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Sustainable Fuel Energy Potential from Agricultural Biomass

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A B S T R A C T

In India, over 370 million tonnes of biomass is generated every year and it contributes to over one third of primary energy (Chauhan, 2010). This biomass can be easily densified in the form of pellets and briquettes. The present study was undertaken to estimate the availability of biomass for major agricultural crops and to work out its energy potential. Based on the area under cultivation and production for the years 2000-01 and 2011-12, ten major agricultural crops of Haryana were selected i.e. rice, jowar, bajra, maize, cotton, sugarcane, wheat, barley, gram, and rapeseed and mustard. Total amount of generated biomass in 2011-12 for kharif season was 10113.69 000 Tonnes and for rabi season was 22774.13 000 Tonnes. In 2011-12, total energy potential from kharif crop was 10.12×10^{8} and from rabi crop was 30.50×10^{7}.

Introduction

Availability and consumption levels of energy are the best indicators of economic and social development of nations and societies. Energy demand is expected to increase considerably in the coming years as a result of increasing population. The largest increase in energy demand will take place in developing countries where population of global energy consumption is expected to increase from 46 to 58 percent between 2004 and 2030.

In many developing countries, crop residues have been the main source of energy, mostly in its traditional forms to meet the demands of domestic users. India produces about 500 million tons (mt) of crop residues annually (MNRE, 2009) which is used as animal feed, composting, thatching for rural homes and fuel for domestic and industrial use. Apart from meeting the needs of energy to such an extent, unfortunately, a large portion of the biomass residue is burnt in field primarily to clear the fields, from straw and stubble after the harvest of preceding crop.

Burning of crop residues in field is unacceptable as it is responsible for emission of greenhouse gases such as carbon dioxide, methane and nitrogen oxide causing global warming, loss of plant nutrients such as nitrogen, phosphorus, potassium and sulphur, adverse impact on soil properties and wastage of valuable carbon and energy rich residues. Likewise, burning of loose biomass at household level in inefficient mud wood stoves, directly affects the health of the women who spend a lot of time in cooking and heating activities for their families. Report of ICMR (2001) revealed that Indoor air pollution caused by burning traditional fuels has been the major cause of acute respiratory tract infections in children, chronic obstructive lung diseases, pneumoconiosis, lung cancer, cataract and adverse pregnancy effects in women.

Due to diversity of biomass residues and different products that can be obtained, there are several techniques that allow transforming biomass in high energy fuels that are easy to transport, handle and storage. Biomass pelletizing is one such appropriate technology for harnessing clean and renewable fuel-energy from the surplus biomass. Not only are the biomass pellets more energy dense, these are also easier to handle and use in the improved pellet stove at household level. Biomass pellets and pellet stoves were perceived as most beneficial by rural homemakers for meeting their cooking needs (Kumari and Singal, 2012).

Therefore, harnessing of clean energy from biomass will help not only in solving the problems of women's health and deteriorating environment, but will also help to create employment opportunities for rural youth and women in rural areas. Pelletizing units can be easily established at village level and managed by and women. This, in turn, will slow down the migration rate from rural areas to cities.

Based on the above rationale, need was felt to make detailed estimation of biomass availability from agricultural crop residues and to work out its energy potential.

The main objectives of this study include estimation of biomass quantum available from major agricultural crops in Haryana and Assessment of energy potential from available agricultural biomass.

Materials and Methods

Methodology followed for estimation of biomass quantum and energy potential is discussed as follows:

Identification of crops for estimation of biomass

Major agricultural crops of Haryana were identified on the basis of area under cultivation and production for the year 2000-01 and 2011-12.

Estimation of biomass

Quantum of biomass generated from each crop was estimated by using Crop Residue Ratio (CRR) for various crops, as given by Rajasthan Renewable Energy Corporation, 2011, as follows:

Biomass (kg) = Yield (kg/Ha) × Crop Residue Ratio

The data on quantum of biomass generated from major agricultural crops in Haryana was calculated for the years 2000-01and 2011-12 to highlight the percent change in availability of biomass over the last ten years.

Assessment of energy potential

Calorific values for various crop residues were obtained from the literature (Hiloidhari *et al.,* 2011; Friedl *et al.,* 2005; Singh *et al.,* 2008 and Jekayinfa and Scholz, 2009).

Quantum of biomass generated for each major agricultural crop was multiplied by its calorific value to assess the energy potential of various crop residues, as follows:

Energy potential (MJ) = ∑ Biomass × Calorific value

The percentage change in energy potential from residues of major agricultural crops in Haryana in 2011-12 over 2000-01 was also calculated.

Results and Discussion

Results were discussed under the following heads:

Identification of crops for estimation of biomass
Estimation of biomass
Assessment of energy potential

Identification of crops for estimation of biomass

Major agricultural crops of Haryana were identified on the basis of area under cultivation and production for the years 2000-01 and 2011-12.

Area under cultivation of various agricultural crops in Haryana

Figure 1 depicts that in 2011-12, rice, cotton and bajra comprised the largest area under cultivation (92.00%) in kharif season. Out of the remaining 8.00 per cent area under cultivation, 7.00 per cent area was cultivated under sugarcane and jowar.

Similar cropping pattern was also observed for the year 2000-01, reflecting that there has been no change in the area under cultivation over the last ten years. Further perusal of Figure 1 reveals that in 2011-12, wheat crop comprised the largest area under cultivation (79.00%) while rapeseed and mustard, gram, and barley comprised 20.00 per cent of the total area under cultivation. Like kharif season, no change in cropping pattern of rabi crops was observed for the year 2000-01.
The area under cultivation by other crops, both in kharif season and rabi season, was negligible i.e. 1.00 per cent only. Therefore, on the basis of area under cultivation, ten crops viz., rice, jowar, bajra, maize, cotton, sugarcane, wheat, barley, gram, and rapeseed and mustard emerged as major crops of Haryana.

Production of various agricultural crops in Haryana

Production of various agricultural crops was also tabulated for the years 2000-01 and 2011-12 to cross check the major crops of Haryana.

Perusal of data presented in Figure 2 reveals that in 2011-12, rice and cotton contributed highest to the total production (77.00%) under kharif crops while bajra and sugarcane contributed to another 22.00 per cent of the total production. Similar pattern was also observed for the year 2000-01, where rice and cotton contributed to 73.00 per cent of the total production. Sugarcane and bajra contributed to another 26.00 per cent of the total production.

Further scrutiny of Figure 2 postulates that under rabi crops of 2011-12, production of wheat was highest (91.00%) while rapeseed and mustard, barley, and gram contributed to another 7.00 per cent of the total production. Similarly, in 2000-01, wheat was highest in production and rapeseed and mustard, barley, and gram contributed the remaining percentage of the total production.

The contribution of other crops to the total production was negligible both, in kharif and rabi seasons. Based on the production of the crops, ten crops viz., rice, jowar, bajra, maize, cotton, sugarcane, wheat, barley, gram, and rapeseed and mustard, emerged as major crops of Haryana.

Conclusively, based on the area under cultivation and the percentage contribution of the crops to the total production, both for the years 2000-01 and 2011-12, the major kharif crops were identified as rice, jowar, bajra, maize, cotton, and sugarcane, whereas, wheat, barley, gram, and rapeseed and mustard were identified as major crops of rabi season.

Estimation of biomass

Estimation of biomass generated from major agricultural crops in Haryana was calculated by multiplying the yield with Crop Residue Ratio (RREC, 2011).As the Crop Residue Ratio (CRR) for different types of biomass generated by various crops i.e. husk, straw, stalk etc. varies, therefore, the quantum of biomass for each crop was calculated by multiplying its yield with the CRR value of its biomass types (Table 2).

The scrutiny of Table 2 unveils that under kharif crops, in 2011-12, the highest amount of biomass was generated by rice i.e. 4507.92 000 Tonnes, followed by bajra (3091.41 000 Tonnes), cotton (2090.22 000 Tonnes), sugarcane (277.53 000 Tonnes), jowar (77.63 000 Tonnes) and maize (68.98 000 Tonnes).

The Table further reveals that the highest percentage increase in the amount of biomass was found in cotton (88.85%) over 2000-01, followed by bajra (79.08%). About 40.00 per cent increase was found in the amount of biomass generated from jowar (42.16%) and rice (39.34%) over 2000-01. It was further revealed that in case of sugarcane and maize, the quantum of biomass generated in 2011-12 decreased by 15.06 per cent and 14.08 per cent, respectively over the base year (2000-01).

Scrutiny of Table 2 highlights that under rabi crops, in 2011-12, the highest amount of biomass was generated by wheat i.e. 20991.56 000 Tonnes. This was followed by rapeseed and mustard (1494.08 000 Tonnes), barley (193.72 000 Tonnes), and gram (94.77 000 Tonnes). The highest percentage increase in the amount of biomass was found in wheat (35.69%) over 2000-01, followed by rapeseed and mustard (33.48%), and barley (25.99%). On the other hand, 8.50 per cent decrease was found in the amount of biomass generated from gram in 2011-12 over 2000-01.

Assessment of energy potential

Data presented in Table 2 clearly reveals that the highest amount of biomass was generated from rice in kharif season and wheat in rabi season. However, it is well established that the biomass generated from these two crops is put to multiple uses. Biomass from rice crop is used for making fireboard, resin binders, paper etc. since last several years (Punia *et al.*, 2008). Wheat straw is used as animal feed till date. Keeping in view the productive end uses of the biomass from these two crops, this amount of biomass was not included for the calculation of fuel energy potential.

Energy potential for the remaining major crops of Haryana was calculated by multiplying the quantum of different types of biomass generated from each crop with its calorific value (Table 3).

Table 3 postulates that in 2011-12, under kharif crops, the highest energy potential was calculated for the biomass generated from bajra i.e. 56.64×10^{7}MJ/Kg, followed by biomass generated from cotton (36.47×10^{7} MJ/Kg), sugarcane (55.50×10^{6} MJ/Kg), jowar (13.93×10^{6} MJ/Kg) and maize (11.57×10^{6} MJ/Kg).

The highest percentage increase in the energy potential in 2011-12 over the year 2000-01 was observed for the biomass generated from cotton (88.85%), followed by bajra (79.08%), and jowar (42.16%).

Table.1 Estimation of biomass generated from major agricultural crops in Haryana

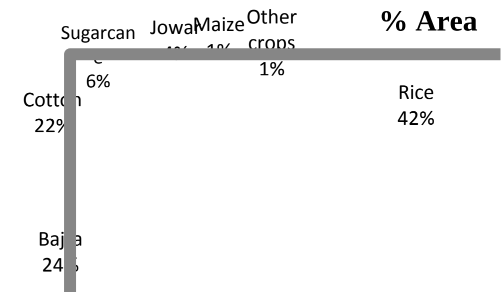
Crop	Biomass types	CRR	2000-01		2011-12		% change over 2000-01
			Yield (Kg/Ha)	Biomass (000 Tonnes)	Yield (Kg/Ha)	Biomass (000 Tonnes)	
Kharif							
Rice	Husk	0.2	2557	539.6	3044	751.32	39.35
	Straw	1.0		2695.84		3756.60	39.34
				3235.00		**4507.92**	**39.34**
Bajra	Cob	0.33	1079	216.59	2040	387.89	79.08
	Husk	0.3		196.90		352.63	79.09
	Stalk	2		1312.71		2350.89	79.08
				1726.20		**3091.41**	**79.08**
Cotton	Stalk	2.5	424	588.72	739	1111.82	88.85
	Boll shell	1.1		259.03		489.20	88.85
	Husk	1.1		259.03		489.20	88.85
				1106.78		**2090.22**	**88.85**
Sugarcane	Bagasse	0.3	5713	245.08	7319	208.15	-15.06
	Top and leaves	0.1		81.69		69.38	-15.06
				326.77		**277.53**	**-15.06**
Jowar	Cob	0.5	208	11.37	500	16.17	42.21
	Husk	0.2		4.55		6.47	42.19
	Stalk	1.7		38.68		54.99	42.16
				54.60		**77.63**	**42.16**
Maize	Cob	0.3	2267	10.47	2727	8.99	-14.13
	Stalk	2		69.82		59.99	-14.07
				80.29		**68.98**	**-14.08**
Total				**6529.6**		**10113.69**	**54.88**
Rabi							
Wheat	Straw	1.3	4106	12569.45	5183	17055.65	35.69
	Pod	0.3		2900.64		3935.91	35.69
				15470.09		**20991.56**	**35.69**
Rapeseed and mustard	Stalk	2	1369	1119.29	1394	1494.08	33.48
Barley	Stalk	1.3	2682	153.75	3617	193.72	25.99
Gram	Stalk	1.1	640	103.58	924	94.77	-8.50
Total				**16846.71**		**22774.13**	**35.18**

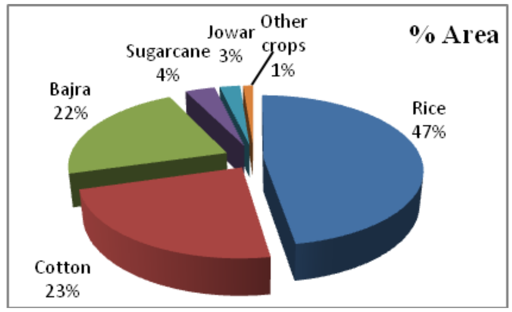
Table.2 Change in energy potential for the year 2011-12 over 2000-01

Crop	Biomass type	Calorific value	2000-01		2011-12		% change over 2000-01
			Biomass (Kgs) 2000-01	Energy potential (MJ/Kg)	Biomass (Kgs) 2011-12	Energy potential (MJ/Kg)	
Kharif							
Bajra	Cob	17.39	216597381	37.67×10^{6}	387897840	67.46×10^{6}	79.08
	Husk	17.48	196906710	34.42×10^{6}	352634400	61.64×10^{6}	79.08
	Stalk	18.60	1312711400	24.42×10^{7}	2350896000	43.73×10^{7}	79.08
				31.62×10^{7}		**56.64×10^{7}**	**79.08**
Cotton	Stalk	17.40	588724000	10.24×10^{7}	1111825500	19.35×10^{7}	88.85
	Boll shell	18.30	259038560	47.40×10^{6}	489203220	89.52×10^{6}	88.85
	Husk	16.70	259038560	43.26×10^{6}	489203220	81.70×10^{6}	88.85
				19.31×10^{7}		**36.47×10^{7}**	**88.85**
Sugarcane	Bagasse	20.00	245087700	49.02×10^{6}	208152360	41.63×10^{6}	-15.07
	Top and leaves	20.00	81695900	16.34×10^{6}	69384120	13.88×10^{6}	-15.07
				65.36×10^{6}		**55.50×10^{6}**	**-15.07**
Jowar	Cob	17.39	11377600	19.79×10^{5}	16175000	28.13×10^{5}	42.16
	Husk	17.48	4551040	79.55×10^{4}	6470000	11.31×10^{5}	42.16
	Stalk	18.16	38683840	70.25×10^{5}	54995000	99.87×10^{5}	42.16
				97.99×10^{5}		**13.93×10^{6}**	**42.16**
Maize	Cob	17.39	10473540	18.21×10^{5}	8999100	15.65×10^{5}	-14.07
	Stalk	16.67	69823600	11.64×10^{6}	59994000	10.00×10^{6}	-14.07
				13.46×10^{6}		**11.57×10^{6}**	**-14.07**
Total				**59.73×10^{7}**		**10.12×10^{8}**	**40.97**
Rabi							
Rapeseed and mustard	Stalk	17.00	1119294400	19.03×10^{7}	1494089200	25.40×10^{7}	33.48
Barley	Stalk	18.16	153759060	27.922×10^{6}	193726520	35.18×10^{6}	25.99
Gram	Stalk	16.02	103584000	16.59×10^{6}	94774680	15.18×10^{6}	-8.50
Total				**23.50×10^{7}**		**30.50×10^{7}**	**29.78**

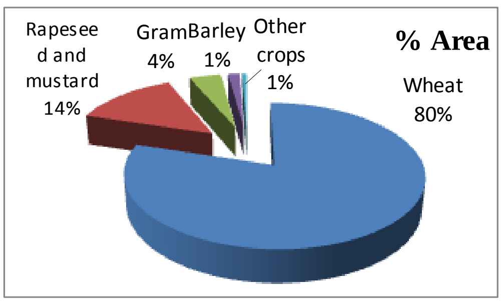
Fig.1 Area under cultivation of various agricultural crops in Haryana

Kharif crops 2000-01 2011-12





Rabi crops



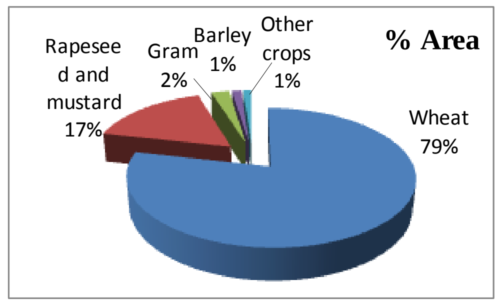
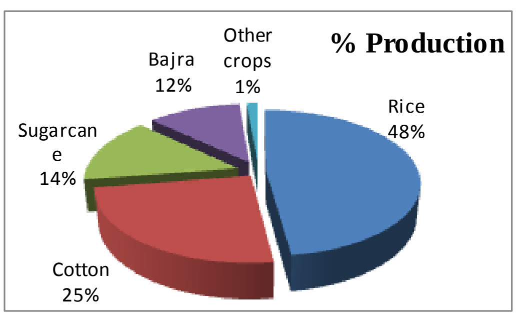
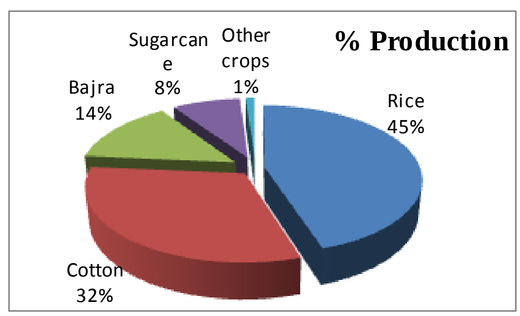


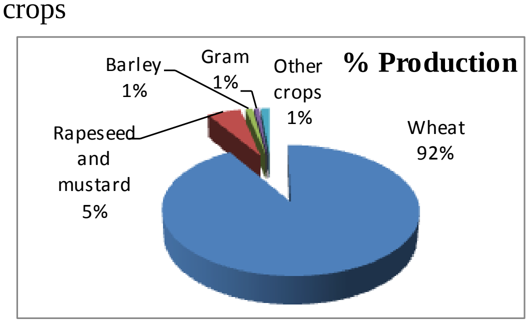
Fig.2 Production of various agricultural crops in Haryana

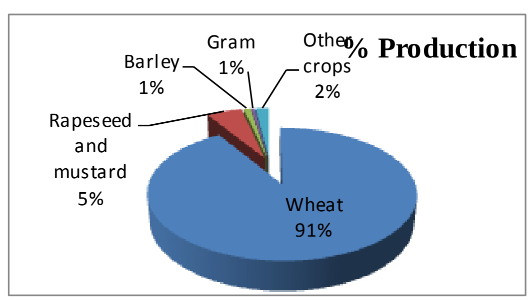
Kharif crops 2000-01 2011-12





Rabi crops





Under rabi crops, the highest energy potential was found in the biomass generated from rapeseed and mustard i.e. 25.40×10^{7} MJ/Kg, followed by biomass generated by barley (35.18×10^{6} MJ/Kg), and gram (15.18×10^{6} MJ/Kg). While comparing this energy potential for the year 2011-12 with the energy potential for 2000-01, the highest percentage increase in energy potential was found in the biomass from rapeseed and mustard (33.48%), followed by biomass from barley (25.99%).

It is, therefore, concluded that the biomass generated from major agricultural crops of both kharif and rabi season (excluding rice and wheat, respectively) has a huge energy potential, which can be used for harnessing clean green energy for household uses through pelletization. It has been found that conversion of biomass into pellets and burning it in improved pellet stoves gives a clean, smoke free flame. Hence, use of biomass in the form of pellets can overcome the problem of inefficient combustion as observed in traditional mud stoves. Use of biomass pellets will also help in mitigating the health problems associated with smoke pollution. Ultimately, this will also result in maintaining sustainable health of the environment and the economy.

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