Energy Reports 2 (2016) 135–140

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Evaluation of energy input and greenhouse gases emissions from alfalfa production in the Sistan region, Iran

Mohammad Reza Asgharipour *, Seyed Mohsen Mousavinik, Fatemeh Fartout Enayat

Unit of Agroecology, Department of Agronomy, Faculty of Agriculture, University of Zabol, Zabol, Iran

HIGHLIGHTS

- The total input energy was 313.52 GJ ha^{-1} where the output was 962.85 GJ ha^{-1}.
- Value of total GHGs emission was estimated at 181,190 kg CO_2e ha^{-1}.
- The highest share of input energy in the production systems belonged to electricity.
- Alfalfa was fairly efficient in terms of energy consumption and GHGs emission.
- In terms of CO_2e, 95.3% of the GWP originate from N_2O, 4.6% from CO_2 and 0.1% from CH_4.

ARTICLE INFO

Article history:
Received 17 February 2016
Received in revised form
6 May 2016
Accepted 19 May 2016

Keywords:
Alfalfa
Energy productivity
Energy use efficiency
Environment
Forage crops
Global warming potential (GWP)

ABSTRACT

The recognition of forage production methods that maximize energy efficiency and minimize Greenhouse Gases (GHGs) emissions is essential. The aims of this survey were to assess the energy consumption, emissions of GHGs and global warming potential (GWP) of alfalfa production systems in Sistan region, Sistan and Baluchestan province in the South–east of Iran. Data were collected randomly from 110 alfalfa farm using face-to-face questionnaire survey. Energy inputs included chemical fertilizers, diesel fuel, pesticides, seed, machinery and human labor. The results indicated that average total input and output energies in alfalfa production during the entire lifetime of the farm were 313.52 GJ ha^{-1} and 962.85 GJ ha^{-1}, respectively. The most important energy inputs belonged to electricity (72.5%), followed by diesel fuel (12.3%) and N fertilizer (6.0%). Energy use efficiency and energy productivity were 3.07 and 0.209 kg MJ^{-1}, respectively. Share of direct and indirect energy were 85% and 15%, respectively. Total emissions of CO_2, N_2O and CH_4 in alfalfa farms were 8262.67 kg ha^{-1}, 557.31 kg ha^{-1} and 7.65 kg ha^{-1}, respectively. Hence, total GWP was 181190 kg CO_2e ha^{-1} and 2.77 kg of CO_2e kg^{-1} of dry hay produced. In terms of CO_2e, 95.3% of the GWP originate from N_2O, 4.6% from CO_2 and 0.1% from CH_4. Accordingly, efficient use of energy is essential to reduce the greenhouse gas emissions and environmental impact in alfalfa agroecosystems.

1. Introduction

Alfalfa (*Medicago sativa* L.) often called queen of the forages, is an important cultivated field crop, originated from northwestern Iran, northeastern Turkey and Turkmenistan. It is cultivated over 618 000 ha in Iran (MAJ, 2011). Sistan and Baluchestan, Kerman and Yazd provinces are the main alfalfa producing zones in central and southeast Iran (Massumi et al., 2012). In Sistan and Baluchestan, where this study has been conducted, the production of alfalfa was near 93 609 ton and the cultivation land area was approximately 16 800 ha (Department of Agriculture, Zabol, personal communication). Good quality alfalfa has digestible fibers and a range of beneficial vitamins and minerals (Rogers et al., 2014).

There is scientific consensus that global warming results from emission of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) put one of the major environmental challenges in the future (Pathak and Wassmann, 2007). Agricultural activities and related farming practices contribute a large proportion of the greenhouse gases (GHGs) emissions. It was estimated that agriculture emits about 5.1–6.1 Pg CO_2e year^{-1}, accounting for 10%–12% of global GHGs emissions (Smith et al., 2007). These emissions are mainly in the form of CH_4, mostly from animal production; N_2O, mostly from arable land; and CO_2 mostly from soil carbon changes and energy

* Corresponding author. Tel.: +98 9153167234; fax: +98 5432232112.
E-mail address: m_asgharipour@uoz.ac.ir (M.R. Asgharipour).

http://dx.doi.org/10.1016/j.egyr.2016.05.007

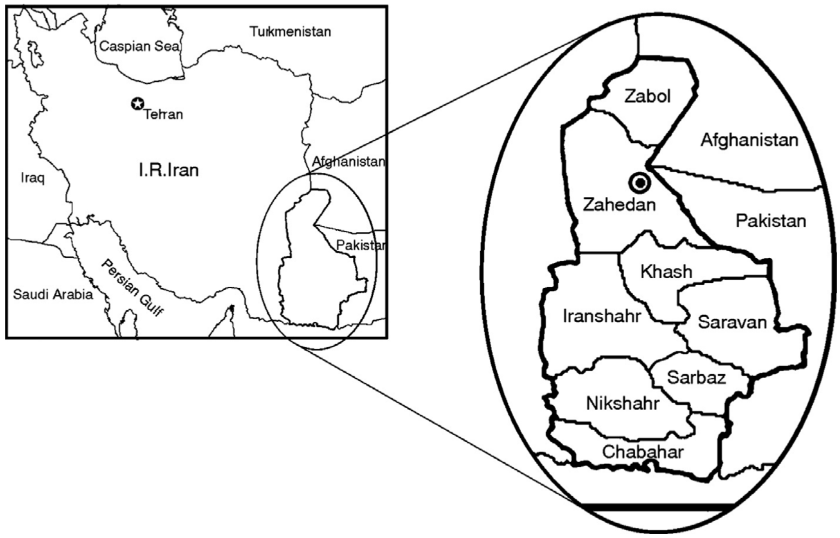

Fig. 1. Geographical situation of Sistan and Baluchistan province, Iran.

use (Smith et al., 2007). As food demand projected to increase in the future, associated GHGs contributions from this sector will also rise (Gilbert, 2011). Minimizing the carbon footprint of agricultural products, i.e., the total GHGs emissions associated with the amount of agricultural products is a challenge (Williams and Wikstrom, 2011).

Production of alfalfa requires intensive use of inputs and therefore has a significant role in the contribution of cropland to global climate change (Camargo et al., 2013). Planting, managing and harvesting of alfalfa using a variety of cultural operations significantly influence the energetics of its production. Although there are an increasing number of studies conducted to evaluate energy balance and GHGs emissions in agricultural crops (Tzilivakis et al., 2005; Khoshnevisan et al., 2013a,b; Ozkan et al., 2007, 2004; Soltani et al., 2013), based on the literature there is no study on the energy consumption and GHGs emissions for alfalfa production in Iran so far.

When assessing the environmental pressures of crop production it is important to differentiates between annual and perennial crops (Mila i Canals et al., 2006). A key difference in energy consumption and GHGs emissions of perennial crop is that some resources are utilized annually while others are existent during the entire lifetime of the farm. Therefore, the objectives of this study were to determine total amount of energy input considering the use of fossil fuels, pesticides, chemical fertilizer, machinery, electricity and labor as well as area-related and product-related GHGs emissions throughout the life of the products in Sistan region of Iran.

2. Materials and methods

2.1. Area of study and data collection

The survey was conducted in Sistan region where is located in Sistan and Baluchestan province, south–east of Iran (Fig. 1). The province is formed of two main parts: the northern part is Sistan and southern part is Baluchistan. The Sistan region (30°5′N–31°28′N and 61°15′E–61°50′E) is one of the driest regions of Iran and famous for "120-day wind of Sistan" during the summer season (Hossenzadeh, 1997). The region has four cities and about 1000 villages, with a population of more than 400 000. The climate of the region is arid with an annual average rainfall of 55 mm and an annual average temperature of 23 °C (Moghaddamnia et al., 2009). The Hirmand River, shared between Iran and Afghanistan, are the major sources for the agricultural, domestic and industrial sectors in this region (Asgharipour and Azizmoghaddam, 2012).

For this investigation 110 alfalfa production systems were randomly selected for the field questionnaire survey in four cities of studied region. The data was collected by using face to face interviews with farmers. The sample size was calculated using the Neyman method (Yamane, 1967) as is shown below:

$$n = \frac{\left(\sum N_h S_h\right)}{N^2 D^2 + \sum N_h S_h^2} \quad (1)$$

where n is the required sample size; N is the number of total population; N_h is the number of population in the h stratification; S_h is the standard deviation in the h stratification, S_h^2 is the variance in the h stratification; D^2 is equal to d^2/z^2; d is permitted error ratio deviated from average population $\bar{x} - \bar{X}$ and z is the is the reliability coefficient (1.96, which represents 95% confidence). The permissible error in the sample population was defined to be 5% within 95% confidence.

2.2. Energy analysis

In accord with other researchers (Mila i Canals and Clemente Polo, 2003; Mila i Canals et al., 2006), not only the one-year field practices were considered, but also all the energy consumption and GHGs emissions relevant to the whole lifetime of the farm. The one-year farm practices were investigated directly on the farms in years 2014, and the life time practices were catered by the farmer. The alfalfa farm life time was estimated to be 6 years, categorized as follow: 1 year of low yield due to establishment of the farm and young plants, 4 years of full production, and 1 years of low yield due to aging plants, and then the destruction of the farms.

The input from environmental sources of energy (radiation, wind, rain, soil organic matter and soil) was not considered in the survey (Tzilivakis et al., 2005). Agricultural inputs comprise electricity, human labor, diesel fuel, chemical fertilizers, pesticides (biocides), machinery and seed. In order to assess the output energy, values of dry hay (15% w.b.) was measured. Flow (all energy input utilized during 2014) and stock (accounting energy inputs utilized for the whole farm lifetime duration) resources were listed in Table 1. Total flow and stock energy inputs and output converted into the energy equivalents by multiplying the quantities of the input and output with appropriate energy coefficients.

Energy indices (energy use efficiency, energy productivity, specific energy and net energy) were computed for alfalfa