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

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✓four major greenhouse vegetables: tomato, pepper, cucumber and eggplant;

✓cucumber production - 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});

✓ in Iran the highest energy inputs - diesel fuel and fertilizers;

✓in Turkey diesel, fertilizer, electricity, chemicals and human power consumed the bulk of energy; greenhouse energy is highly dependent on fossil fuels causing many environmental problems.

Aim of the 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 Data Envelopment Analysis (DEA) was used to discriminate efficient producers from inefficient ones and recognize wasteful uses of inputs by inefficient farmers.

Materials and Methods

1. Data collection

✓geographical location of Greece - between 35° and 43° north, and 19° and 27° east;

✓arable land covers about 37.2 million ha;

✓4860 ha covered with greenhouses - from this area about 4473 ha is for vegetable productions and about 387 ha for flower production;

✓for the Energy Input-Output Analysis, data were collected from the Kountoura area, in West Crete;

✓ for the Cost Benefit Analysis, data were collected from from the Kountoura area, from two areas of Heraklion and Ierapetra area in south-east Crete;

✓a face to face questionnaire was used for the collection of data.

2. Questionnaire

The questions were separated into five categories.

2.1. General information

general information and identification of the area, construction of the greenhouse, the cropping system and practices that were used by each producer, the inputs and the outputs.

2.2. Greenhouse construction

For the level of investment on the part of construction. year of the construction of the greenhouses, the type of greenhouse depending on the materials that were used for the construction and the systems that were used for the environment control (ventilation system, the cooling system, the heating system and the irrigation system).

2.3. Cropping system and practices

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 – needs: plant density of crops and the use of pollinators, using seeds or plants, who was the supplier and if the plants had any resistance or tolerance, depending on the environment of the area.

2.4. Inputs

inputs that were used from the chemicals (fertilizers and pesticides), 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 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. 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.

2.5. Outputs

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.

Results and Discussion

3.1. 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%.

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	

Inputs and yield for the crop cases

- tomato-cucumber crops had the highest yield of the production (kg ha^{-1}), 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;
- energy use efficiency was the highest for tomato-pepper, followed by pepper-eggplant, tomato-pepper-cucumber and tomato-cucumber.

	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

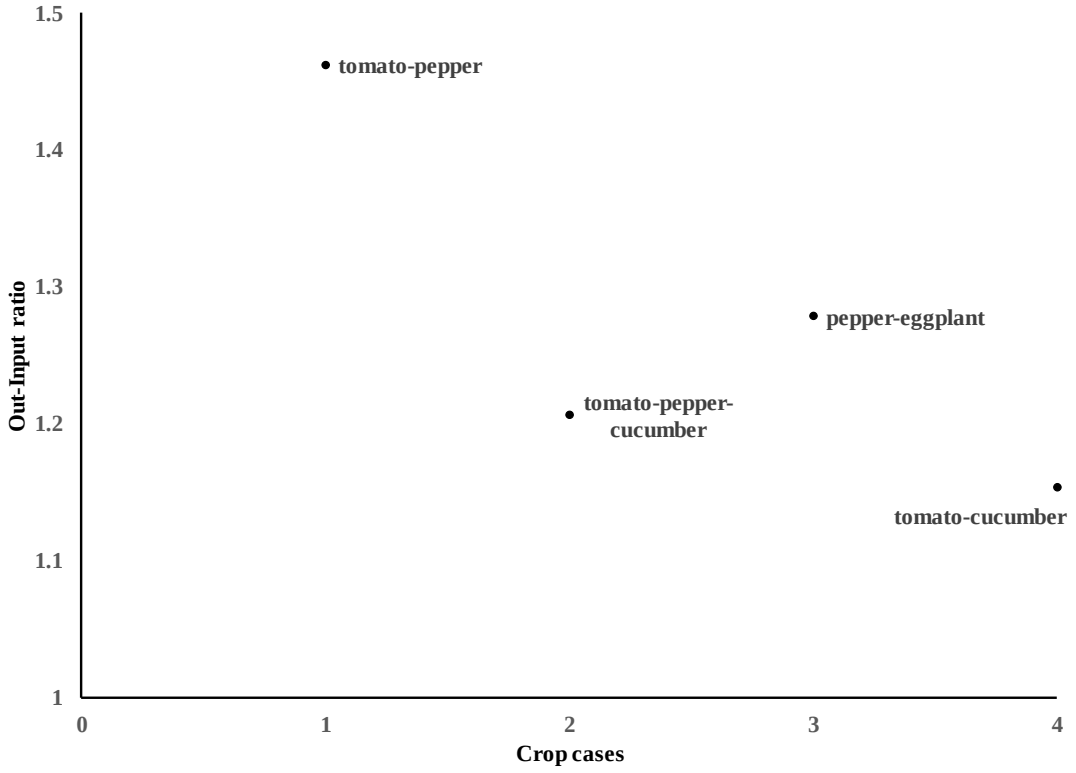
Energy parameters for each crop case

- 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;
- tomato-pepper production has the highest use efficiency, the highest productivity, the lowest energy input per kg of product and the highest net energy - most profitable combination of the four cases;
- an intensive use of inputs is not always accompanied by an increase in the final product.

	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

Output-Input ratio of each crop case

- tomato-cucumber production: highest quantity of total inputs - highest yield in respect of both energy and kilos of product - the lowest energy efficiency, energy productivity and net energy;
- pepper-eggplant: least quantity of inputs - gave the least yield; ranked second in terms of energy use efficiency, energy productivity and energy input per kilo of product;
- the production of tomato-pepper has the highest efficiency.



✓direct energy per hectare for the total of crops - 196742 MJ - 37% of total energy
✓indirect energy per hectare for the total of crops - 334067.15 MJ - 63% of total energy

✓renewable energy - 60888.84 MJ - 11.50% of total energy
✓non-renewable - 469920.31 MJ - 88.50% of total energy

3.2. Data Envelopment Analysis

DEA method - 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.

DEA is used to empirically measure productive efficiency of decision making units (DMUs).

Two kinds of DEA models:

✓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.

The technical efficiency of the BCC model considered to be the Pure Technical Efficiency which formulated as :

SE=TECCR/TEBCC.

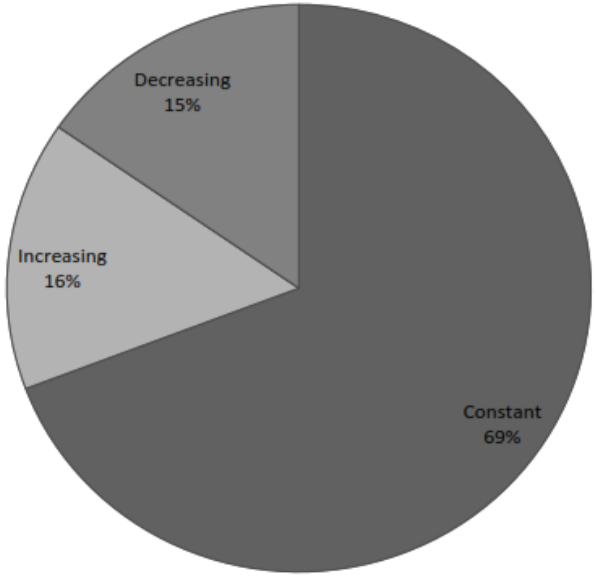
Efficiency estimation results for each producer

CCR model - 9 producers were efficient and 4 were inefficient.
BCC model - one producer was inefficient and 12 were efficient (score of 1).

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	

Return to scale estimation

DMUs
69.23% –constant;
15.38% -decreasing returns to scale;
15.38% -increasing returns to scale.



- farmers with an efficiency rate lower than 1 used the wrong quantity of inputs or had a low yield;

- inputs with the highest costs: labor, crop protection and fertilizers;

- an increase in chemicals do not generate a better product and a better profit;

- excessive doses of chemicals for a normal development of plants bring negative results,

- farmers need to reduce quantities of these parameters to succeed in a higher yield and higher income;

- hours that workers work would be reduced, or seasonal labor would not be necessary for sprayings - the cost of labor would be lower.

- if inefficient producers pay more attention towards this source, they could improve their productivity.

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.


THANK YOU FOR YOUR ATTENTION!