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Sabrija ČADRO*[1], Emir BEĆIROVIĆ[1], Merima MAKAŠ[1], Zuhdija OMEROVIĆ[1], Ćerima ZAHIROVIĆ[1], Benjamin CRLJENKOVIĆ[1]

GEOTHERMAL ENERGY FOR SUSTAINABLE AGRICULTURE: A CASE STUDY SARAJEVO, BOSNIA AND HERZEGOVINA

SUMMARY

Bosnia and Herzegovina is strategically committed to agriculture. Although it has adequate natural resources to engage in modern agriculture, it is also an area that faces a number of problems, such as small landholdings, low technological level of production, abandonment of rural areas, low yields, high exposure and poor adaptability to climate change. Given these conditions, the main goal of this paper was to determine the possibility for the stallholder farmer in Bosnia and Herzegovina to increase its sustainability using geothermal heating system to heat the greenhouse during the winter and achieve safer production with higher yields. Lettuce (*Lactuca sativa*) was chosen as the test crop. By heating, a higher air temperature was achieved in the greenhouse (2.20 - 3.82 ^{o}C), a higher growth intensity was also achieved, as well as much shorter lettuce vegetation, which was only 67 days. However, the economic aspects of sustainability have not been realized, these higher yields are not enough to cover costs. Fixed cost value, was covered with gross margin five times (502%) in the control greenhouse, while achieved gross margin is not sufficient to cover fixed costs in the heated greenhouse, shown by the calculated value of 60%.

Keywords: geothermal heating system, greenhouse, sustainability, gross margin, lettuce

INTRODUCTION

Most of the area of Bosnia and Herzegovina (BiH) belongs to humid climate region (S. Čadro *et al*., 2017) and same situation is within the area around capital city of Sarajevo (Drešković & Mirić, 2013). As a result of climate change, the air temperature in BiH has risen in all regions and for all sessions (Popov *et al*., 2018), this is also true for Sarajevo area where this increase is about 0.37 ^{o}C per decade (Čadro, Uzunovic, *et al*., 2019; Trbic *et al*., 2017).

[1]Sabrija Čadro (corresponding author: s.cadro@ppf.unsa.ba), Bećirović Emir, Makaš Merima, Omerović Zuhdija, Zahirović Ćerima, Crljenković Benjamin. University of Sarajevo, Sarajevo, BOSNIA AND HERZEGOVINA

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Along with the increase in temperature, the frequency of occurrence of extremely low and extremely high temperatures has also increased (Čadro, Uzunovic, *et al*., 2019; Trbic *et al*., 2017).

In addition, the area is increasingly exposed to droughts, late spring frosts and floods (Čadro *et al*., 2018; Sabrija Čadro *et al*., 2017; Zurovec *et al*., 2017; Žurovec *et al*., 2011). It is interesting that during 2021, a drought was recorded at this location in the period from June to September, and abundant rainfall in November, when the deviation of the monthly rainfall from the climatological standard normal (1961-1990) was 259.4% (FHMZ, 2021).

Such climate trends make agricultural production very difficult, especially for smallholder farmers which are most numerous in this location and generally in Bosnia and Herzegovina (Žurovec *et al*., 2015). The solution, both for reducing the contribution to climate change and increasing the security of agricultural production, can be the application of modern technologies, smart agriculture and use green energy sources. The application of modern technologies and smart agriculture certainly has advantages on both large and small-scale farms in BiH (Čadro, 2019; Čadro, Škaljić, *et al*., 2019).

Since the use of on-farm management software's, digital sensors to monitor plant growth and conditions, UAVs or green energy solutions is a relatively new practice in agriculture and it requires both financial resources and certain skills, further research into the justification of using this technology by the farmers is needed. For this reason, it is important to analyze the affordability and acceptance of these approaches among smallholder farmers in BiH, as well as to undertake focused training aimed at raising the knowledge and awareness of the benefits by application of this technology (Čadro, Škaljić, *et al*., 2019).

BiH is a significant agricultural region, with about one-third of its land under cultivation or pastures. There are excellent conditions for greenhouse vegetables production that is performed in all types of greenhouses (temporary and permanent protected areas). According to research by (Karić *et al*., 2016) many small farmer producers in BiH are choosing production in greenhouses, because this is for them economically most profitable production.

The key to making a profit in greenhouses is to ensure the continuity of production throughout the year. Lettuce (*Lectuca sativa*) is one of the most often cultivated vegetable in BiH, that can successfully be grown in almost all seasons, especially in the greenhouse with heating system (Čivić *et al*., 2017). Taking into consideration the fact that lettuce production in the last decade is showing significant expansion in BiH and that introduction of new varieties is frequent, improvement of technical production level in greenhouses is very important. The correct choice of technical equipment often resulted in higher yields or a shortening of the growth period even at low temperatures and less light intensity periods such is winter.

Producing vegetables in greenhouses during the winter period is a big challenge for many farmers. From the energy point of view, greenhouse farming requires high energy use, which results in one of the most energy consuming sectors in industry (Canakci & Akinci, 2006; Hedau *et al*., 2013).

The heating costs represent almost 30% of the operational cost of a greenhouse (Aramyan *et al*., 2007; Heidari & Omid, 2011). Since the energy costs are high, the use of renewable and affordable heating systems would be of primary importance to achieve significant energy savings (Aramyan *et al*., 2007). According to the new Europe 2020 Strategy and it`s main goals, that are to evenly decrease greenhouse gases emissions by 30% and reach a 20% share of total energy consumption from renewable energy (European Commission, 2020), heat pump systems are more acceptable for many farmers for heating greenhouses. For these reasons, many countries have started to use ground-source heat pumps to heat greenhouses. Leaders in annual geothermal energy use for greenhouse heating are Turkey, Russia, Hungary, China and Italy (Lund & Falls, 2012). Generally, different types of heat pump are used in agriculture, such as: air source-air supply, water source-air supply and water source-water supply heat pumps. However, the ground water heat sources have been demonstrated to have higher performance than air heat sources (Furuno & Sugawara, 2012). Ground-source heat pump systems are able to extract the low temperature energy content of a shallow geothermal resource and make it available for practical uses for greenhouse heating or cooling (Wu, 2009). According to (Harjunowibowo *et al*., 2021) using ground-source heat systems in the greenhouse reached from 2 to 7 degrees higher soil temperature then greenhouses without a heat system. Mentioned differences in soil temperature affect the faster and better plant`s root system growth. A lot of authors were researching using ground-source heat pumps for heating greenhouses but most of these works are based on calculations of energy efficiency coefficients of those systems but there wasn`t any mention of their effect on the yield and growth of cultivated plants.

The aim of this research is to determine the possibility for the stallholder urban farmer in Sarajevo to increase its sustainability using renewable energy sources and achieve economic justification in the production of vegetables in a greenhouse with an installed geothermal heating system.

MATERIAL AND METHODS

In order to conduct research and respond to the set goal, two identical greenhouses with an area of 100 m^2 each (6.3 m x 16 m) were set up next to each other in May 2020 at the experimental site of the Faculty of Agriculture and Food Science, University of Sarajevo located in Butmir near Sarajevo.

The basic geographical characteristics of this location are given in Table 1.

Table 1. Basic geographical characteristic of research location

Location	Longitude	Latitude	Altitude (m)	Slope (%)
Sarajevo, Butmir	18.3216	43.8259	503.32	> 0

Butmir is considered an urban zone and part of the city and Canton Sarajevo, so the agricultural production in this area can be considered us urban (El Bilali *et al.*, 2013).

The greenhouse type and construction elements do not deviate from the greenhouses used by farmers locally. However, one greenhouse was equipped with geothermal heating system and other one was a control without heating.

The installed heat pump (Ecoterm, Type 263, max power 3.2 kW) has soil-heat collectors made of plastic pipes, laid down in trenches 120 cm deep and 60 cm wide. For satisfying the heating needs of 100 m^2 of greenhouse (12kW) an earth collector at in three trenches, 50 meters long, were installed.

After the soli-heat collector pipes were installed, the top soil layer was removed. Then, thin 40 cm high metal plates were installed around the edge of the area of the greenhouse, secured by wooden pegs. Their purpose is to physically separate the heated soil from the non-heated surrounding. After that, a layer of PVC foil was laid on the ground, followed by a layer of EPS (50 mm styrofoam) which is used as a thermal insulation, then PVC foil again. The heating pipes were installed at least 5 cm above the mentioned thermal insulation. Soil earlier set aside, was then put back to the area of greenhouse and flattened.

Heat pumps are installed in metal housing alongside the greenhouses, to be protected from physical damage. Two pipes, containing glycol solution, are connecting the heat pumps with the collecting shaft, which is connected directly to earth-heat collectors. One pipe is feeding pre-heated liquid to the heat pumps while the other is feeding cooled down liquid to the earth collectors to be pre-heated again. In addition, heat pumps are connected to the fancoil instilled inside of the greenhouse for purpose of air heating.

After conducting an analysis of the heating power of installed geothermal pump, as well as the resulting soil and air temperatures, it was decided to use the pump as follows:

-Output temperature at the heat pump: 25^{o}C

-Simultaneous operation of the geothermal pump and air fan

-Powering the pump when the air temperature in the greenhouse drops below 10 ^{o}C

-Switching off the pump when the temperature in the greenhouse rises above 10^{o}C

Therefore, the heating system is manually switched on and off depending on the air temperature inside the greenhouse. The date and time of the start and end of the operation of the heating system was recorded, as well as the consumption of electricity during its operation.

To measure climate conditions inside and outside greenhouses, *Spectrum Technlogies, Inc.* WatchDog Micro Stations, equipped with sensors for soil temperature and humidity (SMEC300), leaf wetness and air temperature and humidity were used. All the date were recorded in 30-minute time interval.

Lettuce (NEIL F1) was chosen as the vegetable crop to be tested, as an important winter crop that is intensively cultivated in BiH. Exactly the same methodology from the use of the same planting material, soil preparation and fertilization, the same protective equipment, agricultural techniques and all actions was carried out in booth greenhouses. The total observation period lasted 116 days, ie from October 12, 2020 to February 5, 2021.

During the vegetation period of lettuce, the initial height of plants (seedlings) and plant growth were measured every 7 days. At the end of the vegetation, during the harvest, the number of harvested plants was determined, as well as the width, height, number of leaves and weight of the plant. Based on these data, the intensity of growth and development of lettuce was calculated, as well as the realized yields, depending on the method of production.

Before the beginning of vegetation, the opening of the pedological profile and the analysis of the basic physical and chemical characteristics of the soil in the heated and control greenhouse were performed. Soil in each profile was divided into two separate layers: anthropogenic surface layer depth from 0 - 25 cm and subsurface layer depth from 25 – 40 cm. The following analyzes had been carried out: Soil physical characteristics through analysis of soil texture (international pipette B method) and bulk density (gravimetric method in Kopecky cylinders); Soil water characteristics through soil water retention (Θv) at a given matric potentials using a pressure-membrane extraction apparatus. Following negative potentials (Ψ) were used: -0.33 bar (pF 2.54: field water capacity), and -15.5 bar (pF 4.2: permanent wilting point). Maximum water capacity (MWC) was divided from bulk and absolute density while totally (TAW) available water capacity of soil was calculated from relation TAW = FWC – WP (Čustović & Tvica, 2003).

Analyzed soil chemical characteristics were active (H_2O) and substitution (KCl) pH reaction (electrometrically in suspension 1:2.5 - pH meter) humus content, using colorimetric method (spectrophotometry) and content of easily accessible forms of phosphorus (P_2O_5) and potassium (K_2O) in the soil with AL-method (Hanić *et al*., 2008).

IBM SPSS Statistics software will be used for statistical data processing. To examine the influence of the heating system on the morphological and productive parameters of the lettuce, the parametric independent t-test will be used. Conclusions will be made with a significance level of 0.05.

To analyze the economic aspects of sustainability, the gross margin (GM) was calculated as a basis for further analysis and recommendations. It represents the difference between revenue (R) and variable costs (VC) of all individual productions realized on the farm. Therefore, it can be shown as GM = R – VC. Gross margin serves to cover fixed costs, own labor, and invested capital as opportunity costs (Kay & Edwards, 1999). This paper analyzes how many times the fixed cost can be covered with realized GM.

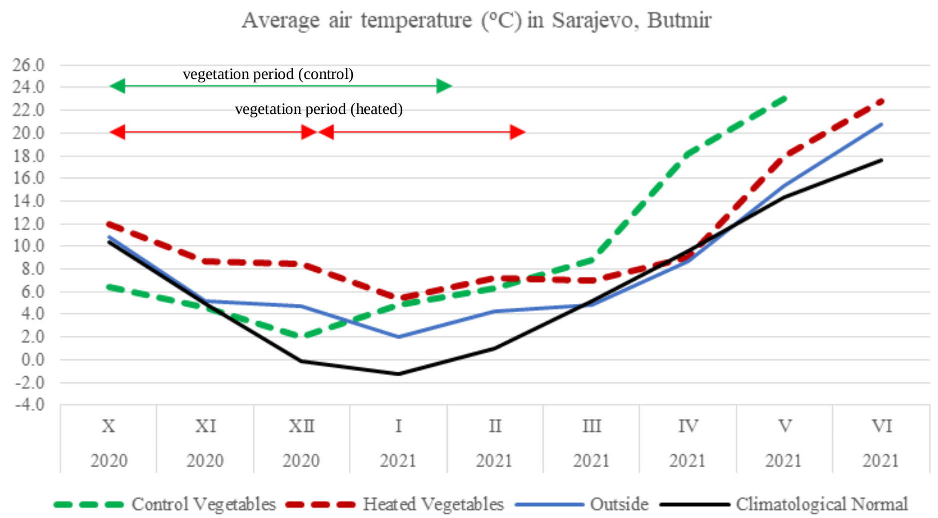
Calculations are based on the achieved yields and used inputs at the experimental site of the Faculty of Agriculture and Food Science in Sarajevo

(Butmir) during the 2020/2021 winter season. The inputs prices are taken from the paid invoices. Average prices on the Sarajevo market during the harvesting period are taken as the assumed sales prices. Only the production of lettuce as a winter crop in the greenhouse was the subject of this study and other crops grown during the warmer part of the year were not taken into account. The reason is that in the area of Sarajevo, only winter production requires heating and heat pump is not used for the rest of the year.

RESULTS AND DISCUSSION

Research conditions

Based on the time period 1967 – 2016 the average amount of annual precipitation in Sarajevo is found to be 938 mm, average air temperature 10.01 °C, relative humidity 71%, wind speed 1.63 m/s and insolation 4.96 h (Čadro, Uzunovic, *et al*., 2019). The following graph (Graph 1) shows the difference between air temperatures outside and inside the greenhouse, as well as the difference between the temperatures in lettuce vegetation period in 2020/21 and climatological normal for Butmir, Sarajevo.



Graph 1. Average air temperature (°C) in Butmir - Sarajevo for control, heated and area outside greenhouse

Compared to the climatic normal, the vegetation period of lettuce, i.e. the period from October 2021 to the end of February 2021, was 2.45 °C warmer. The biggest difference was recorded in December (4.84 °C), then January (3.36 °C) and February (3.31 °C), when the temperatures are the lowest.

Also, comparing to outside or control greenhouse, as the result of soil and air heating higher air temperatures were recorded in the heated greenhouse. The difference in temperature ranges from 2.20 to 3.82 ^oC, with biggest difference in December. The lowest recorded temperature -9.9 ^oC was in the control greenhouse on 19.01.2021 at 7:00h while lowest air temperature in heated greenhouse was -2.6 ^oC, and it was recorded on 01.12.2020. This is a big difference, which can prevent crops from freezing, especially in conditions when such low temperatures persist. In heated greenhouse, air temperature never dropped below its biological minimum (Kurtović, 2008; Maksimović, 2011), which means that lettuce in heated greenhouse had better-growing conditions.

Pedological analysis found that alluvial soil is located at the research site and based on its physical characteristics we can conclude that is a clay loam with approximately equal ratio of clay, silt and sand (Table 2).

Table 2. Soil physical characteristics

	Depth cm	Clay %	Silt %	Send %	BD g/cm^3	WP %	MWC %	FC %	TAW %	RAW %	AC %
C	0 - 25	32.9	33.5	33.6	1.3	20.5	45.0	36.7	16.2	8.1	8.3
	25 - 40				1.6	23.5	43.0	38.4	14.9	7.4	4.6
H	0 - 25	33.1	35.0	31.9	1.3	23.9	45.0	36.7	12.8	6.4	8.3
	25 - 40				1.6	28.6	43.0	38.4	9.8	4.9	4.6

Note: C - control greenhouse; H – heated greenhouse; BD – Bulk density; WP – Wilting point; MWC – maximum water capacity; FC – Filed capacity; TAW – Totally available water; RAW - Readily Available Water; AC – Air capacity

We can also notice a very dense second layer of soil where the bulk density is 1.6 g/cm^3. The surface layer of soil up to 25 cm deep has much better water-physical characteristics than the subsurface. Low values (4.9 – 8.1 %) of readily available water (RAW) show the small plant accessible water capacity and the need for frequent irrigation with smaller amounts of water. It is interesting that, the soil in heated greenhouse, as a result of the installation of the heating system and the disturbance of the natural state of the soil in Sarajevo has a slightly lower water capacity than the soil in control greenhouse.

Soil chemical characteristics were analyzed twice. The results are shown in Table 3. For the analysis of chemical characteristics, the surface layer of the soil was observed.

Table 3. Soil chemical characteristics

	Date	pH in H_2O	pH in KCl	Humus %	P_2O_5 mg/100g soil	K_2O mg/100g soil
Control	5.6.2020	7.45	6.40	3.00	40.00	60.00
Heated		7.45	6.40	3.15	45.00	64.50
Control	5.1.2021	7.50	6.40	2.70	34.00	48.00
Heated		7.40	6.50	2.50	36.00	41.00

According to the chemical characteristics, the soil in the heated and control greenhouse at location of Sarajevo do not differ. Soil has a neutral pH reaction (7.4 – 7.5), while the humus content is at a medium level. The content of easily accessible forms of phosphorus (P_2O_5) and potassium (K_2O) in the soil is very high. Soil fertility was improved by adding organic and mineral fertilizer. Organic manure was added, 100kg/100 m^2, as well as mineral fertilizer NPK 7:20:30 given in the amount of 7 kg/100 m^2 of greenhouse area.

Crop production

Duration of the vegetation period for lettuce was calculated based on the date of planting and harvesting. The obtained length of vegetation between the heated and control greenhouses shows certain differences. In the heated greenhouse vegetation period of lettuce was 67 days. Longer period of time, 49 days more, was needed to achieve a similar yield in the control greenhouse. Based on the results we can claim that heating had a great influence on shortening the vegetation period.

During vegetation period irrigation requirements were based on data from soil moisture sensors placed inside the greenhouse. The drip irrigation system was used, and the source of water is a well located near the greenhouse. In the winter period, that is from the beginning of December 2020 until the end of February 2021, due to very low temperatures, the water was given by manual watering. The total water used, as well as the used water in liters per square meter of production area, is shown in Table 4.

Table 4. Applied irrigation water for lettuce production in Sarajevo, Butmir

Greenhouse	Total area under curtain crop (m^2)	Water used (m^3) per greenhouse		Total water used (m^3)	Total water used (l/m^2)
		Drip irrigation	Manual irrigation		
Control	100	8.228	0.400	8.628	86
Heated	100	9.076	0.264	9.340	93

The total water used for irrigation of the lettuce in the heated greenhouse is 9.340 m^3 and the control slightly less 8.628 m^3. As can be seen there were no substantial differences in water consumption between two methods of production.

Eclectic energy is used to operate the heat pump. To calculate total electricity cost in Euro per 100 m^2 of production of a tested plant species in a greenhouse average electricity price 0.057 Euro/kWh (FERK, 2020) was used (Table 5).

In order to grow lettuce in the first round, in the period from 12.10.2020 to 18.12.2020 or during 67 days of vegetation, a total of 950 kWh of electricity was consumed (54.49 Euro).

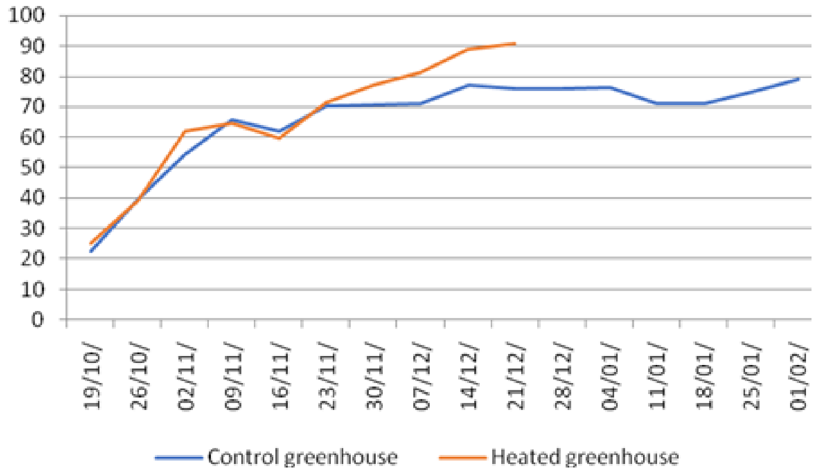
During October (19 days), there was no need for heating because the temperatures in the greenhouse were always above 10 ^{o}C, in November (30 days) we had reheating, while in December (18 days) the heating system worked every day. Usually between 3pm and 11am the next morning, but sometimes constantly.

During the vegetation period, the heating system worked for 27 days, i.e. 40.3% of the total vegetation time. The November consumption is 32.66 kWh for each day of heating, or if we consider 30 days of November 13.1 kWh/day (0.75 Euro/daily). December consumption is much higher and amounts to 37.2 kwh for each day of heating, i.e., for 18 days of vegetation in December 31.0 kwh/day (1.78 Euro/daily).

Table 5. Electricity consumption in kWh

Greenhouse	**Total area under curtain crop (m^2)**	**Monthly electricity consumption in kWh per 100 m^2 greenhouse**		**Total electricity consumption kWh/100 m^2**	**Total electricity cost in Euro/100 m^2**
		November	**December**		
Heated	100	392	558	950	54.49

Measurement of growth intensity was based on the percentage of soil cover with lettuce leaves, since this value depends on a specific heat sum as stated by Bierhuizen *et al*. (1973). Observations calculated in percentage values of soil coverage for control and heated greenhouse are given in Graph 1.



Graph 1. Average soil coverage by lettuce plants (%) for control and heated greenhouse

It is noticeable that the plants in heated conditions reached a soil coverage of over 90% in just under 70 days.

The average, minimum, maximum values and standard deviations for general indicators of some morphological and productive parameters of lettuce depending on the experimental heating are given in Table 6.

Table 6. Diameter, height, mass, number of leaves and yield per m^2 of lettuce

Parameters	Type	Average	St. dev.	Min.	Max.	t-test
Diameter (cm)	Control	24.85	1.73	22.00	28.00	**P<0.001**
	Heated	26.90	1.25	25.00	29.00	
Height (cm)	Control	13.00	1.72	10.00	16.00	**P<0.001**
	Heated	15.65	1.27	13.00	18.00	
Weight (g/plant)	Control	209.00	52.33	125.00	310.00	P=0.723
	Heated	204.00	33.82	155.00	285.00	
Yield (kg/m^2)	Control	3.34	0.84	2.00	4.96	P=0.722
	Heated	3.26	0.54	2.48	4.56	
Number of leaves	Control	40.15	5.76	33.00	56.00	P=0.449
	Heated	41.15	4.65	35.00	51.00	

Independent t-test was performed in order to determine whether there was a statistically significant difference between production of lettuce in heated and control greenhouses. Based on the results, it can be concluded that there are significant differences between the diameter and height of lettuce in heated and control greenhouses. In the heated greenhouse lettuce diameter and height were about 2 cm higher than in the control.

On the other side, there are no significant differences in the weight per plant and yield which means that the weight of lettuce head in control and heated greenhouses is similar. Lettuce weight (g/plant) in heated greenhouse was in range from 155 to 285 which coincides with the results achieved in similar studies (Koudela & Petříková, 2008; Todorović *et al.*, 2012, Barbosa *et al.*, 2015). It can be concluded that the length of vegetation did not affect the yield of lettuce as much as did the heating, which is a consequence of relatively low air temperatures in the control greenhouse during the winter months when lettuce stopped its growth. The factors such as cultivation season and weather conditions influenced the formation of phytomass of leaf rosette, which affected its total weight (Karić *et al*., 2018).

Furthermore, there are also no significant differences between the numbers of leaves. While lettuce in heated greenhouse have a slightly more leaves (41.15±4.65) than in the control (40.15±5.67).

As a result of the higher growth intensity, in the heated greenhouse, the total length of vegetation was 67 days, while in the control it took additional 49 days (116 in total) to achieve similar yields. We can claim that heating had a great influence on shortening the vegetation period. It can be concluded that the length of vegetation did not affect the yield of lettuce as much as did the heating, which is a consequence of relatively low air temperatures in the control greenhouse during the winter months when lettuce stopped its growth. Therefore, in heating conditions, it is possible to achieve two cycles of lettuce production during the winter months (October – February), while in control conditions, only one is possible.

Economic justification

A calculation was made to show the economic aspect of greenhouse lettuce production while using renewable energy sources, implying investments in greenhouses equipment with and without a geothermal pump.

Expected investments in a greenhouse production without a geothermal pump in BiH are 1,348.94 Euro. Considering the 15 years of depreciation, the amount of annual depreciation, in that case, would be 89.96 Euro. However, if the farmer decides on greenhouses with geothermal pump, depreciation would be higher by eight times, and the total amount of investment would be 10,845.68 Euro. As a result, the amount of annual amortization would be 723.28 Euro. So, with a heated greenhouse, it is necessary to have higher GM for 633.32 Euro in one season to justify additional investment in the pump (Table 7).

Table 7. Total investment in the greenhouses with and without heating (in Euro)

Describe	Greenhouse	
	Control	**Heated**
Greenhouse with standard equipment	1,349	1,349
Installation of geothermal heating systems		9,497
Investments	**1,349**	**10,846**
Years of depreciation	15	15
Amount of annual depreciation	**90**	**723**

Lettuce was grown on 100 m^2 of the control greenhouse, opposite to 200 m^2 in the heated greenhouse (two production cycles in one season). The total yield of 336.8 kg was achieved in the control greenhouse, while a total of 652.0 kg was produced in heated one. Thus, heating the greenhouse in the experiment did not increase the average lettuce yield (326 kg/100 m^2). Both of these results are similar to previous research. According to Bećirović (2015) expected yield of lettuce in continental climate type of BiH in the greenhouse is 329 kg/100m^2, while in Canton Sarajevo expected yield is 371 kg/100m^2 (Stojanović, 2016). Also, no significant differences in the price of lettuce were found on the market in the time interval between picking lettuce in the control and the heated greenhouse. Therefore, this expected competitive advantage was not achieved either. The average price of lettuce was 2 Euro/kg.

The revenues are also similar (Table 8), amounting to 689 Euro (on 100 m^2) for the control, i.e., 1,333 Euro (on 200 m^2) for the heated greenhouse. Thanks to the higher selling price, revenues per 100 m^2 have a higher value compared to previous research 289 Euro (Becirovic, 2015) and 367 Euro (Stojanovic, 2015). There was no significant difference in the cost for seeds, fertilizers, and pesticides between those greenhouses. The average price per production unit (100 m^2) is almost identical. There is an expected difference due to the different production amounts, so the total costs are twice as high in a heated greenhouse. However, a significant difference occurs in heating costs, which amount to 436 Euro. These costs represent an additional burden in the cost section for the heated greenhouse, while outputs are similar (per 100 m^2). The variable costs for the control greenhouse are 237 Euro and 900 Euro for the heated greenhouse. GM in the control greenhouse is 452 Euro, while in the heated greenhouse it is 433 Euro. So we can see that Lettuce production in both greenhouses has similar achieved GM. However, we needed 3.7 times more working capital in the heated greenhouse for these results. Therefore, we can say that from the economic aspect, the production in the control greenhouse was more successful because we engaged fewer funds for a similar result.

Table 8. Gross margin for *Lettuce* in control (100 m^2) and heated greenhouse (200 m^2) (in Euro)

Description	Greenhouse	
	Control	**Heated**
REVENUES VARIABLE COST	689.04	1,333.09
Seedlings	61.34	112.68
Fertilizer	12.78	25.56
Pesticide	6.65	28.62
Mechanization	10.22	20.45
Labor	111.43	178.39
Geothermal pump	0.00	436.01
Irrigation	10.22	20.45
Supporting material	12.27	24.54
Other costs	12.27	42.94
TOTAL VARIABLE COST	237.18	899.63
GM	**451.86**	**433.46**
Depreciation coverage with GM (%)	**502**	**60**

This is especially noticeable if we look at the coverage of annual depreciation with realized GM. The depreciated value, i.e., fixed cost value, was covered with GM five times (502%) in the control greenhouse. On the other hand, the achieved GM is not sufficient to cover fixed costs in the heated greenhouse, shown by the calculated value of 60%. Thus, observing the relative indicators, we can say significantly better financial results were achieved in the control greenhouse. Therefore, preference is given to increasing the volume of greenhouse production, ie to possible investment in this type of heating. According to this analysis, in current conditions it is better to expand production capacity instead of investing in a geothermal pump. These results should be taken with caution, above all, these are preliminary results done for just one vegetation period, also, due to COVID-19 crisis the agricultural products market was partially disrupted, and when sales and input prices were volatile and unreliable.

CONCLUSIONS

Since the aim of this research was to analyse the possibility for smallholder urban farmers to increase their sustainability using renewable energy sources all relevant environmental and economic aspects of this production were analysed.

During the winter period in Sarajevo (October – December), by using a heating pump in the greenhouse, compared to control the air temperature increased from 2.20 to 3.82 ^{o}C depending on the month. By this, it was achieved that lettuce grown in the heated greenhouse had better-growing conditions and air temperature never dropped below its biological minimum

As a result, lettuce in the heated greenhouse had a larger diameter and height and grew faster, which shortened the vegetation, which lasted only 67 days, and ensured the possibility of producing two cycles. This was not possible in a greenhouse without heating, where 116 days of vegetation were needed to achieve the same yields.

However, financial results in this study show that there is no economically justified investment in the heat pump. Based on economic analysis we can conclude that in Sarajevo instead of investing in a geothermal pump for lettuce production, it is better to focus on expanding production capacity, i.e., in a larger number of greenhouses. Namely, for the price of one geothermal pump, it is possible to equip seven more greenhouses, leaving a surplus of investment funds. If a particular farm had a sufficient volume of labor, especially its own, the benefit of additional greenhouse areas would be more significant than the investment in a single greenhouse with a geothermal pump. However, future research should consider combining different types of renewable energy sources (solar, wind, biomass, etc.) in order to try to achieve more efficient production results.

Also, we believe that crop selection is very important. Lettuce has not proved to be a good choice, however, such analyzes need to be done on the production of peppers and cucumbers. The first reason is that both crops are expected in greenhouse production in BiH. The second reason is related to the cucumber because it is the only fruitful crop that in spring sowing/planting yields after only a month.

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