Conceptual Assessment of Energy Input-Output Analysis and Data Envelopment Analysis of Greenhouse Crops in Crete Island, Greece.

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Abstract

This study examines the relation between inputs and outputs regarding energy quantities and its corresponded financial value, in greenhouse of vegetable crops on the island of Crete, Greece, for the 2015-2016 cropping seasons. The data used was collected from farmers by using a face to face questionnaire. Two methods were applied: Energy Input-Output Analysis and Data Envelopment Analysis. Regarding energy analysis, four crop cases were examined: tomato-pepper, tomato-pepper-cucumber, pepper-eggplant and tomato-cucumber. The results also showed that fertilizers (53%), diesel fuel (16%) and electricity (12%) consumed the bulk of energy. Average yield and energy consumption for each case were calculated as 94036MJ/ha and 171950 kg ha^{-1}, 115473 MJ ha^{-1} and 173000 kg ha^{-1}, 81196 MJ ha^{-1} and 128893 kg ha^{-1} and 146067 MJ ha^{-1} and 209501 kg ha^{-1}, respectively. The results also showed the energy use efficiency, energy productivity, energy input per kg and net energy for each case and implied that the tomato-pepper case was the most efficient and profitable one. Regarding the DEA approach, 13 producers of greenhouse vegetable crops were asked to answer a set of questions regarding to economic values. Inputs with the biggest shares in total inputs were labour (30%), fertilizers (22%) and crop protection (16%). Based on the DEA approach, the average values of technical efficiency, pure technical efficiency and scale efficiency were 0.90193, 0.97272 and 0.80322, respectively. The average in scale efficiencies was as low as 0.80. The findings of the current research would be valuable to the inefficient producers undertaking into consideration the recommendations made by this method, where the total input in euro could be significantly reduced without any reduction on the total output from its present level.

Keywords: Data Envelopment Analysis, Energy Input-Output Analysis, Green House Crops.

1. Introduction

Many surveys were focused on the four major greenhouse vegetables, tomato, pepper, cucumber and eggplant. An investigation in the Antalya region of Turkey [1] described the level of energy use in four different greenhouse crops, tomato, cucumber, pepper and eggplant for both plastic and glass constructions. Cucumber production was the most energy intensive (total consumption of 134.77 GJ ha^{-1}), followed by the tomato (127.32 GJ ha^{-1}), eggplant (98.68 GJ ha^{-1}) and pepper (80.25 GJ ha^{-1}).

On the other hand, the highest Output-Input ratio was for tomato, 1.26. The crops that followed were pepper with 0.99, cucumber with 0.76 and eggplant with 0.61. Thus, the investigation showed that an intensive use of inputs in greenhouse vegetable production is not accompanied by an increase in the final product.

Another investigation in the same area that included data just for glass greenhouses [2] gave similar results. The results showed that energy requirements were higher for tomato and cucumber than eggplant and pepper while the energy ratio was higher for tomato cultivation followed by cucumber, eggplant and pepper cultivation. It also resulted that the net return values of vegetables of production in the greenhouse in comparison with some field crops i.e. wheat chickpea, soybean etc. were found to be significantly greater.

Having as study data the two major vegetable crops, tomato and cucumber, Heidari and Omid [3] indicated in Iran that the total inputs for cucumber and tomato were 141493.51 and 131634.19 MJ ha^{-1}, respectively. The highest energy inputs were diesel fuel and fertilizers. Energy ratio was calculated as 0.69 for cucumber and 1.48 for tomato.

For the case studies where just one crop was considered it was concluded that in terms of tomato crop, Hatirli et al. [4] examined the different types of inputs that were consumed in a greenhouse vegetable production in the Antalya region of Turkey. The results showed that diesel, fertilizer, electricity, chemicals and human power consumed the bulk of energy and that Turkish greenhouse energy is highly dependent on fossil fuels and consequently many environmental problems are caused.

Heidari et al. [5] studied the efficiency of cucumber production in Iran by using Data Envelopment Analysis (DEA). The parameters estimated were Technical Efficiency (TE) as 0.8235, Pure Technical Efficiency (PTE) as 0.9273 and Scale Efficiency (SE) as 0.8880. The results showed that 21% of the total inputs could be saved if the farmers follow the input recommendations by DEA. Regarding the DEA approach Return to Scale estimation (RTS) for cucumber was 1.29 and 0.76 for tomato production, Net Return (NR) was 22651.13 and 78125 $\$ha^{-1}$ and Benefit-Cost ratio was 1.68 and 3.28 ha for cucumber and tomato respectively. For one more time, it can be observed that tomato cultivation was the most profitable. Omid et al. [6] studied the energy use and yield in greenhouse cucumber production in Iran using DEA. The results showed that 8.5% of overall resources could be saved by raising the performance of the production to the highest level.

In this study the efficiency of the crops and the level of sophistication in greenhouse crops of Crete are examined. To achieve the purpose two methods were used: a) the Energy Input-Output Analysis for the energy quantities that were used and b) the Cost-Benefit Analysis for the economic analysis of the inputs that farmers used. For the economic analysis the method of DEA was used to discriminate efficient producers from inefficient ones and recognize wasteful uses of inputs by inefficient farmers.

2. Materials and Methods

2.1. Data collection

The geographical location of Greece is between 35° and 43° north, and 19° and 27° east. The arable land covers about 37.2 million ha and the area that is covered with greenhouse productions is 4860 ha. From this area about 4473 ha are vegetable productions and about 387 ha are flower productions. Table 1 presents the geographical distribution of greenhouse productions in Greece.

Table 1. Geographical distribution of greenhouses in Greece:

Area	Vegetable production (tons)	Flower production (tons)	Total (tons)	Percentage %
East Macedonia	908	102	1010	2.08
Central Macedonia	5683	501	6184	12.72
West Macedonia	69	40	109	0.22
Thessaly	1617	322	1939	3.99
Epirus	2094	61	2155	4.43
Ionian islands	359	16	375	0.77
West Greece	5759	483	6242	12.84
Central Greece	365	73	438	0.9
Peloponnese	5798	210	6008	12.36
Attica	1571	1426	2997	6.17
North Aegean	563	29	592	1.22
South Aegean	816	29	845	1.74
Crete	19129	581	19710	40.56
Total	44731	3873	48604	100

For the Energy Input-Output Analysis, data were collected from the Kountoura area, in West Crete. In terms of the Cost Benefit Analysis, data were collected from producers not only from the Kountoura area but also from two areas of Heraklion, specifically from the Timpaki area in south Crete and the Gouves area in north Crete, as well as the Ierapetra area in south-east Crete. In addition, a face to face questionnaire was used for the collection of data, the examination of the crop management that producers followed, the technological level of equipment that they used and the amount of money that they were willing to invest in their greenhouses in terms of construction, equipment and cultivation. A variety of questions was asked to producers in different regions of Crete during the 2015-2016 cropping season.

2.2. Questionnaire

For the analysis of the efficiency of the greenhouse constructions on the island of Crete a face to face questionnaire was required. The questionnaire that was used included questions that would lead to the answer of which level of investment the producers choose in this area. The questions were separated into five categories.

2.2.1. General information

The first referred to the general information and identification of the area. The other four referred to the construction of the greenhouse, the cropping system and practices that were used by each producer, the inputs and the outputs. The target was to understand the level of investment, the knowledge that the producers feature and the person that is responsible for the decision making throughout this process.

First, the general information that was needed was the total covered area, the type of construction, the number of plots and their dimensions, the orientation of the greenhouse, the system that was used and the crops that were cultivated. There were also questions like the type of business, characterized that as a family business or not and the method of learning the weather forecast. What follows next is a set of questions that were asked.

2.2.2. Greenhouse construction

For the group of questions based on the greenhouse construction, a variety of questions was used for the study of the level of investment on the part of construction. Farmers were asked to respond about the year of the construction of the greenhouses that they had or obtained in the last years, the type of greenhouse depending on the materials that were used for the construction and the systems that were used for the environment control. Such systems are the ventilation system, the cooling system, the heating system and the irrigation system. In a first step the producers answered if they feature the above systems and subsequently they answered a group of more specific questions based on the methods that they were using, the total price of each investment that was involved, the reason for making these choices and who was consulted.

2.2.3. Cropping system and practices

Based on the cropping systems and the cropping practices that were used, another group of questions was presented to the producers to answer. The target was the study of the choices of each producer and the reasons that led them to make these decisions. Important was the type of cropping system that was followed, the type of crops that were cultivated and the different needs of each crop that need to be considered by the farmers for an efficient result. Such needs are the plant density of crops and the use of pollinators. Also important was if the farmers were using seeds or plants, who was the supplier and if the plants had any resistance or tolerance, depending on the environment of the area. Questions based on the product and the production were also made.

2.2.4. Inputs

The inputs that were used from the chemicals (fertilizers and pesticides) that were required, from parameters like electricity, water, fuels for different purposes and labor. The target was to learn the level of energy consumption and the level of economic investment of the above parameters. Detailed questions were asked for the number and the type of workers and what was provided to them by the farmers, from the cost of salary to weather hygienic uniforms or areas were available for them. For the pesticide use, of importance was what types of chemicals producers were using, for what purposes and who was consulted on the decision of the frequency of application and the dose size. Additionally, important were the most significant pests and diseases of the area, the management of the already contaminated material and the cost of the chemicals for preventive and therapeutic purposes. Depending on the fertilizers, similar questions related to the formulation, method, frequency and doses were made.

2.2.5. Outputs

Regarding the outputs, the parameters that were considered were the production of the crops, the contaminated vegetative material that was thrown out, the possible excess of chemicals or water and the residues of crops or plastic.

3. Results and Discussion

3.1. Input-Output Analysis

The energy input-output analysis data were collected from greenhouse farmers in the Kountoura area in the west part of Crete and they were members of a partnership there. The total covered area of the partnership was 34.75 ha and all the greenhouse productions were integrated. Tomato cultivations covered 68%, pepper 16.3%, eggplant 8.5% and cucumber 7%. Most of the productions had one cycle except in the case of cucumber that had more.

The general view of inputs for all production is shown in Table 2. Each case includes one producer except for the tomato-pepper case where an average value was calculated from two producers of these crops. For the energy analysis the target is to analyze the relationship between inputs and yield. The crops were analyzed as a total for each producer. Producers are not so well organized and information that they were keeping for their productions was kept as a total and not separately for each crop or each greenhouse construction (Tables 3-6).

Table 2. Total energy use for the greenhouse production.

Inputs	Total energy equivalent	Percentage %
A. Input		
Chemicals (kg)	30774.92	5.8
Human power(h)	38359.4	7.23
Nitrogen (kg)	214590.6	40.42
Phosphorus (kg)	18987.53	3.58
Potassium (kg)	47184.66	8.89
Plants	22529.44	4.24
Diesel-oil (l)	86041.68	16.21
Electricity (kW h^{-1})	62031.6	11.69
Water (m^3)	10309.32	1.94
Total	530809.1	
B. Output		
Yield (kg ha^{-1})	684235.2	

Table 3. Energy use pattern for greenhouse tomato-pepper production.

Inputs	Quantity per unit area (ha)	Energy equivalent	Total energy equivalent	Percentage (%)
A. Input				
Chemicals (kg)	59.35	101.2	6006.22	6.39
Human power(h)	3618	2.3	8321.4	8.85
Nitrogen (kg)	499.9	66.14	33063.06	35.16
Phosphorus (kg)	220.9	12.44	2748.18	2.92
Potassium (kg)	690.9	11.15	7703.59	8.19
Plants	16329	0.28	4572.12	4.86
Diesel-oil (l)	325	0.28	18300.75	19.46
Electricity (kW h^{-1})	3231	56.31	11631.6	12.37
Water (m^3)	2682	3.6	1689.66	1.8
Total	**27656.05**	**253.7**	**94036.6**	
B. Output				
Yield (kg ha^{-1})	171950	0.63	137560	

Table 4. Energy use pattern for greenhouse tomato-pepper-cucumber production.

Inputs	Quantity per unit area (ha)	Energy equivalent	Total energy equivalent	Percentage (%)
A. Input				
Chemicals (kg)	36	101.2	3643.2	3.15
Human power(h)	3454	2.3	7944.2	6.88
Nitrogen (kg)	660.4	66.14	43678.86	37.83
Phosphorus (kg)	310.8	12.44	3866.35	3.35
Potassium (kg)	810.4	11.15	9035.96	7.82
Plants	18526	0.28	4533.38	3.92
Diesel-oil (l)	48	0.28	2702.88	2.34
Electricity (kW h^{-1})	10255	56.31	36918	31.98
Water (m^3)	5000	3.6	3150	2.73
Total	**39100.6**	**253.7**	**115472.83**	
B. Output				
Yield (kg ha^{-1})	173000	0.63	138400	

Table 5. Energy use pattern for greenhouse pepper-eggplant production

Inputs	Quantity per unit area (ha)	Energy equivalent	Total energy equivalent	Percentage (%)
A. Input				
Chemicals (kg)	6.4	101.2	647.68	0.8
Human power(h)	2560	2.3	5888	7.25
Nitrogen (kg)	772.3	66.14	51079.92	62.91
Phosphorus (kg)	373.3	12.44	4643.85	5.72
Potassium (kg)	759.3	11.15	8466.19	10.43
Plants	13895	0.28	3890.6	4.79
Diesel-oil (l)	90	0.28	5067.9	6.24
Electricity (kW h^{-1})	0	56.31	0	0
Water (m^3)	2400	3.6	1512	1.86
Total	**20856.3**	**253.7**	**81196.14**	
B. Output				
Yield (kg ha^{-1})	128893	0.63	103114.4	

Table 6. Energy use pattern for greenhouse tomato-cucumber production.

Inputs	Quantity per unit area (ha)	Energy equivalent	Total energy equivalent	Percentage (%)
A. Input				
Chemicals (kg)	143	101.2	14471.6	9.9
Human power(h)	3428	2.3	7884.4	5.4
Nitrogen (kg)	812	66.14	53705.68	36.77
Phosphorus (kg)	400.4	12.44	4980.98	3.41
Potassium (kg)	1280.3	11.15	14275.34	9.77
Plants	19234	0.28	4961.22	3.4
Diesel-oil (l)	740	0.28	41669.4	28.53
Electricity (kW h^{-1})	514	56.31	1850.4	1.27
Water (m^3)	3600	3.6	2268	1.55
Total	**30151.7**	**253.7**	**146067.2**	
B. Output				
Yield (kg ha^{-1})	209501	0.63	167601	

The inputs used in the agricultural production process and output are converted to forms of energy to evaluate the output-input analysis. To estimate the quantities of energy, energy equivalents of inputs and outputs were converted into equivalent energy units as suggested by

Canakci and Akinci [2] and Hatirli et al. [4]. Also, energy demand in agriculture can be divided into direct and indirect energies or renewable and non-renewable energy [7, 8]. Direct energy (DE) covers human labor, water, diesel and electricity, while indirect energy (IDE) includes energy embodied in fertilizers, manure, chemicals, plants and machinery used during the production process, [7, 8].

The results for the total inputs and yield in kg ha^{-1} and in MJ ha^{-1} are provided in Table 7. Moreover, Table 8 provides the energy parameters of energy use efficiency, energy productivity, specific energy and net energy for each group of crops.

Table 7. Inputs and yield for the crop cases.

	Tomato-Pepper	**Tomato-Pepper-Cucumber**	**Pepper-Eggplant**	**Tomato-Cucumber**
Total Inputs	94036,6	115473	81196	146067
Yield (MJ ha^{-1})	137560	138400	103114	167601
Yield (kg ha^{-1})	171950	173000	128893	209501

Table 8. Energy parameters for each crop case.

	Tomato-Pepper	**Tomato-Pepper-Cucumber**	**Pepper-Eggplant**	**Tomato-Cucumber**
Energy use efficiency (MJ MJ^{-1})	1.462834684	1.198548578	1.269939406	1.147425497
Energy productivity (kg MJ^{-1})	1.828543354	1.498185723	1.587430415	1.434280159
Energy Input/kg of product (MJ kg^{-1})	0.546883396	0.667473988	0.629948872	0.697213856
Net energy (energy output-energy input)	43523.4	22927	21918	21534

Regarding yield of the production (kg ha^{-1}) tomato-cucumber crops had the highest, followed by tomato-pepper-cucumber-tomato-pepper and pepper-eggplant. The yield according to energy (MJ ha^{-1}) and the total inputs of each case follow the same rank. Thus, energy use efficiency was the highest for tomato-pepper, followed by pepper-eggplant, tomato-pepper-cucumber and tomato-cucumber. Energy productivity (kg MJ^{-1}) and energy input per kg of product (MJ kg^{-1}) follow the same rank. Net energy was the highest for tomato-pepper, followed by tomato-pepper-cucumber, pepper-eggplant and finally tomato-cucumber. Thus, tomato-pepper production has the highest use efficiency, the highest productivity, the lowest energy input per kg of product and the highest net energy. It is the most profitable combination of the four cases. Also, it is implied that an intensive use of inputs is not always accompanied by an increase in the final product.

Having as a comparison the case of the production of tomato-pepper and cucumber, an increase resulted in inputs higher than the increase in yield in respect of both energy and kilos of product. Specifically, inputs were increased by 21436.4 MJ and the yield only by 840 MJ and 1050 kg of product, respectively. The energy efficiency and energy productivity are much lower in comparison with tomato-pepper production. Energy input per kilogram of product is higher by 0.12 but net energy is almost half of the tomato-pepper production.

Regarding tomato-cucumber production, it is observed that the highest quantity of total inputs was used but even these crops had the highest yield in respect of both energy and kilos of product; it gave the lowest energy efficiency, energy productivity and net energy. In addition, the energy input per kilo of product was the highest. Pepper-eggplant production used the least quantity of inputs and gave the least yield. However, in terms of energy use efficiency and energy productivity it ranked second. It was also second with respect to the energy input per kilo of product. Concerning the net energy, it was ranked third, but with a very small difference compared with the cases of tomato-pepper-cucumber and tomato-cucumber. Next is provided the output-input ratio that is useful to investigate the relationship between the type of the crop and the efficiency (Figure 1).

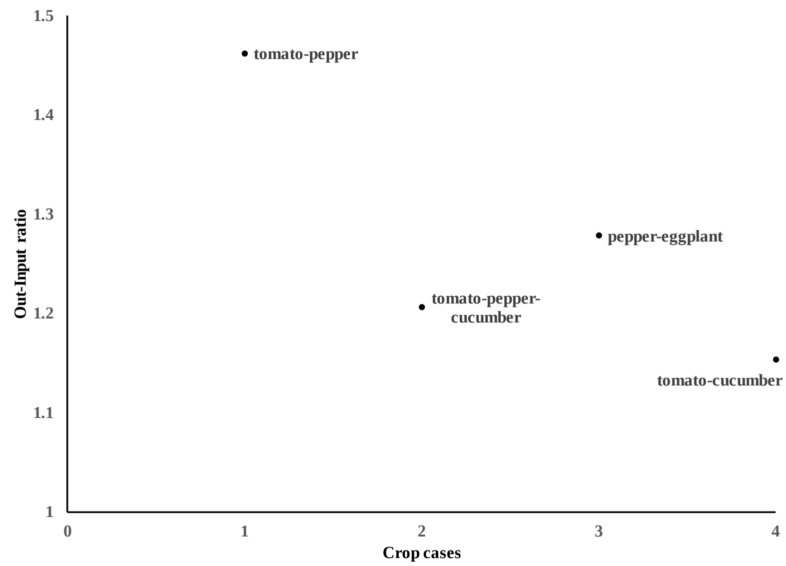

Figure 1. Output-Input ratio of each crop case.

From Figure 1, it can be concluded that the production of tomato-pepper has a higher efficiency, followed by pepper-eggplant, tomato-pepper-cucumber and tomato-cucumber. Pepper-eggplant production had a lower quantity of total inputs in comparison to tomato-cucumber.

Regarding the types of energy, direct energy per hectare for the total of crops was 196742 MJ and indirect energy was 334067.15 MJ. Hence, direct energy occupied 37% of total energy and indirect 63%. Renewable Energy (RNE) consists of human labor and plants, whereas non-renewable energy (NRE) includes diesel, electricity, water, manure, fertilizers and chemicals. Hence, the energy that was consumed is, to a high degree, non-renewable energy. Specifically, renewable energy was 60888.84 MJ and non-renewable was 469920.31 MJ; renewable occupied 11.50% of total energy and nonrenewable occupied 88.50%.

3.2. Data Envelopment Analysis

In this study, the determination of efficient and inefficient greenhouse producers regarding financial data was carried out by using Data Envelopment Analysis, DEA. The DEA method is used to discriminate efficient producers from inefficient ones having as a target to eliminate the energy uses and to propose the right quantities of inputs to each inefficient one.

Based on Liu et al. [9], "DEA is based on a finite sample of observed production units, which uses a linear programming method and does not need to estimate a pre-established functional form. It follows the approach of Farrell [10] and was proposed in 1978 by Charnes et al. [11]. DEA constructs an efficient frontier using the best performing farm business of the sample. The advantage of DEA is its flexibility and the possibility of using it for different firm types and scenario analysis. The possibility to calculate technical efficiency over time makes the analysis of firm efficiency changes over a period possible". DEA is used to empirically measure productive efficiency of decision making units (or DMUs). There are two kinds of DEA models included: Charnes-Cooper-Rhodes (CCR) built on the assumption of Constant Returns to Scale (CRS) and Banker, Charnes, Cooper (BCC) models built on the assumption of Variable Returns to Scale (VRS) of activities.

Efficiency by DEA is characterized by three distinct structures: overall Technical Efficiency (TE), Pure Technical Efficiency (PTE) and Scale Efficiency (SE). Technical Efficiency (TE) is characterized as the accomplishment of the most extreme potential yield from given measures of data sources, considering the physical features. It can be estimated inside two primary systems [12].

First is the input- preoccupied with framework where technical efficiency leads to the potential input reduction that a ranch could use without reducing its yield level; instead, there is the output-preoccupied with framework where technical efficiency leads to information about the potential yield increase that a ranch could use without inputs increment [13].

DMUs are operating at an optimal scale based on the CRS DEA model assumption. The CRS DEA model allows the quantification of global sensitivity analysis to be conducted in lack of dissimilarities in revenues to scale. Still, the optimal performance is generally limited by several aspects includes the financial issues, method limitations and defective competition. DEA was introduced by o the Variable Returns to Scale (VRS) by Banker et al. [14]. VRS was able to discriminate between the scale efficiency and the pure technical efficiency regardless the return scale trend [15].

Cook and Seiford [16] define the Scale Efficiency based on BCC and CCR scores in which the former (BCC) was originally projected by [14]. Therefore, the technical efficiency of the BCC model considered to be the Pure Technical Efficiency which it can be formulated as follows:

SE=TECCR/TEBCC.

In case of scale efficiency is less than 1, the DMU will be effective either at Decrease Returns to Sale (DRS) if a proportional surge of all input levels produces a less-than-proportional surge in output levels or Increasing Return to Scale (IRS) in the opposite case.

In the case of a ranch with a pure technical efficiency less than 1, that leads to excess money spending at that ranch more than its needed from the dissimilar sources. Consequently, it is anticipated to recommend representative levels of spending to be cast-off from each source for each ineffective ranch to avoid expenditure of money without dropping the yield production.

Table 9 indicates the efficiency estimation results for the producers, based on the DEA approach. It provides the technical efficiency in terms of the CRS and VRS models, the Σλ that refers to each DMU under evaluation and the scale efficiency, identifying if increasing, decreasing or constant returns to scale are present.

Table 9. Efficiency estimation results for each producer.

DMU No	Technical Efficiency		SE	Σλ	RTS
	CRS	VRS			
1	1.00000	1.00000	1.00000	1	constant
2	1.00000	1.00000	1.00000	1	constant
3	1.00000	1.00000	1.00000	1	constant
4	1.00000	1.00000	1.00000	1	constant
5	1.00000	1.00000	1.00000	1	constant
6	0.45409	1.00000	0.45409	0.17143	increasing
7	0.90650	1.00000	0.9065	2.52757	decreasing
8	1.00000	1.00000	1.00000	1	constant
9	1.00000	1.00000	1.00000	1	constant
10	1.00000	1.00000	1.00000	1	constant
11	1.00000	1.00000	1.00000	1	constant
12	0.72706	1.00000	0.72706	2.69012	decreasing
13	0.63755	0.64539	0.98785	0.95670	increasing
Mean	0.90193	0.97272	0.80322	1.18044	

Based on the CCR results of this study, 9 producers were efficient and the remaining 4 were inefficient (Table 10). From the BCC model only one producer was inefficient in input use and the remaining 12 were efficient, meaning that they had a score of 1 (Table 10). These producers could use less input to succeed with the same yield.

The outcomes of DEA analysis expressed that the mean values of technical efficiency, pure technical efficiency and scale efficiency were 0.90193, 0.97272 and 0.80322, respectively. The mean of scale efficiencies was 0.80, which shows that if ineffective farmers use their inputs resourcefully substantial revenues are projected, regardless any modification in technological performs. The total input in euro could be decreased enough with no total yield reduction from the current level by approving the endorsements based on the adopted scheme.

The return to scale estimation also provides useful information. The fixed returns to scale specifies that the equivalent increase in outputs in response to an increase in inputs whereas, increasing (decreasing) returns to scale indicate that an increase in the input resources produces more (less) than an equivalent increase in outputs. The findings point out that majority of the greenhouse producers are functioning at the optimal scale with a few producers from the total demanding to enhance their efficiency. The findings of the RTS showed that farmers, 9, 2 and 2 farmers, from the total of 13, were functioning constant, decreasing and increasing returns to scale, respectively. The majority of the DMUs (69.23%) appear to be constant, 15.38% appear to have decreasing returns to scale and the rest (15.38%) appear to have increasing returns to scale (Figure 2).

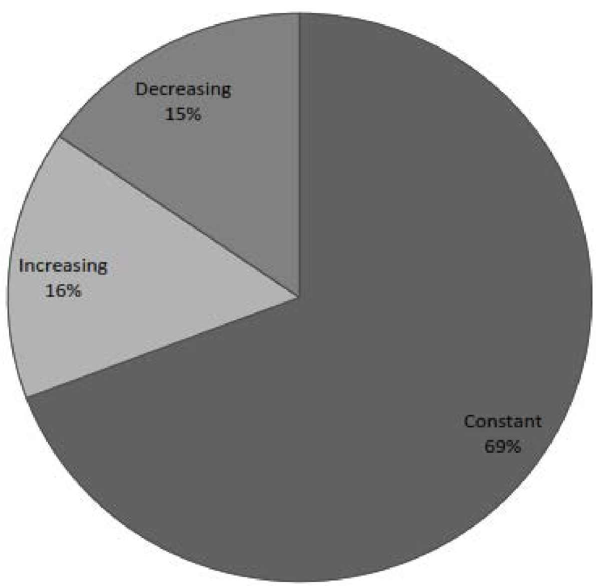

Figure 2. Return to scale estimation

Table 9. Efficiency rate scores under the CRS and VRS DEA Models.

Efficiency rate	CRS DEA model No of Firms	%	VRS DEA model No of Firms	%
$0.9 \leq E \leq 1$	10	76.9	12	92.3
$0.8 \leq E \leq 0.89$	0	0	0	0
$0.7 \leq E \leq 0.79$	1	7.7	0	0
$0.6 \leq E \leq 0.69$	1	7.7	1	7.7
$0.5 \leq E \leq 0.59$	0	0	0	0
$0.4 \leq E \leq 0.49$	1	7.7	0	0

Farmers with an efficiency rate lower than 1 used the wrong quantity of inputs throughout all the cultivation process or had a low yield at the end of the cultivation. The inputs with the highest costs for the farmers were labor, crop protection and fertilizers. Usually, farmers believe that an increase in chemicals would generate a better product and a better profit, but this is not true. Plants need a specific quantity of chemicals for a normal development, as these help for a better control of pests and diseases and for a better soil environment. The excessive doses however bring negative results. Farmers need to reduce quantities of these parameters to succeed in a higher yield and therefore higher income. Consequently, the hours that workers work would be reduced, or seasonal labor would not be necessary for sprayings. Thus, the cost of labor would be lower. As shown by the analysis if inefficient producers paid more attention towards this source, they could improve their productivity.

4. Conclusions

The two methods that were applied (Energy Input-Output Analysis and Data Envelopment Analysis) provided useful information regarding the image of greenhouse crops on the island of Crete, in the 2015-2016 cropping season. Energy input-output analysis showed that the most profitable production case was tomato-pepper with the lowest input per kg of product and the highest energy productivity, energy efficiency and net energy in relation to the other 3 cases. The highest share in inputs was occupied by fertilizers and especially by nitrogen with 40% of total inputs, diesel fuel and electricity. DEA has helped in segregating efficient farmers from inefficient farmers and finding the wasteful uses of inputs by inefficient growers. Based on the BCC model only one from thirteen producers was inefficient; based on the CCR model most of the producers were efficient. Nine out of thirteen were efficient; two were operating at increasing returns to scale and two at decreasing returns to scale. The total input in euro could be significantly reduced without reducing the total yield from its present level. The highest share of inputs with respect to cost was in labor, followed by fertilizers and crop protection.

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