

INTERNATIONAL SCIENTIFIC JOURNAL

MECHANIZATION IN AGRICULTURE & CONSERVING OF THE RESOURCES



Issue 4
2023

Year LXIX, ISSN print:2603-3704, ISSN web 2603-3712

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
BULGARIAN ASSOCIATION OF MECHANIZATION IN AGRICULTURE



PUBLISHERS

SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY-4.0"
BUGLARINA ASSOCIATION OF AGRICULTURAL MACHINERY

ISSN (PRINT) 2603-3704, ISSN (ONLINE) 2603-3712

YEAR LXIX ISSUE 4 / 2023

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Experimental study of transportation of pool materials by a flexible sectional screw conveyor

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Abstract. The article presents the construction of a sectional screw robotic body, the use of which will increase the functional and operational characteristics of flexible screw conveyors when transporting bulk and lumpy materials. An experimental setup of the flexible screw conveyor has been developed to carry out experimental studies. According to the results of the experimental studies of the sectional screw conveyor graphical dependences of torque value changes T and power N on the frequency of rotation of the drive shaft of the working body at full filling of the technological line with the grain material, arising in the process of transporting goods by screw conveyors were plotted.

KEYWORDS: TRANSPORTATION, LOOSE AND LUMPY MATERIAL, FLEXIBLE SCREW CONVEYOR, SECTIONAL SCREW CONVEYOR

1. Introduction

Flexible screw conveyors are widely used in transporting agricultural materials in various production processes and effectively meet the functional requirements that are placed on them. However, existing screw conveyors cannot fully meet the operational requirements for these types of conveyors. Solid screw spirals quickly deteriorate as a result of alternating cyclic loads, and combined and sectional working bodies are material-intensive, which leads to increased energy costs and intensive wear of the inner surface of flexible casings.

From the analysis of literary sources we can conclude that the least resource-consuming technology of moving bulk and lumpy agricultural materials along curvilinear routes is the use of flexible screw conveyors made on the basis of individual screw sections, which are connected articulated to each other [1]. In [2, 3] the constructive, kinematic and technological parameters of screw working bodies in terms of their functional purpose are substantiated. The results of the study of material movement in the screw conveyor with a rotating casing are presented in [4].

The development and study of screw conveyors, as well as their impact on the degree of damage to materials are given in [5].

However, the existing flexible screw working bodies cannot fully meet the operational requirements for such types of conveyors.

The purpose of the study was to improve the functional and operational characteristics of the process of transportation of bulk and lumpy materials by improving and developing new constructions of screw working bodies with articulated connection of their sections and justification of optimal construction and kinematic parameters of screws.

2. Materials and Methods

To improve the functional and operational characteristics of flexible screw conveyors the construction of a flexible sectional screw working body was developed (Fig. 1). It is made in the form of two identical adjacent spirals, left 1 and right 2, the ends of which are rigidly connected by inner diameters with separate splined sleeves 3, in the inner diameters of which semicircular axial splines 4 are made, which are placed evenly around the circle, and are in interaction with the cylindrical joints 5 through balls 6, which are rolled up in seats 7 on the ends of cylindrical joints with the possibility of free twisting, like a cardan gear. And the ends of the cylindrical joints 5 of smaller diameter 8 are in contact with the inner diameters of the expander springs 9.

In addition, the balls 6 at the ends of the cylindrical joints 4 are in interaction with the limiting rings 10, which at the edges of the sections are in interaction with the retaining rings 11. To protect the inner holes of the spline sleeves 3, if necessary, from two ends are closed with sleeves 12.

The operation of the helical working body is as follows. When rotating the helix section 1, the rotational motion is transmitted through the rolling bodies 6 to the cylindrical joints 5 and adjacent sections of the helical working body. The advantages of the proposed flexible helical working body include increased loading capacity and increased technological capabilities.

In order to conduct experimental research, an experimental setup was developed and manufactured, its construction scheme overall view is shown in Fig. 2.

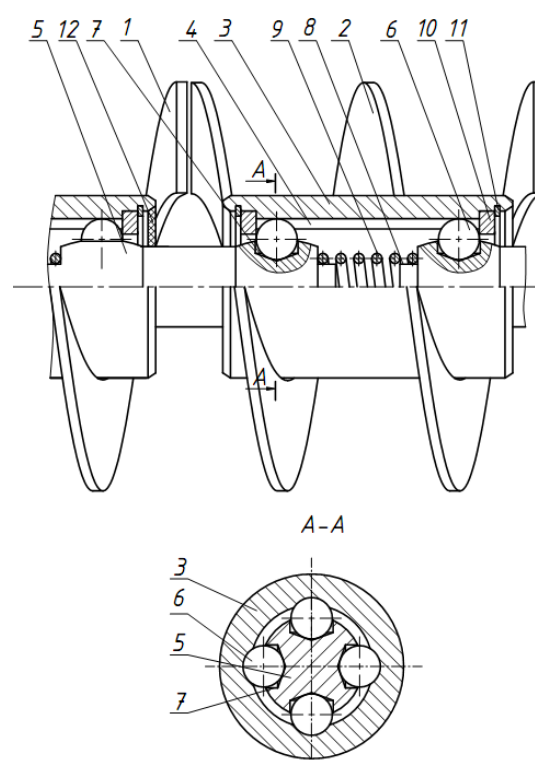
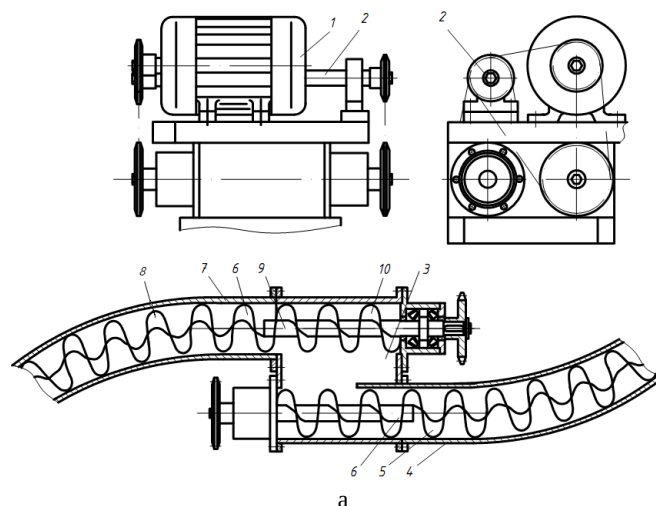


Figure 1. Construction diagram of a flexible sectional helical working body



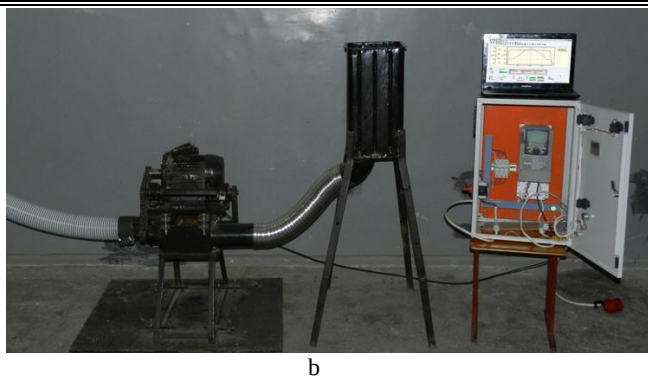


Figure 2. Constructional scheme (a) and general view (b) of the experimental installation of the flexible screw conveyor

Overloading feeder of the experimental installation of a flexible screw conveyor contains loading and unloading branches, which are designed in the form of housings 7 and 4 and parallel placed in them loading 8 and 5 unloading flexible screw elements.

Augers are respectively fixed on the drive shafts 6 and 9, which are placed in the overload feeder 3. The intermediate shaft 2 is located parallel to the drive shafts and is mounted on the reloading feeder. Drive and intermediate shafts outside the reloading feeder are kinematically connected with the shaft of the electric motor 1.

During operation the drive shafts are kinematically connected, the motor shaft and the intermediate shaft allow the working flexible working elements to rotate. When feeding loose or lumpy material, auger 8 transports it in a stationary casing towards the overload feeder. Due to the fact that the drive shafts are located in the horizontal plane, the material transfer to the discharge branch is carried out by means of flat radial plates.

The methodology of the experiment was as follows. During the research, loose and lumpy material is fed from the hopper into the loading line and with the rotation of the working body is transported to the overload branch of the experimental unit and with the help of the unloading line, consisting of an articulated section working body, into the unloading zone.

To start the motor and control its angular velocity, rotation was carried out with the help of Altivar 71 frequency converter and Power Suite v.2.5.0 software. After completion of material overloading process on the computer screen in the window of Power Suite software curves of torque and motor power variation in time were obtained.

The results were obtained in the form of graphical dependences in the opened window of the computer display program.

To analyze the obtained results, graphic dependences of torque T and motor power N on the rotation speed of the working body n , at different values of the height of the bulk material lifting h and the radius of curvature of the technological line R_k were plotted. The peak (maximum) values of the data obtained as a result of the studies were used to construct graphical dependences.

The values of torque and engine power were fixed as a percentage of nominal. The engine power was determined from the product of the nominal engine power (2.2 kW) by the maximum power value for the selected mode. Similarly for the torque.

Exceeding the rated power and torque is due to the fact that the frequency converter can briefly exceed the rated current by up to 170%. If the inverter is selected from a reserve, 170% of the inverter can account for 210% of the motor overload.

It should also be noted that the torque transducer is calculated by a mathematical model and the error can reach 20% (or 5% in the encoder feedback mode). Further on the peak values, the obtained results were recorded in tables.

Experimental studies were conducted with a length of the material conveying line of 3.5 m, and wheat and pea grains and technical salt were used as bulk material.

3. Results and discussions

According to the results of these studies, graphical dependences of the change in the value of torque T and power N on the frequency of rotation of the drive shaft of the working body at full filling of the technological line of loose agricultural material (Fig. 3) were plotted.

The analysis of the graphical dependencies shows that with increasing frequency of rotation n of the working body from 300 to 600 rpm torque T decreases, and for pea and wheat grain ΔT is 7.4%, and for technical salt – $\Delta T = 5\%$.

As for the power N , the dependencies have a fairly pronounced linear growth of N with increasing speed of the working body. So, for pea and wheat grain – $\Delta N = 54\%$, for technical salt – $\Delta N = 59\%$. Experimental studies were also carried out to determine the effect of the material lift height h and the radius of curvature of the technological route R_k on the value of the torque T and power N for the conveyor drive when transporting industrial salt, wheat and peas.

Since in previous studies the effect of the rotation speed of the working body on the value of the torque was studied in detail, when setting the above experiment, the rotation speed of the working body did not change, and its value was 450 rpm.

Based on the results of the experimental studies, graphical dependences of the torque values at the drive of articulated sectional screw working tools on the height h of material movement (Fig. 4) and the radius of curvature R_k of the technological line (Fig. 5) were plotted.

The analysis of graphic dependences (Fig. 5) shows that when the radius of curvature of technological line R_k increases from 0.6 to 1.8 m the torque T decreases, and for wheat grain ΔT is 14%, for pea – $\Delta T = 13\%$, and for technical salt – $\Delta T = 10\%$.

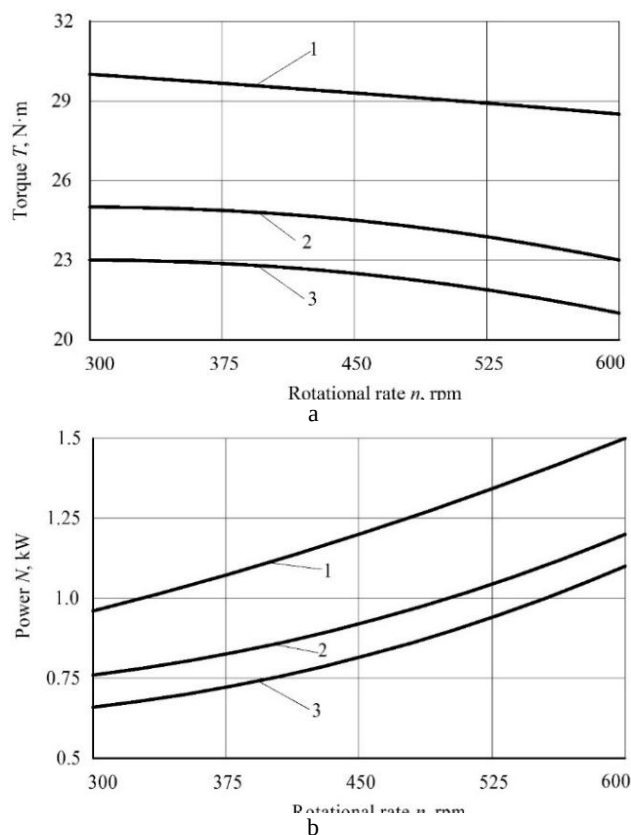


Figure 3. Graphical dependences of torque T (a) and power N (b) on the rotation speed of the working body: 1 – industrial salt; 2 – peas; 3 – wheat

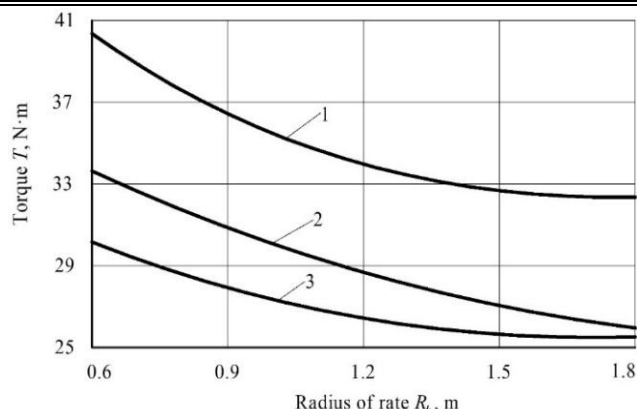


Figure 4. Dependence of change in torque T on the working body on the radius of curvature of technological line R_k at $n = 450$ rpm.
1 – technical salt; 2 – wheat; 3 – peas

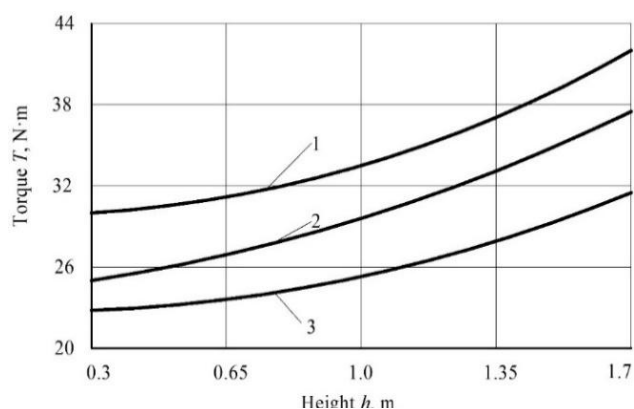


Figure 5. Dependence of change in torque T on the working body on the height of material movement h at $n = 450$ rpm: 1 – industrial salt; 2 – wheat; 3 – peas

When analyzing the graphical dependencies (Fig. 6), it was found that with increasing the height of movement of the material from 0.3 to 1.7 m the torque T increases, and for wheat grain ΔT is 25%, for pea – $\Delta T = 30\%$, and for technical salt – $\Delta T = 29\%$.

4. Conclusion

Based on the analysis of literary sources and patent search, the construction of a sectional screw robotic body was developed and manufactured, the use of which allows to increase the functional and operational characteristics of flexible screw conveyors for transporting loose and lumpy materials. To conduct experimental research on determining the performance of transporting agricultural materials, an experimental setup of a flexible screw conveyor was developed.

On the basis of studies of energy-power parameters of flexible screw conveyors graphical dependences of torque value change T and power N on the frequency of rotation of the working body drive shaft at full filling of the technological line with the grain material, arising in the process of cargo transportation by screw conveyors are constructed.

It was found that with increasing the frequency of rotation n of the working body from 300 to 600 rpm torque T decreases, and for wheat grain ΔT is 7.1%, pea ΔT is 7.4%, and for technical salt – $\Delta T = 5\%$.

As for power, taking into account the speed of rotation of the working body, the graphical dependencies have a fairly pronounced linear increase in the value of power when the speed of rotation of the working body increases. Thus, for wheat grains $\Delta N = 50\%$ pea – $\Delta N = 54\%$, and for technical salt – $\Delta N = 59\%$.

According to the results of the experimental studies of the sectional screw working body to determine the impact of the radius of curvature of the technological line on the torque shows that by

increasing the radius of curvature of the technological line R_k from 0.6 to 1.8 m torque T decreases, and for wheat grain ΔT is 14%, pea – $\Delta T = 13\%$, and for technical salt – $\Delta T = 10\%$.

It was also found that as the height of material movement increases from 0.3 to 1.7 m, the torque T increases, with ΔT is 25%, pea – $\Delta T = 30\%$, and for technical salt – $\Delta T = 29\%$.

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Development of a method for carrying out a multi-factorial experiment on cleaning root crops from soil and vegetable impurities

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Abstract. *Cleaning of root and tuber crops, in particular potato tubers, from soil impurities and plant residues when they are excavated from the soil is an important and urgent problem in the agricultural industry. This article discusses a new construction of a vibrating spiral root and tuber cleaner and a new experimental setup that makes it possible to study the influence of the main structural and kinematic factors on the operation of a spiral type cleaner, as well as to substantiate its rational structural and kinematic parameters. The main constructional difference of the developed cleaner is that the technological process of cleaning root and tuber crops from soil and plant impurities is carried out by moving the heap with coils of cantilevered spiral springs rotating at a certain angular speed and forced oscillatory movements of the ends of the spiral springs themselves in the longitudinal-vertical plane. In this case, soil and plant impurities are effectively sifted not only through the separating gaps and coils of the spirals, but are also significantly destroyed due to oscillatory movements. At the same time, the root and tuber bodies are guaranteed to be transported by the spiral coils themselves towards the unloading conveyor. In the case of covering the spiral coils with a rubber coating, there is no damage to the bodies of root and tuberous crops. The article also presents the developed methodology for conducting a multifactorial experiment on cleaning root and tuber crops from soil impurities and plant residues.*

KEYWORDS: POTATO, SOIL RESIDUES, CLEANER, EXPERIMENT, METHODOLOGY.

1. Introduction

Cleaning root and tuber crops from soil impurities, in particular potato tubers, during harvesting is a very complex, labor-intensive and energy-consuming operation. This is primarily due to the fact that the application of excessive combing forces to the bodies of root and tuber crops will be large, which will significantly improve their quality, but will contribute to damage to their outer surfaces and will be too excessive, which is unacceptable. The technological process of cleaning root and tuber crops should be carried out under the condition that a significant mass of soil and other components of the heap (remains of tops, roots, other plant residues) are immediately separated from the root and tuber crops. This cleaning process, in particular when harvesting potatoes, takes place directly during the process of digging up the entire potato layer or immediately after it is removed from the soil and lifted. And then a significant mass of the dug up heap can get inside the root harvester along with the tubers. This problem is especially acute when digging root and tuber crops out of wet (20% moisture) soil. Therefore, many engineering developments and scientific studies have been devoted to the research and creation of highly efficient and reliable potato heap cleaners, which have been published in the following works [1-9]. At the same time, the analysis of the content of these published works shows that most of the existing constructions of potato harvesters, both domestic and foreign, which operate on different principles of operation of cleaning working bodies, are not always capable of reproducing the process with high quality indicators. That is, not all soil and climatic conditions can achieve a high degree of cleaning of the lateral surfaces of root and tuber bodies from adhering soil and guaranteed and rapid removal of free soil and plant residues from the heap. This is due to soil and plant residues sticking to the separation gaps, as the soil can be very moist and plastic during harvesting. Even under such conditions, significant damage to tubers is observed, and, accordingly, yield losses increase.

Based on the above, we have developed a new root and tuber vegetable cleaner, the construction of which provides for self-cleaning of the cleaning working bodies from adhering soil and plant residues. This is achieved by applying the vibration principles of operation of its working cleaning bodies.

This root and tuber vegetable cleaner from soil impurities and plant residues consists of five cleaning rollers, which are made in the form of cantilever spiral springs connected to the drive in rotational motion, with mutual overlap and separating gaps between the spirals. The cleaning surface formed by the spiral springs performs forced oscillatory movements with appropriate amplitudes and frequencies.

To study the cleaning of root and tuber crops from soil impurities and plant residues, we have created a laboratory experimental installation with five wavy cantilevered cleaning

spirals, which allows to expand the working area of separation, improve the quality of cleaning potato tubers from soil impurities and plant residues and, as a result, increase the productivity of the potato heap separator.

Modern methods of planning multifactorial experiments were used in the laboratory experimental studies. The results obtained from the experimental measurements were further calculated using modern statistical methods on a PC.

The aim of this study is to develop a methodology for conducting a laboratory multifactorial experiment on cleaning root and tuber crops from soil and plant residues using a new construction of a spiral cleaner.

2. Results and discussions

To increase the efficiency of separation of potato heaps dug from the soil, we used a new construction of a root and tuber crop cleaner from impurities, for which we received a patent for an invention [9].

Based on experimental studies, it was found that the dominant factors affecting the operation of the cleaner were oscillations of the separators in the vertical plane; changes in the slope of the working surface of the separators, the speed of rotation of the drive and driven shafts of the separators.

In order to determine the intensity of the influence of these factors on the degree of purification of root and tuberous fruits from impurities on this cleaner, a multifactorial experiment of the BFE P^k was conducted, where P – is the number of levels of variation of the factor; k is the number of factors present in the experiment.

Fig. 1 shows a diagram and general view of the laboratory setup, which was constructed and manufactured specifically for conducting experimental studies of root and tuber crops cleaners from impurities.

The construction of the installation provides for the implementation of a number of factors that actively influence the process of separation of soil impurities and plant residues: frequency and amplitude of oscillatory movements of cleaning spirals in the longitudinal-vertical plane; change in the angle of inclination of the working surface of cleaning spirals, rotation speed of the drive shafts of cleaning spirals.

To measure and record the kinematic parameters of the developed new spiral cleaner, the following sensors are provided in the construction of the laboratory experimental setup. Sensor 29 – the angle of inclination of the cleaning working spiral surface; sensors 30 and 31 – the speed of rotation of the drive shafts of the cleaning spirals; sensor 32 – the frequency and amplitude of oscillations of the working surface formed by the cleaning spirals 10.

To obtain a regression model of the optimization parameter, which was taken in the form of the functional $Y = f(x_1; x_2; x_3)$, where Y – is the degree of purification of root and tuberous fruits from impurities: $x_1; x_2; \dots; x_i$ – natural independent variable factors, we chose the appropriate conditional plan of a multifactorial experiment, the implementation of which was carried out in the following sequence.

To determine the degree of cleaning Y of root and tuber crops from impurities, the following independent variable factors were taken as independent factors: the frequency of oscillations of cleaning spirals in the longitudinal-vertical plane, which was coded by the index X_1 , the angle of inclination of the working surface of the spirals α , which was coded by the index X_2 , the angular velocity ω of rotation of the drive shafts of the cleaning spirals, which was coded by the index X_3 .

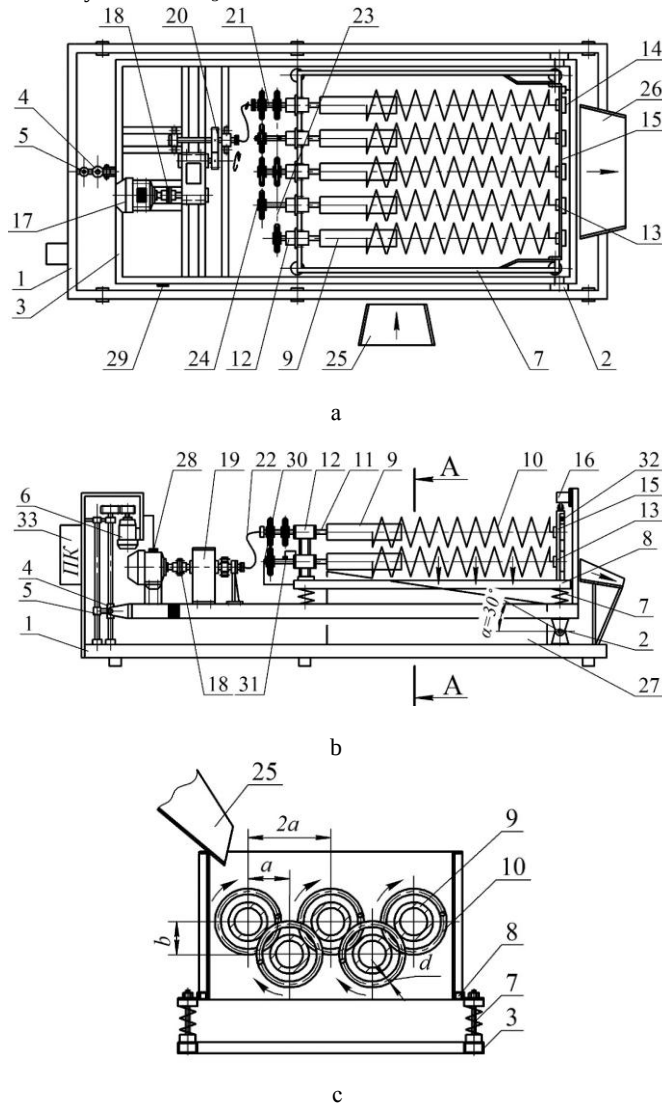


Figure 1. Scheme of the laboratory experimental setup for the study of root and tuber crops cleaners from impurities:

a – top view of the laboratory installation;
b – side view of the laboratory installation;
c – cross-sectional view A-A:

1 – main frame; 2 – joint; 3 – middle frame; 4 – screw pair;
5 – guide; 6 – drive; 7 – elastic supports; 8 – frame; 9 – drum;
10 – cleaning spirals; 11 – shaft; 12 – bearing housing;
13 – bracket; 14 – plain bearing; 15 – movable stand;
16 – vibrator; 17 – electric motor; 18 – coupling; 19 – variator;
20 – spur gear; 21 – drive shaft; 22 – flexible shaft; 23, 24 – chain transmission; 25 – loading tray; 26 – unloading tray; 27 – tray for collecting soil impurities; 28-32 – sensors; 33 – control panel

Fig. 1 shows the main linear and angular dimensions of the spiral root and tuber crop cleaner from impurities.

Next, a mathematical model of a multivariate experiment on cleaning root and tuberous crops from soil impurities was built.

It is well known that when coding factors, the factor space is linearly transformed – the origin is moved to the center of the experiment, and the scale along the axes is chosen in units of factor variation. To code the factors, we used the following relationship:

$$X_i = \frac{2(x_i - x_{i0})}{x_{i\max} - x_{i\min}}, \quad (1)$$

where X_i – coded value of the factor (dimensionless value); x_i – value of the factor in named (natural) units; x_{i0} – is the natural value of the factor at the zero level; $x_{i\max}, x_{i\min}$ – the maximum and minimum values of the factor, respectively.

Next, it was necessary to build a plan-matrix of the multifactorial experiment. When constructing the plan-matrix of the multifactorial experiment, we introduced coded designations for the upper, lower, and zero levels of variation by each factor, which were respectively designated as (+1), (–1), (0). The results of coding the variable factors and their levels of variation are shown in Table.

Table. Results of coding factors and their levels of variation of the multivariate experiment - PFE 3^3

Factors	Designation		Levels of variation, natural/coded		
	Code.	Nat.			
Oscillation frequency of the cleaning spirals in the longitudinal-vertical plane, s^{-1}	X_1	x_1			
The angle of inclination of the working surface of the cleaning spirals α , deg	X_2	x_2			
Angular speed of rotation of the drive shafts of the cleaning spirals ω , $rad \cdot s^{-1}$	X_3	x_3			

After coding the factors, a plan-matrix of the corresponding multifactorial experiment of the PFE 3^3 type was drawn up for the total number of experiments $N = 3^3$.

In order to reliably assess the quality of the root and tuber vegetable cleaner during laboratory experimental studies, the required number of measurements of the controlled parameters (repetition of experiments) was carried out in six replications.

When implementing the compiled plan matrices, to eliminate the influence of uncontrolled and unregulated factors on the results obtained, the plan matrix was randomized by the random balance method, which was implemented randomly.

The processing of the experimental data obtained after the implementation of the planned experiments was carried out in the following order.

The response function (optimization parameter) was taken in the form of an approximating mathematical model of a full square polynomial describing the real experimental process:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2, \quad (2)$$

where Y – experimental value of the output parameter;

$b_0, b_1, b_2, b_3, b_{12}, b_{13}, b_{23}, b_{123}, b_{11}, b_{22}, b_{33}$ – regression coefficients of the corresponding values of the input factors x_i ; x_1, x_2, x_3 – input coded factors.

The coefficients of the approximating polynomial, represented as a full quadratic equation, under the condition of orthogonality and symmetry, were determined by the corresponding general formulas:

– free term b_0 and coefficients b_i i -th factor:

$$b_i = \frac{\sum_{u=1}^N x_{iu} \bar{y}_u}{\sum_{u=1}^N x_{iu}^2} = \frac{\sum_{u=1}^N x_{iu} \bar{y}_u}{N}; \quad (3)$$

– interaction coefficients b_{ij} :

$$b_{ij} = \frac{\sum_{u=1}^N x_{iu} x_{ju} \bar{y}_u}{N}, \quad b_{ij} = \frac{\sum_{u=1}^N x_{iu} x_{ju} x_{ku} \bar{y}_u}{N}, \quad (4)$$

where x_{iu} , x_{ju} , x_{ku} – the value of the coded variable in the corresponding column of the experiment plan;

$\bar{y}_u$ – average result of the u -th experiment;

u – serial number of the experiment;

i – number of the factor;

j , k – number of the factor, different from the i -th;

N – number of conducted experiments.

The reproducibility of the obtained values of the experimental array with an identical number of repetitions for each experiment was checked by the Cochran criterion:

$$G = \frac{S_{v \max}}{\sum_{u=1}^n S_v}, \quad (5)$$

where G – the calculated value of the Cochran criterion;

$S_{v \max}$ – is the numerical value of the maximum variance at the u -th point;

S_v – is the variance that characterizes the scattering of the results of the u -th experiment.

The variance of the reproducibility of the experiments was determined using the following formula:

$$S^2(Y) = \frac{\sum_{u=1}^N (Y_{ui} - \bar{Y}_u)^2}{N(m-1)}, \quad (6)$$

where Y_{ui} – is the numerical value of the i -th response of the u -th experiment;

$\bar{Y}_u$ – is the arithmetic mean of the response of the u -th experiment;

m – is the number of repetitions of each u -th experiment.

The calculated values of the Cochran criterion were compared with the tabulated values. If the condition $G \leq G_T$ (0.05; and the 1) variances are considered homogeneous, it means that the process is reproducible. Otherwise, it is necessary to increase the number of experiments, i.e., to implement the plan-matrix again or several times.

The statistical significance of the coefficients b_i of the regression equation was tested by the Student's t -test and determined in the following sequence:

– determine the variance of experimental errors in the lines of the multifactorial experiment plan:

$$S^2(b) = \frac{1}{N \cdot m} S^2(Y); \quad (7)$$

– determine the reproduction error:

$$S(b) = \sqrt{S^2(Y)}; \quad (8)$$

– determine the condition of significance of the coefficients $b_{i(jk)}$ of the regression equation:

$$b_{i(jk)} > t_T S(b), \quad (9)$$

where t_T – the table value of the Student's coefficient, which is

selected from the table depending on the degree of freedom of correspondence f and the level of significance.

The degree of freedom of compliance is equal to:

$$f = (m-1)N.$$

If the condition of significance is not met, then such a coefficient b_i of the regression equation was taken to be insignificant (equal to zero), and the corresponding term x_i of the regression equation was excluded.

The adequacy of the selected mathematical model to the experimental data, i.e., the correspondence of the mathematical model to the real process, was checked by the Fisher's F -criterion as follows

– the variance of adequacy was determined:

$$S_{ag}^2 = \frac{m}{N-g'} \sum_{u=1}^N (\bar{Y}_u - \tilde{y}_u)^2, \quad (11)$$

where $N-g'$ – is the number of degrees of freedom of the variance of adequacy;

g' – number of significant coefficients in the regression equation;

$\bar{Y}_u$ – is the average response value in the u -th experiment;

$\tilde{y}_u$ – is the response value at the u -th point of the plan, calculated by the regression equation;

– determine the calculated Fisher's conformity criterion F_p :

$$F_p = \frac{S_{ag}^2}{S^2(Y)}, \quad (12)$$

where $S^2(Y)$ – variance of the experiment reproduction;

– determine the table value of the Fisher's criterion F_T or a given level of significance and two degrees of compliance:

$$f_{ag} = N-g \text{ and } f_y = N(n-1).$$

The condition of the adequacy of the chosen mathematical model was checked according to the inequality:

$$F_p < F_T.$$

The obtained value F_p was compared with the table value F_T .

Thus, if the condition of adequacy of the chosen mathematical model is met, that is, the regression equation of a multivariate experiment is adequate to the experimental data. If the adequacy condition is not met, the model is inadequate. It is necessary to repeat the experiments in whole or in part under different conditions.

Next, the multiple correlation coefficient was also determined by the formula:

$$R = \sqrt{1 - \frac{\sum_{u=1}^N (\bar{Y}_u - \tilde{y}_u)^2}{\sum_{u=1}^N (\bar{Y}_u - \bar{Y})^2}}, \quad (13)$$

where $\bar{Y}$ – the average value of the function values determined from the experimental data.

Thus, almost all the conditions for drawing up a regression equation that will reflect the dependence of soil residues (output parameter) on the surfaces of potato tubers that have been cleaned with a spiral-type root and tuber cleaner on independent (input) parameters were obtained. Subsequently, using a computer, it is necessary to perform numerical calculations and obtain graphical dependencies.

3. Conclusion

1. To study the technological process of cleaning root and tuber crops from soil impurities and plant residues, a laboratory experimental setup was created. This installation has five cantilevered cleaning spirals arranged in a transverse-vertical plane, forming a separation zone with two cleaning channels. This allows to improve the quality of cleaning potato tubers from soil impurities and plant residues and, as a result, to increase the productivity of the potato heap separator.

2. The use of this experimental setup with a new potato heap cleaner makes it possible to study the influence of the main structural and kinematic factors on the operation of spiral-type cleaners, as well as to substantiate its rational structural and kinematic parameters.

3. A new methodology for conducting a multifactorial experiment to study the cleaning of root and tuber crops from soil impurities and plant residues has been developed.

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Study of conditions for further development of high-tech agro-industrial production in Ukraine

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Abstract. *The article presents the results of a study of the conditions for further improvement and development of high-tech agricultural production in Ukraine. The purpose of this study is to define conceptual approaches to the technical and technological modernization of the agro-industrial complex as a key element of sustainable development of the real sector of Ukraine's economy and strategic directions of research in agricultural science. The study found that in the context of inevitable climate change, the basis for the formation of highly automated agriculture will be flexible environmentally friendly technological processes in agricultural production, built on fundamentally new technical and technological principles, namely: intellectualization, digitalization, integrated automation and robotization. A concept for the development of high-tech agricultural production in Ukraine based on the principles of sustainable development and the innovative concept of Industry 4.0 was also developed, which will ensure high and sustainable economic growth of the agro-industrial complex, development of domestic agricultural engineering and related sectors of the economy. The strategic tasks for agricultural science in the development of the technical and technological base of highly automated agricultural production are outlined. The study of modern trends in the development of economies of advanced countries and their effectiveness give grounds to assert that the identified strategic directions of technical and technological modernization of the agricultural sector will be the basis for the formation of an effective model for the development of high-tech agro-industrial climate-oriented production in Ukraine.*

KEYWORDS: CLIMATE CHANGE, HIGH-TECH PRODUCTION, AGRICULTURE, TECHNOLOGY, INTELLECTUALIZATION, AUTOMATION, ENGINEERING

1. Introduction

Global climate change is forcing humanity to reconsider its consumer attitude towards nature and the planet's fossil energy resources. International organizations and governments of the world's leading countries are developing programs to reduce the industrial burden on the environment and increase the share of alternative energy in the energy balance of countries. Environmentally responsible production is becoming a trend in economically developed countries, and Ukraine does not stand aside from these processes.

Greening and intellectualization are becoming fundamental components of the development of the latest agricultural production technologies that implement the strategic objectives of the transition to highly automated agriculture, since the sustainable development of modern agro-industrial production is based on the complex automated operation of the human-machine system in close harmony with living objects.

The problems of formation, use and renewal of the material and technical base of agriculture are given considerable attention in the studies of Adamchuk V.V., Pidlisetskyi H.M., Sabluk P.T., Sytnyk V.P., Bilouskyi Y.K., Ivanyshyn V.V., Lupenko Y.O., Zakharchuk O.V., Mykhailov M.G. and others [1-8].

However, in order to achieve the goals of sustainable rural development, the transition to which Ukraine declared to the international community in the National Report "Sustainable Development Goals: Ukraine" [9], it is necessary to accelerate the transformation of the domestic economy in the direction of the innovative concept "Industry 4.0" and to develop a strategy for updating the technical and technological base of agricultural production, which outlines the guidelines and priorities of domestic engineering for the agro-industrial complex.

Taking into account global technological trends, to define conceptual approaches to the technical and technological modernization of the agro-industrial complex as a key element of sustainable development of the real sector of Ukraine's economy and strategic directions of research in agricultural science.

The following methods were used in this study: monographic, system analysis, abstract and logical.

2. Results and discussions

The world's leading countries are demonstrating a long-term trend of industrial development based on the Industry 4.0 concept, which involves process automation, rationalization of logistics and production, intellectualization of enterprises and accelerated implementation of scientific and technological progress.

The current stage of global economic development is characterized by a decrease in the need for human resources, which are being

replaced and modified by robotics, artificial intelligence and remote access technologies. Instead, there are growing requirements for the qualifications of employees who are tasked with managing the latest automated equipment and systems.

Industries are actively adapting to new conditions, and agriculture is no exception. Already today, agricultural enterprises are actively using multicopters, unmanned tractors and machine-tractor units, robots and various information technologies.

It is not surprising that analysts predict fundamental changes in the agricultural sector of advanced countries over the next 10-20 years due to the intensive implementation of artificial intelligence, robotics and automation technologies, which will turn the industry into a high-tech business, ensure rapid productivity growth and reduce unproductive losses.

To ensure economic balance and competitiveness in the markets, it is extremely important for Ukraine to develop a strategy for the development of agricultural production and machine building as key participants in the restoration and development of the state in the postwar period. The paradigm for the formation of high-tech agricultural production should be based on the synergy of the conceptual directions of sustainable development and the tasks of intelligent automation in the format of the innovative concept "Industry 4.0" (Fig.).

From the early 90s of the 20th century to the present, the tasks of sustainable agricultural development have gradually evolved – there has been a shift in emphasis from increasing food production in a sustainable way and ensuring food security to ensuring the social welfare of the population without depleting ecosystems, climate change, and causing environmental damage under the condition of economically efficient production [10].

Sustainable development is a complex, dynamic, manageable and multi-level process of balancing economic, social and environmental benchmarks aimed at ensuring the well-being of the population.

The social vector of sustainable development is aimed at ensuring a high standard of living and working conditions for the company's personnel. Therefore, the strategic direction of the sustainable development concept is to create comfortable living and working conditions, which involves building social infrastructure in rural areas, ensuring high employment and remuneration, social guarantees and environmental protection.

An important component of the sustainable development of the agricultural sector is the environmental block, which includes two components. Firstly, it is the greening of agricultural production and secondly, solving the problems of physical, chemical and biological pollution of rural areas.

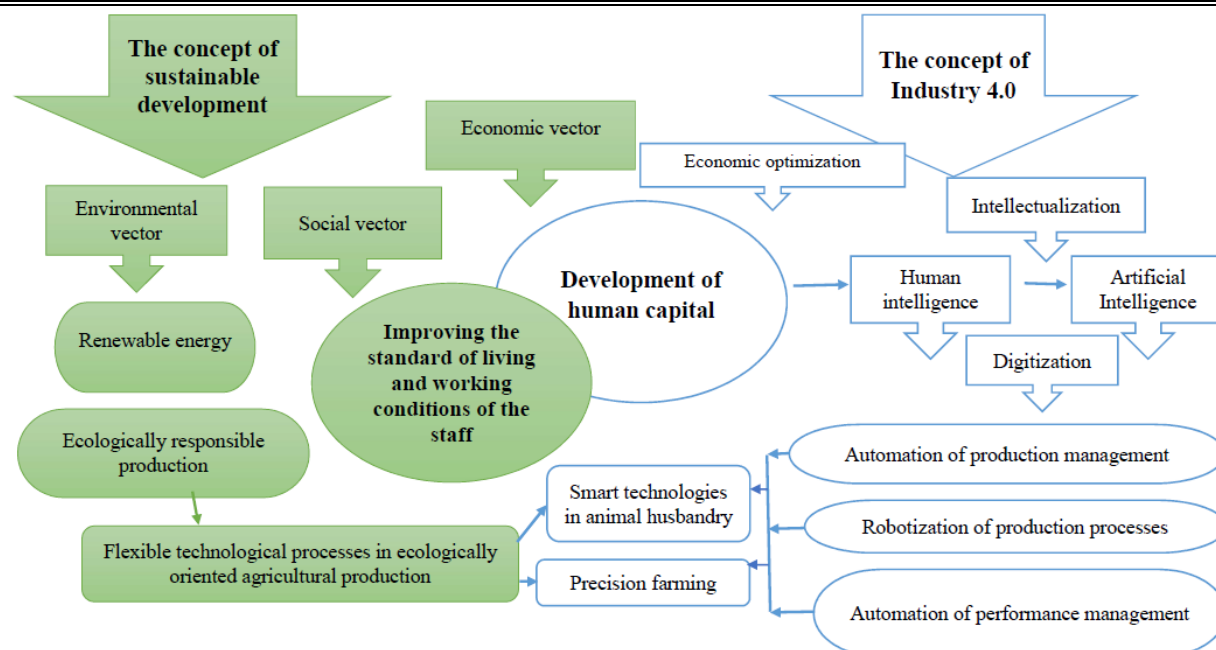


Figure. Concept of development of high-tech agricultural production of Ukraine

Intensive agricultural production methods have resulted in a violation of the ecological balance between economic activity and the natural environment. This has resulted in degradation processes in agroecosystems that cause a number of environmental problems and threats. Therefore, the transition of agricultural production to the biosphere model of nature management, preservation of the integrity and viability of natural ecosystems for future generations are becoming a fundamental part of the sustainable development strategy. This strategy is a long-term forecast of a comprehensive solution to the problem of environmentally balanced development of the agricultural sector and improvement of agroecosystems.

Greening of the agricultural sector implies transition of business entities to environmentally responsible production and development of renewable energy to replace fossil fuels, which will have a positive impact not only on the environment but also increase Ukraine's energy independence as a component of its national security. Under such conditions, bioenergy is becoming a strategic industry whose priority tasks are to find cheap energy bio-raw materials, effective technical and technological solutions for their cultivation and processing, and to create the necessary logistics infrastructure, etc.

Environmentally responsible production involves the creation of agroecosystems capable of maintaining their stability under existing levels of anthropogenic pressure, realizing their internal development potential while reducing the levels of this pressure, and maintaining a favorable state of the environment. The task of eco-oriented agricultural business is to preserve and restore soil fertility by minimizing tillage, combating soil compaction, applying crop rotations with active use of green manure and ground cover crops, balanced application of organic and mineral fertilizers, preserving biodiversity, etc.

The economic component of sustainable agricultural development involves ensuring the economic sustainability of production by increasing its productivity and profitability, diversifying production and markets to generate guaranteed profits.

The algorithm for economic optimization in highly developed countries has become the innovative concept of Industry 4.0, which requires the development of human capital and deepening the intellectualization of production to transition to a new technological mode.

It is the intellectualization of production that is the main condition for the formation of high-tech agriculture in Ukraine and is achieved through the development of human capital, the use of

artificial intelligence technologies, the introduction of the latest equipment, IT technologies, etc.

Automation is one of the most important ways to further develop productive forces in agricultural production. This is the basis on which, given the high level of mechanization and electrification of production, it is necessary to improve agricultural machinery and increase its performance. Without the creation of new automated agricultural machinery and its technical systems, the transition to flexible precision farming technologies will remain an unfulfilled dream.

The development of agricultural automation should be based on the rich experience of the industry. However, the automation equipment required for agricultural production has specific requirements due to the specific conditions of its use.

Automation of production in the agricultural sector should take place in three areas:

- automation of production management through digitalization, automated information systems, artificial intelligence, database creation, etc;
- automation of production processes through robotization, use of autonomous machines and automatic technical systems;
- automation of productivity management, which involves the introduction of precision farming systems and adaptive technologies in livestock production.

Automated information systems allow to automate all types of accounting in an agricultural enterprise, carry out operational and strategic planning, optimize the structure of production and costs, logistics, material and technical support, audit and control of all financial and production activities.

The main feature of agricultural production is the inextricable link between machinery and biological objects (animals and plants), which are characterized by the continuity of product formation processes and the cyclical nature of their production. The level of realization of the potential of biological objects and their productivity depends on the timeliness and quality of technological operations. In this regard, automation in agricultural production must be highly reliable, since such processes cannot be interrupted in time and it is almost impossible to make up for lost time by intensifying the next period. For example, automation in livestock farming should ensure that technological operations are performed cyclically throughout the day, regardless of weather conditions and other factors.

Precision farming is a new stage in the development of the agricultural sector, involving the use of global positioning systems,

on-board computers, management and executive mechanisms that can provide tillage methods, fertilizer application rates, chemical ameliorants and plant protection products, taking into account the heterogeneity of the field background. The main task of the precision farming information system is to map fields, collect and accumulate various data on field history, process and analyze them to improve production efficiency. Precision farming technologies will contribute to a sharp increase in crop yields and production efficiency.

Based on the analysis of the peculiarities of agricultural production processes and their requirements for technical support, it is established that the strategic directions of research on the development of agro-industrial production in Ukraine on the basis of flexible technological processes and automated technical systems are as follows

- continuous improvement of agricultural production and technological processes, increasing their adaptability and flexibility to specific production conditions and suitability for automation;
- scientific generalization of the world experience of automation of agricultural production processes and technical means for their implementation;
- determination of static and dynamic characteristics of agricultural automation objects;
- mathematical description of objects of control of production processes and technical means;
- determination and establishment of functional dependencies between the controlled parameters of soil and agricultural technological materials and their physical properties (electrical, optical, acoustic, thermal, mechanical, etc.) in order to use them for the construction of measuring instruments and converters specific to agriculture, non-electrical quantities into electrical ones;
- development of technical means for agriculture, taking into account their suitability for automation and interaction with foreign analogues;
- improvement of methods for optimal engineering and calculation of automation equipment, taking into account the expansion of their functional tasks and improvement of hardware and operational reliability.

Successful research and development in these areas will accelerate the transition to agricultural production based on SMART technologies.

3. Conclusion

The study of modern trends in the development of economies of advanced countries and their effectiveness give grounds to assert that these strategic directions of technical and technological modernization of the agricultural sector will be the basis for the formation of an effective model for the development of high-tech agro-industrial climate-oriented production in Ukraine.

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Use of numerical methods in generalizing nusselt numbers depending on the reynolds number for a compact tube beam

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Abstract. When developing new types of heat exchanger constructions, such factors as their mass-size characteristics, efficiency of heat transfer through the separating heat-carrier surface, pressure losses in the paths for each of the heat-carriers and other parameters characterizing the heat-exchange apparatus play an important role. CFD modeling of heat and mass transfer processes in a tube bundle at different Re numbers with compact placement of tubes, using ANSYS Fluent software package, has been conducted. The mathematical model is based on Navier-Stokes equation, energy conservation equation for convective flows and continuity equation. The standard $k-\varepsilon$ model of turbulence is used in the calculations. The fields of velocities, temperatures, pressures in the studied channels have been obtained. The hydrodynamic flow conditions in the channels are analyzed and the intensity of heat transfer between the hot and cold coolant through the wall separating them is estimated. Based on the results of CFD modeling, the criterial equation of Nu , number is derived, which can be used in engineering calculations of heat exchange apparatuses with compact tube bundles.

KEYWORDS: HEAT EXCHANGE APPARATUS, CFD MODELING, HEAT AND MASS EXCHANGE, TUBE BUNDLE, NUMBER NU .

1. Introduction

Bundles of smooth cylindrical tubes with chessboard and hallway arrangement are widely used in various heat-exchange apparatuses and devices of power installations. The review of literature sources and results of a significant number of experimental studies of heat-hydrodynamic characteristics of smooth tube bundles in their transverse flow, including studies of heat release of chessboard bundles at Re numbers shows that such bundles have higher heat release in comparison with corridor bundles. However, at the same time, they have higher hydraulic resistance compared to corridor beams.

It should be noted that surfaces of this type, used in shell-and-tube heat exchangers, lead to an increase in their mass and dimensions. One of the ways to improve these characteristics is the use of fins and heat transfer intensifiers on convective surfaces. However, the use of finned surfaces and intensifiers significantly increases the hydraulic resistance in the paths of heat exchanger and requires the use of pumps and fans of higher power for pumping heat-carriers. A promising direction of reducing hydraulic resistance and intensification of heat exchange on convective surfaces of heat exchangers is the use of smooth tube bundles with compact configuration.

Heat exchangers are primarily classified either by flow configuration (counterflow, direct flow and crossflow) or by constructive implementation (concentric tube, shell-and-tube and compact) [1]. The ultimate goal of every heat exchanger or heat transfer study is to find methods or constructions that increase the heat transfer rate. One of the main features of increasing heat transfer is to play with the nature of the flow and change it from laminar to turbulent [2]. The more turbulence, the more it contributes to heat transfer [3, 4]. To increase turbulence, this can be done in two ways, called active and passive methods [5]. Active methods require the use of external energy, which can be mechanical, hydromagnetic or electrohydrodynamic [6, 7]. While the use of extended surfaces, called edges, is a widely used method among passive methods to increase heat transfer. The effective heat transfer area increases with the use of extended surfaces, resulting in turbulent flow, which increases the transfer rate. In passive methods,

the heat transfer rate increases due to modification of the heat transfer interface surfaces [8]. For example, using a method of artificial roughness by using low-height repeating ribs on the heat transfer surface to break the laminar layer and increase turbulence in heat transfer [9]. Others report the use of V-shaped, W-shaped, angular and transverse ribs to create artificial roughness [10, 11].

However, there is another solution to the passive method of increasing the intensity of heat transfer, it is a compact arrangement of tubes in the tube bundle [12, 13].

Therefore, the development of new constructions of shell-and-tube heat exchangers with compact tube bundles is relevant and requires a solution.

Research objective – Development of new constructions with compact placement of bundles of smooth tubes at their cross flowing by coolants and CFD modeling of heat and mass transfer processes in heat exchanger channels with subsequent derivation of criterial equation of number Nu .

2. Materials and Methods

Let us consider a tube bundle of compact configuration in their transverse flowing (Fig. 1). The geometry of arrangement of tubes with diameter $d = 10$ mm is peculiar, different from traditional chessboard, hallway arrangement. The distance between the tubes is 5 mm. Thickness of a pipe is 1 mm. Material of the pipe is "Steel 3". On the third pipe, the boundary condition "wall_L" and "wall_R", set the heat source to $2070.064 \text{ W} \cdot \text{m}^{-2}$. All other pipes are set to the temperature corresponding to the inlet temperature. See Table 1 for details. In order to derive the criterion equation for the number Nu it is necessary to change the number Re , which depends on the air velocity at the inlet. The Re number varied from 332 to 4946.

Numerous simulations of heat and mass transfer processes in tube bundles of compact configuration using the ANSYS Fluent application package have been performed.

Mathematical model is based on Navier-Stokes equations [14-16] and convective energy transfer equation. We chose the standard $k-\varepsilon$ turbulence model [17].

Table 1. Inlet air parameters

Parameter	Value									
Inlet air velocity, $\text{m} \cdot \text{s}^{-1}$	0.5	1.4	2.3	3.4	4.0	4.7	5.4	6.0	6.6	7.4
Inlet air temperature, $^{\circ}\text{C}$	17.1	16.2	16.7	16.4	16.1	15.6	15.5	15.5	15.5	15.5
Number Re	331.9	934.5	1530.5	2254.9	2658.4	3149.2	3609.0	4007.9	4409.9	4946.0

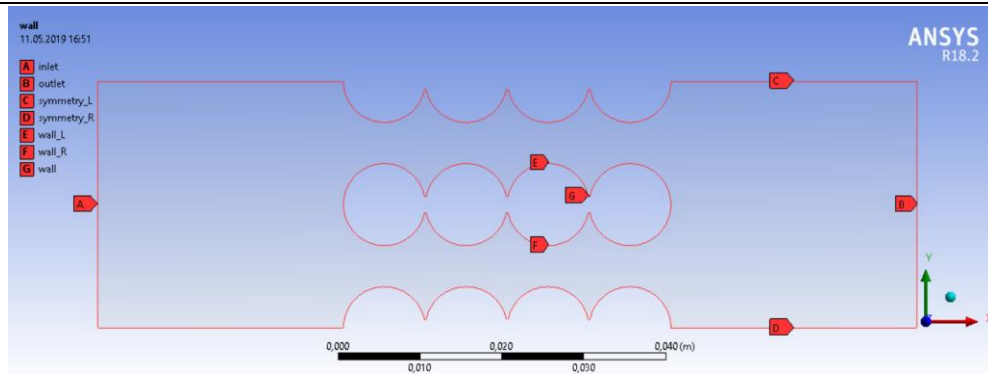


Figure 1. Geometry of the tube bundle arrangement and boundary conditions designation for CFD modeling

3. Results and discussions

The results of numerical calculations are shown in Figures 2-3. Fig. 2 shows the distribution of the temperature field in the channels of the tube bundle. The amount of heat released by the third tube is the same for all models. Due to the increase in air flow in the channels of the tube bundles, the temperature is different and ranges from 288° K (+15° C) to 372° K (+99° C).

Fig. 3 shows the velocity field in the heat exchanger channels. Analysis of the obtained velocity field shows that the maximum values of flow velocity are observed between the pipes in the narrow section.

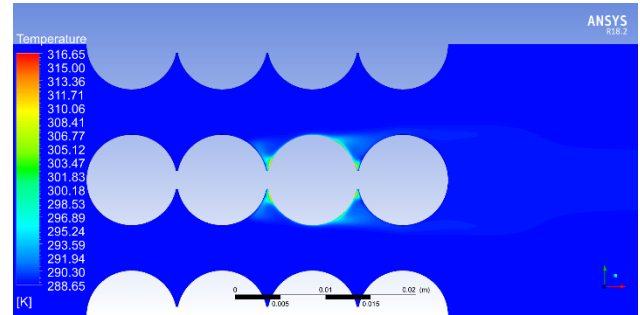
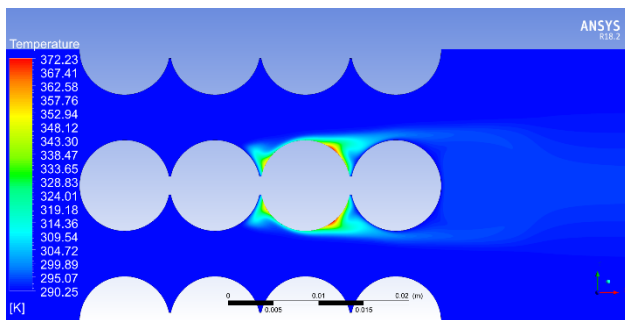
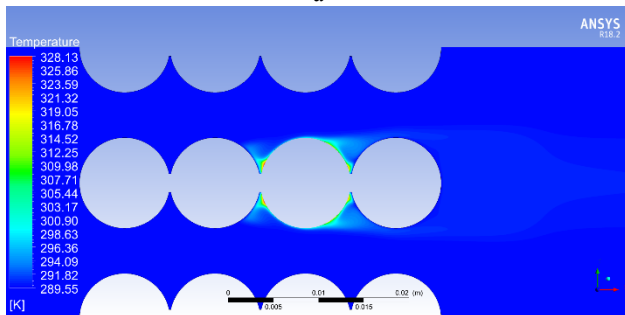


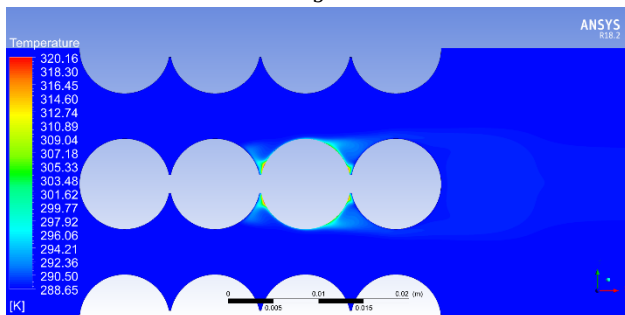
Figure 2. Temperature field in the tube bundle at different numbers Re , °K: a – $Re=332$; b – $Re=2255$; c – $Re=3609$; d – $Re=4946$



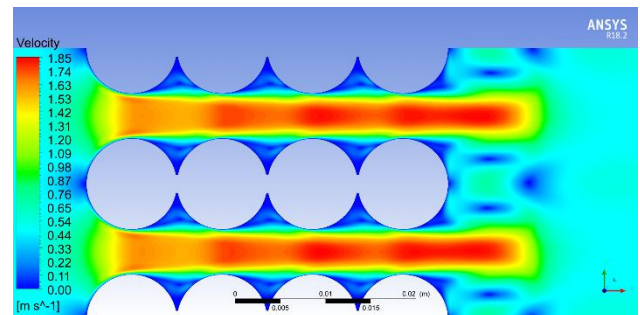
a



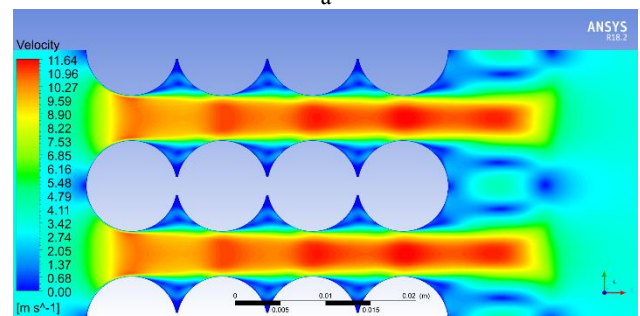
b



c



a



b

The air velocity reaches $24.44 \text{ m}\cdot\text{s}^{-1}$ at $Re = 4946$, at some points in the channel, and the average air velocity in the narrow cross section of the channel is about $22.19 \text{ m}\cdot\text{s}^{-1}$ (Fig. 3d). Detailed CFD simulation results are shown in Table 2.

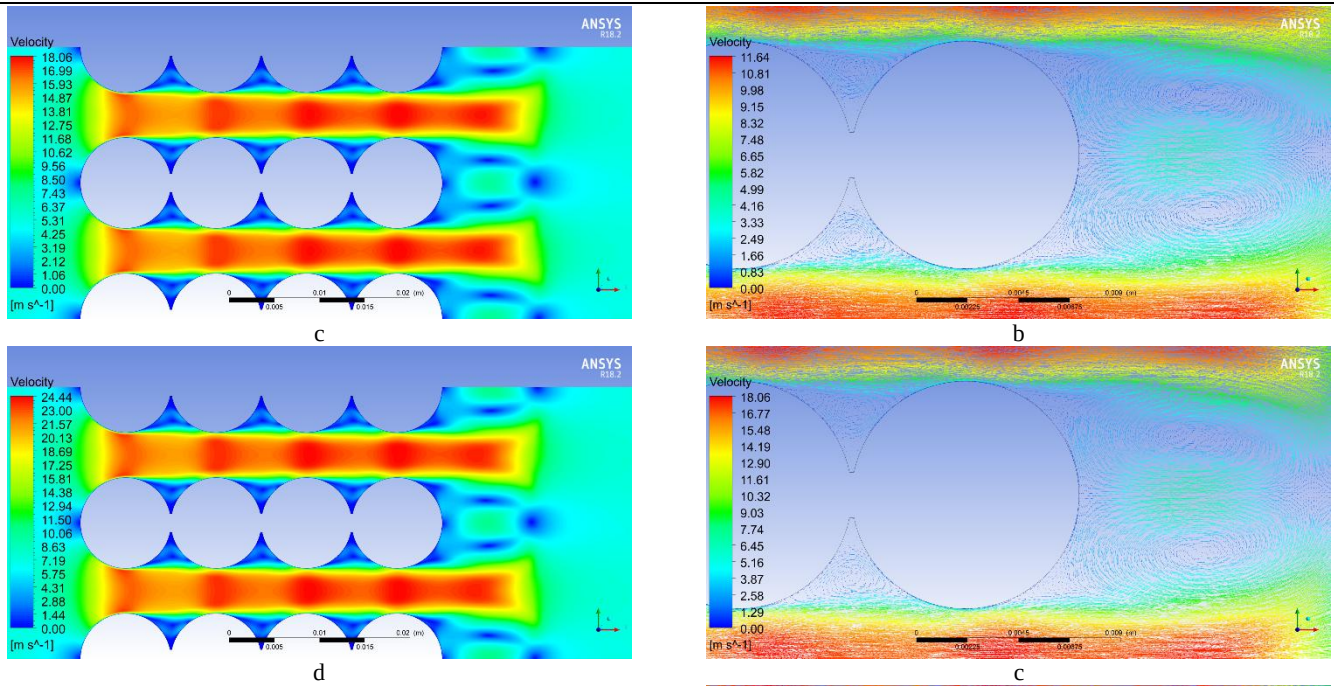


Figure 3. The velocity field in the tube bundle at different numbers $Re, m \cdot s^{-1}$: a – $Re=332$; b – $Re=2255$; c – $Re=3609$; d – $Re=4946$

Fig. 4 also shows the velocity vectors at the outlet of the tube bundle. There is a boundary layer detachment at the upper point of the tube, and there is a stagnation zone at the junction of neighboring tubes. In this zone, a tear-off vortex is observed, in which the flow velocity is significantly lower than in the main flow. Comparing the obtained results of the air velocity field (Fig. 3-4), the hydrodynamics of the air flow in the channels is the same.

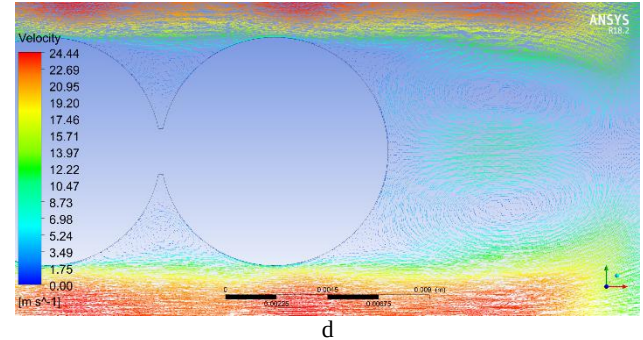


Figure 4. Velocity vector in the tube bundle at different numbers $Re, m \cdot s^{-1}$: a – $Re=332$; b – $Re=2255$; c – $Re=3609$; d – $Re=4946$

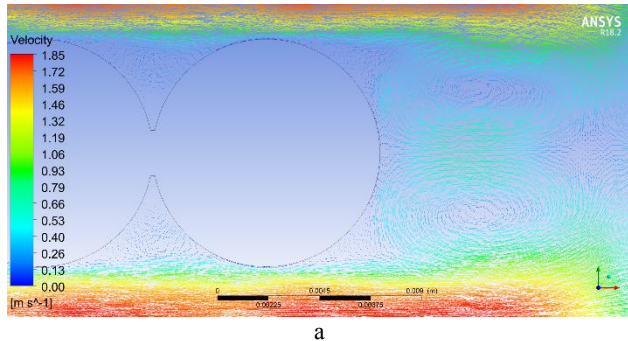


Table 2. CFD simulation results of a compact tube bundle

Parameter	Value									
Reynold's number (Re)	331.9	934.5	1530.5	2254.9	2658.4	3149.2	3609.0	4007.9	4409.9	4946.0
Average air velocity in the narrow section of the rope, $m \cdot s^{-1}$	1.506	4.205	6.903	10.201	11.999	14.096	16.195	17.993	19.792	22.188
Average temperature at the wall of the third pipe, $^{\circ}C$	63.584	44.031	38.334	33.905	32.033	30.056	28.766	27.914	27.181	26.355
Heat transfer coefficient of the tube bundle $W \cdot m^{-2} \cdot ^{\circ}K^{-1}$	59.377	99.173	127.58	157.67	173.24	190.93	208.06	222.36	236.29	254.27
Prandtl number (Pr)	0.703	0.7032	0.7031	0.7029	0.703	0.7033	0.70323	0.70324	0.70325	0.70326
Nusselt number (Nu)	22.668	37.979	48.782	60.172	66.187	73.233	79.678	85.179	90.514	97.413

Criterion equation of Nu number is used in engineering calculations of heat exchange apparatuses. This equation characterizes the intensity of heat transfer (heat transfer) at flow-wall boundaries for stationary convective heat transfer processes in a single-phase incompressible fluid with constant (except density) physical properties. The dependence $Nu = f(Re, Pr)$ can be interpreted as follows: the amount of heat transferred (Nu) depends on the type of velocity field (Re) and its relationship with the temperature field (Pr). A detailed methodology for deriving the

number Nu is described in [18, 19]. Thus, deriving the equation of the number Nu , we obtain the following:

$$Nu = 1.46 \cdot Re^{0.54} \cdot Pr^{1.19}. \quad (1)$$

The error of equation (1) is within 6% relative to CFD simulations of the compact tube bundle, the results of which are shown in Table 2. This equation can only be used for Re from 300 to 5000 and Pr from 0.7029 to 0.7033.

4. Conclusion

1. A new construction of compact arrangement of pipes in tube bundles of heat exchange apparatus is proposed and developed.

2. CFD modeling of heat and mass transfer processes in the channels of tube bundles using ANSYS Fluent software package has been carried out. The fields of velocities and temperatures in the studied channels have been obtained. The conditions of hydrodynamic flow in the channels and heat transfer processes in these channels were analyzed.

3. Based on the results of CFD modeling, a criterial equation for the number Nu is derived, which can be used in engineering calculations of heat exchangers with compact tube bundles. This equation has an error of up to 6%.

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Soil erosion processes and estimation of erosion risk in southern part of Albania

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Abstract: Soil erosion and associated nonpoint pollution pose critical problems affecting the economic welfare, food security, and public health of Albania. Each year nearly 60 million tons of sediment are deposited by Albanian rivers into the Adriatic Sea. Because of favorable natural factors and strong human impact over environment during centuries, area of Albania is characterized with high soil erosion rate. In last decades, faster economic growth of the country and lack of soil resources, fresh water, forests etc., reinforce the need for soil protection and soil conservation. The objective of this paper is to quantify the magnitude of soil erosion and its effects on water quality at three levels of intensity—site-specific, watershed, and nation as a whole and to identify high-risk areas for immediate soil erosion control using a geographic information system.

KEYWORDS: SOIL EROSION, LAND USE, ENVIRONMENTAL CONSERVATION, SEDIMENT PRODUCTION, SEDIMENT, RISK ASSESSMENT

Introduction

Studies in the field of soil loss and at the same time its preservation have been constantly the object of soil researchers in Albania. This article is a summary of the soil erodibility assessment work at the water-induced soil erosion monitoring station in South part (Rathima region) in Albania. The purpose of the study was to highlight, evaluate and identify the factors that affect the erosivity of the soil and water flow, mainly surface erosion and surface water flow. This paper does not overlook the decisive role of climate and vegetation, but through comparative methods and interpretations of the results, their effects were combined with other factors of soil erosion and surface water flow in different time periods. The Radhima area is considered one of the most typical objects of the coastal area with steep and very steep terrain. The study takes into consideration the experience of several other Mediterranean countries that have used the methodology applied to estimate the Universal Equation of Soil Loss and surface water flow over a two-year period. The paper provides scientific information and through it defines the ways and means to make possible the minimization of soil erosion and to contribute to the work that should be done by agricultural extensionists in the field of soil protection.

That increases the interest for erosion research, especially in the areas highly affected by soil erosion. One of those areas is catchments of Vlora area, which is in turn a major area in the Republic of Albania. As a result of very suitable characteristics (soft rocks, sandy soils, steep slopes, climate, sparse vegetation, anthropogenic influence) upper part of its catchments has very high soil erosion rate. Aside of that are numerous deposition fans in the torrents bottom, as well as large flats of sedimentation. In last decades, faster economic growth of the country and lack of soil resources, fresh water, forests etc., reinforce the need for soil protection and soil conservation. That increases the interest for erosion research, especially in the areas highly affected by soil erosion. As a result of very suitable characteristics (soft rocks, sandy soils, steep slopes, climate, sparse vegetation, anthropogenic influence) almost all parts of its watershed have very high soil erosion rate.

Methodology

The methodology used for the assessment of soil erosion has respected the indicators and elements that are applied in the Universal Equation of Soil Loss. The methodology used serves as an indicator of the alignment and integration of our research and scientific work in the field of soil protection and conservation, with colleagues in the Mediterranean countries and beyond. The results obtained for soil erodibility and surface water flow have been analyzed and interpreted interwoven with the role played by plant cover, the coefficient of land use, the land itself and its slope,

climatic conditions and specifically precipitation and temperature. The paper makes a real and modest contribution to soil conservation and protection, becoming part of the country's literature fund in this field, which presents a disturbing and sensitive problem with consequences for the environment in general. The land and climate conditions in our country, the steep and very steep terrain, with low, medium and high vegetation, which in many cases is destroyed; are indicative of a massive, ubiquitous and extremely aggressive erosion. Factor analysis completes the factor analysis by giving each the impact it has on soil erodibility, and the coefficient of surface water flow.

The study is based on the scheme constructed with the dimensions and parameters used when studying the Universal Soil Loss Equation. The assessment of soil loss from water and the coefficient of surface water flow, were evaluated on a land surface with a length of 12 m and a width of 1.2 m. The soil slope for the test areas is 12%, while the planted plants are perennial meadow with a mixture of Dactyl + Festuk + Lolium, corn and wheat. In the selection of plants, the coefficient of land use or the degree of plant cover on the surface of the soil and the shape of the root system below the surface of the soil were taken into consideration.

Results and discussion

The analysis of the results has become complex and in two main aspects for climatic, biological and hydrotechnical factors. The first aspect was the role of vegetation in soil loss from surface erosion, while the second aspect was the role of vegetation in evaluating the coefficient of surface water flow. Regardless of the above points of view, we have aimed to evidence the erodibility of the soil, and on the other hand, we have tried to evaluate the influence of the surface water flow on the amplification of the erodibility of the soil. Regardless of the theoretical and scientific interpretation that was given to the obtained results of soil loss and surface runoff coefficient, the role of the above two factors in the climatic and soil conditions of Radhima and similar areas was important for us.

In our conclusions and judgments, the studies carried out by Albanian researchers have also contributed to the land and especially to that of its protection and conservation. The factors analyzed in this study in the case of rainfall refer to their measurements with pluviometers located at these stations, while other climate indicators are referred to measuring stations in their vicinity. Below is a clear overview of some analytical indicators related to average temperatures (at sea level) for the months of July and January, average annual temperatures (in degrees C for the months of January and July, average height of annual rainfall, the average number of days with precipitation > 10 mm as well as the number of days covered with snow).

Table 1. Climate indicators for the monitoring point Radhime (Vlore)

Nr	Station	Average Temperature		Average yearly Temperature (in degree C) for months		The average height of the annual rainfall in the two years of the study	Average number of days with raining > 10 mm	Number of days with snow
		January	July	January	July			
1	Radhim	6 -8	>26	0 – 8	> 22	1500 - 2000	45 - 55	0 – 5

Referring to the table above, the soil erosion monitoring point in Radhime is a characteristic coastal area of the abrasive type. The area in the lower part is bordered by the sea, while the mountainous part extends up to 300 m above sea level. The average temperatures for the winter months and specifically in the month of January vary from 6 degrees C to 8 degrees C, while during the summer period in the month of July above 26 degrees C. The presence of high temperatures during the winter means that the number of days covered with snow should be from 0 to 5 days per year. Which means that the ground is always uncovered by snow and at the same time unaffected by its frosts

and freezing. The average annual rainfall for the two years of the study is relatively high compared to other areas of the country.

The surface water flow identified with surface erosion appears and acts on the surface of the earth, thanks to the kinetic force of the raindrop hitting the structural aggregates and soil particles. The formation of the rainsplash, through which the soil particles detach and then create the leaf-shaped water network, is the beginning and the first step of the surface water flow process. The water flow already with a much higher soil content in its formation, and with a higher power acquired by the forces of gravity, amplifies and strengthens becoming a dangerous part of soil erosion

Table.2 Assessment of soil loss at the erosion monitoring station Radhime (Vlore)

Nr Parcels	Cropping system	Area (m ²)	The amount of soil removed from the observed surface and its calculation Ton/ha/year.				The average of the removed land for the two years of the study Ton/ha/Year
			2019 Year		2020 Year		
			Soil quantity (kg)	Soil loss in Ton/ha/year	Soil quantity (kg)	Soil loss in Ton/ha/year	
1	Perennial meadow (dactyl + fescue + Loliu)	18	12.24	6.8	13.8	7.7	7.25
2	Wheat	18	14.22	7.9	13.5	7.5	7.7
3	Land without plant cover (Fallow land)	18	54.0	30.0	57.6	32.1	31.05
Average soil loss for the three fields taken together		-	-	14.9	-	15.7	

In 2019, it turns out that the difference in soil loss in plots planted with different plants is relatively small and does not exceed 16 percent or 1.1 tons/ha/year. While the comparison made for soil loss between the plots with wheat vegetation and the plot without vegetation, the difference is extremely large with a difference of about 22.1 tons/ha/year or about 3.7 times more. The comparison made for soil loss between the plot planted with meadow and the fallow plot, results that the difference is about 23.2 tons/ha/year.

The above results expressed in tabular and graphical form show that the removal of soil through surface water flow is dependent on the degree of plant cover on the soil, the type of plant and the coefficient of land use, etc.

In 2020, the soil loss in plots planted with wheat and perennial meadow is 7.7 tons/ha/year and 7.5 tons/ha/year, respectively. The comparison made with the surface of the land that is without vegetation, shows us that even during this year the difference is greater than the year before. The difference between the area planted with wheat and the area planted with meadows is only 0.2 tons/ha/year, while the comparison made between the plots with wheat vegetation and the plot without vegetation the difference is about 24.4 tons/ha/year or about 4 times more.

Conclusions

The analyses of climatic factors in the determination of soil loss through water erosion is extremely difficult to bring equal across the years of study. Rainfall, its duration, the intensity of the fall and the presence of frost often means that these elements of the climate unfairly receive the 'weight' and attribute of the factors to be studied. In order to draw conclusions, we have tried to reflect the influence of real factors that have influenced the process of soil

erosion. Also, during the study period, we were able to keep in relatively equal conditions all the elements related to the good growth of agricultural plants and the condition of the soil on the test surface. The results achieved and the conclusions drawn in this paper bring attention to the role of plant cover in the climatic and land conditions of the coastal area in the region of Radhime (Vlore). The role and effectiveness of plants in reducing erosion is different and depends on the biological characteristics of the above/underground soil system. Soil losses on the surface where meadows are planted is about 6 percent lower than the surface planted with wheat. Soil loss on a surface planted with 1 and 2-year-old cultivated meadows is about 5 times lower than on land without vegetation (fallow land).

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Assessing the Potential of Pálinka Spent Wash Compost as Soil Organic Amendment

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Abstract: In Hungary, the production of Pálinka, a Hungarian hard liquor, generates a significant amount of organic waste, specifically a residual liquid waste known as spent wash (SW). The environmental impact of SW pollution is a pressing concern mainly due to its high organic load, low pH, notable content of recalcitrant compounds, and high biochemical and chemical oxygen demand. Composting presents an eco-friendly management solution for SW by its stabilization into a humified material and inactivation of phytotoxic substances. Monitoring of physicochemical parameters and enzyme activity of the SW before and after the composting process was conducted, alongside germination tests to assess its seed growth suitability. The application of Bokashi composting and co-composting with various materials resulted in notable improvements in the SW parameters. The findings validate the potential of SW compost as an effective soil amendment, promoting soil health and fertility.

Keywords: COMPOSTING, PÁLINKA SPENT WASH, CO-COMPOSTING, BOKASHI COMPOSTING, GERMINATION TEST

1. Introduction

Pálinka, a Hungarian hard liquor, contributes annually to the generation of around 300,000 tons of mash residue, a biodegradable food waste byproduct [1]. Known as spent wash, mash, lees, spirit wash, or cooked mash, this residue resulted from distillation, represents 85% of the input material, and holds 90-95% water and negligible ethanol content, depending upon the fruit used. Characterized by low pH (3-4), rich organic content, polyphenols, macro/micronutrients, and heavy metals, improper disposal can lead to foul odor generation due to volatile organic compounds (VOCs) and disrupt natural nutrient cycles, particularly nitrogen, and phosphorus, resulting in water pollution, eutrophication, and oxygen depletion [2].

Hungary's eco-friendly management of Pálinka spent wash (SW) presents challenges, impacting distilleries both financially and logistically. Addressing this, SW harnessing for compost production emerges as a promising solution.

Composting addresses odor through controlled decomposition, yielding stable products. This technique, sustainable and cost-effective, rectifies nutrient imbalances and enhances soil structure, enacting efficient organic waste treatment. Despite SW's low pH, composting curtails climate impact, improves soil attributes, and promotes sustainable practices [3].

Effective composting includes pH adjustment through additives such as diatomaceous earth, wood ash, and mature garden compost, fostering microbial activity and enhancing biological soil management. SW compost enriches soil organic matter (SOM) through organic addition and nutrient cycling, promoting microbial activity [4]. Additionally, it improves soil structure and stability, sequestering organic matter, and introducing humic substances [5] that enhance SOM persistence [6].

Successful composting involves optimal practices: balanced waste ratio, system design, parameter monitoring [1], and maintaining an ideal carbon-to-nitrogen ratio, temperature, moisture, and odor control. Compliance with regulations and environmental considerations further ensures quality. Pálinka waste composting yields high-quality compost, enhancing soil, nutrient cycling, and promoting sustainability. Effective waste management and responsible utilization follow, highlighting the comprehensive benefits of Pálinka waste composting for soil health and fertility.

2. Materials and Methods

This study presents two distinct composting approaches for Pálinka spent wash (SW):

1) Anaerobic Composting using Bokashi Compost (BC): Bokashi Organico bin-produced compost was combined with varying quantities of SW in 150 ml Mason Jars over a 4-week period. The treatments consisted of different BC and SW ratios: 100% BC + 0% SW, 75% BC + 25% SW, 50% BC + 50% SW, 25% BC + 75% SW, and 0% BC + 100% SW, each replicated three

times, resulting in a total of 15 samples. Germination tests involving lettuce, wheat, corn, and mustard seeds were conducted both before and after anaerobic composting. The seeds were placed on Petri dishes atop filter papers, receiving either Pálinka spent wash or distilled water. After the 4-week period, samples were collected, mixed with distilled water, centrifuged, and filtered to obtain an aqueous extract at a 1:10 ratio (w/v). Control treatments used drinking water, while Bokashi compost and the other treatments utilized aqueous extract.

2) Aerobic Composting with Additives: A comprehensive 12-week composting experiment was conducted in controlled laboratory conditions. Perforated plastic boxes served as incubation vessels for SW composting. Initial mash residue conditions included a pH of approximately 3.5, moisture content of 93.82%, and organic matter content of 99.60%. The treatments encompassed garden compost, diatomaceous earth, wood ash, and combined mixtures. The diatomaceous earth sourced from Miocene-aged organic sedimentary rock contributed to soil structure and moisture balance due to its water-retention capabilities. Notably comprising silt-sized particles, it featured amorphous silica (76–78%), calcite (15–17%), and montmorillonite (6–7%). Wood ash, recognized for its potassium-rich nature, neutralized acidic mash residue while enhancing water retention. The experimentation involved wood ash-treated mash residue, revealing its potential as an organic fertilizer for acidic sands. The composting treatments and additive weights used are summarized in Table 1.

Table 1: Treatments and additive weights used in the Pálinka spent wash aerobic composting experiment. Unit: grams (g)

Treatments and additives	SW	GC	DE	WA
C	5000			
GC+SW	2500	2500		
DE+SW	5000		2500	
WA+SW	3750			2500
CT	4000	1000	1000	1000

Abbreviations: C=control, GC=garden compost, SW=Pálinka spent wash, DE=diatomaceous earth, WA=wood ash, CT=combined treatments.

In both composting methods, an array of physicochemical, chemical, and biological parameters was assessed. The parameters encompassed: pH, Electrical Conductivity (EC), and Total Dissolved Salts (TDS) measured by the device Mettler Toledo – SevenCo Duo; Nitrogen forms (ammonium, nitrate, nitrite) and phosphate measured by the device PF-12 Macherey-Nagel; Total microbial activity measured through Dehydrogenase enzyme (DHA) and Fluorescein diacetate (FDA) assays by absorbance using the device LibraS22 – Biochrom; Copper concentration using spectrophotometry; and Sodium and Potassium levels via flame photometry. Organic matter was determined employing Tyurin's methodology.

3. Results and Discussion

The chemical parameters of Pálinka spent wash (SW), Bokashi compost, and the different treatment mixtures are presented in Table 2.

Table 2: Parameters of Pálinka spent wash, Bokashi compost, and the different treatments with Bokashi compost and spent wash.

Treatments and Parameters	pH (H ₂ O)/pH (KCl)	EC (mS/cm)	Total Dissolved Salts (mg/L)
Pálinka Spent Wash (SW)	3.5/3.44	3.59	1976.73
Bokashi Compost (BC)	4.27/4.27	3.27	1633
0% BC + 100% SW	3.47/3.41	1.32	658.33
25% BC + 75% SW	3.69/3.63	1.71	853.00
50% BC + 50% SW	3.83/3.78	2.31	1155.33
75% BC + 25% SW	4.01/3.93	2.78	1387.00
100% BC + 0% SW	4.29/4.19	3.77	1886.33

As shown in Table 2, the pH slightly increases upon mixing Bokashi compost and Pálinka spent wash. However, all treatments remain highly acidic due to the distillation process-originated mash and the anaerobic degradation of Bokashi compost. Total dissolved salts in both mash and Bokashi compost are noticeable, particularly in treatments with higher Bokashi compost ratios.

Additional parameters of the mash include density (0.993 g/cm³), sodium (Na) (34.94 mg/L), potassium (K) (1277.13 mg/L), ammonium (NH₄⁺) (5.4 mg/L), nitrate (NO₃⁻) (64 mg/L), nitrite (NO₂⁻) (0.13 mg/L), and phosphate (PO₄⁺) (11.6 mg/L). The substantial potassium content in Pálinka spent wash is evident.

A germination test conducted before anaerobic composting demonstrated the unsuitability of applying SW directly to the soil. No seed germination occurred within 72 hours when using only SW, prior to Bokashi compost treatment. Table 3 outlines the seed germination percentages after 4 weeks of anaerobic composting and Bokashi compost treatment. Enhanced germination conditions, particularly for wheat, were observed after anaerobic composting.

Table 3: Seed germination percentages of anaerobic composting treatments and Bokashi compost after 4 weeks; control with drinking water only

Treatments	Lettuce	Wheat	Corn	Mustard
Control	41%	95%	67%	59%
Bokashi compost (BC)	0%	60%	61%	3%
100% BC + 0% SW	0%	71%	45%	7%
75% BC + 25% SW	3%	76%	52%	33%
50% BC + 50% SW	3%	84%	52%	48%
25% BC + 75% SW	1%	75%	30%	49%
0% BC + 100% SW	0%	80%	45%	21%

Microbial activity, as indicated by enzyme activity through FDA and DHA measurements, was notably low in Pálinka spent wash, Bokashi compost, and their respective treatments (Table 4).

Table 4: Values of enzyme activity measured by FDA and DHA

Treatment	FDA average (μg/g fluorescein/dry soil)	DHA activity (TPFμg/dry soil g)
Pálinka Mash (SW)	0.265	0.023
Bokashi compost (BC)	0.064	0.179
100% BC + 0% SW	0	0
75% BC + 25% SW	0	0.147
50% BC + 50% SW	0	0.067
25% BC + 75% SW	0	0
0% BC + 100% SW	0.226	0.002

For the second composting method, the aerobic, controlled fermentation preceded the distillation of the utilized mash residue. This involved enzymatic apple pectin extraction, yeast introduction, and specific yeast inoculation. Optimal performance necessitated pH adjustment to 3.69 using phosphoric acid. The suspension exhibited a slightly low total dissolved salt concentration (1331 mg/l). Absorbable macro elements analysis indicated a K₂O content of 37,440 mg/kg and a phosphorus content of 1231.2 mg/kg in dry matter. Nitrite (NO₂⁻) and nitrate (NO₃⁻) levels were below detection limits, with ammonium (NH₄⁺) registering a mere 2 mg/kg. The suspension's dry matter content stood at 3.5%, predominantly composed of organic matter (93.2%). Physico-chemical characteristics of treatment materials for aerobic composting are summarized in Table 5.

Table 5: Chemical characteristics of the additives used for Pálinka spent wash aerobic composting.

Chemical Parameters	Garden compost	Diatomaceous earth	Wood ash
pH(H ₂ O) / pH(KCl)	7.7/7.28	7.93/7.35	13.65/13.79
Total Dissolved Salts (mg/kg)	1480	356.5	104 500
NO ₂ ⁻ , NO ₃ ⁻ , NH ₄ ⁺ (mg/kg) of dry matter	42.3	6.15	5.5
P ₂ O ₅ (mg/kg) of dry matter	2232.35	587.49	576.24
K ₂ O (mg/kg) of dry matter	3666	331	66 400
Cu (mg/kg) of dry matter	Under detectability	-	-
Organic material (%)	92.43	15.19	60.78

The conducted tests on compost samples revealed remarkable observations, shedding light on the efficacy of different treatments. Diatomaceous earth stood out for its exceptional buffering capacity. All applied treatments exhibited a tendency to maintain chemical impact within or near the neutral spectrum, a critical factor in relation to microbiota concerns. Among the treatments, garden compost displayed the highest mineralized nitrogen levels. Conversely, wood ash showed modest nutrient provision, yet excelled in nitrogen supply capability. Wood ash samples also exhibited notable water retention capacity (Figure 1).

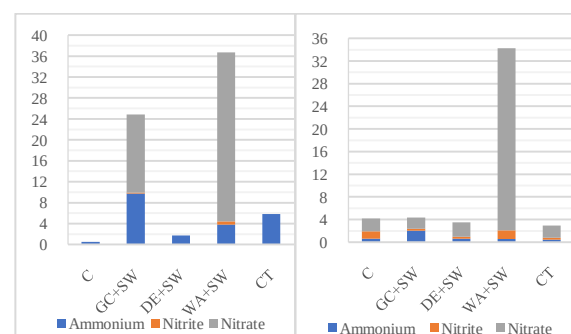


Figure 1: Nitrogen forms available to plants from treatments. Unit: mg/kg. Abbreviations: C= control, GC= garden compost, SW= Pálinka spent wash, DE= diatomaceous earth, WA=wood ash, CT=combined treatments. Results from the 6th week (left) and the 12th week (right).

Addressing soil protection, copper content within the residue emerged as a significant concern. Copper analysis indicated a considerable range, spanning 0.34–20.1 mg/l, with average values of 3.06–6.77 mg/l. Experimental outcomes exhibited notably lower values of 2.91 mg/l and 2.14 mg/l, reflecting minimal increases of 0.57 and 1.27 mg/l, respectively, compared to initial pre-distillation values (Figure 2).

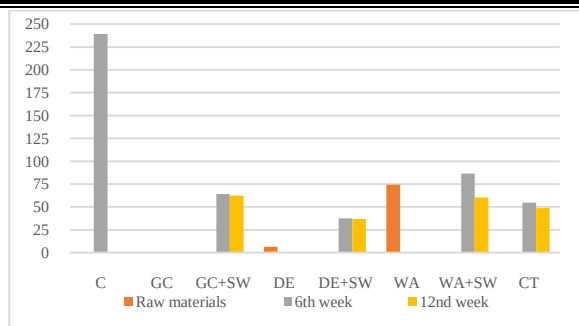


Figure 2: Effective reduction of higher copper content in mash residue by organic and mineral substances. Unit: mg/kg. Abbreviations: C= control, GC= garden compost, SW= Pálinka spent wash, DE= diatomaceous earth, WA=wood ash, CT = combined treatments.

The measured copper (Cu) concentration at the midpoint of the experiment was 65.29 mg/kg for mash residue and compost. Diatomaceous earth exhibited notably lower copper concentration at 5.324 mg/kg. However, amalgamation with mash residue (DE + SW) escalated the concentration to 37.37 mg/kg. Similarly, wood ash, initially at 72.14 mg/kg, intensified to 86.30 mg/kg when combined with the residue (WA + SW). Over time, copper content reduction across treatments was evident due to the amalgamation of heterogeneous substances.

The analysis using Tyurin's methodology revealed significant insights into organic matter content. The residual mash contained 1.93% oxidizable organic matter (H), with garden compost having the highest content (12.31%), followed by diatomaceous earth (0.356%) and wood ash (0.647%). Combining garden compost with the mash residue led to the emergence of additional humus compounds during the experiment, observed in treatments with diatomaceous earth and wood ash. Humus quality (Q) and stability were indicated by the proportion of fulvic and humic acids.

The impact of garden compost treatment on mash residue was examined through Q values, indicating the dominance of larger molecular humic acids. Similar trends were observed with diatomaceous earth, showing favorable humus initiation in mixtures of organic and mineral components. In contrast, the wood ash-mash residue blend exhibited moderate humus stability, and comprehensive treatment led to increased proportions of less stable humus components over time. The study established a correlation between humus formation pace and the prevalence of lower-value, low molecular-weight humic substances, with larger, stable humus molecules forming later due to chemical processes, leading to system stabilization.

Laboratory tests confirmed the enrichment potential of mash residue for garden compost, yielding humic substances exceeding 20%, beneficial for various soil types. The variation in humus content highlighted significant augmentation when mash residue was incorporated with compost, illustrated in Figure 3 displaying 6th and 12th-week results.

Pálinka waste compost significantly enhances soil's microbial activity and diversity, nurturing a healthy ecosystem. This compost enriches the soil with organic matter, nurturing beneficial microorganisms [7]. Microscopic analysis reveals varied microbial inhabitants in composts, including bacteria, fungi, algae, and microfauna. Wood ash shows minimal activity, and sealed mash residue displays limited microbial presence. Over 12 weeks, microbial communities flourish, with bacterial activity prevailing.

Biochemical processes within the experimental media, even under extreme conditions, induce a pH shift towards neutrality, promoting nutrient discovery and organic synthesis. Diatomaceous earth's residual mixture drives this, complemented by balanced macro elements and reduced copper levels. This composite

enhances soil mineralization, benefiting acidic sandy soils, and fosters nutrient solubility. Remarkable nitrogen provision results from wood ash-mash residue, with 1:3 phosphorus-to-potassium ratio suitable for potassium replenishment (Figure 4).

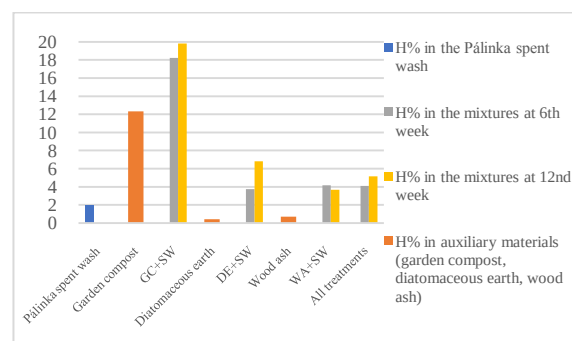


Figure 3: Humus quantity. Unit: %. Abbreviations: GC=garden compost, SW=Pálinka spent wash, DE=diatomaceous earth, WA=wood ash

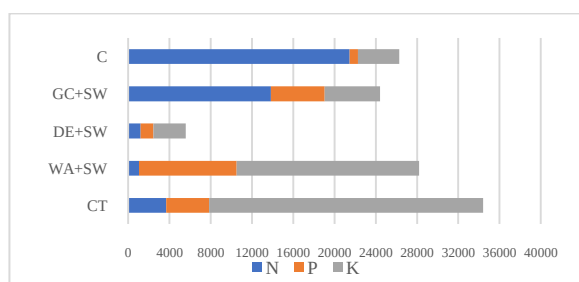


Figure 4: The ratio of macro elements (N,P,K) in each treatment. Unit:mg/kg. Abbreviations: C= Control, GC=Garden compost, SW= Pálinka spent wash, DE= Diatomaceous earth, WA= Wood ash, CT= combined treatments

Structural attributes enhance soil's physical properties, but calcareous soil application warrants addressing chemical effects. Copper content consideration is vital in acidic environments due to heavy metal mobilization risk. Garden compost-treated mash residue excels in 3:1:1 N:P:K ratio for nitrogen enhancement. Diatomaceous earth treatment yields potassium-rich fertilizer (3:2:5), ash-mash residue blend follows 0:1:3, while mash residue combined with treatments presents 1:1:5, a potassium-based fertilizer.

Intricate nutrient composition is evident in compost-mash residue blend, displaying buffer capacity, nutrient supply, dynamic humus formation, diverse microbiological traits, and water resistance, enhancing soil properties.

Research highlights humus formation's centrality in soil fertility, spanning nutrient supply, chemical dynamics, and water resistance. The experimental medium's role transforms it into compost and soil enhancer. Garden compost, diatomaceous earth, and wood ash materials bolster mash residue application, mitigating heavy metal risk.

4. Conclusion

Pálinka waste composting offers a promising solution for sustainable soil management, enriching soil organic matter, and improving overall soil health. Through composting, Pálinka waste can significantly impact soil health by enhancing nutrient cycling and microbial activity. The resulting compost provides essential organic matter, nutrients, and beneficial microorganisms, leading to improved soil fertility and ecosystem function. To maximize benefits, careful consideration of compost application rates, timing, and management practices is essential. Monitoring soil properties and organic matter dynamics aids in evaluating compost effectiveness and guiding future soil management decisions. By

adopting Pálinka waste composting, agriculture can align with circular economy principles, reducing waste and promoting greener agricultural systems.

In conclusion, the utilization of Pálinka waste through composting offers a multifaceted strategy, intertwining waste management, soil enrichment, and environmental preservation. This approach holds promise for sustainable agriculture, shaping a greener and more productive future.

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Water resource management problems and their possible solutions in the Lower Tisza river basin Water for the landscape, but from where, how and at what cost?

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Abstract: One of today's biggest challenges is to manage the extremes in water resource management associated with climate change. Central Europe and Hungary are among the regions most affected by the impacts of water management extremes. The study area is one of the most vulnerable regions of Hungary, with a high climate sensitivity. Although there is a significant network of infrastructure in place to mitigate water shortages, it is both overstretched and burdened by significant operating costs. The recent energy price explosion has focused attention on the operational issues of these systems. However, for areas beyond their reach, only locally available primary and secondary water resources offer the potential for prevention and mitigation. These have a limited reach and are costly to use. One of today's popular slogans is 'water to the landscape', and the paper will discuss the possibilities and limitations of this in the sample area.

Keywords: WATER RESOURCES, CLIMATE CHANGE, WATER SCARCITY, PRIMARY WATER RESOURCES, SECONDARY WATER RESOURCES, IRRIGATION

1. Introduction

Water resource management has always been a focus of interest. This interest has become more intense and has become a priority issue as water scarcity has worsened. It is typically approached from the water resources side, but a complex analysis of the issue is needed to approach it properly, although this is often not done.

The primary expectation when considering the issue is that efforts should be made to maintain water resources in place, but these interventions alone rarely lead to long-term results because the impact of all elements of the hydrological cycle must be taken into account. Such analyses often underestimate the role of natural factors that cause water stress, even though their impact can be many times greater than that of factors that reduce water resources (e.g. evaporation). It is essential that such effects are taken into account when developing long-term sustainable measures.

The changes experienced due to climate change affect all elements of the hydrological cycle [1]:

- the amount of precipitation, its spatial and temporal distribution,
- changes in the extremes and average characteristics of temperature,
- evapotranspiration and its intensity,
- the amount and distribution of runoff over the year,
- the amount of soil moisture, ground and deep water.

The increase in the scale of water scarcity will exacerbate situations that are likely to occur in areas already water scarce.

2. Short description of the study field

The study area is located in Europe, in Hungary. In the country, 12 regional water management organisations coordinate and implement the state's water management tasks. The tasks cover:

- maintenance, organisation and enforcement activities related to water damage management (floods, inland floods, droughts, water quality damage),
- identifying, conserving, developing and ensuring the use of surface and groundwater resources,
- monitoring and coordination of water management activities of local governments,
- assisting in the activities of public authorities in the field of water management,
- operating environmental monitoring systems for hydro-meteorological elements,
- the operation, maintenance and development of infrastructure systems to meet agricultural water needs.

The inspections were carried out in the operational area of the

Lower Tisza Water Directorate (ATIVIZIG).

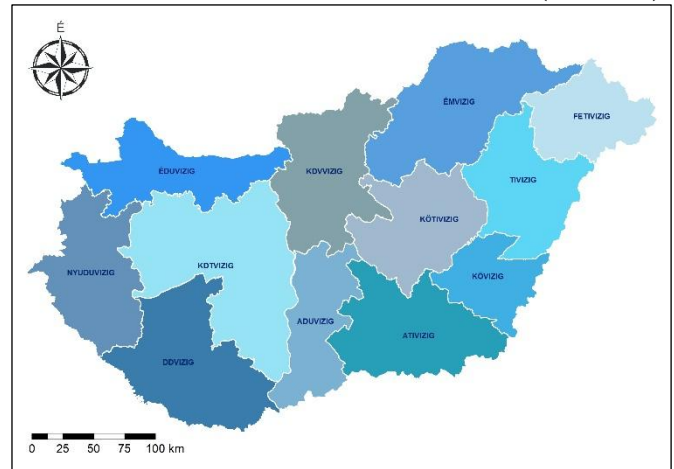


Figure 1 Operational area of Water Management Directorates Source: ATIVIZIG

The inspections were carried out in the operational area of the Lower Tisza Water Directorate (ATIVIZIG).

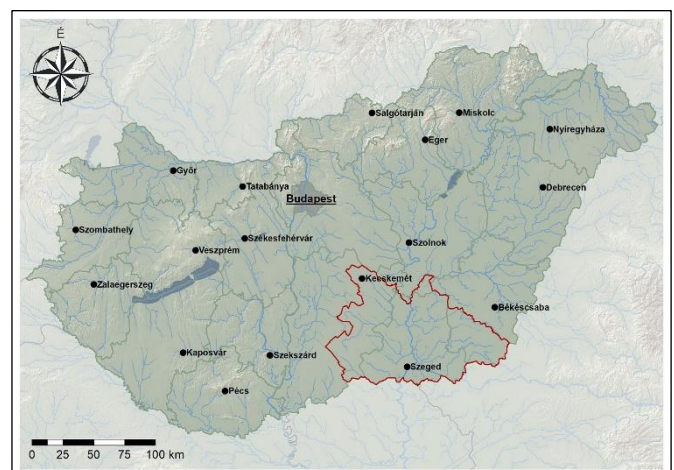


Figure 2 Operational area of the Lower Tisza Rural Water Management Directorate, Source: www.ativizig.hu

The country's geography means that 95% of its surface water comes from upstream countries. Within the country, ATIVIZIG's area of operation is located in the south-eastern part of the country, in a low-lying area of approximately 8 400 km².

Based on measurements taken since 1901, annual rainfall totals

have ranged from a minimum of 369 mm in 1983 to a maximum of 914 mm in 2010. The average multiannual rainfall over the reference period 1981-2010 in force in the area covered by the Directorate is 546 mm. The distribution of precipitation over the year is characterised by the fact that 40 % of precipitation falls in the winter and 60 % in the summer. The annual rainfall pattern is characterised by a maximum in early summer (May-June), followed by a secondary maximum in late autumn due to the Mediterranean effect (which may also be missed, as it has a probability of 20-30 %). The minimum rainfall is in the winter/early spring period. However, this average situation rarely occurs. It is typical that shorter or longer periods (3-6 months) are sometimes droughty and sometimes very abundant.

Due to the minimum precipitation during the winter period, snow cover of significant and persistent thickness is rare. The average maximum snow thickness is around 20 cm.

The mean annual air temperature is +11,2 °C. The southern areas are 0,2-0,4 °C warmer than the northern areas, with a uniform air temperature in between. The difference between the mean temperature of the coldest and warmest years is less than 5 °C. The coldest year had a mean temperature of 8,6°C and the warmest year 12,4°C.

The average number of sunny hours per year is 2100 hours. Sunshine duration is also evenly distributed over the area, with only a slight downward trend towards the north-east, where the annual number of sunshine hours is slightly below the mean.

Ground frosts typically occur in the period from December to early March. Based on data from the 1960s and 1970s, the average number of days with ground frost during this period is 60 days, with 25 days in January and 15 days in December and February, the months with the lowest temperatures. The maximum depth of ground frost averages 25 cm, reaching 60-70 cm in extreme cases.

Groundwater levels are on average 2-4 m below the surface. Due to climatic factors, the annual groundwater flow is characterised by a maximum in late spring and a minimum in autumn. The maximum groundwater levels (NV) are sometimes less than 1 m below the surface. These areas occur in patches in the exempted floodplain, in the Tisza valley. The groundwater levels in the settlements in these areas (Makó, Hódmezővásárhely, parts of Szeged, Mindszent, etc.) are particularly high. The highest groundwater levels were recorded in 1940-1942, 1956, 1966-1967, 1970-1971 and 1975, when groundwater levels were closer than 100 cm to the ground surface. The horizontal flow rate of groundwater is low, less than 100 cm per day. Since the 1990s, there has been a significant decline in groundwater levels, primarily due to meteorological changes and hydrocarbon exploration activities in the area [2].

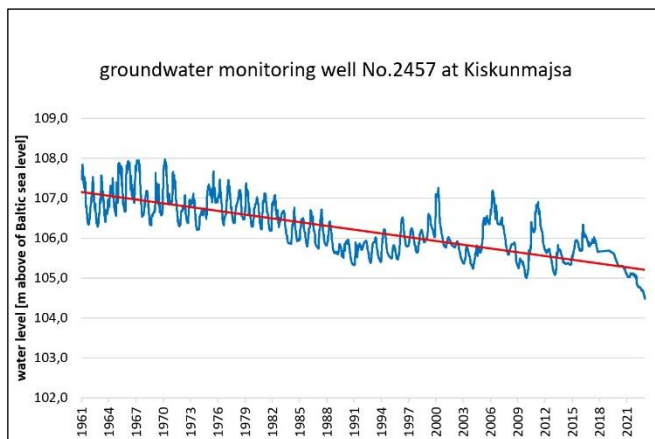


Figure 3 Changes in groundwater levels in the area of Homokhátság located in the Danube-Tisza Interfluvium, on the right bank of the Tisza River, Source: own editing

There are three rivers in the study area: the Tisza, the Maros and the Hármas-Körös.

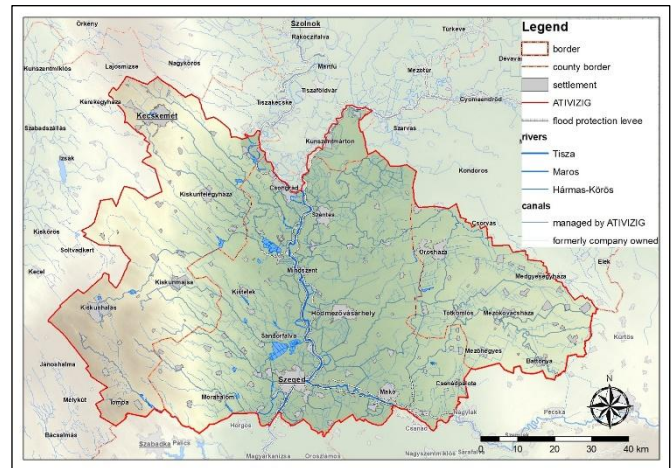


Figure 4 Watercourse network of the study area, Source: ATIVIZIG

Of all the rivers, the Tisza has the highest flow capacity, with maximum values of (Tabl.1):

Table 1 Typical river flows in the study area

Name of river, Station	Maximum of discharge [m ³ /s]	Discharge in August with 80% durability [m ³ /s]
Tisza, Szeged	4200	207
Hármas-Körös, Kunszentmárton	1500	30,6
Maros, Makó	2500	62,8

Authorisations for the use of the water resources are issued on the basis of the water yields available in August at 80% capacity. It is important to note the fact that these water flows run off below the banks of the river banks at water levels of 2-4 metres, and can therefore be delivered to agricultural users by means of cask pumping stations. The availability of river water resources is significantly reduced by the following impacts:

- riverbeds are experiencing significant bed subsidence, with subsidence rates of up to 1-1.5 metres over 5-10 years,
- the area is located in the lower reaches of rivers and is therefore particularly affected by the effects of the upstream dams, especially on the lower reaches of the Maros, where some 30 dams have been built on the Romanian territory.

These adverse effects have resulted in river water levels rising by up to 10-12 metres during periods of water scarcity, instead of the average of around 6 metres.

The surface water network in the area covers a total length of about 7000 km. These typically serve to drain stormwater, but the flow of these watercourses is significantly reduced during periods of low tide, leaving them without usable surface water resources during such periods.

3. Effects of the climate change and the quantity of the water shortage

Climate change has resulted in a small decrease in annual precipitation, but there is a significant change in its spatial and temporal distribution. Instead of the previous uniform distribution of precipitation, there is a significant spatial variation in annual precipitation, especially in areas vulnerable to water scarcity (Fig. 5).

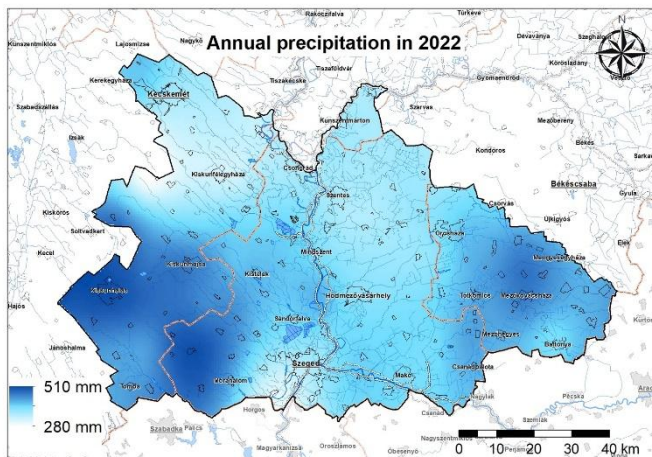


Figure 5 Distribution of annual rainfall in water scarce 2022, Source: ATIVIZIG

There is also an increase in average temperatures, particularly in areas already affected by water scarcity (Fig.6.).

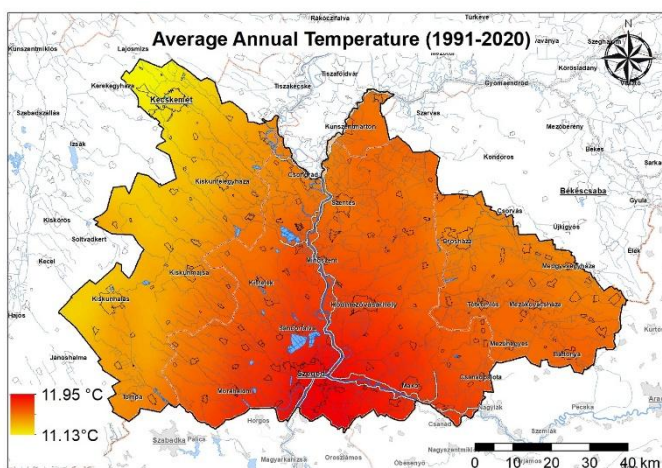


Figure 6 Average annual mean temperatures 1991-2020, Source: ATIVIZIG

Evaporation directly affects surface water resources, while groundwater is indirectly affected. The potential evaporation in the extremely droughty year 2022 is illustrated in the figure below (Fig.7):

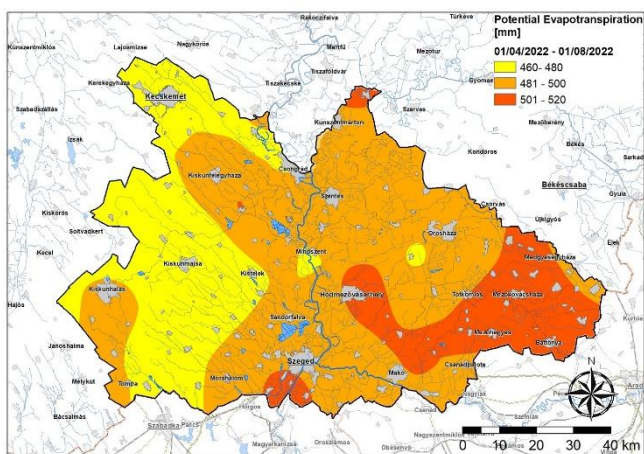


Figure 7 Spatial distribution of potential evapotranspiration values in 2022, Source: ATIVIZIG

The extent of the drought in 2022 is illustrated by the annual cumulative precipitation deficit in the study area.

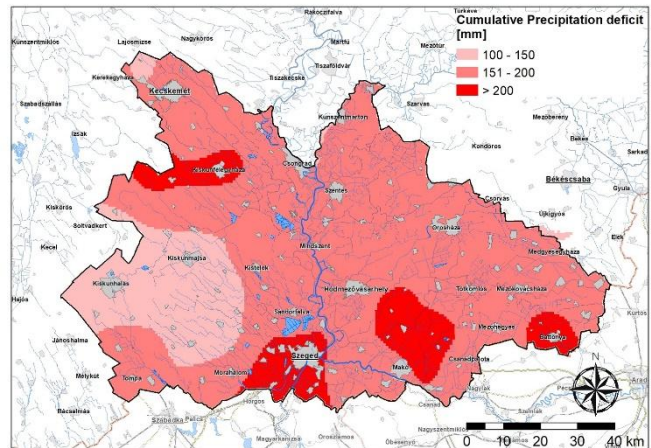


Figure 8 Cumulative rainfall deficit in 2022, Source: ATIVIZIG

In Hungarian practice, the PaDI [3] has been used to characterise drought in previous periods, while from 2019 onwards the Hungarian Drought Index (HDIs) has been used. The study area, typically located in the drought-prone area of the country [4]. The spatial distribution of HDIs is illustrated in Figures 9-10.

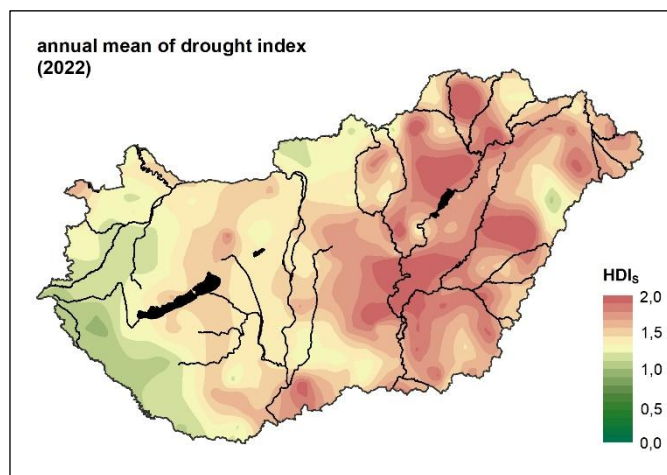


Figure 9 Spatial distribution of mean HDIs, Source: ATIVIZIG

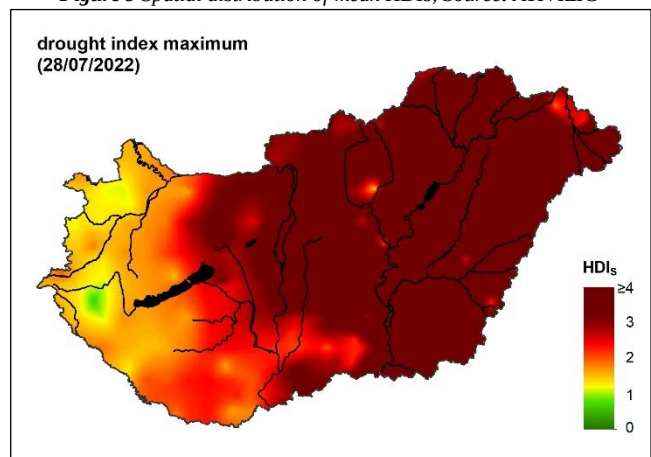


Figure 10 Spatial distribution of maximum HDIs, Source: ATIVIZIG

The temporal distribution of drought in 2022 has produced extraordinary extremes. In the study area, there were a total of 26 non-drought days during the year. The extreme meteorological conditions have had a significant impact on groundwater resources, resulting in further declines in groundwater levels. Groundwater levels for the period 1991-2020 were further reduced by the drought of 2022. This is illustrated by the groundwater levels in May 2023 (Fig.11).

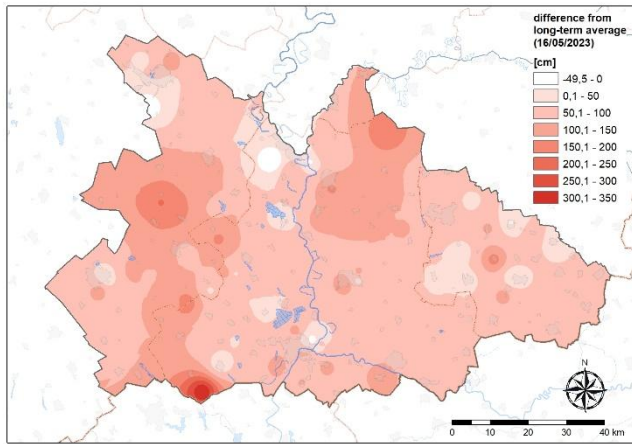


Figure 11 Groundwater aquifer status compared to the 1991-2020 average, Source: ATIVIZIG

An analysis of groundwater aquifer levels shows that a 1 m drop in groundwater aquifers results in a loss of about 4 billion m³ of water resources. This trend has practically eliminated the real use of groundwater resources in some areas (e.g. in Kecskemét the 600 cm deep groundwater well has dried up).

4. The current infrastructure systems against the drought, and their problems

Irrigation systems have been built in the area over the past 60 years to meet agricultural water needs. These primarily meet the water needs of arable crops. In the study area

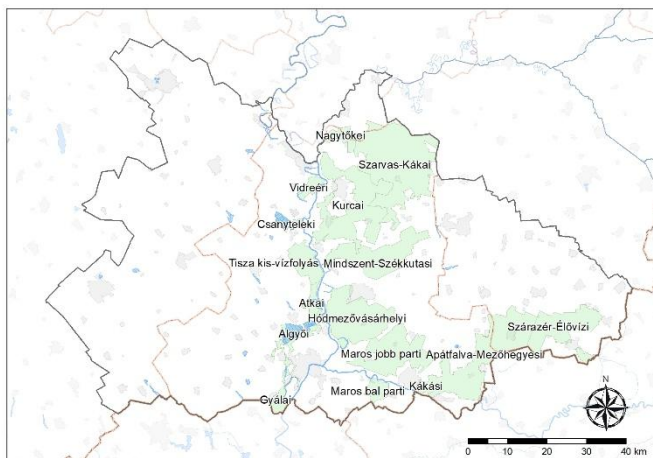


Figure 12 Scope of irrigation systems, Source: ATIVIZIG

The operation of irrigation systems will supply significant quantities of water to meet agricultural needs. In 2022, a very drought-prone year, around 400 million m³ of water was supplied nationally. Of this, more than 100 million m³ was delivered to farmers in the study area.

Due to the topography of the terrain, these systems are typically able to deliver water to farmers' land at higher elevations by pumping from rivers or by operating intermediate pumps along canals. These systems are equipped with pumping stations, but their operating costs (mainly due to recent changes in energy prices) result in significant water charges (in Hungary, users do not have to pay for the water supplied, but have to recover the costs incurred in transporting the water), which have to be paid by the users (Fig.13).

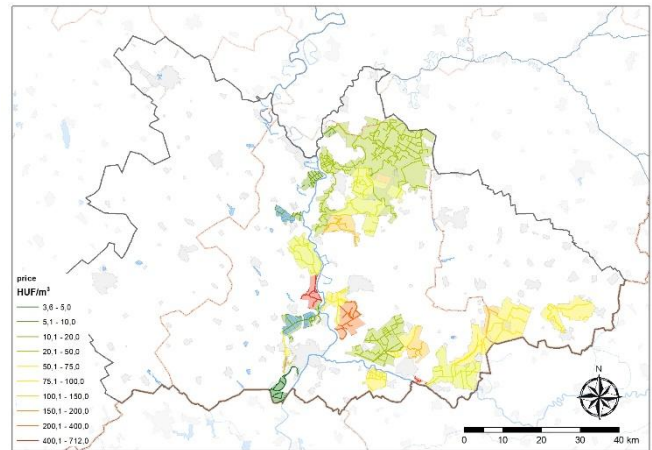


Figure 13 Distribution of water prices by irrigation system in 2023, Source: ATIVIZIG

Most of the water resources available for use are along rivers. However, their gravity discharge is only possible for short periods due to the subsidence of river beds, as illustrated by the hatched red line in Figure 14.

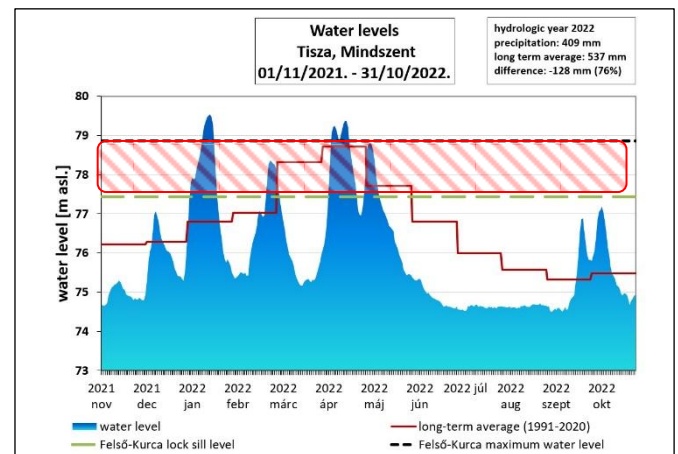


Figure 14 Temporal distribution of gravity outlets on the Tisza River, Source: ATIVIZIG

The reach of gravity outlets is very limited (around 1000 km²) due to topography, as illustrated in Figure 15:

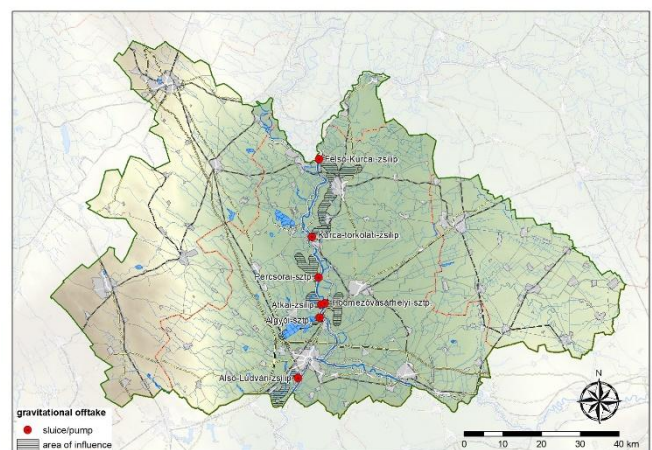


Figure 15 Scope of gravity outlets, Source: ATIVIZIG

In addition to the irrigation systems installed, there is significant potential for discharges of used water from municipalities. The source of these is treated wastewater discharged by municipal drinking water and industrial water uses based on groundwater resources. Their volume can generate significant stocks for larger agglomerations. It is important to note that these can be used to mitigate water shortages only after adequate treatment. The use of such waters in agriculture is limited by public health regulations. At present, these water resources are discharged into the surface water drainage network and typically help to replenish groundwater supplies through infiltration. Practical experience shows that infiltration is most effective in large reservoirs in replenishing groundwater supplies. This effect is less pronounced along canals. It should be noted, however, that in Hungarian practice, if used water is retained in a canal or reservoir, all landowners must legally contribute to the flooding of the area in order to retain the water. If 100% of the owners do not contribute, the retention of the water cannot be achieved. Although the overwhelming majority of landowners are in favour of flooding for water retention, in many cases such a plan fails due to the opposition of 1-2 landowners.

A summary diagram of the reaches affected by gravity recharge, pumping systems and municipal treated water is shown in Figure 16.

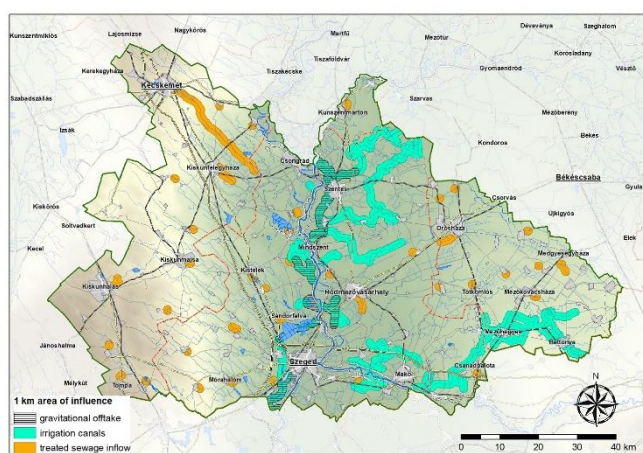


Figure 16 Scope of the areas to be covered by water recharge, Source: ATIVIZIG

If the areas that can be supplied with recharge (Fig 16) are subtracted from the spatial distribution of cumulative precipitation deficits (Fig 8), we can get an idea of the spatial limitation of recharge.

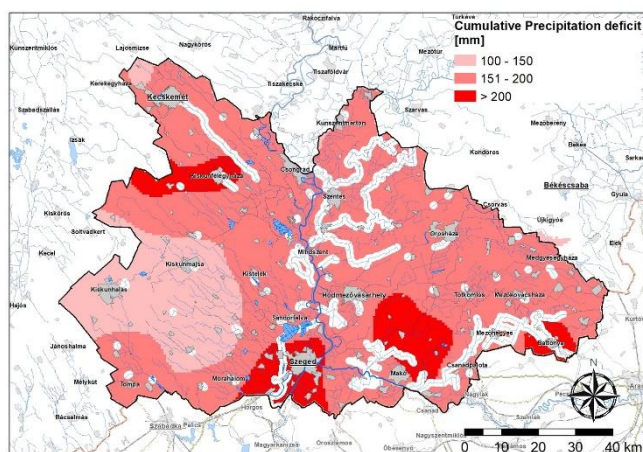


Figure 17 Difference between recharge areas and cumulative precipitation deficit in 2022, Source: ATIVIZIG

Figure 17 shows that an area of about 1200 km² (14% of the total area) is covered by the water compensation schemes, but 7200 km² (86% of the total area) cannot be included in the coverage of the water compensation schemes. In the period January-August, 150 mm of water would have been needed to recharge 1.09 km³, i.e. **1.09 billion m³** (compared to **0.1 billion m³** for the whole year). Losses during operation are not included in the calculation!

4. Next steps, the possible aims

Based on the studies carried out, it can be concluded that the study area is not covered by the available water resources or the water supply systems that convey them. The available infrastructure and irrigation systems make surface water resources accessible on 10-15% of the total area.

The objectives needed to improve the situation should be considered in the following spatial breakdown:

- for areas already included in water replenishment,
- for areas not included in water replenishment,
- land use issues,

For areas already included in water replenishment:

- For systems already in operation, the aim should be to reduce operating costs, preferably while reducing energy dependency. A good solution could be to use a solar energy generation system to help supply the pumps.
- As most systems are built from open sewer networks, efforts should be made to reduce leakage losses. Although reliable technical solutions are available, these can be implemented at high unit costs, which further increase the cost of water services.
- Efforts should be made to increase efficiency in water supply systems. To this end, effective water demand management should be developed, in which the maximum possible coordination of water demands in space and time is implemented.
- In the case of gravity outlets, technical improvements are needed to ensure that gravity operation is possible for as long as possible.

For areas not included in water replenishment:

- The available water resources in the catchments concerned, which are available through pooling, do not allow for predictable management, as a steady increase in evaporation is expected due to rising temperatures. However, even under these conditions, efforts should be made to maintain the surface water resources in place, as appropriate.
- As evaporation is very high in the areas concerned, land use should be managed in such a way that no till cultivation is used. In this way, it is possible to reduce water deficits during evaporation.
- Efforts should be made to recycle as much as possible of the used water available in the area. In the reuse of used water, it is important to determine the appropriate purification efficiency associated with the use.
- Groundwater dams constructed perpendicular to horizontal flow directions can have a positive effect in raising groundwater levels. These can be used to achieve effective groundwater level elevations over

longer periods. Such interventions should always be subject to a detailed impact assessment. Their consequences should be widely explored.

- Where water demands are sufficiently concentrated in winter and free water resources are available to meet them, either the development of existing water recharge systems or the development of new water recharge systems may be justified. In all such cases, the water demand that can be met and the operating costs of the improvements should be determined in advance..

Land use issues:

- In relation to land use, long-term visions/societal expectations that require land use changes should be identified.
- Land use planning should be used as a basis for identifying the societal expectations for the operation of water systems, on the basis of which the technical tasks can be carried out. The necessary interventions on the water system elements should then be implemented.
- The expectations of each element of the water system must be precisely defined and the owners/managers of each element must adapt their activities accordingly.
- Modifications to tillage techniques should be implemented as necessary to reduce evaporation.
- Efforts should be made to retain stormwater runoff. Due to the high evaporation losses in the area, it is recommended to retain water preferably below the surface, using the soil's water storage capacity.
- Land use should be chosen and modified to reduce or at least delay run-off.

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Carbon farming practices for soil and water management

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Abstract : *The purpose of this report is to present the objectives and the legal framework laid down in the EU strategies for introducing carbon farming practices in soil management, for introducing the principles of the circular economy, as well as for achieving the objectives laid down in the European Green Deal.*

KEYWORDS: EU STRATEGIES, CARBON FARMING, CIRCULAR ECONOMY, GREEN DEAL .

1. Introduction.

In the regulations adopted by the **European Commission (EC)** regarding the goals and tasks in the field of agriculture of the member states of the **European Union (EU)** for the implementation of the complex of strategies contained in the decisions of the Paris Climate Agreement of 2015 for the implementation of **the initiative "4 for 1000"** also signed by a representative of the Republic of Bulgaria - Deputy Minister of the Ministry of Health, the strategy for the implementation of **"Circular Economies"** and that of the **"Green Pact"** substantiating the need to introduce **regenerative low-carbon and socially acceptable practices** to reduce and mitigate the causes and consequences of emissions from greenhouse gases from agriculture and land use and from here the consequences of climate change in our national agriculture, the new policies of the European Union related to climate change and the reduction of carbon emissions, directly related to the goals that Bulgaria must achieve by 2030 - significant reduction of net **CO₂ greenhouse gas emissions and the commitment to collectively achieve climate neutrality by 2035 in the land use, forestry and agriculture sector** (EU Annex Amending Regulation 2018/841, 2021), (New Circular Economy Action Plan, 2020).

The basic document for policies proposed by the European Commission, which should make Europe climate neutral by 2050, is the so-called **European Green Deal (EGD)**. In order to achieve these reductions in greenhouse gas emissions, changes to all climate-related policy instruments will be proposed (The European Green Deal, 2019).

In connection with the fulfillment of the goals of the **EGD** , **proposals for absorption, recycling and sustainable storage of carbon** are considered, summarized in a communication on "Sustainable carbon cycles", which indicates the ways to increase the absorption of atmospheric carbon (New Circular Economy Action Plan 2020) , (Sustainable Carbon Cycles, 2021) .

At the meeting of the Agriculture and Fisheries Council of the EC held on 17.01.2022, the three main tasks during the French presidency were outlined. One of the main ones for the program period has been defined as a priority of the Common Agricultural Policy, **introduction of low-carbon agriculture and carbon sequestration in agricultural areas** (Agriculture and Fisheries Council of EU, 2022). The Commission will propose an EU regulatory framework for the certification of carbon sinks based on robust and transparent carbon accounting rules and requirements.

The rules will provide the necessary legal framework to scale up carbon sequestration in agricultural soils and industrial solutions to remove it from the atmosphere.

With the introduction of innovative approaches for the implementation of the principles of the "Circular Economy" in the agricultural and forestry farms and the sectors processing the products produced in them, it will be possible to utilize the biodegradable waste generated in them by applying decentralized and decarbonized practices for generating alternative energy and retaining and storage of organic carbon in soils (**BioCCS practices**) (Kostov O., Iordanov J., 2020)

In the long term, the creation of a system through justified and socially acceptable utilization of biodegradable waste from agricultural production as resources includes the following sectors:

- **Agriculture:** soils and soil fertility, limiting direct pollution by partially replacing mineral fertilizers with microbiological, composts and biological carbon in land use, improving the moisture-retaining characteristics of the soil for adaptation to droughts;

- **Waste management:** utilization of biodegradable waste to restore and maintain soil fertility, to restore and increase soil carbon content, BioCCS practices;

- **Renewable energy sources:** efficient technologies and systems for the carbonization of waste biomass for decentralized energy production and soil improvers to overcome the effects of climate change, BioCCS practices;

- **Sustainable development of the regions:** creation of economically justified incentives for utilization of waste biomass, improvement of soil quality and introduction of highly efficient production of biological products;

2. Prerequisites and ways to solve the problem

To achieve the specified system of measures, it is necessary to implement the following sequence of actions:

1. Assessment of the consequences of droughts, erosion and destruction, the emerging trends of losses in the content of organic carbon, humus and highly disturbed soil microbiology, the emerging trends of loss of soil fertility. With the introduction of innovative practices for biological capture and storage of carbon (**BioCCS practices**), integrated solutions for overcoming and adapting to climate change will be achieved. With their introduction, integrated benefits of:

- On the one hand, the utilization of biodegradable waste through appropriately selected technological and technical solutions will fulfill the goals of limiting their quantities intended for landfilling.

- On the other hand, through their carbonization and composting and subsequent application of the obtained products to the soil, carbon capture and storage will be carried out for a significant period and the generated emissions polluting the atmosphere will be significantly reduced.

- From a third party, the input products will improve a number of important elements of soil fertility: increasing the content and availability of nutritional elements, improving soil structure and moisture retention, soil microflora, soil moisture retention, etc.

- Fourthly, but not least, with the introduction of a system of low-carbon practices, conditions will be created for the introduction of decentralized, decarbonized alternative energy production systems using waste as resources.

2. Development and introduction of integrated measures and practices for:

- reducing and preventing atmospheric pollution from carrying out agricultural activities, creating conditions for sustainable

management of the main components of the environment - soils, water and atmospheric air to guarantee soil fertility, stable moisture retention, storage and maintenance of soil microflora;

- introduction of decentralized systems for economically expedient production of low-carbon energy and stable accumulation and storage of organic carbon in soils, creation of an opportunity for rapid restoration of disturbed soils, prevention of groundwater pollution, regeneration of soil microflora and soil fertility;

3. Introduction of highly efficient urban ecosystems for the extraction and retention of CO₂ for sustainable prevention of natural disasters as a result of climate change.

4. Introduction of BioCCS practices, defined as some of the most socially acceptable and recommended by UN, EU, World Bank, World Food Organization - FAO studies to mitigate the global consequences of climate change.

5. Introduction of a justified system for sustainable development by creating economically justified incentives for the utilization of waste biomass in agricultural practice, forestry, animal husbandry and processing industry.

6. Characterization of management objects with standardized methods and standardized tools.

7. Planning and implementation of projects for the implementation of measures and practices for the integration of agricultural and climate change policies, when evaluating them using the cost-benefit method.

8. Implementation of circular economy projects using products and waste from agricultural production through demonstrable socially acceptable Public-Private Partnerships by creating on the basis of Contracts for joint consortia with private entrepreneurs.

The mentioned measures will introduce a wide range of assessable practices in agriculture for: restoring and guaranteeing moisture retention, improving the structure of soils and soil microflora, implementing highly effective in-situ practices for the reclamation of disturbed soils, including and landslides with products from waste utilization, measures for the sharp reduction of atmospheric pollution with N₂O from the land use system due to the uncontrolled application of mineral fertilizers, as well as the protection of groundwater from significant nitrate pollution which, taken together with the processes of soil destruction, lead to permanent expansion of the territories designated as sensitive nitrate zones

The study by the European authorities shows that carbon farming can support the EU's efforts to capture and store non-carbon emissions. These practices can be encouraged through EU policies and efforts of national governments (through the Common Agricultural Policy) as well as through private business initiatives. Depending on the outcome of the CAP renewal negotiations on green schemes, farmers in the community are expected to receive additional billion euros for the introduction of carbon farming.

3. Results and discussion.

Carbon farming is a way to achieve the EU's environmental goals. The new European climate legislation increases the EU's 2030 emissions reduction target from 40% to at least 55%. It provides European citizens and businesses with the legal certainty and predictability they need to plan for this transition. After 2050, the EU will aim for negative emissions. This practice will be encouraged through the EU policies of the new Common Agricultural Policy (CAP) which will support the transition to more sustainable agriculture with increased ambition for climate, environment and animal welfare.

One of the most frequently applied technological schemes and technical systems for the introduction of carbon agriculture in world practice is the utilization of green waste through composting carried out through activated composting with the application of specially

developed gamma activators for composting (Kostov O. and Iordanov J., 2019) (Kostov O. and Oswald van Cleemput, 2019) in closed vessels and through various technical solutions of systems for carbonization of the biodegradable waste generated in the agricultural sector.

Selection of a certain type of composting system is based on an evaluation of the parameters: volume for composting, volume of a single charge, possibilities to control the composting process, time for composting, guaranteeing the sanitization of the final product and hence the performance of the system, guaranteeing the sanitization of the final product the requirements for the final product determined both by the Bulgarian legislation and those of the EU such as (REG EC 1069/2009,2009) mainly setting the requirements for public health and (REG EC 2019/2009,2019) for unifying the qualities of all types of fertilizers produced and applied in EC.

There are various technical solutions of systems for carbonization of biodegradable waste. The qualities and possibilities of application of the obtained final product - **biochar** depend on the technical indicators of the carbonization systems - combustion in an oxygen-free environment, the conditions created for the utilization of the compartments in the process, gases inside the system, the temperature of carbonization, etc.

In a number of articles (Pelovski Y., at al. 2018) , (Serafimova E. at al.2018) , (Iordanov J. at al.2018) , (Kostov O.,Iordanov J. 2019) , (Kostov O.at al. 2019) (Serafimova E., Iordanov J.2020) technical solutions of carbonization systems, parameters, qualities of the final product and the possibilities of using biochar in various sectors of agriculture and forestry with the aim of introducing carbon agriculture. The final products from the utilization of biodegradable agricultural waste have been developed and studied, both of vegetable origin - corn, energy grass crops - muscantus and Sudanese, and of animal origin - waste from animal husbandry and manure from poultry farms, waste from the processing of agricultural products - viticulture and wine production through gasification and controlled pyrolysis with the aim of integrated resource utilization to obtain energy and biochar. A prototype of a pyrolysis installation for heat energy generation and biochar production at the poultry farm level was designed, manufactured and tested. The energy will be used to heat the farms themselves, and the biochar will be used in carbon farming (Serafimova E., Iordanov J., 2020).

The practices discussed above will enable implementation through national strategic plans in line with the Green Deal and its strategies "Farm to Fork" and "Biodiversity" (Nieuws EP: Political agreement on new Common Agricultural Policy, 2021). Although a quarter of all EU agricultural spending for the period 2014-2020 (over €100 billion) was dedicated to combating climate change, greenhouse gas emissions from agriculture have not decreased since 2010. This is due to the fact that most measures financed under the CAP have a low potential to mitigate the effects of climate change, and the CAP does not encourage the use of effective climate-friendly practices.

With the implementation of such a system of feasible low-carbon decentralized practices, it is possible to quickly and efficiently multiply the effects in a purely economic and social plan and, as the ultimate goal, to build the foundations for introducing an economically justified "green infrastructure", "carbon agriculture" and "green economy" .

4. SWOT analysis of carbon farming in Bulgaria.

Strengths

- Bulgarian technologies for carbon farming are qualitative and competitive;
- Practical experience in applying technologies for carbon farming, including by adapting foreign experience;

- Carbon farming is recognized as a tool for sustainable local development;
- Competitive prices for production;
- Contributes simultaneously to the fulfillment of the objectives of 3 United Nations conventions: Convention on Biological Diversity, United Nations Framework Convention on Climate Change, United Nations Convention to Combat Desertification (European Landscape Convention);
- Carbon farming offers opportunities for additional employment in rural areas of the country;

Insufficiency

- Lack of tax incentives and other incentive measures for carbon farming;
- Insufficient knowledge of the nature, production methods and philosophy of carbon farming among farmers;
- Insufficiently qualified and motivated workforce;
- Insufficient level of modern knowledge and insufficient application of scientific achievements in Bulgaria;
- Weak connection between science, business and the state;

Threats

- There is a lack of a realistic assessment of the increasingly clear need to introduce integrated decentralized practices mitigating the causes and consequences of climate change;
- Bulgaria is seriously lagging behind in terms of the plans to achieve climate neutrality, with which the countries within the European Union (EU) are committed, shows a draft of a detailed strategy under Priority 4 "Circular and low-carbon economy" of the National Development Program "Bulgaria 2030" ;
- The lack of innovative approaches for implementing the principles of the circular economy for the utilization of the generated waste in agricultural production, processing enterprises in logging and in wood processing;
- Strong fragmentation of agricultural properties, including small farms;
- Lack of a real market for agricultural land in Bulgaria;
- Lack of entrepreneurial culture among Bulgarians, including low organizational culture of Bulgarian farmers;
- Aging population;
- Migration;

4. Conclusion

A priority in the implementation of the main policies in the agricultural sector is the utilization of the waste generated in the sector as a resource for the protection and restoration of soils and soil fertility, macro and micro organisms, protection from pollution of groundwater and atmospheric air, mitigating the causes and adapting to climatic changes.

The development of national minimum standards for predicting and estimating soil carbon sequestration is essential. In order to implement the indicated priorities, it is necessary, with targeted actions by all participants in the agriculture and forestry sector, to develop and provide measures in the new CAP 2021-2027 for the introduction of decentralized integrated practices for the resource recovery of waste from the agricultural and forestry sectors. forestry and processing industry, measures to mitigate the causes and adapt to the consequences of climate change and those ensuring the introduction of carbon agriculture.

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Soil biological indicators under sunflowers field in a long-term tillage experiment of luvisol

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Abstract: Tillage is the common practice in crop production, providing a suitable environment for root development. However, many studies suggest that long-term tillage practice affects the deterioration of soil properties. Soil biological indicators can be employed to evaluate the soil changing due to the long-term tillage application. The evaluation of soil biological indicators in the long-term tillage application has not been widely discussed in Hungary. We investigated two types of 19 years of long-term tillage experiments, i.e., conservation tillage, reduced tillage and leaving 30% or more crop residue after harvesting (CT), and conventional tillage, a mouldboard ploughing technique (PT). The soil was sampled thrice during the growing season at 0-5, 10-15, and 20-25 cm depths. The activity of dehydrogenase (DHA), β -glucosidase (BGA), phosphatase (PHA), labile carbon concentration (POXC), and soil water content (SWC) were measured in this investigation. Our results indicated that the tillage system significantly affected the BGA ($p < 0.001$). Meanwhile, soil depth remarkably regulated the DHA ($p < 0.05$). The highest activity of DHA and BGA was identified near the surface layer of CT. In contrast, the PHA was relatively distributed uniformly in all depths, reflecting that this enzyme activity was more dominated by the root effect. Tillage practice notably increases substrate availability, representing the higher POXC concentration in the CT and PT in all soil layers. POXC concurrent with SWC were remarkably associated with DHA ($r = 0.51$, $p < 0.01$), BGA ($r = 0.29$, $p < 0.05$), and PHA ($r = 0.28$, $p < 0.05$). On the other hand, POXC was notably correlated only with the DHA ($r = 0.46$, $p < 0.01$). CT practice also indicated a remarkably positive effect on stem and flower diameter growth.

KEYWORDS: DEHYDROGENASE, GLUCOSIDASE, PHOSPHATASE, LABILE CARBON, TILLAGE

1. Introduction

Soil tillage plays an essential role in agriculture by creating good soil conditions for crop establishment and initial shoot and root development. For decades, conventional tillage (PT) by deep ploughing and soil inversion has dominated Hungary's land preparation [1]. In the long run, conventional tillage practice has adverse side effects, including increased runoff and soil erosion, which deplete soil fertility [2,3].

Conservation tillage (CT), reduced tillage and leaving 30% or more crop residue after harvesting, was introduced in the 1980s in Hungary. Hungary researchers have revealed CT implementation's effect on soil physical improvement, soil erosion reduction, and soil organism activities [4,5,6,7]. In addition, the investigation of the impact of CT on crop production was also well-recorded [8,9].

The minimum soil disruption and the abundance of soil organic matter of the CT practice induces soil biological indicators, viz. microbial biomass carbon, microbial biomass nitrogen, and soil enzyme activity [10]. However, only a few investigations address the effect of long-term CT application on soil biological indicators in Hungary. This study presents a comparative study of soils from long-term different tillage practices and soil depths by evaluating soil biological indicators.

2. Materials and Methods

2.1 Site description

The experimental field was in Szentgyörgyvár, Hungary (N 46°44'53.32" E 17° 8'48.54") at the attitude 150 m above sea level with 10% inclining. The climate is categorized as warm-summer humid continental [11]. The mean annual precipitation and air temperature (2022) are 626 mm and 13.48°C, respectively. The soil type is Luvisol developing from sandy Loess material with low organic matter content [12]. Two tillage systems, conservation tillage (CT) and ploughing tillage (PT), were established in 2003. CT was defined as non-inversion reduced tillage (up to 8–12 cm depth), leaving ~30 % of the previous crop residues covering the soil surface. A cultivator machine controlled the weed (8–10 cm depth). Otherwise, a mouldboard ploughing (to a depth of 25–30 cm) was conducted in PT. Each tillage system has four replication plots, and the plot size is 25 × 24 m (length × width). During this study, we planted sunflowers with a density of 56.000 seeds ha⁻¹.

2.2 Soil sampling and analysis

A composite soil sample by the four random points of each plot was taken from 0-5, 10-15, and 20-25 cm depth. Soil samples were conducted three times during the growing season. The soil was then

carried to the laboratory and kept in the fridge at 4°C until the analysis of soil enzyme, and the maximum preservation is four weeks [13]. Meanwhile, the soil for chemical analysis was prepared at room temperature (20°C) until the soil reached air-dried condition.

We used the permanganate oxidation method to examine the labile carbon concentration, POXC [14]. A 0.02 M KMnO₄ solution was reacted with the air-dried soil samples. The mixture was then shaken and centrifuged. The supernatants were then measured by spectrophotometer at 565 nm wavelength.

Dehydrogenase activity (DHA) was determined by the triphenyl tetrazolium chloride (TTC) method [15]. TTC solution was added to a test tube and incubated at 30 °C for 24 hours. The addition of a Methanol solution then suspended the enzymatic reaction. The soil mixture was centrifuged to get the supernatants. The DHA was determined spectrophotometrically at 546 nm wavelength. The β -glucosidase activity (BGA) was assessed by the p-nitrophenol (PNP) method [16]. The PNP- β solution was added into 1 ml soil-water mixture (1: 20) in the test tube, while the Na-acetate buffer was reacted into two test tubes containing the same mixture of soil and water, then incubated for 2 hours at 30 °C. The enzymatic reaction was terminated by tris-hydroxymethyl (aminomethane) (0.5 M at pH 12) and 0.5 M CaCl₂ solutions addition. β -glucosidase activity was measured spectrophotometrically at 410 nm wavelength. The phosphatase activity (PHA) was determined by a similar protocol of [16], in which the amount of p-nitrophenol (PNP) converted from p-nitrophenyl-phosphate (PNP-PO₄) was determined spectrophotometrically at 410 nm wavelength. The measurement of Soil enzyme activity and POXC in this study employed Libra S22, UV/Visible spectrophotometer, Biochrom. Ltd, UK.

2.4 Plant measurement

Stem and flower diameter were measured of ten randomly selected plants of each plot (CT and PT) in the flowering phase, and the sampling plants had to represent the plot size. The stem diameter measurement was conducted at 5 cm above the soil surface. The chlorophyll content was measured by chlorophyll meter SPAD-502 at the same plant sample of diameter measurement. The chlorophyll value of each sampling plant was the average of three times measurement of chlorophyll of different leaves.

2.5 Data analysis

A two-way analysis of variance (ANOVA) and Pearson correlation was employed to check how the tillage system and soil

depths affected the soil biological indicators in CT and PT plots. Statistical analysis was performed using IBM SPSS statistics for Windows, version 27.0 [17], with a significantly different level of $p < 0.05$. The normality check for all parameters was proved by the D'Agostino test, in which the $p > 0.001$. Levene's test for heterogeneity of variance indicated that the heterogeneity of variance for BGA and PHA was not "violated" with $p > 0.05$; therefore, Tukey's test was employed for the posthoc test.

Otherwise, the Games Howell test was used for DHA and POXC due to the p of Levene's test < 0.05 .

3. Results and Discussion

The ANOVA results for each soil biological indicator varied, suggesting that the soil enzyme activity and POXC concentration depended on the tillage system and soil depths (Table 1).

Table 1. The two-way ANOVA table for means of assessed soil biological indicators in the different tillage systems.

Dependent	Independent	df	Mean Square	F	Sig.
POXC	Tillage system	1	215489.560	28.779	0.000
	Soil depth	2	7854.708	1.049	0.356
DHA	Tillage system	1	0.248	3.028	0.087
	Soil depth	2	0.281	3.436	0.038
BGA	Tillage system	1	3.540	7.471	0.008
	Soil depth	2	0.015	0.031	0.970
PHA	Tillage system	1	6.906	0.212	0.647
	Soil depth	2	16.234	0.498	0.610

POXC= Permanganate oxidizable carbon, DHA= Dehydrogenase activity, BGA= β -glucosidase activity, PHA= Phosphatase activity; SWC= Soil water content

POXC concentration

The POXC concentration was significantly affected by soil tillage, in which POXC concentration was higher in the CT than PT in all depths (Fig. 1a). The POXC concentration in the CT and PT was well distributed in 0-25 cm depths, and there was no difference among the soil depth (Table 1). The circumstance in the PT suggested an effective incorporation between soil and crop residue by the *mouldboard* tillage practice. On the other hand, in the case of CT, a long-term application of CT perhaps alters the soil's physical properties, improving water percolation. This situation allows the movement of soil organic carbon, accumulating in the soil surface of CT to the deeper layer. This result confirms the previous study by [18] that indicated a trend of soil organic carbon accumulation at greater depths in the soil profile in some form of conservation tillage treatments.

DHA

DHA was significantly affected by soil depth but not tillage practices (Table 1). DHA in the 0-5 cm depth was notably higher than the deeper layer of CT, otherwise in PT, indicating the same DHA in each depth (Fig. 1b). The POXC concentration and SWC play an essential role in the DHA suggested by the significant moderate positive Pearson correlation, $r=0.498$ and $r=0.501$, respectively, for POXC and SWC (Table 2). POXC is the available source of energy for soil microorganisms. High POXC will increase the population and performance of microorganisms, impacting soil enzyme activity [19]. Redox potential is also an important factor in inducing DHA. Redox potential is closely related to SWC and oxygen availability. Too much water and drought adversely affect the rate of microbial respiration [20].

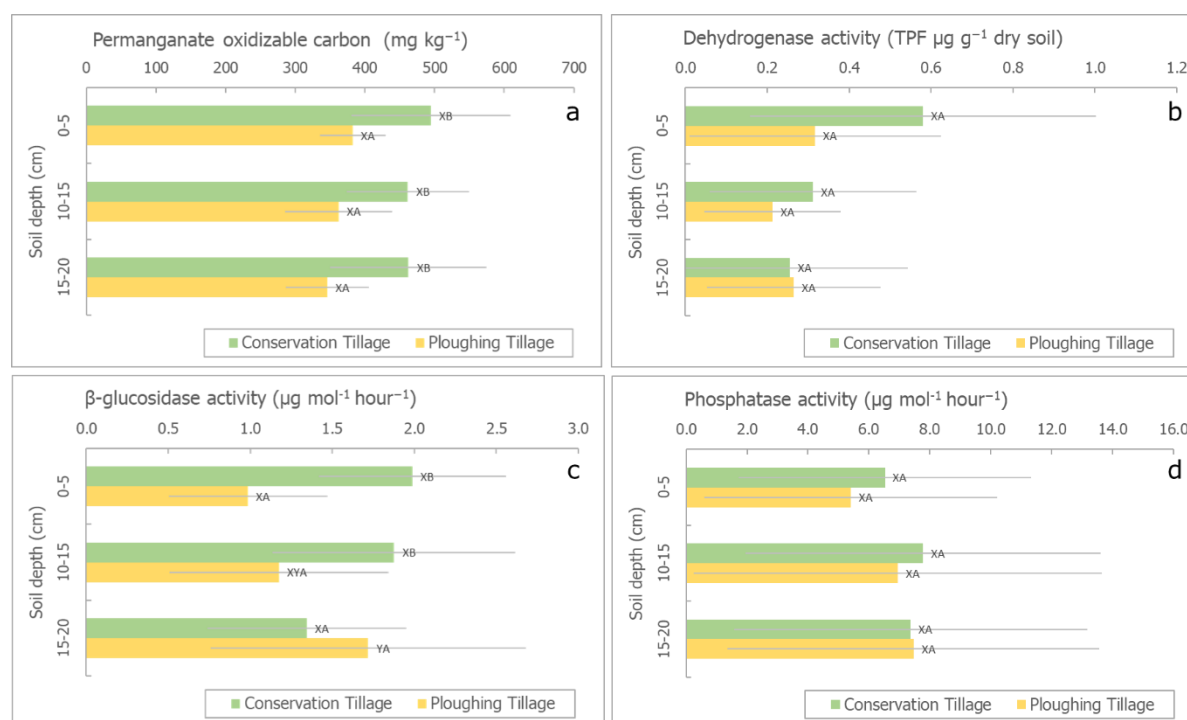


Figure 1. Soil biological indicators under different soil tillage and soil depth. Different capital letters (X and Y) indicate significant differences between soil tillage ($p < 0.05$). Different capital letters (A and B) indicate significant differences among the soil depth ($p < 0.05$).

BGA

Implementing soil tillage significantly alters the BGA, which is higher in the CT than in PT. The changes in SWC (which ranged from 3.28 to 28.22 v/v %) during the growing seasons were significantly correlated with BGA in this study, $r=0.286$ (Table 2). Soil depth did not affect the BGA. BGA is strongly correlated with the decomposition of litter and soil organic carbon [21,22]. The insignificant BGA in all soil depths (Table 1) indirectly revealed that the soil organic content in the whole depth was relatively homogeny. Regardless of the statistical result, the trend of BGA of two soil tillage systems was the opposite. The highest BGA in the CT was in the surface layer and decreased gradually to deeper layers. Conversely, in PT, the lowest BGA was at the top and increased continuously to the deeper layers (Fig. 1c); this finding was consistent with the study [23].

PHA

The CT and PT practice did not induce PHA in this current study. PHA was more active in the deeper than the surface layer (Fig. 1d). This result explained that PHA was more impacted by the root activity in which the root density of sunflowers was higher in the 10-25 cm than 0-5 cm [24]. PHA is also affected by the phosphorus concentration in the soil. When the phosphorus concentration decreases by the plant uptake, PHA will be activated automatically [25]. Phosphorus uptake was significantly correlated with soil water content; the phosphorus uptake in the dried soil was slower than in the moist soil, influencing the PHA [26], which was in line with our present study.

Table 2. Pearson correlation table of assessed soil biological indicator

	DHA	BGA	PHA	POXC
BGA	0.242*			
PHA	-0.112	0.498**		
POXC	0.459**	0.194	-0.188	
SWC	0.510**	0.286*	0.281*	0.116

*) Correlation is significant at the 0.05 level, **) Correlation is significant at the 0.01 level

BGA= β -glucosidase activity; PHA= Phosphatase activity; POXC= Permanganate oxidizable carbon; SWC= Soil water content; DHA= Dehydrogenase activity,

Stem and flower diameter and chlorophyll content

The plant measurement indicators suggested a higher CT than PT but were statistically significant only on stem and flower diameter (Fig 2).

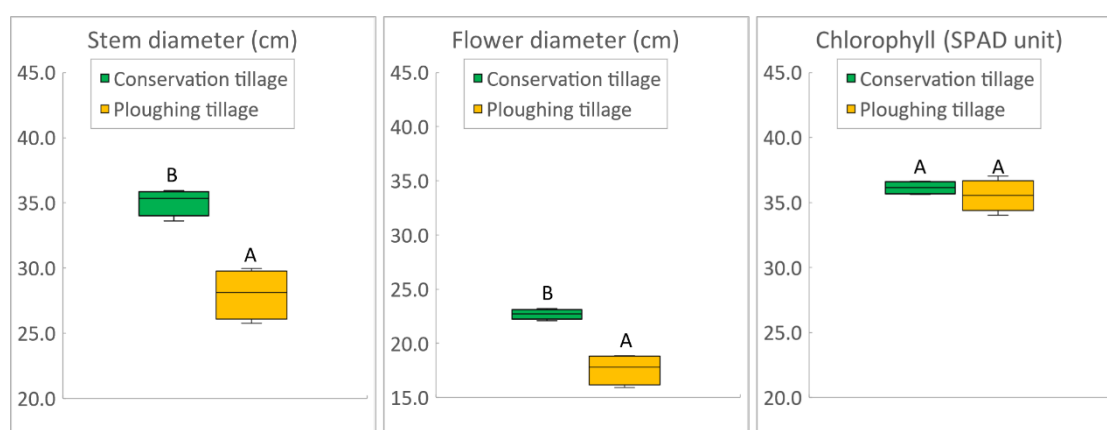


Figure 2. Plant measurement indicator. Different capital letters (A and B) indicate significant differences between soil tillage ($p<0.05$).

Previous studies also reported the positive effect of conservation tillage on plant growth indicators through the combination of soil physical and chemical improvement, soil biological indicator stimulation, runoff, and soil erosion reduction [27,28,29]. Leaf chlorophyll concentration was similar between CT and PT, suggesting adequate nitrogen uptake by root associating with the reduction of nitrate leaching through water infiltration and runoff in CT [30]. This result disagrees with [31] stating that chlorophyll content in CT was lower than in PT due to the lower nitrogen uptake.

Conclusions

We evaluated soil biological indicators of Hungarian Luvisol soil under different tillage systems, CT, and PT. The minimum disturbance of soil results in a higher POXC concentration and BGA in the CT than PT uniformly in all soil depths, suggesting the inversion effect of PT and the possibility of organic matter particle movement to the deeper layer of CT. DHA is more active in the surface layer, affected by soil moisture and POXC concentration. The tillage system has no effect on PHA that is more associated with the plant root. The higher root density in the deeper layer was linked to the higher PHA than the surface layer correlated to the soil

moisture content. These situations are which, in turn, contribute to better plant growth indicators.

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Acknowledgment

The authors express their cordial thanks to Syngenta Hungary Ltd. for their technical and financial support. The support of the National Research, Development, and Innovation Office (No. K143005) is gratefully acknowledged.