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Studies on the Improvement of Saline Soils in Complex Agricultural Experiments with Salinity-Tolerant Species, Green Crops and Different Types of Fertilizers

Daniela Trifan[1*], Victoria Amelia Anghel[2], Alin Ionel Ghiorghe[1,3], Emanuela Lungu[1,4], & Vlad Dumitru Mihăilă[1,3]

[1]*Agricultural Research and Development Station of Brăila, Romania*
[2]*National Research and Development Institute for Pedology, Agrochemistry and Environmental Protection – ICPA Bucharest*
[3]*University of Agriculture and Veterinary Medicine, Bucharest, Romania*
[4]*Dunărea de Jos" University from Galați, Romania*

[*]**Corresponding author:** Daniela Trifan, Agricultural Research and Development Station of Brăila, Romania.

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Abstract

The physicochemical properties of the soil influence the aerohydric regime of the soils, the development of the root system of crop plants and the absorption of mineral elements necessary for their physiological growth and development processes.In Romania, alkaline soils cover around 500-600 thousand hectares, which must be improved through various methods and technologies to bring them into the range necessary for the favorable growth and development of crop plants.The paper presents experimental results from a complex project to remediate saline soils through the use of amendments, fertilizers, green crops and salinity-tolerant species, ADER 20.1.3., entitled "Measures and recommendations for reducing the risk of soil salinization and erosion under the influence of climate change" which is being implemented between 2023 and 2026, being funded by the Ministry of Agriculture and Rural Development, Bucharest, Romania. The results showed that the effectiveness of amendments increases with the application of a complex of agropedoamelioration measures to improve the physical, chemical and biological properties of the soil, respectively with the use of green crops and crop rotation with salinity-tolerant species.

Keywords: Saline Soils, Salinity Tolerant Species, Green Crops, Fertilizers, Soil Fertility, Climatic Changes.

Introduction

The increase in production in agricultural crops is conditioned by the application of mineral and organic fertilizers, in accordance with the pedological conditions and the specific consumption of plants. The protection, resistance and increase in soil fertility are achieved through a correct and rational application of fertilizers, to ensure the necessary production of plants, but also to increase soil fertility. In long-term experiences with mineral fertilizers, a tendency to reduce the content of C-organic, N-organic and humus is observed, which is why the periodic use of organic fertilizers is recommended, C + NPK fertilization systems being much more sustainable (organic + NPK) than only NP or NPK.

Given the current inflationary situation and the war in the neighborhood, which will continue to have a negative impact on Romanian agriculture, the fertilization plan must be simplified, respecting the standard of maximum nitrogen quantities (170kg/ha etc.) that can be applied to agricultural land and to ensure a uniform distribution of fertilizers on the land, in order to maintain soil fertility. The calculation of fertilizer doses must be done correctly, both for economic reasons and for environmental protection requirements, the forecasted production must be realistic, considering both local pedoclimatic conditions and the productive potential of the cultivated varieties and hybrids.

Material and Method

The fertilizer experiments carried out at Agricultural Research and Development Station of Brăila, Romania were in the three

experimental centers (Chiscani, IMB and Corbu Nou), for two research directions:

- Evaluation of the NP interaction and the effect on crops and indicators in the soil-plant system.
- Evaluation of the effect of organo-mineral fertilization on crops and the evolution of soil fertility indicators.

Thus, it was possible to study the evolution of production yields, under different agricultural conditions, in order to develop the bases for the scientific substantiation of the application of organo-mineral fertilizers to different agricultural crops.

The experiments were located according to the experimental plan and soil analyses were performed before and after the establishment of crops, on each experimental variant.
Images From the Experiments Are Shown in the Figure 1.

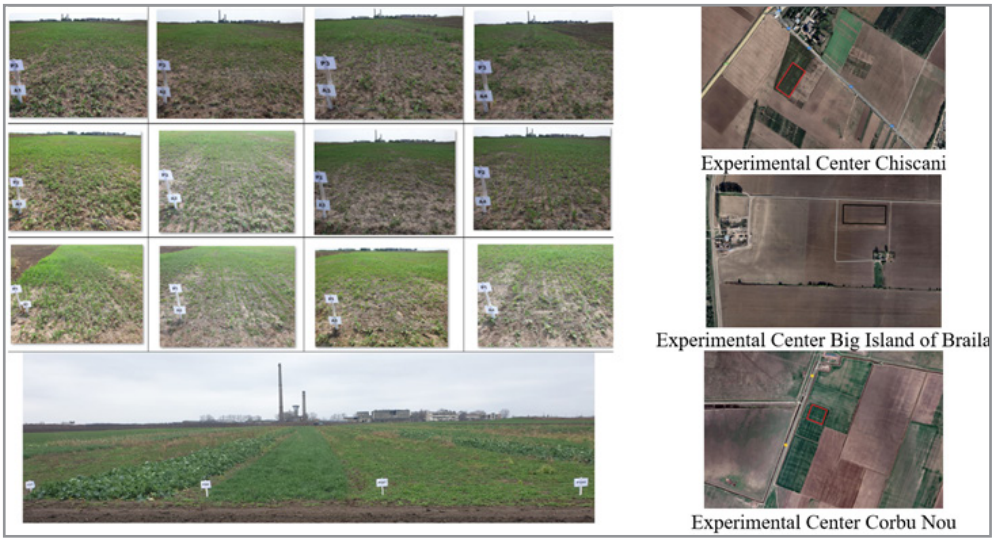

Figure 1: Images from the Experience at CE Chişcani (Câmpia Brăilei), ARDS Brăila

Within the SCDA Brăila, the experimental plan and the layout of the experiments with fertilizers, amendments and green crops were created for three experimental centers, with different pedo-climatic conditions: CE Chişcani - in the Brăila Plain, CE Insula Mare a Brăila - in the Danube Meadow and CE Corbu Nou - in the Siret Meadow.

The Experimental Scheme (Figure 2) included three Experimental Factors

- Type of fertilizers and/or amendments, with 10 graduations, each variant having 16 m width: V1 = untreated, V2 = gypsum, V3 = phosphogypsum, V4 = lignite dust, V5 = calcium chloride, V6 = acid fertilizer 16-10-25 (+2), V7 = biochar, V8 = potassium sulfate, V9 = ammonium sulfate, V10 = regular NPK fertilization 15-15-15, V11 = unfertilized and without green crops.
- Agricultural and tolerant crops, sown perpendicular to the fertilizer and amendment variants, 4 seeders each, with the following graduations: P1 = wheat, P2 = triticale, P3 = rye, P4 = parsley, P5 = carrot, P6 = beans, P7 = sorghum.
- Cover crops/greens, sown after the main crops are harvested, one seeder each, with four graduations for autumn crops (A1-A4) and four graduations for spring crops (A5 – A8): A1 = red clover, A2 = white clover, A3 = phacelia, A4 = spring vetch, A5 = rapeseed, A6 = rye, A7 = red clover, A8 = alfalfa.

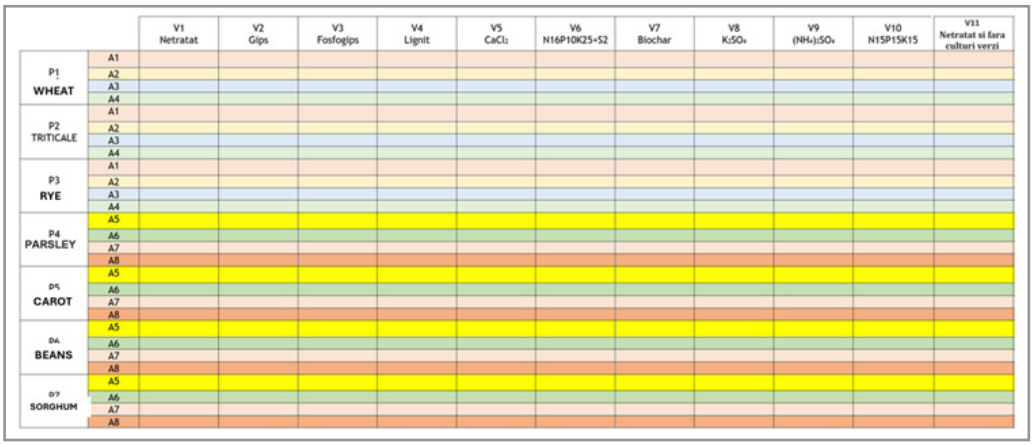

Figure 2: The Scheme of Experiences

The Following Aspects Were Analyzed

- effect of applying different amendments and fertilizers on soil agrochemical indices,
- effect of different crops on soil agrochemical indices,
- effect of different cover crops on soil agrochemical indices.

Results and Discussion

Chemical and physical characterization of the Chişcani experi-

mental field
Calcary Alluvic Chernozem (SRTS, 2012) (Figure 3)

Apk 0 – 11 cm: clay, very dark brown (10YR 2/2) and very dark gray brown (10YR 3/2) in dry state, structure modified by cultivation, reavon, weakly compact, weakly cohesive, weakly plastic, hard in dry state, thin roots frequent; coprolites frequent, moderate effervescence, gradual transition;

Aptk 11 – 32 cm: clay, very dark brown (10YR 2/2) and very dark gray brown (10YR 3/2) in dry state, medium developed grain structure, reavon, moderately compact, weakly cohesive, weakly plastic, friable in wet state, hard in dry state, thin roots rare, coprolites frequent, strong effervescence, wavy transition;

Am/Ck 32 – 48 cm: dusty clay, very dark gray-brown (10YR 3/2) when wet and dark gray-brown (10YR 4/2) when dry, poorly developed granular structure, weakly compact, friable when wet, hard when dry, weakly cohesive, weakly plastic, very strong effervescence, gradual wavy transition;

Ck 48- 67 cm: dusty clay, dark grayish brown (10YR 4/2) when wet and grayish brown (10YR 5/2) when dry, massive, revan, hard, rough, weakly cohesive, weakly plastic, frequent friable CaCO3 concretions, violent effervescence, gradual straight transition;
Cca1 67- 100 cm: dusty clay; yellowish brown (10YR 5/6) when wet and brownish yellow (10YR 6/6) when dry, massive, revan, weakly cohesive, weakly plastic, frequent friable CaCO3 concretions, violent effervescence, gradual wavy transition;

Cca2 100-120 cm: dusty clay, pale yellow (10YR 7/4) when wet and yellow (10YR 7/6) when dry, massive, moist, weakly cohesive, weakly plastic, violent effervescence.

Figure 3: The Soil Profile in Experimental Center Chiscani

The soil profile from Experimental Center Chiscani (Figure 3), in the Apk horizon (0-11 cm) presents the following characteristics (Table 1 and Table 2):

- Loamy texture;
- Very low apparent density (1.18 g/cm3);
- Medium saturated hydraulic conductivity (6.86 mm/h);
- Weakly alkaline soil (pH = 8.15);
- Degree of saturation in bases is 100% saturated;
- Low humus content (2.86%);
- Medium total nitrogen content (0.156%);
- High corrected mobile phosphorus content (50 mg/kg);
- Medium mobile potassium content (174 mg/kg);
- The humus reserve in the first 50 cm has moderate values (121 t/ha).

Table 1: Physical Properties of Soil Profile no. 1. EC Chișcani

Horizon	UM (cm)	Apk	Aptk	Am/Ck	Ck	Cca1	Cca2
Deep		0-11	11-32	32-48	48-67	67-100	100-120
wi	(%g/g)	15,1	15,9	16,7	11,7	10,4	9,7
Dawi	(g/cm3)	1,18	1.38	1,18	1,17	1,31	1,28
RP	(Kgf/cm2)	14	25	18	19	32	27
IC	(-)	0,0090	0,0044	0,0042	0,0064	0,0077	0,0078
ksat	(mm/h)	6,86	8,57	35,16	54,36	14,92	3,60
PTwi	(%v/v)	55,5	48,1	55,5	56,1	50,8	51,9

Table 2: Chemical Properties of Soil Profile no. 1. EC Chișcani

Horizon Deep	UM cm	Apk 0-11	Aptk 11-32	Am/Ck 32-48	Ck 48-67	Cca1 67-100	Cca2 100-120
pH in water	unitați pH	8,15	8,19	8,32	8,37	8,43	8,59
Humus (Cx1,72)	%	2,86	1,91	1,37	1,07	0,89	0,48

N total	%	0,156	0,136	0,103	0,091	0,064	0,044
P AL	mg/kg	115	74	36	25	21	15
P AL corected in function of pH	mg/kg	50	31	13	8	6	15
Kmobile	mg/kg	174	257	160	255	201	169
Conductometric residue	mg/kg	49	51	44	41	43	40

Chemical and physical characterization of the Big Island of Braila experimental field

Molic Calcaric Gleic Alluviosol (SRTS, 2012) (Figure 4)

Apk 0 – 14 cm: clayey clay, very dark grey brown when wet (10YR 3/2) and dark grey brown (10YR 4/2) when dry, structure modified by cultivation, revan, weakly moderately compact, hard when dry, frequent thin roots, weak effervescence, gradual transition;

Aptk 14 – 24 cm: clayey clay, dark grey brown when wet (10YR 4/2) and grey brown (10YR 5/2) when dry, poorly developed subangular polyhedral, moderately compact, hard when wet, very hard when dry, rare thin roots, moderate effervescence, wavy transition;

ACGok 24 – 41 cm: clayey clay, grayish brown (10YR 5/2) in wet state with 25% frequent dark yellowish brown (10YR 5/4) and light grayish brown (10YR 6/2) spots with yellowish brown (10YR 6/4) spots in dry state, poorly developed subangular polyhedral, revan, moderately compact, hard in wet state, very hard in dry state, locally shell fragments, strong effervescence, gradual wavy transition.

Ck1Go 41- 67 cm: clayey clay, grayish brown (10YR 6/2) with 25% frequent dark yellowish-brown spots (10YR 4/4) in the wet state and pale brown (10YR 6/3) with yellowish brown spots (10YR 5/6) in the dry state, angular polyhedral structure, revan, hard, rough, locally shell fragments, strong effervescence, straight gradual transition.

CkGr1 67- 91 cm: clayey clay, olive gray (5YR 4/1) with 50% intense brown spots (7.5YR 5/6) in the wet state and gray (5YR 5/1) in the dry state, massive, revan, shell fragments, strong effervescence, wavy gradual transition.

Ck3Gr2 91-130 cm: loamy clay, olive gray (5YR 4/1) with 55% intense brown spots (7.5YR 5/6) in the wet state and gray (5YR 5/1) in the dry state, massive, wet, shell fragments, strong effervescence.

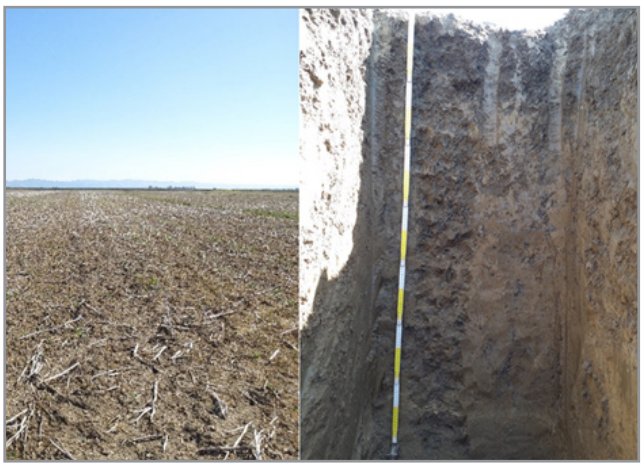

Figure 4: The Soil Profile in the Experimental Center Big Island of Braila

This profile, in the Apk horizon (0-14 cm) presents the following characteristics (Table 3, and Table 4).

- clayey-loamy texture
- very low apparent density (1.18 g/cm3)
- high saturated hydraulic conductivity (34.12 mm/h)
- weakly alkaline soil (pH = 7.85)
- degree of saturation in bases is 100% saturated
- medium humus content (4.11%)
- high total nitrogen content (0.289%)
- very high corrected mobile phosphorus content (185 mg/kg)
- high mobile potassium content (228 mg/kg)
- The humus reserve in the first 50 cm has high values (163 t/ha)

Table 3: Physical Properties of Soil Profile no. 2. EC Big Island of Braila

Horizon Deep	UM cm	Apk 0-14	Atpk 14-24	ACGok 24-41	C1Gok 41-67	C2Gok 67-91
wi	(%g/g)	23,1	25,5	26,4	28,5	23,3
Dawi	(g/cm3)	1,18	1,18	1,35	1,30	1,31
RP	(Kgf/cm2)	22	12	41	34	53
IC	(-)	0,0091	0,0083	0,0085	0,0063	0,0052

ksat	(mm/h)	34,12	52,99	14,75	32,75	44,59
PTwi	(%v/v)	55,7	55,7	49,1	51,1	50,8

Table 4: Chemical Properties of Soil Profile no. 2. EC Big Island of Braila

Horizon Deep	UM cm	Apk 0-14	Atpk 14-24	ACGok 24-41	C1Gok 41-67	C2Gok 67-91
pH in water	unitați pH	7,85	8,14	8,25	8,33	8,21
Humus (Cx1,72)	%	4,11	2,92	1,85	1,55	1,07
N total	%	0,289	0,203	0,136	0,116	0,074
P AL	mg/kg	325	147	68	50	37
P AL corected in function of pH	mg/kg	187	65	26	17	15
Kmobile	mg/kg	228	216	170	183	268
Conductometric residue	mg/kg	48	43	44	46	80

Chemical and physical characterization of the Corbu Nou experimental field

GLEIC SALINIC CALCARE ALLUVIOSOL (SRTS, 2012) (Figure 5)

Apk 0 – 23 cm: medium clay, brown in wet state (10YR 4/3) and brown (10YR 5/3) in dry state, structure modified by cultivation, dry, weakly compact, weakly cohesive, weakly plastic, hard in dry state, frequent thin roots, moderate effervescence, gradual transition.

Aptk 23 – 28 cm: medium clay, brown in wet state (10YR 4/3) and brown (10YR 5/3) in dry state, structure modified by cultivation, dry, moderately compact, weakly cohesive, weakly plastic, hard in wet state, very hard in dry state, rare thin roots, strong effervescence, wavy transition.

Ck/Asc 28 – 40 cm: dusty clay, grayish brown (10YR 5/2) when wet and light grayish brown (10YR 6/2) when dry, massive, dry, moderately compact, hard when wet, very hard when dry, weakly cohesive, weakly plastic, very strong effervescence, gradual wavy transition.

Cksc 40- 58 cm: dusty clay, light yellowish brown (10YR 6/4) in wet state and very pale brown (10YR 7/4), massive, dry, hard, rough, weakly cohesive, weakly plastic, violent effervescence, straight gradual transition.

CkGosc 58- 78 cm: dusty clay, yellow (10YR 7/6) in wet state and yellow (10YR 8/6) in wet state, massive, dry, 25% intense yellowish-brown spots in dry state, violent effervescence, weakly cohesive, weakly plastic, wavy gradual transition.

CkGr1sc 78-105 cm: clayey clay, olive grey (5YR 4/1) with 50% intense brown spots (7.5YR 5/6) in the wet state and grey (5YR 5/1) in the dry state, massive, dry, moderately cohesive, moderately plastic, violent effervescence, straight gradual transition.

CkGr2sc 105-140 cm: clayey clay, olive grey (5YR 4/1) with 55% intense brown spots (7.5YR 5/6) in the wet state and grey (5YR 5/1) in the dry state, massive, reavan, moderately cohesive, moderately plastic, violent effervescence.

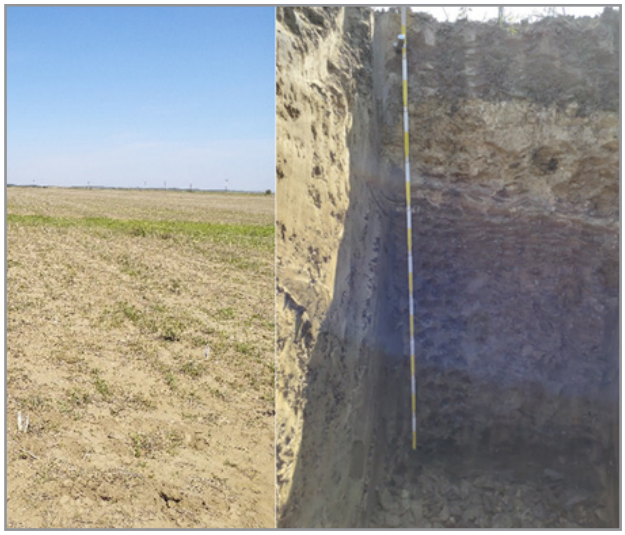

Figure 5: The Soil Profile in the Experimental Center Corbu Nou

This profile, in the Apk horizon (0-23 cm) presents the following characteristics (Table 5, and Table 6):

- loamy texture
- low apparent density (1.31 g/cm3)
- medium saturated hydraulic conductivity (7.38 mm/h)
- weakly alkaline soil (pH = 8.23)
- degree of saturation in bases is 100% saturated
- low humus content (3.04%)

- medium total nitrogen content (0.190%)
- high corrected mobile phosphorus content (69 mg/kg)
- medium mobile potassium content (195 mg/kg)
- The humus reserve in the first 50 cm has moderate values (134 t/ha)

Table 5: Physical Properties of Soil Profile no. 3. EC Corbu Nou

Horizon	UM (cm)	Apk	Aptk	Ck/Asc	Cksc	CkGosc	CkGr1sc
Deep	(%g/g)	0-23	23-28	28-40	40-58	58-78	78-105
wi	(g/cm3)	10,8	11,9	12,8	10,9	15,4	36,7
Dawi	(Kgf/cm2)	1,31	1.36	1,37	1,29	1,27	1,31
RP	(-)	33	38	68	29	23	54
IC	(mm/h)	0,0160	0,0093	0,0000	0,0010	0,0010	0,0046
ksat	(%v/v)	7,38	3,77	3,60	1,89	0,86	0,34
PTwi		50,6	48,9	48,5	51,5	52,3	50,8

Table 6: Chemical Properties of Soil Profile no. 3. EC Corbu Nou

Horizon Deep	UM cm	Apk 0-23	Aptk 23-28	Ck/Asc 28-40	Cksc 40-58	CkGosc 58-78	CkGr1sc 78-105
pH în water	unitați pH	8,23	8,32	8,20	8,30	8,31	8,00
Humus (Cx1,72)	%	3,04	2,56	0,89	0,83	0,72	0,54
N total	%	0,190	0,164	0,83	0,71	0,92	0,059
P AL	mg/kg	174	112	46	48	45	55
P AL corected in function of pH	mg/kg	69	39	19	17	16	28
Kmobile	mg/kg	195	201	160	179	166	170
Conductometric residue	mg/kg	44	60	207	286	343	711

In the figure 6, 7 and 8 are presented the results of agrochemical analysis for soil in each variant from Experimental Center Chiscani, Experimental Center Big Island of Braila, and Experimental Center Corbu Nou, after application of desalinization measurements, in 2024.

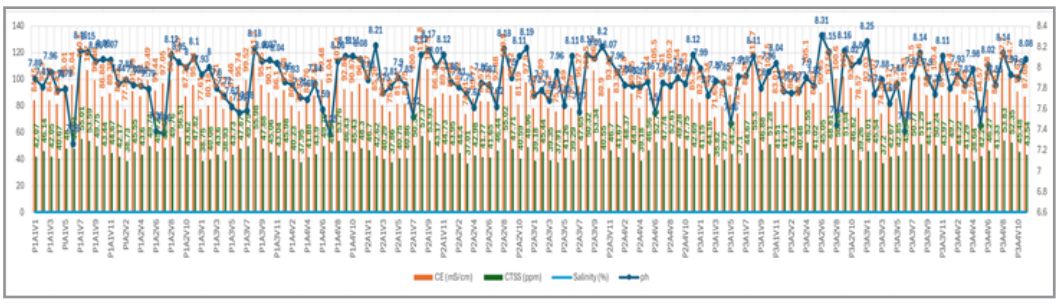

Figure 6: Results of Agrochemical Soil Analysis in the Experimental Center Chiscani, in 2024

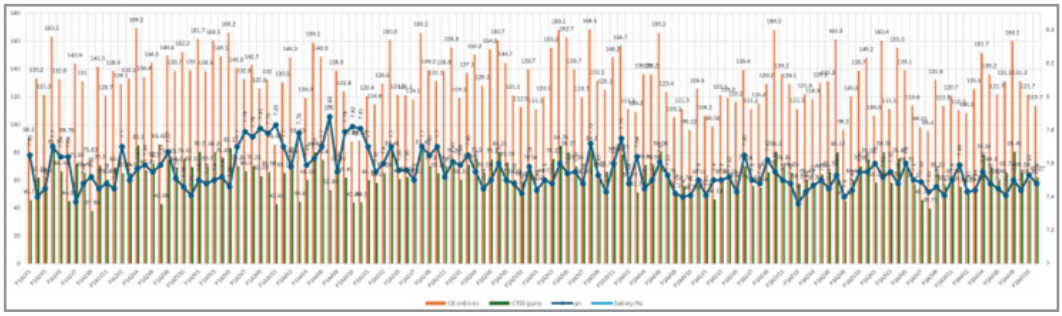

Figure 7: Results of Agrochemical Soil Analysis in the Experimental Center Big Island of Braila, in 2024

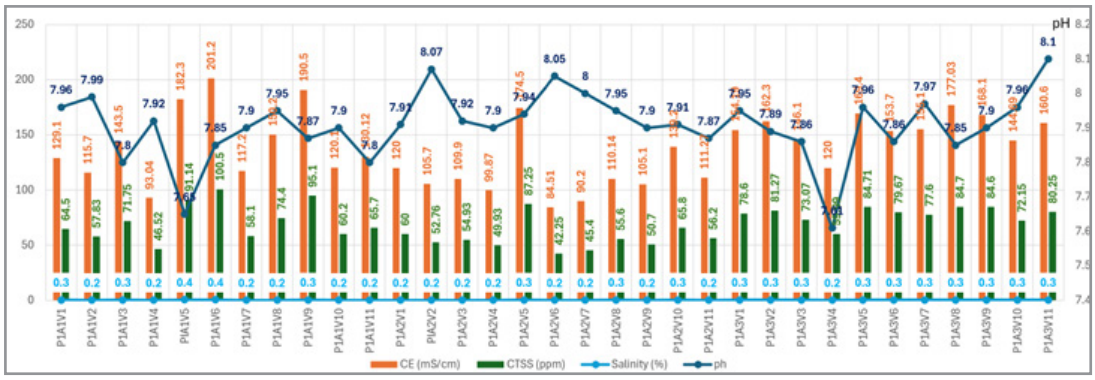

Figure 8: Results of Agrochemical Soil Analysis in the Experimental Center Corbu Nou, in 2024

Conclusions

- In Southeast Romania, agricultural years have become increasingly drier in the last 10 years, so that the land is becoming increasingly arid and subject to salinization and desertification phenomena.
- Crop irrigation accentuates the phenomenon of soil salinization, which is why it is recommended to rotate field crops with salinity-tolerant crops, at least once every 4 years.
- Soil improvement measures must be taken before the salinization phenomenon occurs, through technology measures, crop rotation, green crops, and soil enrichment with organic matter.
- Also, the soil work required in practicing the rotation of cereal crops with root crops and legumes, as well as practicing green or cover crops, contributes to improving soil structure, increasing organic matter content and decreasing the carbon footprint on the farm.

Acknowledgements

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