RELATIONSHIP BETWEEN THE INFLUENCE FACTORS OF THE SOIL TILLAGE PROCESS

Sorin-Ștefan Biriș[1], Neluș-Evelin Gheorghiță[1]*, Nicolae-Valentin Vlăduț[2], Mihai-Gabriel Matache[2], Edmond Maican[1], Mihaela-Florentina Duțu[1], Ramona-Maria Chiru[1]

[1]University "Politehnica" of Bucharest, Faculty of Biotechnical Systems Engineering, Splaiul Independenței, 313, Bucharest, 060042, Romania

[2]National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry Bucharest, B-dul Ion Ionescu de la Brad nr. 6, Bucharest, 013813, Romania

Abstract

It is known that the soil tillage process for the sowing of the crops is one of the most important agricultural works involving both large energy consumption and high costs. The quality of seed-bed preparation influences the degree of germination and crop productivity. The soil tillage process is influenced by many factors. Usually, these factors are: pedological factors (soil texture, organic matter, clay mineralogy, soil structure, soil bulk density, moisture content, respectively: external friction, soil-metal adherence, soil cohesion, soil resistance to penetration), technological factors (forward speed, working depth, working width), and constructive factors (type of tool, geometry of tool, technical condition of tool, adjustment mode of tool). All these factors determine the mechanical energy necessary to effectuate the soil tillage process, energy which contain the following terms: energy required to cut the soil, energy required to overcome the external friction forces, energy required to move the soil, energy required to overcome the adhesion forces, energy required for displacement of the tools, and the energy required to overcome the inertia forces (if the speed of the agricultural machine is not constant). In this paper, more complex scheme of the soil tillage process and the relationships between the factors of influence are presented, with concrete application for the agricultural vibro-cultivator used in conservation tillage systems, which can make the preparation of the seedbed for sowing in one pass with minimum consumption of energy, without causing the degradation of agricultural soil.

Keywords: *agricultural machine, tillage, mathematical modeling, seedbed, cultivator*

1. INTRODUCTION

Agricultural soil is one of the most diverse and important ecosystems on Earth [1], and the process of tillage in order to prepare the germination bed is very complex and involves the most important energy consumption of all agricultural works and high costs [2]. The quality of seedbed preparation influences the degree of germination and crop productivity [3].

Traditional tillage operations are growing more costly in terms of time, fuel, and equipment expenditures, as well as creating significant soil damage and compaction due to the increased number of passes necessary for traditional implements during seedbed preparation [4]. In the present drought-induced climate change, conservative soil cultivation operations offer an alternative to traditional soil processing (ploughing). Combined tillage is the way in which two or more different tillage implements operates at the same time in order to manipulate the soil and reduce the number and time of field operations. It was envisaged that such an implement would affect considerable saving of time, fuel and energy. This would also reduce the cost of operation. There was an efficient and potential reduction in the soil compaction, labour and fuel cost, saving in time and reduction of multiple tillage operation in single pass. The conventional tillage practices are becoming increasingly expensive in terms of time, fuel and equipment costs and are also causing more soil damage and compaction due to higher number of passes required for the conventional implements during seedbed preparation [4].

The combinator, which can be fitted with active bodies, type notched disks, chisel, and levelling, is currently one of the most widely used pieces of equipment for processing the germination bed in a conservative system. [5].

All the researchers who approached the issue of the tillage process, pointed out that this process is complex and is influenced by a number of different factors such as: initial soil conditions [6], technological factors [7], [8] factors of the tillage machines [9], [10], the final conditions imposed on the worked soil layer (by qualitative indices) [3], and the energy intensity of the tillage process depends on all of them [4].

This paper presents a more complex system of the soil tillage process and the interrelations between the factors of influence. A concrete application for the agricultural vibro-cultivator used in conservation tillage systems is show, by preparing the seedbed for sowing in one pass with minimal energy consumption and without going to cause agricultural soil degradation.

2. MATERIALS AND METHODS

2.1. Tractor-combinator unit used for experiments

The experimental researches for the determination of the qualitative and energetic indices with the soil processing equipment (seedbed preparation) in a conservative system, were made in Arad Region (Romania), on an area of about 30 ha, using a John Deere 8530 (350 HP) tractor (Fig. 1).

The experimental model of SANDOKAN 2 vibrocombinator is designed to perform tasks such as seedbed preparation, soil loosening, and ground leveling at depths of up to 12 cm for grain crops, technological plants, and vegetables. It is outfitted with Gamma, Delta1 or Delta 2 active vibrating tools installed on four 1.75 m wide modules. The experimental model utilized in the testing is made up of two 3.5-meter-wide foldable sections outfitted with leveling blades, roller blades, crosskill rollers, and active tool modules. In order to determine the experimental data, a National Instruments acquisition system, tensometric marks, humidity meter, penetrometer, stopwatch, fuel consumption meter, furrowmeter, metric frame, 100 kg scale, bags and milestones were used [5]. The field test conditions are presented in Table 1.

Fig. 1. Soil processing equipment working in a conservative system

Source: D. Vlăduţ, et al., INMATEH - Agricultural Engineering, vol. 55, no. 2, 2018, p. 28.

Characteristics	**Results**
Type of soil	vertisol
Previous work	scarification
Previous culture	Corn
State of soil	Flat and smooth
Slope of field	2°
Mass of vegetable waste	370-380 g/m^2

Table 1. Field test conditions

2.2. The general model of the soil tillage process

For the preparation of the seedbed, tillage process is determined and influenced by a large number of factors (Fig. 2), the soil -characterized by a series of initial conditions (Fig. 4) being processed so as to satisfy a series of final conditions (Fig. 3) to allow the establishment and development of crops, after additional shredding operations, as needed.

The studies and researches in the field carried out worldwide aim to identify the way and the weight of the influence of each factor on the process of preparation of the seedbed, respectively on the final soil conditions and on the mechanical energy necessary to carry out the process.

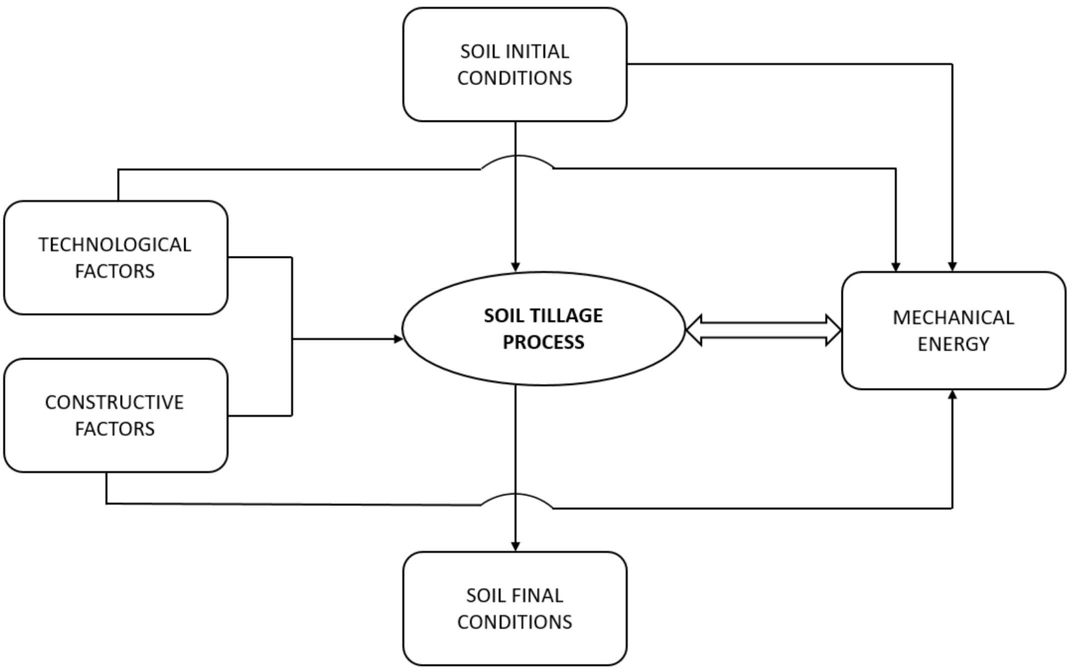

Fig. 2. Block diagram of the soil tillage process

Analyzing the block diagram in figure 2, result the dependency relations:

$$C_{fs}=C_{fs}(C_{is},W,F_T,F_C) \qquad (1)$$

where: C_{fs} –represents the soil's final conditions (Fig. 3); C_{is} –the soil's initial conditions (Fig. 4); W – the necessary energy applied to the soil (Fig. 5); F_T –the technological factors (Fig. 6); F_C –the constructive factors (Fig. 7).

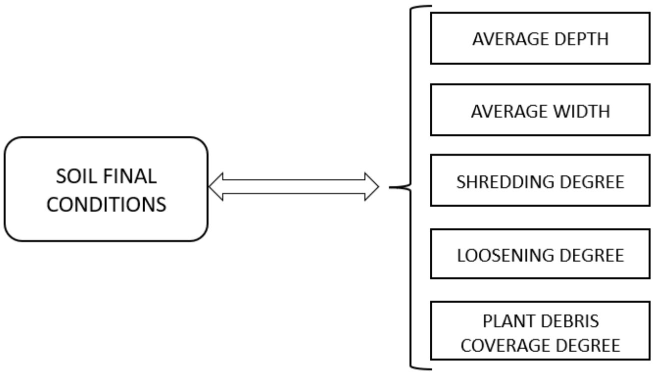

Fig. 3. Characteristic factors of the final soil conditions

Also [9]:

$$W=W(C_{is},v_m,a,b,T_C,G_C,S_t,R_t) \quad (2)$$

where: v_m –represents the forward speed of the tillage machine; a –the working depth; b –the working width of the tillage tools; T_C –the type of tillage tools; G_C –geometric characteristics of the tillage tools; S_t –the technical conditions of the tillage tools; R_t – the adjustment mode of the tillage tools.

It follows [2]:

$$C_{fs}=C_{fs}(C_{is},v_m,a,b,T_C,G_C,S_t,R_t) \quad (3)$$

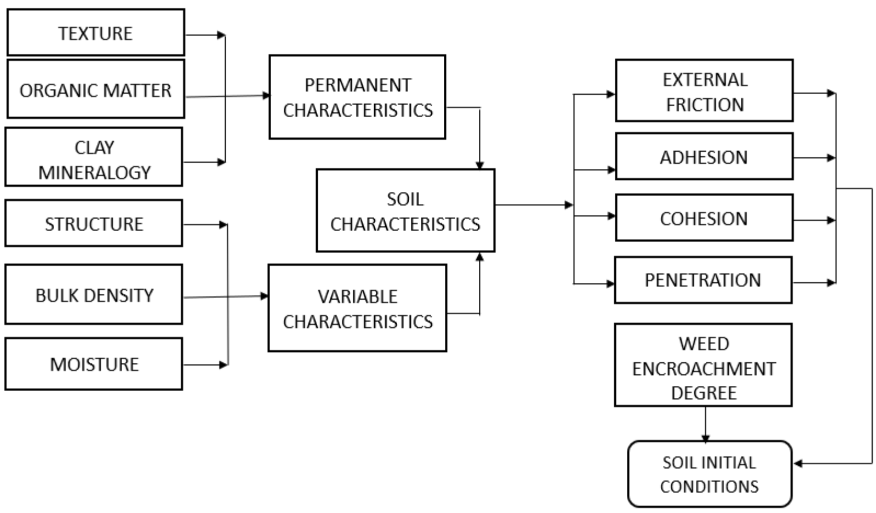

Fig. 4. Physical properties that determine the soil initial's conditions

The soil's initial conditions (Fig. 4) are determined by different physical features as [6]: soil texture (T), organic matter (O), the clay mineralogy (M_a), the soil structure (S), soil bulk density (ρ_a), moisture content (w), which the wedding degree is added to (G_b):

$$C_{is}=C_{is}(T,O,M_a,S_s,\rho_a,w,G_b) \quad (4)$$

and a series of physical-mechanical features as: the external frictional coefficient soil-metal (μ), soil adhesion (A), soil cohesion (C) and the soil's resistance to penetration (R_p) [2]:

$$C_{is}=C_{is}(\mu,A,C,R_p,G_b) \quad (5)$$

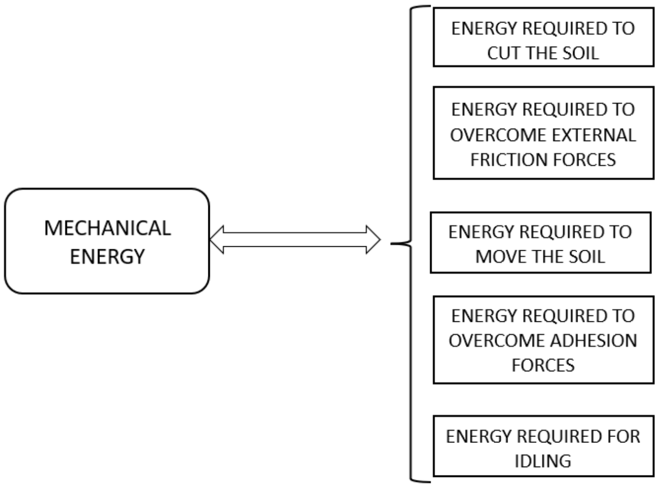

Fig. 5. Characteristics that influence the mechanical energy

Thus, the energy required to cut the ground W_1 is a function of the specific resistance to cutting the ground per unit length of the tool edge k (N/m), the length of the tool edge l (m), the speed of the tillage machine v_m (m/s), but also by the technical condition of the working bodies S_0, respectively [2]:

$$W_1=W_1(k,l,v_m,S_0) \quad (6)$$

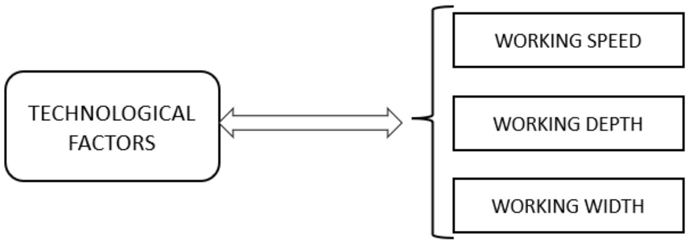

Fig. 6. Characteristics that influence the technological factors

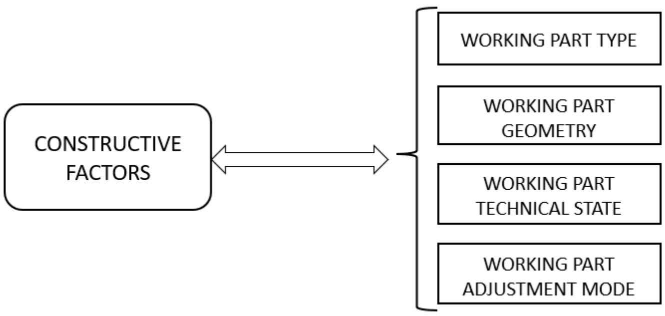

Fig. 7. Characteristics that influence the constructive factors

From the above results the special complexity of the seed-bed preparation process and also the complexity of the related research in order to optimize it. It also results the special influence that the geometry of the tillage tools has.

3. RESULTS

As a result of the experimental research carried out in the field, for the SANDOKAN combiner of the company Maschio Gaspardo, the dependence of the tensile strength (Rm) was obtained for the three variants of equipment with working elements (constructive factors) of Delta 1 type (Fig. 8) , Delta 2 (Fig. 9) and Gamma (Fig. 10), depending on the technological factors (vm - the forward speed of the tillage machine, and a - the working depth), for the same initial soil conditions.

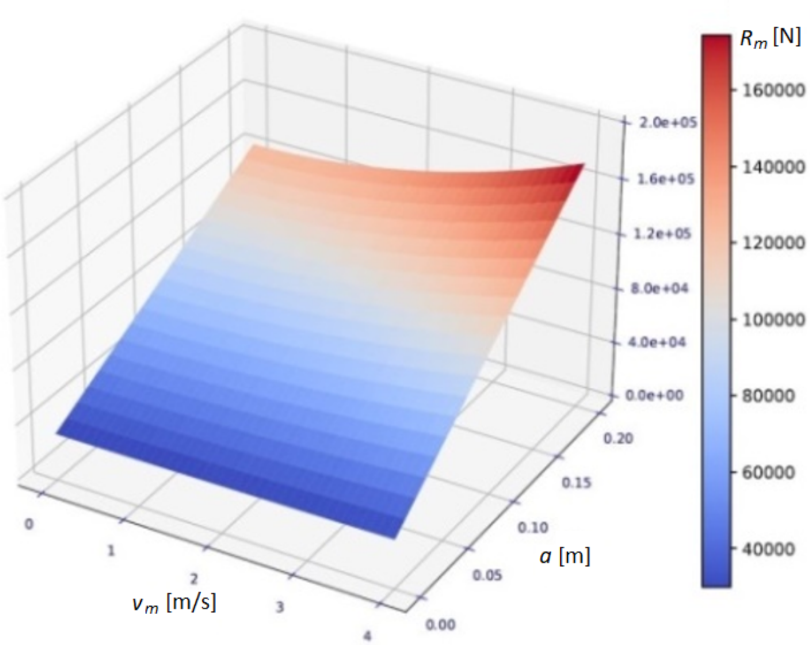

Fig. 8. Dependence of the resistant force on technological factors for Delta1 tool

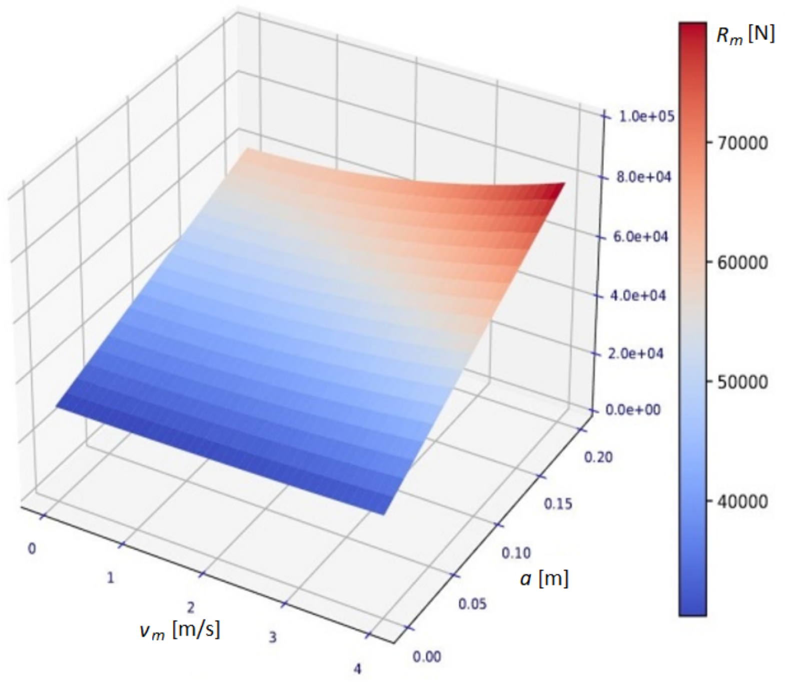

Fig. 9. Dependence of the resistant force on technological factors for Delta2 tool

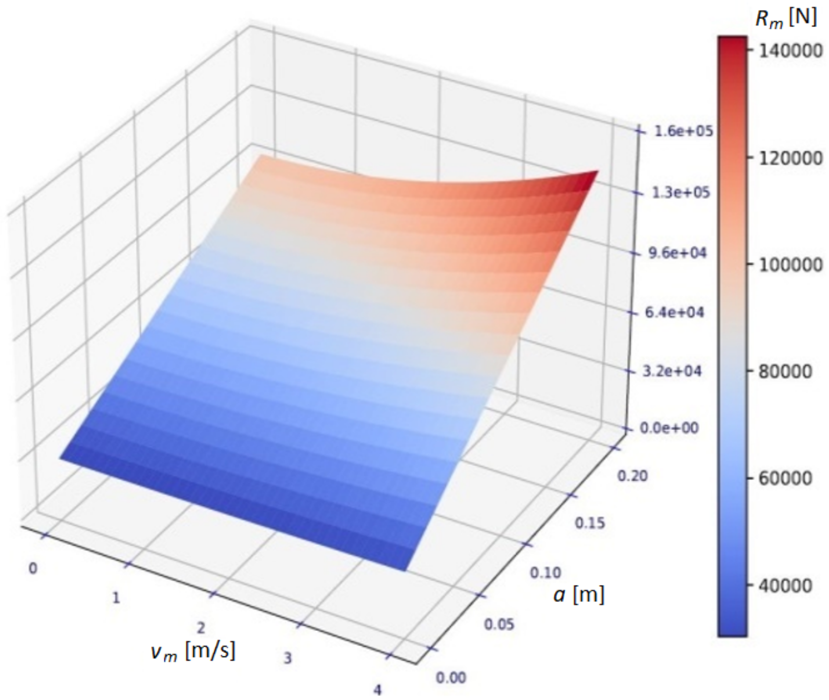

Fig. 10. Dependence of the resistant force on technological factors for Gamma tool

Table 2 shows the average values for working depth, working speed, and draft force obtained in the experimental field tests performed with the SANDOKAN combinator.

Tool type	Average working depth, a_s [cm]	Average working speed v_m [m/s]	Average draft force in field [kN]
Delta1 tool	6.09	3.37	60.29
Delta2 tool	8.95	3.32	67.26
Gamma tool	10.82	2.54	59.9

Table 2. Average values of the functional parameters for the three types of working tools

4. DISCUSSION

The working depth has the greatest impact on the researched process, according to the study of Figure 8, which shows the dependency of the resisting force on functional parameters. At a maximum speed of 4 m/s and a depth of 0.10 m, the resistant force recorded values of roughly 75 kN, which may be deemed small enough not to have a substantial influence on the equipment's optimal performance.

In Figure 9, the highest resistant force is 72 kN, which is the lowest of the three. In compared to the first, the resistant force is just around 50 kN at a working depth of 0.1 m and a speed of 4 m/s. Figure 10 shows that the values are all within the same range.

5. CONCLUSIONS

The works carried out by the equipment for seedbed preparation in conservative system can replace the classic plowing work, realizing, in a single pass, the preparation of the germination bed for sowing, even in very heavy soils. The use of this equipment aims to reduce the compactness of the soil while reducing fuel consumption.

For a more efficient process of preparing the germination bed, which means improving the quality and energy indices in terms of preserving soil properties and avoiding the phenomenon of compaction and destructuring of the soil, reducing costs and increasing productivity, it is very important to know the interdependence of influencing factors. soil processing process (constructive, technological), for different initial soil conditions and depending on the desired requirements for the final conditions of the cultivated soil.

The qualitative and quantitative dependency of the resisting force on functional parameters, constructive factors, and soil beginning state may be seen in the data reported in this work. More than the working speed, the working depth has the greatest impact on the resisting force.

REFERENCES

1. J. Roger-Estrade, C. Anger, M. Bertrand and G. Richard, "Tillage and soil ecology: Partners for sustainable agriculture," *Soil & Tillage Research,* vol. 111, pp. 33-40, 2010.

2. A. Koolen and H. Kuipers, Agricultural soil mechanics, Berlin-Heidelberg-New York-Tokyo: Springer-Verlag, 1983.

3. C. Hammond, J. Reid and W. Seigler, "Seedbed preparation behind row subsoilers," *Trans. of ASAE,* vol. 24, p. 897–901, 1981.

4. M. Prem, R. Swarnkar, V. D. K. Kantilal, P. S. K. Jeetsinh and K. B. Chitharbhai, "Combined Tillage Tools– A Review," *Current Agriculture Research Journal,* vol. 4, no. 2, pp. 179-185, 2016.

5. D. Vlăduţ, S. Biris, V. Vladut, D. Cujbescu, N. Ungureanu and I. Gageanu, "Experimental researches on the working process of a seedbed preparation equipment for heavy soils," *INMATEH - Agricultural Engineering,* vol. 55, no. 2, pp. 27-34, 2018.

6. A. Canarache, Soil physics, Bucharest: Editura Ceres, 1990.
7. M. Askari, G. Shahgholi and Y. Abbaspour-Gilandeh, "The effect of tine, wing, operating depth and speed on the draft requirement of subsoil tillage tines," *Research in Agricultural Engineering,* vol. 63, no. 4, pp. 160-167, 2017.
8. G. Shahgoli, J. Fielke, C. Saunders and J. Desbiolles, "Simulation of the dynamic behaviour of a tractor-oscillating subsoiler system," *Biosystems engineering,* vol. 106, no. 2, pp. 147-155, 2010.
9. M. Gheres, "Mathematical model for studying the influence of tillage tool geometry on energy consumption," *INMATEH - Agricultural Engineering,* vol. 42, no. 1, pp. 5-12, 2014.
10. A. Abo Al-Kheer, M. G. Kharmanda, A. El-Hami and A. M. Mouazen, "Estimating the variability of tillage forces on a chisel plough shank by modeling the variability of tillage system parameters," *Computers and Electronics in Agriculture,* vol. 78, no. 1, pp. 61-70, 2011.
11. S. Mudarisov, I. Gabitov, Y. Lobachevsky, N. Mazitov, R. Rakhimov and R. Khamaletdinov, "Modeling the technological process of tillage," *Soil and Tillage Research,* vol. 07, no. 190, pp. 70-77, 2019.