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Renewable Energy Use in Agriculture in Iran

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Abstract: Agriculture is one of the most important economic sectors of Iran in which both renewable and non-renewable energies are major input for any farming operation. In fact, the relation between agriculture and energy is very close. For many years, the country has used renewable energy in agriculture and allied activities and acquired experiences with indigenous technologies in using renewable energy for agricultural purposes. Since, introduction of fossil fuel its use in agricultural operations increased, which increased the socio-environmental cost of farming in Iran. There is a need to revisit this area and revitalize the use of these safe renewable energy sources. The country attempts to develop plans for use of renewable energy in agriculture so that sustainable farming goals are rapidly achieved.

Key words: Renewable energy, agriculture, sustainable, Iran.

In most of the developing countries, including Iran, farming has an important role for economic stability in agriculture. It may result in decreasing source of poverty, ensuring food security and permanent income for growing population (Bhutto and Bazmi, 2007). Agriculture is one of the most important economic sectors of Iran. Its contribution to GDP, employment and non-oil exports is 27%, 23% and 24%, respectively. In recent years, the agriculture sector has shown a significant development potential. It can meet 85% of Iran's food need and 90% of the raw material needs of its food processing industries. Therefore, the agriculture sector has the most important place in the Iranian economy (Shabanali Fami *et al.*, 2009).

With population growth, agriculture will need to produce enough food to feed expected over eight billion people by 2030 (FAO, 1992). Hence, growth of agricultural sector for providing more food needed by the increasing population will increasingly depend on energy sources (Hatirli *et al.*, 2005; Hiremath *et al.*, 2007).

Energy is the main component of the economic sector. The lack of energy causes serious limitation in developing countries and countries with low income (WEC, 2000). To improve the situation in developing countries, since energy consumption cannot be avoided, the energy resources need to be used much more efficiently (Bolatturk, 2008; Ucar and Balo, 2009). The relation between agriculture and energy is very close. Energy use in agriculture has been increasing in response to increasing population, limited availability of arable land, and a desire for higher standards of living (Kizilaslan, 2009). Agriculture itself is an energy user and energy supplier in the form of bio-energy. Productivity and profitability of agriculture depends on extend of energy consumption (Alam *et al.*, 2005). In totality, energy in agriculture is important in terms of crop production and agro processing for value addition to farm produce (Karimi *et al.*, 2008).

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For the growth and development, energy demand in agriculture can be direct or indirect, and for both renewable and nonrenewable energies (Alam *et al.*, 2005). Energy efficiency in farming is one of the criterias of agricultural stability consideration, which results in economic saving, resources conservation and decreasing pollution (Pervanchon *et al.*, 2002).

Energy Use in Iran

Energy has a critical role in the development of key sectors of economy, particularly in agriculture (Taheri Garavand *et al.*, 2010). There are many alternative new and renewable energy sources, which can be used instead of fossil and other conventional fuels. The energy resources have been grouped into three categories: fossil fuels, renewable resources, and nuclear resources (Demirbas, 2000). The demand for the new kinds of energy has grown in recent years. The renewable energies can be good substitutes for the conventional energies. In fact, the increase in the population, industrial development and the environmental pollution the growing demand for the energy are the crucial reasons for using the renewable energy recourses (Ameri *et al.*, 2006).

Renewable energy resources are also often called alternate sources of energy. This energy that uses locally available resources has the potential to provide energy with zero or almost zero emissions of both air pollutants and greenhouse gases. Renewable energy technologies produce marketable energy by converting natural resources into useful forms of energy. Development of renewable energy technology is viewed both as a diversification of energy sources and as a creation of an alternative energy option that will help curb down global climate change and create energy security for the future. These technologies use different sources of energy for example solar radiation, wind, falling water, biomass, tides and geothermal (Kalogirou, 2004).

Iran has a high potential of renewable energy sources. There are favorable conditions for the profitable use of wind energy, very good opportunities for the extension of hydropower use, as well as an ideal setting for the use of solar energy. The average global radiation available for Iran is about 19.23 MJ m^{-2} day^{-1} (5.3 kWh m^{-2} day^{-1}) and it is even higher in the central region of Iran, with more than 7.7 sunshine hours per day (CEERS, 2005).

In Tafresh Township of Iran, farmers use the sun to dry various agricultural products. The extent of using solar energy to dry agricultural products is high for drying fodder, husked nuts, sliced dried fruits, garlic and onion, legumes, cherries and plums, and low for drying edible seeds, vegetable seeds, whey and medicinal plants. The extent of using wind energy to dry agricultural produce is medium for drying husked nuts, leafy vegetables and animal manure, and low for separating bean seeds fodder seeds and wheat and barley seeds from chaff. The smallholder farmers of Tafresh use different types of biomass wastes for making direct or indirect profits without applying new technologies. Mixing crop residues with soil for increasing the fertility as well as composting biomass (such as leaves, crop residues after harvesting, overripe fruits), using crop residues for feeding animals, and setting them into fire for heating and cooking purposes are three main areas of farm waste biomass management (Shabanali Fami *et al.*, 2010).

Gholami and Sharafi (2009) determined the energy use in agricultural production in Iran for the period 1980-2005 to evaluate the impact of energy input to agricultural production. The energy inputs included human labor, machinery, electricity, fertilizers, seeds and output. energy included yields of 16 crops. The results indicated that the total energy input increased from 55.64 x 10^9 MJ ha^{-1} in 1980 to 150.71 x 10^9 MJ ha^{-1} in the year 2005. Similarly, total output energy rose from 325.56 x 10^9 to 535.15 x 10^9 MJ ha^{-1} in the same period. It was found that energy efficiency declined from 5.85% in 1980 to 3.55% in 2005, which indicated that the energy input increased faster than energy output. It also indicated that the use of inputs in agricultural production in Iran was not accompanied by similar trend in the final product.

A research showed that wheat production in the Ardabil province of Iran consumed a total of 47.08 GJ ha^{-1} energy. About 31.19% was due to chemical fertilizers, 26.05% from diesel oil and machinery 76.44% of total energy input was nonrenewable while 23.56% was renewable energy (Shahan *et al.*, 2008).

The entire energy input for wheat under dry farming in Kuhdasht county of Iran accounted 10143 MJ ha^{-1} and output energy 39541 MJ ha^{-1}. The input energy included 39% diesel, 33% fertilizer and 21% seed. About 78% of the input energy was not renewalable, whereas the output energy for grain and straw accounted for 66% and 34%, respectively (Asakereh *et al.*, 2010a).

Arayesh and Farajollah Hoseini (2010) conducted a study role of people participation in protecting, revitalizing, developing and using renewable natural resources in Ilam province. Sample was taken from natural resource's experts and managers of Ilam province. The results indicated that, there was a significant relationship between social, political, cultural, economical, and psychological factors as well as extension planning with peoples' participation in using renewable natural resources in Ilam province.

In Behshahr county canola is cultivated under dry farming. Total input energy in production was 28705.3 MJ ha^{-1}. Of all the inputs, the fertilizer had the biggest share in the total energy with a 65.5% (18809.8 MJ ha^{-1}) that showed, canola production was severely dependent on fertilizer. Energy for fertilizer was followed by diesel fuel energy which was 30% (8604.2 MJ ha^{-1}). Diesel fuel was mainly used for operating tractor and combine harvester. Because of mechanized operation in canola production, use of human labor was low (0.25% of total input energy), but it was very important input in increasing productivity. Energy of machinery and seed was 3.2% and 0.5% of total input energy, respectively. Average output energy of canola was found to be 41230 MJ ha^{-1}. Direct energy was 30.2% while indirect energy was 69.8% of total input energy. 99.2% of the total energy input was from nonrenewable and 0.8% from renewable sources. The results indicate that the current energy use pattern among the investigated farms is based on non-renewable energy in the canola production (Taheri Garavand *et al.*, 2010).

Energy inputs and outputs in a chickpea production system in Kurdistan showed that total energy consumed in various farm operations during chickpea production was 5880 MJ ha^{-1}. Diesel energy consumed 37.9% of the total energy, followed by chemical fertilizer 29.6% during production period. Diesel energy was mainly consumed for land preparation, other agricultural practices, and transportation. The total energy input consumption can be classified as direct energy (40.4%) and indirect energy (59.6%), and also renewable energy (13.3%) and non-renewable energy (86.7%). The economic analysis showed profit-cost ratio tobe 1.17 (Salami and Ahmadi, 2010).

Asakereh *et al.* (2010b) examined the energy consumption in apple production in the Esfahan province of Iran. Their results showed that the average input energy increased with the extent of farm's mechanization. Information revealed that 44938.57 MJ ha^{-1} energy were consumed by the first group (medium mechanized) and 33100.82 MJ ha^{-1} by the second group of farms. Fuel used for land preparation, pruning practices, transportation and pesticides were the major energy inputs in both types of orchards. Output-Input energy ratio, energy productivity and net energy gain were higher on the second group as compared to the first group. In first and second group of farms the nonrenewable form of energy input encompassed 88.45 and 77.93% of the total energy input.

Mousavi-Avval *et al.* (2010) in their study examined the energy consumption for canola production under irrigated and rain-fed conditions in Golestan province, the main center of oilseed production in Iran. The results revealed that, total energy input under irrigated and rain-fed conditions was 31809.9 and 15078.5 MJ ha^{-1}, respectively. The main energy consumers in irrigated conditions were electricity (45.3%), chemical fertilizers (28.3%) and diesel fuel (15.2%); also, about 85% of total energy input in rain-fed conditions was consumed by chemical fertilizers and diesel fuel inputs. Under irrigated and rain-fed conditions, the energy-use efficiency was 1.85 and 3.5 and the energy intensity was found to be 13.54 and 7.13 MJ kg^{-1}, respectively. Moreover, for irrigated conditions the water energy-use efficiency and water productivity were 3.67 and 1.55 kg m^{-3}, respectively. In order to reduce energy consumption and improve energy-use efficiency and water productivity, it is suggested that canola in the region may be cultivated under rain-fed conditions.

Ghasemi Mobtaker *et al.* (2011) in their study found that the ratio of direct energy is higher than that of indirect energy, and the rate of non-renewable energy is higher than that of renewable energy consumption in alfalfa production in Iran.

Asakereh *et al.* (2010c) evaluated the energy use in organic and conventional farming of lentil in Kuhdasht county of Iran. The results revealed that total energy consumption and output energy in organic lentil production was less than under inorganic production, but energy ratio was higher in organic lentil production with 2.12.

Namdari (2011) carried out a study to estimate the amount of input and output energy per unit area and made an economic analysis of watermelon production in Hamadan province, Iran. The area investigated was divided into two groups. Group I consisted of 54 farmers (owner of machinery and high level of farming technology) and Group II of 31 farmers (non-owner of machinery and low level of farming technology). The results indicated that total energy inputs were 67674.24 MJ ha^{-1} for Group I and 68788.37 MJ ha^{-1} for Group II. Only 21.03% and 19.94% of the total energy inputs used in watermelon production was renewable in Group I and Group II respectively. Cost analysis expressed that benefit–cost ratio in the surveyed groups were 2.61 and 2.06, respectively. Results revealed Group I had a better condition than Group II.

Naderi Mahdei (2010) conducted a study to explore appropriate policies for agricultural energy sustainability in Hamedan province by using a semi-structured interview with key informants (farmers) involved in energy unsustainability issues. The results showed that energy resources management, protection, techno-environmental, micro and macro economic policies were conceptualized in the theme of eco-environmental policies. Therefore reforming policies of energy sustainability that are detrimental to both the economy and the environment are necessary.

Ardehali (2005) conducted a study in Iran to identify problems and difficulties encountered in the social-economic infrastructure related to rural energy development and present the nonrenewable and renewable energy resources and assess the current energy generation and consumption rates. The results showed that while there are numerous non-renewable and renewable energy resources available, problems such as cultural barriers and lack of appropriate mentality about energy impede the much-needed development of renewable energy in the rural areas of country. To fulfill rural energy needs, renewable energy plans must be developed locally all across the country: hydro and geothermal in the northern and western areas, wind in the eastern and the southern planes, and solar energy in the central desert plateaus.

Renewable Energy Organization of Iran (SUNA)

History and objectives

In Iran, apart from the Ministry of Energy's Deputy Directorate for Energy, Iran Renewable Energy Organization (SUNA) has been attending to this matter since 1995 in order to achieve updated information and technology for utilization of renewable energy resources, potentials and execution of various projects (solar, wind, geothermal, hydrogen and biomass).

In 2003 SUNA was changed to government company to develop the application of energies from renewable resources, and assumed responsibility, as manager of Energy Deputy Directorate's projects, for carrying out R&D activities, rendering design and consultation services, manufacturing and operating renewable energy systems until the end of the year 2003 (mid March 2003) after which, it started executing relevant projects directly (SUNA, 2011b). In the middle of the year 2006, concurrent with structural changes introduced in the Ministry of Energy, the Ministry's Renewable Energy Office was practically amalgamated with SUNA and all related officials and projects were also transferred to this organization (SUNA, 2011a).

Assignments and duties

The main thrusts include stabilization and diversification of energy resources, development of capacities and minimization of long-term expenses associated with energy generation, conservation of environment and supplementing non-renewable energy resources of Iran through management of renewable resources of energy. The above-mentioned assignments and duties will be realized through the following activities:

- Active participation in the establishment of the national energy plan and new energies strategy in Iran.
- Active participation in the establishment and management of a secure market for generators of new energies in Iran.
- Preparation of atlas and feasibility report of different resources of new energies in Iran.
- Establishment and protection of relations between domestic organizations and experts active in the field of new energies on the one hand and international organizations, experts and associations on the other.
- Identification of international resources and endeavoring to attract and allocate such resources to generation/research activities in connection with new energies in Iran.
- Introducing technology development strategies in connection with new energies and determining research priorities associated with such energies in order to protect generation/research centers towards the development of relevant technologies.
- Tracing technological changes in connection with new energies and providing information on the outcome of such changes to the Iranian generation/research centers.
- Paving the way for transfer, attraction and export of technologies related to new energies and supporting relevant agencies in connection with utilization and commercialization of such energies.
- Active participation in establishment of laws and standards to protect generation and R&D activities in connection with new energies.

- Educating and encouraging people to use new renewable sources of energy (SUNA, 2011a).

Solar energy

Solar energy is clean and unlimited. Capturing the sun's energy for light, heat, hot water, and electricity can be a convenient way to save money, increase self-reliance, and reduce pollution. Using the solar energy for drying crops, heating buildings, or operating a water pump makes the farm operations more economical and efficient (Union of Concerned Scientists, 2009).

The average solar radiation for the whole of Iran is about 19.23 MJ m^{-2}, and it is even higher in the central part of Iran. The daily radiation varies from 2.8 kWh m^{-2} in the south-east part to 5.4 kWh m^{-2} in central region. The calculations show that the amount of useful sun shine hours in Iran exceeds 2800 hours per year. The first photovoltaic (PV) site, with capacity of 5 KW DC was established in the central region of Iran in Doorbid village Yazd in 1993. Following this, in 1998, the second photovoltaic site with 27 KW AC capacity was installed in Hosseinian and Moalleman villages in Semnan 450 km inland from Tehran.

Solar energy for grain drying and water heating has been in use in the country for many years. Domestic water heating system is a primary active solar technology. The Ministry of Energy has installed several solar water heating units in rural areas of Iran under the renewable energy development program. Under this program, 30, 10 and 5 KW photovoltaic (PV) systems are also installed in hot and dry rural areas of Iran. The potential of Iran as a PV market is very large, since the country is quite suitable in terms of insolation and availability of large areas of land for solar farms (Statistic Centre of Iran, 2001). Using the sun to dry crops and grain is one of the oldest and most widely used applications of solar energy in Iran. The simplest and least expensive technique is to allow crops to dry naturally in the field, or to spread grain and fruit out in the sun after harvesting. This is a common practice in most of villages in Iran to make dried fruits.

Wind energy

Wind energy is one of the renewable energies that has attracted great attention. The potential of wind energy has been estimated to be about 6500 MW through the data obtained from 26 meteorological sites in Iran by two organizations, Centre of Renewable Energy Research and Application (CRERA) and Ministry of Energy (MOE). Iran's first experience in installing and using modern wind turbines dates back to 1994, which is fast growing now. The cost of electricity produced by wind turbines in Iran is estimated to be 4-5 cents/kWh, while the cost of electricity from steam and gas power plants is about 2 and 2.5 cents/kWh, respectively, plus the social costs of the three major air pollutants (CO_2, SO_2 and NO_2), which ranges from 3 to 4 cents/kWh (2002). Comparing this total cost to the price of electricity generated by wind power plants, could easily demonstrate the cost advantage of wind power plants (CRED, 2002).

The application of wind energy in Iranian agriculture goes back to 200 years BC. The Persian windmills with wind-catching surfaces as long as 5 m and as high as 10 m were used for grinding grain in the area known as Nehbandan in the western part of Iran up to a few years ago (Ameri *et al.*, 2006). These mills played important role in processing of wheat and barley to make edible flours.

Biomass energy

Biomass is the general term for material derived from growing plants or from animal manure. It is a rather simple term for all organic materials that are known as plants, trees, crops and algae. The components of biomass include cellulose, hemicelluloses, lignin, extractives, lipids, proteins, simple sugars, starches, water, HC, ash, and other compounds. Two larger carbohydrate categories that have significant values are cellulose and hemicellulose. The lignin fraction consists of non-sugar type molecules. The solar energy, which is stored in plants and animal wastes that they produce, is called as biomass energy (Demirbas, 2005).

Biomass in the form of fuel-wood and animal wastes are the main fuels that have been used since many years for heating and cooking in the rural areas of Iran. Fuel-wood is still an important source of energy in rural areas in Iran as in other developing countries. In addition, the total forest area in Iran is about 12.4 M ha. Forestry is an important sector of employment and fuel generation in the rural areas. A total of 1.2 million m^3 wood products were mainly produced from the forests of Gilan, Golastan and Mazandran provinces of Iran in 2001 (Energy Statistical review of Iran, 2002).

Nafaji *et al.* (2009) investigated the production of bioethanol from agricultural residues in Iran. There are approximately 17.86 MT of wasted crops in Iran that can potentially produce 4.91 GL of bioethanol per year. Wheat, sugar cane bagasse, rice, barely and corn are the most favorable source for bioethanol production in Iran. This study showed that there is a considerable potential for utilization of agricultural residues in Iran. If the agriculture wastes are efficiently utilized there will be no need to import conventional fuel. Producing bioethanol from the agriculture wastes can ideally replace 25% of total gasoline fuel consumption in this country.

Geothermal energy

Iran has large geothermal energy potential and the main regions for geothermal energy generation are Sabalan, Makoo, Khoy (Azerbaijan Province) and Damavand (Tehran Province). The total potential of geothermal energy is approximately 60 billion Giga Jules (Ministry of Energy, 1998). Although it is not widely used directly in agriculture, there is a great potential to capture and make use of this energy in the Iranian farming.

Recent since years 2000 great attention has been directed at generating power from geothermal energy in Iran, notwithstanding direct utilization of thermal waters will provide a tangible flow of income to the remote areas as well. Geothermal energy has been proved to be of great importance for environmental protection. On this basis, developed facilities in the tourism industry will significantly raise the number of tourists (local and overseas) to the areas with combined scenic landscapes and thermal manifestations (e.g. Sabalan, Damavand and Ramsar) in the short run. Greenhouse development in specific areas such as Mahallat (central Iran) may convert the needs of the people to the clean source of geothermal energy to heat the local greenhouses (Noorollahi *et al.*, 2008).

Conclusions

Energy has a critical role in the development of agriculture sector. Agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energy, such as seed, manure and animate power, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. In view of increasing consumption of energy for sustainable development of agriculture in Iran, it should make efforts toward increased utilization of renewable energy in place of fossil fuels in agriculture. Renewable energy is supposed to be encouraged as a means for improving the accessibility and diversity of energy supplies while minimizing environmental degradaton. The country has a long lasting experience on indigenous technologies for using renewable energy, which needs to be revitalized and renewed again. This will reduce both the cost of farming and environmental pollution such as emission of green house gases. Therefore, strategies for using renewable energy in agriculture and developing the necessary technologies should be taken into account in the 5-year development plans of the country.

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