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Spatial Analysis the Potential for Energy Generation from Crop Residues in Shodirwan, Iran

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Abstract

The purpose of this study was to analyse the spatial potential of crop residues with geographical information system (GIS) to generate energy in Shodirwan region, Iran. The available agriculture residues in Shodirwan were bagasse, sugarcane top, rice husk and straw of wheat, barley, bean, rice and mung bean. Results show that the total of crop residues that generated in this region was 1038525 tonnes/year and 668128 tonnes of them was available residues. The total potential of energy generation from available residues was 969589405 kWh/year that sugarcane residues have the highest share with 79.15%. Potential of energy generation from processing and field residues was 511946175 and 457643230 kWh/year, respectively. Spatial potential of residue to generate energy was calculated between 2900 to 61000 kWh/hectare/year. As a result of using energy of crop residues in Shodirwan, mitigation potential of CO_2 emission was 554605 tonnes/year.

Keywords: *Biomass energy, Crop residue, Energy, GIS, Iran*

1. Introduction

Energy is an integral part of society and plays a pivotal role in its socio-economic development by raising the standard of living and the quality of life [1]. Fossil fuels have limited resources and, at current rates of exploitation, they are expected to deplete within the next century [2, 3]. Furthermore, their over-utilization can cause environmental degradation due to incomplete combustion when used as an energy source. In addition to these issues, as the world population increases, demand for energy resources increases as well. These cases are the main reasons why clean, sustainable and environmentally friendly alternative energy resources are currently sought. Renewable energy has the capacity to provide cost-effective energy for remote communities without added investment of providing fossil generation. By 2050, demand for energy could be doubled or even tripled as global population grows and developing countries expand their economies. Accordingly, all aspects of energy production and consumption, including energy efficiency, clean energy, global carbon cycle, carbon sources, sinks and biomass and their relationships with climatic and natural resource issues should be explored [4].

Biomass is a renewable energy source and its importance will increase as national energy policy and strategy focuses more heavily on renewable sources and conservation. Biomass energy has been attracting attention from the viewpoint of carbon dioxide mitigation by replacing fossil type fuel. If biomass is grown in a sustainable manner, utilization this energy does not add ‘‘new’’ carbon dioxide to the atmosphere, because the carbon dioxide released during combustion is offset by the carbon dioxide biochemically fixed by photosynthesis [5-7]. The energy stored within biomass can be effectively utilized as a carbon-neutral energy;

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hence countries throughout the world are pursuing the introduction of biomass energy systems [8].

Biomass energy still is the main energy source in many developing countries and regions so that provides roughly 35% of energy demand in developing countries [7, 9, 10].

Iran's economy is heavily dependent on fossil fuels. Table 1 shows the present primary energy supply for Iran [11]. It is clear that primary energy supply of Iran depend on fossil fuel. Present biomass energy utilization is only a very small share with 0.365% of total Primary energy supply. Accordingly, this study mainly focuses on the agricultural residue of crop production.

Table 1. Primary Energy Supply Share of Iran (2011)

Energy resource	Energy supply share (%)
Oil	38.614
Natural gas	60.002
Coal	0.530
Solid biomass and biogas	0.368
Hydro	0.443
Solar and wind	0.006
Nuclear	0.037

The main objective of the present study is to assess the potential of crop residues as sustainable sources of renewable energy in Shodirwan region, Iran. The biomass sources considered in this study include available residues from main types of agricultural crops.

2. Methods and Materials

2.1. Study Area

The study was carried out for Shodirwan region in Khuzestan province, Iran. This region is peninsula between Karun and Dez rivers and is the one of the important agriculture crop areas in Iran. Imam Khomeini agro-Industry with about 15000 hectares located in the middle of Shodirwan that sugarcane is cultivated in it. Data of different crop yield were collected by field random sampling and GPS was used to determine the location of sampling but data of sugarcane yield was obtained from Imam Khomeini agro-industry. Complementary data were collected from 300 farms by using a face-to-face questionnaire, corresponding governing, research institutes and available literature. Also GIS data have been obtained from the database published by Jahad Agriculture Organization of Khuzestan province and Iran National Cartographic Center. In the present work we used Arc GIS 9.3 as GIS software. The locations of the sampling points are shown in Figure 1. It is observed that the sampling wasn't done in the middle of study area, because yield data were obtained from the Imam Khomeini agro-industry.

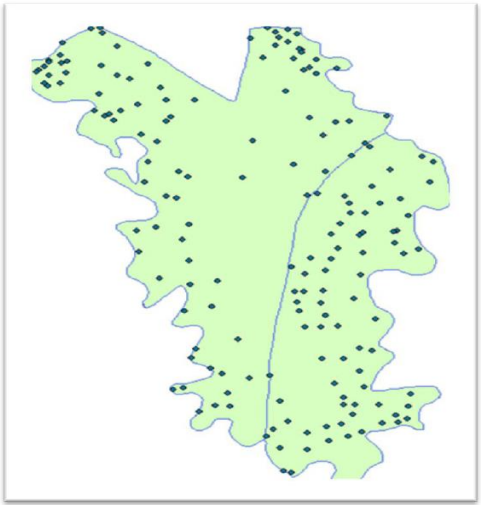


Figure 1. The Locations of the Sampling Points and Study Area

2. 2. Potential of Crop Residues in Shodirwan

The most important crops in Shodirwan are wheat, barley, sugarcane, rice, bean, mung bean, jat and vegetable. There are two types of agricultural crop residues: field residues and processing residues [12]. Field residues can be collected, mostly by bailing, either at the same time or after the primary crop has been harvested. The most important field residues in Shodirwan are straw of wheat, barley, rice, bean, mung bean and sugarcane top and for processing residues are paddy husk and bagasse.

The annual gross potential of crop residues were obtained by calculating the production of agriculture crops in terms of yield and area in hectares for the year 2012 and then using residue to product ratio (RPR) to determine the amount of residue produced. RPR defined as the amount of residue production divided by agricultural production. The following form is used to cumulate potential of the gross potential of residue in each hectare [13, 14]:

$$(CR)_i = (RPR)_i \times (PrC)_i \quad (1)$$

where (CR)i is the amount of crop residues of ith crop in ton/hectare, (RPR)i the RPR of the ith crop and (PrC)i the yield of crop production in ton/hectare. The all of field residues cannot be recoverable and utilized as an energy source, because percentage of field residues of a crop to be recycled onto the land depends upon the specific local climatic and soil conditions or use for domestic purposes, animal fodder, *etc* [12, 14]. Up to now, in Shodirwan, agriculture residues are not being used for energy generation in any case but only for animal feed and produce alcohol and MDF (medium density fibreboard) in Imam Khomeini agro-industry and most of them is burned by farmers in the field. However, in developed countries, it has been established that only 35% of field crop residues can be removed without adverse effects on future yields. Crop processing residues, on the other hand, have a 100% recovery factor [12].

Energy potential from recoverable crop residues can be determined by multiplying the net supply potential of recoverable crop residue by the lower heating value (LHV). The RPR, recoverable factor (RF) and LHV used in the present analysis are presented in Table 2 [12, 15-17].

Table 2. RPR, Recoverable Factor and LHV of Crop Residues

Product	Residue	RPR	LHV (MJ/kg)	RF
Sugar	Bagasse	0.357*	17.81*	0.9
	Sugar cane top	0.25*	16.52*	0.7
Paddy	Paddy husk	0.2	12.98	0.9
	Paddy straw	1.7	16.7	0.35
Wheat	Wheat straw	1.75	17.9	0.35
Barley	Barley straw	1.75	17.9	0.35
Bean	Bean straw	1.9	17.46	0.35
Mung bean	Mung bean straw	1.9	17.5	0.35

* Calculated in the Agro-industry

Energy potential of residue is estimated by [14, 18]:

$$Q_i = \sum_{i=1}^{n} (CR_i \times RF_i \times LHV_i) \times n_c \quad (2)$$

where Qi is the energy potential (GJ/h/year) of ith crop, LHVi the LHV of ith crop (GJ/t) and nc the conversion efficiency. A number of technologies with different efficiency exist for power generation from biomass. Agriculture biomass energy potential of wheat, corn, barley, rye, paddy, bagasse and other crops was estimated with combustion processes as direct fuel [1, 8, 19-21]. An overall efficiency of 30% was chosen, which a reachable level under current available technology is [21].

The geographical potential of biomass from crop residues can be developed with GIS. The results from field sampling and complementary data were plotted on a map of Shodirwan with longitude and latitude based on World Geodetic System 1984 (WGS84), and then, interpolated using inverse distance weighted (IDW), on ArcGIS. IDW is the interpolation method to estimate cell values by averaging the values of sample data points in the vicinity of each cell.

3. Results

Land use plays important role to use of renewable energy in each region. Figure 2 demonstrates Land use map classes for Shodirwan. It is obvious that the irrigated farming lands and Imam Khomeini agro-industrial have the largest share of Shodirwan area. Total irrigated farming land in Shodirwan is 88546 hectares while Total dry farming land is 4556 hectares. Non-agricultural land that don’t have potential to produce crop residues, were identified with using land use map.

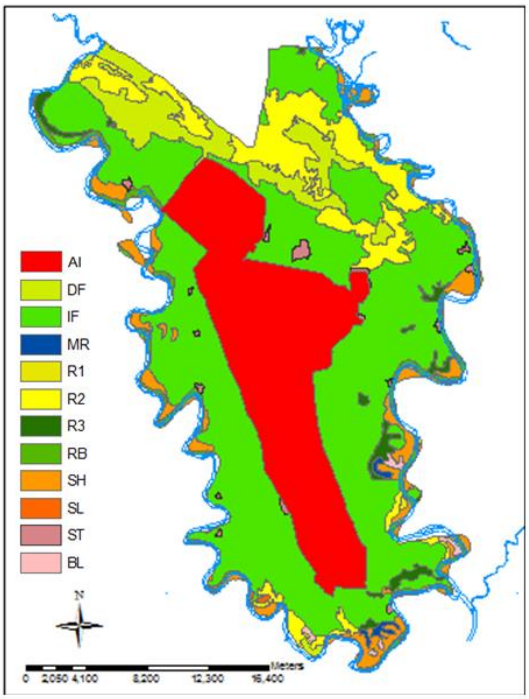
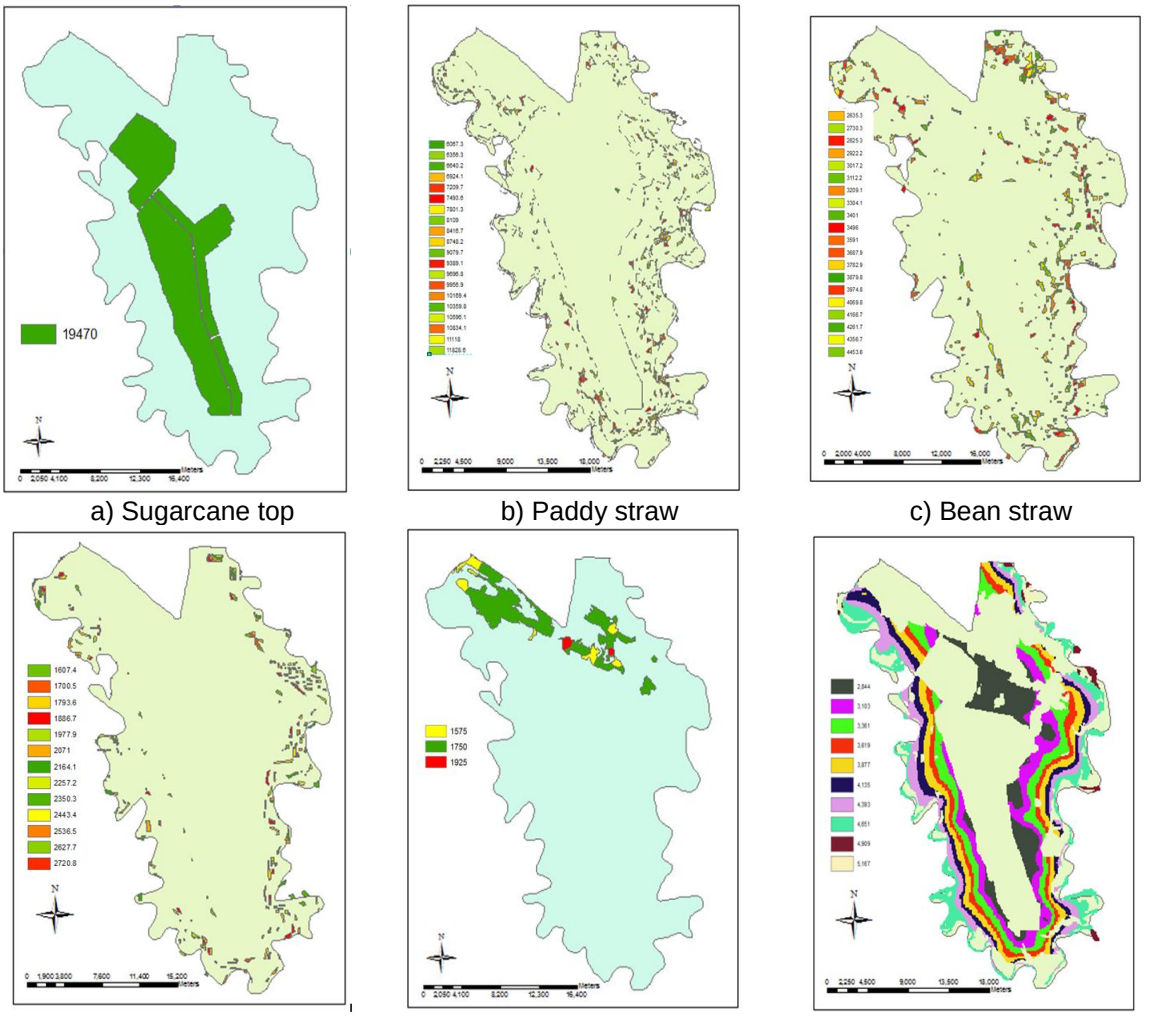


Figure 2. Land use (AI: Agro-industry, BL: Rocky protrusions, DF: Dry Farming, IF: Irrigated farming, MR: Marsh Land with High Level of Surfaces water, R1: Dense Rangeland, R2: Medium Dense Rangeland, R3: Poor Rangeland, RB: Large River Beds, SH: Shrub Land with more than 10 Percent Canopy Cover, SL: Salty Land, ST: Urban and Rural Area and Installations

Using land-use map and interpolation results, mops of available field crop residues were plotted and illustrated in Figure 3. Since the average sugarcane yield was between 77 to 80 tonnes/hectare, the sugarcane residues are far more than other crop residues. The large area of cultivation and good yield of irrigated wheat and barley caused good potential of available straw while in dry farming wheat and barley, yield is low and straw of them is little. So, dry farming was regardless to produce available residues. There are two cultivation seasons in Shodirwan: warm and cool season. Wheat and barley is cultivated in cool season while bean, paddy and mung bean are cultivated in warm season. The annual agricultural residue production and energy potentials of them in Shodirwan are presented in Table 3. The total of crop residues that produced in this region was 1038525 tonnes/year that 668128 tonnes of it was available residues. Maximum of available crop residue related to bagasse with 343591 tonnes. Total sugarcane residue (bagasse and top) was 649031 tonnes/year and available residue of it was 530675 tonnes. Sugarcane residues were followed by available straw of wheat and barley with 88545 tonnes/year.



a) Sugarcane top b) Paddy straw c) Bean straw

d) mung bean straw e) Dry farming wheat and barley straw f) Irrigated farming wheat and barley straw

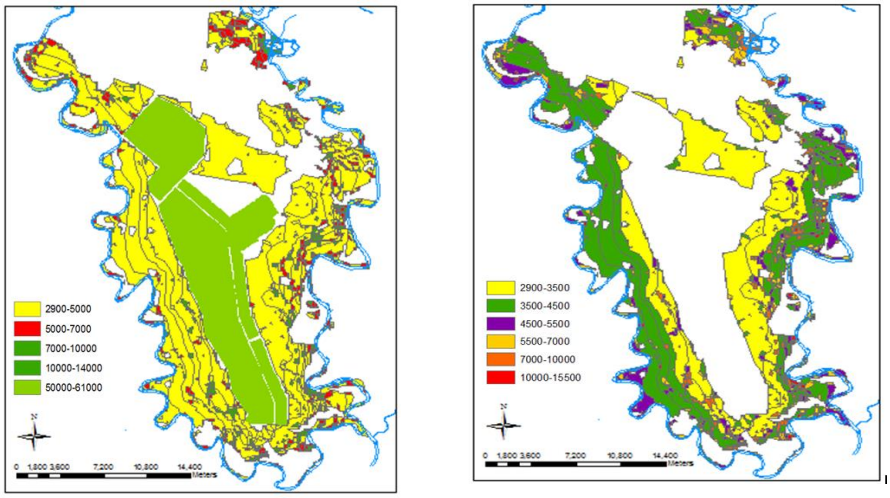
Figure 3. Available Field Crop Residues (kg/hectare)

Potential of energy generation from available residues in Shodirwan was 969589405 kWh/year. Of all the residues, the sugarcane residues had the greatest share of the total potential of energy generation with 79.15%. Energy potential of sugarcane residues was 767420725 kWh/year that 509945975 kWh related to bagasse and 257474750 kWh related to sugarcane top. Potential of energy generation from wheat and barley straw and paddy straw and husk were 132080000 (13.62% of total potential) and 57280100 (5.91% of total potential) kWh/year, respectively. Potential of energy generation from processing residues was 511946175 kWh/year (52.80% of total potential) while from field residues was 457643230 kWh/year (47.20% of total potential). Base on the CO2 emission from electrical energy production in Iran that is 0.572 kg/kWh [21, 22], mitigation potential of CO_2 emission, as a result of using crop residues energy in Shodirwan, was 554605 tonnes/year.

Table 3. Annual Agricultural Residue Production in Shodirwan

Residue	Total residue (tonnes/year)	Available residue (tonnes/year)	Residue energy	
			kWh/year	%
Bagasse	381767.5	343590.8	509945975	52.59
Sugarcane top	267263.3	187084.3	257474750	26.56
Total sugarcane residue	649030.8	530675.1	767420725	79.15
Wheat and barley straw	252986.4	88545.3	132080000	13.62
Mung bean straw	4509.3	1578.2	2301600	0.24
Bean straw	112479.3	39367.8	57280100	5.91
Paddy straw	17464.7	6112.7	8506780	0.88
Paddy husk	2054.6	1849.2	2000200	0.21
Total paddy residue	19519.4	7961.8	10506980	1.09
Total	1038525.2	668128.2	969589405	100

Spatial potential of energy generation from crop residues in Shodirwan are illustrated in Figure 4. Spatial potential of residues to produce energy was calculated between 2900 to 61000 kWh/hectare/year. It can be seen from Figure 4 that spatial potential of energy generation from sugarcane residues in agro-industry is much greater than other crop residues in Shodirwan. Apart from the Imam Khomeini agro-industry, the spatial potential of residues to produce energy was between 2900 and 15500 kWh/hectare/year and classified in 6 classes that classes of 2900-3500 and 3500-4500 kWh/hectare/year together were included 76.37% of total irrigated farming land (Except the agro-industry land) wile class of 10000-15500 kWh/hectare/year was included 1.62% of it (minimum area). The share of 4500-5500, 5500-7000 and 7000-10000 kWh/hectare/year classes were 10.13%, 7.29% and 4.59% of total irrigated farming land (Except the agro-industry land), respectively.



a) Total b) Without agro-industry

Figure 4. Spatial Potential of Energy Production from Crop Residues in Shodirwan (kWh/hectare/year)

4. Conclusion

In this study, spatial potential of energy generation from agriculture residues was analyzed with using GIS in Shodirwan region of Iran. Data were collected by field random sampling, face to face questionnaire and, corresponding governing, research institutes and available literature. The available agriculture residues in Shodirwan were bagasse, sugarcane top, rice husk and straw of wheat, barley, bean, rice and mung bean. The total of crop residues that produced in this region was 1038525 tonnes/year that 668128 tonnes of it was available residues. Maximum of available crop residue related to bagasse. The total potential of energy production from available residues was 969589405 kWh/year that sugarcane residues have the highest share with 79.15%. The spatial potential of energy production from sugarcane residues was much greater than other crop residues. Spatial potential of residue to produce energy is calculated between 2900 to 61000 kWh/hectare/year.

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