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Research Article

Bio-Energy Potential from Crop Residues: A Study from Southern Rural Part of Rajasthan, India

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ABSTRACT

Traditional biomass continues to provide important source energy throughout the world especially the developing countries. Commercial bio-energy is assuming greater importance and concern as it has the potential to lower the impacts of global warming. Bio-fuels are known to emit less carbon as compared to other conventional fuels. In the present study, energy generation potential of a few predominant agricultural crop residues, such as Groundnut (*Arachis hypogaea L.*) Shell, Mustard (*Brassica juncea L.*) Husk, Sesame (*Sesamum indicum L.*) Stalk, Soybean (*Glycine max L.*) Husk and Taramira (*Garden Rocket*) (*Eruca sativa L.*) Husk were estimated and compared for their future prospects. The crop production figures were taken for the year 2009-2010 to 2013-2014 during the present study. Based on the high biomass availability records six districts of Udaipur region, namely Banswara (23.55°N to 75.45°E), Chittorgarh (24.88°N to 74.63°E), Dungarpur (23.84°N to 73.72°E), Pratapgarh (24.03°N to 74.78°E), Rajsamand (25.07°N to 73.88°E) and Udaipur (24.58°N to 73.68°E) in Southern Rajasthan India, were chosen for the bio-energy assessment. The total area under crop cultivation in the study area was 15.60 lakh hectares. Correspondingly, the gross crop residues and surplus crop residues estimated were around 2.474 and 0.841 Million Metric Tonnes respectively during the study period (2009-2010 to 2013-2014). The gross bio-energy potential from crop residues calculated was around 35.617 thousand Giga Joule which is sufficiently high and can serve the energy deficiency or shortage problem of the region. About 0.387 lakh Tonnes of CO_2 can be saved annually from going in to environment. The study suggests that the bio-energy potential of different agricultural crop residues in the region is promising and need concern for an integrated energy management. It can serve the energy needs of the industries and local inhabitants of the region in a 'Clean and Green' way.

Keywords: Bio-mass; energy; Fossil fuels; Greenhouse gases; Heating value

INTRODUCTION

In today's concern petroleum and other fossil fuels prices are increasing worldwide. As per simple economic model, prices would go up because of supply and demand gap. This is also a proven fact that the availability of these resources are limited in nature for our use. Presently to fulfill the energy needs, we mostly depend on fossil fuels (80%) and the dominant fossil fuels are being utilized; oil, coal and natural gas. Energy demand is also growing fast year after year due to rapid growth in population, urbanization and industrialization [1]. In near future, it may not be possible to provide the amount of energy needed to the world by using fossil fuels only. To meet and secure the energy supply, it's become urgent need of era to adopt sustainable and alternatives sources of energy. There are amply of means to meet energy needs without consumption of fossil fuels, and many of are being used, but not nearly to their full potential. Among various sources of energy generation resources available, biomass is one of them, which considered as renewable, cheap and clean source of energy. The substitution of conventional fossil fuels with available biomass for energy generation is resulting into a net reduction of greenhouse gases emission [2].

Worldwide, according to Renewable Energy Policy Network for the 21st Century (REN21-2014) report, renewable energy resources were utilized 19% and 22% for generation of electricity during the year 2012 and 2013 respectively. This energy consumption is distributed as 9% coming from traditional biomass, 4.2% as heat energy (non-biomass), 3.8% hydroelectricity and 2% electricity from wind, solar, geo-thermal and biomass. Largely, biomass is

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contributing to more than 14% of the global total energy supply.

Like, other developing counties, India's economy is also largely based on agriculture. India has fifteen different agro climatic zones with a variety of both tropical and temperate crops grown in highly diverse regions. India has enormous availability of biomass and produces about 450-500 Million Tonnes of biomass per year [3]. Currently, about 32% of total primary energy is being used in India and more than 70% of the country's population depends upon biomass for its energy needs. According to World Bank Report (2010) in India 60.9% agricultural land is available and almost 90% land is being cultivated under crop every year. After harvesting there is a large amount of agricultural waste residues left behind, this could be good source of clean energy. The utilization of biomass as energy sources not only mitigate greenhouse effects but also reduce our dependency on conventional fossil fuels.

A number of studies have estimated that in India huge potential of surplus agro residues is available and the same can be significantly exploited as a fuel for power generation. The aim of present study is to assess the surplus crop residues and their energy generation potential in southern part of Rajasthan [4]. The study can helpful in planning of proper utilization and formation of energy policy for the tribal areas of southern Rajasthan. By proper utilization of such an available clean energy source, we can move towards a sustainable world.

REVIEW OF LITERATURE

Biomass source are considered clean, renewable and sustainable basis of energy. Biomass resources comprise of residues from agriculture, harvests from forest (firewood, charcoal, residues), crop residue, energy crops and other biological resources. Prevailing knowledge on biomass availability and its utilization as energy source is reviewed below.

Biomass resources could be directly utilized for basic energy needs (e.g. firewood, charcoal, dung cake etc.) or transformed into invaluable renewable energies (e.g. biogas, biofuel, bioelectricity, hydrogen energy etc.) for household as well as industrial and transportation sectors [5].

Biomass accounts for 35% of primary energy consumption in developing countries, constituting about 14% of the world's total primary energy consumption and is only organic petroleum substitute that is renewable [3]. It is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities. Biomass based electricity schemes already provide over 9 Giga Watt of worldwide generation capacity [6].

In a recent study conducted on Assessment of biomass fuel resource potential and utilization in Ethiopia: sourcing strategies for renewable energies [7], described that in standard efficiency measurement, diverse biomass fuel sources have varied degree of efficiency. The energy efficiency of various biomass fuels presented for fuel wood 15.5 MJ/Kg; Biome leave and litters 15.5 MJ/Kg; roots 14.3 MJ/Kg; Charcoal 29.0 MJ/Kg; Saw dust 18.6 MJ/Kg; Agro-residue 15 MJ/Kg; Maize Stalk 15 MJ/Kg and Dung 13.8 MJ/Kg. The result revealed that developing appropriate institutions and technologies for renewable energies sourcing from biomass is invaluable.

A study done by Buragohain et al. on Biomass gasification for decentralized power generation: The Indian perspective and demonstrated that in Indian scenario, biomass based energy has several distinct advantages such as wide availability and uniform distribution that puts it ahead among the renewable energy [8].

Like similar study was conducted on biomass gasification technology – a route to meet energy needs and concluded that, the energy generation from gasification of biomass resulted in a saving of about 350 tons of fossil fuel, implying a saving of about 1120 tons of CO_2 - a promising candidate for Clean Development Mechanism (CDM), other than reduction in toxic gases like NOx and SOx [9].

MATERIALS AND METHODS

Study area at a glance

The State of Rajasthan, is located in the North-Western corner of India. The state covers 10.4% of the total geographical area of India. The region to the west and north-west comprising of eleven districts spreading in 61.11% of the total area is characteristically either desert or semi-desert type.

In the present study, six districts of southern Rajasthan were selected namely, Chittorgarh, Pratapgarh, Udaipur, Rajsamand, Banswara and Dungarpur. Geographically, the total study area covered is approx. 41254.35 km^2. The study area and their respective coordinates are depicted in the Table 1 and Figure 1.

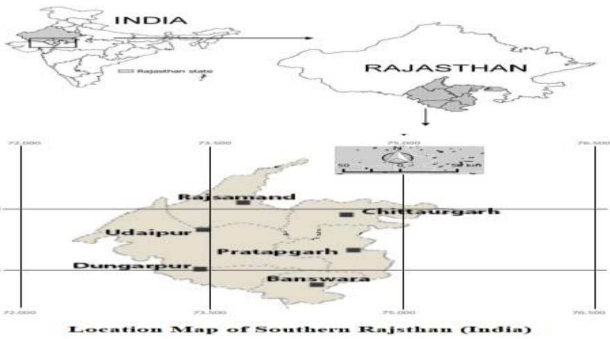

Figure 1: Map of Rajasthan–with showing study region

Table 1: Inter-comparison statistics using Sentinel-2 images.

S. No.	Name of District	Coordinates
1	Banswara	23.55°N to 75.45°E
2	Chittorgarh	24.88°N to 74.63°E
3	Dungarpur	23.84°N to 73.72°E
4	Pratapgarh	24.03°N to 74.78°E
5	Rajsamand	25.07°N to 73.88°E
6	Udaipur	24.58°N to 73.68°E

Further, secondary data like irrigation pattern, cropping pattern, crop production, rainfall etc. were collected from the Statics Department, Directorate of Agricultural, Government of Rajasthan (GoR) [10]. The average crop production figures of five years (study period 2009-10 to 2013-14) were considered to analyze and compute the crop residue and energy generation potential.

Selection of crops

For the present study, the crop residues of Groundnut shell, Mustard husk, Sesame stalk, Soybean husk and Taramira husk were selected under the non-fodder criteria (residues are not consumed as fodder by animals). The biomass crop residues generally burnt in the field by the farmers to clean and make ready for taking next crop. These type of biomass residues also known as non-essential class biomass crop residues [11]. Estimation of crop residue biomass potential

To estimate the amount of agricultural biomass residue; annual gross potential of the agricultural biomass was determined by using the Residue to Product Ratio (RPR). The formula is given as [12];

$(CR)i=(RPR)i \times (PrC)I$

where,

(CR)i=Amount of agricultural biomass residue in Tonnes (RPR)
i=ith crop on dry mass basis

(PrC)i=Amount of crop production in Tonnes

Further, the bioenergy potential was estimated by following formula, as given under;

$Qi=(CRi * HVi)$

where,

Qi is the energy potential of ith crop (GJ/t)

CRi crop residue of ith crop in Tonnes

HVi the Heating Value of ith crop (kcal/kg)

HVi the Heating Value of ith crop (kcal/kg)

Characterization of agriculture crop residues

Further, for the effective utilization of biomass as a fuel and selection of optimum energy conversion technology, the knowledge of characteristics of biomass is very important. Chemical properties (qualitative analysis) and elemental composition (quantitative analysis) are used for characteristic of biomass [13]. The proximate and ultimate analyses were tested by following American Society for Testing and Materials (ASTM) methods of analysis. To determine the Calorific Value (CV) or Heating Value (HV), method IS: 1350 (PART-II)-1970 (Method of test for coal and coke, determination of calorific value) was followed.

RESULTS AND DISCUSSION

According to secondary data the total cultivated area of studied crops in the region was 15.60 lakh hectares. Other than the monsoon period, the irrigation water demand is being met by ground water [14]. The district wise annual average rainfall pattern is 950 mm in Banswara, 840 mm in Chittorgarh, 730 mm in Dungarpur, 845 mm in Pratapgarh, 550 mm in Rajsamand and 685 mm in Udaipur. During the study period, the lowest rainfall (421.10 mm) was recorded at district Rajsamand in year 2009-10 and the highest rainfall (1156.40 mm) was recorded at district Banswara in the year 2012-13 Table 2 and Figure 2.

Table 2: Area under cultivation (hectare) (study period 2009-10 to 2013-14).

Year	Groundnut	Mustard	Sesame	Soybean	Taramira
	(Arachis hypogea L)	(Brassica juncea L)	(Sesame indicum L)	(Glycine max L)	(Eruca sativa L)
2009-10	25015	55184	13646	158207	1162
2010-11	25494	81256	14781	159478	38642
2011-12	25124	64115	14853	178798	3587
2012-13	22893	81584	12591	206576	1539
2013-14	22301	88546	9993	251419	2856
Average	24165.4	74137	13172.8	190895.6	9557.2

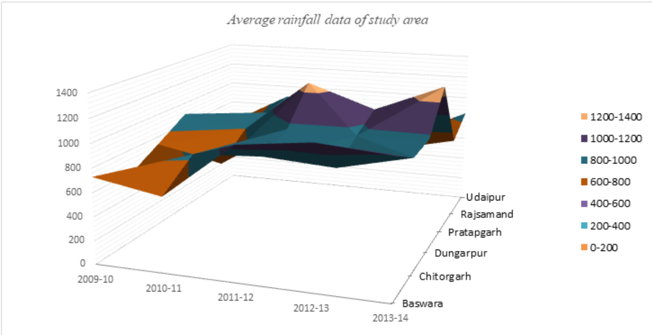

Figure 2: Rainfall (mm) recorded in study region

Proximate and ultimate analysis

The results of the proximate analysis and calorific value for five agriculture crop residues are given in the [Table 3]. Similarly, the results of the ultimate analysis for studied agriculture crops residues are given in the [Table 4]. The results found are having closer values except for calorific values which is ranges between lowest for Mustard husk (2682 kcal/kg) and obtained highest for Groundnut shell (4241 Kcal/kg).

Table 3: Proximate analysis (weight %).

S. No.	Crop residue	Volatile matter	Moisture content	Fixed carbon	Ash content	Calorific value
1	Groundnut shell	72.02±0.50	7.27±0.17	18.21±0.17	4.21 ± 0.98	4249 ± 8.50
2	Mustard husk	75.64 ± 1.00	5.51 ± 0.3	15.06 ± 0.56	3.02±0.08	2686 ± 3.78
3	Sesame stalk	75.08± 0.54	6.43 ± 0.09	16.2 ± 0.22	3.85 ± 0.30	3450 ± 12.85
4	Soyabean husk	74.46 ± 0.72	5.25 ± 0.19	16.82 ± 0.91	4.73 ± 0.48	3905 ± 3.05
5	Taramira husk	74.09 ± 0.55	5.58 ± 0.11	15.97 ± 0.07	4.31 ± 0.59	2698 ± 8.00

Table 4: Ultimate analysis.

S. No.	Crop Residue	Carbon (C%)	Hydrogen (H%)	Oxygen (O%)	Nitrogen (N%)	Sulphur (S%)
1	Groundnut shell	45.79±1.96	6.64±1.05	41.42±1.86	1.28±0.25	0.03±0.015
2	Mustard Husk	45.97±1.04	6.49±0.32	45.16±1.05	0.58±0.17	0.24±0.36
3	Sesame Stalk	43.25±0.45	6.32±0.57	43.11±0.49	0.95±0.07	0.43±0.055
4	Soybean husk	43.32±0.72	6.77±0.26	45.84±1.04	0.97±0.4	0.23±0.101
5	Taramira husk	45.47±0.27	5.88±0.19	41.46±1.15	1.8±0.37	0.09±0.015

Similarly, the secondary data of crop production was collected and then quantifies of crop residues were calculated by Residue to Product Ratio (RPR). Next, the bio-energy potential from estimated crop residues was determined by using calorific value, as shown in below Tables 5-9.

Table 5: Crop residue estimation (Tonnes) and energy potential (GJ) in the year 2009-10.

Year 2009-10								
	District	Groundnut shell (T)	Mustard husk (T)	Sesame stalks (T)	Soybean husk (T)	Taramira husk (T)	Total Crop residue (T)	Energy Potential (GJ)
Rajasthan	Banswara	282.7	234	90.2	16944.4	15	17566.3	287.19
	Chittorgarh	22936.1	96430	1857.9	40356.8	419	161999.8	2188.6
	Dungarpur	14.3	1404	324.5	1076	26	2844.8	38.7
	Pratapgarh	1153.9	13600	253	171180	96	186282.7	2987.4
	Rajsamand	1623.6	1394	348.7	1.1	17	3384.4	49.86
	Udaipur	2460.7	15356	464.2	1159	21	19460.9	242.76
	Total	28471.3	128418	3338.5	230717	594	391538.9	5794.5

Table 6: Crop residue estimation (Tonnes) and energy potential (GJ) in the year 2010-11.

Year 2010-11								
	District	Groundnut shell (T)	Mustard husk (T)	Sesame stalks (T)	Soybean husk (T)	Taramira husk (T)	Total Crop residue (T)	Energy Potential (GJ)
Rajasthan	Banswara	409.2	346	294.8	20147.6	12	21209.6	346.18
	Chittorgarh	34113.2	143086	2933.7	51075.2	19516	250724.1	3420.1
	Dungarpur	67.1	2888	728.2	1939.3	35	5657.6	76.45
	Pratapgarh	1732.5	17420	470.8	150317	795	170735.5	2709.5
	Rajsamand	2072.4	12396	991.1	0	2305	17764.5	216.96
	Udaipur	2214.3	54714	650.1	2895.2	2148	62621.6	736.99
	Total	40608.7	230850	6068.7	226375	24811	528712.9	7506.2

Table 7: Crop residue estimation (Tonnes) and energy potential (GJ) in the year 2011-12.

Year 2011-12								
	District	Groundnut shell (T)	Mustard husk (T)	Sesame stalks (T)	Soybean husk (T)	Taramira husk (T)	Total Crop residue (T)	Energy Potential (GJ)
Rajasthan	Banswara	434.5	240	226.6	17000.5	16	17917.6	292.86
	Chittorgarh	29444.8	113540	1554.3	80931.4	1130	226600.5	3166.7
	Dungarpur	86.9	1838	352	3429.8	64	5770.7	84.33
	Pratapgarh	1124.2	14138	117.7	140256	114	155749.4	2483.8
	Rajsamand	1919.5	6224	84.7	0	266	8494.2	108.54
	Udaipur	3513.4	27886	654.5	3203.2	300	35557.1	442.1
	Total	36523.3	163866	2989.8	244820	1890	450089.5	6578.3

Table 8: Crop residue estimation (Tonnes) and energy potential (GJ) in the year 2012-13.

Year 2012-13								
	District	Groundnut shell (T)	Mustard husk (T)	Sesame stalks (T)	Soybean husk (T)	Taramira husk (T)	Total Crop residue (T)	Energy Potential (GJ)
Rajasthan	Banswara	278.3	230	148.5	25111.9	21	25789.7	422
	Chittorgarh	26439.6	158114	2083.3	108885	556	296077.5	4075.1
	Dungarpur	92.4	2552	183.7	6076	41	8945.1	133.21
	Pratapgarh	677.6	40074	179.3	141607	48	182586.3	2790.3
	Rajsamand	2230.8	3762	376.2	3.3	29	6401.3	87.92
	Udaipur	2728	26612	631.4	2945.8	162	33079.2	407.82
	Total	32446.7	231344	3602.4	284629	857	552879.1	7916.4

Table 9: Crop residue estimation (Tonnes) and energy potential (GJ) in the year 2013-14.

Year 2013-14								
	District	Groundnut shell (T)	Mustard husk (T)	Sesame stalks (T)	Soybean husk (T)	Taramira husk (T)	Total Crop residue (T)	Energy Potential (GJ)
Rajasthan	Banswara	413.6	200	83.6	35635.6	4	39908.8	595.63
	Chittorgarh	17427.3	167836	772.2	87953.8	1086	278647.3	3667.7
	Dungarpur	149.6	2418	196.9	6296.4	47	12679.9	136.59
	Pratapgarh	437.8	33100	94.6	149274	246	186724.8	2834.3
	Rajsamand	1474	6274	452.1	0	138	11910.1	105.01
	Udaipur	2548.7	31332	432.3	4589.2	254	42728.2	482.75
	Total	22451	241160	2031.7	283749	1775	572599.1	7822

From the above tables, this is clear that, overall in the study region huge energy potential is available in terms of bio-energy generation. In the study area, the crops Groundnut, Mustard, Sesame, Soybean and Taramira was average sown in around 3.12 lakh hectares annual per year, with the largest share contributed to crop Soybean and was average cultivated in around 1.91 lakh hectares annual per year [15]. Respectively, the total crop production in the region was around 1.845 le metric Tonnes (MMT) with the largest contribution of Soybean i.e. around 1.154 MMT, followed by Mustard (0.498 MMT), Groundnut (0.146 MMT), Taramira (0.030 MMT) and Sesame (0.016 MMT). On the basis of crop production, the gross and surplus crop residues estimated was around 2.474 MMT and 0.841 MMT respectively (as assumed 34%) according to study done by Hilloidhari et al [16]. Similarly, the gross and surplus bio-energy potential was calculated as 35.617 thousand GJ and 12.109 thousand GJ respectively, which can generate 140 MW of power. The estimated bio energy potential is enough to fulfill energy needs of the study region for agriculture and domestic use.

GREENHOUSE GAS MITIGATION

This is a well-known fact that the emission of greenhouse gases are increasing due to excessive burning of fossil fuels (like coal and oil) which releases a large amount of carbon dioxide into the atmosphere. To save our environment from the bed effects of global warming, this is suggested to discontinue the usage of fossil fuels as early as possible and switch over to the usage of alternative renewal energy sources, like biomass fuel based processes. According to study done by Panwar et al. to operate 1 MW biomass based power plant, on an annual basis 7200 Tonnes of biomass crop residues needed and by this, wecan cut 1656 Tonnes of CO_2 from going in to atmosphere [17]. Likewise, in this study, the average surplus crop residue was estimated around 0.168 MMT annually, which is promising to operate 23 MW biomass based power plant considering 300 working days in a year. In the same way, we can cut 0.387 lakh Tonnes of CO_2 annually from going in to environment. This shows that the utilization of biomass crop residues is not only promising to meet energy needs of local inhabitants but also having wider scope to reduce the atmospheric emissions [18].

CONCLUSION

In the present study, the availability of the five different crop residues (Groundnut shell, Mustard husk, Sesame stalk, Soybean husk and Taramira husk) in the Udaipur region was assessed. The studied crop residues are having similar characteristics and divulge that these five crops residues can be used in the single energy conversion process. Bio-energy potential from crop residues in the region have a wide scope, which is promising to support an essential contribution to a sustainable energy generation. The utilization of these surplus biomass in energy generation not only fulfill the energy requirement of the region but also provide the solution to overcome with the problem of waste disposal in 'clean and green' way. The proper planning will certainly serve and contribute in a better way to the great 'Clean India Campaign'.

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