IRRIGATION COSTS MANAGEMENT AT THE FAMILY FARMS

Marko Jeločnik
Ph.D., Senior Research Associate, Institute of Agricultural Economics,
Volgina Street no. 15, 11060 Belgrade, Serbia,
Phone: +381 11 64 66 88 357, e-mail: marko_j@iep.bg.ac.rs,

Jonel Subić
Ph.D., Principal Research Fellow, Institute of Agricultural Economics,
Volgina Street no. 15, 11060 Belgrade, Serbia,
Phone: +381 11 63 296 111, e-mail: jonel_s@iep.bg.ac.rs

Abstract: *in currents climate conditions, so often stable and profitable vegetable production on open field strongly requires implementation of irrigation. In order to maintain economic sustainability, small family farms usually irrigate crops by the use of fossil fuel engines, thereby undermining their environmental sustainability. Change of fossil fuels (dominantly diesel) with the energy primarily derived from renewable sources could direct them to ecologically more welcomed production. The main paper goal is to present the economic implications of the change of fossil fuels used for irrigation within the sector of vegetable production with much cleaner alternative (solar energy). By the application of cost analysis, it was shown that mentioned substitution could save the farmer significant financial assets, meanwhile greening the derived production, or substitution boosts both economic and environmental sustainability of certain farm.*

Key words*: irrigation, vegetable production, fossil fuels, clean energy, solar-electric aggregate, sustainability.*

Introduction

Agriculture represents the term that describes the number of processes in which primarily domesticated plants and animals serves to overall human population, before all offering to them food, fibre, labour, etc. (Harris, Fuller, 2014). In present time, rapid growth in global population change the basic function of the agriculture and make it very complex, as from agriculture is required not just to provide the food, but valuable inputs for many sectors of economy, while aspect of globalization pulled farmers out of their local market, expecting to serve to world market (Shekara et al., 2016). It has to be underlined that agriculture represents one of the basic human activities organised on the border where society mutually impacts the nature (Kulshreshtha, 2009).

In recent decades, usually non-controlled development of agriculture, linked from run for higher yields and profitability, has opposed it with the environmental issues, such are endangerment of water, soil and air cleanness, rapid consumption of non-renewable natural resources, etc. (Weil, 1990; Yu, Wu, 2018). This put in the foreground the sustainability of agriculture, as it has to serve in unchanging volume and quality to present and future generation. So, in addition to primarily driven economic side of agriculture, the environmental and social aspects become very important too (Earles, Williams, 2005). Generally, agriculture has to precisely copy and conduct the principles of nature in order to grow crops and animals in self-sustaining way, that will not irreversibly spent or pollute available natural resources. Besides, it has to offer decent living space for farm members and rural communities, employing the existing labour and leaning sectors of economy.

So, sustainability of agriculture supports the sustainability of farms. It defines, analyses and implements environmental, economic, and social objectives at farm, jointly and at the same time, providing the comprehensive production solutions (Sullivan, 2003). From farm or agricultural sustainability is expected to be highly correlated to globally recognized systems of management and conservation of natural resources, as well as with their technological, economic, environmental or administrative modifications (Oberč, Arroyo Schnell, 2020). Practicing the prescribed receipts of sustainable agriculture, it could surely improve all segments of farm sustainability, i.e. overall farm sustainability.

There are several obstacles that slow down or jeopardize agriculture or farm sustainability. In the broadest sense, they are framed by occurrence of notably visible and now even economically or ecologically harmful expression of climate changes, unrestrainable growth of global population, narrowing of available stock of non-renewable natural resources, additional pressure on unbalanced cover of nutritional requirements, food security or food safety, intensified pressure on environmental cleanness, more frequent occurrence of energy, economic, or price shocks, globalisation, etc. (Calicioglu et al., 2019; Siebrecht, 2020).

On the other hand, up today there is initiated and even proven in practice several ways how the farm and further agricultural sustainability could be boosted. These are upgrading of primary production towards the involvement of certain level of processing, even the implementation of more complex production approach of vertical integration. Then there are influence on and rise of awareness in benefits that come from cooperation at farm level. Among the available alternatives are changes in structure of agricultural production, or diversification of agro and non-agro activities at farm level. Besides, verified tools are change in used production system (e.g. skip to organic production), automatization or digitalisation of agriculture, involvement of certain agro-technical measures or quality schemes, as well as production of locally recognized food products. At the end change in used source of energy and elimination of fossil fuels could remarkably affect the depth of farms' environmental footprint (Pretty, 1994; Michel Villarreal et al., 2019).

Linked to all previously mentioned, the research and development (R&D) activities, or shortly science, have to be in service of agriculture (Stoop, Hart, 2005), especially in segments that affect its greening, or making it more environmentally friendlier. So greening of agriculture will surely initiate the greening of farm and farm activities.

The general goal of the paper is to present the possible way how the farm could influence the improvement of its sustainability, in order to reduce or eliminate the use of fossil fuels during the conduction of ordinary farm activities. So, the main goal is to describe one step of potentially gradual "greening" of agricultural activities at certain farm, assuming the substitution of fossil fuel (diesel) used for irrigation in vegetable production with solar energy, i.e. the purchase and use of solar-electric aggregate at the farm estate.

Methodology

Used methodological framework is based on simple cost analysis. It supposes the calculation of increase in gross profit after substitution the costs of used fuel with the „cheap" or "green" energy available at the farm. Besides it partly provides the overview of the cost-effectiveness of investment into the implementation of certain solar-electric aggregate. Obtained analytical inputs come from the field research done during the practical testing of Mobile Robotized Solar Electro-Generator during the period 2016-2021. Testing was conducted by the IMP and IAE from Belgrade, at the selected farms in Serbia involved in vegetables production (farms located in Banat or Belgrade district). All financial values cover one cycle of production, while they are given in Euro (EUR) what enables any further comparison. Theoretical background to the observed topic is previously supported by the use of adequate literature sources.

Results with Discussion

Agriculture is among the rare sectors of economy that in same time deeply suffers the pressure of climate changes, while it strongly affects their occurrence. From the aspect of economy, it is globally under the impact of disturbed rainfalls patterns, rise in global temperature, intensification of heat waves and drought, occurrence of frequent storms and floods, etc. Meanwhile, agriculture contributes the deterioration of climate changes primarily by the constantly high emission of GHGs derived from livestock breeding, use of agro-chemicals, or fossil fuels, etc. It is estimated that momentarily agriculture contributes up to 14% of the total GHGs emission worldwide (Nelson et al., 2009; Jantke et al., 2020).

In many areas, in plant production, specifically vegetables growing, the use of irrigation (as main or additional measure) for a long time has been representing the production necessity. Yields and further stability of farm incomes are so sensitive to lack of water in veggie production, regardless it is organized in open field or protected area (De Pascale et al., 2011; Mal, Kaur, 2019). So implementation of irrigation, no matter to applied type of irrigation system, represents specific tech-tech tool that provides to producer higher probability to secure market orientation and economic sustainability (Singh et al., 2005). On the other hand, over use of irrigation could lead to depletion of available water reserves (Scanlon et al., 2012), while the use of fossil fuels for the system running could tackle the cleanness of all natural resources, as well as quality of final products (Sims, 2011). On this way, besides indisputable benefits irrigation could affects the aspect of ecological sustainability of the farm. So, the appliance of irrigation must adequately balance the economic strivings and environmental impact of the producer

Underlying the conducted research lays sustainability, the term that usually colours the sectors of economy into the green. Paper background is framed by the development and testing of the one machine that is primarily in service of agriculture and its sustainability (Picture 1.).

Picture 1. Mobile Robotized Solar Electro-Generator

Source: IMP, 2022.

Use of solar aggregate could be good solution for the agriculture and rural areas. It could be energy supplier to many processes such are irrigation, feeding or drinking the animals, fishponds aeration, acclimatisation of production and processing facilities, fresh products drying, crop products manipulation within the storage, etc., or the best possible approach to the electricity in remote rural areas, or development of eco-tourism (Prinsloo, 2013; Kata et al., 2021; Miravet Sanchez et al., 2022).

Here is presented the basic model of the machine (Picture 1.) initially developed by the IMP from Belgrade, while it is further advanced and tested in field jointly with the IAE from Belgrade. This is highly mobile machine with guaranteed life period of over the 20 years. It has been supplied by the adequate software in order to behave as sunflower trying to use in the most effective way available solar energy and transfer it into the electric energy. Related to available batteries, it has certain level of working autonomy in period out of sun (up to 4 hours under sprinkler irrigation or much more under drip irrigation). It does not make a noise, or it does not need the fuel making the zero level GHGs emission. Malfunction in such a machine are really rare, while maintaining costs in average are so low. Handling with machine is user friendly, it’s highly movable and persistent to negative weather conditions, while it could be operated from distance. Basic model has been produced as single-phase solar generator with a power of 2.2 KW or three-phase generator with a power of 5.5 KW (Despotović et al., 2015). Furtherly advanced models give for more than 50% stronger power, while they are equipped with stronger batteries, or they could be made as hybrid electric aggregate, joining the wind turbine to solar panels (Subić, Jeločnik, 2017).

This aggregate is perfect solution for strengthening the farm overall sustainability, as well as for organisation of organic or environmentally oriented crop production. Its usage in crop irrigations leave extremely shallow environmental footprint, fitting the derived final products into the higher quality group. In plant production, as the target group are mostly considered the small family farms that cultivates up to 5 ha of arable surfaces.

It has to be underlined that Serbia has significant environmental preconditions and long tradition in vegetables growing (Vlahović et al., 2010). Previously made testing of the solar aggregate in vegetable irrigation tries to show primarily its potential in strengthening of farms' economic sustainability, assuming that elimination of usually used fossil fuels automatically boosts farms' environmental sustainability (Subić, Jeločnik, 2016). So, the main assumption that substitution of fossil fuels with renewables positively benefits the farm profitability was analytically tested with field data. General assumptions that were followed the calculations done consider that price of basic version of solar electric generator is around 8 thousands EUR, as well as that farm could apply for public subsidies in amount of at least 50% of equipment price. In period of constant growth of fuel prices, price of diesel used for water pump starting and running in veggie irrigation was sharply set at 1.6 EUR/l.

Calculations are linked to annual production cycle organised at the open field in surface of 1 ha and the use of drip irrigation based on low-pressure pump. Aggregate was tested under the production of few vegetables in pairs (considering crop as main or additional), as are: early (young) potatoes and cabbage, tomatoes and green onions, or red papers and spinach. Skipping to "cleaner" energy (Table 1.) shows that farm could expect savings in total expenditure in amount of couple hundred EUR per each line of veggie production. Derived results of aggregate testing in irrigation process within the vegetable production on the open field show that by skipping the used energy (from diesel to electric energy gained from solar energy) farm could advance its economic sustainability from 422.4 EUR to even 480.0 EUR on annual basis at one hectare (depending to pair of grown veggie crops).

Of course, cutting of energy costs could be even greater, if farm engages the larger production surfaces (initially, under the use of drip irrigation, aggregate could serve up to 3 ha of areas under the vegetables, assuming that irrigation of whole surface is made partially during the season), or by re-pairing certain crops, or creating specific production portfolio of grown crops at whole production surface.

Table 1. Costs savings in vegetable production

Crop	Cycle of irrigation	Diesel (l/cycle)	Diesel l/season	Price of diesel (EUR/l)	Costs of irrigation: diesel (EUR)	Costs of irrigation: solar energy (EUR)
Early potatoes	6	12	72	1.6	115.2	0.0
Cabbage	19	12	228	1.6	364.8	0.0
Total	*	*	*	*	480.0	0.0
Tomatoes	15	12	180	1.6	288.0	0.0
Green onions	7	12	84	1.6	134.4	0.0
Total	*	*	*	*	422.4	0.0
Red peppers	15	12	180	1.6	288.0	0.0
Spinach	8	12	96	1.6	153.6	0.0
Total	*	*	*	*	441.6	0.0

Source: IAE, 2022

Additionally, after eliminating the use of fossil fuels, farmer will surely improve quality (food safety) of grown products or farm environmental ambient. So, technically he will also boost the farm ecological sustainability, and potentially reach the higher prices at the local market.

In next table (Table 2.) is presented the farm financial potential to repay the invested assets into the solar aggregate from savings derived after substitution of energy source. Payback period generally depends on few factors, as are the initial value of investment, observed production line or established structure of production, level of public subsidies, size of used production surface, etc. In order to simplify calculations, it is assumed that in each year same pair of crops is grown under the whole production surface.

Under predefined circumstances, it could be seen that the appliance of solar aggregate will enable farmer savings in value of used energy for irrigation that are enough to settle the payback period in range from 2.8 to 18.9 years (Table 2.).

Table 2. Payback period of investment into the solar-electric aggregate

Pair of crops	Value of investment (EUR)	Size of parcel (ha)	Level of subsidies (%)	Energy savings (EUR)	Payback period (years)
Early potatoes & Cabbage	8,000.0	1	0	480.0	16.7
Early potatoes & Cabbage	8,000.0	1	50	480.0	8.4
Early potatoes & Cabbage	8,000.0	2	0	960.0	8.4
Early potatoes & Cabbage	8,000.0	2	50	960.0	4.2
Early potatoes & Cabbage	8,000.0	3	0	1,440.0	5.6
Early potatoes & Cabbage	8,000.0	3	50	1,440.0	2.8
Tomatoes & Green onions	8,000.0	1	0	422.4	18.9
Tomatoes & Green onions	8,000.0	1	50	422.4	9.5
Tomatoes & Green onions	8,000.0	2	0	844.8	9.5
Tomatoes &Green onions	8,000.0	2	50	844.8	4.7
Tomatoes & Green onions	8,000.0	3	0	1,267.2	6.3
Tomatoes & Green onions	8,000.0	3	50	1,267.2	3.2
Red peppers & Spinach	8,000.0	1	0	441.6	18.1
Red peppers & Spinach	8,000.0	1	50	441.6	9.1
Red peppers & Spinach	8,000.0	2	0	883.2	9.1
Red peppers & Spinach	8,000.0	2	50	883.2	4.5
Red peppers & Spinach	8,000.0	3	0	1,324.8	6.0
Red peppers & Spinach	8,000.0	3	50	1,324.8	3.0

Source: IAE, 2022.

Of course, although the investment in solar aggregate is kind an expensive business undertaking for in general economically weak single farms, there is always an opportunity for its services sharing between few farms (making of joint investment).

So, it is visible that payback period of investment into the considered solar aggregate could be started from around 3 years if its repaid just from costs of fuel, while it could be even lesser if energy or food prices continue to rise on global market.

Conclusion

Any step done for greening the vegetable production or in general agricultural production is socially desirable, while in presented case is cost effective and environmentally very welcomed. Use of solar energy in agriculture, or more precisely substitution of fossil fuels with electric power derived from solar energy in order to supply energy needs in irrigation within the vegetable production could perfectly fit the farm sustainability requirements. It was shown that the use of solar aggregate will boost economic sustainability of farm in value of up to 480.0 EUR/ha annually, depending on grown crops. Besides, it was calculated that depending on size of used production areas, number and species of grown vegetables, or level of public support, farmer could repay investment in solar aggregate for 2.8 to 18.9 years just from cut in costs of fuel. Also, there are strong expectations that by the use of clean or green energy in production activities, farm will also impact the quality of produced agricultural products, i.e. it will boost the farms' environmental sustainability too.

Paper is a part of research financed by the MESTD RS and agreed in decision no. 451-03-68/2022-14 from 17.01.2022.

Статья является частью исследования, финансируемого MESTD RS и согласованного в решении № 451-03-68/2022-14 от 17.01.2022.

Reverences:

1. Calicioglu, O., Flammini, A., Bracco, S., Bellu, L., Sims, R. (2019). The future challenges of food and agriculture: An integrated analysis of trends and

solutions. *Sustainability*, 11(1/222):1-21.

2. De Pascale, S., Dalla Costa, L., Vallone, S., Barbieri, G., Maggio, A. (2011). Increasing water use efficiency in vegetable crop production: From plant to irrigation systems efficiency. *Hort-Technology*, 21(3):301-308.

3. Despotović, Ž., Rodić, A., Stevanović, I., Jovanović, M., Popić, S. (2015). *Primena mobilnog robotizovanog solarnog generator u novim ekolo[kim tehnologijama u poljoprivredi*. In: Informacione tehnologije: Razvoj i primena u unapređenju životne sredine (IT EKO 2015), Belgrade, Serbia, proceedings, vol. 1, pp. 15-25.

4. Earles, R., Williams, P. (2005). *Sustainable agriculture: An introduction*. National Sustainable Agriculture Information Service (ATTRA), Butte, USA, pp. 1-7.

5. Harris, D., Fuller, D. (2014). *Agriculture: Definition and Overview*. In: Smith, C. (Ed.) Encyclopedia of Global Archaeology, Springer, NY, USA, pp. 104-113.

6. IAE (2022). *Agro-economics aspect of the use of Mobile Robotized Solar Electro-Generator in vegetable irrigation*. Internal documentation, Institute of Agricultural Economics (IAE), Belgrade, Serbia.

7. IMP (2022). *Mobile Robotized Solar Electro-Generator*. Internal documentation, Institute Mihajlo Pupin (IMP), Belgrade, Serbia.

8. Jantke, K., Hartmann, M. J., Rasche, L., Blanz, B., Schneider, U. A. (2020). Agricultural greenhouse gas emissions: Knowledge and positions of German farmers. *Land*, 9(5/130):1-13.

9. Kata, R., Cyran, K., Dybka, S., Lechwar, M., Pitera, R. (2021). Economic and Social Aspects of Using Energy from PV and Solar Installations in Farmers' Households in the Podkarpackie Region. *Energies*, 14(11/3158):1-21.

10. Kulshreshtha, S. (2009). *Agricultural practices as barriers to sustainability*. In: Public Policy in Food and Agriculture, Encyclopaedia of Life Support Systems (EOLSS), UNESCO, Paris, France, pp. 220-231.

11. Mal, D., Kaur, M. (2019). Irrigation practices in vegetable crops: A review. *Plant Archives*, 19(2):2177-2180.

12. Michel Villarreal, R., Hingley, M., Canavari, M., Bregoli, I. (2019). Sustainability in alternative food networks: A systematic literature review. *Sustainability*, 11(3/859):1-20.

13. Miravet Sanchez, B., Garcia Rivero, A., Yuli Posadas, R., Inostroza Ruiz, L., Fernandez Guzman, V., Chavez Juanito, Y., Rutti Marin, J., Apesteguia Infantes, J. (2022). Solar photovoltaic technology in isolated rural communities in Latin America and the Caribbean. *Energy Reports*, 8(2022):1238-1248.

14. Nelson, G., Rosegrant, M., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte Santos, R., Ewing, M., Lee, D. (2009). Climate change: Impact on agriculture and costs of adaptation. Food policy report no. 21, IFPRI, Washington, USA.

15. Oberč, B. P., Arroyo Schnell, A. (2020). *Approaches to sustainable agriculture*: *Exploring the pathways towards the future of farming*. International Union for Conservation of Nature (IUCN), Brussels, Belgium.

16. Pretty, J. N. (1994). Alternative systems of inquiry for a sustainable agriculture. *IDS bulletin*, 25(2):37-49.

17. Prinsloo, F. C. (2013). *Impact of renewable energy structures on tourism*. Research report, Stellenbosch University, Stellenbosch, SAR.

18. Scanlon, B. R., Faunt, C. C., Longuevergne, L., Reedy, R. C., Alley, W. M., McGuire, V. L., McMahon, P. B. (2012). Groundwater depletion and sustainability of irrigation in the US High Plains and Central Valley. *Proceedings of the national academy of sciences*, 109(24):9320-9325.

19. Shekara, P. C., Balasubramani, N., Sharma, R., Shukla, C., Kumar, A., Chaudhary, B. C., Baumann, M. (2016). *Farmer's handbook on basic agriculture.* Desai Fruits & Vegetables Pvt. Ltd, Navsari, Gujart, India.

20. Siebrecht, N. (2020). Sustainable agriculture and its implementation gap: Overcoming obstacles to implementation. *Sustainability*, 12(9/3853):1-27.

21. Sims, R. E. (2011). *Energy-smart food for people and climate: Issue paper*.

Food and Agriculture Organisation of the UN (FAO), Rome, Italy.

22. Singh, B., Granberry, D., Kelley, T., Boyhan, G., Sainju, U., Phatak, S., Sumner, P., Bader, M., Webster, T., Culpepper, S., Riley, D., Langston, D., Fonsah, G. (2005). *Sustainable vegetable production*. In: Vegetables: Growing Environment and Mineral Nutrition. WFL Publisher, Helsinki, Finland, pp. 1-38.

23. Stoop, W. A., Hart, T. (2005). Research and development towards sustainable agriculture by resource-poor farmers in sub-Saharan Africa: Some strategic and organisational considerations in linking farmer practical needs with policies and scientific theories. *International Journal of Agricultural Sustainability*, 3(3):206-216.

24. Subić, J., Jeločnik, M. (2016). *Economic Effects of New Technologies Application in Vegetable Production.* In: Emerging Technologies and the Development of Agriculture, 152nd EAAE Seminar, SAAE, Belgrade, Serbia, pp. 15-35.

25. Subić, J., Jeločnik, M. (2017). *Economic Effects of the Solar and Wind Energy Use in Irrigation of Vegetable Cultures*. In: Sustainable Agriculture and Rural Development in Terms of the Republic of Serbia Strategic Goals Realization within the Danube Region: Development and Application of Clean Technologies in Agriculture. Institute of Agricultural Economics, Belgrade, Serbia, pp. 37-55.

26. Sullivan, P. (2003). Applying the principles of sustainable farming. National Sustainable Agriculture Information Service (ATTRA), Butte, USA, pp. 1-16.

27. Vlahović, B., Puškarić, A., Červenski, J. (2010). Characteristics of vegetable production in the Republic of Serbia. Ratarstvo i povrtarstvo, 47(2):461-466.

28. Weil, R. R. (1990). Defining and using the concept of sustainable agriculture. *Journal of Agronomic Education*, 19(2):126-130.

29. Yu, J., Wu, J. (2018). The sustainability of agricultural development in China: The agriculture – environment nexus. *Sustainability*, 10(6/1776):1-17.