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COMPARATIVE ANALYSIS OF SOIL TILLAGE SYSTEMS REGARDING ECONOMIC EFFICIENCY AND THE CONVERSION EFFICIENCY OF ENERGY INVESTED IN THE AGROSYSTEM OF WINTER WHEAT

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Abstract

The paper presents the experimental results on the influence of different soil tillage systems and technological subsystems on the production and conversion efficiency, on the energy invested in the winter wheat crop cultivated in the Transylvanian Plain. The methodology was based on an econometric model, taking into account the combination of production factors and their limited character, as well as the two aspects of economic activity, to maximize profit and to minimize effort. The results show that by practising reduced tillage and no-tillage, the total power consumption can be reduced by 7.8%, and 12.4%, respectively, compared to the conventional system in the case of winter wheat. Up to the sowing phase (including) a decrease of 59.5% fuel consumption per hectare was achieved in the case of reduced tillage compared to the conventional system and a decrease of 78.7% fuel consumption in the no-tillage system. The highest average production was obtained whilst using the reduced tillage, followed by the one from the conventional and no-tillage systems. The highest degree of total energy efficient use (R_{EE} =5.84) as well as the highest net energy (E_N)were obtained in the reduced tillage system, followed by the no-tillage. The econometric analysis shows that any additional energy consumption of input factors in the conventional system, like human labor requirement, energy incorporated in machinery and fuel consumption had negative effects on yield and leads to a comedown of the economic and energetic balance. The aforemention factors had the following negative values of elasticity coefficients: -0.5264, -0.5965 and -0.2629. The chemical fertilizers (+0.3237) and chemicals (+0.1074) had positive effects on the wheat yield. Surprisingly, the effect of seeds was not significant. The highest quantity of energy spent for the production of winter wheat was indirect and non-renewable.

Key words: *soil tillage system, winter wheat, econometric analysis, energy use efficiency.*

INTRODUCTION

In order to satisfy the growing need for food, for a population continually growing, the intensification of agricultural technologies, and the practice of an energo-intensive agriculture is imperative.On the other hand, this intensification, due to a continually decreasing of productive arable surfaces, led to physical soil degradation.

Today it is unanimously accepted that certain components of the intensive agricultural technological systems like: excessive soil loosening (by deep plowing), elimination of vegetal debris (or deep incorporation), excessive fertilization etc., together with the reduction of organic matter from the soil can have a significantly negative influence upon the productivity of agricultural ecosystems and the preservation of basic natural resources (soil and water; Rusu, 2013).

Current preoccupations for adopting conservation agricultural systems resulted in the need for intensifying research in order to introduce new technological systems. These new systems need to take into consideration the cultivated species, crop rotation, soil and climate conditions, having as major objectives to optimize the soil productivity and at the same time to preserve the basic natural resources and reduce the risk of environment pollution.

The most important advantages of conservation tillage systems (minimum tillage, no-tillage, mulch tillage etc.) (Stošić et al., 2017) are: restoring the organic matter and preserving water, especially during the drought years (Melaj et al., 2003); reducing soil erosion (Basic et al., 2004); improving and ensuring the biological life of the environment and natural habitat for many species of living micro-organisms (with an important role in the biological nitrogen fixation and in the normal ongoing of physical, chemical and biological natural processes in the soil which result in maintaining fertility) (Bottinelli et al., 2010); improving the level of organic carbon, with an important role in the crop production (Reicosky and Aecher, 2007); improving the soil physical characteristics, with an important role in ensuring the best vegetation conditions for plants (Gus and Rusu, 2011; Esfahani et al., 2017); and reducing the energy and labour consumption (Rathke et al., 2007; Nail et al., 2007).

There are also a few disadvantages of applying reduced tillage systems, ,ike: the modification of pedomorphological and physical soil indicators in a certain direction takes place slowly (Constantin, 2008); morphological heterogeneity of soil horizons transversally (Cara et al., 2008); low protein content in the case of wheat (Cociu and Alionte, 2011); low protein and gluten content in the case of durum wheat, both in the reduced and no-tillage systems compared to the conventional system (Andrzej et al., 2014); an increased emission of N_2O (Rochette, 2008); more sources for diseases and pests (Fernandez et al., 2008); reduced productions (Jug et al., 2011; Stošić, 2012); production reductions of up to 20-25% for corn (Filipović et al., 2004; Sartori and Peruzii, 1994) more evident in the no-tillage system; losses can limit to 5-10% in the case of winter wheat, which is considered the most highly adapted to reduced or no-tillage systems (Filipović et al., 2004).

Using only certain production indicators to highlight how agrosystems work does not reflect exactly the ecological impact of the crop system practised. The energetic analysis is a multidisciplinary concept with both energetic and technologically specific connotations (Zadmirzaei et al., 2015).

The multilateral evaluation of energetic consumptions in the producing agrosystems may suggest solutions to the applied technological systems and subsystems with a view to optimize their agroecological placement, taking into account the soil agrophysical characteristics, the climate, the biological resources, and the technical capital; all in a sustainable context, in order to improve the relation consumption-efficiency and the soil pedomorphological and physical indicators by reducing the risk of erosion.The objective of this paper is to obtain a comparative analysis of soil tillage systems regarding economic efficiency and the conversion efficiency of energy and determine the laws of variation in time and space of some economic and energy indicators (depending on the variation of quantifiable inputs) using an econometric model - the Cobb-Douglas function.

MATERIALS AND METHODS

Starting with the very important role of winter wheat in the agro-food system, analysis of the conversion efficiency of the energy invested in the wheat agrosystem allows us to evaluate the specific energy consumed in order to obtain harvest units under different production conditions. In order to convey as accurately as possible the effects of practising soil tillage systems and technological subsystems, in other words to *know the variation of physical laws governing in time and space* of certain economic and energetic indicators, according to the variation of input, quantifiable factors, an *econometric model* was used (Cobb-Douglas function) like:

$$Y = f(x) * \exp(u) \qquad (1)$$

which can also be written as:

$$\ln Y_i = a_0 + \sum \alpha_i * \ln X_{ij} + e_i; \ i = 1, 2, .., n$$

and j = 1, 2, ..., m (2)

where:

Y_i - economic indicator (production);

α_i - production elasticity coefficients compared to the input factors;

X_{ij} - vector of the input factors used by the producer;

a_0 - proportionality coefficient;

e_i - term of the experimental error.

The management decisions regarding the combination of production factors taking into consideration their limited character and also the two aspects of an economic activity are *to maximize profit in order to minimize effort*. This decisions will be facilitated by these production functions.

The most important indicator of these functions is the production elasticity. The production elasticity, compared to the factors determining it is defined as a ratio between the percentage modification of production and the percentage modification of resources (the changeable factor).

The production percentage increases when the consumption in a certain factor increases by one percent. Therefore, if we have Q-production and K-capital factor (input) we will have:

$$\%\Delta Q = \Delta Q/Q \quad and \quad \%\Delta K = \Delta K/K,$$

where:

$$\epsilon_K = \frac{\%\,\Delta Q}{\%\,\Delta K} = \frac{\Delta Q/Q}{\Delta K/K} = \frac{\Delta Q/\Delta K}{Q/K} = \alpha$$

(ratio between the marginal and average efficiency).

Also, for the complete study, the following indicators of energetic efficiency shall be calculated:

- rate of energy efficiency (energetic efficiency) (R_{EE}):

$$R_{EE} = \frac{E_O\,(output\ energy,\ Mj*\ ha^{-1})}{E_i(input\ energy,\ Mj*\ ha^{-1})} \quad (3)$$

- productive energy (Ep):

$$\mathrm{Ep} = \frac{Y(productia,\ kg*\ ha^{-1})}{E_i(input\ energy,\ Mj*\ ha^{-1})} \quad (4)$$

- specific energy (E_S):

$$E_S = \frac{E_i(input\ energy,\ Mj*\ ha^{-1})}{Y(productia,\ kg*\ ha^{-1})} \quad (5)$$

- net energy (E_N):

$$E_N = E_O - E_i[Mj * ha^{-1}] \quad (6)$$

In order to estimate the equivalent energy of input factors, the standard energetic indicators were used (Table 1).

Table 1. Energies specific to agriculture production

No.	Input/output	Unit	Energy equivalent [MJ/unit]	Reference
1	**Input**			
1.1	Human labor	h	1.96	Beheshti et al., 2010; Hatirli et al., 2005
1.2	Diesel fuel	l	56.31	Naderlloo et al., 2013; Singh, 2002
1.3	Machinery	h	62.7	Naderlloo et al., 2013; Singh, 2002
1.4	Nitrogen (N)	kg	78.1	Fakher et al., 2014; Beheshti et al., 2010
1.5	Phosphate (P_2O_5)	kg	17.4	Fakher et al., 2014; Esengun et al., 2007
1.6	Potassium (K_2O)	kg	13.7	Beheshti et al., 2010; Esengun et al., 2007
1.7	Herbicides	kg	269	Karaagac et al., 2011; Ferrago, 2003
1.8	Fungicides	kg	115	Fakher et al., 2014; Hussain et al., 2010
1.9	Insecticides	kg	214	Karaagac et al., 2011; Ferrago, 2003
1.10	Transportation	$\mathrm{MJ}\cdot t_0^{-1}\cdot Km^{-1}$	4.5	Kitani, 1999; Fluck and Baird, 1982
1.11	Wheat seeds	kg	15.7	Gökdoğan et al., 2016; Cicek et al., 2011
2	**Output**			
2.1	Wheat	kg	14.7	Ozkan et al., 2004; Cicek et al., 2011;
2.2	Straw	kg	9.25	Moghimi et al.,2013;Tabatabaeefar et al., 2009

The balance of energy to achieve productivity energy was achieved with the relationship:

$$E_i = E_d + E_{ind} + E_p \qquad (7)$$

where:

E_d - direct active energy (energy coming from: human labor, diesel fuel, irrigation, electricity);

E_{ind} - indirect active energy (energy necessary to produce certain products consumed in one production process: seeds, pesticides, fungicides, herbicides, chemical fertilizers etc.);

E_p- passive energy (it refers to expenses related to the energy incorporated in machinery and which is transmitted to the agricultural product: depreciations etc.).

For the study of the maximum efficiency of energetic resources and the reduction of energy consumptions, another energy balance was also researched:

$$E_i = E_r + E_{Nr} \qquad (8)$$

where:

E_r - energy of renewable resources (human labor, seeds, water for irrigation);

E_{Nr} - energy of non-renewable resources (fuel, pesticides, fertilization,electricity, machinery).

The vector $\widehat{\beta}$, estimator of model parameters is determined from Gauss' normal equations by M.C.M.M.P. with the relation:

$$\hat{\beta} = [X^T * X]^{-1} * [X^T * y] \qquad (9)$$

Testing the hypothesis for autocorrelation or non-correlation of errors and the validation of results supposes finding out the Durbin-Watson indicator (Jula, 2011) with the relation:

$$\text{DW} = \frac{\sum(e_i - e_{i-1})^2}{\sum e_i^2} \qquad (10)$$

The residual sum from the above relation (11) is calculated using the formula:

$$\sum e_i^2 = y^T * y - \hat{\beta}^T * X^T * \text{y} \qquad (11)$$

where:

X - matrix of experimental conditions;

y - matrix of experimental results;

β - column vector of coefficients b_i;

n - number observations;

The correlation is expressed in % as an indicator of association, and was determined with the relation:

$$\eta^2 = \frac{\widehat{\beta}^T * X^T * \text{y} - \text{n} * \bar{y}^2}{y^T * y - \text{n} * \bar{y}^2} \qquad (12)$$

The data used in this study is based on the results obtained in the experiments at the Agricultural Research and Development Station Turda, during 2009-2013, on a Phaeosiom, with a clayey-loamy texture, neutral pH and 3.5% content of humus. The energy required for each tillage system was determined by measuring the fuel consumption with the volumetric machine and the labour was recorded by monitoring the time up to the end of each activity from each treatment. For the levelling action, the experimental field was left as a fallow field for one year, after which it was plowed.

The experiment was organized on batches of 50 m x 8 m each, disposed in subdivized parcels as follows:

- **conventional tillage system (CT)** included: mouldboard plowing 22-25 cm deep, disk harrow (8 cm) + rotary harrow (2 passings), combination harrow, sowing + fertilization (SUP 29 - pneumatic seed drills);
- **conservative tillage with reduced tillage (RT)** included: heavy disk harrow (10-12 cm), sowing + fertilization (Directa 400 - direct sowing);
- **no-tillage system (NT)** included: sowing + fertilization (Directa 400- direct sowing).

The main plots were represented by the soil tillage system, where as the subplots were represented by blocks, initially randomly disposed, with the crop rotation, in a 4 year rotation: *soybean-winter wheat-corn- spring two-row barley*.

The experimental agricultural years, characterized by temperature and rainfall regime were very different. Year 2009/2010 was warm, with annual average temperatures of 10.3°C, which meant +1.4°C above the multiannual average over 55 years (8.9°C). As far as rainfall, there was a deficit of 27.2 l/mp compared to the multiannual average (520.6 mm).The agricultural year 2010-2011 was a rainy year, precipitation exceeding the multiannual average by 226.2 mm and temperature by 0.6°C.

The agricultural year 2011-2012, was a normal year from regarding temperature. Rainfall was scarce, making it a slightly droughty year, with a deficit of 20.6 mm compared to the multiannual average.

The agricultural year 2012-2013 was a normal from the point of view of rainfall, with just one deficit of 12.2 mm, but when it comes to temperature it was a very hot year, exceeding the multiannual average by +1.5°C, the hottest months being July-August.

RESULTS AND DISCUSSIONS

The experimental results on the characteristics studied for each cultivated species, according to the soil tillage practised were evaluated on each year. Based on the analysis of tillage systems in the case of the winter wheat crop (Table 2), results show that the conventional soil tillage recorded the highest fuel consumption. By practising the reduced tillage system, 34.7 liters of fuel were saved, meaning a reduction of 59.5% of the energy spent per hectare, compared to CT system, and a reduction of 78.7% in the NT variant. By calculating one of the most important energetic indicators, *partial specific energy* ($M_j \cdot Kg^{-\mathbf{1}}$) (the consumption from the systems tested up to the sowing phase), and comparing it to the production average during these 4 years, we noticed that in the NT system is the highest saving of energy per kilogram/product, that is 0.121$M_j \cdot kg^{-\mathbf{1}}$, which means a reduction, up to this technological phase, of the specific expense, by 78.2% compared to the CT system and by 41.8% compared to the RT system.As far as human labor requirement is concerned (productivity), there is a reduced productivity in the CT system, of 4.284 $\mathrm{h \cdot ha^{-1}}$, while in the RT and NT systems there is a saving of 70.1%, respectively 79.1%.

The energy invested in the agrocenosis of the winter wheat crop is presented in Table 3. Setting up the percentages of the energy consumed per unit of main agricultural productwas assessed up to harvest and transport (including) time. By analyzing the values of energy equivalent to input factors one can notice that total input/hectare in the production of winter wheat varies according to the system applied. The highest consumption was registered in the CT system, 23538.9 $[Mj/unit]$, followed by the RT system with an energy saving of 7.8% and by the NT, of 12.4%, compared to the CT system. The highest contribution to total energy (E_i) in all systems was the *fertilization factor* with a variation of up to 7% among the systems. The contribution of the fuel factor to *total input* varied according to the tillage system as follows: 21.81% in the CT system, 16.5% in the RT system, and 14.5% in the NT system.

Table 2. Energy and labour requirement of different soil tillage systems (up to sowing)

Tillage system	Fuel diesel $\mathrm{L \cdot ha^{-1}}$ (average years)	Energy $\mathrm{M_j \cdot kg^{-1}}$ (average)	Rate work $\mathrm{ha \cdot h^{-1}}$	Productivity	
				$\mathrm{h \cdot to^{-1}}$	$\mathrm{h \cdot ha^{-1}}$
Conventional tillage system, average yield = 5920 kg·ha^{-1}					
Ploughing with reversible plough	29.5	0.281	0.630	0.268	1.587
Discing + harrow	2 x 7.5	0.143	1.371	0.123	0.729
Combinator	6.8	0.065	1.560	0.108	0.641
SowingFertilization	5.2	0.049	1.02	0.165	0.980
	1.8	0.017	2.875	0.059	0.347
Total	58.3	0.555	-	0.723	4.284
Conservative system with reduced work, average yield = 6370 kg·ha^{-1}					
Discing with heavy disk	13.4	0.118	2.08	0.076	0.481
Direct sowing + fertilization	10.2	0.090	1.25	0.125	0.800
Total	23.6	0.208	-	0.201	1.281
No-tillage system, average yield = 5780 kg·ha^{-1}					
Direct sowing + fertilization	12.4	0.121	1.12	0.154	0.893

Table 3. Energy balance of wheat crops production for the period 2009-2013 (for the whole production)

Type of energy	Unit	Consumption, (average years)[$unit$)/ha]			Energy equivalent, [Mj/ha]		
		CT	RT	NT	CT	RT	NT
Human labour	h	13.6	8.4	7.9	26.65	16.46	15.48
Energy incorporated in machinery	h	32.5	27.7	14.6	2037.7	1736.8	915.4
Diesel fuel	L	91.2	63.9	53.2	5135.5	3598.2	2995.6
Fertilizer	kg				11630	11630	11630
Nitrogen (N)		120	120	120			
Phosphate (P_2O_5)		92	92	92			
Potassium (K_2O)		48	48	48			
Chemicals: herbicide, fungicides, insecticides	kg				470.1	470.1	811.5
Wheat seed	kg	270	270	270	4239	4239	4239
Total input energy					23538.9	21690.6	20607
Total output energy					117756	126703	115509
Wheat grain	kg	5920	6370	5780	87024	93639	84966
Straw	kg	3322	3575	3302	30732	33064	30543

Considering the human labor, the lowest consumption, of 15.48 Mj/ha,was emphasized in the NT system. Due to the machine system used, a high expense with the incorporated value, (2037.7 Mj/ha) in the case of the CT system was noticed.

The results regarding the use of energy in the winter wheat crop (Table 4) we noticed that the highest degree of efficient energy use was obtained in the RT system (R_{EE} =5.84). The lowest indicator of the productive energy was in the CT system (Ep=0.25) which together with the indicator of the specific consumption which was the highest (E_S=3.97) in this study showed that the conventional soil tillage system is a low efficiency system ($R_{EE} = 5$), with the lowest net energy (94220 Mj $* ha^{-1}$). Net energy close to this value was also obtained in the case of the NT system, but for this technological variant, the efficiency rate of using the energy was much higher ($R_{EE} = 5.61$).

The other energy balances were also researched for the study of maximum efficiency of energetic resources and the reduction of energy consumptions (Table 5). The energy distribution according to this classification is as follows: direct energy in the CT system was 21.93%, in the RT system 16.66%, and in the NT system 14.61%; differences up to 100% of total energy is indirect energy. Table 5 shows that the highest quantity of energy spent in the production of winter wheat was *indirect and non-renewable energy*. To this end, the following components contributed greatly (in order): *fertilization, seed, fuel consumption, and energy incorporated in machinery*. At the same time, the high contribution of the components highlighted show their intensive use in current agrosystems, which calls for a detailed study on the relation between the energy of input factors and the productive energy (output).

Table 4. Indicators of energy use of wheat crops production

Type of indicators	Unit	Quantity		
		CT	RT	NT
Input energy	Mj $* ha^{-1}$	23538.9	21690.6	20607.0
Output energy	Mj $* ha^{-1}$	117756	126703	115509
Energy use efficiency (R_{EE})	-	5.00	5.84	5.61
Energy productivity (Ep)	$kg * ha^{-1}$ / Mj $* ha^{-1}$	0.25	0.29	0.28
Specific energy (E_S)	Mj $* ha^{-1}$ $kg *$ ha^{-1}	3.97	3.41	3.56
Net energy (E_N)	Mj $* ha^{-1}$	94220	105012	94902

Table 5.Total energy input in the form of direct, indirect, renewable, non-renewable energy for wheat

Type of energy	Unit	Quantity		
		CT	RT	NT
Direct energy	$\text{Mj} * ha^{-1}$	5162.15	3614.66	3011.08
Indirect energy	$\text{Mj} * ha^{-1}$	18376.75	18075.94	17595.92
Renewable energy	$\text{Mj} * ha^{-1}$	4265.65	4255.46	4254.48
Non-renewable energy	$\text{Mj} * ha^{-1}$	19273.25	17435.14	16352.52
Total energy input	$\text{Mj} * ha^{-1}$	23538.9	21690.6	20607.0

In order to emphasize the different impact of input factors on the level of production obtained, in other words in order to determine the contribution rate for each one with positive or negative effect on the production obtained we decided to use the *Cobb-Douglas* function with it's specific indicators.

We will approach this study in the case of the *the conventional wheat cultivation system*, using the econometric model according to equation 2, both for the analysis of the input factor with the productive energy relation as well as for the impact of direct, indirect, renewable and non-renewable energies on the production. Thus, we will emphasize *the physical laws governing in time and space* of these indicators with economic and energetic effect, according to the variation of input factors.

The values of equivalent energies of the input factors, as well as the final form determined from the models and the values of elasticity coefficients which appreciate each one's effect are presented in Table 6. The results show that the input energies of the factors: *chemical fertilization, preventing and treatment products* have a positive effect on the output, which means that in the case of an increase by one unit for each one, the production increases by 0.32%, respectively by 0.11%. On the contrary, one can say that any additional energy consumption for the other factors: *consumption of human labour, energy incorporated in machinery and the one associated to the fuel* consumed, with negative values of the elasticity coefficients (- 0.5264; - 0.5965; - 0.2629), results in worsening of the economic and energetic balance.

In order to test the series correlation of errors, in other words in order to see if a previously dependent value is or is not affected by the error of the other dependent value, the Durbin-Watson indicator was calculated (DW). For the significance threshold of $\alpha = 0.05$, and the number of exogenous factors, k=6, from the Durbin-Watson table, the two indicators: $d_L = 0.268$ (lower limit) and $d_U = 2.832$ (upper limit) were taken. Using relation 11, the calculated Durbin-Watson indicator fits into the following interval: $d_L < \text{d} = 1.08 < d_U$, which allowed us to make decisions (one cannot decide upon autocorrelation).

The results of this study, in the case of cultivating wheat in the CT system, during a period with oscillating climate phenomena (2009-2012), significantly reflected the variations of temperature and rainfall, which shows once again that climate changes have a negative effect upon production and production costs.

A secondary objective of this study was to determine the relation between the total output and the balance components of the input energy. One can notice the big percentage of energy consumption from the indirect category (78.07%) and from the non-renewable one (81.87%), as well as their different impact on the total output. From the econometric model used for studying the relation of renewable and non-renewable components of energy, results showpositive effect of renewable energy upon production. According to the size and sign of the elasticity coefficients (Table 6) one can appreciate the influence of renewable and non-renewable components of energy upon total output in this wheat cultivating system.

Table 6. Econometric estimation results of input for wheat production for the period 2009-2013

Type of energy / exogenous factors	Consumption, ln[Mj/ha]				Average
	2009	2010	2011	2012	
Human labor $[X_1]$	3.375	3.476	2.861	3.406	3.2795
Machinery $[X_2]$	7.567	7.625	7.636	7.647	7.6187
Diesel fuel $[X_3]$	8.492	8.549	8.561	8.571	8.5432
Fertilizer $[X_4]$	9.328	9.216	9.215	9.626	9.3462
Chemicals $[X_5]$	5.925	6.066	6.019	6.498	6.1270
Wheat seed $[X_6]$	8.191	8.223	8.456	8.501	8.3427
Renewable energy	8.1981	8.2317	8.4600	8.5067	8.3491
Non-renewable energy	9.8219	9.7817	9.7829	10.0514	9.8599
Direct energy	8.497	8.556	8.564	8.577	8.5485
Indirect energy	9.751	9.697	9.755	10.036	10.0603
Total input	10.0018	9.9741	10.0206	10.2448	10.065
Outputs (endogenous factor)-Production	11.672	11.500	11.809	11. 700	11.6702
Model: $y=\alpha_0+\alpha_1 \ln X_1+\alpha_2 \ln X_2+\alpha_3 \ln X_3+\alpha_4 \ln X_4+\alpha_5 \ln X_5 + \alpha_6 \ln X_6+e_i$					
Constant	$\alpha_0 = +16.4904$				
Human labor $[X_1]$	$\alpha_1 = -0.5264$				
Machinery $[X_2]$	$\alpha_2 = -0.5965$				
Diesel fuel $[X_3]$	$\alpha_3 = -0.2629$				
Fertilizer $[X_4]$	$\alpha_4 = +0.3237$				
Chemicals $[X_5]$	$\alpha_5 = +0.1074$				
Wheat seed $[X_6]$	$\alpha_6 = +0.000139$ (ns)				
Durbin – Watson (DW)	DW = 1.08				
Correlation, η^2	0.98				
Model: $y=\alpha_{00}+\alpha_{11} \ln X_{11}+\alpha_{22} \ln X_{22}+e_{ii}$					
Constant	$\alpha_{00} = +9.1364$				
Renewable energy $[X_{11}]$	$\alpha_{11} = +0.7195$				
Non-renewable $[X_{22}]$	$\alpha_{22} = -0.3523$				
Durbin–Watson (DW)	DW = 2.38				
Correlation, η^2	0.99				

The standard deviations of the coefficients are calculated with the relation (Jula, 2011):

$$\boldsymbol{s_{b_i}} = \sqrt{\boldsymbol{s_{b_i}}^{2}} = \sqrt{\boldsymbol{s_i}^{2} * \boldsymbol{c_{ij}}} \qquad (13)$$

where :

$s_i^2 = \frac{\sum e_i^2}{n-k-1} = 0.00262$ - mean square of residual error;

$\boldsymbol{c_{ij}}$ -element situated on the main diagonal line of the reverse matrix: $[X^T * X]^{-1}$;

The sum of squares of standard deviations of estimators $\boldsymbol{s_{b_i}}^{2}$ is calculated:

$$s_{b_i}{}^{2} = 0.00262 * \begin{bmatrix} 1939 & - & - \\ - & 21.466 & - \\ - & - & 31.434 \end{bmatrix} = \begin{bmatrix} 5.080 \\ 0.0556 \\ 0.0823 \end{bmatrix}$$

For the significance threshold of $\alpha = 0.05$ from the Student table, the theoretical value of the test, $t_{\alpha,n-k-1}$ is compared to the calculated value , $t_{calc} = b_i * (\sqrt{s_{b_i}}^{2})^{-1}$, in order to appreciate the significance of each coefficient.

From an econometric point of view, by analyzing the process of cultivating winter wheat according to the elasticity scalewe conclude a production process with a decreasing scale efficiency, $\alpha_{11} + \alpha_{22} < 1$ *-which practically means that a certain increase of the input factors generates an increase of the output, to a smaller extent.*

Testing the autocorrelation error hypothesis, starting from the supposition of the lack of correlation between the terms of the error variable from the econometric model imposed the calculation of Durbin-Watson indicator.

For the significance threshold of $\alpha = 0.05$ and the number of exogenous factors, k = 2 from Durbin-Watson table, the two indicators: $d_L = 0.861$ (the lower limit) and $d_U = 1.562$

(the upper limit) were taken; the Durbin-Watson indicator was calculated, to fit into the following interval: d_U <DW= $2.38 < 4 - d_U$which allowed us to take the decision: errors are independent, therefore one can accept the independence hypothesis of the values of residual variables.

CONCLUSIONS

Mechanized systems are energy intensive, but by practising reduced tillage and no-tillage systems the energy consumption can be reduced by 7.8%, respectively, 12.4% compareed to the conventional system in the case of winter wheat crop. The highest degree of energy efficient use ($R_{EE} = 5.84$) as well as the highest net energy was obtained in the reduced tillage system, followed by no-tillage system.

The use of an increased number of machinery for conventional tillage leads to water reduction in the soil, soil compacting and destruction of soil structure, most of the times accounting for reduced productions. The lowest indicator of productive energy is found in the conventional tillage system (Ep = 0.25) which, together with the indicator of specific consumption, the highest (E_S= 3.97) in this study, showed that the conventional system is a low efficiency one ($R_{EE} = 5$).

Regarding the production of winter wheat, the highest percentage of energetic consumptions is held by indirect energy given mainly by the energy of consumed chemical fertilization. The economical and energetic analyses, in order to improve the relation *consumption - efficiency,* emphasized that any additional energy consumption in the conventional system of input factors like: *consumption of* human labor*, energy incorporated in machinery and the one due to the fuel consumed,* with negative values of the elasticity coefficients (-0.5264; -0.5965; -0.2629), results in the worsening of the economic and energetic balance. Also, the chemical fertilizers (+0.3237) and chemicals (+0.1074) had positive effects on the wheat yield. The effect of seeds was not significant.

The results show that the process of cultivating winter wheat in the conventional system can be seen as a production process with a decreasing scale efficiency, *which practically means that a certain increase of the „input" factors generates an increase of the output, to a smaller extent.*

In order to get the best energy consumption in the agricultural production, there are two ways: either we increase productivity by maintaining existing consumptions at the same level or we reduce consumed energy by using different methods without affecting productivity.

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