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On-farm Energy Use (Case of Dire County, Kermanshah Province)

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Abstract

This paper focuses on the amount of diesel consumption as one of the non-renewable energy sources consumed by the agricultural machinery and water pumps in wheat and corn farms in Dire County, Kermanshah Province, Iran. The population of the study was determined by Bartlett *et al*. (2001)'s table. Stratified random sampling method and census was used for the selection of respondents. The sample was composed of 247 wheat growers, 235 corn growers, and 57 tractor drivers selected by Bartlett *et al*. (2001)'s table. Combine drivers as well as farm irrigation diesel owners were selected by census (n=15, n=48, respectively). The data collection tool was a questionnaire and the data were analyzed by SPSS software package. The findings revealed that in wheat farms, soil preparation had the highest consumption of diesel by 49% and in corn farms inter culturing had the highest diesel consumption by 38%. Moreover, the amount of diesel consumed in 3600 ha wheat and a corn farm in Dire County was 403,852.6 lit/year equivalent to 15,346,399 MJ. Burning this amount of diesel produces about 1, 058,094 kg CO_2/year. Overall, farm machinery, water pumping and irrigation for two major crops in the county are extremely reliant on nonrenewable fossil fuel resulting in large amount of CO_2 emission. Hence, an aggressive and innovative policy is required to restructure and redesign energy system in agriculture sector at national and local levels. Finally, it seems that paradigm shift to sustainable agriculture and development of clean and renewable energy in Iran's agricultural sector is unavoidable.

Keywords:
Energy consumption, Sustainable Agriculture, Wheat and Corn farms, Renewable energy, Energy sources

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INTRODUCTION

Having about 13 million hectares of land suitable for agriculture, the agricultural sector is one of the major contributors to Iran's economy. It accounts for almost 13% of Iran's GDP, 20% of the employed population, 23% of non-oil exports, 82% of domestically consumed food stuffs and 90% of raw materials used in the food processing industry. Key data reflecting the potential of Iran's agricultural industry include access to 37 million hectares of productive land, 130 billion cubic meters of renewable water [1], wide spectrum of climatic conditions, 102.4 million hectares of forests and grasslands, 2,700 kilometers of water border, and diverse genetic reserves, which have led to the sector's considerable growth. Due to its climatic diversity, Iran produces a wide range of agricultural products, from cereals and pulses to citrus fruits and sugar cane. Moreover, both irrigation and rainfed farming are used in Iran (Atieh Bahar Consulting 2008 in Shabanali Fami *et al*., 2010).

Iran energy use in agricultural production has become more intensive due to the use of fossil fuel, chemical fertilizers, pesticides, machinery and electricity to provide substantial increases in food production. However, more intensive energy use has brought some important human health and environmental problems (Figure1). According to Bagherzadeh and Amirtaimuri (2009), petroleum products supply 71% of energy demand in the agricultural sector and the share of diesel in these products is around 97%. Unfortunately, according to Asakereh *et al.* (2010), the social costs of greenhouse gas emissions and air pollution have been more than the added value of the agriculture sector during 1997-2007. It should be noted that the energy consumption by the agricultural sector increased from 265.1 PJ in 1997 to 411.2 PJ in 2007. Among the various sectors contributing to greenhouse gas (GHG) emissions at a global level, agricultural sector has a significant share. Agriculture is responsible for 10–12% of global GHG emissions (Khoshnevisan *et al.*, 2014) that intensified climate change. Iran is amongst the countries affected by climate change due to its arid and semi-arid weather and poor forest cover. It is also threatened by natural disasters such as floods, droughts, desertification, and outbreaks of pests in the agricultural sector that is often associated with climate changes (Banihashmi, 2009). Based on Keane *et al*. (2009) climate change can influence agricultural production in a number of ways. One can roughly group the drivers into six categories:

- Temperature as it affects plants, animals, pests, and water supplies. For example, temperature variations directly affect crop growth rates, livestock performance and appetite, pest incidence, and water supplies in soil and reservoirs.
- Precipitation as it alters, for example, the water directly available for crops, the drought-stress that crops are placed under, supply of forage for animals, animal production conditions, irrigation water supplies, aquaculture production conditions and river flows supporting barge transport.
- Changes in atmospheric CO_2 as it influences the growth of crop plants and weeds by altering one of the basic inputs for photosynthesis.
- Extreme events as they influence production conditions destroy trees or crops, drown livestock, alter water supplies, and influence waterborne transport and ports.
- Sea level rise as it influences the suitability of ports and waterborne transport, in undated producing lands and may alter aquaculture production conditions.
- Climate-change-motivated greenhouse gas net-emissions reduction efforts as they would influence the desirability of production processes and the costs of inputs adding new opportunities.

However, this situation necessitates considering strategies for greenhouse gas emissions and sustainable agriculture. One of the most important strategies is the management of alternative clean energy supply in agriculture sector. In this regard, designing a pattern of energy consumption based on clean energy such as renewable energy is one of the important necessities for Iran's agriculture sector at national and local levels.

[1] *Water can be considered a renewable material when carefully controlled usage, treatment, and release are followed. If not, it would become a non-renewable resource at that location (United States Geological Survey in Irena et al., 2011).*

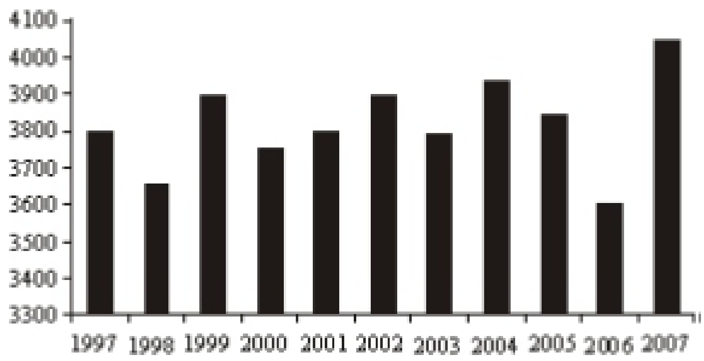

Figure 1: Social cost of GHG and air pollutants emission resulting from the consumption of fossil fuel and electricity in agriculture (Milliard Iranian Rial, 1USD =8910 IRR (Papzan and Papzan, 2012).

Obviously, the first step for the implementation of any energy planning is to understand regional energy consumption pattern in agricultural sector. Frequently, it is necessary to assess inequality levels of consumption for various resources. In this regard, it was tried to unpack the direct energy use in wheat and corn farms by selecting a case for study - Dire County located in Gilan-e-Qarb Township, Kermanshah Province and Western Iran. It should be noted that energy is consumed both directly and indirectly by various farming operations. For example, energy is consumed directly in crop production, livestock production, poultry production, animal products production, other farm products production and transportation of farm products. Indirect energy use consists of the energy used in manufacturing, packaging and transporting of fertilizers, pesticides, and farm machinery. Based on CAEEDAC (2000), the majority of studies on energy consumed by the agriculture and food sector have been carried out in the United States, the United Kingdom and Australia. Stout (1984) reported that according to a study prepared for the US Federal Energy Administration, 16.5% of the total US energy consumption was used by the agriculture and food processing sectors (Food System). This percentage varied between 12% and 20% depending on the boundaries given to the food system and the extent to which indirect energy usage (machinery, buildings, roads, etc.) was charged to the food system. The scope of this report is on energy used in farm production, food and beverage processing, residential and commercial food and beverage processing and residential and commercial food preparation (CAEEDAC, 2000).

In a study on energy consumption pattern of a decentralized community in northern Haryana, Devi *et al.* (2007) indicate that in agricultural sector, maximum energy consumption is in irrigation (41.7%) and the minimum is in transplanting. In this sector, maximum energy comes from conventional energy sources (about 60%), whilst only about 30% comes from non-conventional energy sources.

In Iran, some studies have been carried out on energy consumption in agricultural sector. In an attempt to forecast energy consumption in agricultural sector of Iran using neural network, Ziaabadi *et al*. (2013) indicated that intensity of energy consumption variable in agricultural sector and Gross Domestic Product (GDP) were of great importance and have a decisive and considerable impact on energy consumption in agricultural sector of Iran. Jadidi *et al.* (2012) assessed energy use pattern for tomato production in the Marand region, Iran and indicated that the rate of direct, indirect, renewable and non-renewable energy were 37.2, 62.8, 30.9 and 69.1% of total energy input, respectively. Shabanali Fami *et al.* (2010) studied renewable energy use in smallholder farming systems in Tafresh Township of Iran. They revealed that the majority of the respondents used renewable energy and materials directly in their traditional forms without enabling technologies, and they lacked access to renewable technologies to improve the efficiency of energy use. They preferred fossil energy for many activities due to its lower cost and ease of access. In an analysis of input-output energy use in sugar beet production, Soltanpanahi *et al.* (2013) indicated that input energy used during (1988-2008) was increased by 1.7% but fertilizers and seed energy use was declined by 0.59% and 2.59%, respectively. The highest growth rate of energy use was for chemicals (5.17%) followed by labor (4.32%), machinery (2.3%) and diesel (2.4%). The authors stated that although energy efficiency and all other energy indices were improved during the study period, sugar beet production depended largely on indirect energy (55.79 %) and the share of renewable energy in the total energy use was a miniscule (5.45%). Rajabi *et al.* (2012) evaluated fuel consumption in wheat fields in Gorgan and revealed that seedbed preparation had the highest rate of fuel consumption (59.5 % of total) followed by harvesting, irrigation and sowing operations at 10.5, 9.4 and 8.1 %, respectively. Canakci *et al.* (2005) examined energy use pattern of some field crops and vegetable production in the Antalya Region, Turkey and showed that the maximum amount of fuel consumed in the production of wheat by 46.5 liters per hectare was related to land preparation operations. Moradi Tochaee *et al.* (2013) investigated energy balance indices by seed chemical compounds in corn production in north of Iran and showed 110 L diesel fuel was used by all operations in agro ecosystems corn production on a hectare basis.

MATERIALS AND METHODS

This study was conducted to investigate diesel consumption pattern by farm machinery and water pumping [2] in wheat and corn farms in Dire County, Kermanshah Province by a descriptive survey design. It should be noted that wheat and Corn are two major crops in terms of cultivated areas in this county. Based on Agricultural Jihad Organization of Gilan-e-Qarb Township (2011), wheat was cultivated in 2000 ha and corn in 1600 ha. The cultivation areas paddy, barely and alfalfa are 100, 30 and 30 ha, respectively.

As mentioned above, the rural site selected for the present investigation was Dire County, Kermanshah Province. This agriculture-based county is approximately 700 km far from Tehran. The survey period was between autumn and winter 2013. The population of the study was determined according to Bartlett *et al.* (2001)'s table. Stratified random sampling method was employed for the selection of the respondents among 22 villages across the site. The population of the study consisted of 826 wheat growers and 600 corn growers, and 150 tractor drivers, out of which 247 wheat growers, 235 corn growers and 57 tractor drivers were selected as sample using Bartlett *et al.* (2001)'s table. Combine drivers, and diesel water pump owners were selected by census (n=15 and n=48, respectively). The instrument of the study was questionnaire and the data analysis was carried out by using SPSS software package.

Annual diesel pumps consumption was calculated from the following formula:

Annual diesel pumps consumption = the amount of diesel consumed per hour × the time (hour) required for irrigation per ha × irrigation frequency × irrigated area (ha).

Finally, average of all pumps was calculated. For the calculation of annual diesel consumption on farms by various practices in the county, average diesel consumption per ha was explored by questionnaire that was completed by tractor drivers. Frequency percentage required to determine the percentage of farmers that was down various practices such as disk. Since farmers use some practices in different times, frequency of operation related to some practices were explored.

RESULTS

Based on findings, diesel consumption was as follows in two main farms of Dire County.

Diesel consumption in wheat farms

Tables 1 and 2 show the amount of diesel consumption as one of the non-renewable energies consumed by the agricultural machinery and water pumps in 2000 ha irrigated wheat

[2] *Electricity was used to power irrigation for 11 electrical pumps in the county.*

Table 1: Annual diesel consumption in wheat farms by various practices in Dire County (liter)

Type of operations	Diesel consumption per ha	Frequency percentage		Annual diesel consumption
Tiling	25.44		100	50880
Disk	12.78		79.3	20269.08
Cultivator application	12.38		99.1	25329.96
Leveling	12.75		4.1	10455
Seeding	10.32		96.8	19979.52
Spraying	6.17	1times	81.1	10007.74
		2times	18.4	4541.12
Fertilization	5.68	2times	28.6	6497.92
		3times	71.4	24333.12
Harvesting	15.13		100	30260

Table 2: Annual diesel consumed in wheat farms for irrigation (liter)

Feature	Annual diesel consumed
Diesel pump consumption	14478

farms in Dire County. Findings revealed that land preparation accounted for more than 49% of all diesel consumption by farm machinery. Amongst different activities to land preparation, tiling by 50,880 liter diesel consumption was the highest. Results also indicated that leveling consumed minimum fossil energy as reported in table 1.

As Table 3 shows annual diesel consumed in Dire County wheat farms is equivalent to 8,247,193.

Diesel consumption in corn farms

In this sector, the total energy used by different activities in corn farms in Dire County (1600 ha) was investigated. Table 4 indicates the quantities of energy used by various practices. As Table 6 shows, inter -culturing has the highest consumption of diesel (38.66) in corn farms against wheat farms. Other agricultural activities like seeding and harvesting consume comparatively less energy than inter -culturing as shown in Table 6. However, based on Table 7, 7,099,206 (MJ) is consumed by diesel water pumps and farm machinery in corn farms.

CO_2 emission

Diesel consumed by 3600 ha wheat and corn farms in Dire county was 403,852.6 (lit/year).

Table 3: The share of different activities in diesel consumption in Dire County (wheat farms)

Feature	Diesel consumption in wheat farm (liter/year)	Equivalent energy (MJ)[3]	Percentage of total consumption
Soil preparation	106934	4063492	49.27121
Seeding	19979.52	759221.8	9.205819
Inter- culturing	59857.9	2274600	27.58029
Harvesting	30260	1149880	13.94268
Total	217031.4	8247193	100

Table 5: Annual diesel consumption by water pumps in corn farms (liter)

Feature	Annual diesel consumed
Diesel pump consumption	33268

[3] *Based on Iran's Hydrocarbon balance sheet (2007), l lit diesel = 38 MJ*

Table 6: The share of different activities in diesel consumption (corn farms)

Feature	Diesel consumption in corn farms (liter/year)	Equivalent energy (MJ)	Percentage of total consumption
Soil preparation	69572.24	2643745	37.24001
Seeding	11696	444448	6.26053
Inter- culturing	72241	2745158	38.66852
Harvesting	33312	1265856	17.83095
Total	186821.2	7099206	100

Burning this amount of diesel produces about 1,058,094 of CO_2.[4]

DISCUSSION AND CONCLUSION

The present study indicates diesel consumption in wheat and corn farms as major crops in Dire County. In wheat farms, soil preparation had the highest consumption of diesel by 49% and in corn farms inter culturing had the highest diesel consumption by 38%. These results are in agreement with Rajabi *et al.* (2012) and Canakci *et al.* (2005). According to Canakci *et al.* (2005) land preparation in wheat farms of Dire County used more energy as compared to the Antalya Region (63.35 per hectare against 46.5 liters). But the amount of diesel consumption for total operations in corn production (per hectare) was less than north of Iran (100.65 against 110 litr) as Moradi Tochaee *et al.* (2013) reported.

According to the results, as one of the rural areas in western Iran, the county is extremely reliant on fossil fuels. According to Shabanali Fami *et al.* (2010) and Soltanpanahi *et al.* (2013), fossil energy is preferred by farmers for many activities. Unfortunately, the energy consumption pattern in Iran's agricultural sector over last decades has been inefficient and has contributed towards the excessive consumption of fossil fuels which emits several quantities of pollutants and greenhouse gases. It is clear that the costs of climate change are a direct function of fuel consumption and are independent of the location of the emission. However, it seems that agriculture sector in developing countries such as Iran needs to be reformed because its worldwide trends lead to monoculture, specialization and higher dependence on inputs of distance origins which are mostly non-renewable (SSNC, 1999). According to Lichtfouse *et al.* (2009), reducing dependence on non-renewable resources, such as fuel, is one of the primary goals of sustainable agriculture. Nowadays, the various sources of energy, e.g. solar, wind, hydraulic, biomass, organic wastes, biofuels, and combined heat and power provide a simple, sustainable, effective solution for reducing dependence on non-renewable resources (Chel and Kaushik, 2011). According to Irena *et al.* (2011) solar energy can supply and/or supplement many farm energy requirements such as irrigation, green house heating, and crop drying. Modern, well-designed, simple-to-maintain solar systems can provide the energy needed at a given location and for a given time period. These are systems that have been tested and proven around the world to be cost-effective and reliable, and they are already raising levels of agricultural productivity worldwide (Gustav *et al.*, 2008). Generally, Renewable Energy Source Water Pumping Systems (RESWPSs) are categorized into five major groups: (i) Solar Photovoltaic Water Pumping Systems (SPWPSs); (ii) Solar Thermal Water Pumping Systems (STWPSs); (iii) Wind Energy Water Pumping Systems (WEWPSs); (iv) Biomass Water Pumping Systems (BWPSs); and (v) Hybrid Renewable Energy Water Pumping Systems (HREWPSs) (Gopal *et al.*, 2013). Chel and Kaushik (2011) stated that many water pumps on the market were specifically designed to be powered by a solar photovoltaic (PV) panel, but any pump with a direct current motor can operate with PV. Regarding technical and economic indicators, Hirbodan Company (2003) showed that wind turbines are ideal for pumping water from semi-deep wells (up to 50 m) in 50 sites in Iran. However, in some developing country solar pump seriously considered

[4] *According to Valsecchi et al. (2009), burning a liter of diesel produces about 2.62 kg of CO_2*

(Hirbodan Company 2003 in Jadidi *et al*., 2012).

As mentioned earlier, in Iran agricultural system has large dependency on diesel. The system is obviously unreliable, unsecure and unsustainable. Fortunately, there are safe, environmentally-friendly alternative fuels that can substitute diesel or can be blended with them to reduce toxic air emissions. Using renewable fuels also reduces greenhouse gas buildup and the dependence on non-renewable fuels, while supporting local agriculture and rural economies. Renewable fuels are not petroleum-based; hence, they are cleaner fuels. These fuels include:

a) Biodiesel – a low-polluting diesel alternative fuel made from vegetable oils, animal fats, and even recycled cooking greases.

b) Ethanol – an alcohol-based fuel derived from crops, usually corn, barley and wheat. Ethanol can be blended with gasoline in varying concentrations (Chel and Kaushik, 2011).

However, on the one hand, Iran's latest five-year Development Plan has laid emphasis on the measures to ensure sustainability of the agricultural development process not only in economic terms, but also on social and environmental factors to drive the country towards sustainable development. On the other hand, based on International Energy Agency (2010) Iran is among the top ten emitting countries in the world. Also, according to German Watch and Climate Action Network Europe (2013) based on the Climate Change Performance Index (CCPI), Iran was ranked 60th among 61 countries in 2013. The CCPI included emission level, development of emission, renewable energies, efficiency, and climate policy. Therefore, to deal with the shortage of commercial energy, protect the local environment and mitigate the climate change, a national strategy to improve the share of clean and renewable power generation to agriculture sector is necessary. Overall, it seems that in rural areas of Iran, given the huge potential of renewable resources as well as their capacity of job creation, diversifying income sources and use of local capacities, they are a better alternative to replace fossil energy in rural areas and to move toward designing native rural development pattern. Diversifying the income sources in Iranian rural areas is very important because these areas suffer from large dependency on agriculture, and very small diversification in rural economy as well as land fragmentation. Accordingly, an aggressive and innovative policy making is required for renewable energy development and moving agriculture sector toward sustainability. This approach will alter the relationship between the agriculture and energy sectors from one-way to two-way. In addition, it can help the sector moving toward self-sufficiency and sustainability in energy.

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چکیده

این پژوهش بر میزان مصرف گازوئیل به عنوان یکی از انرژی‌های تجدیدناپذیر توسط ماشین‌آلات و پمپ آب کشاورزی در مزارع گندم و ذرت دهستان دیره در استان کرمانشاه تمرکز کرده است. حجم نمونه در این مطالعه با استفاده از جدول بارتلت تعیین شد. برای انتخاب پاسخ‌دهندگان، ازروش‌های نمونه‌گیری طبقه‌ای تصادفی و سرشماری استفاده شد. نمونه‌ها مشتمل بر ۲۴۷ کشاورز گندم‌کار، ۲۳۵ ذرت‌کار و ۵۷ راننده تراکتور بودند که بر مبنای جدول بارتلت انتخاب شدند. رانندگان کمباین و صاحبان پمپ‌های دیزلی آبیاری سرشماری شدند (N= ۱۵، N =۴۸). ابزار گردآوری داده‌ها پرسشنامه بود و تحلیل داده‌ها توسط نرم‌افزار SPSS انجام شد. این یافته‌ها نشان داد هم در مزارع گندم و هم مزارع ذرت، آماده‌سازی خاک بالاترین مصرف گازوئیل را به ترتیب با ۴۹ درصد و ۳۷ درصد دارا بود. افزون بر این، مقدار گازوئیل مصرف شده در ۳۶۰۰ هکتار مزارع گندم و ذرت دهستان دیره معادل ۴۰۳۸۵۲/۶ لیتر/سال معادل MJ ۱۵/۳۴۶/۳۹۹ بود. سوزاندن این مقدار از گازوئیل سالانه حدود ۱/۰۵۸/۰۹۴ کیلوگرم CO_2 تولید می‌کند. به‌طور کلی، ماشین آلات کشاورزی، پمپاژ آب و آبیاری برای دو محصول عمده‌ی دهستان به نحو گسترده ای وابسته به سوخت‌های فسیلی و تجدیدناپذیر است که نتیجه‌ی آن انتشار مقدار زیادی CO_2 می‌باشد. این رو، به نظر می‌رسد یک سیاست تهاجمی و نوآورانه برای بازسازی و طراحی مجدد سیستم انرژی در بخش کشاورزی در سطح ملی و محلی مورد نیاز جدی کشوربوده و تغییر پارادایم به کشاورزی پایدار و توسعه انرژی پاک و تجدیدپذیر در بخش کشاورزی ایران اجتناب ناپذیر است.

واژگان کلیدی:
مصرف انرژی، کشاورزی پایدار، مزارع گندم و ذرت، انرژی تجدیدپذیر، منابع انرژی

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