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Performance evaluation of forest management plans (Case study: Iranian Caspian forests)

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ABSTRACT

The aim of this research was to measure the relative efficiency of forest management plans in north of Iran. In order to fulfill the research, data of 12 forest management plans were collected from the financial balance sheets of Shafaroud Forest Company during a ten years period. First of all, basic Data Envelopment Analysis (DEA) models (BCC and CCR) were used to determine the efficiency. Then, due to the structure of the forest management plan, cost efficiency and revenue efficiency models based on DEA were used in order to measure the efficiency. Results indicated that 8 forest management plans were efficient based on BCC and CCR models. Furthermore, the results indicated that only one forest management plan was efficient based on cost efficiency and revenue efficiency models. These results could be due to the input oriented properties of the models, rational management and optimal use of resources.

Key words: Data envelopment analysis, cost efficiency models, revenue efficiency models, Iranian Caspian Forests.

INTRODUCTION

A forest management plan is a plan in which the amount, the location and the time of harvest along with performance duration and utilization method as well as practical and civil work is written carefully.

There are many forest management companies are involved in management of forest and wood supply in north of Iran. One of the biggest of them is Shafaroud Forest Company. This company is located in Guilan province, north of Iran. About 135000 ha of forests are managed under supervision of Shafaroud Forest Company which is located in north of Iran. This forest is divided to 73 districts and each district is managed based on a forest management plan regulation (Shafaroud Forest Company, 2013).

One of the optimal ways of improvement and progress in forest activities is to perform the procedures and activities in these plans in order to increase efficiency. In this regard, there are different methods for measurement of efficiency of different plans in which one of the most appropriate and suitable method of measurement is data envelopment analysis (DEA). This method is a non-parametric approach that used to measure the efficiency of decision making units. In operations research and economics, DEA is used for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units. Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations. Efficiency is an important prerequisite for profitability, but maximum profits and efficiency do produce as close to the point of maximum profits as possible to

ensure future productivity gains and participation. Operations working at the point of maximum profitability can offer several benefits to the wood supply system including, flexibility during periods of high and low demand, improved safety performance, improved environmental performance, and increased professionalism (Shannon, 1998).

One way to promote forestry activities in the implementation of projects and increase productivity and efficiency, is doing things right (Jason *et al,* 1991).

Building on the ideas of Farrell (1957), the seminal work "Measuring the efficiency of decision making units" by Charnes *et al.,* (1978) applies linear programming to estimate an empirical production technology frontier for the first time. Therefore, DEA was introduced by Charnes *et al.,* (1978) as an efficient model to evaluate the performance of organizations in the field of operations research.

Many papers have been presented about DEA and various models are introduced for evaluating the performance of homogenous decision making units. DEA is used to measure the efficiency of forest industries in the various countries. For example, the use of DEA in the analysis of forestry area, forest management, operation, sawmills factories, paper mills and etc. Non-parametric models can easily combine several inputs and outputs regardless of their market values. (Kao & Yang, 1991, 1992) were in fact among the first people who used DEA to measure the efficiency of forest industries. Their research began to establish new branches in performance studies in forestry development to future, for example Joro and Viitala (1999), and Bogetoft *et al* (2003) on forest management, Lebel & Stuart (1998), and Hailu & Veeman (2003) on forest exploitation, Fotiou (2000), Nyrud & Baardsen (2008), Salehirad & Sowlati (2005) in sawmill factories.

Mohammadi Limaei (2013) investigated the efficiency of 14 Iranian forest companies and forest management units in north of Iran. Efficiency of the companies was estimated using a traditional DEA model and a two-stage DEA model.

Zadmirzaei & Mohammadi Limaei (2013) investigated the efficiency of Mazandaran Wood and Paper Company using DEA in Iran. Network DEA models with parallel structure were used to evaluate and measure its performance. Results showed that the company in all studied years had good performances according to the parallel models in constant and variable returns to scale (CCR, BCC models) and the scale efficiency (SE). There is not any research related using DEA in a different forest management plans at a company so far in Iran. Therefore, the aim of this research is to investigate the performance evaluation and determine the relative efficiency of Shafaroud Forest Company using DEA models to disseminate the necessary information for manager of forest plans until they will be able to adjust the units' operating scale and become more efficient through growth.

MATERIALS AND METHODS

Data collection

In this study the required data were collected from financial balance sheets and the profit-loss sheets of Shafaroud Forest Company. All forest management plans managed for 10 years periods (2001 to 2011). Nominal data of 12 forest management plan including 4 inputs (fixed costs, variable costs, area of forest management plan and stock) and 3 outputs (total revenue, profit and amount of wood production) were collected (Table 1). The nominal data were deflated using Consumer Price Index (CPI) of Iran on the base year of 2004 (Table 2).

Methods

CCR Model

Performance evaluation is an important task for a decision making unit (DMU) to find its weaknesses so that subsequent improvements can be made. DEA model introduced by

Charnes, Cooper and Rhodes in 1978 is called CCR model. Since the pioneering work of Charnes *et al.* (1978), DEA has demonstrated to be an effective technique for measuring the relative efficiency of a set of DMUs which utilize the same inputs to produce the same outputs. Suppose there are n DMUs. The kth DMU utilizes m inputs $X_{ik} = 1,$ m to produce s outputs Y_{rk}, r = 1. . . s. Its efficiency E_k is calculated via the following CCR model (Charnes *et al.,* 1978):

$$
\begin{aligned}
E_K &= Max \sum_{r=1}^{s} u_r Y_{rk} \\
s.t \quad & \sum_{i=1}^{m} V_i X_{ik} = 1, \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \le 0, \; j = 1,...,n, \\
& u_r, v_i \ge \varepsilon, r = 1,...,s; i = 1,...,m.
\end{aligned} \qquad (1)
$$

X_{ij} = amount of input i used by unit j,

Y_{ij} = amount of output r produced by unit j,

V_i = the weight given to input i. Where u_r and v_i are the most favorable multipliers to be applied to the rth output and ith input for DMUk in calculating its efficiency E_k and e is a small non- Archimedean quantity (Charnes *et al.,* 1978; Charnes and Cooper, 1984) which prohibits any input/output factor to be ignored. CCR model is a constant return to scale model.

Table 1. Forest management plans in Shafaroud Forest Company, north of Iran.

Number of plan	Name of plan
1	Avardim-9
2	Siyahbil-8 Loomir
3	Dasht Daman -8
4	Nave Asalam
5	Raze Darposht
6	Janbe Sara
7	Nave Asalm, district 1
8	Kheje Dare, district 2
9	District 16, region 9
10	District 5,region Shanderman
11	District 3,region Chafrood
12	District 2,region Chafrood

Table 2. The real (deflated) data.

Plans	Input				Output		
	Fixed cost (Iranian million Rials)	Variable costs(Iranian million Rials)	Area of forest management plan (ha)	Stock (m^3/ha)	Total revenue(Iranian million Rials)	Profit(Iranian million Rials)	Amount of wood production(Iranian million Rials)
1	1705	1247	2203	45101	2219	9460	9980
2	8936	1280	1772	18350	1638	43000	1638
3	8227	1612	1353	21496	1169	1336	6327
4	1805	1227	3222	61750	4569	1376	9593
5	1134	2379	2041	22450	1781	3253	5395
6	3771	4039	1849	13840	1142	3563	1142
7	5679	4158	2252	34408	3048	1894	2474
8	6525	5242	1742	19650	12044	3041	4549
9	1474	2590	1324	17900	8680	2891	1363
10	6305	5357	2378	28800	2086	5475	4472
11	8964	3183	172	21700	2139	3353	2161
12	8706	4118	2240	36000	2713	7886	4917

BCC model

BCC introduced by Banker, Chames and Cooper (1984). The input-oriented BCC model evaluates the efficiency of $DMU_{\circ}$ {o=1…n) by solving the following linear program form (Mehrgan, 2004):

$$\begin{aligned} Max\ Z &= \sum_{r=1}^{s} u_r y_r + w \\ s.t & \\ & \sum_{i=1}^{m} v_i x_i = 1 \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + w \le 0 \qquad (j = 1,...,0) \\ & u_r, v_i \ge 0 \end{aligned} \tag{2}$$

BCC model is a variable return to scale model. The difference between this model and CCR model is a free variable (W). In BCC model for each unit we can determine the W variable returns to scale.

If w<0, we have decreasing return to scale.

If w=0, we have constant return to scale.

If w>0, we have increasing return to scale.

Data weighting

In order to determine the appropriate weight of the data in DEA model, the questionnaires were used.

Questionnaires were prepared in order to weight the input and output data due to differences in their importance based on the interviewer's views at different forest management plans. Therefore, 35 questionnaires were distributed and completed by the professionals.

The score of weight was from 0 to 100% in questionnaires. The average weight gained from questionnaires is given in Table 3.

Table 3. Input and output weight of different plans.

	Input(percent)				Output (percent)		
Plans number	**Fixed cost**	**Variable costs**	**Area of forest management plan**	**Stock**	**Total revenue**	**Profit**	**Amount of wood production**
1	62.1	63.25	31.75	59.6	60.55	74.65	64.25
2	67.65	62.2	28.75	55.7	52	71.6	56.05
3	77.3	68.85	23.45	63.1	55.95	68.55	57.8
4	75.3	76.45	31.2	59.5	62.85	74.25	59.4
5	72.8	66.5	31.7	62.25	62.35	73.3	71.3
6	70.45	68.65	28.15	55.5	61.2	70.65	65.8
7	78.55	73.55	27.05	63.35	58.8	70.6	68.45
8	71.3	66.4	31.05	60.85	58.25	68.45	67.3
9	75.45	71.65	30.5	61.1	59.3	71.3	63.8
10	73.1	69.55	27.1	68.15	54.35	59.55	56.7
11	73.4	71.55	25.85	65.6	65.85	79.4	62.95
12	70.8	62.1	24.45	55.7	57.35	70.95	61.1

Cost efficiency model

The cost efficiency model is presented such as:

$$
\begin{aligned}
&Min \sum_{i=1}^{m} p_i^o \bar{x}_{io} \\
&s.t \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le \bar{x}_{io} \quad i = 1,2,...,m; \\
&\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{ro} \quad r = 1,2,...,s; \\
&\lambda_j, \bar{x}_{io} \ge 0
\end{aligned}
\tag{3}
$$

Revenue efficiency model

The revenue efficiency model is given below:

$$
\begin{aligned}
&Maxr \sum_{r=1}^{s} q_r^o y_{ro} \\
&s.t \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le x_{io} \quad i = 1,...,m \\
&\sum_{i=1}^{n} \lambda_j y_{rj} \ge \tilde{y}_{ro} \quad r = 1,...,s \\
&\lambda_j, \tilde{y}_{ro} \ge 0
\end{aligned}
\tag{4}
$$

Where p_i^o and q_r^o are the unit price of the input i and unit price of the output r of DMU_0, respectively. These price data may vary from one DMU to another. The cost efficiency and revenue efficiency of DMU_0 is defined as:

$$
\frac{\sum_{i=1}^{m} p_i^o \tilde{x}_{io}^*}{\sum_{i=1}^{m} p_i^o x_{io}} \text{ and } \frac{\sum_{r=1}^{s} q_r^o y_{ro}}{\sum_{r=1}^{s} q_r^o \tilde{y}_{ro}^*}
$$

The cost and revenue efficiency scores are within the range of 0 and 1 (Zhu, 2008).

Data analysis

In order to do the analysis, first of all the basic DEA models (BCC and CCR) were analyzed using DEA Solver software (Cooper *et al,* 2007). Then, for advanced models (cost efficiency and revenue efficiency) GAMS software was used.

RESULTS

Results of BCC and CCR models are shown in Tables 4 and 5.

Results indicated that the forest management plans numbers (2, 4, 7, 9, 10 and 12) are efficient and their score efficiency is 1 and the rest are deficient.

As it shown in Table 5, plans numbers (2, 3, 4, 6, 7, 9, 10 and 12) are effective and the rest are deficient. Table 6, shows the input-oriented CCR model. Input and output must be modified for each forest management plan in order to reach the efficiency frontier.

It means that each plan should decrease its input and increase its output.

For example plan number 1 is not efficient and in order to reach the efficiency we should change all of inputs. For instance, the first entry is the fixed costs and the amount is 1705 Iranian million Rials (Table 2) and the company should decrease 82.05% of this input in order to be efficient.

The second input which includes the variable cost and its value is 1247 Iranian million Rials (Table 2) and the company should decrease 83.58%of this input in order to be efficient and so on. As it shown in Table 5, plans (2, 4, 7, 9, 10 and 12) are efficient. Table 7 shows how much ineffective plans in term of percentage have to change to achieve the efficiency frontier model (BCC).

The results of cost efficiency and revenue efficiency models are shown in Table 8. Plans number 6, 7 and 12 have efficiency score of 1 or efficient in cost efficiency model. Furthermore, Plans number 3, 4, 6 and 9 are efficient in revenue efficiency model. Results also show that just plan number 6 is efficient in both cost efficiency and revenue efficiency model.

Table 4. Results of CCR model.

Plans	Efficiency (CCR)	Rank	
		Rank	Efficiency, Rating
1	0.522	7	0.522
2	1	6	1.187
3	0.154	11	0.154
4	1	1	29.094
5	0.409	9	0.409
6	0.515	8	0.515
7	1	2	2.940
8	0.096	12	0.096
9	1	3	1.559
10	1	5	1.214
11	0.382	10	0.382
12	1	4	1.396

Table 5. Results of BCC model.

Plans	Efficiency (BCC)	Rank	
		Rank	Efficiency, Rating
1	0.779	12	0.779
2	1	3	1.313
3	1	5	1.112
4	1	6	1
5	0.807	11	0.807
6	1	1	606.004
7	1	6	1
8	0.874	9	0.874
9	1	2	1.560
10	1	4	1.237
11	0.871	10	0.871
12	1	6	1

Table 6. The percentage changes of deficient plans in order to achieve the efficiency frontier model (CCR).

	Input				Output		
Plans	Fixed cost (Iranian million Rials)	Variable costs(Iranian million Rials)	Area of forest management plan (cubic meters)	Stock (ha)	Total revenue (Iranian million Rials)	Profit(Iranian million Rials)	Amount of wood production (Iranian million Rials)
1	-82.05%	-83.58%	-47.78%	-60.58%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	-90.96%	-84.5%1	-85.36%	-84.51%	%92.21	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	-82.37%	-59.02%	-71.48%	-59.02%	0.00%	0.00%	0.00%
6	-48.45%	-48.45%	-99.94%	-99.89%	0.00%	0.00%	0.00%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8	-91.85%	-98.3%5	-93.82%	-90.37%	0.00%	99.90%	0.00%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	-80.76%	-72.5%6	-68.72%	-61.73%	0.00%	0.00%	0.00%
12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 7. Percentage change ineffective Plans to achieve the efficiency frontier model (BCC).

	input				output		
Plans	**Fixed cost (Iranian million Rials)**	**Variable costs(Iranian million Rials**	**Area of forest management plan (cubic meters)**	**Stock (ha)**	**Total revenue (Iranian million Rials)**	**Profit(Iranian million Rials)**	**Amount of wood production (Iranian million Rials)**
1	-80.41%	-74.30%	-22.05%	-44.56%	0.00%	%0.00	%0.00
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	-0.00%	-0.00%	-0.00%	-0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	-55.96%	-35.42%	-19.24%	-19.24%	0.00%	0.00%	13.91%
6	-0.00%	-0.00%	-0.00%	-0.00%	0.00%	0.00%	0.00%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8	-81.28%	-67.14%	-12.60%	-12.60%	0.00%	99.90%	99.90%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	-60.31%	-33.25%	-12.83%	-12.83%	0.00%	0.00%	51.58%
12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 8. Results of cost efficiency and revenue efficiency models.

Plans	Cost efficiency	Revenue efficiency
1	0.211	0.14
2	0.536	0.83
3	0.098	1.000
4	0.997	1.000
5	0.217	0.33
6	1.000	1.000
7	1.000	0.34
8	0.056	0.23
9	0.909	1.000
10	0.951	0.43
11	0.215	0.41
12	1.000	0.38

DISCUSSION

Evaluation of forest management plan after its implementation is an important task for forest decision makers in economics and environmental aspects. In this research the relative efficiency of Shafaroud Forest Company in Iran was determined. The advanced models of DEA (cost efficiency and revenue efficiency models) were used, according to the structure of the company and for more accurate performance assessment. The input oriented of DEA models is used for efficiency evaluation because the manufacturing units can optimally use theirs inputs by reduction of inputs as much as possible with keeping constant output level. This procedure can increase the efficiency and profitability of the company.

In fact by using the advanced models of DEA we can compare the forest management plans together and check that how the efficient forest management plans use their resources and their inputs for example forest management plan number 4 and number 9 are efficient in all of DEA basic models and they also are efficient in revenue efficiency model with 100% efficiency score.

Furthermore, these forest management plans have rather good efficiency score in cost

efficiency model. Therefore, we can say that they use the resources and inputs in good ways and can be used as a sample for the other forest management plans. Forest management plan number 7 and 12 are efficient in all of DEA basic models and in cost efficiency model with 100% efficiency score. These forest management plans have rather good efficiency score in revenue efficiency model. Therefore, we can say that they use the resources and inputs in good manner and can be used as a sample for the other forest management plans. (Hu *et al,* 2009) used DEA approach to measure cost, allocative and overall technical efficiencies of international tourist hotels (ITHs) in Taiwan during 1997 – 2006.The cost efficiency of these hotels is from overall technical inefficiency International tourist hotels in Taiwan have an average efficiency of 57%. Chain systems, non-metropolitan areas and occupancy rate have significantly positive impacts on all efficiency scores. The distance from the nearest international airport significantly worsens their efficiency scores. Fundamental DEA model was used to measure the productive efficiency of forest enterprises in Mediterranean Region of Turkey (Korkmaz, 2011). Results indicated that the lowest efficiency scores were evaluated to be on the employee productivity with an average value of 0.698. The inefficiency of the total productivity was thought to be due to the amount of workers and thus the amount of fees paid in big amounts. Efficiency of the Iranian forest companies was estimated using traditional DEA model and two-stage (harvesting and marketing sub-processes) DEA model (Mohammadi Limaei, 2012). Wilcoxon's signed-rank test was used to identify the main reason of weakness between efficiency average of harvesting sub-process and marketing sub-process. Results showed that weakness performance of the companies in harvesting sub-process is the cause of their low efficiency in 2010. Färe & Grosskopf (2000) proposed a network model for measuring the efficiency of the system. However, the operation of each component of the system is treated independently, without considering the relationship among the components. Also, there is one study using parallel structure of DEA model in forestry (Kao 2009). Traditional DEA models deal with measurements of relative efficiency of DMUs regarding multiple-inputs versus multiple outputs (Tone & Tsutsui, 2007). These models neglect linking activities. Traditional DEA does not make any assumptions concerning the internal operations of a DMU. Kao and Yang (1991) were, in fact, among the first to use DEA for performance measurement of forest industries. Their research started a new branch of performance studies in forestry that has since expanded. A two-stage DEA model was used for efficiency evaluation of banks (Luo, 2003). Eight forest area of Taiwan performance was evaluated by the parallel model of the DEA. The results indicated that all the were inefficient, while the basic models as the only two areas had been considered inefficient, because of its higher resolution and differentiated network models with parallel structure in the inefficient units as efficient units. At this research, the input was costs, forest management area and stock. The output was total revenue, profit and amount of harvested wood. However, the results can vary if we include more input and output at the DEA models such as number of employee, spices type etc. as the input as well as the number of regeneration, growth etc. as the output. The forest companies may use the results of this research in order to increase the efficiencies of the forest management units by reducing their fixed and variables costs or increasing the profit and income.

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ارزیابی عملکرد طرح‌های جنگلداری (مطالعه موردی: جنگلهای خزری ایران)

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چکیده

هدف از این پژوهش اندازه‌گیری کارایی نسبی طرح‌های جنگلداری شمال ایران است. برای انجام تحقیق مزبور، داده‌های مربوط به ۱۲ طرح جنگلداری از ترازنامه مالی شرکت شفارود در طی یک دوره ده ساله اجرای طرح جنگلداری جمع‌آوری شده است. ابتدا برای تجزیه و تحلیل از مدل پایه تحلیل پوششی داده‌ها (DEA) (BCC و CCR) برای تعیین کارایی استفاده شد. سپس با توجه به ساختار طرح-های جنگلداری مدلهای DEA کارایی هزینه‌ایی و کارایی درآمدی به منظور اندازه‌گیری کارایی استفاده شده است. نتایج نشان داد که ۸ طرح مدیریت جنگل بر اساس مدلهای BCC و CCR کارا بوده‌اند. علاوه بر این، نتایج نشان داد که تنها یک طرح جنگلداری بر اساس کارایی هزینه-ایی و کارایی درآمد کارآمد بوده است. این نتایج می‌تواند به خاطر خاصیت ورودی محور بودن مدلها، مدیریت منطقی و استفاده بهینه از منابع باشد.

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