Is there a correlation between economic and energy use efficiency in soybean production?

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Abstract

Modern society faces problems that are closely linked to the use of energy and food production. Due to population growth, it is necessary to grow food production. On the other hand, the potential shortage of fossil fuels can endanger energy security. Therefore, it is very important that in agriculture, production systems are sustainable, both from the energy and the economic aspect. The subject of this paper is economic and energy use efficiency in soybean production in Serbia. The aim of the paper is to determine if there is a correlation between these two indicators. In addition, organic and conventional production systems are compared. Data Envelopment Analysis (DEA) results indicate that organic soybean producers are more economic efficient than conventional. Energy efficiency is calculated as ratio of energy output and energy input. In organic system, total energy input was 9,533 MJ /ha and total energy output was 66,656 MJ/ha, resulting in energy use efficiency of 7.32. On the other hand, in conventional system energy use eficiency was lower 5.95 (total energy input was 12,362 MJ/ha and total energy output was 69,841 MJ/ha). Finnaly, the results showed that there is a correlation between economic and energy use efficiency in soybean production.

Keywords: Energy use efficiency. Eeconomic efficiency. Organic. Conventional. Soybean.

1. Introduction

Soybean is very important in the human diet due to its favorable nutritional composition of the grain (approximately 40% protein and about 20% of the oil). In addition, it is also important for the production of animal feed. In the Republic of Serbia soybean production, in significant proportions, began in the second half of the 1970s. In the period from 1976 to 2016 soybean production grew at an average annual rate of 5.5%. Soybean is predominantly produced in the plain region (northern Serbia). According to data for the period 2005-2016, farms in this region participated, on average per year, with 96% of total soybean production, and with 95% of the total seeded areas.

Average yields of soybean in this region, compared to the region Serbia – south, are higher by 24%. In 2016 the average share of soybeans in the total used arable area under annual crops in Serbia reached 7.2%. According to Popovic et al. (2016) there is several drivers that motivate farmers to increase soybean production in Serbia. First is, the stable profitability potential. It comes from more stable yield comparing with corn and higher average yield and better price stability comparing with sunflower. Second, lower fertiliser cost and cost savings for later crop. Additionally, good storage ability enables farmers to sell soybean in longer period.

Soybean production, as well as other lines of conventional crop production has a significant impact on the environment, primarily because of the uncontrolled use of chemical inputs. In order to cut down the harmful effects of excessive use of these inputs, it is necessary to rationalize and reduce their use. It is very important that this reduction does not lead to production losses. According to Bruinsma (2009) it is necessary to soybean production increase by 140% globally by 2050, to match a rise in demand due to growth of income and population (Bruinsma 2009). In Serbia, there are two systems of soybean production, organic and conventional. Unlike conventional, organic production involves the use of inputs, which are exclusively of organic origin, and they have no harmful impact on the environment. It is clear that the environmental performance of organic production is useful for society, but the question is whether it is economically sustainable. In addition, in the modern world, there is the rise of importance of the question of energy use efficiency in agricultural production. Nowadays, agricultural sector has become more energy-intensive in order to supply more food to increasing population and provide sufficient and adequate nutrition. (Hatirli et al. 2005). It is considered that any increase in the efficiency of energy use contributes to economy through increased profitability, productivity and sustainability of agricultural production in rural areas (Singh 2002). The use of energy is now considered as one of the key indicators of sustainable development. The agricultural sector consumes significant amounts of energy. It is estimated that the UK agricultural sector accounts for about 5% of the total energy consumption (Bailey et al. 2003). It can be expected that in Serbia this percentage is even higher due to high share of agriculture in Serbian economy. Any reduction in energy use due to changes in the system of agricultural production has an impact on energy consumption at the national level. It is commonly assumed that organic farming has a lower energy consumption and that is more energy efficient than conventional production (Zhang et al. 2015). On the other hand, when economic aspects are concern, results very differ between these production systems. According to Nieberg and Offermann (2000), government support is necessary for organic producers to achieve similar economic performance as conventional producers. Aim of this paper is to find out if there is a correlation between economic and energy use efficiency in soybean production. In order to answer this question, economic and energy use efficiency in organic and conventional soybean production will be analyzed partially.

2. Literature Review

Many authors have examined economic efficiency by using DEA aproach in agricultural production. Chebil et al. (2015) used DEA to analysed technical, allocative and economic efficiencies under constant returns to scale (CRS) in case of irrigated wheat farms in Tunisia. Results showed that average TE, AE and EE are 70.7%, 85.1% and 59.7%, respectively. In their study of rice production in Arkanzas, Watkins et al. (2014) revealed that most fields have high technical and scale efficiencies, implying inputs are used in minimum levels necessary to achieve given output levels and fields are close to optimal in size, while, most fields exhibit allocative and economic inefficiencies and do not use inputs in the right combinations necessary to achieve cost minimization. In case of apple production in Shaanxi (China), Wang et al. (2013) indicate that TE and EE are very low due to the inefficient apple orchards operation of farmers and the disadvantageous environmental conditions which heavily affect apple growth. Mahjoor (2013) revealed that under constant return to scale (CRS) and variable returns to scale (VRS) specification, on average, the broiler farms technical, allocative and economic efficiencies were 82, 70, 57 per cent and 82, 73, 64%

respectively in Iran. Also, DEA method is used for comparison of efficiency of organic and conventional production. Lansink et al. (2002) analyzed the difference in efficiency and productivity between organic and conventional producers in Finland using the DEA method (Data Envelopment Analysis). The results showed that organic producers are more productive and more efficient than conventional ones. Likewise, in its analysis of the technical efficiency of coffee farms in Nepal, Paudel et al. (2015) showed that organic producers are more efficient than conventional ones.

Comparison between economic and energy use efficiencies are not so often represented in scientific literature. By comparing the economic and energy performance of organic and conventional agricultural production, Pimentel et al. (2005) have shown that conventional production is more costly than organic in California, and that it also uses slightly less energy inputs. In addition, they believe that conventional production, with the partial adoption of technology that is characteristic of organic production, would be more sustainable and environmentally friendly. Sartori et al. (2006) concluded that conservation farming systems have used more energy, but with higher economic net return than organic in Italy. When EU subsidies were considered, net return was higher in the organic farming system for soybean and wheat. In their study of energy efficiency in soybean production in China, Zhang et al. (2015) have shown that conventional soybean production is more energy efficient than organic and, in addition, economically more profitable.

3. Materials and Methods

Energy use efficiency is calculated on the basis of the relationship of output and input energy according to the following formula (Turhan et al. 2008; Guzman et al. 2008; Mandal et al. 2009; Zhang et al. 2015):

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

The energy output is obtained based on the energy values of achieved yields per hectare, and the total energy input obtained as the sum of energy values for each of the inputs involved in the soybean production. Energy value of inputs and outputs are calculated based on energy equivalents (Table 1). Energy consumption in agricultural production in connection with the use of all inputs for given line of production. Energy inputs can be classified into two main groups: inputs that involve the direct use of energy and inputs that include indirect energy consumption (Kitanni, 1999). Regarding energy use efficiency, research results in the UK have shown that integrated agricultural production is more energy efficient than conventional (Bailey et al. 2003). In their study of energy use in organic and conventional olive oil production in Spain, Guzman and Alonso (2008) concluded that organic olive oil production has greater non-renewable energy efficiency in comparison with conventional production.

Turhan et al. (2008) has showed that the energy output-input efficiency ratio in organic tomato production (0.213) is higher than in conventional tomato production (0.197). While the direct and renewable energy consumption of organic production is higher, the indirect and non-renewable energy consumption is lower than in conventional production. By comparing energy efficiency in soybean production using NPK fertilizer and manure production, Mandal et al. (2009) concluded that there are no significant differences in energy efficiency in soybean production, depending on which type of fertilizer is used. Based on energy efficiency in small-scale biointensive organic onion production in Pennsylvania (that is 50 times higher than in mechanized agriculture), Moore R. S., (2010) realized that biointensive production offers a viable energy use alternative to current production practices and may contribute to a more sustainable food system. In their analysis of energy inputs in organic and conventional paddy rice production, Pagani et al. (2017) showed that conversion to organic practice has potential to reduce significantly the overall energy input by more than 50%, with a yield loss of only 8%.

Table 1: The energy equivalent of inputs and outputs in agricultural production.

	Unit	Energy equivalent (MJ)	Source
Output			
Soybean	kg	16.72	Zhang et al. 2015.
Input			
Labour	h	2.01	Zhang et al. 2015.
Machinery	h	62.7	Turhan et al. 2008.
Disel	l	44.09	Zhang et al. 2015.
Seed	kg	21.04	Zhang et al. 2015.
Fertilizers			
N	kg	60.14	Zhang et al. 2015.
P	kg	16.22	Zhang et al. 2015.

K	kg	7.89	Zhang et al. 2015.
Herbicide	l	336.07	Zhang et al. 2015.

DEA method is used in order to calculate economic efficiency in this study. DEA is an analysis method to measure the relative efficiency of a homogeneous number of organizations that essentially perform the same tasks (Cooper et al. 2007). It involves the use of linear programming methods to construct an non-parametric piece-wise surface (or frontier) over data (Coelli et al. 2005). DEA is apply on set of pear organisations or entities called Decision making units (DMU) which convert multiple inputs to multiple outputs. Consider n farms (j=1,...,n) as DMUs. Each DMU produces s outputs (r=1,...,s) from m inputs (i= 1,...,m). Suppose x_{ij} and y_{rj} are amount of *i*th input consumed and amount of *r*th output produced by *j*th farm, respectively. Let λ_j be a weight given to *j*th farm in the construction of best practice frontier. Let, s_i^-, and s_r^+ be input excesses and output shortfalls, respectively. Assume that the objective of each farm is to minimize its inputs, keeping the output level constant in the constant returns to scale (Charnes et al., 1978). Technical efficiency (TE) of target farm *o* (*o*=1,...,n) is then solution to the following linear programming (LP) problem.

$$Min\ \theta o - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_o x_{io}, \quad i = 1, \dots, m,$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} + s_r^+ = y_{ro}, \quad r = 1, \dots, s,$$

$$\theta_o, \lambda_j, s_i^-, s_r^+ \geq 0;\ \forall i\ and\ r;\ \varepsilon \geq 0,$$

where θ_o is a scalar value representing a proportion of current inputs that produce the chosen level of outputs. For the DEA analysis LP problem had to be solved n times, one for each DMU. Each LP problem yields a set of solution values for θ, λ_j, s_i^-, and s_r^+. The optimal value of θ is minimum value over all possible values of θ that satisfy the set of constraints in the LP problem and is the efficiency score for target farm *o*. TE= θ, and if TE=1 while s^-, and s^+ are equal to zero, the target farm is technically efficient. Otherwise, if TE<1 target farm is technically inefficient. Allocative efficiency (AE) measures the ability of a technically efficient DMU to use inputs in proportions that minimize production costs given input prices. Allocative efficiency is calculated as the ratio of the minimum costs required by the DMU to produce a given level of outputs and the actual costs of the DMU adjusted for TE. Economic efficiency (EE), also known as cost efficiency, is the product of both TE and AE (Farrell, 1957). Thus, a DMU is economically efficient if it is both technically and allocative efficient. Economic efficiency is calculated as the ratio of the minimum feasible costs and the actual observed costs for a DMU.

In focus of this research are economic and energy use efficiency of soybean production across farms in main production regions in Serbia. Data were collected on a sample of 39 farms in Serbia. Some farms are chosen by random choice and some from the list provided by GIZ (German Corporation for International Cooperation GmbH). After data quality control, all farms are included in analysis. Data were collected from 12 organic farms and 19 conventional farms participated in the project, as well as 8 conventional control farms. Classification and farm choice are done by two criteria: production system, and region (Figure 1). There are two production systems in Serbia: conventional and organic, that were analysed separately. Geographically, the sample is divided into two regions: Vojvodina-North and Vojvodina-South. Due to the similar climatic characteristics of the given regions, it is possible to assume that the weather conditions do not significantly affect the achieved results of the farmers. Although the climatic conditions influenced favourably to soybean production in the first half of the growing season, the second half of the soybean growing season was atypical due to frequent and above average rainfall. Because of that harvest season has been stretched to the end of November. The average soybean yield was at 3.2 t/ha in 2016 in Serbia (also in Vojvodina) (Statistical Office of the Republic of Serbia).

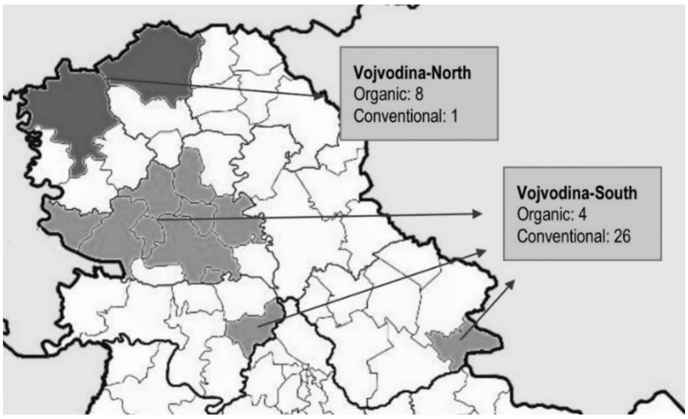

Figure 1: Classification of farms by region and production systems

All inputs in soybean production are aggregated in seven groups: seed, labour, diesel, fertilizers, pesticide, fixed and other costs and land. First five are concerened in calculation of economic and energy efficiency, while fixed and other costs and land are used only for economic efficiency. Additionaly, working hours of machinery is incorporated in calculation of energy efficiency. In case of economic efficiency two outputs are taken in consideration: net profit and adjusted gross margin. Only output in calculation of energy efficiency is energy equivalent of produced soybean grain per one hectare (Table 2).

Table 2: Descriptive statistics of variables

Variable	Unit	AVG	MAX	MIN	STDEV	CV
Outputs (Economic efficiency)						
Net profit	RSD/ha	106,810	215,885	5,141	61,397	0.57
Adjusted gross margin	RSD/ha	128,597	228,451	70,030	52,331	0.41
Inputs (Economic efficiency)						
Diesel	l/ha	105	143	70	17	0.16
Seed	kg/ha	92	120	62	11	0.12
Fertilizers	kg/ha	344	692	187	80	0.23
Labour	h/ha	71	254	7	76	1.07
Land	ha	1	1	1	0	0.00
Pesticide	n/ha	2	5	0	1	0.81
Fixed and other costs	n/ha	1	1	1	0	0.00
Input prices (Economic Efficiency)						

Diesel price	RSD/l	129	135	110	5	0.04
Seed price	RSD/kg	89	107	46	14	0.15
Fertilizer price	RSD/kg	97	97	94	1	0.01
Labour price	RSD/ha	185	250	125	29	0.16
Pesticide price	RSD/n	3,525	9,882	0	2,925	0.83
Land	RSD/ha	46,279	77,720	21,291	18,042	0.39
Fixed and other costs	RSD/ha	8,888	26,256	0	7,101	0.80
Energy output						
Energy output of soybean	MJ/ha	68,861	86,944	39,660	9,977	0.14
Energy inputs						
Disel	MJ/ha	4,622	6,290	3,086	728	0.16
Seed	MJ/ha	1,933	2,525	1,295	236	0.12
Fertilizers	MJ/ha	3,342	10,104	0	3,021	0.90
Labour	MJ/ha	142	511	13	152	1.07
Pesticide	MJ/ha	581	1,680	0	471	0.81
Machinery	MJ/ha	878	1,398	289	274	0.31

Net profit is difference of total revenues and total related costs at one farm. In case of economic efficiency, analysis of exhausted fertilisers (nitrogen, phosphorous and potassium) in soybean production has been performed. Analysis includes amounts of active mineral nutrients: applied by mineral or organic fertilizers, amount of nitrogen fixed in lend by biological fixation, as well as amounts of nutrients removed by soybean yield and way of soybean hay use. In calculation were used two sets of data. With one tone of soybean grain were removed 44 kg nitrogen, 15 kg P_2O_2 and 20 kg K_2O. With one tone of soybean grain with related soybean hay were removed 65 kg nitrogen, 22 kg P_2O_2 and 48 kg K_2O. There were taken in account amount of nitrogen that migrate in deeper soil layers during a year and nitrogen amount originated by biological fixation.

Prices of nitrogen, phosphorous and potassium were calculated based on prices of mineral fertilisers supplied during 2016 production year. Calculated value of not exhausted nutrients (difference of applied and removed) was used as corrective element for adjusted gross margins of soybean production, that are more adequate indicator of achieved result in analysed year. Cost of pesticide is calculated by number of application. Each aplication involves the use of different pesticides. The amount of some pesticides is expressed in liters, and others in grams. For this reason, the simplest solution is to calculate cost for each aplication, and the physical input is considered as the number of application. Labour used in hours per hectare include paid seasonal labour and unpaid family labour. The computation of physical input and price of fixed and other costs is far from satisfactory. It seems that only solution is to assume that physical input is one, and that price is amount of its cost. Similar solution is given by Sharma et al. (1999) in their study of economic efficiency in swine production in Hawaii. All data is presented by one hectare. Therefore, the assumption is that input is one and that the price of the land is an annual rent, whether the farmers possesed it or lease it. All prices are actual market prices from given region. Energy inputs and output are calculated on the basis of energy equivalents (Table 1). Depending on the context, manure may be considered either a valuable source of nutrients replacing synthetic fertilizers, a waste product from livestock production, or a potential energy source, e.g., for biogas production (Liu et al. 2010). In this study, farmyaard manure is concerned as by-product or waste from livestock production, so there is no energy value of it.

4. Results and discussion

The results of energy use efficiency are shown in Table 3. The average energy use efficiency in the total sample is 6.37. The maximum value was recorded in organic production and amounted to 9.62, while the lowest value was achieved by the conventional production farm (3.83). There are great variations in energy use efficiency (CV = 0.27). The research has shown that organic producers are more energy use efficient than conventional ones. In the total sample, the average value of the output is 68,860 MJ/ha. Higher average energy value of output was recorded in conventional production (69,841 MJ/ha compared to 66,656 MJ/ha in organic). However, higher energy consumption in conventional production (12,362 MJ/ha compared to 9,533 MJ/ha) has led to lower energy use efficiency than in organic. There is no statistically significant difference in the output values and the energy consumption per hectare between the farms of different size. Regarding the structure, the largest share in total energy consumption has a diesel (about 40%), followed by fertilizer with 30%. Diesel is also the only in category of direct use of energy. Hence, inputs that represent indirect use of energy account for 60%.

Table 3: Energy efficiency in soybean production

	AVG	MAX	MIN	STDEV	CV
Total	6.37	9.62	3.83	1.73	0.27
Conventional	5.95	9.38	3.83	1.55	0.26
Organic	7.32	9.62	4.13	1.80	0.25

Greater application of fertilizers has a negative impact on energy use efficiency. In addition to ecological consequences, the excessive usage of fertilizers also affects the reduction of energy use efficiency. The use of manure in organic production has certainly contributed to the greater efficiency of this production system. The economic efficiency results obtained with DEAP software are shown in Table 4. Economic efficiency was obtained as a product of technical and allocative efficiency. In the calculation, the input-oriented model is used. Cooper et al. (2001) propose that the number of DMU (farms) should be three times bigger than number of inputs and outputs used in DEA model. In this study number of farms is more than triple the number of inputs and outputs considered. Economic efficiency ranges from 0.26 to 1. Average economic efficiency is 0.52 for the entire sample. The best result was achieved by a farm from a group of conventional producers, although organic farms are more efficient. The main cause of higher efficiency of organic producers is higher price of this product. The price of organic soybean in Serbia was 74 RSD/kg in 2016, while the price of conventional soybean was 40 RSD/kg. It is important to note that in a given sample, the only large farm that produces an organic soybean is economically inefficient (0.4).

Table 4: Economic efficiency in soybean production

	AVG	MAX	MIN	STDEV	CV
Total	0.52	1.00	0.26	0.20	0.38
Conventional	0.46	1.00	0.26	0.17	0.36
Organic	0.66	0.98	0.35	0.21	0.32

In the end, it is necessary to give the answer to the question posed in the title of this paper. Correlation analysis has shown that there is a strong and positive link between economic and energy use efficiency (Table 5). This result indicates that if soybean production is carefully managed economically, it will also mean that farm has good management from the point of energy use efficiency and vice versa. This is also very important for the creators of agricultural policy because adequate agricultural measures can contribute to greater economic and energy use efficiency. In this way it is possible to achieve a positive impact on the sustainability of soybean production. However, it is necessery to be careful with conclusions. The results differ significantly depending on how the manure is treated in context of energy input. As already mentioned, it is assumed that the manure is waste and that energy is not consumed in its production. However, it is possible to assume that nutrients (N, P, K) from manure have an energy value, i.e. if the farmer does not have a manure, he would have to buy a factory-produced organic fertilizer. With these calculations, the results show that there is no correlation between the two given efficiencies. Therefore, it can be concluded that the key factor is manure and the method as the fertilizer is observed. For example, if all the farmers were to use the factory-produced fertilizer exclusively, it would not be possible to claim that there was a correlation.

Table 5: Correlation between economic and energy efficiency in soybean production

	Valid	Spearman	t(N-2)	p-value
Energy & Economic Efficiency	39	0.643049	5.107579	0.000010

5. Conclusions

Based on the results given, it is possible to summarize the conclusions in the following way:

- There is a correlation between economic and energy use efficiency in the soybean production system.
- Organic production is more energy efficient than conventional in the case where it is assumed that the manure does not require energy consumption. If the manure is regarded as any other fertilizer, conventional soybean production becomes more efficient.
- The key factor for energy efficiency is the use of fertilizers.
- Organic soybean production is more economicaly efficient than conventional. The main cause is higher prices for organic soybeans. However, it is important to note that in a given sample, the only large holding that produces an organic soybean is extremely economically inefficient. This indicates that in the case of large farms, the

rule is unlikely to apply (in order for this to be certain it is necessary to have a larger sample, however, there are not enough such farms in the territory of Serbia).

These conclusions can help farmers in making production decisions, first of all when it comes to the use of chemical inputs. Also, the results could be interesting for the creators of agricultural policy. Adequate measures of agricultural policy can contribute to increasing both economic and energy use efficiency in soybean production. The results suggest that special attention should be paid to small farms that produce organic soybeans. Organic production could be a solution for other farms with limited resources.

Like many other studies, this study also encounters some limitations. The most important limit is a relatively small sample. The sample is representative at a level of the given territory, however, in order to make general conclusions, it is necessary for the study to include a large number of farms from other regions. The second limitation is that the data relate only to one production year characterized by extremely good weather conditions and the question is whether these conclusions would apply in long run. As already mentioned, the results vary depending on the method used to calculate the energy value of the fertilizer. Furthermore, in order to examine the correlation between energy and economic efficiency in agriculture, it is necessary to analyze all production lines. It can not be concluded that what is valid in the production of soybeans is valid for corn or wheat, for example. Removing these restrictions will be the subject of future researches.

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