; 22°04′00″E), on Arenosol soil, with the objective of testing the efficiency of clay application at different rates, combined with organic fertilizers, in improving soil moisture conservation and determining the most effective treatment variant. The experiment was organized using the randomized block method, consisting of 3 blocks with 13 treatment variants and 3 replications, each experimental plot having an area of 24 m². Statistical analysis of the experimental data identified the most efficient treatment variant. To implement the obtained results, in 2022 the research field was organized into two experimental units, each with an area of 5.000 m² (Experimental Unit 1 - the demonstration plot where the ameliorative treatment was applied: 12.5 t of clay + 12.5 t of organic fertilizer; Experimental Unit 2 - considered the control plot), and an experimental crop rotation representative of the area was established for a four-year period: maize, rye, rapeseed, and sunflower. Between 2022 and 2025, the efficiency of clay and organic fertilizer application was comparatively assessed with respect to soil moisture conservation, crop growth dynamics, and yield. Field monitoring and statistical processing of the experimental data revealed that the application of clay and organic fertilizers to Arenosols significantly increased soil water retention capacity, enabling crops to maintain vegetative growth even under prolonged drought conditions. At the same time, soil particle cohesion and resistance to wind erosion were improved. Given that climate-induced changes have led to the aridization of many Arenosol-dominated areas, the research results demonstrated that the use of clay and organic fertilizers can represent an effective strategy for mitigating desertification processes in these regions.

Keywords: climate changes, aridization, desertification, water matric potential.

INTRODUCTION

In the north-western part of Romania, within the Niru Plain, Arenosols occupy a total area of 31876 ha (ICPA Bucharest, 2011; OSPA Bihor, 2023). The research on the application of clay and organic fertilizers to Arenosols, aimed at improving water retention capacity and soil stability against wind erosion, was carried out in the locality of Șimian, Bihor County, through the establishment of a research field in 2021. The total area of Șimian is 9194 ha, of which 7140 ha are arable lands. Arenosols cover 2347.9 ha of arable land, supplemented by 1470 ha of pastures and forest areas. Wind-driven surface erosion processes are manifested over approximately 1100 ha of Arenosols, of which 740 ha are agricultural lands and 380 ha are natural grasslands located within protected areas belonging to the Natura 2000 Network - Special Protection Area ROSPA0016 “Câmpia Nirului” (ANANP, 2020, 2025). Arenosols are characterized by a specific set of physical, chemical, and microbiological properties determined by the dominance of sandy textural fractions: high permeability, low water retention capacity (approximately 700 - 800 m³ of water/ha within the upper 100 cm soil layer), rapid gravitational drainage and evaporation losses, weak structural

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Received 21 November 2025; accepted 2 April 2026.

development, and low content of humus and essential nutrients (ANM, 2014; Hunter, 2017; Tahat et al., 2020; Berchez and Hodişan, 2021). The reduced humus and clay content result in poor cohesion of soil particles, favoring deflation processes and surface geological erosion (Smith and Gregory, 2012; Niacșu, 2019; EEA, 2022; FAO, 2022a, 2022b). High soil porosity, correlated with the water deficit regime during the summer months (June-September), has driven the pedogenetic processes toward pronounced aridization and desertification (Brandon et al., 2015; Bradford et al., 2019; Smith el al., 2020; Lal et al., 2021). Evidence from research by Dökmen (2025) highlights that soil moisture dynamics - and thus water storage and availability - are among the most important factors affecting agricultural outcomes, especially under changing precipitation patterns associated with climate change.

The climate of north-western Romania is characterized by a long-term (1970-2024) mean annual precipitation of 575.2 mm and a mean annual temperature of 10.7°C. During the research period (2021-2024), the mean annual temperature was 12.4°C, while the mean annual precipitation was 546.67 mm (ANM, 2025). The mean annual air humidity, measured at a height of 2 m above ground level, was 72%. The dominant wind directions were from the northeast (NE) with an average frequency of 10.46%, and from the southwest (SW) with an average frequency of 11.26%. The mean wind speed was 2.52 m/s, with a recorded maximum of 10.71 m/s. The highest air temperatures and the greatest atmospheric moisture deficits were recorded during the months of June, July, August, and September (Tables 1 and 2).

Table 1. Mean monthly air temperatures (June, July, August, September) during the period 2021-2025 (data provided by the National Meteorological Administration - Săcuieni Meteorological Station)

Month	Mean monthly air temperatures (°C)				
	2021	2022	2023	2024	2025
June	+22.0	+22.6	+20.0	+21.9	22.7
July	+24.3	+23.8	+23.3	+24.7	23.3
August	+21.2	+23.8	+23.3	+24.5	22.4
September	+16.6	+16.0	+23.3	+19.0	20.0

Table 2. Monthly precipitation (June, July, August, September) during the period 2012-2025 (data provided by the National Meteorological Administration - Săcuieni Meteorological Station)

Month	Monthly precipitation (mm)				
	2021	2022	2023	2024	2025
June	7.5	39	55	113	20.7
July	127	45	80	37	76.6
August	40	41	62	22	26.2
September	27	137	30	64	48.3

These climatic parameters reinforce the necessity of understanding soil water content and crop response under drought conditions (Burtan et al., 2026).

MATERIAL AND METHODS

Research on the application of clay in combination with organic fertilizers to Arenosols, aimed at increasing soil water retention capacity, has not been previously conducted. The study was carried out in the locality of Șimian, Bihor County, Romania, where a research field was established in 2021. The soil taxonomic unit on which the experiments were implemented was classified as Mollic Arenosols (Florea and Munteanu, 2012; FAO, 2014). Within the experimental field, 39 experimental plots were organized using the randomized block design, consisting of 3 blocks with 13 treatment variants and 3 replications. Different application schemes combining clay and organic fertilizers in various doses were tested. To determine the most efficient treatment, the time interval (in hours) required for the soil moisture content to decrease from the Field Capacity (FC) to the Permanent Wilting Point (PWP) was measured. Soil moisture was determined indirectly by measuring the soil water matric potential, representing the force with which water is retained in the soil (soil water tension) (Clapp and Hornberger, 1978; van Genuchten, 1980; Varga and Csiszér, 2020; Berchez et al., 2021). For Mollic Arenosols, a matric potential value of 300 mBar corresponds to the minimum soil moisture threshold, while a value of 350 mBar marks the critical limit for the onset of pedological drought, when root water extraction becomes difficult and plants experience water stress. At values exceeding 480 mBar, severe pedological drought occurs, posing a high risk of crop wilting (Hillel, 1998; Tyronese et al., 2007; NRCS, 2010). Field Capacity was achieved through irrigation of the experimental plots (Allen et al., 1998). Measurements were performed using electronic tensiometers installed at a depth of 20 cm in each plot, with readings recorded every 8 hours. The clay was ground using mills to particle sizes smaller than 2 mm, applied by surface spreading, and incorporated into the soil at a depth of 20 cm. The clay material was obtained from the Șuncuiuș clay quarry, Bihor County. Semi-decomposed farmyard manure was used as the organic fertilizer. Statistical data analysis was performed using the ANOVA statistical package, which identified the most effective treatment combination: 25 t/ha organic fertilizer + 25 t/ha clay. Climatic parameters were analyzed based on data provided by the Romanian National Meteorological Administration, Bucharest, Săcueni Meteorological Station (ANM, 2025). Based on the obtained results, in 2022, two experimental units, each covering 5000 m², were established within the research field: Experimental Unit 1 received the ameliorative treatment (25 t/ha organic fertilizer + 25 t/ha clay), Experimental Unit 2 served as a control plot. A four-year crop rotation was implemented: maize (Year I), rye (Year II), rapeseed (Year III), and sunflower (Year IV). A uniform crop management technology was applied throughout the experiment (ICPA, 2020; Varga and Csiszér, 2020). Measurements of soil water matric potential were conducted and recorded every three days throughout the growing season of each crop. On days with precipitation, measurements were taken approximately 10 hours after rainfall cessation. Based on the monitoring of soil matric potential, precipitation, crop development rate, and crop yields, the efficiency of clay combined with organic fertilizer application in improving soil moisture conservation in Arenosols was determined.

RESULTS AND DISCUSSION

Results Obtained in Identifying the Most Effective Soil Amelioration Variant

Research on the use of clay and organic fertilizers to enhance the water retention capacity and wind erosion stability of Arenosols commenced in September 2021 with the establishment of the experimental field located in Șimian, Bihor County, Romania. The experiment was conducted using a randomized block design, consisting of three blocks and thirteen treatment variants, each applied in three replications. To determine the most effective treatment variant, the time period (expressed in hours) required for the soil water matric potential to decrease from a value corresponding to field capacity (20 mBar) to that corresponding to the minimum moisture threshold (300 mBar) was measured. The soil moisture level equivalent to field capacity was achieved by irrigating the experimental plots. Soil moisture was monitored indirectly, by measuring the soil water matric potential using electronic tensiometers installed in each plot at a depth of 20 cm. Measurements were recorded at 8-hour intervals. The results are expressed as the time interval (in hours) required for the matric potential to decrease from field capacity (20 mBar) to the minimum moisture threshold (300 mBar), as shown in Table 3. For the statistical analysis of the experimental data, the costs associated with the ameliorative treatments were also considered, calculated at 12 EUR per ton of clay and 30 EUR per ton of organic fertilizer.

Table 3. Results of the measurements expressed as the time interval (hours) required for the soil to reach a matric potential value equivalent to the minimum moisture threshold (300 mBar)

Ameliorative treatment (t/Ha)												Control plot
Variants of improvement Clay (t/Ha)				Variants of improvement Organic fertilizer (t/Ha)				Variants of improvement Clay + organic fertilizer (t/Ha)				
V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
15	20	25	30	15	20	25	30	15+15	20+20	25+25	30+30	-
Measured time interval (variant mean) - hours												
V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
120	144	176	184	128	144	168	176	152	160	192	208	87
Ameliorative treatment cost - EU/Ha												
180	240	288	360	450	600	750	900	630	840	1038	1260	-

Based on the statistical processing of the experimental data using the ANOVA software package, Variant 11 was identified as the most effective treatment, consisting of the application of 25 t ha/ha organic fertilizer and 25 t ha/ha clay.

Results Obtained from Monitoring Soil Moisture Levels During the April-September 2022 Period in Maize Crop

In November 2021, within the experimental field, two experimental units were established, each with a surface area of 5000 m²: Experimental Unit 1 - the plot for the application of the ameliorative technology, and Experimental Unit 2 - the control plot. On Experimental Unit 1 , 12.5 tons of organic fertilizer were applied (corresponding to a rate of 25 t/ha). The organic fertilizers were incorporated into the soil simultaneously with the autumn plowing, at a depth of 25 cm. Between April 1 and April 15, 2022, an additional 12.5 tons of clay (corresponding to a rate of 25 t/ha) were surface-applied on Experimental Unit 1. The clay material was ground to particles with a diameter smaller than 2 mm, then incorporated into the soil to a depth of 15 cm. Concomitant with the clay incorporation procedure, seedbed preparation was performed for the sowing of maize (*Zea mays* L.), representing the first crop in the established rotation sequence. Hybrid maize seeds - Cera 440, were used for sowing. All field operations were conducted following standard agronomic practices to ensure uniform germination and optimal soil conditions for crop establishment. Measurements of the soil water matric potential were conducted *in situ* using installed sensors positioned at a depth of 20 cm. Data recordings were performed at three-day intervals throughout the entire maize growing season. In cases where rainfall occurred within the scheduled interval, measurements were taken 10 hours after the cessation of precipitation. A value of 300 mBar corresponds to the minimum moisture threshold, below which plants can easily extract water from the soil. A value of 350 mBar represents the critical threshold for the onset of pedological drought, where water becomes increasingly difficult for roots to access. Values exceeding 480 mBar indicate a severe pedological drought, with a high risk of plant wilting. Figure 1 presents a graphical representation of the soil water matric potential (mBar) recorded in Experimental Unit 1 and Experimental Unit 2 throughout the maize growing season (April-September 2022), compared with the critical thresholds of 300, 350, and 480 mBar.

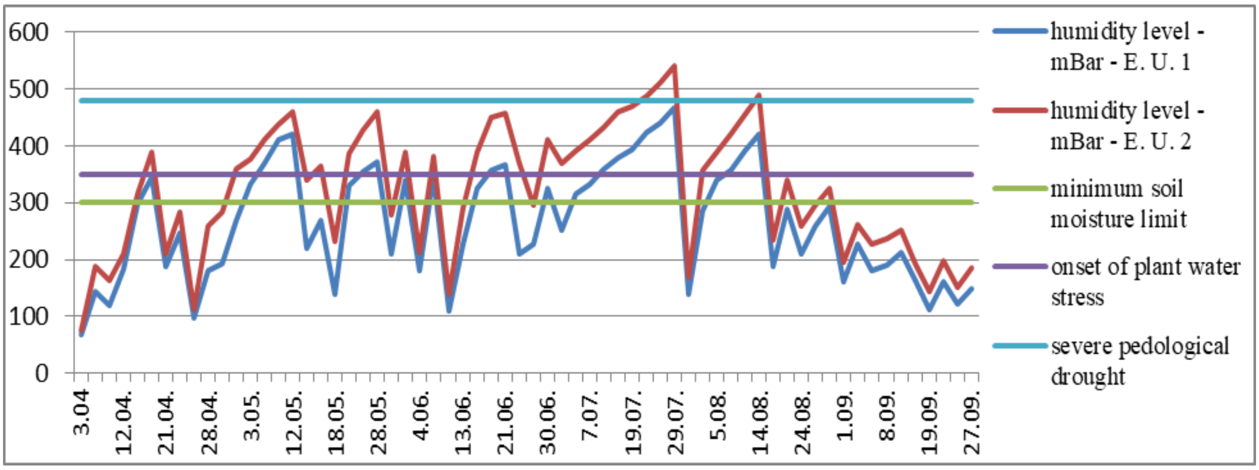

Figure 1. Graphical representation of the soil water matric potential (mBar) recorded in Experimental Unit 1 (E.U. 2) and Experimental Unit 2 (E.U. 2) throughout the maize growing season (April-September 2022), compared with the critical thresholds of 300, 350, and 480 mBar

Table 4 presents the water consumption of maize, analyzed by month and developmental stage, in comparison with the monthly precipitation recorded in 2022 during the period April-September.

Table 4. Water consumption of maize, by month and developmental stage, compared with monthly precipitation recorded in 2022 (April-September)

Month	Main Vegetation Phase	Monthly stages of vegetation	Specific Water Use (mm)	Precipitation (mm)
April	Emergence, first leaves	1	30 - 50	65
May	Vegetative growth	2	60 - 80	14
June	Stem elongation	3	90 - 110	39
July	Flowering and fertilization (critical)	4	120 - 150	45
August	Grain filling	5	100 - 130	41
September	Maturation	6	40 - 60	137

Based on the measurements conducted, the time periods during which soil moisture deficits occurred - defined as periods when the soil water matric potential exceeded 300 mBar - could be identified (Table 5).

Table 5. Periods of soil moisture deficit by calendar month, April-September 2022

Month	Experimental Unit	Periods with water stress (matric potential >300 mBar)		
		Periods with values 300 - 350 mBar	Periods with values 350 - 480 mBar	Periods with values >480 mBar
April	E.U. 1	18 - 22	-	-
	E.U. 2	-	18 - 22	-
May	E.U. 1	5 - 8, 20 - 23	9 - 12, 24 - 27	-
	E.U. 2	14 - 16	1 - 12, 20 - 27	-
June	E.U. 1	1 - 3, 6 - 8, 13 - 15	16 - 24, 29 - 30	-
	E.U. 2	-	1 - 3, 6 - 8, 13 - 24, 29 - 30	-
July	E.U. 1	3 - 9	11 - 26	
	E.U. 2	-	3 - 20	21 - 26
August	E.U. 1	3 - 6	7 - 15	-
	E.U. 2	-	3 - 10, 25 - 28	11 - 15
September	E.U. 1	-	-	-
	E.U. 2	-	-	-

Figure 2 presents the temporal variation of the soil water matric potential (mBar), correlated with the monthly phenological stages of maize (*Zea mays* L.) development.

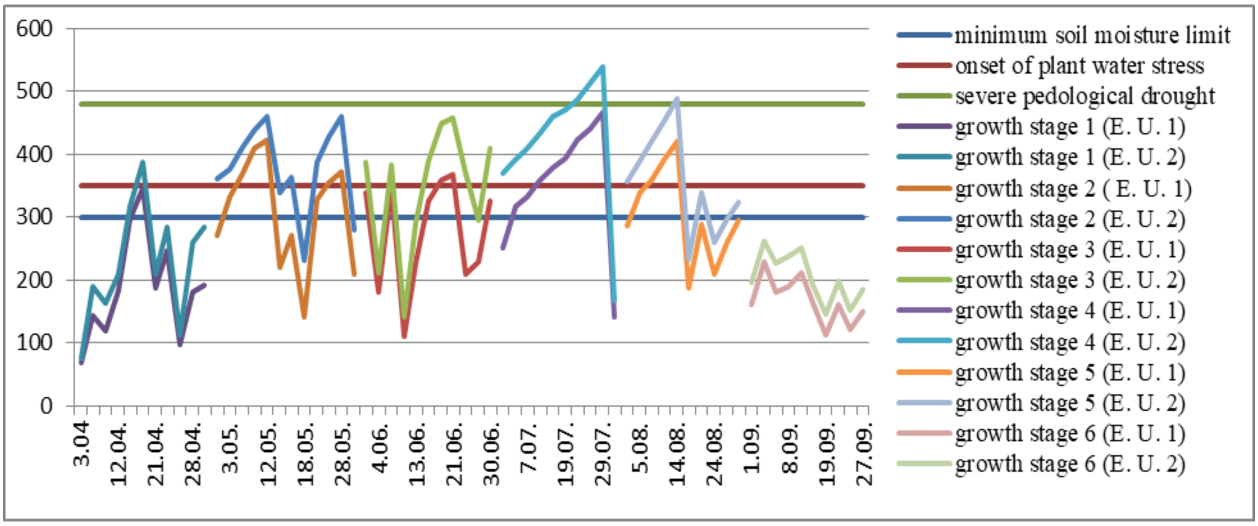

Figure 2. Temporal variation of the soil water matric potential (mBar), correlated with the monthly phenological stages of maize (*Zea mays* L.) development

Results obtained from monitoring soil moisture levels during the September 2022 - July 2023 period, rye crop

At the end of September 2022, the two experimental units within the Research Field were sown with rye (*Secale cereale* L.), variety Inspector. Measurements of soil water matrix potential were performed at 3-day intervals, at a depth of 20 cm, throughout the growing season of the rye crop.

Figure 3 graphically illustrates the soil water matric potential values (mBar) recorded in Experimental Unit 1 and Experimental Unit 2 throughout the entire vegetative period of the rye crop (September 2022 - July 2023), in comparison with the critical thresholds of 300, 350, and 480 mBar.

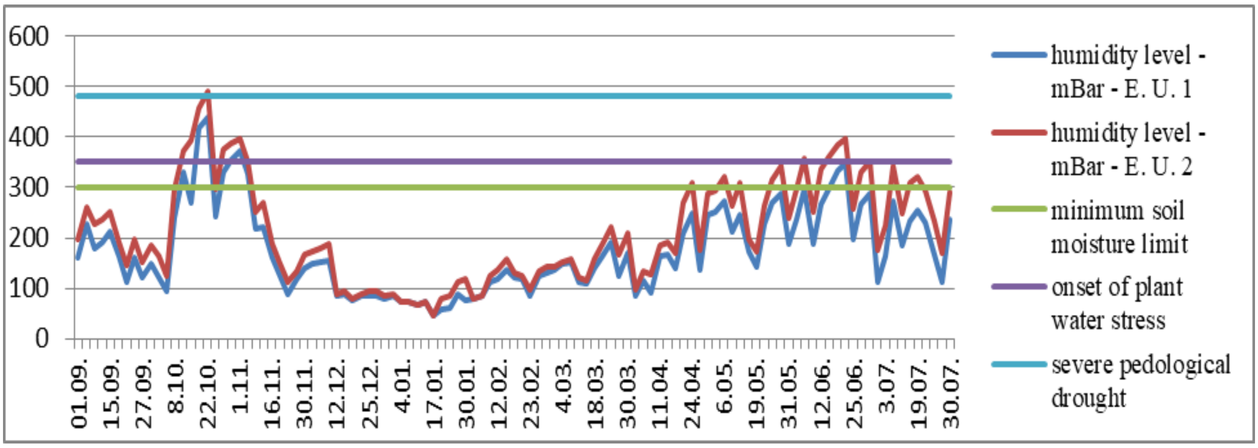

Figure 3. Graphical representation of the soil water matric potential values (mBar) recorded in Experimental Unit 1 (E. U. 1) and Experimental Unit 2 (E. U. 2) throughout the entire vegetative period of the rye crop (September 2022 - July 2023), compared with the critical thresholds of 300, 350, and 480 mBar

Table 6 presents the monthly water consumption of the rye crop, distributed according to the main phenological growth stages, in comparison with the monthly recorded precipitation during the period September 2022 - July 2023.

Table 6. Monthly water consumption of the rye crop, by phenological development stages, compared with the monthly recorded precipitation, during the period September 2022 - July 2023

Month	Main Vegetation Phase	Monthly stages of vegetation	Specific Water Use (mm)	Precipitation (mm)
September	Emergence	1	20 - 30	137
October	Early tillering	2	20 - 30	6.0
November	Tillering	3	10 - 20	65,6
December	Dormancy period (overwintering)	4	5 - 10	70.3
January	Dormancy period (overwintering)	5	5 - 10	49.0
February	Vegetation resumption	6	20 - 30	27.7
March	Stem elongation initiation	7	40 - 60	28.4
April	Stem elongation (critical stage)	8	60 - 80	33.6
May	Heading and flowering (critical stage)	9	80 - 100	59.7
June	Grain filling (critical stage)	10	60 - 80	54.9
July	Ripening and harvest	11	20 - 30	79.4

The periods of time in which moisture deficit was recorded (the soil water matrix potential exceeded 300 mBar) by calendar month are presented in Table 7.

Table 7. Periods of moisture deficit by calendar month, September 2022 - July 2023

Month	Experimental Unit	Periods with water stress (matric potential > 300 mBar)		
		Periods with values 300 - 350 mBar	Periods with values 350 - 480 mBar	Periods with values >480 mBar
October	E.U. 1	8 - 12, 26 - 28	13 - 22, 29 - 31	-
	E.U. 2	7 - 10	11 - 17, 27 - 31	17 - 22
November	E.U. 1	3 - 6	1 - 3	-
	E.U. 2	-	1 - 6	-
April	E.U. 1	-	-	-
	E.U. 2	20 - 23	-	-
May	E.U. 1	-	-	-
	E.U. 2	3 - 6, 10 - 12, 26 - 28	-	-
June	E.U. 1	-	-	-
	E.U. 2	12 - 15, 23 - 27	19 - 22	
July	E.U. 1	-	-	-
	E.U. 2	7 - 10, 15 - 21	-	-

Figure 4 presents the temporal variation of the soil water matric potential (mBar), correlated with the monthly phenological stages of rye (*Secale cereale* L.) development.

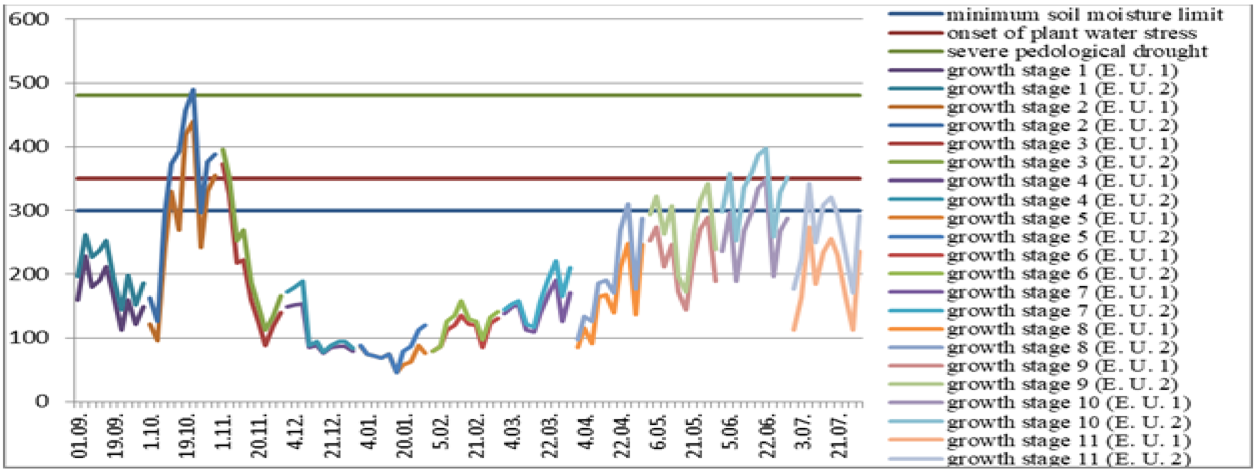

Figure 4. Temporal variation of the soil water matric potential (mBar), correlated with the monthly phenological stages of rye (*Secale cereale* L.) development

Results Obtained from Monitoring Soil Moisture Levels, August 2023 - September 2024, Rapeseed Crop

In August 2023, rapeseed (*Brassica napus L.* - Lhybrid PT 298 Agile) was sown on the two experimental units. Figure 5 graphically illustrates the values of the soil water matric potential (mBar) recorded in Experimental Unit 1 and Experimental Unit 2 throughout the entire vegetation period of the rapeseed crop (August 2023 - July 2024), in comparison with the critical thresholds of 300, 350, and 480 mBar.

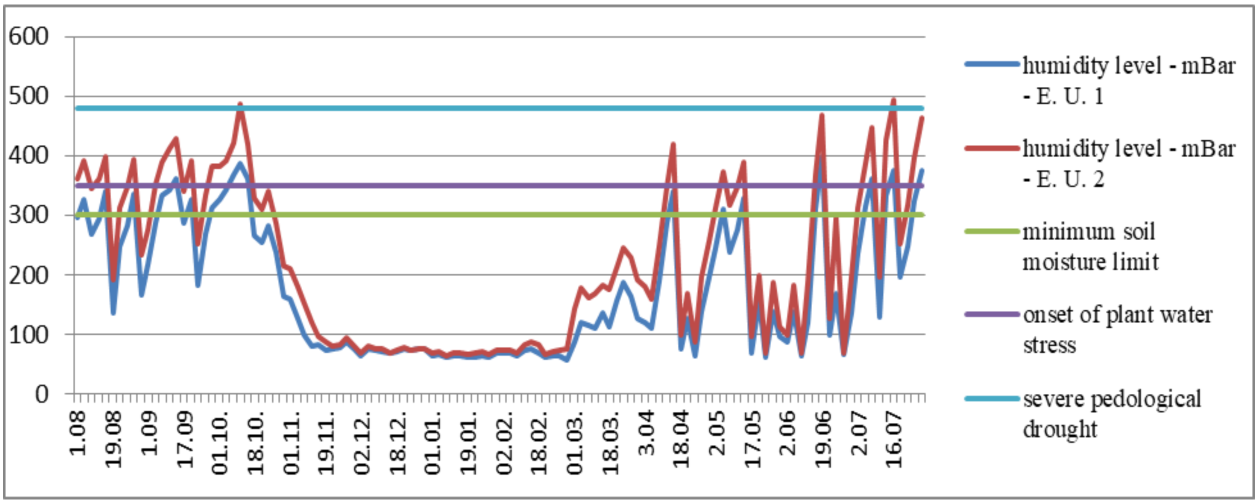

Figure 5. Graphical representation of the soil water matric potential (mBar) recorded in Experimental Unit 1 (E.U. 1) and Experimental Unit 2 (E.U. 2) throughout the entire vegetation period of the rapeseed crop (August 2023 - July 2024), compared with the critical values of 300, 350, and 480 mBar

Table 8 presents the water consumption of the rapeseed crop by month and developmental phenophase, in comparison with the recorded monthly precipitation during the period August 2023 - July 2024. Periods of moisture deficit by calendar month are presented in Table 9.

Table 8. Water consumption of the rapeseed crop by month and developmental phenophase, in comparison with the recorded monthly precipitation during the period August 2023 - July 2024

Month	Main Vegetation Phase	Monthly stages of vegetation	Specific water use (mm)	Precipitation (mm)
August	Emergence - onset of leaf development	1	20 - 30	61.9
September	Leaf development stage	2	30 - 40	30.2
October	Rosette formation stage	3	20 - 30	36.1
November	Pre-wintering stage/Onset of winter dormancy	4	10 - 20	154.7
December	Dormancy period Winter	5	5 - 10	81.9
January	Vegetative dormancy phase	6	5 - 10	41.7
February	Resumption of vegetative growth	7	20 - 30	9.2
March	Stem elongation phase following vegetative regrowth	8	40 - 60	17.5
April	Flower bud formation - beginning of flowering	9	70 - 90	45.0
May	Flowering - pod formation	10	80 - 100	34.9
June	Pod filling - seed maturation stage	11	40 - 60	108.2
July	Harvest maturity/Harvest stage	12	10 - 20	37.5

Table 9. Periods of moisture deficit by calendar month, September 2022 - July 2023

Month	Experimental Unit	Periods with water stress (matric potential >300 mBar)		
		Periods with values 300 - 350 mBar	Periods with values 350 - 480 mBar	Periods with values >480 mBar
August	E.U. 1	12 - 16, 21 - 28	-	-
	E.U. 2	7 - 9	1 - 4, 12 - 16, 21 - 28	-
September	E.U. 1	6 - 9	10 - 13, 20 - 23, 27 - 30	
	E.U. 2	-	5 - 7, 18 - 20	8 - 13, 20 - 23, 27 - 30
October	E.U. 1	2 - 4,	5 - 12	-
	E.U. 2	17 - 24	2 – 12	
April	E.U. 1	13 - 15	-	-
	E.U. 2	10 - 12	13 - 15	
May	E.U. 1	4 - 5, 12 - 14	-	-
	E.U. 2	1 - 3, 10 - 12	4 - 6, 13 - 14	
June	E.U. 1	15 - 17	18 - 21	-
	E.U. 2	-	15 - 21	-
July	E.U. 1	4 - 6, 11 - 13, 24 - 26	7, 14 - 16, 27 - 31	-
	E.U. 2	1 - 3, 22 - 23	4 - 7, 12 - 14, 24 - 31	15 - 16

Figure 6 illustrates the temporal variation of water matric potential (mBar), correlated with the monthly phenological stages of rapeseed (*Brassica napus* L.) development.

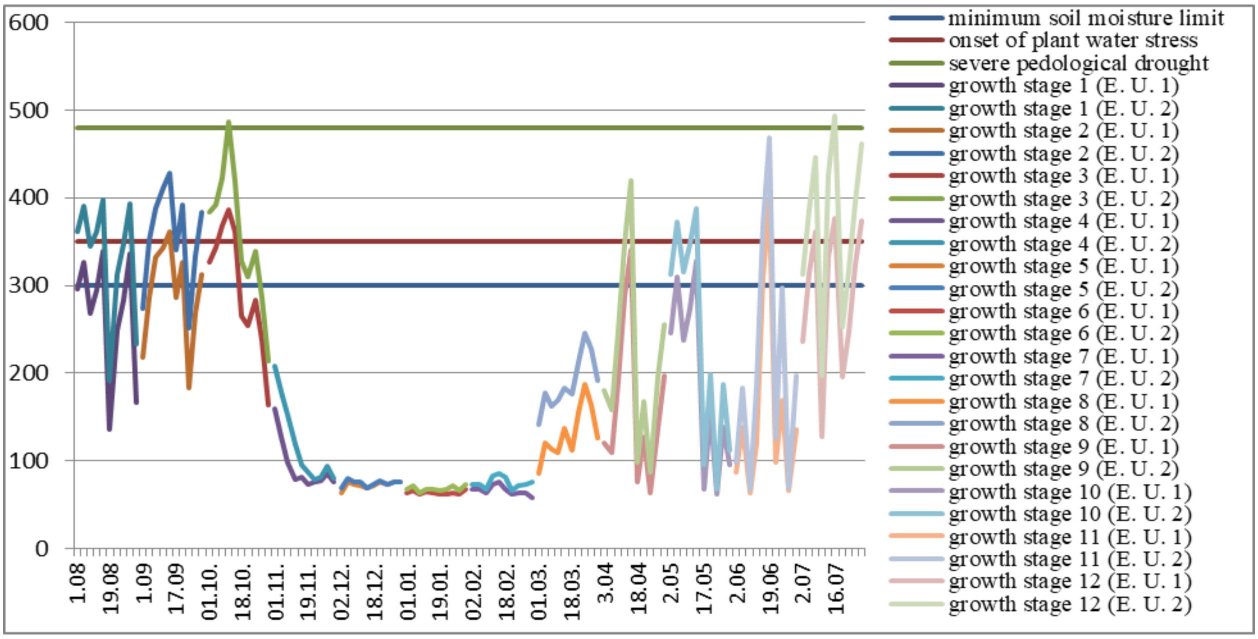

Figure 6. Temporal variation of soil water matric potential (mBar),
correlated with the monthly phenological stages of rapeseed (*Brassica napus* L.) development

Results obtained from monitoring soil moisture levels during the April - September 2025 period, sunflower crop

In April 2025, the experimental units within the Research Field were sown with sunflower (*Helianthus annuus* L.), this crop representing the final stage in the established crop rotation sequence: maize - rye - rapeseed - sunflower. For sowing, the hybrid Fundulea 708 was used.

Figure 7 graphically illustrates the soil water matric potential values (mBar) recorded in Experimental Unit 1 and Experimental Unit 2 throughout the entire vegetation period of the sunflower crop (April - September 2025), compared with the critical thresholds of 300, 350, and 480 mBar.

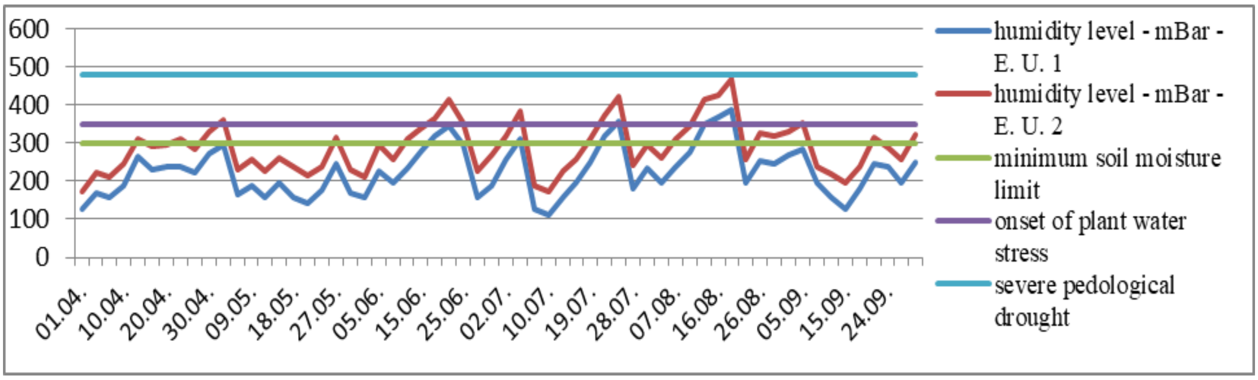

Figure 7. Graphical representation of the soil water matric potential values (mBar) recorded in Experimental Unit 1 (E.U. 1) and Experimental unit 2 (E.U. 2) throughout the entire vegetation period of the sunflower crop (April - September 2025), compared with the critical thresholds of 300, 350, and 480 mBar

Table 10 presents the water consumption of the sunflower crop, expressed by months and phenological development stages, in comparison with the recorded monthly precipitation during the April - September 2025 period.

Periods with soil moisture deficit, by calendar month, are presented in Table 11.

Table 10. Water consumption of the sunflower crop by month and phenological development stage, compared with the recorded monthly precipitation during the April - September 2025 period

Month	Main Vegetation Phase	Monthly stages of vegetation	Specific water use (mm)	Precipitation (mm)
April	Emergence and early leaf development	1	20 - 40	16.5
May	Vegetative growth stage	2	50 - 70	36.1
June	Capitulum (inflorescence) formation stage (critical phase)	3	90 - 110	20.7
July	Flowering stage (critical phase)	4	120 - 140	76.6
August	Seed filling stage (critical phase)	5	100 - 120	26.2
September	Physiological maturity (ripening stage)	6	40 - 60	48.3

Table 11. Periods with soil moisture deficit by calendar month, April - September 2025

Month	Experimental Unit	Periods with water stress (matric potential >300 mBar)		
		Periods with values 300 - 350 mBar	Periods with values 350 - 480 mBar	Periods with values >480 mBar
April	E.U. 1	18 - 22	-	-
	E.U. 2	-	18 - 22	-
May	E.U. 1	5 - 8, 20 - 23	9 - 12, 24 - 27	-
	E.U. 2	14 - 16	1 - 12, 20 - 27	-
June	E.U. 1	1 - 3, 6 - 8, 13 - 15	16 - 24, 29 - 30	-
	E.U. 2	-	1 - 3, 6 - 8, 13 - 24, 29 - 30	-
July	E.U. 1	3 - 9	11 - 26	
	E.U. 2	-	3 - 20	21 - 26
August	E.U. 1	3 - 6	7 - 15	-
	E.U. 2	25 - 28	3 - 10	11 - 15
September	E.U. 1	-	-	-
	E.U. 2	1 - 8, 26 - 30	-	-

Figure 8 graphically illustrates the temporal variation of soil water matric potential (mBar), correlated with the monthly phenological stages of sunflower (*Helianthus annuus* L.) development.

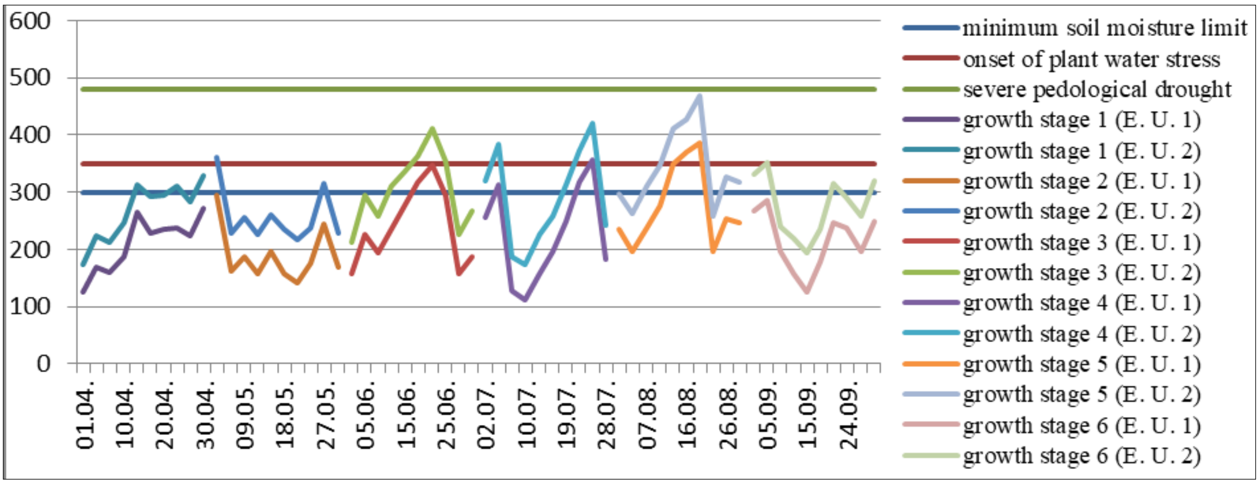

Figure 8. Temporal variation of soil water matric potential (mBar), correlated with the monthly phenological stages of sunflower (*Helianthus annuus* L.) development

CONCLUSIONS

Prolonged drought periods exceeding six consecutive days with soil water matric potential above 350 mbar consistently reduced crop growth and yields, with early-season droughts affecting germination and initial development. Plots that received the ameliorative treatment (25 t/ha organic fertilizer + 25 t/ha clay) showed better soil moisture retention, higher yields, and greater resilience to drought compared to control plots. Maize and sunflower suffered severe yield losses during summer droughts, while rye and rapeseed in treated plots performed above regional averages. Treated plots also experienced no wind-induced soil erosion, whereas control plots were prone to wind deflation.

The research confirms that applying clay and organic fertilizers on Arenosols increases soil water-holding capacity, enabling crops to utilize water more efficiently under prolonged drought. Considering climate change impacts on soil water regimes and crop productivity, this approach represents an effective strategy to mitigate drought, stabilize yields, limit soil degradation, and prevent desertification).

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