Subsurface Drip Irrigation as a Factor Ensuring Productive and Ecological Functions of Soils

Nadiya Maksymenko, Olena Gololobova and Oleksiy Shovkun
Department of Environmental Monitoring and Nature Use, Karazin Institute of Environmental Sciences, V. N. Karazin Kharkiv National University, Svobody sq., 6, 61022, Kharkiv, Ukraine

Keywords: Subsurface Drip Irrigation, The Ecological and Reclamation Condition of the Soil, The Ecological and Reclamation Monitoring of the Irrigated Soil.

Abstract: Irrigation is a powerful factor influencing soil. Given the accelerated and significant change of ecosystems under the influence of reclamation load and prevention of degradation processes, soil monitoring using modern innovative methods becomes especially important. Soil fertility management for irrigated land should be aimed at developing models of sustainable, environmentally friendly and cost-effective use of natural resources. It is also essential to preserve and enhance soil productivity and its environmental and social functions for the long term. This has set high demands for energy efficiency, environmental safety and the economic feasibility of irrigation technologies, including in urban landscaping. The aim of the study was to investigate the ecological and reclamation condition of the soil during long-term subsurface drip irrigation of ornamental grass plot, linden (Tilia cordata Mill.), and white cedar 'Brabant' (Thuja occidentalis 'Brabant'). The experiment was conducted during 2018–2021. Research methods: the assessment was carried out on a set of diagnostic indicators following the recommendations for the survey of ecological and reclamation conditions of lands under drip irrigation. The recommendations were developed by the National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky". The results of the study show that the scoring of diagnostic agrophysical indicators is the most favorable. Subsurface drip irrigation does not change the content of organic matter; there is no direct dependence of humus content on irrigation. Subsurface drip irrigation does not change the nutrient status of the soil; the determining influence of soil genetic characteristics on the content of mineral nutrients is observed. Assessment of diagnostic indicators for the cation-anion composition of the aqueous soil extract revealed a poor soil condition in terms of the percentage of Na++K+ from the amount of absorbed alkaline cations. The soil condition in terms of the content of toxic salts was rated to be close to good. The degree of soil salinization by the Ca/Na ratio was > 2.5 for both irrigated and natural grass plots. The soil condition in terms of this indicator was rated to be good. The total pollution rates Zc under subsurface drip irrigation was similar to that for uncontaminated soils. Assessment of the soil microelement status indicated probable excess of zinc and manganese under the influence of irrigation. Conclusion. The scoring of the ecological and reclamation condition of the studied soil according to diagnostic indicators showed the possibility of using subsurface drip irrigation with compulsory further ecological and reclamation monitoring of the irrigated soil

1 INTRODUCTION

Recognition of the fundamental role of soil in climate change adaptation and mitigation has made it one of FAO's top priorities. This should contribute to improving environmental security and social development, understanding the importance of maintaining productive and ecological functions of soils, in particular for the functioning of terrestrial ecosystems (Baliuk & Drozd, 2017). At the same time, in the context of ecological reconstruction of the green infrastructure of many Ukrainian cities, preservation of existing cultivars and hybrid forms of ornamental plants and introduction of new ones make actual the introduction of modern innovative technologies of landscape irrigation, including, of course, subsurface drip irrigation.

Given the accelerated and significant change of ecosystems under the influence of reclamation loads and the need to prevent degradation processes, monitoring of land in the area of these loads becomes especially essential, with the obligatory involvement of modern

Maksymenko, N., Gololobova, O. and Shovkun, O.
Subsurface Drip Irrigation as a Factor Ensuring Productive and Ecological Functions of Soils.
DOI: 10.5220/0011345200003350
In *Proceedings of the 5th International Scientific Congress Society of Ambient Intelligence (ISC SAI 2022) - Sustainable Development and Global Climate Change*, pages 126-134
ISBN: 978-989-758-600-2

innovative and methodological approaches. Irrigated land fertility management should be aimed at developing models of sustainable, environmentally safe, and cost-effective use of natural resources (Baliuk & Drozd, 2017, Baliuk, Kucher & Maksymenko, 2021,), preserving and increasing productive, environmental and social functions of soils for the long term, which puts high demands on energy efficiency, environmental safety, and economic feasibility of irrigation technologies, including in urban landscaping (National soil protection program of Ukraine, 2015, Maksymenko et al., 2021).

Irrigation is a powerful factor influencing agro-ecosystems in general and soils as their main component in particular. All constituents of the soil as a whole system are more or less subject to the transformative effect of irrigation. The transformation causes the disequilibrium of the system with the further stabilization at a qualitatively and quantitatively new level. These changes are as follows: the transformation of water, air, thermal and redox regimes; intensification of biological processes; increase in the mobility and reactivity of minor and major plant nutrients and toxic pollutants; increase in the dynamism and variability of some soil physical parameters (density, hardness, stickiness, structural properties, permeability, etc.); in some cases, redistribution of granulometric particles of different sizes throughout the soil profile; and quantitative and qualitative changes in the colloidal part (Baliuk et al., 2018).

The analysis of literature sources indicates a water-saving effect when applying subsurface drip irrigation: for example, water consumption has decreased to 25–50% compared to surface irrigation (Camp, 1998; Sinobas & Rodríguez, 2012; Camp et al., 2020). According to USDA-NASS calculations, the use of subsurface drip irrigation in the United States in 2006–2016 increased by 89% (Lamm, 2016).

With the long-term use of drip irrigation, diagnostic agrophysical indicators in moistened areas have been favorable for plants and soils (Usatova & Ryabkov, 2018).

The microbial soil coenosis structure was determined in the Sector of Soil Microbiology in the National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky". The results have proved that microorganisms that take up organic forms of nitrogen for 0–30 cm soil layer increased their number from 9.25 to 10.68 million CFU/g under the influence of subsurface drip irrigation. Organotrophic microorganisms activation indicates that subsurface drip irrigation has created conditions contributing to more active assimilation of nutritious organic substrate. According to the assessment proposed by Zvyagintsev, the degree of enrichment of soil with microorganisms was high without irrigation and very high with irrigation. The number of microorganisms assimilating nitrogen of mineral compounds was also higher under subsurface drip irrigation: 10.29 million CFU/g versus 7.25 million CFU/g without irrigation. According to Zvyagintsev, the variant without irrigation is moderately enriched; with irrigation, it is highly enriched. Under subsurface drip irrigation, the number of actinomycetes increased from 5.10 million CFU/g to 6.68 million CFU/g. This indicates a favorable trophic regime of soil. According to the calculation, the oligotrophic index of soil was 0.37 without irrigation and 0.50 with subsurface drip irrigation. The oligotrophic index indicates that the studied agricultural method provides a higher content of easily assimilable nutrients in the soil. Nitrogen mineralization and immobilization rate characterizes the intensity of nitrogen mineralization and assimilation of nitrogen compounds by microbial coenosis. In both variants, namely in the control without irrigation and in the variant with subsurface drip irrigation, the processes of organic matter synthesis were found to prevail over the processes of its destruction: in particular, this rate was 0.86 in the control and 0.95 in the variant with subsurface drip irrigation (Gololobova, 2020).

About 80% of arable land in Ukraine (over 24 million hectares) has such types of water regime of soils, which form the dominance of deficient (or periodically deficient) moisture. This makes the water regime an extremely important factor. Irrigation is a cardinal measure of optimization and stabilization. However, it should be noted that the introduction of subsurface drip irrigation into the nature management system is possible according to the monitoring results, subject to compliance with technological processes of crop cultivation, environmental reclamation monitoring (ERM) and its variety – soil reclamation monitoring (SRM) on irrigated areas (*Recommendations for the survey*, 2012).

2 RESEARCH METHODOLOGY

The study area is situated within the scientific and experimental functional zone of the Dendrological Park of national importance in Kharkiv National Agrarian University named after V. V. Dokuchaiev (Fig. 1). A field experiment was established in autumn 2017 to survey the ecological and reclamation condition of the soil with long-term subsurface drip irrigation.

Figure 1: Geographic location of study area - Dendrological Park in Kharkiv National Agrarian University named after V. V. Dokuchaiev.

The experiment involved experimental sites under ornamental grass plot, with plantings of small-leaved linden (*Tilia cordata* Mill.), white cedar 'Brabant' (*Thuja occidentalis* 'Brabant'), and control sites without irrigation.

The assessment was carried out on a set of diagnostic indicators according to the recommendations for the survey of ecological and reclamation condition of land under drip irrigation (*Recommendations for the survey*, 2012). Ecological and reclamation condition of irrigated land is the land condition, which is assessed by hydrogeological (level, hydrochemical composition and mineralization of groundwater), environmental engineering (porosity coefficient and degree of manifestation of exogenous geological processes), soil reclamation (degree of salinization, alkalinization and salinity of soils, their water-salt and nutrient regimes, and irrigation water quality according to agronomic criteria), ecological-toxicological (the content of heavy metals and pesticides in the soil and water pollution) and agronomic criteria (Baliuk & Drozd, 2017).

Diagnostic soil indicators were determined in the Laboratory of Instrumental Methods of Soil Research and the Laboratory of Soil Geoecophysics in the National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky" according to certified methods (*Soil quality*, 2005; *Soil quality*, 2009; *Method of soil sampling*, 2013).

Soil diagnostic indicators were determined by conventional methods:

- soil density was determined according to Kachinsky's method in 0–10 cm, 10–20 cm, 20–30 cm and 30–40 cm soil layers in spring at the beginning of the growing season;
- macroaggregate analysis was carried out by the dry sieving method according to Savinov; water stability of soil aggregates was investigated by wet sieving method in soil layers of 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm;
- content of nitrate and ammonium nitrogen was determined according to DSTU (State Standards of Ukraine) 4729:2007 Soil Quality. Determination of Nitrate and Ammonium Nitrogen in Modification of NSC ISSAR named for O.N. Sokolovskiy;
- content of mobile compounds of phosphorus and potassium was determined following DSTU 4114–2002 Soils. Determination of Dynamic Compounds of Phosphorus and Potassium by the Modified Method of Machigin;
- cation-anion composition in the soil-water extract was determined according to DSTU 8346:2015, DSTU 7943:2015, DSTU 7908:2015, DSTU 7909:2015, DSTU 7944:2015, and DSTU 7945:2015;
- content of mobile fractions of heavy metals in a buffer ammonium acetate extract (pH 4.8) was defined using atomic absorption spectrophotometry, following DSTU 4770.1:2007, DSTU 4770.2:2007, DSTU 4770.3:2007, DSTU 4770.4:2007, DSTU 4770.5:2007, DSTU 4770.6:2007, DSTU 4770.7:2007, DSTU 4770.8:2007, and DSTU 4770.9:2007.

Scoring of diagnostic indicators of soil was carried out by the recommendations for the survey of ecological and reclamation conditions of lands under drip irrigation (*Recommendations for the survey*, 2012).

3 RESEARCH RESULTS

Among the physical conditions for the fertility of medium- and heavy-textured soil, the soil density andstructural status should be considered the most important.

Soil density was determined at the experimental sites according to the *Recommendations for the* *survey* (2012) before the start of the irrigation period; the results are presented in Tables 1–2.

The equilibrium density for the soil under the grass plot had the optimal values after each irrigation season during 2019–2021 for both 0–15 cm and 15–30 cm soil layers.

The average values of soil density over the years of the study were 1.10 g/cm^3 for the 0–15 cm layer and 1.13 g/cm^3 for the 15–30 cm layer.

The equilibrium soil density recorded at the beginning of the 2021 growing season showed the optimal values after three years of subsurface drip irrigation for white cedar both for all 10 cm soil layers and for the 0–40 cm layer.

The score of the diagnostic indicator (*Recommendations for the survey*, 2012) was maximally positive both for the control and for the studied variant (Table 2).

Table 1: Soil density in the experiment with subsurface drip irrigation of the grass plot, g/cm^3, 2019–2020.

Soil layer, cm	2019	2020	2021	Average over years	Scored ecological and reclamation assessment
0–15	1.08	1.11	1.12	1.10	0
15–30	1.12	1.12	1.14	1.13	0

Table 2: Soil density in the experiment with subsurface drip irrigation of white cedars, May 2021.

Variant	Soil layer, cm	Soil density, g/cm^3	Scored ecological and reclamation assessment
Control	0–10	1.08	0
	10–20	0.91	0
	20–30	1.01	0
	30–40	1.01	0
	0–40	1.00	0
Subsurface drip irrigation	0–10	0.91	0
	10–20	0.95	0
	20–30	1.06	0
	30–40	0.94	0
	0–40	0.96	0

Thus, long-term use of subsurface drip irrigation during 2018–2021 did not result in soil compaction.

In particular, an optimal value of this diagnostic indicator of the soil agrophysical condition was recorded both under the grass plot and white cedars.

The absence of soil compaction contributed to the soft and porous top layer preservation, promoting the growth and development of both the root system and the aboveground part of ornamental plants.

In modern sustainable agriculture, the structure of soil is considered as a kind of regulator of the processes occurring in it. It is the final result of natural processes of soil formation and development and therefore determines the suitability of the soil as the habitat of the entire agrobiocenosis.

The top layer of the soil should be maintained to have a high level of soil aggregation. Such conditions improve moisture conservation and enhance the efficiency of water consumption by plants (Baliuk et al., 2018).

Table 3 shows the soil structural condition assessed by the content of air-dry agronomically valuable particles with a size of 0.25–10 mm. The subsurface drip irrigation provided an excellent structural condition according to the classification proposed by Dolgov in terms of the content of air-dry agronomically valuable particles with a size of 0.25–10 mm (Dolgov et al., 1983).

The average content of air-dry aggregates was 86.24% in the control, whilst it was 88.36% under subsurface drip irrigation. Thus, subsurface drip irrigation has maintained excellent soil condition by this diagnostic soil indicator. The soil structure index was 6.35 in the control and 8.55 in the studied variant.

It has been demonstrated that the most effective moisture consumption occurs at the following ratio of structural fractions: from 20 to 5 mm – 20–25%, from 5 to 0.25 mm – 60–65%, less than 0.25 – up to 15% (Baliuk et al., 2018).

Table 3: The content of air-dry aggregates in dry sieving in the experimental variants with white cedar plantings, May 2021.

Variant	Soil layer, cm	Amount of air-dry aggregates (0,25–10 mm), %	Soil structure index	Scored ecological and reclamation assessment
Control	0–10	87.53	7.02	0
	10–20	86.87	6.62	0
	20–30	83.60	5.10	0
	30–40	86.96	6.67	0
	0–40	86.24	6.35	0
Subsurface drip irrigation	0–10	88.87	7.98	0
	10–20	83.14	4.93	0
	20–30	93.25	13.81	0
	30–40	88.18	7.46	0
	0–40	88.36	8.55	0

Therefore, the assessment of the ratio of soil structural fractions will be relevant in analysing the soil structural composition. The ratio of structural fractions in the soil under the white cedar plantings at the above ranges is presented in Table 4.

Table 4: The ratio of the soil structural fractions at the specified ranges, %, May 2021.

Variant	Soil layer, cm	<0.25 mm	0.25–5 mm	5–10 mm	>10 mm
Control	0–10	6.50	70.97	16.56	5.97
	10–20	3.96	72.77	14.1	9.17
	20–30	0.99	63.37	20.23	15.41
	30–40	2.02	65.62	21.35	11.02
	0–40	3.37	68.19	18.06	10.39
Subsurface drip irrigation	0–10	3.90	74.62	14.25	7.24
	10–20	2.11	61.61	21.53	14.76
	20–30	2.15	73.43	19.82	4.61
	30–40	1.35	68.45	19.73	10.47
	0–40	2.38	69.53	18.83	9.27

The results show that the ratio of soil structural fractions at the specified ranges corresponds to the optimal parameters for the soil structural composition both in the control and under the subsurface drip irrigation; in particular, the fraction of 0.25–5 mm is 68.19% in the control and 69.53% in the studied variant. The established optimal ratio of structural fractions is a factor improving the moisture balance and the efficiency of its consumption by plants. The score of the structural condition is the most favorable.

The results on the number of waterproof aggregates (7–0.25 mm) in wet sieving are presented in Table 5.

The results indicate that subsurface drip irrigation provided the good structural condition of the soil in terms of the content of waterproof aggregates sized 0.25–7.00 mm, according to Dolgov. The average values of this indicator for the 0–40 cm soil layer were 51.65% in the control and 54.20% under irrigation.

The score of waterproof aggregates (0.25–7 mm) content is also the most favorable.

The study of diagnostic agrophysical indicators therefore showed that subsurface drip irrigation preserved the soil structure. In this case, the ratio of structural fractions corresponded to the optimal parameters, equilibrium density was within optimal values, and the scoring was the most favorable.

Table 5: Content of waterproof aggregates (0.25–7.00 mm) according to the experimental variants with white cedar plantings, May 2021.

Variant	Soil layer, cm	Content of waterproof aggregates (0.25–7.00 mm), %	Scored ecological and reclamation assessment
Control	0–10	42.00	
	10–20	49.52	
	20–30	57.88	
	30–40	57.22	0
	0–40	51.65	
Subsurface drip irrigation	0–10	47.54	
	10–20	56.56	
	20–30	62.76	
	30–40	49.94	0
	0–40	54.20	

The soil indicators describing the soil nutrient status are presented in Table 6.

The content of mineral nitrogen according to the grouping of soils by this indicator is very low for both irrigated and natural grass plots, amounting to 9.78 and 13.59 mg/kg, respectively.

In the variant with subsurface drip irrigation of white cedar, the mineral nitrogen content is medium and makes 18.14 mg/kg.

The results indicated good phosphate status for the grass plot with subsurface drip irrigation, as well as for the control site of natural grass plot.

In the soil under the white cedars, the availability of labile phosphorus forms was very high, accounting for 88.7 mg/kg. The availability of labile potassium forms was high for control and irrigated sites (187.21 and 187.18 mg/kg, respectively).

Table 6: Diagnostic indicators for soil nutrient status under subsurface drip irrigation and their scoring, 0–30 cm soil layer, 2019–2020.

Variant	P_2O_5 content, mg/kg	Score	K_2O content, mg/kg	Score	Mineral nitrogen content, mg/kg	Score
Grass plot with subsurface drip irrigation	54.05	0	269.51	0	13.59	5
White cedars, subsurface drip irrigation	88.70	0	187.18	0	18.14	2
Control	53.47	0	187.21	0	9.78	5

Thus, the determining influence of soil genetic characteristics on mineral nutrient contents was observed. Poor nitrogen status was due to the natural characteristics of the soil and the peculiarities of nitrogen uptake by ornamental plants. It is obvious that the studied soil requires the application of nitrogen fertilizers on the grass plot to maximize the potential of the ornamental plants, in particular not only at the beginning of the growing season but also after each mowing. As for the nitrogen status of the soil under the white cedars, small amounts of nitrogen fertilizers should be applied once during the period of active needle growth.

A special function of soil humus is that it contributes to the formation of close to optimal soil properties, even at unfavorable chemical composition (Baliuk et al., 2018). Subsurface drip irrigation did not change the content of organic matter: in particular, the content values were 2.06 and 2.33% for the control and irrigated grass plots, respectively. According to the grouping of soils by humus content, it is assessed as medium (Fateev & Samokhvalova, 2012b). Such humus content is a characteristic natural feature of the studied soil, i. e. there was no direct dependence of the humus content on irrigation during the observation period.

Diagnostic indicators of the cation-anion composition in soil-water extract for the grass plot with subsurface drip irrigation and the control (without irrigation) in the 0–40 cm soil layer are presented in Table 7, as well as their scoring. The degree of soil salinity by the Ca/Na ratio has a value above 2.5 for both irrigated and natural grass plots.

That is, the subsurface drip irrigation did not cause a noticeable transformation in the qualitative composition of water-soluble salts towards the narrowing of the calcium-to-sodium ratio. The condition of the soil on this indicator was rated to be good.

Table 7: Scoring of diagnostic indicators for the cation-anion composition in soil-water extract when using subsurface drip irrigation, 2020.

Variant	pH aqueous / Score*	Ca/Na / Score*	$HCO_3^- - Ca^{2+}$, mEq/100 g / Score*	$Na^+ + K^+$, % of tota absorbed cations / Score*	Content of toxic salts, mEq/100 g / Score*
Grass plot with subsurface drip irrigation	8.18 / 2	3.18 / 0	0.45 / 0	16.00 / 10	0.35 / 5
Control (natural grass plot without irrigation)	8.24 / 2	3.48 / 0	0.51 / 1	15.79 / 10	0.37 / 5

*According to *Recommendations for the survey* (2012).

By the content of toxic salts, the soil condition was rated to be intermediate between satisfactory and good (close to good) in both cases.

Secondary soil alkalinity was estimated by the percentage of Na^++ K^+ of the amount of absorbed alkaline cations. According to this indicator, the condition was unsatisfactory both for the control site and for the studied agricultural practice.

The speed and extent of the detected process are determined by the quality of irrigation water (the content of alkaline salts of sodium and potassium in an equivalent ratio exceeds the content of calcium, magnesium, and iron salts), the initial properties of the soil, including the carbonates content and calcium ions activity, and condition of the irrigated land. For the soil with shallow carbonates (40–50 cm), the effective environmental and economic practice would be deep reclamation plowing, which is an alternative to gypsum treatment (Baliuk et al., 2018).

The alkaline reaction of the soil solution was preferred by the white cedars: the plants developed well and rapidly, the annual growth of the studied *Thuja occidentalis* was 25–30 cm.

The content of heavy metals in the 0–30 cm soil layer in the experimental variants is presented in Table 8.

Table 8: Content of heavy metals in the experimental variants, 0–30 cm soil layer, 2020, mg/kg.

Variant		Cu	Fe	Mn	Ni	Co	Pb	Cr	Zn	Cd	Zc	Score
White cedars with subsurface drip irrigation		0.09	2.07	13.95	0.14	0.02	0.61	0.66	0.68	0.12	2.11	0
Grass plot with subsurface drip irrigation		0.24	2.86	8.92	0.14	0.11	2.29	0.49	0.70	0.08	4.54	0
Control		0.26	0.86	5.80	1.30	0.13	2.61	0.40	0.17	0.06	4.59	0
Threshold limit value*		3.0	-	-	4.0	5.0	6.0	6.0	23.0	0.7		
Background value*	min	0.01	0.02	0.89	0.01	0.01	0.02	0.04	0.01	0. 02		
	max	2.91	32.16	59.47	2.2	1.08	5.3	2.82	4.28	1.12		
	mean	0.36	3.22	14.9	0.94	0.2	0.62	0.5	0.38	0.15		

*According to Fateev and Samokhvalova (2012b)

The results indicate that heavy metals content in the soil in none of the variants exceeded the threshold limit value (Fateev & Samokhvalova, 2012a).

The calculations of the total pollution rates Z_C (Gutsulyak, 2001), which are presented in Table 8, indicate that subsurface drip irrigation does not cause soil contamination with heavy metals; the soil of the experimental site, according to the polyelement contamination indicators, belongs to the uncontaminated (Z_C < 16) (Gutsulyak, 2001). The expected scoring is presented in Table 8.

According to the gradation provided by Medvedev, chemical degradation of soils is absent if zinc content < 11 mg/kg, copper content < 1.5 mg/kg, cobalt content < 2.5 mg/kg, lead content < 3.0 mg/kg, and cadmium content does not exceed three times the background content (Medvedev, 2012).

The comparison indicates no probability of chemical degradation of the soil for any of these chemical elements.

The resistance of plants to biotic and abiotic factors is determined both at the cellular level and by the processes that take place under the harmonious influence of all plant organs. Micronutrients play an essential role in that regard as cofactors of various enzymes, which have their specific action in redox processes; in some cases, there is their interchangeability. Bobko, Vlasyuk, Peive, Shkolnik, Gedz, Toma, and others drew attention to the positive effect of micronutrients on the resistance of plants to adverse conditions and, in particular, to drought, due to changes in the chemistry of the plant body (Baliuk et al., 2018).

The microelement status of the soil in the experimental sites was assessed using the grouping of soils by the content of labile forms of micronutrients extracted with acetate-ammonium buffer (pH 4.8), mg/kg of soil (Fateev & Samokhvalova, 2012b). The results showed that the availability of micronutrients in the soil from the experimental site with subsurface drip irrigation of white cedars was as follows: high for Mn, very low for Cu and Co, and very high for Zn. In the soil from the experimental site with subsurface drip irrigation of the grass plot, the availability of micronutrients was as follows: medium for Mn and Co; very low for Cu, and very high for Zn. In the control site, the micronutrients content was low for Mn and Cu and medium for Zn and Co.

The assessment provides an opportunity to predict possible changes in soil conditions in the context of determining the lack or excess of micronutrients. Irrigated soil will be characterized by a high content of zinc and manganese, and in the future, they are likely to be in excess. At the same time, subsurface drip irrigation does not contribute to the accumulation of labile forms of copper and cobalt.

4 CONCLUSIONS

The presented findings of the 2019–2021 study allowed us to draw the following preliminary conclusions.

1. The equilibrium soil density showed the optimal values at the beginning of the growing season in 2020–2021 for all soil layers: 1.08–1.16 g/cm^3 for grass plot and 0.91–1.08 g/cm^3 for white cedar plantings.

2. The use of subsurface drip irrigation provided an excellent structural condition in terms of air-dry agronomically valuable particles with a size of 0.25–10 mm; the ratio of structural fractions corresponded to the optimal parameters. The average content of air-dry aggregates was 86.24% in the control, whilst it was 88.36% under subsurface drip irrigation. The soil structure index was 6.35 in the control and 8.55 in the studied variant.

3. Subsurface drip irrigation provided good structural condition of the soil in terms of the content of waterproof aggregates sized 0.25–7.00 mm. The average values of this indicator for the 0–40 cm soil layer were 51.65% in the control and 54.20% under irrigation. The score of diagnostic agrophysical indicators is the most favorable.

4. Subsurface drip irrigation did not change the content of organic matter: in particular, the content values were 2.06 and 2.33% for the control and irrigated grass plots, respectively. This humus content value was a characteristic natural feature of the studied soil, i. e. there was no direct dependence of the humus content on irrigation during the observation period.

5. Subsurface drip irrigation did not change the soil nutrient status, namely the content of mineral nitrogen, labile phosphorus and potassium; the scoring was the same for both the irrigated and the control sites. No direct dependence of nutrient content on irrigation was observed. There was the determining influence of soil genetic characteristics on the content of mineral nutrients. Poor nitrogen status was due to the natural characteristics of the soil and the peculiarities of nitrogen uptake in ornamental plants. The studied soil requires the application of nitrogen fertilizers on the grass plot to improve fertility, in particular not only at the beginning of the growing season but also after each mowing. As for the nitrogen status of the soil under the white cedar, the application of small amounts of nitrogen

fertilizers once during the period of active needle growth is relevant.

6. Assessment of diagnostic indicators for the cation-anion composition of the aqueous soil extract revealed a poor soil condition in terms of the percentage of Na^{+}+K^{+} from the amount of absorbed alkaline cations in both variants. By the content of toxic salts, the soil condition was rated to be intermediate between satisfactory and good (close to good) in both cases. The degree of soil salinization by the Ca/Na ratio was more than 2.5 for both irrigated and natural grass plots. The soil condition in terms of this indicator was rated to be good.

7. The results indicate no probability of chemical soil degradation for any chemical element. The total pollution rates Zc in both white cedar sites and the grass plot were similar to that for uncontaminated soils.

8. The assessment of the microelement status of the soil enables forecasting of possible changes in soil status in the context of determining the lack or excess of micronutrients. The content of zinc and manganese may increase due to the irrigation, and their excess is likely to continue. At the same time, subsurface drip irrigation does not contribute to the accumulation of labile forms of copper and cobalt.

9. Score assessment of the ecological and reclamation condition of the studied soil by diagnostic indicators revealed subsurface drip irrigation utility with compulsory further ecological and reclamation monitoring of the irrigated soils.

REFERENCES

Baliuk, S. A. & Drozd, O. M. (Eds.). (2017). *Assessment of ecosystem services of saline soils under the influence of land reclamation (Guidelines)*. Kharkiv: FOP Brovin O.V.

Baliuk S.A. , Kucher A.V. & Maksymenko N.V. 2021, Soil resources of Ukraine: state, problems and strategy of sustainable management. *Ukrainian Geographical Journal.* № 2: 03-11.

Baliuk, S. A., Medvedev, V.V., & Nosko, B.S. (Eds.). (2018). *Adaptation of agro-technologies to climate change: Soil and agrochemical aspects.* Kharkiv: Stylna Typografiya.

TruCamp, C. R. (1998). Subsurface drip irrigation: A review. *Transactions of the ASAE*, *41*(5), 1353.

Camp, C. R., Lamm, F. R., Evans, R. G., & Phene, C. J. (2000, November). Subsurface drip irrigation – Past, present and future. In *Proc. Fourth Decennial Nat'l Irrigation Symp.*, Nov (pp. 14–16).

Dolgov, S.I., Bakhtin, P.U., & Rastvorova, O.G. (1983). *Soil physics*. Leningrad.

Fateev, A.I. & Samokhvalova, V.L. (2012a). *Detoxification of heavy metals in the soil system. Guidelines*. Kharkiv: KP Miskdruk.

Fateev, A.I. & Samokhvalova, V.L. (Eds.). (2012b). *Diagnosis of the state of chemical elements of the soil-plant system*. Kharkiv: KP Miskdruk.

Gololobova, O.O. (2020). Assessment of ecological status of the soil under subsurface drip irrigation using microbiological indicators. *In Ecology, environmental protection and sustainable use of nature: Education – Science – Production – 2020. Proceedings of the XXIII International Scientific and Practical Conference, December 17-18, 2020* (pp. 30–31). Kharkiv.

Gutsulyak, V.M. (2001). *Landscape-geochemical ecology*. Chernivtsi: Ruta.

Lamm, F. R. (2016). Cotton, tomato, corn, and onion production with subsurface drip irrigation: A review. *Transactions of the ASABE*, *59*(1), 263–278.

Maksymenko, N. V, Burchenko S. V., Utkina K. B. & Buhakova M. V. (2021) Influence of green infrastructure objects for quality of surface runoff (on the example of green roofs in Kharkiv). *Visnyk of V. N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", 55,* 275-285.

Medvedev, V.V. (2012). *Soil monitoring in Ukraine. Concept. Outcomes. Tasks*. Kharkiv: KP Gorodskaya Tipografiya.

Method of soil sampling in perennial crop plantations under drip irrigation. Recommendations. (2013). Kharkiv: KP Miskdruk

National soil protection program of Ukraine. (2015). Kharkiv: Smugasta Typografiya.

Recommendations for the survey of ecological and reclamation condition of lands under drip irrigation. (2012). Kharkiv: NNC ISSAR.

Sinobas, L. R., & Rodríguez, M. G. (2012). A review of subsurface drip irrigation and its management. In *Water Quality, Soil and Managing Irrigation of Crops* (pp. 171–194).

Soil quality. Sampling. DSTU 4287-2004. (2005). Kyiv: Derzhspozhivstandart Ukrayiny.

Soil quality. Determination of the content of labile compounds of manganese (zinc, cadmium, iron, cobalt, copper, nickel, chromium, and lead) in the soil in a buffer ammonium acetate extract with a pH of 4.8 by atomic absorption spectrophotometry. DSTU 4770.1-9:2007. (2009). Kyiv: Derzhspozhivstandart Ukrayiny

Usatova, L.G., & Ryabkov, S.V. (2018). Spatial heterogeneity of soil properties in fruit plantations under drip irrigation. In *Agrochemistry and Soil Science. Special issue. Volume 2. Amelioration, reclamation, soil protection, humus status, soil biology, organic farming* (pp. 60–63). Kharkiv: PP Styl-Izdat