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Assessment of crop residue potential for power generation using geographical information system

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Punjab being a major agricultural state of India produces main crops such as paddy, wheat, pulses, barley, cotton, maize, arhar, mustard, rapeseed, sesamum, sugarcane and ground nut. Presently about half of the crop residue is being utilized for local needs like food for animals, home fuel and thatching materials. Remaining crop residue is being burnt in the field causing national energy loss, environment pollution and decreasing the land fertility. The annual production of total crop residue is 29.46 MT and total unused crop residue as 14.53 MT. Main hurdle for the conversion of crop residue into cleaner energy is its wide spatial distribution across the state. In this paper nature of crop residue, its availability and corresponding energy potential was carried out using geographical information system (GIS) in Punjab.

Keywords: crop residue, energy potential, environmental pollution, geographical information system (GIS).

Introduction

In India 64% of the nation's workforce is engaged in agriculture and agriculture contributes 29.4% of GDP[1,2]. The fuel wood, crop residue and animal manure are the dominant biomass fuels which are mostly used in rural areas at very low efficiencies[3]. Total potential of energy from all these sources was estimated equivalent to be 5.14EJ, which amounts to a little more a third of the total fossil fuel used in India. The energy potential in 2010 was estimated to be about 8.26EJ. Today biomass is the world's fourth largest source of energy, contributing 15% of the world's primary energy needs[4]. It is estimated that total biomass energy consumption in India was about 321 billion kg or 380 kg/capita/ year in 1990-91. This amounted to 45% of the total primary energy consumption of the country[5]. The share of the fuel wood in the traditional energy is about 53%. The household sector is the major end user which consumes 83% of the total biomass energy. The traditional cook stoves are the major end user of the biomass energy which is 76% of the total consumption. Punjab is an agricultural state with only 1.5 % of the geographical area of India, producing 22.5% wheat, 12% rice and 13% of cotton in annual productions in 2002-03 in India with producing a large amount of crop residue[6]. Crop residues in the mechanized farms in Punjab are burned to minimize residue management cost[7]. Burning of residue results in loss of organic matter and nutrients while increasing pollution. The increase in pollution is evident from the fact that one ton of straw burning releases 3kg of particulate matter, 60 kg of CO, 1460 kg of CO_2, 199 kg of ash and 2 kg of sulphur[8]. Agricultural scientists favour plowing the crop residue into the soil to improve soil organic matter content, nutrients and other properties associated with soil productivity, however this increases the cost of seed bed preparation[7]. Beside the seed bed preparation cost the other bottlenecks are spatial distribution of agricultural biomass across Punjab and the associated cost of collection and transportation of residue to the biomass energy conversion facility[9]. In order to motivate the disposal of agro waste in an ecofriendly way a state government implemented new energy policy since year 2006. This policy offered a financial and fiscal incentives to add power generation capacity of 1000MW by year 2020 bringing the share of New and Renewable Sources of Energy (NRSE) to the level of 10% of conventional power[10,11]. Estimation of spatial distribution of economically exploitable crop residue is the backbone of future success of NRSE policy and ultimately instrumental in the designing of agro waste bioenergy power plants across the state with sustainable supply of crop residue.

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So far reliable data regarding the availability of crop residue across the state is not available and in this paper geographical information system has been implemented to analyze the crop residue data across the state.

Materials and Methods

Potential of unused crop residue

GIS is the dynamic technique for the analysis of spatial availability of crop residue. In this study the crop residue was divided into four categories namely A1, A2, A3 and A4. The nature of crop residue and its yield vary from region to region across the state, but once availability of crop residue has been ensured then detailed analysis of crop residue may be conducted to ascertain the various characteristics of the crop residue for further consideration.

Potential of energy for power generation from unused crop residue

By considering all practical losses and inefficiencies, the energy potential from unused crop residue has been estimated for power generation. Overall conversion efficiency, handling and storage losses are the key factors for estimating the power potential of unused crop residue. The availability of crop residue, its collection cost and transportation cost may also be estimated using GIS. The cost of the unit electricity including cost of power supply grid network will act as the criteria for the success of proposed power plant. The data generated using GIS will set as the bench mark case study for designing crop residue-based power plants for sustainable supply of crop residue to power plants at the competitive cost.

Results and Discussions

The input data of crop residue from all major crops of the state was taken from the statistical abstract Punjab 2010. Unused crop residue potential and energy potential from unused crop residue were estimated for categories A1, A2, A3 & A4 as shown in Table 1.

Availability of unused crop residue

It is observed from Table 1 that the category A1 representing the straw of wheat, paddy, pulses and barley contributes 83% of the unused crop residue, amounting to 12 MT/Year beside the current use which includes rural fuel, animal food, paper industry and other domestic and industrial uses. The category A2 representing the stalks of cotton, maize, arhar, mustard & rapeseed and sesamum contributes 5% of the unused crop residue, amounting to .74 MT/Year. The category A3 representing the sugarcane bagasse and sugarcane tops & leaves is the least important which contributes less than one percent of the unused crop residue, amounting to .04MT/Year. The category A4 representing the maize cobs, groundnut shells and paddy husk contributes 11% of the unused crop residue, amounting to 1.7 MT/Year. Table 1 shows the district wise distribution of crop residue potential and energy potential from unused crop residue for categories A1 to A4. District wise distribution of unused crop residue is very important for designing of new power plant. The intensity of each category of crop residue is also very important. Depending upon the availability of particular crop residue intensity, certain design modifications of power plant may be incorporated. Distribution intensity of crop residue of a particular category is helpful to calculate the category wise surplus (unused) crop residue produced across the district. It forms a basis for the optimum location of the power plants in the district. As the design of the power plant depends upon nature of crop residue, the estimation of crop residue in different categories helps in designing specific type of power plant (combustion or gasification).The unused crop residue potential observed from Table 1, in the various districts of Punjab state as following;

Districts Hoshiarpur, SBS Nagar (Nawan Shehar), Kapurthala, Rup Nagar, Fatehgarh Sahib, Faridkot, Mukatsar and Mansa lies in the low range (247-496 k T) production of unused crop residue in category A1 and districts Amritsar, Firozpur, Ludhiana, Patiala, Moga, Bathinda, Gurdaspur and Jalandhar lies in the medium range (497-1216 kT). District Sangrur lies in the high range (1217-1795 kT).

In category A2, districts Fatehgarh Sahib, Patiala, Sangrur, Faridkot, Mansa, Bathinda, Muktsar, Firozpur, Amritsar, Kapurthala and Ludhiana lies in low range (2-23kT) of production of unused crop residue. Districts Jalandhar, SBS Nagar, Gurdaspur and Rup Nagar lies in medium range (24-113 kT) and district Hoshiarpur lies in the high range (114-328 kT).

The low range (0-0.91kT) districts in category A3 are Moga, Faridkot, Mukatsar, Bathinda, Mansa, Firozpur, Ludhiana, Sangrur and Patiala. Districts Amritsar, Kapurthala, Rup Nagar, Fatehgarh Sahib,

Table 1—Unused Crop Residue Potential (CRP) and Energy Potential (EP)

Sl. No.	District	Crop residue potential (CRP) in Thousand Ton					Energy potential (EP) in 10^{14}J				
		CRP from category A1	CRP from category A2	CRP from category A3	CRP from category A4	Total CRP	EP from category A1	EP from category A2	EP from category A3	EP from category A4	Total EP
1	Gurdaspur	695.66	36.05	14.13	96.96	842.79	108.19	6.01	2.82	15.23	132.25
2	Amritsar	1122.04	12.28	2.05	144.43	1280.8	174.52	2.06	0.41	22.9	199.89
3	Kapurthala	453.26	19.64	02.05	67.18	542.13	69.88	3.28	0.41	10.53	84.1
4	Jalandhar	654.57	49.06	04.78	99.94	808.36	101.22	8.20	0.95	15.76	126.13
5	SBS Nagar	247.47	77.21	03.53	51.73	379.94	38.41	12.87	0.70	8.4	60.38
6	Hoshiarpur	310.55	328.49	08.65	119.46	767.16	48.94	54.77	1.73	20.15	125.59
7	Rupnagar	284.81	113.34	2.05	61.4	461.6	44.78	18.9	0.41	10.09	74.18
8	Ludhiana	1216.16	15.84	00.68	169.19	1401.87	187.63	2.68	0.14	26.36	216.81
9	Firozpur	1106.71	20.31	00.68	132.74	1260.44	173.06	3.52	0.14	20.63	197.35
10	Faridkot	426.77	02.25	Nil	57.00	486.02	66	0.39	nil	8.86	75.25
11	Shri Muktsar Sahib	495.77	13.85	Nil	53.29	562.91	78.3	2.4	nil	8.28	88.98
12	Moga	806.84	01.75	Nil	111.81	920.40	124.27	0.3	nil	17.38	141.95
13	Bathinda	582.86	23.03	Nil	65.56	671.45	91.7	4	nil	10.19	105.89
14	Mansa	402.60	12.58	Nil	44.63	459.81	63.41	2.18	nil	6.93	75.52
15	Sangrur	1794.84	6.39	0.91	243.61	2045.76	277.06	1.12	0.18	37.86	316.22
16	Patiala	1035.05	04.32	00.91	141.65	1181.93	159.78	0.72	0.18	22.03	182.71
17	Fatehgarh Sahib	396.41	04.20	01.71	54.90	457.22	61.2	0.7	0.34	8.54	70.78
Total Crop Residue						14530.59		Total Energy			2273.98

Jalandhar and SBS Nagar lie in the medium range (0.92 – 4.78 kT) and districts Gurdaspur and Hoshiarpur lies in high range (4.79-14.13 kT).

It is observed that the low range (44.73-67.18 kT) districts in category A4 are Rup Nagar, Mansa, SBS Nagar, Fatehgarh Sahib, Mukatsar, Kapurthala, Faridkot and Bathinda. Districts Hoshiarpur, Jalandhar, Moga, Patiala, Ludhiana, Amritsar, Gurdaspur and Firozpur lie in the medium range (67.19-169.19 kT) and the district Sangrur lies in the high range (169.2-243.61 kT).

It is also observed from Table 1 & Fig. 1 that for the total production of unused crop residue, the low range (379.94-671.45 kT) districts are Rup Nagar, Faridkot, SBS Nagar, Fatehgarh Sahib, Kaurthala, Mukatsar, Bathinda and Mansa. Medium range (671.46-1401.87 kT) districts are Amritsar, Hoshiarpur, Jalandhar, Moga, Patiala, Ludhiana, Gudaspur and Firozpur. District Sangrur has the highest production of total unused crop residue & lies in the range (1401.88-2045.76 kT).

Energy potential from unused crop residue

The energy potential from unused crop residue, observed from Table 1, in the various districts of Punjab state as following;

Districts Rup Nagar, Hoshiarpur, Kapurthala, SBS Nagar, Fatehgarh Sahib, Faridkot, Mukatsar and Mansa lie in the low range (3841-7830 TJ) energy potential of unused crop residue in category A1. Districts Gurdaspur, Amritsar, Ludhiana, Firozpur, Patiala, Moga, Bathinda and Jalandhar lie in the medium range (7831-18763 TJ). District Sangrur lies in the high range (18764-27705 TJ).

In category A2, the districts Fatehgarh Sahib, Patiala, Sangrur, Moga, Faridkot, Mansa, Bathinda, Mukatsar, Firozpur, Amritsar, Kapurthala and Ludhiana lie in low range (30-400 TJ) energy potential of unused crop residue. Districts Gurdaspur, Jalandhar, SBS Nagar and Rup Nagar lie in the medium range (401-1890 TJ). District Hoshiarpur lies in the high range (1891-5477 TJ).

The low range (0-18 TJ) energy potential districts in category A3 are Moga, Faridkot, Muktsar, Bathinda, Mansa, Firozpur, Ludhiana, Sangrur and Patiala. On the other hand the districts Amritsar, Kapurthala, Rup Nagar, Fatehgarh Sahib, Jalandhar and SBS Nagar lie in the medium range (19-95 TJ). Districts Gurdaspur, Hoshiarpur lies in high range (96-282 TJ).

It is observed that the low range (693-886 TJ) energy potential in category A4 lies in the districts

SBS Nagar, Fatehgarh Sahib, Mansa, Mukatsar, Faridkot and. Districts Gurdaspur, Hoshiarpur, Jalandhar, Moga, Patiala, Rup Nagar, Ludhiana, Amritsar, Kapurthala, Bathinda and Firozpur lie in the medium range (887-2636 TJ). District Sangrur lies in the high range (2637-3786 TJ).

It is also observed from Table 1 & Fig. 2 that for total energy potential from unused crop residue, districts Rup Nagar, Kapurthala, Faridkot, SBS Nagar, Fatehgarh Sahib, Mukatsar and Mansa lie in low range (6038-8898 TJ). In the medium range (8899-21691 TJ) districts are Gurdaspur, Hoshiarpur, Jalandhar, Moga, Bathinda, Patiala, Ludhiana, Amritsar, Firozpur and the district Sangrur has the highest energy potential of total unused crop residue (21692-31622 TJ).

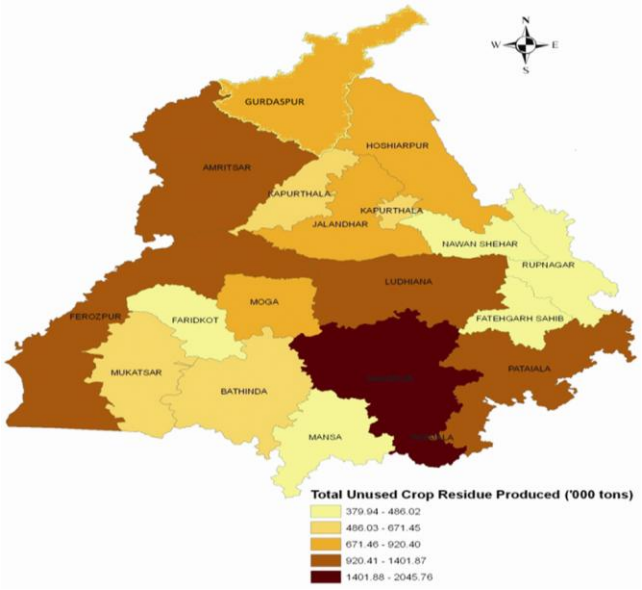

Fig. 1—Total unused crop residue potential

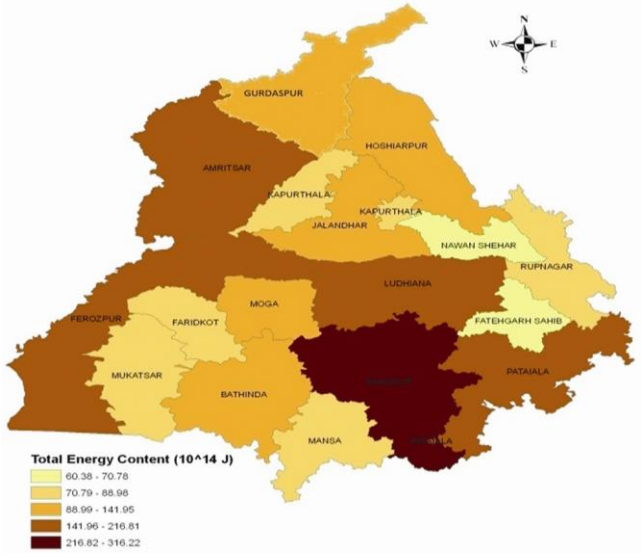

Fig. 2—Total energy potential from unused crop residue

Conclusions

Total unused crop residue available in Punjab state was 14.53 MT. Total energy potential from unused crop residue in Punjab state was 227300 TJ and total power potential from unused crop residue across the state was 1000 MW. The district Sangrur had the highest production of unused crop residue in category A1 and corresponding energy potential. The district Hoshiarpur had the highest production of unused crop residue in category A2 and corresponding energy potential. The district Gurdaspur had the highest production of unused crop residue in category A3 and corresponding energy potential. The district Sangrur had the highest production of unused crop residue in category A4 and corresponding energy potential. Using GIS technique, the nature of crop residue, its availability and corresponding energy potential was discussed in this paper which will act as the bench mark to design the future power plant in each district of Punjab state.

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