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Assessing the technical efficiency of energy use in different barberry production systems

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ABSTRACT

The main objectives of this study were to analyze the technical and scale efficiencies of farmers and to identify the wasteful uses of energy in different farm sizes of barberry production in Iran. For these purposes the data envelopment analysis approach was applied to the data of energy use for barberry production in individual farms. The results indicated that total energy input and yield value of small farms were higher than those of large farms. Also, energy resources are used more efficiently in small farms; technical efficiency of farmers in small and large farms was calculated as 0.66 and 0.50, respectively; also, scale efficiency was 0.82 and 0.62 for the respective farms. Total energy input in small and large farms could be reduced by 13.2% and 15.2%, respectively; accordingly, total energy requirement in target conditions was calculated as 20,702.4 and 13,761.2 MJ ha^{-1}. The highest potential improvement was derived from diesel fuel, followed by electricity and biocides. Improving energy use efficiency of water pumping systems, improving timing, amount and reliability of water application, employing the conservation tillage methods and applying integrated pest management technique are suggested for improving energy use efficiency and reducing the environmental footprints of barberry production.

1. Introduction

Global climate change and population growth are placing new pressures on food production systems; demanding increases food security while safeguarding the natural resources by reducing the environmental footprints (Khan et al., 2009). Energy use is of great concern within agricultural productions, due to both associated environmental effects and the cost of inputs. Efficient use of energy within farming systems is critical for reducing the environmental footprints of energy inputs in food production, and so, providing sustainable agricultural production. Improving energy use efficiency is becoming increasingly important for combating rising energy costs, depletion of natural resources and environmental deterioration (Dovì et al., 2009).

There are several parametric and non-parametric techniques to measure the efficiency in agricultural production systems. In some studies the indicators of output energy to input energy ratio and specific energy (i.e., input energy to yield ratio) in crop production systems have been used to evaluate the performance of farmers (Meisterling et al., 2009; Iriarte et al., 2010; Liu et al., 2010; Börjesson and Tufvesson, 2011). Similarly in a number of recent researches, the econometric approach has been used to identify the relationship between energy consumption from different inputs and yield values of crop productions (Mohammadi et al., 2010; Mousavi-Avval et al., 2011a). Kulekci (2010) applied the stochastic frontier analysis technique in the Cobb–Douglas form to determine the technical efficiency for a sample of 117 randomly selected sunflower farms in Turkey. This method is parametric and requires a pre-specification of the functional form and an explicit distributional assumption for the technical inefficiency term (Hjalmarsson et al., 1996).

On the other hand, Data Envelopment Analysis (DEA) technique is a non-parametric linear programming (LP) based technique of frontier estimation for measuring the relative efficiency of a number of decision making units (DMUs) on the basis of multiple inputs and outputs (Malana and Malano, 2006). In this case the efficiency of a unit is defined as the ratio of weighted sum of its outputs to the weighted sum of its inputs and it is measured on a bounded ratio scale. The weights for inputs and outputs are determined to the best advantage for each unit so that to maximize its relative efficiency (Despotis et al., 2010). Due to the high advantages of DEA, it has been demonstrated to be effective for benchmarking in different systems involving complex input–output relationships (Zhu, 2003).

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Nomenclature

BCC	Banker–Charnes–Cooper (DEA model)
CCR	Charnes–Cooper–Rhodes (DEA model)
CRS	constant returns to scale
DEA	data envelopment analysis
DLP	dual linear programming
DMU	decision making unit
DRS	decreasing returns to scale
EMS	efficiency measurement systems
ESTR	energy saving target ratio
FYM	farmyard manure
IRS	increasing returns to scale
LP	linear programming
SE	scale efficiency
TE	technical efficiency
VRS	variable returns to scale

In the last decades, there have been numerous applications of DEA to measure the efficiency in agricultural production systems. Abay et al. (2004) applied the DEA technique to analyze the efficiency of input use in tobacco production in Turkey. They used data obtained from 300 farmers in different regions of Turkey. According to their results, mean technical efficiency was found to be 0.456 for all regions, and Eastern and Southeastern Anatolia were relatively more successful regions in terms of input use. In another study, DEA was applied to investigate the efficiency of individual farmers and to identify the efficient units in citrus production in Spain (Reig-Martínez and Picazo-Tadeo, 2004). From this study, they suggested the DEA as an appropriate analytical tool to explore the possibilities of short-term viability of individual farms, after eliminating the inefficient practices. In another study by Nassiri and Singh (2009), the DEA technique was subjected to the data of energy use for paddy production; also, technical efficiency of farmers in different farm sizes was analyzed. Banaeian et al. (2010) applied DEA technique to benchmark the productive efficiencies of farmers with respect to energy use for walnut production in Iran. The inputs were energy consumption from human labor, farmyard manure, fertilizers and transportation, and yield as output. Also, they analyzed energy efficiencies of farmers in different farm sizes. In another study by Mousavi-Avval et al. (2011a), the DEA technique was subjected to the data of energy use for apple production in Iran. In this study, the technical, pure technical and scale efficiencies of farmers were estimated and the productivity performance of apple producers based on the amount of various energy inputs and output of apple yield was analyzed.

Seedless barberry (*Berberis vulgaris* (L.)) is a perennial shrub plant belongs to the Berberidaceae family and grows in Asia and Europe; it is a well known medicinal plant in Iran and has also been used as a food additive. Barberry fruit is used in medicine to cure liver, neck and stomach cancer, blood purification and mouth scent (Duke, 1991; Aghbashlo et al., 2008). Barberry cultivation in Iran is concentrated in the South Khorasan province where environmental condition (i.e. hot weather, low relative humidity, water shortage and soil condition) is unfavorable for the growing of other horticultural crops. Total barberry fruit production in Iran was about 37,000 tones from 11,000 ha land area, in 2008, from which about 99% was produced in this province (Anonymous, 2008).

Qaen region is the main center of barberry fruit production in South Khorasan province. Barberry production has much greater socio-economic significance for the study area as compared to other regions of South Khorasan province, since it is a region with small-scale farms, high labor potential, and limited alternative income sources.

Due to the indispensable function of barberry production in this region, efficiency studies play an important role in determining alternative policies. So, the main objectives of the present study were to analyze the technical and scale efficiencies of barberry producers and to compare small and large farms from an energy efficiency point of view. The study has also aimed to segregate efficient farmers from inefficient ones, identify wasteful uses of energy from different sources by inefficient farmers and to suggest reasonable savings in energy uses from different inputs.

2. Materials and methods

2.1. Sampling design

Data used in this study were collected from 144 barberry producers from Qaen region in South Khorasan province, Iran. In this study South Khorasan province was chosen as a representative of the Iranian barberry production enterprises. This province is located in the east of Iran, within 30° 32′ and 34° 50′ north latitude and 57° 57′ and 60° 57′ east longitude.

For collecting the data, an interview was conducted in the production year of 2008/2009. For sampling, stratified random sampling method was used. The sample size was calculated using the Neyman method (Yamane, 1967). So, the research sample size was found to be 144; then the 144 barberry producers from 11 villages from the target region were randomly selected.

2.2. Energy analysis

A standard procedure was used to convert each agricultural input and output into energy equivalent. The inputs were in the form of chemicals, chemical fertilizers, farmyard manure (FYM), diesel fuel, electricity, water for irrigation, human labor or machine power. The energy equivalent may thus be defined as the energy input taking into account all forms of energy in agricultural production. The energy equivalents were computed for all inputs and outputs using the conversion factors presented in the previous study (Mousavi-Avval et al., 2011a). Multiplying the quantity of the inputs used per hectare with their conversion factors gave the energy equivalents.

2.3. Descriptive statistics of inputs and output

Descriptive statistics for energy inputs and output in barberry production are presented in Table 1. An initial analysis of the surveyed results demonstrates the substantial variation in the

Table 1
Descriptive statistics for energy inputs and output in barberry production in South Khorasan, Iran.

Item (unit)	Total energy equivalent	Standard deviation	Correlation coefficient with output
Inputs (MJ ha^{-1})			
Human labor	3670.46	1780	0.758*
Machinery	804.20	698	0.368*
Diesel fuel	2659.52	1359	0.427*
Total fertilizer	7221.32	3693	0.816*
Biocide	193.70	150	0.211**
Water for irrigation	4633.89	3336	0.574*
Electricity	2024.60	2104	−0.191***
Total energy input	21,208.04	9176	
Output (kg ha^{-1})			
Barberry yield	7349.29	3444	
Land area (ha)	0.65	0.55	

* Indicates significant at 1% level.** Indicates significant at 5% level.*** Indicates significant at 10% level.