ESTIMATION OF THE RANDOM INTENSITY OF THE SOIL TILLAGE DRAFT FORCES IN THE SUPPORTS OF THE WORKING BODIES OF A CULTIVATOR
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ESTIMAREA INTENSITĂȚII ALEATORII A FORȚELOR DE TRACȚIUNE ÎN SUPORTURILE ORGANELOR DE LUCRU ALE UNUI CULTIVATOR

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ABSTRACT
The investigation on the unpredictability of the distribution of traction resistance forces on the working bodies of a specific type of MCLS complex cultivator is presented in the paper. The validation of the random character of the force that loads the active bodies is used to indicate the mathematical model that must be followed for the research of the soil processing system. Also, the research results elucidate some hypotheses issued in the conception and design of the machine: the more intense load for the working bodies located immediately after the tractor, the existence of working bodies that are constantly more intensively stressed and the causes. According to the literature, it is to be assumed that the forces that demand the working bodies, the supports, and the machine frame have a random nature. The conclusions of the descriptive, inferential statistical study (which do not quantify the random intensity) are explained together with the results. The experimental loads are compared to some of the most random strings to produce a quantitative estimate of the random intensity. As a result, processes that use random functions and the entirety of their approach are recommended in mathematical modelling for further research.

REZUMAT
În această lucrare este prezentată cercetarea cu privire la imprevizibilitatea distribuției forțelor de rezistență la tracțiune pe organele de lucru ale unui anumit tip de cultivator complex MCLS. Validarea caracterului aleator al forţei care încarcă organele active este utilizată pentru a indica modelul matematic care trebuie urmat pentru cercetarea sistemului de prelucrare a solului. De asemenea, rezultatele cercetării elucidează unele ipoteze emise în conceperea și proiectarea mașinii: sarcina mai intensă pentru organele de lucru situate imediat după tractor, existența unor organe de lucru care sunt solicitate în mod constant mai intens și cauzele. Conform literaturii de specialitate, se presupune că forțele care solicită organele de lucru, suporturile și cadrul mașinii au o natură aleatorie. Concluziile studiului statistic descriptiv, inferenţial (care nu cuantifică intensitatea aleatorie) sunt explicate împreună cu rezultatele. Încărcările experimentale sunt comparate cu unele dintre cele mai aleatorii șiruri pentru a produce o estimare cantitativă a intensității aleatorii. Ca urmare, procesele care folosesc funcții aleatoare și întreaga abordare a acestora sunt recomandate în modelarea matematică pentru cercetări ulterioare.

INTRODUCTION
The measurement of the soil tillage draft forces generated by the action of the working bodies in the soil in the agricultural machines intended for soil processing is a widely discussed problem in the literature. From the measurement with the dynamometer to complex measurements with force sensors or tensometric methods (simple or using complex tensometric frames), the authors tried to estimate the soil tillage draft forces during its processing, *(Askari M., et al., 2013; Carman K., et al., 2021; Rashidi M., et al., 2013; Afify M.T., et al., 2020; Abbaspour_Gilandeh Y., et al., 2020), (Abbaspour-Gillandeh M., et al., 2020; Markinos A., et al., Croitoru St., et al., 2016; Vlăduţ D.I., et al., 2017).* The resistance of the soil to deformation has a direct impact on energy usage and the effectiveness of agricultural work.

The parameters that influence the soil deformation resistance are, on the one hand, the mechanical and structural characteristics of the soil, its humidity, but also the geometry of the working bodies (working depth and width, orientation angles in relation to the direction of advance, shape and the quality of the contact surfaces) and their location on the load-bearing structure, the weight of the farm machinery, etc.

Elementary and complex statistical analyses are made in order to obtain formulas for the prediction of tensile strength. The operating speed, which is crucial to the energetics of soil processing, is another fundamental characteristic of the equipment designed for soil processing *(Mahmood H.F., et al., 2011).*

Estimating the soil tillage draft force per working body by tensometric means, using calibration techniques, is a simpler way, but with complex sources of errors in relation to classic measurements with the help of a dynamometer or some force doses. The tensometric signals recorded in the deformation sensors mounted on the supports of the working bodies of the cultivator have, at least at first glance, an irregular shape, they cannot be modelled with signals given by common laws used in the approximation of simple experimental functions. The need for a measurement procedure that is more practical than the traditional ones is just one reason why it is interesting to characterise the variation of resistance forces on the working body. Another reason is that mathematical modelling of the process can be used for practical purposes, such as predicting the intensity of the resistance force and designing safe and supple. Obviously, it is also about the optimization of load-bearing structures for the economy of material and the simplification of manufacturing technology. It is critical to ascertain if the loads the working body supports are deeply random or deterministic in light of these goals. Depending on the estimation results, the mathematical model usable in the prediction of aggregate dynamics and in the design of load-bearing structures will be a deterministic or a statistical one.

The literature is in agreement regarding the random nature of the physicochemical properties of the soil, (*Dharumarajan S., et al., 2017; Nia M.Z., et al., 2023; Wijiewardane N.K., et al., 2018; Amad M., et al., 2021; Wang Y.,et al., 2018; Cofie P., 2001; Ly H-B., et al., 2020; Liu K., et al., 2020; Garcia N.P., et al., 2016; Sadouki A., et al., 2013; Kumar V., et al., 2022; Sherkuziev D.Sh., et al., 2020)* in particular with the mechanical properties involved in the generation of resistance forces (*Cardei P., et al., 2021, Gill W.R., 1967; Zobeck T.M., et al., 1987; Obour A.K., et al.,2021).* Other authors simulate soils or mixtures of soil and rock with random characteristics, in order to predict their behaviour in various dynamic processes *(Gao W., et al.; 2021; Zhang J-Z., et al., 2022).* Under the name of spatial variability, the random nature of some soil properties is also studied and evaluated *(Delhome, J.P., 1979; ISSMGE-TC304, 2021; Mashalaba L., et al., 2020).* Interesting study examples for spatial variability are presented in (*Jurado C. S., et al., 2012; Tekeste M., et al., 2005; Uzielli M., et al., 2005),* and *(Pieczyńska-Kozlowska J., et al., 2021; Lu H., et al., 2022; Salgado R., et al., 2015; Zhang W., et al., 2015)* for a property used in the characterization of soil resistance, namely the cone penetrometer test. A large number of works describe the variability of the tensile strength of agricultural machines intended for soil processing (*Al_Neema K.A., et al., 2021; Al-Kheer A.Al-K.A., et al., 2011; Markinos A.).* The random nature of the forces generated by the action of the working bodies of the soil processing machines is primarily motivated by the inhomogeneous characteristics of the soil (density, granular composition, physical composition, humidity, chemical composition, etc.), also not infrequently, due to the irregular geometry.

However, there is no research that validates the random nature of the interaction process between the working bodies of agricultural machines intended for soil processing and which, based on the validation of the random nature of the stresses of such agricultural machines, recommends the approach to modelling work processes within the theory of random functions (*Hajek B., 2015; Knill O., 2009; Kobayashi H., et al., 2012; Leon-Garcia A., 2008).* More precisely, regarding the series of experimental recordings that form the subject of the analysis whose results are described in this article, they fall into the category of random vibration systems, for which specific approaches are recommended *(Meirovitch L., 1976; Buzdugan Gh., et al., 1982; Lalane Ch., 2002; Sireteanu T., et al., 1981).* In mechanized work processes in agriculture, vibration analysis has become very frequent, especially with the increase in the quality of agricultural working, with the emergence of precision agriculture and with automation, digitization and robotization in this field *(Gong Y., et al., 2023; Yue Y., et al., 2022; Biriş S.Şt., et al., 2022, Yanovych V., et al., 2022; Brăcăcescu C., et al. 2014, Geng C.X., et al., 2019; Samadi M., et al., 2019),* for example. Most of the specified authors work for prediction using descriptive statistical estimators, especially the mean value, and lately, inferential statistical analysis is used, especially based on linear regressions, (*Rogovskii I., et al., 2020; Colombi T., et al., 2019; Alonso A., et al. 2022; Al-Janobi A., et al., 2020).*

In this context, compared to the current and older literature, this work proposes an evaluation of some experimental data series for a quantified decision to approach the analysis through methods specific to deterministic phenomena or methods specific to random phenomena. At a higher level, the work aims to study the distribution of resistance forces on each working body, to confirm or refute some hypotheses.

For example, it will be appreciated if some working bodies are more loaded than others, if the most intense load remains on the same working body, and what the cause is. The hypothesis of the higher intensity of the resistance force on the working bodies in the line closest to the tractor is researched, and the result may show certain errors in the hypothesis and their causes.

MATERIALS AND METHODS

The subject of the research whose results are described in this article consists of one of the working configurations of a cultivator designed for research and farm exploitation. More precisely, the behaviour of the working bodies is targeted, in order to estimate the soil tillage draft forces that appear in the working process of the cultivator.

The agricultural equipment for which the analysis described in this article is made is one of the possible working configurations of the MCLS complex cultivator, capable of working in three variants, with different working widths (1 m, 2 m and 4 m). The description of this complex machine, fig. 1, intended for research and exploitation in the field of soil processing, can be found in *(Cardei P., et al., 2021; Cardei P., et al., 2021).*

Fig. 1 - The MCLS complex cultivator operating with an 80 HP tractor, in full configuration (working width of 4 m)

In this work, the statistical analysis of the experimental data is made only for the substructure formed by the left wing of the complex cultivator, having as a power source a 45 HP tractor, fig. 3. This is the 1 m working width configuration of the MCLS complex cultivator, intended for processing soils in narrow spaces (for example vineyards with narrow rows). In Fig. 2, the frame of the left wing of the cultivator is shown, with the working bodies together with the deformation sensors and the indices of the channels for collecting signals from the deformation sensors glued to the supports of the twelve working bodies.

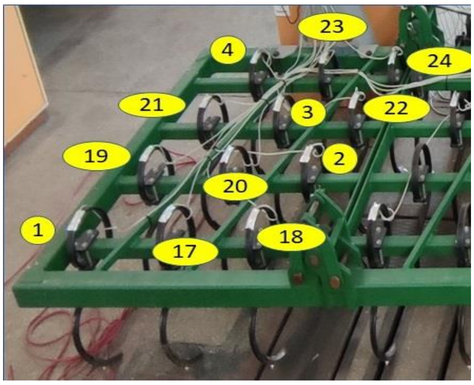


Fig. 2 - The left wing of the cultivator with the indexing of the data collection channels from the deformation sensors (working width 1 m).

Fig. 3 - The aggregate formed by the left wing of the cultivator in operation with a 45 HP tractor.

The acquisition of the experimental data was done exclusively with the help of the deformation sensors numbered as in Fig. 3, numbering that corresponds to the digital registration label in the computer. In Fig. 4, 6, 8 and 10 are graphically represented the finite time series collected during 40 s, in a work experiment, grouped according to the four lines of working bodies successively positioned on the supporting frame, facing the back of the tractor. In the text or in the comments of the figures, the group of letters *ch* signifies the channel of the data acquisition channel from the sensor with the same number which is marked on the structure (Fig. 2).

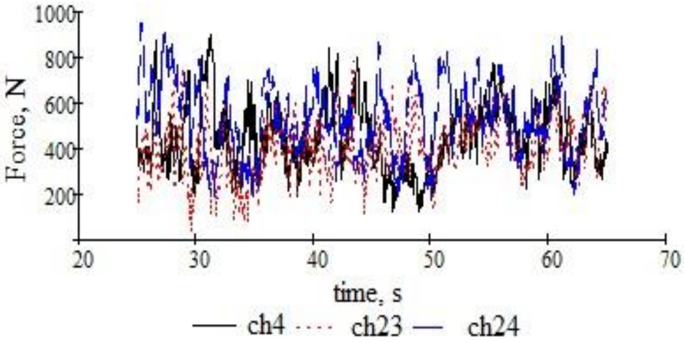


Fig. 4 - The graphs of the loads for the support of the working bodies of the first line after the tractor

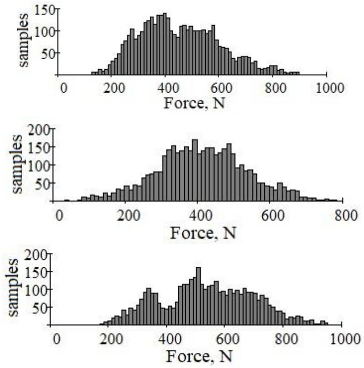


Fig. 5 - Histogram of the sequences: ch4, ch23, ch24

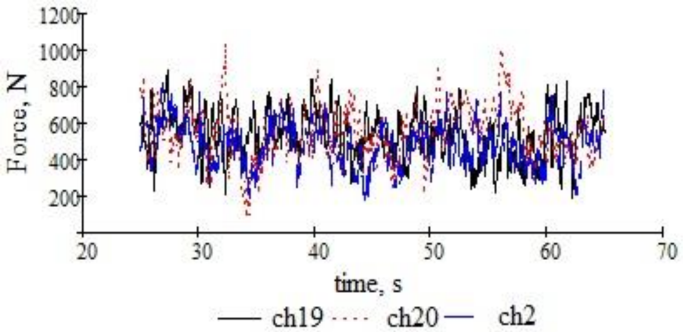


Fig. 6 - The graphs of loads of the supports of the working bodies in the second line after the tractor

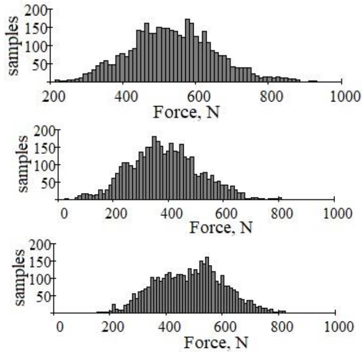


Fig. 7 - Histogram of the sequences: ch21, ch3, ch22

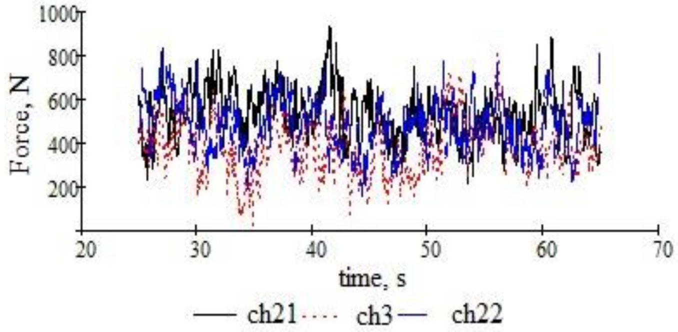


Fig. 8 - The graphs of loads of the supports of the working bodies in the third line after the tractor

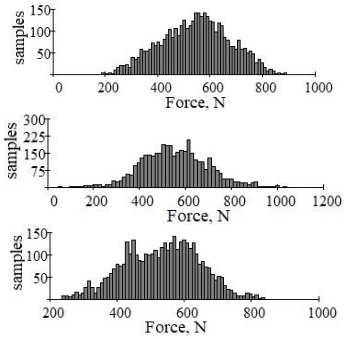


Fig. 9 - Histogram of the sequences: ch19, ch20, ch2

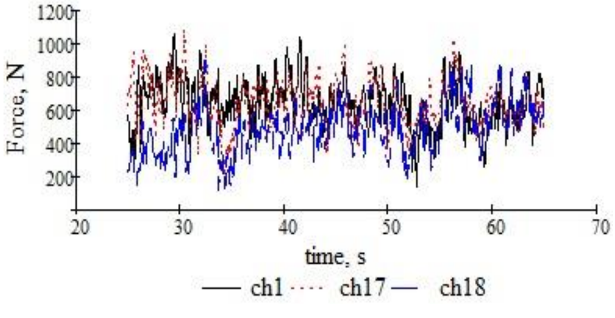


Fig. 10 - The graphs of loads of the supports of the working bodies in the last line of working bodies after the tractor

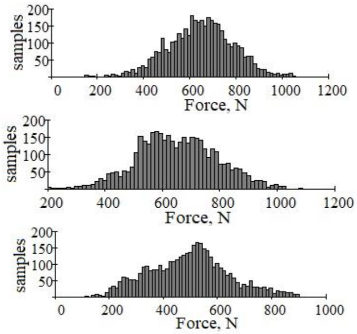


Fig. 11 - Histogram of the sequences: ch1, ch17, ch18

RESULTS

The results included in this chapter refer to the descriptive statistics of the time series collected from the supports of the twelve working bodies of the working variant with a working width of 1 m of the cultivator, signals represented graphically in Fig. 4, 6, 8, 10, and also to the analysis of the intensity of the random nature of these signals.

1. The basic and descriptive statistical analysis of the sequences of the loading of the working bodies' supports

A synthetic analysis of the experimental data gives first information about the random or deterministic character of the experimental data sequences registered for each support of the analysed structure. Estimators that characterize the basic statistics of the temporal series examined, according to *Wolfram Language, (2023*), are the minimum and maximum values, the average value of the standard deviation, variance, and median, which are given in Tables 1 and 2, for all sequences corresponding to the twelve working bodies, shown in Fig. 4, 6, 8 and 10 or as in Fig. 2. Also, the basic statistics contain also part of the quartile calculus presented in Tables 4 and 5 and the graphic, in Fig. 12. The descriptive statistics include also the estimators of Table 3: the asymmetry index (Skewness), the flattening index (Kurtosis*), (Clocotici V., 2023)* and the variation coefficient (CV), *(https://en.wikipedia.org/wiki/Coefficient_of_variation).*

Table 1

The minimum, maximum and average values of the sequences corresponding to the twelve working bodies of the cultivator

The minimum value, N			The maximum value, N			The average value, N		
125.72	32.35	172.7	897.83	784.96	952.14	453.12	410.58	537.52
212.62	23.03	154.4	930.94	808.89	819.48	536.51	385.6	483.49
187.09	45.99	235.69	888.56	1037.85	837.4	541.7	552.88	532.07
144.37	195.29	109.33	1057.49	1086.08	899.81	644.27	650.43	493.19

Table 2

The standard deviation, variance and median of the numerical sequences corresponding to the twelve working bodies of the cultivator

Standard deviation, N			Variance, N			Median, N		
149.5	124.46	158.34	22351.17	15490.2	25072.4	438.22	408.95	533.8
117.74	125.93	120.15	13863.58	15859.29	14434.94	533.04	379.44	488.24
131.68	145.76	112.19	17338.93	21245.42	12586.1	547.39	547.46	538.53
141.61	141.79	147.94	20054.74	20105.32	21887.41	647.45	645.22	498.41

Table 3

The values of the asymmetry index, the flattening index and the variation coefficient corresponding to the twelve working bodies of the cultivator.

Skewness			Kurtosis, N			CV		
0.41	0.02	0.04	-0.33	-0.08	-0.64	0.33	0.303	0.295
0.22	0.19	0.04	-0.02	-0.07	-0.48	0.219	0.327	0.248
-0.08	0.09	-0.08	-0.49	0.38	-0.43	0.243	0.264	0.211
-0.12	0.02	0.16	0.1	-0.07	-0.23	0.22	0.218	0.3

The statistical dependencies, expressed by the correlation coefficients between every two numerical sequences, are given in Table 6. The maximum value of the correlation coefficient between the numerical sequences coming from the supports of the twelve working bodies is 0.645. This value corresponds to the indexed sequences ch22 and ch24, i.e. the working bodies on the extreme right (in the forward direction of the machine), in the first two lines after the tractor. Therefore, the most intense dependence between the variations of the two numerical series is a weak one. Thus, there are no significant linear dependences between the sequences of the analysed forces.

Table 4

Characteristic values of the numerical sequences recorded on the supports of the working bodies on the first two lines of the cultivator, fig. 2

Estimator	channel4	channel23	channel24	channel21	channel3	channel22
Quartile 25%	339.273	327.172	428.674	455.728	299.328	392.892
Quartile 50% (average)	438.217	408.952	533.797	533.042	379.442	488.238
Quartile 75%	555.615	491.625	658.193	613.606	466.197	565.227
Minimum value	125.722	80.596	172.700	219.69	50.931	154.398
Maximum value	878.235	737.772	952.144	848.898	708.142	819.484

Estimator	channel4	channel23	channel24	channel21	channel3	channel22
Outliers	883.493	32.355	0	212.62	23.03	0
	884.456	40.473	0	213.598	25.838	0
	890.717	49.488	0	216.438	39.745	0
	891.415	72.519	0	852.363	717.214	0
	894.117	73.86	0	855.184	718.327	0
	896.248	75.725	0	856.582	718.479	0
	896.642	78.402	0	856.896	719.878	0
	897.831	741.669	0	857.943	720.053	0
	0	748.853	0	859.074	726.072	0
	0	749.196	0	859.23	728.523	0
	0	750.194	0	859.727	730.287	0

Table 5

Characteristic values of the numerical sequences recorded on the supports of the working bodies on the last two lines of the cultivator, fig. 2.

Estimator	channel19	channel20	channel2	channel1	channel17	channel18
Quartile 25%	447.741	453.983	447.364	549.359	553.246	387.216
Quartile 50% (average)	547.388	547.463	538.532	647.453	645.225	498.408
Quartile 75%	633.375	645.753	613.511	737.416	745.357	583.189
Minimum value	187.088	168.468	235.692	269.748	265.451	109.325
Maximum value	888.558	932.78	837.404	1017.000	1031.000	876.94
Outliers	0	45.992	0	144.373	195.285	878.22
	0	47.423	0	145.925	197.299	878.774
	0	54.576	0	148.274	199.931	884.484
	0	62.594	0	152.759	200.239	885.01
	0	68.012	0	157.282	205.016	886.038
	0	83.789	0	160.3	210.232	887.059
	0	94.841	0	163.122	218.006	887.376
	0	95.706	0	173.422	220.185	887.995
	0	98.932	0	186.968	223.329	889.027
	0	99.315	0	191.447	230.535	893.136
	0	103.517	0	212.417	236.918	893.692

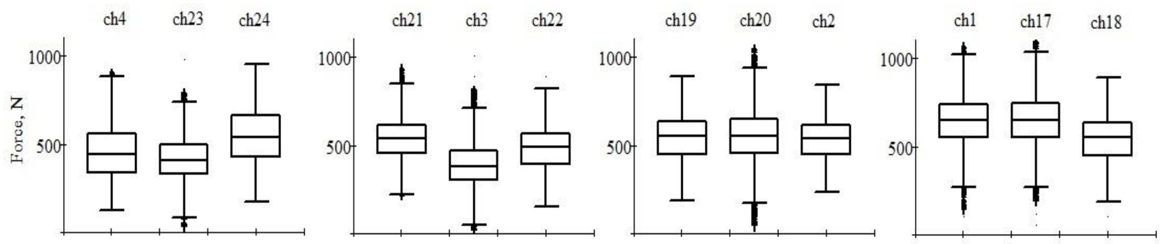
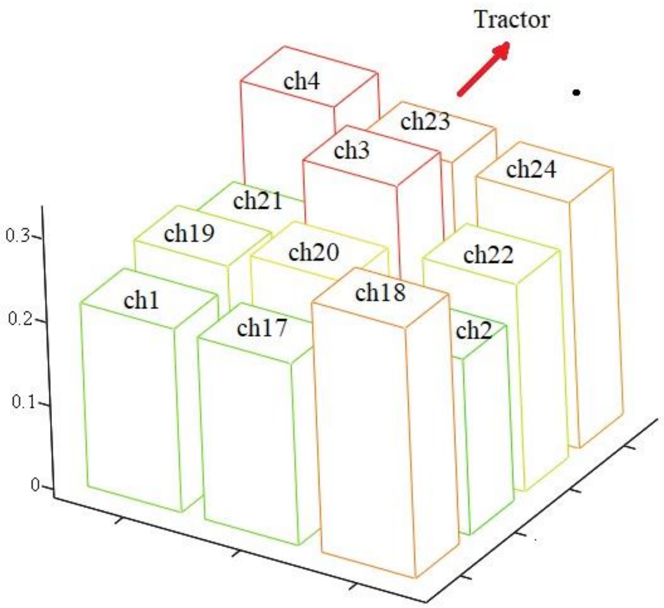


Fig. 12 - Statistical boxplot for the twelve numerical series

Table 6

The values of the correlation coefficient between the numerical sequences recorded from the supports of the 12 working bodies

	ch4	ch23	ch24	ch21	ch3	ch22	ch19	ch20	ch2	ch1	ch17	ch18
ch4	1	0.143	-0.053	0.317	0.210	0.006	0.101	0.170	0.024	0.072	0.105	0.064
ch23	0.143	1	0.323	-0.157	0.193	0.298	-0.031	0.192	0.204	-0.031	0.238	0.250
ch24	-0.053	0.323	1	-0.119	0.224	0.645	0.080	0.300	0.314	0.034	0.403	0.117
ch21	0.317	-0.157	-0.119	1	0.038	-0.038	0.409	0.035	0.161	0.370	0.149	0.071
ch3	0.210	0.193	0.224	0.038	1	0.241	0.123	0.434	0.213	0.007	0.145	0.062
ch22	0.006	0.298	0.645	-0.038	0.241	1	0.195	0.297	0.394	0.176	0.356	0.097
ch19	0.101	-0.031	0.08	0.409	0.123	0.195	1	0.043	0.091	0.502	0.171	-0.051
ch20	0.170	0.192	0.300	0.035	0.434	0.297	0.043	1	0.299	0.196	0.401	0.251
ch2	0.024	0.204	0.314	0.161	0.213	0.394	0.091	0.299	1	0.192	0.363	0.364
ch1	0.072	-0.031	0.034	0.370	0.007	0.176	0.502	0.196	0.192	1	0.404	0.092
ch17	0.105	0.238	0.403	0.149	0.145	0.356	0.171	0.401	0.363	0.404	1	0.320
ch18	0.064	0.250	0.117	0.071	0.062	0.097	-0.051	0.251	0.364	0.092	0.320	1



0.330	0.303	0.295
0.219	0.327	0.248
0.243	0.264	0.211
0.220	0.218	0.300

Fig. 13 - The distribution of the coefficient of variation (CV) on the twelve supports of the working bodies.

2. The migration of the maximum effort on the set of the supports of the working bodies

Although there is a global maximum of the load that is recorded throughout the experimental sequence, over all the working bodies (1057.49 N at the left rear body, respectively channel ch1, Table 1), a maximum of the loads exists at each time point of the recordings. An image related to the random intensity of the process can be given by the displacement or migration of this maximum load between the supports of the twelve working bodies. If the maximum load would not move or would oscillate between two, maximum three working bodies, then the information would raise the suspicion of a certain determinism, which could be explained either by constructive defects or by special structuring of the soil in which the work was done.

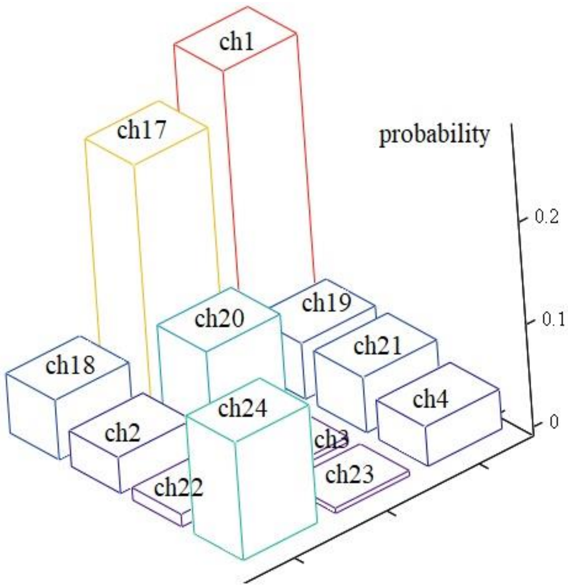


Fig. 14 - The probability of locating the maximum demand during the experiment

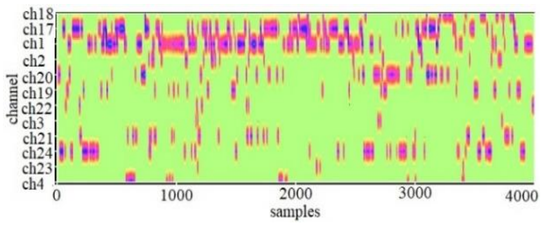


Fig.15 The migration of the maximum value of the stress on the set of supports of the working bodies.

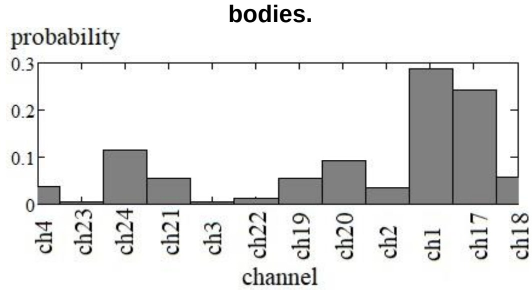


Fig. 16 - The probability of locating the maximum demand during the experiment

3. Analysis of the randomness of experimental data sequences

To estimate the random or deterministic character of the twelve strings of numerical data from the supports of the working bodies, relative entropy was used as a measure *(Cardei P., 2022).* The calculus of the relative entropy uses histograms of the 12 data series, similar to those in Fig. 5, 7, 9 and 11.

The histograms contain 200 classes each, in order to obtain the best possible precision. The obtained results are given in Table 7: the signal identified by the channel of origin, the number of classes required to reach the stopping criterion, n_h, the entropy value, E, of the maximum entropy, E_{max}, and of the relative entropy e_r. Also, in the last two columns, the coefficient of variation (see also fig. 13), CV, and the amplitude of the string values above the average value, SM, are given.

Table 7

Relative entropy values for the twelve numerical sequences, using two criteria for stopping the iterations, according to *Cardei (2022)*

	Discreet stopping criterion				Continuous stop criterion					
channel	n_h	E	E_{max}	e_r	n_h	E	E_{max}	e_r	CV	SM
4	85	6.043	6.443	93.790	84	5.997	6.392	93.818	0.330	2.974
23	80	5.779	6.358	90.894	84	5.812	6.392	90.920	0.303	3.038
24	85	6.106	6.443	94.765	83	6.038	6.375	94.721	0.295	2.618
21	79	5.744	6.340	90.597	84	5.795	6.392	90.650	0.219	3.350
3	87	5.840	6.476	90.189	84	5.761	6.392	90.118	0.327	3.361
22	81	5.911	6.375	92.726	84	5.928	6.392	92.742	0.248	2.797
19	82	5.986	6.392	93.648	84	5.986	6.392	93.648	0.243	2.693
20	80	5.598	6.358	88.056	84	5.630	6.392	88.076	0.264	3.477
2	81	5.950	6.375	93.338	84	5.968	6.392	93.356	0.211	2.721
1	83	5.738	6.409	89.531	84	5.721	6.392	89.506	0.220	3.530
17	86	5.818	6.459	90.064	84	5.750	6.392	89.951	0.218	3.209
18	80	5.930	6.358	93.268	84	5.963	6.392	93.287	0.300	2.748

According to the classification criteria proposed in *(Cardei P., 2022),* all the twelve numerical strings examined have an intensely random character, the relative entropies generally having values higher than 90%. For comparison, the string of the first 4000 prime numbers has an entropy value between 99.665% and 99.753%, calculated with histograms having 200 classes. It is found that the relative entropies obtained using two different criteria for stopping the iterations give similar results and hierarchies, the correlation coefficient between the two columns being 1. It is found that the strings of relative entropies in Table 7 are not correlated with the coefficient of variation, CV and are intensely anticorrelated with the series of amplitudes above the average, for the analysed experimental data sequences.

4 Cumulative probabilities

This subchapter presents the first applications in the analysis of numerical series as random strings, for the design of the supports of such working bodies.

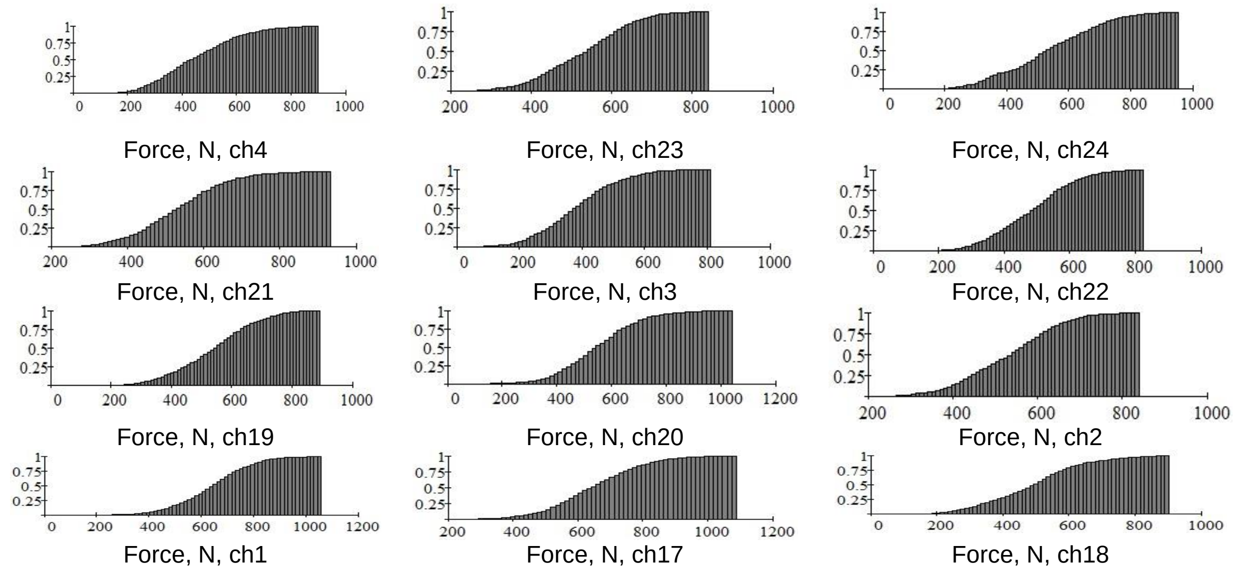


Fig. 17 - Cumulative probabilities for the twelve locations from which the signals were recorded with the deformation sensors

Starting from the histograms in Fig. 5, 7, 9, and 11, were calculated the cumulative probabilities which are plotted in Fig. 17. The cumulative probabilities thus calculated allow the determination by a convention of the resistance characteristics of the shape and material of the supports of the working bodies accepting a probability of the occurrence of an unwanted event (overload or reaching a limit value of the Von Mises stress in the measured or dangerous section).

The results given in Fig. 17 show that, for example, for the working body indexed ch1, the probability of registering load values lower than 1008 N is 99.5% or 0.995, and the probability of registering load values lower than 508 N is 18.2%. In other words, to cover 99.5 of the load cases at working body 1, it is necessary to design resistance to more than 1000 N.

These factors are taken into account for each working body during a later statistical analysis phase together with the determination of resistance to the relevant load and, given the presence of vibrations, resistance to fatigue.

Comments: The analysis of the results obtained for the experimental data series generated by the soil work process carried out with the 1 m width work variant of the MCLS, refers to those aspects examined in connection with the characterization of data randomness. All the statistics used for the analysis of the signals whose records are shown in Fig. 4, 6, 8, and 10, are used in aim to diagnose them as deterministic or random. Visual examination of the signals does not reveal the details necessary to decide whether the twelve signals are random or deterministic. The histograms (Fig. 5, 7, 9, and 11) show that the distribution of values of the experimental series does not fall, in general, between the classic ones used in statistics (normal, Gamma, exponential, Rayleigh, etc.). Many of the histograms of the twelve experimental series examined could be roughly approximated by the normal, Rayleigh, Poisson, Gamma, Beta or other distributions. However, such approximations do not help us in the random or deterministic characterization of the examined strings. There is a path of investigation in this direction, but it is being developed. However, it is important that between the twelve histograms, there are visible differences, not only in value but also in shape. Most show more than one maximum concentration of values, so an approximation with a normal or Poisson distribution cancels this information, for example. The differences between the characteristic histograms of the examined strings are the first piece of information that leans towards their random characterization.

Before examining the results of the basic and descriptive statistics, the results were arranged in Tables 1, 2 and 3, the statistical estimators were written in a matrix of four lines and three columns, corresponding to the placement of working bodies with supports on the resistance frame of the cultivator, fig. 2. It should be mentioned that the supports and the working bodies are not aligned in the direction of movement, but, to facilitate the passage of vegetable remains, they are slightly offset from each other.

The maximum values above 700-800 N and the minimum values, below 100 N, are excluded from the analysis of the quartiles in the representations in Fig. 12, where the specified values are declared outliers, according to *(MathSoft, Inc., 2000).* For practical purposes, it is observed that the average value over all the working bodies varies between 385.6 and 650.4 N, and the average value over all the working bodies has the value 518.4 N. The coefficient of variation of the average values over the twelve signals is 0.149 or 14.9%, which shows that the average variation is not very large, however, over 10% (a usual reference value). The standard deviation and the variance are implied in the comments about the estimators in Tables 1 and 3. The median is approximately equal to the average value for all twelve signals. These small differences affirm the central tendency of the examined experimental data and implicitly the small values of the asymmetry coefficient (skew). The asymmetry coefficient is still approximately null for each series of data, three of them with deviations to the right, the remaining nine with deviations to the left compared to the centre given by the average value.

The flattening index (or curvature coefficient, kurtosis) is zero for distributions with tails, generated by the presence of outliers. The distributions with thin and high peaks, having positive values of the buckling index, correspond to series with long tails and are called leptokurtic, and those with thick and small peaks, with negative values of the buckling index, have small tails and are called platykurtic. The distributions for which the vaulting index is zero are called mesokurtic *(Clocotici V., 2023).* In the case of the experimental strings examined in this article, there are two leptokurtic strings (channels 1 and 20, the rest being platykurtic). The data series collected on channels 1 and 20 have the most outliers, Fig. 12. The coefficient of variation, CV, allows the comparison of two series of experimental data from the point of view of the standard deviation. A small coefficient of variation indicates a better clustering around the mean value. From Table 3, it can be seen that the coefficients of variation are appreciable for all data series, higher for those with lower average loadings and lower for those with the highest average loadings.

The absolute size of the coefficients of variation and the differences between the coefficients of variation of the different signals are additional arguments for appreciating that the examined strings have a random character rather than a deterministic one. The value of the coefficient of variation over all the values of the CV matrix has the value 0.167 or 16.7%, which leads to the same conclusion of the randomness of the examined signals. Representations of the distribution of the coefficient of variation over the spatial distribution of the working bodies are given in Fig. 13. The graphic representation confirms the conclusions resulting from the examination of the numerical results in Table 3.

A numerical breakdown of the graphic representations in Fig.12 is given in Tables 4 and 5. Tables 4 and 5 also provide the values considered aberrant according to *(MathSoft, Inc., 2000)*, readers being able to see how many such values there are for each data string. It is found that there are four strings without outliers *(Nia M.Z., et al. 2023; Cardei P., 2022; Gill W.R., et al., 1967; Gao W., et al., 2021).*

Possible connections between the twelve strings (of a linear nature) can be detected by calculating the correlation coefficient. Table 6 presents the matrix of correlation coefficients in the rows of the set of experimental data examined. It was noticed that the dependencies are negligible, the highest value being 0.645, an insignificant value for linear dependency. This means that the twelve strings vary relatively independently, so another suggestion for the random characterization of the twelve strings.

The last test, which is specific to the estimation of the random character of a numerical sequence, proposed by *Cardei P., (2022),* clearly shows that the twelve strings are part of the first fourth of the strings with the most intense random character. For example, they are comparable to the randomness of the sequence of the first 4000 prime numbers, but below it.

In addition to the above, an important aspect in deciding the random character of the structure formed by the twelve working bodies is given by the migration of the maximum load over all the bodies, preferentially for some, but none excepted, which can be seen from the representations graphs from Fig. 14.

Fig. 18 - Photographic identification of one of the reasons that lead to the overloading of the working bodies on the last line of the cultivator

After the theoretical analysis, it was found through the analysis of the images (Fig. 18) taken during the experiments that one of the reasons why the working bodies from the rear of the cultivator are more intensively stressed. It is observed that the method of connecting to the tractor and maintaining the working depth is not able to eliminate the inclination of the supporting structure from the tractor to the back, so that the working bodies from the back of the structure work at a greater depth, in general than those in front of the cultivator.

CONCLUSIONS

The results presented in Chapter 3 and discussed in Chapter 4 show that posing the problem of the degree of randomness of the experimental data series makes sense, and has chances of solution and quantification.

The characterization of the intensity of the random character can be done first, even if only suggestively, through a series of estimators of descriptive and inferential statistics. Even if they do not quantify the randomness of a lot of experimental data, classical estimators can suggest the random character of the examined data as it was showed in the comments chapter.

The special estimator that is proposed as a quantifier of randomness (the degree of randomness or random intensity), the relative entropy, undoubtedly places all the data strings examined in the first quarter of the random strings, slightly below the randomness of prime numbers, but on par, in general, with pseudorandom strings generated by various methods.

In addition, as a confirmation of the decision given by means of relative entropy, it is worth mentioning the convergence of the assessment given by relative entropy with that obtained by using descriptive and inferential statistical estimators.

Consequently, it is recommended that the approach to the dynamics of such agricultural machinery be made as much as possible in terms of statistics and statistical dynamics. Thus, the stress sequences of the machines will be considered random sequences, given by random signals that must be treated in terms of reference to the theory of random signals. Also in these terms, the design of such machines must be done, especially their resistance structures.

The last conclusion refers to the fact of having already succeeded in using the MCLS complex cultivator to obtain some results and some consequences:

-for the soil that was worked with, there is no specific working body or a series of working bodies that are permanently the most stressed;

-the detection of a reason why the working bodies in the last line, counting from the tractor, due to the backward tilt given by the clamping system, register higher stress forces, this aspect also being noted on the photos.

The experimenters and designers of agricultural machines for soil processing know a number of physical reasons why the working processes of these machines are considered to have a random character: the anisotropy and inhomogeneity of the soil including the inhomogeneity of its moisture, the play in the joints of these machines, the deformations of the soil surfaces, the inclusions of plant residues, etc. This article brings in addition the possibility of quantifying the random character and the indication of the investigation of the problems of these machines using statistical dynamics, the theory of random functions.

As directions for the continuation of these researches, there are:

- mathematical modelling of the working process of agricultural machines intended for soil processing within the random systems theory;
- the inclusion of the working speed parameter in the mathematical modelling, although, in general, the critical speeds at which the component generated by the forward speed exceeds the static component of cutting the soil, are not reached (the desire for high productivity often leads to a decrease in the quality of the works);
- continuation of investigations in search of precise quantifications of the degree of randomness of some numerical strings.

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