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Original article

A source-wise and operation-wise energy use analysis for corn silage production, a case study of Tehran province, Iran

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Abstract

This study aims at finding the input–output energy use and the relationship between energy input levels on yield in southern part of Tehran province, Iran. Besides, the energy analysis was carried out based on different farm operations. Data were collected from 40 corn silage (as animal feed) farms, using face to face questionnaire method. The total energy input consumption was 36.5 GJ ha^{-1}; in which chemical fertilizers with 11.8 GJ ha^{-1}(with 32.3%), followed by diesel fuel and water for irrigation (with 26.5% and 24.9%, respectively) were highly contributed to the total energy use. Energy ratio, energy productivity, specific energy and net energy indices were 3.49, 1.45 kg MJ^{-1}, 0.69 MJ kg^{-1} and 90563.3, respectively. The operation-wise analysis showed that land preparation and plant protection operations had significantly high energy consumption (4224.6 and 2446.0 MJ ha^{-1}, respectively). The econometric results revealed that chemical fertilizers, fuel, water, human labor had a positive impact on output level. Moreover, as a result of this study, corn silage production has experienced a substantial increase in non-renewable energy use. Additionally, land preparation, planting and post-harvest operations were used in excess.

Keywords: Corn silage; Sensitivity analysis; Energy ratio; Farm size levels; Plant protection

1. Introduction

Silage can be made from many different crops. Corn silage (including grain) is a widely used crop and popular forage for ruminant animals because of the following reasons: (1) High yields of high-energy feed per acre, (2) High digestibility, (3) Palatable, consistent feed, (4) storable directly at the time of cutting when plant characteristics for storage are near ideal, (5) Rapid harvest, and (6) Low-cost storage (Wheaton et al., 1993; Schroede, 2004).

The world production of corn silage in 2008 was 9.2 million tones with an average yield of 8.8 ton per hectare

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Nomenclature

N	required sample size
N	number of holdings in target population
S	standard deviation
N_h	number of the population in the h stratification
S_h^2	variance of h stratification
D	precision $(\bar{x} - \bar{X})$
Z	reliability coefficient(1.96 in the case of 95% reliability)
D^2	d^2/z^2
Y_i	yield level of the ith farmer
X_1	diesel fuel energy
X_2	labor energy
X_3	machinery energy
X_4	seed energy
X_5	chemical fertilizer energy
X_6	irrigation energy
X_7	biocide energy
e_i	error term
α_i	coefficients of the exogenous variables
β_i	coefficients of the exogenous variables
γ_i	coefficients of the exogenous variables
DE	direct energy
IDE	indirect energy
RE	renewable energy
NRE	non-renewable energy
MPP_{xj}	marginal physical productivity of jth input
α_j	regression coefficient of jth input
$GM(Y)$	geometric mean of yield (the 'i'th root product of 'i' yields)
$GM(X_j)$	geometric mean of jth input energy (the 'j'th root product of 'j' energy inputs)

(Anonymous, 2007). The Iranian cultivated land area, annual production and the average yield of forage crops (expect alfalfa and clover) were about 280,381 ha, 9411 tons (wet matter basis) and 36 tons (wet matter basis), respectively in 2008.

In agriculture, the maximization of crop yield per unit of cultivated area and minimization of energy inputs require the formulation of the interaction between them in the form of pre-harvest energy, fertilizer, irrigation, etc. (Singh et al. 1994). The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bioenergy (Ghasemi Mobtaker et al., 2010; Alam et al., 2005). Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an improved standard of living (Esengun et al., 2007). Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resource preservation and air pollution reduction (Uhlin, 1998). Energy budgets for agricultural production can be used as building blocks for life-cycle assessments that include agricultural products, and can also serve as a first step towards identifying crop production processes that benefit most from increased efficiency (Piringer and Steinberg, 2006). The use of renewable resources such as sunlight, water flow, wind and biomass have been always considered as sources of energy, since they are renowned as environmentally friendly resources (Hakala et al., 2009).

Energy requirements in agriculture are divided into four groups: direct and indirect, non-renewable and renewable. Direct energy is the form of energy used to perform various tasks related to crop production processes such as land preparation, irrigation, plant protection, threshing, harvesting and transportation of agricultural inputs and farm produce (Singh, 2000). Direct energy consumption in Iranian agriculture amounts to around 204.37 PJ yr^{-1} (Peta Joule = 1015 J) which makes up 3.5% of the national consumption of fuel and electricity (Anonymous, 2006). However a large part of the energy consumption in agriculture is in indirect form. Indirect energy consists of the energy used in the manufacture, packaging and transport of fertilizers, biocides and farm machinery (Mohammadi et al., 2008). Non-renewable energy is mentioned as diesel, chemicals, fertilizers and machinery; whereas renewable energy consists of human labor, seeds and manure (Ozkan et al., 2004). Energy analysis of agricultural ecosystems seems to be a promising approach to investigate and assess the energy use efficiency, environmental problems and their relation to sustainability (Giampietro et al., 1992). There has been increasing use of fertilizers, chemical pesticides and new crop varieties, and this is the main reason for the increase in the yield per hectare. In the meanwhile the energy consumption in the agriculture sector has also increased (Pishgar-Komleh et al., 2011b).

In the literature review, Pishgar Komleh et al. (2011a) examined the energy input and output of corn silage production. The total energy input was found to be 68,928 MJ ha^{-1} and the energy ratio and energy productivity were 2.27 and 0.28 kg MJ^{-1}, respectively. According to their results larger farms consume less input energy and corn silage production is significantly related to seed and chemical fertilizer inputs. Heichel (1982) studied energy use for forage production systems (corn silage, alfalfa and oat). Phipps et al. (1976) compared the energy output-input ratio for forage maize and grass leys (a rotational grass which is sown every few years as part of an arable crop rotation). The results indicated 4.8 and 2.7 for forage maize and grass energy ratio, respectively. With respect to the fact that, however, several studies have been carried out on the use of energy in various crops (Yadav et al., 1991;