Application of mathematical methods for identification of efficient and inefficient farms in production of vineyards in Albania

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Abstract

Grape is a fruit with extraordinary value, whose consumption guarantees a healthy life.100 grams of grapes contain a total of 69 kilocalories. 80% of grapes consist of water, 17% sugar, followed closely by the protein, amino acids, fats, minerals and vitamins.
Grapes contain antioxidants which are very rich in mineral salts such as potassium, phosphorus, zinc, magnesium, calcium, iron, selenium and important vitamin. Vitamin A is the most prevalent ingredient followed by vitamins B, C and K. Grape is very beneficial to three organs: the kidneys, the liver and the intestines. Grapes contain flavonoids or powerful antioxidants that significantly reduce damage which may be caused by free radicals and early aging. Grape skins contain most of the nutrients. Recently, in its skin there has been found an antioxidant called resveratrol, which helps with the circulation of blood. It is a fruit that can be consumed by everyone, except for patients with diabetes. The grape varieties are red, black and green. Main objective of this manuscript is the application of mathematical methods for identification of efficient and inefficient farms in production of vineyards.

Keywords: mathematical methods, identification, farms, production of vineyards, Albania.

Introduction

Among the environmental elements which are established to be the most important for the smooth growth and development of the grape vines are the following: air temperature; soil temperature; air humidity and soil; light; aeration; wind; the presence of nutritional elements in the soil, etc. Each of these elements has its importance and place in the life of this plant. The values of these elements for a certain area or micro zone are different. Theydepend on the sea level altitude, counter clocking to the sun, the relief, the chemical and physical composition of the earth, the geographic width, and many others.

Water requirements

To ensure high yields and high quality of production per unit of surface, first of all it is necessary to be well acquainted with the requirements of the vine for this vital element. Needs for moisture are different throughout the different stages of growth and development. The optimal water regime in the soil during the vegetation period should be about 60-70% of its water retaining ability.

Light requirements

The vine belongs to the group of plants with high demands on solar light. When light is not in the right intensity, the vegetative processes decrease and in its absence the plant growth is discontinued. Under inadequate light the leaves do not perform properly the photosynthesis and they are not able to produce the appropriate amount of organic matter, thereby interrupting the supply of grape seed with organic matter. With an inadequate amount of light, the grains stop growing and those that come to mature have very low food values, a limited amount of juice and insignificant amounts of sugar.

Soil requirements

The composition of the soil and its physical qualities are of particular importance to obtain grapes with high quality products and customer satisfaction and it's processing into wine. The best soils are those that possess food stuffs in significant amounts. The deep, friable, humid, airy, sandy, clayey structures, cleaned by many years of weeds, are the most ideal for the grape vine. In addition to table grapes with or without flavor in Albania there are other varieties of grapes for wine-processing including Kallmet, Moscow, White Square, and Black Square etc.

Given the great value of this fruit, farmers have increased the number of vineyards in the appropriate areas for the cultivation of grape vines. Setting up and managing vineyards requires collaboration, investment, balance and incorporation of scientific technology. The establishment of the vineyard is achieved through the cooperation of the landowner, the finance people, the planner and the implementer. A brief description of the origin, distribution and destination of cultivars of varietal structures is shown in the table below (Table 1).

Table 1. Cultivars proven in terms of climate and soil Tirana

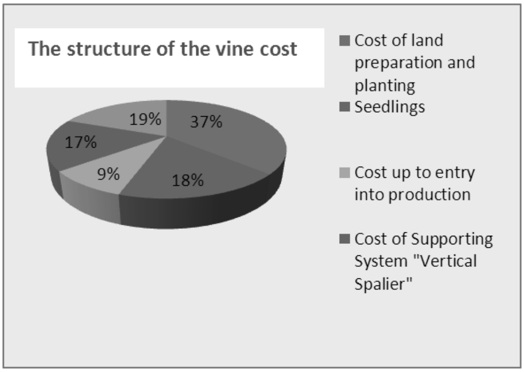
Nr.	Name of cultivar	Comments on the origin and spread
I	For red wine	
1	Kallmet	Local cultivars in Mirdita, Lezha, Shkodra, etc.
2	Shesh i Zi	Local cultivars, mainly in Middle Albania
3	Vranac	Local cultivars, in Shkodra, Koplik, etc.
4	Game	French cultivars, in Tropoja, Gjakova, Rahovec
5	Debinë e Zezë	Local cultivars, Leskovik, Permet, Tepelena, etc.
6	Vlosh	Local cultivars, in Berat, Fier, Lushnje, etc.
7	Merlot	French cultivars, very widespread
8	Cabernet Sovignon	French cultivars, very widespread
9	Primitivo	Widespread in Croatia and Italy, etc.
10	Syrah	Widespread in Persia and the Balkan countries
11	Tempranillo	Spanish cultivars, widespread in Albania
12	Prokupa (Dibraku)	regional cultivars, in Rahovec region, Debar, etc.
II	For white wine	
1	Shesh i Bardhë	Local growers in Middle Albania
2	Puls i Bardhë	Local cultivars in Berat, Skrapar
3	Cëruja	Local cultivars, in Mat, Mirdita, Debar, Kruja
4	Tokaj	Hungarian cultivars, in Korça, Pogradec, etc.
5	Muskat i bardhë	Italian cultivars, prevalent in Tirana

6	Trebiano	Italian cultivars, very widespread
7	Riesling Italian	Italian cultivars, very widespread
8	Riesling Gjerman	German cultivars with scent, little widespread
9	Shardone	French cultivars, very widespread
10	Verdichio	Cultivar Italian (Marche Region), a bit widespread

Table 2. The cost of the basic investment (total cost of building the vineyard)

Nr	The total cost of building the vineyard	The cost for 1 ha		%to total
		ALL	Euro	
1	Cost of land preparation and planting	1000700	7358	36.6
2	Seedlings	495000	3639	18.1
3	Cost up to entry into production	250200	1839	9.1
4	Cost of Supporting System "Vertical Spalier"	46200	3397	17
5	Cost of Irrigation System with Points	524800	3859	19.2
	TOTAL	2316900	20092	100

From the analysis of the above results, it turns out that: the total cost (based on investment) for setting up a vineyard consisting of a one-hectare area held in vertical spoiler four-wire, including costs for drip-irrigation of plant and technological services in the first three years after planting (until he enters production), is 2316900 ALL, equal to 20090 euro (course 1: 1.36).[6],[7],[8]



Graphical presentation of the foundation investment structure (in %)

Graph 1. Cost structure (expressed in %)

Source: Data provided by the authors

The graph shows that in terms of the main investment items, most of the costs are recorded on seedlings, irrigation systems, support systems, preparatory work and planting of seedlings. In the study, 15 farms with vineyards in the district of Tirana have been surveyed, each possessing the same area of 1 ha. Production, income and net profit pertain to the year 2016. The differences between farms show in the form of efficiency and sales price which varies depending on the quality and production (high yield, lowest selling price, etc.).The aim of the study is to analyze and consequently improve the efficiency of these vineyards through the use of the Dea (Data Envelopment Analysis) mathematical model.

Materials and Methods

The study in question aims at identifying efficient and inefficient farms for vineyard production in the district of Tirana. The study included 15 farms with equal surface area of 1 ha. The collected information pertains to the year 2016. In order to carry out the study, mathematical methods were employed which yielded results of rapid and effective problem solving. A mathematical, non-parametric DEA model was used, based on the linear programming method (case: 3 outputs and 3 inputs).
Outputs: Income (000/ALL); Production (q/ha); Profit (000/ALL)
Inputs used; Annual expenses (000/ALL)(including expenses on salaries of employees, costs of the mechanization, costs for the purchase of pesticides and fertilizers, costs for equipment such as pumps, pruning-shears, etc.);The sales price (ALL/kv); Number of workers for 1 hectare(ha).This study was based on information obtained from specialists of vineyard farms, reviewing the relevant literature, using the results of other studies as well as statistical reports. The references used will contribute to the attainment of the study goals. To analyze and improve production efficiency of this activity was used mathematical model, non-parametric Dea, a methodology based on linear programming. The model is used to achieve the purpose of the study, is oriented to inputs, to minimize the amount of inputs used (production costs), to produce a given level of outputs. The model requires the assignment of output or outputs and inputs which will be used in the model. Concretely, selected outputs are: production (q/ha), annual incomes (ALL) and net profit (ALL) while inputs are: sales price (ALL/q), annual expenses (ALL) and the number of workers. Efficiency unit to

$$h_0(u,v) = \frac{weighted\ sum\ of\ unit\ output\ U_0}{weighted\ sum\ of\ inputs\ unit\ U_0} =$$

$$= \frac{\sum_{r=1}^{s} y_{r0} \times u_r}{\sum_{i=1}^{m} x_{i0} \times v_i}$$

The importance of using this model lies in assignment of weights (portions) u_r $u_r$and $v_i v_i$which represent the decision variables in the problem solving linear programming. Further set the target, which each unit ($U_0 U_0$) to be assessed, it is the same:

$$Max: \sum_{r=1}^{s} y_{r0} \times u_r$$

With appropriate restrictions for each unit that investigated:

$$\frac{\sum_{r=1}^{s} y_{r_0}\mu_r}{\sum_{i=1}^{m} x_{i_0} v_i} \leq 1 \sum_{r=1}^{s} y_{r_0} \; or \; u_r - \sum_{i=1}^{m} x_{i_0} v_i \leq 0_{v_i} \leq 0$$

2. $\sum_{i=1}^{m} x_{io} v_i = 1 \sum_{i=1}^{m} x_{io} v_i = 1$

3. $u_r \geq 0 \; and \; v_i \geq 0, \forall \, r$ and $i. \, u_r \geq 0 \; and \; v_i \geq 0, \forall \, r$ and $i.$

Implementation of the model is done in Excel, Data and Solver Solution. Units that are efficient will have outcome 100% Dea efficiency. Efficient units are the best choice in the group. If coefficient $h_0 h_0$ is less than 1, the unit is relatively inefficient. The model $U_0 U_0$ is further used in determining the best weights of the inputs used to obtain at least the same output. [1],[2]

Implementation of the model

The following model has been applied to assess the efficiency of the unit7. PL problem for the study unit is as follows:
Max: $92\mu_1 + 763600\mu_2 + 405408\mu_3 92\mu_1 + 763600\mu_2 + 405408\mu_3$ output weights for unit 7.
Conditions:

$$\begin{cases} 97864u_1 - 112v_1 - 831244v_2 - 10510v_3 - 9957v_4 \leq 0 & condition\ of\ efficiency\ of\ unit\ 1 \\ 110231u_1 - 110v_1 - 832187v_2 - 10210v_3 - 10234\ v_4 \leq 0 & condition\ of\ efficiency\ of\ unit\ 2 \\ 109734u_1 - 110v_1 - 829650v_2 - 9620v_3 - 9957\ v_4 \leq 0 & condition\ of efficiency\ of\ unit\ 3 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \\ \dots\dots\dots\dots\dots\dots\dots\dots & \\ \dots\dots\dots\dots\dots\dots\dots & \\ 100000u_1 - 80v_1 - 874000v_2 - 6967v_3 - 0v_4 \leq 0 & condition\ of efficiency\ of\ unit\ 16 \\ 112v_1 + 831244v_2 + 10510v_3 + 9957\ v_4 = 1 & condition\ of efficiency\ of\ unit1 \\ u_1, v_1, v_2, v_3, v_4 \geq 0 & conditions\ not\ negativity \end{cases}$$

After solving the problem with the PL, with the relevant limitations, the solution is done with Excel software (Solver Solution). [3],[4],[5].

Findings and their interpretation

Figure 1 shows the results of the Dea efficiency analysis (unit 7 and other units). By applying the Solver, we find the optimal solution for unit 7, which results in efficient Dea equal to 82%. To complete the analysis of efficiency for the other units, is needed to change the content of the cell "Unit" (B21) manually 1, 2, 3, 4, ..., 15 and optimize with Solver each unit. Further, put their efficiency in the column "Dea of Efficiency".

B22 =INDEX(H3:H17,B21,1)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Units	Output1	Output2	Output3	Input1	Input2	Input3	Weight	Weight	Diference	Efficiency	Efficiency
2	Nr. Farms	Production (kv / ha)	Annual income (000.All	Net profit	Price (All/kv)	Annual expenses (All)	Number of employees /ha	Outputs	Inputes	≤0	Dea	Dea%
3	1	113	904000	527768	8000	376232	3	0.987	1.037	-0.050	0.97	97%
4	2	137	1068600	665729	7800	402871	4	1.180	1.180	0.000	1.00	100%
5	3	96	787200	563490	8200	314710	3	0.851	0.911	-0.060	1.00	100%
6	4	84	756000	425878	9000	330122	3	0.787	0.942	-0.155	0.87	87%
7	5	120	1020000	609824	8500	410176	3	1.086	1.107	-0.021	0.98	98%
8	6	141	1128000	657898	8000	470102	4	1.232	1.318	-0.086	1.00	100%
9	**7**	**92**	**763600**	**405408**	**8300**	**358192**	**3**	**0.821**	**1.000**	**-0.179**	**0.82**	82%
10	8	118	1026600	627926	8700	398674	3	1.083	1.083	0.000	1.00	100%
11	9	76	699200	352911	9200	346289	3	0.722	0.976	-0.254	0.77	77%
12	10	135	1131600	666468	8200	465132	4	1.212	1.308	-0.096	0.99	99%
13	11	108	972000	593388	9000	378612	3	1.012	1.042	-0.030	0.99	99%
14	12	91	846300	497550	9300	348750	3	0.870	0.981	-0.111	0.93	93%
15	13	131	1113500	664887	8500	448613	3	1.186	1.186	0.000	1.00	100%
16	14	118	8300	979400	384476	594924	3	0.438	1.487	-1.049	1.00	100%
17	15	129	8000	1032000	438947	593053	4	0.478	1.571	-1.093	1.00	100%
18												
19	Weights	0.004	0.000	0.000	0.000	0.000	0.088					
20												
21	Unit	7		Variable Cells								
22	Output	0.82		Set Cell								
23	Input	1.00		Constraint Cells								
24												

Max: C22
Variables: B19:G19
Constrains: B23=1
B19:G19>=0
J3:J17<=0

Sensitivity Report 8 | Sensitivity Report 9 | Sensitivity Report7 | Analiza Dea | Anal

Figure 1. The results of the Dea analysis for the study units.

Source: Data provided by the authors.

The model provides an opportunity to improve efficiency for farm's inefficient. The analysis resulted that units (farms) 2, 3, 6, 8, 13, 14 and15 have 100% efficiency Dea, while other units are less efficient or inefficient by Dea-s.

To improve their efficiency, we act as follows; At first, solve the Dea problem for the other units. In Solver Results dialog box, select the option Sensitivity Report. In the results of the sensitivity report, the absolute value of shadow prices(Shadow Price) in the column "Difference", are composed weights unit. The hypothetical unit produces at least outputs equivalent to the outputs of the unit under study seeking smaller amounts or equivalent to those used by inefficient units. In figure 2 are presented the results of sensitivity analyses per unit 7 (farm), while in figure 3 is presented the best combination of inputs that make unit 7 efficient by Dea. The improved Dea efficiency for unit in study is showed in figure 4.

B	C	D	E	F	G	H
Variable Cells		Final	Reduced	Objective	Allowable	Allowable
Cell	Name	Value	Cost	Coefficient	Increase	Decrease
B19	Weights Production(kv/ha)	0.003668741	0.00	92	2.167312438	0.577996756
C19	Weights Annual incomes (All)	6.33527E-07	0.00	763600	4827.70348	17574.67357
D19	Weights Net Profit	0	-64014.27	405408	64014.27438	1E+30
E19	Weights Price(All/kv)	0	-765.05	0	765.0513524	1E+30
F19	Weights Annual expenses (All)	2.05745E-06	0.00	0	4765.785989	31022.46068
G19	Weights Number of employees/ha	0.087679069	0.00	0	0.259825407	0.039915347
Constraints		Final	Shadow	Constraint	Allowable	Allowable
Cell	Name	Value	Price	R.H. Side	Increase	Decrease
B23	Input Production(kv/ha)	1	0.821	1	1E+30	1
J3	≤0	-0.050	0.000	0	1E+30	0.049840721
J4	≤0	0.000	0.284	0	0.105889565	0.079752686
J5	≤0	-0.060	0.000	0	1E+30	0.059626664
J6	≤0	-0.155	0.000	0	1E+30	0.155127032
J7	≤0	-0.021	0.000	0	1E+30	0.020508604
J8	≤0	-0.086	0.000	0	1E+30	0.086018106
J9	≤0	-0.179	0.000	0	1E+30	0.178714975
J10	≤0	0.000	0.375	0	0.016586924	0.029653976
J11	≤0	-0.254	0.000	0	1E+30	0.253724091
J12	≤0	-0.096	0.000	0	1E+30	0.095524322
J13	≤0	-0.030	0.000	0	1E+30	0.030001359
J14	≤0	-0.111	0.000	0	1E+30	0.110564613
J15	≤0	0.000	0.067	0	0.042400167	0.031743869
J16	≤0	-1.049	0.000	0	1E+30	1.048894974
J17	≤0	-1.093	0.000	0	1E+30	1.092558456

Sensitivity Report 8 | Sensitivity Report 9 | Sensitivity Report7 | Analiza Dea | Anal

Figure 2. The results of the sensitivity of the unit 7 (farm)

	A	B	C	D	E	F	G	H
1	Units	Output1	Output2	Output3	Input1	Input2	Input3	Weight
2	Nr. Farms	Production (kv / ha)	Annual income (000.All)	Net profit	Price (All/kv)	Annual expenses (All)	Number of employees /ha	Values
3	1	113	904000	527768	8000	376232	3	0.000
4	2	137	1068600	665729	7800	402871	4	0.284
5	3	96	787200	563490	8200	314710	3	0.000
6	4	84	756000	425878	9000	330122	3	0.000
7	5	120	1020000	609824	8500	410176	3	0.000
8	6	141	1128000	657898	8000	470102	4	0.000
9	7	92	763600	405408	8300	358192	3	0.000
10	8	118	1026600	627926	8700	398674	3	0.375
11	9	76	699200	352911	9200	346289	3	0.000
12	10	135	1131600	666468	8200	465132	4	0.000
13	11	108	972000	593388	9000	378612	3	0.000
14	12	91	846300	497550	9300	348750	3	0.000
15	13	131	1113500	664887	8500	448613	3	0.067
16	14	118	8300	979400	384476	594924	3	0.000
17	15	129	8000	1032000	438947	593053	4	0.000
18								
19		The values of the composition			Additional inputs used			
20		92	763600	469422	6052	294178	2	
21		0	0	-64014	2248	64014	1	
22								

Figure 3. The Composite unit values for unit 7 (farm)
Source: Data processed by the authors

	A	B	C	D	E	F	G	H	I	J	K
25	Units	Output1	Output2	Output3	Input1	Input2	Input3	Weight	Weight	Diference	Efficiency
26	Nr. Farms	Production (kv / ha)	Annual income (000.All)	Net profit	Price (All/kv)	Annual expenses (All)	Number of employees /ha	Outputs	Inputes	≤0	Dea%
27	1	113	904000	527768	8000	376232	3	1.202	1.263	-0.061	97%
28	2	137	1068600	665729	7800	402871	4	1.436	1.436	0.000	100%
29	3	96	787200	563490	8200	314710	3	1.036	1.109	-0.073	100%
30	4	84	756000	425878	9000	330122	3	0.958	1.147	-0.189	87%
31	5	120	1020000	609824	8500	410176	3	1.323	1.348	-0.025	98%
32	6	141	1128000	657898	8000	470102	4	1.500	1.605	-0.105	100%
33	**7**	**92**	**763600**	**469422**	**6052**	**294178**	**2**	1.000	1.000	0.000	100%
34	8	118	1026600	627926	8700	398674	3	1.319	1.319	0.000	100%
35	9	85	699200	431482	5530	267718	2	0.918	0.918	0.000	100%
36	10	135	1131600	666468	8200	465132	4	1.476	1.592	-0.116	99%
37	11	108	972000	593388	9000	378612	3	1.232	1.269	-0.037	99%
38	12	91	846300	497550	9300	348750	3	1.059	1.194	-0.135	93%
39	13	131	1113500	664887	8500	448613	3	1.444	1.444	0.000	100%
40	14	118	8300	979400	384476	594924	3	0.534	1.811	-1.277	100%
41	15	129	8000	1032000	438947	593053	4	0.582	1.913	-1.330	100%
42											
43	Weight	0.004	0.000	0.000	0.000	0.000	0.107				
44											
45	Unit	7									
46	Output	1.00									
47	Input	1.00									
48											

Analiza Regresit / Vlerat e kompozimit9 / **Vlerat e kompozimit 7**

Figure 4.Improved Dea efficiency for unit 7.

Source: Data processed by the authors

Conclusions and Recommendations

In this paper, the efficiency of 15 grapevine farms of 1 ha, was comprehensively analyzed through the use of mathematical model Dea (Data envelopment Analysis) BY solving the problem of linear programming model restrictions Dea, which is shown in Figure1. shows that units: 2,3,6,8,13,14 and 15 have Dea 100% efficiency, while other units in the study are inefficient. For inefficient units, Dea gives the possibility of finding the best alternative using less inputs or equal ones, to produce at least the same outputs. For example, unit 7 has a 82% efficiency result and so is inefficient by Dea. Referring to the report of the sensitivity results, the absolute value of shadow prices (Shadow Prices) are composed with the unit weights, which resulted more efficient than in the study of unit 7. This unit produces at least the same outputs requiring smaller amounts of inputs (figure 3).The results show that, if we reduce the sales price from 8300 ALL/q to 6052 ALL/q, the annual expenses from 358192 ALL to 294178 and the number of employees from 3 to 2 workers, then we will get the same production of 92q/ha, the same annual income of 763600 ALL and higher net profit from 405408 ALL to 469422 ALL (difference 64014 ALL).With this reduction in inputs, unit 7 results in 100% Dea efficiency(figure4).These conclusions are illustrated with figures calculated in spreadsheet Excel software, giving a clear picture of the study in question.This method can be efficiently used to do similar analysis in solving various problems encountered in various fields of economy and production.

References

Cooper, W.W, Seiford, L. M. and Tone, K. (2007). Data Envelopment Analysis:
A Comprehensive text with Models, Applications, References, and DEA- Solver Software, Vol.2, Springer, New York.

Cooper, W.W, Seiford, L. M. and Tone, K. (2000). Data Envelopment Analysis: Comprehensive Text with Models, Applications, References and DEA-Solver Software, Kluwer Academic Publishers, Boston.

Mikula, L. (2009). Mathematical Optimization and Economic Analysis. Vol. 36, Issue 5, 136-184.

Ragsdale, C.T. (2008). Spreadsheet Modeling and Decision Analysis, 5th Edition. South-Western.

Sharma, K.R., Leung, P.S. and Zane, L. (1999). “Performance measurement of Hawaii State public libraries: an application of data envelopment analysis (DEA),” Agricultural and Resource Economics Review, Vol.28, No.2, 190-198. Susaj, L. (2012). "Vineyards" Text, Publishing House MORAVA, Tirana.

Susaj, L. (2015) "Mechanization of Vineyards" Text, Publishing House ENJA, Tirana.