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Energy efficiency and soil conservation in conventional, minimum tillage and no-tillage

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Abstract

The objective of this research was to determine the capacity of a soil tillage system in soil conservation, in productivity and in energy efficiency. The minimum tillage and no-tillage systems represent good alternatives to the conventional (plough) system of soil tillage, due to their conservation effects on soil and to the good production of crops (Maize, 96%–98% of conventional tillage for minimum tillage, and 99.8% of conventional tillage for no till; Soybeans, 103%–112% of conventional tillage for minimum tillage and 117% of conventional tillage for no till; Wheat, 93%–97% of conventional tillage for minimum tillage and 117% of conventional tillage for no till. The choice of the right soil tillage system for crops in rotation help reduce energy consumption, thus for maize: 97%–98% energy consumption of conventional tillage when using minimum tillage and 91% when using no-tillage; for soybeans: 98% energy consumption of conventional tillage when using minimum tillage and 93 when using no-tillage; for wheat: 97%–98% energy consumption of conventional tillage when using minimum tillage and 92% when using no-tillage. Energy efficiency is in relation to reductions in energy use, but also might include the efficiency and impact of the tillage system on the cultivated plant. For all crops in rotation, energy efficiency (energy produced from 1 MJ consumed) was the best in no-tillage — 10.44 MJ ha^{-1} for maize, 6.49 MJ ha^{-1} for soybean, and 5.66 MJ ha^{-1} for wheat. An analysis of energy-efficiency in agricultural systems includes the energy consumed-energy produced-energy yield comparisons, but must be supplemented by soil energy efficiency, based on the conservative effect of the agricultural system. Only then will the agricultural system be sustainable, durable in agronomic, economic and ecological terms. The implementation of minimum and no-tillage soil systems has increased the organic matter content from 2% to 7.6% and water stable aggregate content from 5.6% to 9.6%, at 0–30 cm depth, as compared to the conventional system. Accumulated water supply was higher (with 12.4%–15%) for all minimum and no-tillage systems and increased bulk density values by 0.01%–0.03% (no significant difference) While the soil fertility and the wet aggregate stability have initially been low, the effect of conservation practices on the soil characteristics led to a positive impact on the water permeability in the soil. Availability of soil moisture during the crop growth period led to a better plant watering condition. Subsequent release of conserved soil water regulated the plant water condition and soil structure.

Key Words: No-tillage, Minimum tillage, Yield, Energy efficiency, Soil conservation

1 Introduction

Cultures respond to the system of soil tillage in a way that is hard to predict. The results depend on one hand on the soil characteristics and microclimate and on the association of different practices, such as: the amount of soil preparation, the sowing dates, the equipment used, the crop rotation, the species or the hybrid used, the way in which it is fertilized (the time and the way it is applied), and weed control. The relation between the production – its profit & energy efficiency and the systems of soil tillage, is mostly influenced by the previous management of the soil and by weather. Consequently, the use of new systems of soil tillage must occur with managerial input, considering the results acquired by research and the creation of new species & hybrids

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and technology.

Sustainable agricultural activity must be organized in a system, scheduled in a sequence and always analysed as part of the relationship: soil-plant-climate area-socio-economic conditions-crop-efficiency (Wang et al., 2008; Bucur et al., 2011; Afzalinia et al., 2012; Domuta et al., 2012). Recommendation of flexible and multifunctional technologies consequently aims at reducing the consumption of energy, particularly in the field of aggressive soil tillage, as well as obtaining high yields, soil conservation and environmental protection (Jitareanu et al., 2006; Li and Mu, 2006; Marin et al., 2011; Ailincai et al., 2011; Gao et al., 2012).

The essence of the living system consists in the unique capacity of plants to convert, through photosynthesis, the solar energy, carbon dioxide and water into biochemical alimentary energy. Therefore, a successful measure in agriculture is the quantity of energy gathered under the form of biomass, as a result of efficient human and fossil energy use (Jones, 1989; Glendining et al., 2009; Coman and Rusu, 2010; Jackson et al., 2011; Akdemir et al., 2012).

Soil tillage has as its main purpose a series of immediate effects (with a positive side), resulting from the objectives of the soil tillage themselves: basic tillage, germinal layer preparation, field maintenance. Still, the effects of soil tillage can often have an immediate positive or negative short or long term lasting effects, (Marin et al., 2012; Molnar et al., 2012; Moraru and Rusu, 2012; Ranta et al., 2012; Rusu and Bogdan, 2012; Stanila et al., 2012; Zhou et al., 2012).

The influence of soil tillage systems on soil properties and energy efficiency is shown by the important factors of soil fertility conservation and evaluation of the sustainability of the agricultural system (Uhlin, 1998; Rusu, 2001; Sarauskis et al., 2009; Vural and Efecan, 2012). Long-term field experiments have provided excellent opportunities to quantify the long-term effects of soil tillage systems on accumulated soil water (Rusu et al., 2006; Romaneckas et al., 2009; Ponjican et al., 2012). The hydrological function of the soil (especially the capacity to retain optimum water quantity, and then gradually make this available for plant consumption) is one of the most important functions determining soil fertility, productivity and soil evolution. Intrinsic soil properties such as organic matter and texture, along with applied tillage practices combine to modify the soil structure, porosity, permeability and water capacity. This, in turn, is a critical factor in the water cycle and affects water accumulation in the soil. The conservation of soil fertility requires a tillage system that optimizes the plant needs in accordance with the soil modifications, that ensures the improvement of soil features and the continuous producing of high crop yields. Thus, the conservation of soil fertility is tied to maintaining and improving the soil fertility indices and to the productivity of the tillage system.

The objective of this paper is to determine the capacity of the soil tillage system in soil conservation, in productivity, and in ensuring optimized energy efficiency.

2 Materials and methods

The experiments were conducted at the University of Agricultural Sciences and Veterinary Medicine in Cluj Napoca, Romania (Fig. 1; 46º 46' N, 26º 36' E), on a moderately fertile Fluvisoil (SRTS, 2003). The humus content was 3.01%, pH was 7.2, and soil texture was clay (42% clay in the arable stratum). The experimental field has an annual temperature of 8.2℃ and annual rainfall of 613 mm.

Fig. 1 Experimental field

Treatments used in the study were:

A. Conventional tillage (CT): V_1-classic plough (20–25 cm) + disc harrow-2 times (8 cm).

B. 3 Minimum tillages (MT):

a. V_2-paraplow (18–22 cm) + rotary harrow (8 cm);

b. V_3-chisel plough (18–22 cm) + rotary harrow (8 cm);

c. V_4-rotary harrow (10–12 cm).

C. No-tillage (NT): V_5-direct drill with Accord Optima Hard Drive (HD) for hoeing and Universal Pneumatic Seeders (SUP) adapted for wheat.

All soil tillage was accomplished during the autumn period for wheat; for maize and soybeans the plough, paraplow, chisel plough were used in the autumn. For the germinal layer preparation, the disc harrow and rotary harrow were used in the spring. The crop rotation was: maize-*Zea mays* L., soy-bean-*Glycine hispida* L. Merr. and wheat-*Triticum aestivum* L.

The experimental design was a randomized complete block design with three replications. The area of a plot was 300 m^2. Except for the soil tillage system, all other variables were held constant, including the herbicide used: wheat-post emergent dicamba 120 g l^{-1} + 2.4D 300 g l^{-1}, 0.9 l ha^{-1}; maize-pre emergent acetochlor 820–860 g l^{-1} + antidote, 2.5 l ha^{-1} and post emergent dicamba 120 g l^{-1} + 2.4D 300 g l^{-1}, 0.9 l ha^{-1}; soybeans-pre emergent acetochlor 820–860 g l^{-1} + antidote, 2.5 l ha^{-1} and post emergent bentazon 480 g l^{-1} + Wettol 150 g l^{-1}, 2.5 l ha^{-1}.

To quantify the change in soil properties under different tillage practices, determinations were made for each culture in four vegetative stages (spring, 5–6 leaves, bean forming and harvest). Soil parameters monitored included soil water content (gravimetric method, Aquaterr probe-Frequency domain reflectometry), soil bulk density (determined by volumetric ring method using the volume of a ring 100 cm^3), water stable aggregates (Czeratzki method), soil permeability (using the Infiltrometer method) and organic matter content (Walkley-Black method). The indicators were determined according to the methodology described in the Agrotechnics-practical work (Rusu et al., 2012), the aim being the knowledge of soil functions. The average values obtained during the vegetal phases were statistically analysed using ANOVA and Duncan's test (PoliFact, 2010). A significance level of $P \leqslant 0.05$ was established a priori.

Regarding energy assessment, the most realistic means of comparison of various agricultural technologies remains energy efficiency, using the following indicators: Energy Efficiency Factor: e = (Er-Ec)/Er (MJ); Energy Yield: γ = Er/Ec (MJ); Energy Report r = Ec/Er (MJ). Where: Er —energy as gathered biomass (MJ); Ec — technologically consumed energy to produce this biomass (MJ).

Consumed and produced energy represent in fact a sum of inputs and outputs in the technological process. Consequently: Er = Erp+Ers (MJ). Where: Erp — energy corresponding to primary harvest; Ers — energy corresponding to secondary harvest.

Technologically consumed energy has several components: Ec=Ect+Ecm+Ecs+Ecf+Ecp+Ecu+Eo (MJ). Where: Ect — energy consumption related to the tractor (MJ); Ecm — energy consumption related to agricultural machinery (MJ); Ecs — energy consumption related to seeds (MJ); Ecf — energy consumption related to fertilization (MJ); Ecp — energy consumption related to pesticides (MJ); Ecu — energy consumption related to human work resources (MJ); Eo — energy consumed in other ways (MJ). Each component is the sum of elementary energies specific to each technological operation. Quantification of consumed energy and of the produced energy has been achieved on the basis of equivalents mentioned in specialty literature (Fluck and Baird, 1980; Tesu and Baghinschi, 1984; Pimentel, 1992).

The equivalence indicators are:

Energy consumed: basic tillage-classic plow: 1,102.98 MJ ha^{-1}; paraplow: 853.92 MJ ha^{-1}; chisel: 782.76 MJ ha^{-1}; rotary grape: 711.6 MJ ha^{-1}; direct sowing: 978.24 MJ ha^{-1}. Preparation of the germinative layer-disc: 426.96 MJ ha^{-1}; rotary grape: 640.44 MJ ha^{-1}. Fertilization:135.97 MJ ha^{-1}. Materials — 1 kg N: 92.51 MJ; 1 kg P_2O_5: 20.34 MJ; 1 kg K_2O: 14.84 MJ; 1 l diesel oil: 35.58 MJ; 1 kg bentazone: 252.5 MJ; 1 kg acetochlorine: 101.3 MJ; 1 kg dicamba: 294 MJ; 1 kg insecticide, fungicide: 205.2 MJ. Sowing-maize: 160.11 MJ ha^{-1}; soy bean: 160.11 MJ ha^{-1}; wheat: 192.13 MJ ha^{-1}. Herbicides: 46.25 MJ ha^{-1}. Harvest: 511.99 MJ ha^{-1}. Human work force: 1.318 MJ/person/hour. Other energy inputs: 426.96 MJ ha^{-1}.

Energy produced — 1 kg maize: 16.41 MJ; 1 kg maize cob and straw: 15.29 MJ; 1 kg soy bean: 20.79 MJ; 1 kg soy stems: 15.42 MJ; 1 kg wheat: 16.06 MJ; 1 kg wheat straws: 15.26 MJ.

3 Results and discussion

The soil tillage system influences the yields obtained in a differentiated way, depending on the culture type (Table 1). The highest maize yield is with plough and no-tillage systems. Paraplow and chisel give smaller yields (6,710–6,730 kg ha^{-1}), with statistically ensured differences (significantly negative) and confirmed by the test of multiple comparisons, Duncan's test (ab). The smallest maize productions were obtained with rotary harrow, the differences being distinctly negative, statistically ensured (b). Soybean culture had the best reaction within the rotation, both with the no-tillage (very significant positive differences as compared to the plough), as well as with minimum soil tillage system, with paraplow and rotary harrows (ab). For wheat culture no-tillage ensure highest yield, 3,986 kg ha^{-1}, and the lowest production has been achieved with chisel (93.4%).

Table 1 The influence of different soil tillage systems upon plant yield for maize, soybean and wheat crops

Soil tillage systems	Classic plough +disc-2x	Paraplow+rotary harrow	Chisel plow+rotary harrow	Rotary harrow	No Tillage
Maize (kg ha^{-1})	6,860 a	6,730 ab	6,710 ab	6,583 b	6,849 a
Significance (%)	^{wt}(100)	^{0}(98.1)	^{0}(97.8)	^{00}(96)	^{ns}(99.8)
Soybean (kg ha^{-1})	3,025 b	3,385 ab	3,113 b	3,313 ab	3,546 a
Significance (%)	^{wt}(100)	**(111.9)	^{ns}(102.9)	**(109.5)	***(117.2)
Wheat (kg ha^{-1})	3,730 ab	3,615 ab	3,486 b	3,612 ab	3,986 a
Significance (%)	^{wt}(100)	^{ns}(96.9)	^{0}(93.4)	^{ns}(96.8)	*(106.9)

Note: wt — witness, ns — not significant, *positive significance, ^{0}negative significance (*^{,0}significantly; **^{,00}significantly distinct; ***^{,000}very significantly), a, ab, b, c — Duncan's classification (the same letter within a row indicates that the means are not significantly different).
Maize: DL5%=100.01 kg ha^{-1}, DL1%=151.45 kg ha^{-1}, DL0.1%=243.30 kg ha^{-1};
Soybean: DL5%=190.75 kg ha^{-1}, DL1%=271.16 kg ha^{-1}, DL0.1%=392.62 kg ha^{-1};
Wheat: DL5%=241.21 kg ha^{-1}, DL1%=338.57 kg ha^{-1}, DL0.1%=477.99 kg ha^{-1}.

Quantity of energy consumed and produced depends primarily on the culture, values being higher, especially in energy produced from maize, but it also depends on the soil tillage system. The quantity of energy produced in maize depends on the soil tillage system, and is highest for the plough system (Table 2). Energy efficiency is influenced by the soil tillage system, and is higher in no-tillage (e=0.9042, 101%), followed by the chisel and paraplow systems (100.1%). the Energy efficiency is influenced by the energy consumed within every technologic system, the smaller the consumed energy within the system, the higher the efficiency. The high energy yield in no-tillage (γ=10.44 MJ ha^{-1} energy produced for each unit of energy input, chisel (γ =9.66 MJ ha^{-1}) and paraplow (γ =9.65 MJ ha^{-1}), as compared to the plough system (γ =9.54 MJ ha^{-1}), shows that these systems had a higher energy efficiency. The amount of produced energy, in maize culture, was highest for the plough system. The intense soil mobilization, in conjunction with the effects produced in the soil linked to the release of adequate nutrients and providing necessary conditions for maize development ensures the highest production. Intense impact on soil does not, however, always have positive effects. Eventually, the energy efficiency demonstrates the superiority of the no-tillage and minimum tillage systems, in terms of energy consumption reductions and optimization of the agricultural technologic system.

Table 2 The influence of the soil tillage system on energy efficiency in maize culture

System	Energy (MJ)		Energy Efficiency		Energy yield (γ)	Energy report (r)
	Consumption (%)	Produced	e	%		
Classic plough + disc-2x (wt)	22,364.09 (100)	213,418.78	0.8952	100	9.54	0.104
Paraplow + rotary harrow	21,902.55 (97.9)	211,284.48	0.8963	100.1	9.65	0.103
Chisel plow + rotary harrow	21,830.39 (97.6)	210,956.28	0.8965	100.1	9.66	0.103
Rotary harrow	21,759.23 (97.3)	200,646.19	0.8915	99.6	9.22	0.108
No-Tillage	20,425.41 (91.3)	213,237.27	0.9042	101.0	10.44	0.096

The energy required for setting up and maintaining the soybean culture for the conventional system represents 25,364 MJ ha^{-1} and decreases to 97.6%–98.2% for MT and decreases to 92.8% for NT (Table 3). Energy efficiency is superior in all systems as compared to the plough, soy reacting very well with the MT and NT systems. Energy yield confirms this positive reaction, the results being 6.49 MJ ha^{-1} for NT and 5.51–5.97 MJ ha^{-1} for MT, for each MJ ha^{-1} consumed.

Table 3 **Influence of soil tillage system on energy efficiency in soybean culture**

System	Energy (MJ)		Energy Efficiency		Energy Yield (γ)	Energy report (r)
	Consumption (%)	Produced	e	%		
Classic plough + disc-2x (wt)	25,364.09 (100)	132,858.00	0.8091	100	5.23	0.191
Paraplow + rotary harrow	24,902.55 (98.2)	148,669.20	0.8325	102.9	5.97	0.167
Chisel plow + rotary harrow	24,830.39 (97.9)	136,723.98	0.8184	101.1	5.51	0.182
Rotary harrow	24,759.23 (97.6)	145,507.96	0.8298	102.5	5.88	0.170
No-Tillage	23,546.75 (92.8)	152,740.32	0.8458	104.5	6.49	0.154

In the case of the autumn wheat culture, technology is the energy equivalent to 23,272 MJ ha^{-1} through the CT system (Table 4). Application of MT reduces energy consumption to 97.4%–98%, and NT to 91.6%, compared with the plough system. The influence of the soil tillage system on the amount of gathered energy reflects on energy efficiency, where, in comparison with the plough system, a higher efficiency for NT has been calculated (100.4%). Energy efficiency has been reduced in the other systems, but it does not fall below 99%. Energy yield shows that for each MJ ha^{-1} consumed a larger amount of energy is obtained with no-tillage (γ=5.66 MJ ha^{-1}), and the lowest yield was recorded with the chisel plough system, 5.32 MJ ha^{-1}. The energy report has the best value in no-tillage (0.177), followed by the plough system (0.179).

Table 4 **Influence of soil tillage system on energy efficiency in wheat culture**

System	Energy (MJ)		Energy efficiency		Energy yield (γ)	Energy report (r)
	Consumption (%)	Produced	e	%		
Classic plough + disc-2x (wt)	23,272.38 (100)	129,458.88	0.8202	100	5.56	0.179
Paraplow + rotary harrow	22,809.84 (98.0)	125,475.58	0.8182	99.7	5.50	0.182
Chisel plow + rotary harrow	22,738.68 (97.7)	120,992.76	0.8121	99.0	5.32	0.188
Rotary harrow	22,667.52 (97.4)	125,366.36	0.8192	99.9	5.53	0.181
No-Tillage	21,315.48 (91.6)	120,586.40	0.8232	100.4	5.66	0.177

Statistical analysis of the results demonstrated that the differences in accumulated soil water depended on the systems of soil tillage (Table 5). Soil texture and structure have a strong effect on the available water capacity. The results clearly demonstrate that MT and NT systems promote increased humus content (2%–7.6%) and increased water constant aggregate content (5.6%–9.6%) at the 0–30 cm depth as compared to conventional tillage. Multiple analysis of soil classification and tillage systems on the hydric stability of soil structure and water supply accumulated in soil have shown that all systems with minimum tillage are superior (b, c), having a positive influence on soil structure stability. The increase in organic matter content is due to the vegetal remnants at the soil surface (NT) or partially incorporated (MT) and adequate biological activity in this system. In the case of humus content and also in the hydro stability structure, the statistical interpretation of the data shows an increasing positive significance of the MT and NT systems application. The soil fertility and wet aggregate stability were initially low, the effect being the conservation of the soil features and also their reconstruction, with a positive influence on the permeability of the soil for water. More aggregated soils permit more water to reach the root zone. This does not only increase productivity, but it also reduces runoff, and thus the erosion potential.

The bulk density values at 0–30 cm increased by 0.01%–0.03% under minimum and no-tillage systems. This raise was not significant in any of the experimental systems. Multiple comparing and classification of experimental systems align all values at the same level of significance (a). On molic Fluvisoils, soils with good permeability, high fertility, and low susceptibility to compaction, accumulated water supply was higher (representing 12.4%–15%) for all minimum and no-tillage soil systems.

Table 5 **The influence of soil tillage system upon soil properties (0–30 cm)**

Soil tillage systems	Classic plough + disc –2x (wt)	Paraplow + rotary harrow	Chisel plow + rotary harrow	Rotary harrow	No-tillage
OM (%)	3.03 a	3.12 ab	3.09 ab	3.23 b	3.26 b
Significance (%)	^{wt}(100)	^{ns}(103.1)	^{ns}(102.0)	^{ns}(106.5)	^{ns}(107.6)
WSA (%)	71.33 a	76.00 b	75.33 b	76.33 b	78.21 b
Signification (%)	^{wt}(100)	* (106.5)	*(105.6)	*(107.0)	*(109.6)
BD (g cm^{-3})	1.34 a	1.34 a	1.35 a	1.34 a	1.38 a
Signification (%)	^{wt}(100)	^{ns}(100.0)	^{ns}(100.6)	^{ns}(100.0)	^{ns}(102.9)
W (m^3 ha^{-1})	878 a	1.010 c	998 b	987 b	995 b
Signification (%)	^{wt}(100)	*(115.0)	*(113.7)	*(112.4)	*(113.3)

Note: wt — witness, ns — not significant, *positive significance, a, ab, b, c — Duncan's classification (the same letter within a row indicates that the means are not significantly different). OM — organic matter. WSA — water stability of structural macro-aggregates. BD — bulk density. W — water supply accumulated in soil.

4 Conclusions

The minimum tillage and no-tillage systems represent excellent alternatives to the conventional system of soil tillage, due to their conservation effects on the soil and to crop yield increases as compared to the conventional system. Correct choice of the right soil tillage system for the crops in a rotation help reduce energy consumption. Energy efficiency is related to reductions in energy savings, but also is related to the impact of the tillage system on the cultivated plant, maize: 99.6%–100.1% for MT and 101% for NT; soybean: 101.1%–102.9% for MT and 104.5% for NT; wheat: 99%–99.9% for MT and 100.4% for NT. For all crops in a rotation, energy efficiency was highest in no-till, with 10.44 MJ ha^{-1} produced for each MJ of energy used for maize. For soybeans, 6.49 MJ ha^{-1} was produced for each MJ of input energy, for Wheat 5.66 MJ $ha^{-1}$was produced for each MJ of input energy.

For an energy-efficient agricultural system: the energy yield (energy produced-energy yield) necessarily has to be supplemented by soil energy efficiency to estimate the conservative effect of the agricultural system. Only then can the agricultural system be sustainable-durable in agronomic, economic and ecological terms.

This study demonstrated that increased organic matter content in soil, aggregation, and permeability are all promoted by minimum and no-tillage systems. The implementation of such practices ensures a greater water supply. The practice of reduced tillage is ideal for enhancing soil fertility, water accumulation capacity, and reducing erosion. The advantages of minimum and no-tillage soil systems for Romanian pedoclimatic conditions can be used to improve methods in low producing soils with reduced structural stability on sloped fields, as well as measures of water and soil conservation on the whole ecosystem.

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References

Afzalinia, S., Khosravani, A., Javadi, A., Mohammadi, D., & Alavimanesh, S. M. (2012). Effect of Tillage and Planting Methods on the Soil Properties, Grain Drill Performance, and Wheat Yield. *Journal of Agricultural Science and Technology A2, 21* (5), 537-543.

Ailincai, C., Jitareanu, G., Bucur D., & Mercus, A. (2011). Influence of tillage practices and fertilization on crop yields and soil properties in long-term crop rotation (soybean-wheat-maize) experiments. *Journal of Food, Agriculture & Environment, 9* (1), 285-289.

Akdemir, S., Akcaoz, H., & Kizilay, H. (2012). An analysis of energy use and input costs for apple production in Turkey. *Journal of Food, Agriculture & Environment,10*(2), 473-479.

Bucur, D., Jitareanu, G., & Ailincai, C. (2011). Effects of long-term soil and crop management on the yield and on the fertility of eroded soil. *Journal of Food, Agriculture & Environment, 9*(2), 207-209.

Coman, M. & Rusu, T. (2010). New ways in using far-infrared radiations for agricultural production. *Journal of Food, Agriculture & Environment, 8* (3-4), 714-716.

Domuta, C., M. Sandor, Gh. Ciobanu, A. Samuel, C. Ciobanu, A. Domuta, C. Borza, Cr. Domuta, R. Brejea & Gatea, M. (2012). Influence of the crop system on soil erosion and on the soil physical properties under the Romanian north-western area conditions. *Journal of Environmental Protection and Ecology, 13*(2), 736-745.

Fluck, R. C. & Baird, C. D. (1980). Agricultural energetics. AVI Publishing Co., Westport, Connecticut.

Gao, S., X. Tong & Wu, L. (2012). Environmental constraints and transformation of China's export structure. *Journal of Food, Agriculture and Environment, 10*(1), 919-922.

Glendining, M. J., A. G. Dailey, A. G. Williams, F. K. van Evert, K.W.T. Goulding & Whitmore, A. P. (2009). Is it possible to increase the sustainability of arable and ruminant agriculture by reducing inputs? *Agricultural Systems, 99*(2-3), 117-125.

Jackson, T. M., M. A. Hanjra, S. Khan & Hafeez, M. M. (2011). Building a climate resilient farm: A risk based approach for understanding water, energy and emissions in irrigated agriculture. *Agricultural Systems, 104*(9), 729-745.

Jitareanu, G., C. Ailincai & Bucur, D. (2006). Influence of Tillage Systems on Soil Physical and Chemical Characteristics and Yield in Soybean and Maize Grown in the Moldavian Plain (North – Eastern Romania) (pp. 370-379). In International Symposium, Soil Management for Sustainability, Adavances in GeoEcology 38, Catena Verlag Ed., Germany.

Jones, M. R. (1989). Analysis of the use of energy in agriculture — Approaches and problems. *Agricultural Systems, 29*(4), 339-355.

Li, R. & Mu, X. (2006). Challenges and Conservation Measures: Water Resources of the North China Plain. In Water for Irrigated Agriculture and the Environment (pp. 38-42).

Marin, D.I., M. Mihalache, C. Ciontu, C. Bolohan & Ilie, L. (2011). Influence of soil tillage of pea, wheat and maize crop in the Moara Domneasca-Ilfov area. In Risoprint Cluj-Napoca (Ed.), *5th International Symposium — Soil Minimum Tillage System* (pp. 111-118) .

Marin, D. I., T. Rusu, M. Mihalache, L. Ilie & Bolohan, C. (2012). Research on the influence of soil tillage system upon pea crop and some properties of reddish preluvosoil in the Moara Domneasca area. *Annals of the University of Craiova – Agriculture, Montanology, Cadastre Series, 42*(2), 487-490.

Molnar, A., I. Drocas, O. Ranta & Stanila, S. (2012). Development of Software for Soil Compaction Assessment. *Bulletin UASVM Agriculture, 69*(1-2), 88-93.

Moraru, P. I. & Rusu, T. (2012). Effect of tillage systems on soil moisture, soil temperature, soil respiration and production of wheat, maize and soybean crops. *Journal of Food, Agriculture & Environment*, *10*(2), 445-448.

Pimentel, D. (1992). Energy inputs in agriculture production. In Fluck, R. C. (ed.). *Energy in World Agriculture. Vol. 6* (pp. 13-29). Elsevier Sci. Publ. Co.: Amsterdam.

PoliFact. (2010). ANOVA and Duncan's test pc program for variant analyses made for completely randomized polifactorial experiences. USAMV Cluj-Napoca, Romania.

Ponjican, O. O., A. M. Bajkin, G. P. Jacimovic, M. D. Tomic, L. D. Savin, N. M. Dedovic & Simikic, M. D. (2012). Tillage quality affecting physical characteristics, number of plants and carrot root yield under flat and ridge cultivation. *Journal of Food, Agriculture & Environment, 10*(2), 304-311.

Ranta, O., I. Drocas, S. Stanila, A. Molnar, M.V. Muntean & Marian, O. (2012). Analysis of Working Qualitative Parameters for No-Till Machines. *Bulletin UASVM Agriculture, 68*(1), 308-313.

Romaneckas, K., V. Pilipavicius, E. Sarauskis & Sakalauskas, A. (2009). Effect of sowing depth on emergence and crop establishment of sugar beet (*Beta vulgaris* L.). *Journal of Food, Agriculture & Environment, 7*(2), 571-575.

Rusu, T. (2001). The influence of Minimum Soil Tillage upon the soil, yield and efficiency (PhD Thesis). University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Romania.

Rusu, T., P. Gus & Bogdan, I. (2006). The influence of minimum soil tillage systems on weed density, frequency of phytopatogenous agents and crop yields of soybean, wheat, potato, rape and maize. *Journal of Food, Agriculture & Environment, 4*(1), 225-227.

Rusu, T. & Bogdan, I. (2012). Influence of Degree Infestation with Echinochloa crus–galli Species on Crop Production in Maize. In

Mohammed Naguib Abd El-Ghany Hasaneen (Ed.), *Herbicides — Properties, Synthesis and Control of Weeds*. InTech Ed.
Rusu, T., I. Bogdan, & Pop, A. I. (2012). Agrotechnics-practical work. Ed. Risoprint Cluj-Napoca.
Sarauskis, E., E. Vaiciukevicius, K. Romaneckas, A. Sakalauskas & Baranauskaite, R. (2009). Economic and energetic evaluation of sustainable tillage and cereal sowing technologies in Lithuania. *Rural Development, 4*(1), 280-285.
SRTS. 2003. Romanian System of Soil Taxonomy. Estfalia Ed., Bucharest, Romania.
Stanila, S., I. Drocas, O. Ranta, A. Molnar & Nagy, M. (2012). Studies regarding comparative analysis of main working indicators at primary soil tillage's. *Bulletin UASVM Agriculture, 69*(1-2), 114-119.
Tesu, I. & Baghinschi, V. (1984). Energy and Agriculture. Methodology for calculation and analysis of energy efficiency in Agriculture. Ceres Ed., Bucharest, Romania.
Uhlin, H. E. (1998). Why energy productivity is increasing: An I-O analysis of Swedish agriculture. *Agricultural Systems, 56*(4), 443-465.
Vural, H. & Efecan, I. (2012). An analysis of energy use and input costs for maize production in Turkey. *Journal of Food, Agriculture & Environment, 10*(2), 613-616.
Zhou, X. M., Z. F. Zuo & Liu, B. (2012). The dynamic distribution of Mn element between soil and plant in Northeast *Leymus chinensis* grassland. *Journal of Food Agriculture & Environment, 10*(2), 891-895.
Wang, F., Mu X., Li, R. & Jiao, J. (2008). Runoff and sediment change based on paired-years with similar precipitation in the Beiluo River. *Journal of Water Resources and Water Engineering, 19*(6), 24-28.