Final report

Consultancy Services to Assess the Biomass Availability and Determination of Biomass Price in the six Districts of Gujarat



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Abbreviations

- APY : Area Production Yield
- CRR : Crop to Residue Ratio
- DGVCL : Dakshin Gujarat Vij Corporation Ltd
- GCV : Gross Calorific Value
- GEDA : Gujarat Energy Development Agency
- ICDP : Integrated Cereal development Programme
- JAU : Junagadh Agriculture University
- MC : Moisture Content
- MDM : Mid-Day Meal
- MGVCL : Madhya Gujarat Vij Corporation Ltd
- NODP : National Oilseed Development Programme
- PGVCL : Paschim Gujarat Vij Corporation Ltd
- SEZs : Special Economic Zones
- SHG : Self-Help Group
- SNA : State Nodal Agency
- UGVCL : Uttar Gujarat Vij Corporation Ltd

Acknowledgements

This report has been written as part of the project "Consultancy Services for the Availability of Biomass and Determination of Biomass Price in the State of Gujarat" commissioned by Gujarat Electricity Regulatory Commission (GERC). The focus of the study is to assess the gross availability of biomass, cropping pattern, seasonal variation, present utilization pattern, etc. with special emphasis on the districts of Amreli, Bhavnagar, and Junagadh. The broader scope of the project includes visit(s) of various districts, district-wise evaluation of the potential of biomass, interaction with the state agencies and other stakeholders, besides desk work for collection, compilation, and analysis of information/data including a report on biomass price and its quantum. We would like to thank GERC for their support in conceptualizing and sponsoring the study.

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Project Team

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Executive Summary

India's power market is confronted with the challenges related to quantity as well as quality of the electricity supply. This is largely on account of the increasing gap between the power demand and the amount of power generated (the installed capacities). In contrast, biomass had always been a valuable local energy resource available to meet the energy needs in India and other developing countries. According to estimates of The Ministry of New and Renewable Energy (MNRE), India produces about 500 million metric tonnes of biomass (including forest and agro-residues) annually, of which 120–150 million metric tonnes per annum is the surplus generated. MNRE has been promoting biomass power/ cogeneration through different programmes since the mid-nineties. A total of approximately 500 biomass power and cogeneration projects aggregating to 4,831 MW capacity have been installed in the country for feeding power to the grid. The leading states for biomass power projects are Andhra Pradesh, Chhattisgarh, Maharashtra, Madhya Pradesh, Gujarat, and Tamil Nadu. Gujarat has a total installed power generation capacity of 18,270 MW (as on January 1, 2013). The power requirement and availability deficit in Gujarat have decreased considerably in the last five years (Central Electricity Authority). Renewable energy has played a significant role in reducing this energy gap in the recent years.

The progress with respect to distributed biomass is still slower, with only about 400 MW of capacity being added annually at the national level. This has been mainly due to a number of barriers. One of the important barriers is a lack of authentic information regarding the availability of biomass resources, biomass price, etc.

The aim of this study is to assess the gross availability of biomass, cropping pattern, seasonal variation, present utilization pattern, biomass price, etc. with a special emphasis on the districts of Amreli, Bhavnagar, and Junagadh, Vadodara, Bharuch, and Sabarkantha.

In this report, a structured database with respect to biomass availability has been developed based on a secondary research followed by a primary survey and field visits for the above-mentioned six districts. Information was collected from secondary sources, such as published reports and interaction with state agencies and district agencies related to gross availability of biomass (type of agricultural residues, etc.), cropping pattern, and seasonal variation. Primary survey was carried out with different stakeholders, such as farmers, oil mills, and other industries to gather information about the present utilization pattern and biomass pricing.

The study found that major crops grown in Junagadh, Bhavnagar, and Amreli districts are cotton and groundnut. A major quantity of biomass that is generated and available are groundnut shell, cotton stalk, wheat straw, groundnut husk, Bajara stalks, etc. Out of these residues, only groundnut shell and cotton stalk generate surplus while the other residues are used as fodder, heating application, and other local uses. The current annual production of cotton stalk is estimated to be about 3.6 lakh tonnes in Junagadh. In addition, about 1.95 lakh tonne of groundnut shell is generated annually in Junagadh. In the case of Amreli, the current annual production of cotton stalk and groundnut shell is estimated to be around 15.69 lakh tonnes and 29,000 tonnes, respectively. In case of Bhavnagar, current annual production of cotton stalk and groundnut shell is estimated to be around 8 lakh tonnes and 34,000 tonnes, respectively.

As per the primary survey with farmers and industries, it was found that cotton stalk in the six districts is consumed for domestic cooking, bio-coal industries, manure and for open

burning; groundnut shell is consumed majorly in oil mills and bio-coal industries. The estimated cost of groundnut shell including moisture and handling losses of all the districts is in the range of Rs. 3,300–3,950 per tonne. As per the current practices followed by all the six districts, cotton stalk is partly burnt in the fields. There is no current efficient utilization of cotton stalk despite its huge availability. The estimated cost of cotton stalk including moisture and handling losses was found to be Rs. 2,500–2,938 per tonne. The estimated weighted average of fuel in all the districts lies in the range of Rs. 3,060–3,460 per tonne. Variation in the price of biomass depends upon the availability of biomass throughout the year as groundnut and cotton both are seasonal crops and their production is highly dependent upon rainfall and other climatic conditions.

It was found form the study that major crops grown in Bharuch, Vadodara, and Sabarkantha districts are cotton, sugarcane, castor, pigeon pea, maize, and rice. Major sources of generating biomass are sugarcane bagasse, stalks of cotton, castor, maize, pigeon pea, wheat straw, etc. Out of these residues, stalks of cotton, castor, pigeon pea, rice husk, and sugarcane bagasse are generated in surplus while the other residues are used either as fodder, heating applications, or for other local uses. The current annual production of cotton stalk is estimated to be about 3.1 lakh tonnes in Bharuch. In addition, about 4.17 lakh tonnes sugarcane bagasse is generated annually in Bharuch. In the case of Vadodara, the current annual production of cotton stalk, castor stalk, and pigeon pea stalk is estimated to be around 4.10 lakh tonnes, 1.02 lakh tons and 43 thousand tonnes, respectively. In the case of Sabarkantha, the current annual production of cotton stalk and castor stalk is estimated to be around 2.80 lakh tonnes and 2.98 lakh tonnes, respectively.

Most of the sugarcane bagasse is generated from sugar mills and utilised by bio-coal, paper mill and plywood industries. As per the current practices followed by all the six districts, cotton stalk is partially burnt openly in the field and remaining is used for domestic cooking and ploughed back into the farm field. There is no current efficient utilization of cotton stalk despite of its huge availability. The price of bagasse in the study of all the districts is in the range of Rs 3.5 per kg while the estimated price of stalks of cotton, castor and pigeon pea is Rs. 2.7 to 3.2 per kg including moisture and handling losses. The estimated price of paddy husk is Rs. 3.4/ kg including losses. Variation in the price of biomass depend upon the availability of biomass throughout the year as these are seasonal crops and their productivity is highly depend upon the rainfall and other climatic conditions.

There is no institutional demand for biomass in Gujarat state as all institutions, such as midday-meal serving schools which provide cooked food to the students of primary and upper primary schools are LPG based and do not consume any kind of biomass at all.

Limitations and mitigations of the Present Study

Table below shows various constraints emerged during the assessment study and actions taken during study in order to mitigate these assumptions in best possible way

Table: Limitations and mitigations of the Present Study

Limitations	Mitigations
Data bank of District Industrial Centre (DIC) doesn't cover the information of biomass consuming industries in districts. Moreover, industry people are also reluctant to share energy and biomass fuel consumption information/ data.	Information from local sources has been taken to visit the industries to get the relevant information and inputs from visited industries has been taken to estimate number of different relevant agro based industries
Moisture, moisture loss during logistics, and other handling losses are not available during study.	The values of moisture loss are considered based on literature values/ relevant biomass stakeholders such as pellet manufacturers in other states while handling losses are considered based on inputs from biomass power project developers
There is no commercial use and no established supply chain mechanism for field residues.	Price determination is largely based on inputs from farmers.
The area and crop production data in case of Junagadh, Vadodara and Sabarkantha districts is not similar because of sub-division of these districts in 2013.	In the present study, latest data of year 2014-15 (obtained from Directorate of Agriculture, Gandhinagar) is considered for all six districts.

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Background of the study

Objective

To assess the biomass availability and determination of biomass price in six districts (Amreli, Bhavnagar, Junagadh, Bharuch, Vadodara and Sabarkantha) of Gujarat

Scope of the study

The scope of the study involves visit(s) to the various districts, evaluating the potential of biomass in that area, district-wise interaction with the state agencies and other stakeholders; besides desk work for the collection, compilation, and analysis of information/data, the scope would also include submitting a report on biomass price and its quantum.

The scope of work under the project consists of:

a) Preparation of a structured database with respect to biomass availability.

b) Collection and compilation of information/ data from the published reports/ studies/ literatures and directly from on-site visits, state nodal agencies and other stakeholders on the gross availability of biomass (type of agricultural residues, etc.), cropping pattern, seasonal variation, present utilization pattern, etc. with special emphasis on the districts of Amreli, Bhavnagar, Junagadh, Bharuch, Vadodara and Sabarkantha.

c) Collection and compilation of information/ data with respect to specified districts for various types and quantity of biomass availability is based on various agricultural residues.

d) Collection and compilation of information/ data on:
   - Utilization of biomass by villagers for animal fodder, household use, composting, and other domestic purposes and its impact on the availability of the quantum of biomass and its price.
   - Utilization of biomass for other purposes including commercial and industrial purposes in the district and a study of the biomass price structure and the competitive use of biomass therein.
   - Compare the actual availability of biomass and its utilization vis-à-vis fuel management and fuel procurement plan needed by the project developers.
   - Evaluate the month-wise and annual availability of biomass and its impact on biomass pricing within the vicinity of the biomass project.

e) Best practices for the collection, storage, and supply of biomass to the power plants and fuel supply arrangement.

f) Cost of collection and processing, transportation, storage/ fuel preparation/ processing, and utilization of biomass from field to plant side and loaded cost per MT of biomass.

g) Analysis of the data to arrive at the seasonal availability and delivered cost of biomass.

Methodology

In order to achieve the objective of biomass assessment in the six districts (Amreli, Bhavnagar, Junagadh, Bharuch, Vadodara and Sabarkantha), the methodology adopted was based on primary and secondary data collection.

Data collection

Secondary data collection

For secondary data collection, many concerned departments, such as the Directorate of Agriculture, Industrial Commissionerate, Gujarat Energy Development Agency, and State MDM departments were contacted and information in the form of reports was sought from the respective departments. Details of meeting held with various SNAs and stakeholders are given in Annexure I. On the completion of this exercise, the survey teams were divided in to groups to visit their respective districts.

At a district level, many departments, such as district agricultural departments, district industry centres, district statistical offices, collectorate offices, etc. were visited and meetings with the concerned officers were held. District-wise total cultivated area and classification of crops, annual production of crops, production of crops per hectare, and wasteland biomass production was collected from the District Agriculture Office (DAO). The statistical office was contacted to get agricultural area, cropping area, waste land details and demography, etc.

Primary data collection

For primary data collection, a participatory approach was adopted wherein interactions and discussions with the farmers and industries were done. Field visits and group discussions were carried out to understand the current practices with major crop cultivation, harvesting, and alternate utilization of residues.

Data collection from agricultural field

A survey of the local farmers in the agricultural fields was carried out. The information on major crop cultivation, harvesting practices, and consumption of stalk was gathered. The types of crops grown in the district were also noted with their corresponding physical verification. The production of crops from the cultivated land was gathered from the local farmers/ landlords as a sort of verification against that provided by the agriculture department.

Data collection from industries

Meetings with agro-based industries were conducted to generate the information on the type of fuel used, use of biomass, such as cotton stalk and groundnut shell in their industry, availability of the resource, biomass supply chain, prices of fuel, etc. To study the availability of resource and its present utilization, all mentioned resources were identified with the help of the officials of the agriculture department of the six districts— Amreli, Bhavnagar, Junagadh, Bharuch, Vadodara and Sabarkantha.

However, it cannot be said that this will represent the true picture of the surplus availability. On the completion of the field level survey, other tasks, such as cost at source and trend, availability, transportation cost, and destination of biomass were also gathered.

Calculation for biomass generated

Biomass is calculated crop-wise by applying the CRR of a particular crop with yield. The CRR may be defined as the ratio of total residue generated (in kg) in various forms, such as husk, stalk, straw, shell, bagasse, leaves, etc. from a crop (in kg). Generally, crop to residue ratio is calculated with the formula given below. CRR values of different biomass produced from identified crops are given in Annexure VIII.

$$\text{Total crop residue (tons)} = \text{Total crop production (tons)} \times \text{CRR of particular crop}$$

Chapter 1 Gujarat Profile

1.1 Location and geographical area

Gujarat is located on the western coast of India and has the longest coastline spanning 1,600 km.[1] It has an area of 196,024 km^2 and is surrounded by the Arabian Sea to the west and the south-west and by Pakistan in the north. It has the states of Rajasthan and Madhya Pradesh towards the northeast and east, while it has Maharashtra and the Union Territories of Daman, Diu, and Nagar Haveli towards the south.

1.2 Demography

According to the census data, 2011, Gujarat has a total population of 6.03 crore which is approximately 4.99% of the total Indian population. Gandhinagar is the capital city of Gujarat and is located close to Ahmedabad—its commercial capital. The state's urban population is 42.6% and its rural population is 57.4%. Ahmedabad is the most populated district in the state with 7.20 million people followed by Surat with 6.07 million people as per Gujarat's directorate of census operations.

The state currently has 33 districts and 249 *taluks*. Figure 1.1 shows the political map of Gujarat.

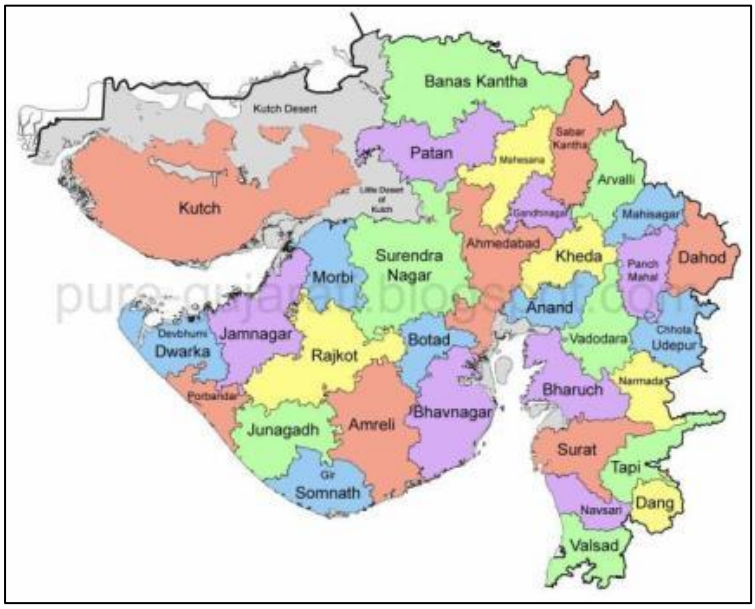


Figure 1.1 Political map of Gujarat

1.3 Climate

The climate of Gujarat is diverse. The winters are mild, pleasant, and dry with average daytime temperatures around 29 °C (84 °F) and nights around 12 °C (54 °F) with 100% sunny days and clear nights. The summers are extremely hot and dry with daytime temperatures around 49 °C (120 °F) and at night no lower than 30 °C (86 °F). Though mostly dry, it is deserted in the north-west, and wet in the southern districts due to heavy monsoons.

[1] http://www.gujaratindia.com/state-profile/socio-eco-review.htm

1.4 Biomass energy potential

Gujarat Energy Development Agency (GEDA) works in the field of renewable energy development and energy conservation. GEDA is a state nodal agency (SNA) for the MNRE and the state designated agency (SDA) for the Bureau of Energy Efficiency (BEE). GEDA has played a pioneering role in the development of a long-term renewable policy and implementing of sustainable energy programme across the state. Table 1.1 gives the biomass energy potential in Gujarat.

Table 1.1[2] Biomass energy potential in Gujarat

Source	Resource	Energy Generation/Saving Potential
Biomass	24 million tons	900 MW of electric power could be generated to meet the energy requirements of almost all the villages in Gujarat
Biogas	200 lakh cattle population (Dung available at 70% collection efficiency)	Could generate 5.6 million cubic metre of biogas per day to cater cooking gas to 2.8 million families or generate electric power equivalent to 933 MW
Biomass Energy Plantation	67 lakh hectare wasteland	Could yield 67 million tonnes of biomass which can sustain power generation to the order of 15,000 MW

The following are the key power generation projects that have been set-up in the state of Gujarat:

- Biomass projects of 31.20 MW capacity have been commissioned in Amreli, Bhavnagar, Junagadh, and Vadodara. Details are mentioned in the Annexure II.
- Waste-to-energy power generation projects of 14.389 MW have been commissioned.
- Institutional biogas plants with a total capacity of 15,730 m^3/ day have been setup across the state

1.5 Agricultural scenario and crop production

Two-thirds of the population are engaged in agricultural activities from which they earn their living. Agriculture is the main source of employment in rural areas. The total geographical area of Gujarat is 19,602,400 hectares, of which crops take up 10,630,700 hectares. The average rainfall in the state varies widely from 250 mm to 1,500[3] mm across various zones. Gujarat is the dominant producer of cotton and groundnuts in India. Other major crops produced in the state are rice, wheat, bajra, sugarcane, and pigeon pea. Castor, groundnut, and mustard are the important oilseed crops of the state.

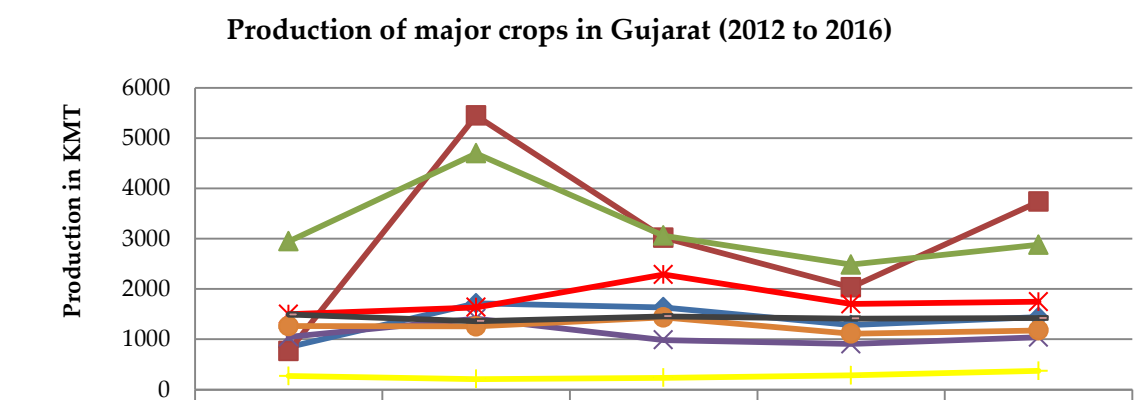
Cropping pattern

In the year 2014–15, the total area for oil seeds, food grains, and cereals was 25.40, 35.15, and 29.46 (in lakh hectares), respectively. Apart from these, in Gujarat, cotton is an important crop which covers 27.73 lakh hectares. As per the data from the directorate of agriculture, the area allotted to the cultivation of cotton and its production was 96.24 lakh bales in 2014–15. Gujarat has the highest area and production of castor (approximately 84% of the total

[2] https://geda.gujarat.gov.in/background.php#Renewable
[3] http://niti.gov.in/writereaddata/files/Gujarat.pdf

castor production) in the country. Area under castor production is 7.15 lakh hectares with production of 14.56 lakh metric tonnes. The state produces 30.18 lakh metric tonnes of groundnut that is grown over an area of 14.02 lakh hectares.

Figure 1.2 shows some major and minor crop production trends in Gujarat from 2012 to 2017. It can be observed that the production of cotton, groundnut, and wheat has increased drastically in the financial year 2013–14 as compared to the production in 2012–13.



	2012-13	2013-14	2014-15	2015-16	2016-17
Cotton	841.65	1714.96	1636.08	1281.8	1440.07
Groundnut	762.59	5446	3018	2032	3736
Wheat	2944	4694	3059	2484	2879
Bajra	1044.9	1413	987	906	1041
Rice	1497.3	1636	2287	1703	1745
Sugarcane	1261.28	1255	1433	1112	1176
Pigeon Pea	270.2	209.15	236.2	282	371
Castor	1493	1361	1456	1413	1420

Figure 1.2: Production of major crops in Gujarat (2012 to 2016)[4]

The major kharif crops in Gujarat are cotton, groundnut, bajra, rice, and sugarcane and these are sown in the months of May–July and harvested during the months of October–January. Wheat is the major Rabi crop in Gujarat. Table 1.2 below shows the sowing time and harvesting time for the major crops in Gujarat.

Table 1.2: Almanac of the major crops in Gujarat

S. No.	Crop	Sowing time	Harvesting time
1	Groundnut	June	October–November
2	Wheat	October–November	February–March
3	Bajara	June–July	September–October
4	Cotton	May–June	October–December
5	Sugarcane	June–October	October–January
6	Rice	June–July	October–November
8	Pigeon Pea	June–July	November–January
9	Castor	July–Aug	January–February

[4] Directorate of agriculture

Table 1.3 District-wise biomass generation (Kilo MT) for 2014–15

S. NO	NAME OF DISTRICT	Cotton stalk	Ground nut Shell	Groun dnut Husk	Wheat Stalk	Bajra Stalk	Bagasse	Tops and leaves	Rice Husk	Rice straw	Rice stalk	Pigeon Pea Stalk
1	KUTCH	215.40	22.52	150.14	76.22	10.88	0.00	0.00	0.00	0.00	0.00	0.00
2	BANASKANTHA	157.29	36.73	244.90	400.30	646.21	0.00	0.00	0.00	0.00	0.00	2.38
3	PATAN	212.32	0.04	0.29	146.30	43.14	0.00	0.00	0.00	0.00	0.00	0.00
4	MAHESANA	223.61	5.73	38.19	301.67	92.14	0.00	0.00	5.41	40.56	40.56	0.00
5	ARAVALLI	248.65	11.80	78.69	223.74	19.37	0.00	0.00	0.18	1.33	1.33	18.25
6	SABARKANTHA	281.75	36.44	242.95	359.45	37.74	0.00	0.00	2.68	20.09	20.09	16.44
7	GANDHINAGAR	104.10	4.07	27.13	155.49	67.86	0.00	0.00	68.50	513.72	513.72	0.74
8	AHMEDABAD	489.85	0.04	0.29	575.70	6.08	0.00	0.00	88.40	662.97	662.97	1.85
9	ANAND	25.03	0.00	0.00	290.71	185.01	0.00	0.00	77.82	583.62	583.62	1.86
10	KHEDA	93.69	0.35	2.32	224.84	145.66	0.00	0.00	72.01	540.09	540.09	1.62
11	PANCHMAHAL	45.77	0.47	3.13	64.61	7.85	0.00	0.00	9.11	68.35	68.35	82.93
12	CHOTA UDEPURA	269.20	2.12	14.15	2.66	0.00	0.00	0.00	5.10	38.23	38.23	75.15
13	MAHISAGAR	39.73	0.81	5.39	155.50	12.23	0.00	0.00	15.29	114.68	114.68	30.23
14	DAHOD	3.99	0.82	5.43	157.90	0.00	0.00	0.00	6.50	48.78	48.78	34.14
15	VADODARA	409.90	0.00	0.00	83.11	20.64	8.14	1.23	12.64	94.82	94.82	43.76
16	SURENDRANAGAR	1246.03	21.83	145.54	149.58	11.88	0.00	0.00	4.13	30.97	30.97	0.00
17	RAJKOT	873.53	89.25	595.02	71.35	0.82	0.00	0.00	0.00	0.00	0.00	0.88
18	JAMNAGAR	684.29	89.96	599.73	6.97	0.27	0.00	0.00	0.00	0.00	0.00	1.83
19	PORBANDAR	80.71	40.51	270.04	86.11	0.24	0.00	0.00	0.00	0.00	0.00	0.00
20	GIR SOMNATH	131.16	79.93	532.85	483.06	29.24	27.44	4.16	0.00	0.00	0.00	0.10
21	MORBI	612.86	34.09	227.25	79.87	0.54	0.00	0.00	0.00	0.00	0.00	0.00
22	BOTAD	645.67	0.10	0.64	21.34	0.27	0.00	0.00	0.00	0.00	0.00	0.17

S.	NAME OF											
23	DEVBHUMI DWARKA	169.20	74.20	494.69	11.26	0.30	0.00	0.00	0.00	0.00	0.00	0.00
24	JUNAGADH	360.56	195.86	1305.74	449.66	5.26	0.00	0.00	0.00	0.00	0.00	0.55
25	AMRELI	1569.22	29.49	196.59	22.21	0.95	0.00	0.00	0.00	0.00	0.00	2.66
26	BHAVANAGAR	800.91	34.12	227.48	41.84	19.95	0.22	0.03	0.00	0.00	0.00	1.39
27	SURAT	25.53	0.44	2.94	23.89	0.00	221.25	33.52	31.30	234.74	234.74	27.01
28	NARMADA	177.84	0.26	1.75	4.45	2.41	16.77	2.54	2.21	16.58	16.58	51.51
29	BHARUCH	310.73	0.29	1.95	73.22	1.47	82.81	12.55	5.17	38.80	38.80	136.11
30	DANG	0.00	1.28	8.53	6.28	26.13	0.41	0.06	8.92	66.94	66.94	6.87
31	NAVASARI	0.00	0.00	0.00	0.72	0.14	41.36	6.27	52.85	396.40	396.40	2.24
32	VALSAD	0.00	0.15	0.97	0.00	8.07	13.64	2.07	49.18	368.82	368.82	8.74
33	TAPI	31.94	4.04	26.91	16.00	0.00	50.33	7.63	41.20	309.00	309.00	41.10
GUJARAT (Total)		**10,540.44**	**817.75**	**5,451.64**	**4,766**	**1,402.76**	**462.38**	**70.06**	**558.60**	**4,189.46**	**4,189.46**	**590.49**

Table 1.3 clearly indicates that the biomass generation from the major crops in the year 2014–15 is as follows: cotton stalk (10 million tonnes) has the highest production and is followed by groundnut husk (5.45 million tonnes), wheat stalk (4.76 million tonnes), and rice husk (4.18 million tonnes). The potential districts that produce cotton stalk are Amreli, Surendranagar, Bhavnagar, and Rajkot.

A detailed biomass assessment for the six districts has been discussed in the following sections.

Chapter 2 Junagadh District

2.1 Brief profile of Junagadh District

2.1.1 Location and geographical area

Junagadh District forms a part of the Saurashtra region of Gujarat State with an area of 8,848 sq km. The district is located on the Kathiawar peninsula in western Gujarat. Situated in the south-western corner of the Paninsula, it is surrounded by Rajkot District (north), Porbandar District (north-west), and Amreli District (east). To the south and west is the Arabian Sea and the district of Gir Somnath. Thus, this district is endowed with the natural wealth of the Gir forests, mountainous region, and, grounds. Rivers and waterfalls further beautify the Gir Sanctuary—the only abode of the Asiatic lion. Also, the mountain range of Girnar is a major pilgrimage destination. Figure 2.1 shows the political map of the Junagadh District.

Figure 2.1: Political map of Junagadh District

2.1.2 Climate and rainfall

The climate of the district varies from hot to moderately hot throughout the year except in winter. The climate is humid in the coastal belt. (The temperature varies between 10.5°C, this being the minimum in December, and 40.2°C, this being the maximum in March. The district receives rains from the south-west monsoon from June to September. The average rainfall of last 3 years is 559 mm[5].

2.1.3 Demography

As per the 2011 census, the population of the district was 1,525,605 out of which the number of males and females were 784,330 and 741,275, respectively. There were 311 persons per km^2 of the area. The overall literacy rate of the district was 75.80% as per the 2011 census. The sex ratio of Junagadh District in the 2011 census was 953. A *taluka*-wise demographic profile of Junagadh District is attached in Annexure III.

[5] The collectorate from Junagadh District, Government of Gujarat

2.1.4 Administrative set-up

Junagadh District comprises 9 *talukas*, namely, Junagadh, Keshod, Bhesan, Malia, Mangrol, Manavadar, Mendarda, Visavadar, and Vanthali. Table 2.1 shows the different particulars of Junagadh District, such as the geographical data, administrative setup, population, agriculture, forest, education, etc.

Table 2.1 District at a glance

S. No.	Particulars	Statistics	Unit	Year
1	**Geographical features**			
A	**Geographical data**			
	a) Latitude	20.44 to 21.44 North	Degree	2010–11
	b) Longitude	69.40 to 71.05 East	Degree	2010–11
	c) Geographical area	513,893	Hectares	2013–14
B	**Administrative units**			
	a) Talukas	09		2010–11
	b) Patwar circle	20		
	c) Panchayat samitis	09		
	d) Nagar nigams	01		2010–11
	e) Nagar palika	12		2010–11
	f) Gram panchayats	821		2010–11
	g) Revenue villages	915		2010–11
	h) Assembly areas	09		2010–11
2	**Population**			
	a) Male	784330	Persons	2011
	b) Female	741275	Persons	2011
	Total population	1525605	Persons	2011
3	**Forest**			
	a) Forest	236.86	Sq. Km.	2010–11
4	**Education**			
	a) Primary schools	766	Numbers	2010–11
	b) Secondary schools	429	Numbers	2010–11
	c) Higher secondary schools	192	Numbers	2010–11
	d) Colleges	75	Numbers	2010–11

Source: District Industrial Potentiality Survey Report of Junagadh District (2016–17)

2.2 Agricultural scenario of Junagadh District

2.2.1 Agricultural land holding pattern

There are total 168,616 farmers having total land area of 347,650 hectares in Junagadh District. The percentage share of different land holdings as shown in Figure 2.2 indicates that 08% land holding are less than one hectare, 28% are between 1 to 2 hectares, and 64% are above 2 hectares. Table 2.2 shows the number of farmers with different scale of land holdings that includes small, medium, and large holdings. Figure 2.3 shows 39% of total farmers in Junagadh District have a medium-scale land holding, 35% farmers have large-scale land holding, while 26% farmers have small-scale land holding. *Taluka*-wise land holding pattern and the number of farmers are given in Annexure V.

Table 2.2: Number of farmers based on their land holdings

S.No	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Small	Below 1 Hectare	44,444	29,110
2	Medium	1 to 2 Hectare	65,736	96,273
3	Large	Above 2 Hectare	58,436	222,267
Aggregate			**168,616**	**347,650**

Source: District statistical book, Junagadh

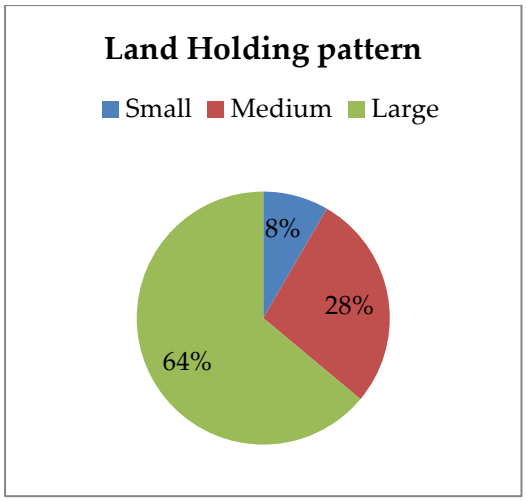


Figure 2.2: Percentage share of different land holdings

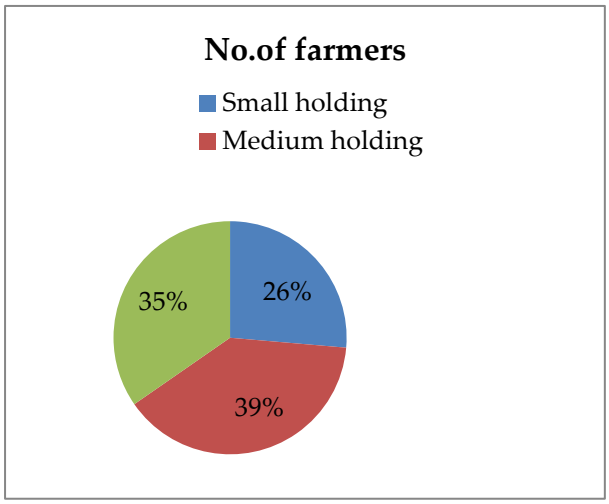


Figure 2.3: Number of farmers belonging to a different scale of land holding

2.2.2 Land use pattern

The total geographical area of the district is 586 kilo hectares out of which nearly 507 kilo hectare (or 86%) is under cultivation. Another area of the land under other uses includes non-agricultural uses, permanent pastures, grazing land, and land under miscellaneous uses. *Taluka*-wise land use pattern including area under forest, non-agricultural land, residential land, grassland, and net cultivated land is given in Annexure VI. Figure 2.4 shows the percentage share of *taluka*-wise different land use patterns.

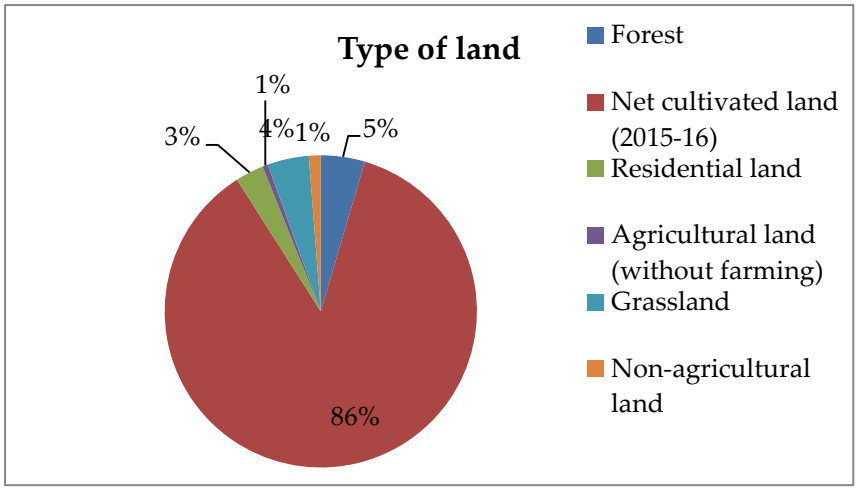


Figure 2.4: Taluka-wise land use pattern

2.2.3 Year-wise area, production, and yield pattern

Agriculture is the main occupation of the people in the district. The major businesses of Junagadh District includes mineral-based industries, such as cement and soda ash, agriculture-based industries, such as edible oil, groundnut units, solvent plants, and oil cakes, and marine-based industries, such as fish processing units and frozen fish. Junagadh is the largest producer of groundnut and garlic. Total production of groundnut in Junagadh in 2014–15 was 652 kilo metric tonnes which was the highest in the state. In the present report, we consider only four crops in our study including groundnut, cotton, wheat, and bajara. Figure 2.5 shows the year-wise crop production data of Junagadh district for last three years.[6] It can be easily seen from the figure below that there is a large variation in the production of groundnut in all the years. It is due to the fact that groundnut production is highly dependent on rainfall. The ideal rainfall for groundnut production is about 12 cm. Figure 2.6 shows the area under crop production for the last three years.[7] The area under groundnut production is the highest every year.

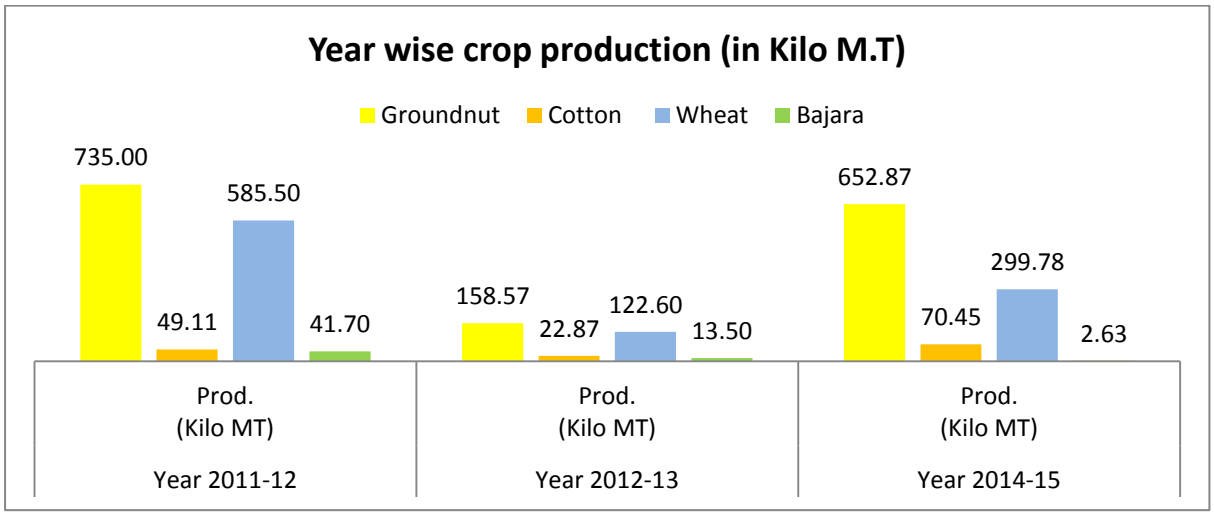


Figure 2.5: Year-wise crop production trend[8]

[6] Data for year 2013–14 has been excluded due to anomalous figures of the area and crop production
[7] Data for year 2013–14 has been excluded due to anomalous figures of the area and crop production
[8] Data for year 2013–14 has been excluded due to anomalous figures of the area and crop production

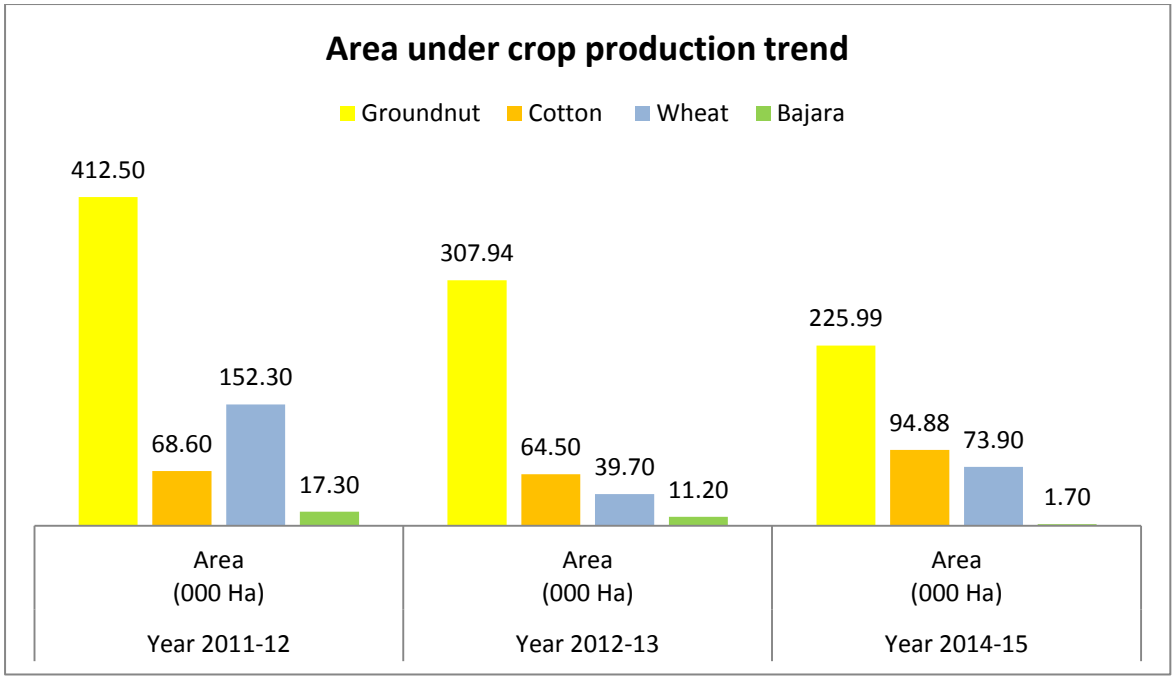


Figure 2.6: Year-wise land under crop production for different crops

Table 2.3 shows the area, production, and yield data of the selected crops for the year 2014–15. It can be easily seen from the table that groundnut is the major crop with a production capacity of 652 kilo metric tonnes. All the above-mentioned crops except wheat are cultivated during the kharif season. Typically, groundnut is cultivated both in kharif and summer seasons. During summer months, the area under groundnut cultivation is about a mere 5%. Hot and humid climate of this region with good rain has contributed to good groundnut and cotton yield in the year. A year-wise area, production, and yield of the major crops in Junagadh district have been given in Annexure IV.

Table 2.3: APY data of selected crops

Sr. No.	Name of the Crop	Year 2014-15		
		Area (000 Ha)	Prod. (Kilo MT)	Yield (Tons/ Ha)
1	Groundnut	225.99	652.87	2.89
2	Cotton	94.88	70.45	0.74
3	Wheat	73.90	299.78	4.06
4	Bajara	1.70	2.63	1.55

Source: Directorate of agriculture

2.2.4 Cropping pattern

There is a change in cropped area due to the partition of Junagadh District. The district is covered under the ICDP for wheat and NODP for oilseeds production. However, the area under wheat, groundnut, and cotton has been increased considerably in the recent past. The main crops of the district are groundnut followed by cotton, bajra, wheat, cumin, onion, isabgul, castor, etc.

Table 2.4 shows the area under crop production for identified crops for year 2014–15 in the district. As shown in pie chart in Figure 2.7, out of the total crop produced, 44.6% area under

cultivation is for groundnut only followed by cotton whose area sown is 18.7%. Other crops include vegetables, such as onion, garlic, etc.

Table 2.4: Area under production in the district for each crop for year 2014–15

Sr. No	Types of crop sown	Area (in 000 hectares)
1	Groundnut	226
2	Cotton	94.88
3	Bajra	1.7
4	Wheat	73.90
5	Others	109.05
Aggregate		**506.69**

Source: District Statistical Book, Junagadh (UPDATED-2015–16)

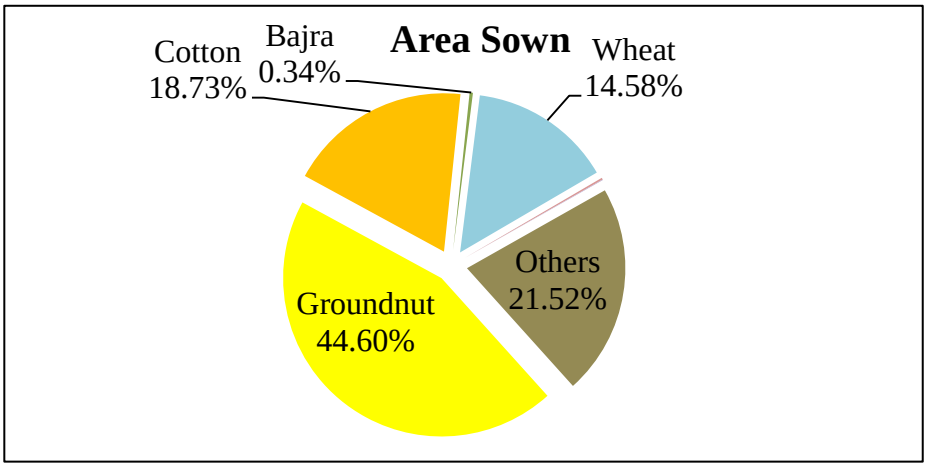


Figure 2.7: Per cent share of area of different crops sown in the district

2.3 Biomass resource analyses

The biomass of identified crops has been calculated with the formula mentioned in methodology. Table 2.5 shows the major crop residue generated from different crops in the district.

Table 2.5: Major crop residue generated in the district for year 2014–15

Crop Residue	Year 2014–15 (in kilo metric tonnes)
Groundnut shell	195.86
Groundnut husk	1,305.74
Cotton stalk	360.56
Cotton husk	77.49
Cotton boll shell	77.49
Wheat stalk	449.66
Wheat pod	89.93
Bajra husk	0.79
Bajra stalk	5.26
Bajra cob	0.87
Castor stalk	3.6
Total	**2371**

Out of this generated biomass, only cotton stalk and groundnut shell are taken into consideration. Other biomass is either used by the farmers for fodder, compost, and other domestic applications such as cooking or is available in a small quantity. The total available quantity of the considered crop residues in the district is 556 kilo metric tonnes.

In case of groundnut crop, husk along with seed pods are harvested and separated at the farmer's field. Shells are separated from groundnuts at the agro-industrial level, that is, oil mills at a later stage for seed or oil extraction purposes.

In case of cotton, lint along with seed is picked from the standing crop and the stalks are left drying at fields. Cotton stalks are removed from the field only after a gap of 15 to 30 days from its last picking in order to prepare the field for the next season of crop.

2.4. Primary data collection

Primary data includes farmers as well as industrial visits. The types of crops grown in the district are noted down with their physical verifications. In case of Junagadh District variations in the data have been observed because the district has been divided into two districts (Junagadh and Gir Somnath). On the completion of the survey work, classification of crop into major and minor was done. The crop yield at the field was gathered from the land owners and was compared with the yield given by the agriculture department.

Thus, the district level survey and the verification of biomass residue generation at the field were carried out.

However it cannot be said that this will represent the true picture of the surplus availability. On the completion of the field-level survey, other tasks, such as the cost at source and trend, availability, transportation cost, and destination of biomass were also gathered.

2.4.1 Farmers' survey

The major crops grown by farmers in the Junagadh District are groundnut, cotton, wheat, and bajara. Other than this they also grow, onion, garlic, and other vegetable crops. The survey is done in two selected *talukas*, namely, Bhesana and Visavadar; of which Bhesana has the maximum area under cotton production and Visavadar has a huge quantity of groundnut shell. The main aim to interact with farmers was to get a holistic view of the agricultural scenario of the region along their viewpoints. Crop yields vary from year to year and place to place depending upon rainfall, soil conditions, and farm-management practices.

Based on the source of generation, crop residues generated from agricultural activities at the field/ household level are identified as field-level residues (stalks and straw) that are the leftovers of agricultural crops post harvesting either found at fields or at the farmer's habitation.

As observed during the field survey, crops that generate a substantial quantity of residues and harvesting surplus are considered for assessment. Residue generated from crops, such as pulse, maize, and bajra stalks are not considered for assessment since the residue from these crops are either entirely used for fodder purposes or their generation is widely dispersed in small quantities.

At a field level, stalks are residues of cotton, castor, and pigeon pea. Cotton lint with seed is picked from standing crops at regular intervals depending upon the maturity of the fruit. High moisture level in the soil during the flowering period increases the number of pickings thereby increasing the crop yield.

As per the interaction with farmers, only cotton stalk is available as field residue which is available in a huge quantity. As per their current practices they used to burn cotton stalk in the field itself. Currently, almost all the cotton stalk is burnt in the open by farmers to clear the fields. Rural households, especially marginal farmers and agricultural labours use cotton stalks as a supplementary fuel for domestic cooking and heating. As per the interactions with farmers, generally, cotton stalk is not a preferred fuel due to its fast ignition, smoke emission, and storage problems. Barring this, its usage is attributed to its free availability in the region. Moreover, with the easy availability of LPG, the usage of cotton stalks has reduced drastically and is restricted to heating and boiling purposes restricted only to low-income households. Given this, such farmers are willing to sell the cotton stalk at a low price ranging from Rs. 200 to 500 per tonnes.

Wheat straw and groundnut husk goes to fodder. Other residues, such as pigeon pea stalks, cotton stalks, and bajara stalks are produced in less quantity as these are not the major crops in the district.

A summary of the farmers' interviews have been shown in Table 2.6. The details of this interview have been given in Annexure X.

Table 2.6: Summary of the farmers' interviews

Crop	Yield (Tons/Hect)	Biomass	Uses	Crop Selling price (Rs./20 kg)
Cotton	1.2-2	Cotton Stalk	• Burnt in field • Converted to manure in field	800–1000
Groundnut	0.75-2.4	Groundnut Shell	To Oil mills	600–800
		Groundnut husk	100% fodder	100–200
Wheat	2-3	Wheat Straw	60% fodder and 40% manure	250–300
Pigeon Pea	2.5	Stalk	To domestic cooking	600–800
Castor	5	Stalk	Information not available	600–700

Figure 2.8: Cotton field

Figure 2.9: Processed cotton in APMC

Figure 2.10: A heap of groundnut

2.4.2 Industrial survey

In Junagadh District, major biomass-related industries are oil mills and bio coal (briquetting) industries. These industries are mostly based on groundnut only as groundnut is the major crop grown in Junagadh District. The details of industrial interviews have been given in Annexure IX.

2.4.2.1 Oil mills

Groundnut shells are the only biomass residue generated at the agro-industrial level in the fuel-collection region. Groundnut shells are separated from nuts in oil mills. As per the survey, around 80% of the total groundnut crop produced in the area is processed in the oil mills. The remaining quantity is either stored by the farmers for the next sowing season or consumed by them or even sold in the local market. The farmers in this region sell their entire produce to APMC. As per the survey, the average residue generation in the form of shells from groundnuts is 25% to 30%.

As per the interaction with oil mill owner, they purchase groundnut from APMC or traders at a price of Rs. 38–50 per kg. Minimum Support Price (MSP) of groundnut is Rs. 41.5/ kg. The oil mill separates groundnut shells from the seeds during the oil extraction process. The capacity range of oil mills is 10–20 tonnes of groundnuts per day out of which 2.5 to 5 tonnes of shells are produced. The self-consumption of groundnut shells by oil mill is 0.5 to 1 tonne a day. The rest is sold to bio-coal industries at a price of Rs. 3–4.5 per kg. The oil mills directly use the groundnut shells in their boilers (Figure 2.8). One kg of groundnut contains 700–50 grams of seed which is separated by the oil mills itself. The seed contains 60% of the oil content (Figure 2.9). Rest is oil cake which is sold at Rs. 23.50 per kg. The cost of oil produced is Rs. 100 per kg. There are around 60 groundnut-based oil mills in Junagadh as informed by the oil mill industry. These mills are operational 300 days in a year.

Figure 2.11: Bio coal fire in an oil mill boiler

Figure 2.12: An oil collection unit in an oil mill

2.4.2.2. Bio-coal industries

As per the survey, there are around 20 bio-coal industries in Junagadh District out of which three were visited for data collection. As was found, most were using groundnut as the primary fuel. These units use 90% groundnut and 10% other local fuels including cotton stalk. The capacity of the plant was three tonnes per hour (2 machines of 1.5 tonne per / hour each). All these plants are based on piston press technology. The production cost was found to be 0.6 to 1.00 per Rs. / kg including labour, electricity, and maintenance. The cost of raw material varies from 3.5 Rs. / kg to 4.5 Rs. / kg depending upon the seasonal availability and production of groundnut. These machines are operational for eight hours every day. Transportation cost of bio coal is Rs. 15–20/ km/ ton. The selling price of bio-coal ranges from 5 to 6 Rs. / kg. These bio-coals are used in chemical industries, dairies for cheese and butter production, and boiler industries. The cost of groundnut shell varies widely as groundnut is a seasonal crop. Figure 2.13 shows the bio-coal unit in Junagadh. The estimated annual groundnut shell consumption in bio-coal industries is 54 kilo MT.

Figure 2.13: Bio coal unit in Junagadh

2 4.3 Observations and analysis

2.4.3.1 Cotton stalk consumption and surplus

The cotton stalk does not have much commercial use in the Junagadh Districts. The cotton stalks are often ploughed back into the soil or disposed of by burning in the agricultural field itself. The main use of cotton stalks (the thicker stems) is cooking as domestic fuel. As per the survey, about 20% of the cotton stalk is used as a fuel by small farmers and rest 80% is disposed of in fields by burring it. A biomass-based power plant of capacity of 10 MW is already implemented at Keshod but it is non-operational as of now. Besides, bio-coal industries were also visited; they seldom use cotton stalk blending with groundnut in very small quantity. The entire openly burnt cotton stalk can be estimated as a surplus. Table 2.7 shows the per cent consumption of cotton stalk as per the current practices. Table 2.8 shows the annual estimated surplus cotton stalk.

Table 2.7: Percentage consumption of cotton stalk considered for Junagadh District

District	Current practice with cotton stalk (360 kilo M.T)[9]		
	Cooking and other domestic uses (%)	Bio-coal industries (%)	Open field burning (%)
Junagadh	20	5	75

[9] The information and approximate percentages on utilization of cotton stalk for different purpose was obtained from the farmers' survey

Table 2.8: Estimated surplus cotton stalk

Estimated utilization of cotton stalk in domestic cooking and other works (Kilo M.T.)	**72**
Estimated utilization of cotton stalk in Bio coal industries (Kilo M.T.)	18
Total annual utilization of cotton stalk (K.M.T.)	90
Estimated net available cotton stalk (Kilo M.T.)	270

2.4.3.2 Groundnut shell consumption and surplus

As per the above observation, it has already been seen that groundnut shells are mostly produced in oil mills. The total shell produced from oil mills has been estimated at 67,500 tonnes per annum. Groundnut shells are majorly consumed by bio-coal industries. Ninety per cent of total fuel consumed in bio-coal industries is groundnut shell. About 20% total groundnut produced can be estimated to be used as a food commodity. Table 2.9 shows the percentage consumption of groundnut shell.

Table 2.9: Percentage consumption of groundnut shell

Estimated number of bio coal industries in Junagadh District	**20**
Average capacity of a plant (tons/ hour)	1.5
Groundnut consumption (tons/ hour)	1.35
Av. No. of hours of operation/ day	8
Total numbers of days of operation/ year	250
Estimated annual groundnut shell lost while groundnut eating (Kilo M.T.)	39
Estimated annual groundnut shell consumed by oil mills (kilo M.T)	13.5
Total annual utilization of groundnut shell (Kilo M.T.)	52.5
Estimated potential surplus groundnut shell (Kilo M.T.)	142.5

As per the survey and calculations, around 2.7 lakh tonnes of cotton stalk and 1.42 lakh tonnes of groundnut shell will be potentially available in a year from Junagadh District that can be used for power production.

2.4.3.3 Consumption and surplus of castor stalk and pigeon pea stalk

As per the interaction with farmers, it was found that castor stalk was used for cooking and heating in very small quantity due to its hollowness; castor stalks are lower in density as compared to cotton stalks and emit massive smoke when used as a fuel. Unfortunately most of the stalk is left in field for decaying.

Cropping of pigeon pea is very limited in Junagadh District. Hence, no solid information about pigeon pea stalk was achieved during the survey. Although not much information could be procured from the farmers, it was conveyed to us that the pigeon pea stalk was burnt in the field itself.

2.4.4 Institutions

In Junagadh there are a total of 861 mid-day-meal serving institutions through which a total of 53,828 students are served. These mid-day meal serving institutions cook their food through LPG. There is no single institution in the whole district which is based on fuel other than LPG. Hence, the institutional demand of biomass for cooking is nil.

District	Total no. of Institutions	Mode of cooking (No. of Schools)			
		LPG	Solar Cooker	Fire wood	Others
Junagadh	861	861	0	0	0

2.4.5 Summary of biomass generation, consumption, and surplus

Table 2.10 shows the generation, consumption, and surplus of the available biomass. In this study, biomass consumption does not include burning it in open fields. The total generated quantity of the crop residues in the district is 23.7 lakh tonnes out of which residue generated from the considered crop residues, that is, cotton stalk and groundnut shell are 5.55 lakh tonnes

Table 2.10: Biomass Generation, Consumption, and Surplus (Kilo M.T./ annum)

Biomass	Generation	Consumption	Available
Cotton stalk	360	90	270
Groundnut shell	195	52.5	142.5

2.5. Biomass cost analysis

As per the interactions with farmers, at present there are no transactions with respect to crop residues. However, when asked during the survey, farmers have opined that if at all they sell crop residue, they would consider factors, such as labour cost for collecting residues from field before being transported to other places. Normally, as per the interaction with biomass power plant officials, a tonne of cotton stalk collection from the field requires five to six man-days. The cost of man-day is around Rs. 200 as per the interaction with farmer groups. Hence, the cost works out between Rs. 1000 to Rs. 1200 per tonne of residues. Though the farmers are not expecting any consideration apart from labour cost at present, in actual terms they might demand an additional amount. Based on observation in the field, remuneration to farmer is assumed to be Rs. 200 to 500 per tonne for cotton stalk apart from handling charges and transportation. Cost of biomass available in the open market mentioned by the GEDA is given in Annexure XI.

2.5.1 Modes and cost of transportation

It has been observed that in Junagadh District crop residues are being transported mostly in tractors. Presently, surplus crop residues are disposed of in fields itself. As oil mills are the groundnut-producing place in the district, groundnut shells become a major source of biomass. Hence, in the district, some modes of transportation for groundnut shells were already in place. It was found that groundnut shells are currently packed loosely in gunny bags and are transported in large trucks with a carrying capacity of about 10 tonnes. Generally, the market price for transportation of groundnut shells is fixed by taking into consideration labour cost for packing and loading groundnut bags along with raw material price. As per the high availability of cotton stalk, transportation of cotton stalk is assumed in the range of 0-25 km radius, while for groundnut shell, transportation is assumed in the range of 0-50 km. Table 2.11 and 2.12 shows the estimated total cost of cotton stalk and groundnut shell, respectively.

Table 2.11: Cost of cotton stalk

Particulars	Cotton stalk (Rs/Ton)	Reference
Farmer's remuneration	200-500 *	From the farmer
Labor charges for uprooting, bundling and loading[10]	800-1000	From the farmers
Shredding cost	350	From the farmer
Transportation cost (0–25 km)	350	Interacted locally
Unloading cost	100	From farmers
Av. Landed cost	**2050**	

*Farmers were not aware of the fluctuation in price due to moisture loss

Table 2.12: Cost of groundnut shell

Particulars	Groundnut Shell (Rs/Ton)	Reference
Cost of groundnut shell charged by oil mill	2800–3400	From oil mill
Loading and Unloading	200	From oil mill
Transportation cost (0 – 50 km)[11]	450	From oil mill
Av. Landed cost	**3,750**	

2.5.2 Cost of fuels including losses

After getting the landed cost of fuels, interaction was done with the project developers/ biomass power plant officials to calculate the losses in biomass. Loss in weight due to moisture and dust/ sand/ stone present in the fuel from the oil mills or the farmer's field was in need of consideration. In case of groundnut shell, 5% loss in weight due to moisture and due to dust/ sand/ stone have been registered while in the case of cotton stalk, 15% loss in weight due to moisture and 5% loss in weight due to dust/ sand/ stone have been considered. Table 2.13 shows the biomass price per ton considering moisture and dust/ sand losses.

Table 2.13: Final cost of Groundnut shell and cotton stalk considering losses

Description	Biomass Price/ton	Moisture[12]		Dust/sand/stone		Total Weight losses in kg per ton	Biomass Price Per ton considering losses
		%	Weight loss in kg per ton	%	Weight loss in kg per ton		
GN Shell	3750	5*	50	-	-	50	3947
Cotton Stalk	2050	15	150	5	50	200	2563

* In case of GN shell, moisture and handling losses together have been considered at 5%.

2.5.3 Weighted average

Weighted average of the fuel cost has been calculated based on considering the fact that cotton stalk is available for during harvesting season, that is, October to December and maintaining inventory of cotton stalk for more than a month is difficult as long term-storage has its own problems of safety and deterioration in quality due to degradation. Other than this it has a self-heating property if stored in large piles because of temperature

[10] The collective cost of uprooting and labor cost was obtained from the interaction with the farmers
[11] This information was collected from the oil mills and the interaction with transport person was not done.
[12] In the case of cotton stalk and groundnut shell, moisture values were assumed from literature and project developer. Experimental value needs to be assessed

development due to high moisture content. So, it is assumed that cotton stalk is feasibly available for four months in a year while groundnut can be available in the remaining 8 months in a year. Hence, 35% weightage is taken for cotton stalk while 65% weightage is considered in the case of groundnut shell while calculating the weighted average of fuel cost. So, weighted average cost of fuel comes out to be **Rs. 3463 per tonne at** corresponding weighted average GCV of 4370 kcal/ kg.

Chapter 3 Amreli District

3.1. Brief profile of Amreli District

3.1.1 Location and geographical area

Amreli District is an important district of Gujarat located at North latitude 20.45° to 22.15° and East longitude 70.13° to 71.45°. It is surrounded by Bhavnagar District in the east, Rajkot District in the north, Junagadh District in the west, and by the Arabian Sea in the south. It has a coastal line of about 62 km. The geographical area of the district is 7,438.6 square km. In Amreli District, about 76% of the total geographical area, which forms 5,653.3 square km is the area under cultivation. However, the coverage of forest area is approximately 5%. The district has 7% of their area under non-agricultural use. Figure 3.1 shows the political map of Amreli District.

Figure 3.1: Political map of Amreli District

3.1.2 Climate and rainfall

The district climate varies from hot to moderately hot throughout the year except during the winter months whereas the coastal belt of the district is mostly found humid. Temperature of the district varies between 8.01 °C to 43.7 °C from January to May, respectively. The district receives its rain from the south-west monsoon starting from of June until September and the average rainfall for the last three years is 706 mm.

3.1.3 Administrative set-up and demography

As per district industrial potentiality survey report 2016–17, the total population of the district is 1,513,614 out of which the count of female and male members are 742,963 and 770,651, respectively.[13] The District is mostly rural and around 55.45% of the population resides in the rural area. The district has 11 *taluks*, which includes Amreli, Babra, Dhari, Bagsara, Kunkavav, Khambha, Jafrabad, Lathi, Liliya, Rajula, and Savarkundla with

13 District industrial potentiality survey report of Amreli district [2016-17]

headquarters in Amreli itself. Taluka wise demographic profile of Amreli district is given in Annexure III. Table 3.1 shows the different particulars of Amreli District, such as the geographical data, administrative set-up, population, agriculture, forest, etc.

Table 3.1: District at a glance

S No	Particulars	Statistics	Unit
1	**Geographical features**		
A	**Geographical data**		
	Latitude	20.45 to 22.15 North	Degree
	Longitude	70.13 to 71.45 East	Degree
	Geographical area	736,366	Hectares
B	**Administrative units**		
	Sub Division	05	Nos
	Tehsil	11	Nos
	Sub-Tehsil	--	Nos
	Patwar Circle	15	Nos
	Panchayat Samitis	09	Nos
	Nagar Nigams	--	Nos
	Nagar Palika	09	Nos
	Gram Panchayats	596	Nos
	Revenue villages	626	Nos
	Assembly areas	05	Nos
2	**Population**		
	Male	770,651	Persons
	Female	742,963	Persons
	Rural population	1,127,808	Persons
	Urban Population	906,242	Persons

3.2. Agricultural scenario of Amreli District

Agriculture and its allied activities are the main occupation in the district as about 64% of the total workforce is engaged in agriculture and its allied activities. The gross irrigated area of Amreli District is 189,171.3 hectares which is around 28.86% of the gross cropped area (655,376.3 hectare)[14]. Further, 16% of the total agricultural area of Amreli District falls under the Savarkundla block. The lowest irrigated area under agriculture is in the Amreli block with only 2% of total irrigated land in the district, while Savarkundla has the highest irrigated area with 25% of the total irrigated area in the entire district.

14 Pradhan Mantri Krishi Sinchayee Yojna, District Irrigation Plan-Amreli (2016-2020)

3.2.1 Land use pattern

As per the data obtained from the District Statistical Office, Amreli, the total reported area for the purpose of land use is 715,846 hectares, of which nearly 544,043 hectares (or 76%) is the net sown area. Other than the net sown area, land is classified under different categories, such as permanent pasture and grazing land, cultivable fallow land, forest land, land under non-agricultural use, barren and uncultivable land, etc. Figure 3.1 shows the percentage share of the different land use pattern. *Taluka*-wise land use pattern including the area under forest, non-agricultural land, grassland, and net cultivated land is given in Annexure VI.

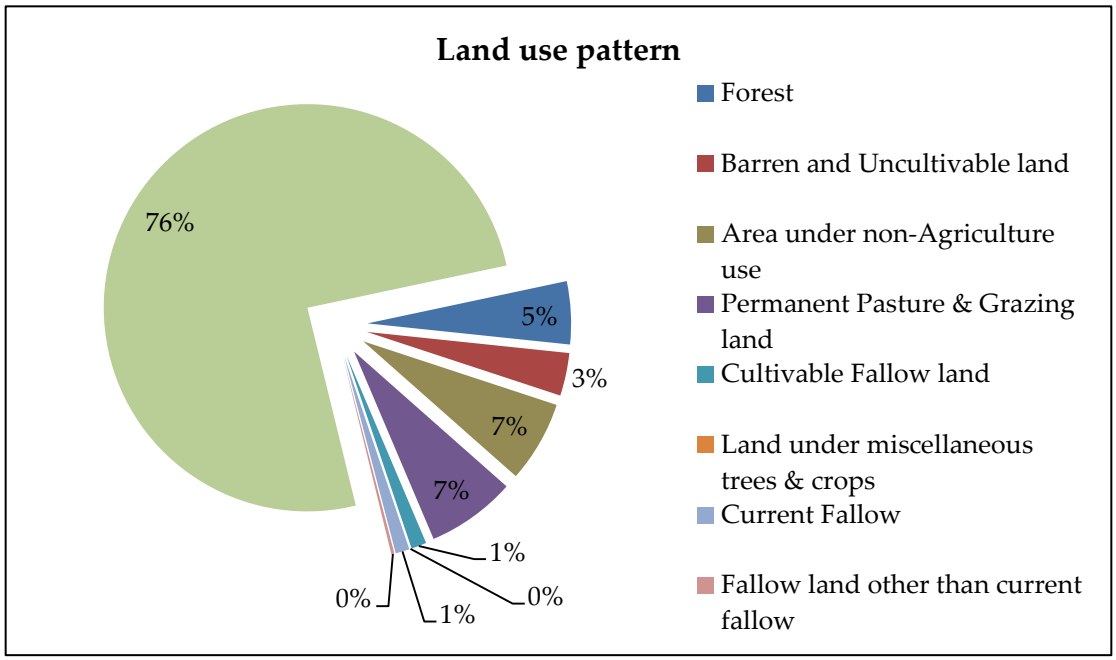


Figure 3.1: Land use pattern

3.2.2 Land holding pattern

As per the data obtained from the District Statistical Office, Amreli, there are total 236,434 farmers with a total land area of 558,536 hectares in the district. Percentage share of different land holdings shown in Figure 3.4 indicates that approximately 6% land holding are less than one hectare, 22% are between 1 to 2 hectares, and 72% are above 2 hectares. Table 3.3 shows the number of farmers with different land holdings. *Taluk*-wise land holding pattern and number of farmers are given in Annexure V.

Table 3.2: No. of farmers and area based on their land holdings[15]

S.no	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Small	0-1	52,891	32,672
2	Medium	1-2	89,756	132,332
3	Large	Above 2	106,457	425,421
Aggregate			236,434	558,536.34

[15] District Statistical Office, Amreli (2014–15)

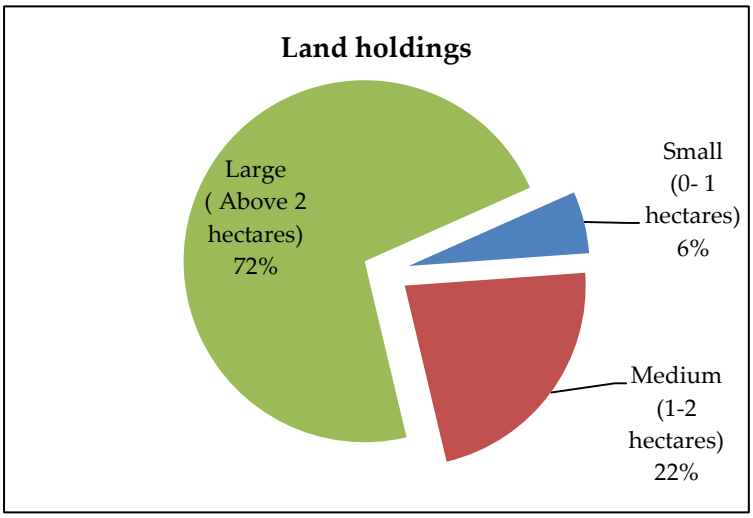


Figure 3.2: Percentage share of different land holdings

3.2.3 Cropping pattern, area, and production of major crops

The main crops of the district are cotton followed by groundnut, bajra, wheat, castor, pigeon pea, cumin, onion, etc. Cropping pattern in Amreli is mostly groundnut wheat, cotton wheat, and horticulture based. Cropping pattern is mostly uniform in all the blocks. Under irrigated conditions, oilseed crops are cultivated in most blocks.

As per the data obtained from the Directorate of Agriculture, figure 3.3 shows the crop-wise area sown in the district. Out of the total net area sown (544 thousand hectares), around 75.91% area under cultivation is only for cotton (413 thousand hectares). Groundnut (70 thousand hectares) is the second major crop in the district with around 12.87 % area under production. Year wise Area, production and yield data of selected crops for three years is given in Annexure IV

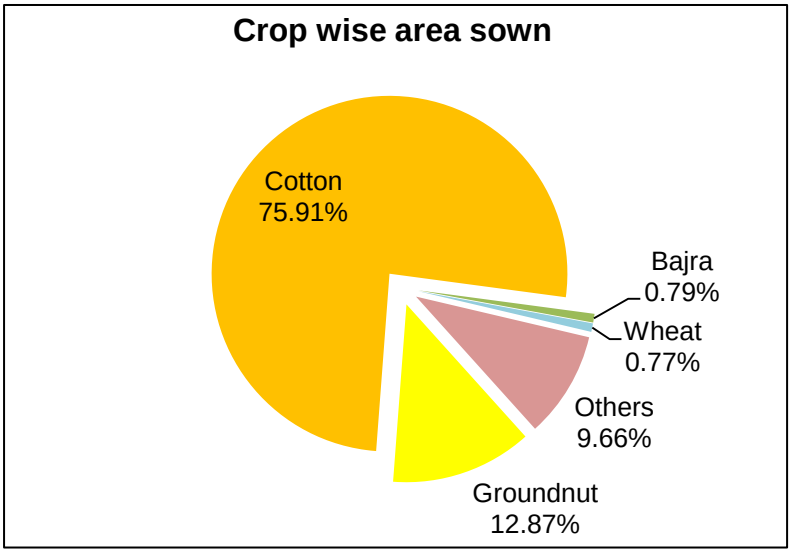


Figure 3.3: per cent share of different crops sown in the district

Figure 3.4 gives the trend of area under cultivation for major crops, such as cotton, groundnut, wheat, and bajra. Data for castor and pigeon pea was not considered because of less acreage. From 2011 to 2015, the area under cultivation for cotton has increased whereas

the area under cultivation for other crops, such as groundnut and wheat has decreased in the past years. The data for 2013–14 was not included during the analysis as the data set obtained from the agricultural department was incomplete.

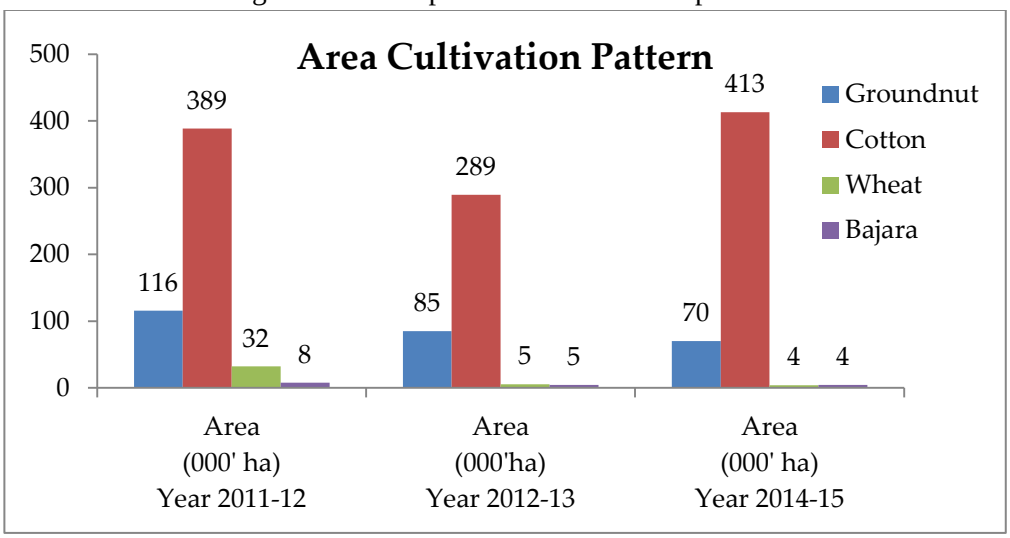


Figure 3.4: Year wise land under cultivation for different crops

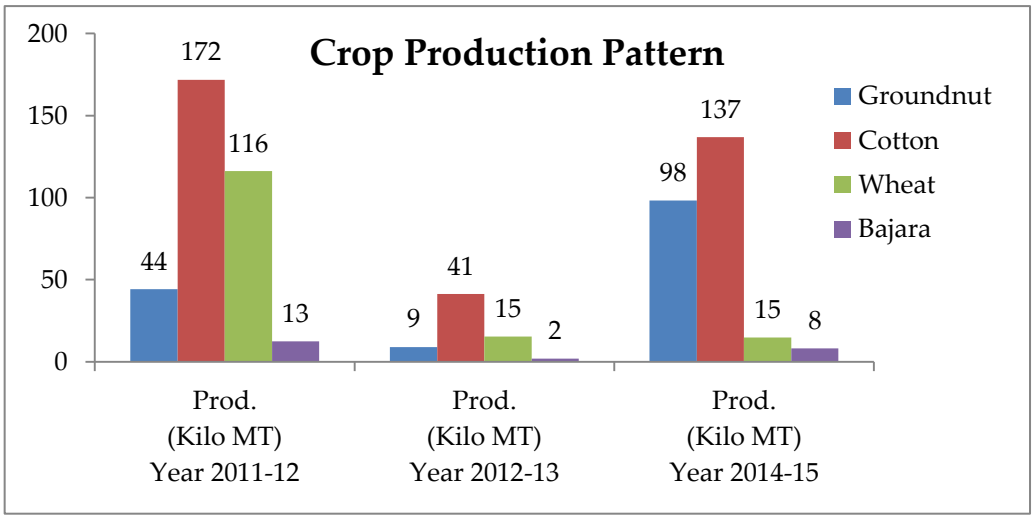


Figure 3.5: Year wise crop production trend

3.3 Primary data collection

A team of two persons accompanied by an executive officer from PGVCL visited the farmer groups, traders, and industries during the duration of February 28 to March 4, 2017 in Amreli. To understand the utilisation of biomass and its pricing, farmers and industries were contacted. Contact details of farmer groups and industries were provided by the district agriculture office and district industrial centre, respectively.

3.3.1. Farmers' survey

Selection of *talukas* for farmer interviews were done on the basis of the production potential for two major crops (cotton and groundnut) in the district obtained from secondary information and in consultation with the District Agricultural Officer at Amreli. The three *talukas* thus selected were Bagasara, Amreli, and Savarkundla. A total of 15 farmers were surveyed that included farmers with small, medium, and large land holdings.

Table 3.3: Indicative list of farmers surveyed

Name of Taluka	Number of farmers surveyed	Range of land holdings (hectares)
Bagasara	4	1.2 to 13
Amreli	6	0.8 to 4.8
Savarkundla	5	0.8 to 10

Figure 3.6: Interview with farmers in three blocks of Amreli District

Table 3.4 presents a summary of the farmers which were essentially interviewed during the team visit to Amreli.

Table 3.4: The summary of the farmers' interviews conducted in Amreli District

Crop	Crop production (Tons/Hectare)	Biomass residue from crops	Use
Cotton	1.2-2	Cotton Stalk	Burnt in field Converted to manure in field
Groundnut	0.75-2.5	Groundnut Shell	Given to Oil mills/ Traders/ APMC
		Groundnut husk	100% fodder
Wheat	2-3.5	Wheat Straw	60% fodder and 40% manure

Crop	Crop production (Tons/Hectare)	Biomass residue from crops	Use
Pigeon Pea	0.5	Pigeon Pea Stalk	Used for cooking purpose
Chana	1.5	Chana straw	Fodder
Bajra	1.5	Bajra Stalk	Used for cooking purpose
Castor		Castor Stalk	Used for cooking purpose

As per the table shown, the major crops grown by farmers in Amreli District are groundnut, cotton, wheat, and bajra. Other than this they also grow pigeon pea, chana, and onion but in limited quantities. As per interaction with the farmers, it was found that the crop yield varied from year to year depending up on rainfall.

Based on the source of generation, crop residues generated from agriculture activities at field/ household level are identified as field-level residues. Field-level residues (stalks, straw) are left after the harvesting of agricultural crops.

3.4.1 Observations

During the interaction with farmer groups, the following observations were made:

Cotton stalk: According to the farmers, currently only 20%–25 % of the total cotton stalk is used as a fuel for purposes of domestic cooking and the rest is burnt in the open fields. This is done after a week from the harvesting season. The reasons stated for burning the stalk are due to the cost involved in uprooting it from the field with no alternative use of the stalk thereafter. However, a few farmers in the Savarkundla *taluka* have now started purchasing/ renting shredder machines for chipping the cotton stalk and thereafter using it as manure in their agricultural fields.

Groundnut Shell: According to the farmers, the entire groundnut is purchased from the farmers at the market price by the traders, APMC, oil mills.

Other residues: According to the farmers, wheat straw, groundnut husk goes to fodder. Other residues, such as pigeon pea stalks, chana straw, and bajara stalks are produced with very less in quantity and are used for fodder purposes.

Therefore, it can be inferred from the field survey that cotton stalk is available as a field residue which is available in very large quantity. The farmers are ready to sell the cotton stalk rather than burn it in the open fields. As per the interactions with farmers, they are willing to sell the cotton stalk at very low price ranging from Rs 800 to Rs 1,000 per tonne. This is majorly the cost of labour involved in uprooting the stalk form the field and loading it onto trucks/ tractors.

Detailed information about the farmer visits has been shared in Annexure X.

3.4.2 Industrial survey

In Amreli District, major biomass-related industries are oil mills and bio-coal (briquetting) industries. These all industries are mostly based on groundnut and its shell.

3.4.2.1 Oil mills

Farmers in Amreli District sell their entire produce of groundnut to traders. Some traders are involved in processing the groundnut (oil mills), whereas some directly sell the produce in the market. Amreli District has around 30 oil mills as discussed with the mills that were visited. The team visited two oil mills (one small and one medium) in the district. As per the

survey, around 80%[16] of total groundnut crop produced in the district is used for crushing in the oil mills and the remaining 20% of the groundnut is sold in the local market.

In case of oil mills, groundnut shells are separated from nuts. The following are the key observations from the oil mills:

- Capacity of groundnut crushing ranges from 2.5 tonnes per day (small) to 40 tonnes (medium) per day.
- APMC or traders sell groundnut at a price of Rs 40–50 per kg. Oil mill separates groundnut shells from the seeds during the oil extraction process.
- Some oil mills use around 20% of the groundnut shells of the total, as a fuel in the boiler, while the remaining 80% is supplied either to the bio-coal industries or other agro-based industries outside the district or to the power plants. However, some oil mills use 100% groundnut shell as fuel in the boiler.
- Price for groundnut shell varies from 2.5 Rs/ kg (Oct–Dec) to 4 Rs/ kg (Jul-Sept) depending on the season.
- Price of groundnut shell sold to power plants from the mills ranges from Rs 2.5 to 4 Rs / kg and there is an increase in the price to around 0.5 Rs/ kg if it is sold through a contractor as shown in Table 3.5.

Table 3.5: Prices of groundnut and its shell in Amreli

Selling price of groundnut from APMC to oil mills (Rs/kg)	Selling price of groundnut shell from oil mills to power plant, bio-coal, and agro-industries (Rs/kg)	Selling price of groundnut shell at power plants via a contractor
40–50	2.5 to 4	3 to 4.5

The number of total oil mills in the district is 30; the total shell produced from the oil mills can be estimated as 24,000 tonnes per annum.

Figure 3.7: Visit to oil mill industries in Amreli District

[16] Percentage of utilization of groundnut and groundnut shell obtained from the oil mill visited

3.4.2.2. Bio-coal industries

As per the survey, there are three bio-coal industries in Amreli District, and all the three were visited by the team for data collection. All of them are using groundnut as the primary fuel. Some units are running on 100% groundnut shell whereas other units use 85%–90% of groundnut shell and 10%–15% castor shell. The groundnut shell was procured either directly from the traders or from the oil mills. The following observations were made after the interaction with the industries:

- The range of capacity of three plants visited is 5,000–7,000 tonnes/ year
- All these plants are based on piston press technology. The production cost was found Rs 600 to Rs 700 / ton including labour, electricity, and maintenance.
- The cost of raw material varies as per Table 3.8 depending upon the seasonal availability, and is inclusive of transportation cost. The price of raw material is high during the months of October to January and less during the months of July to September.
- Selling price of bio-coal is given in Table 3.6 and it varies with the price of raw material. Chemical properties of the bio-coal as obtained from the industry are mentioned in the Annexure IX. The bio-coal is used in chemical industries, pharmaceutical industries, rolling mills, etc. based in cities, such as Vadodara and Ankleshwar.

Table 3.6: Cost analysis of groundnut shell and its bio-coal in Amreli District

	Bio- coal Industry		
Parameters	**Unit 1**	**Unit 2**	**Unit 3**
Capacity (tons/ year)	5,000	7,000	5,000
Purchasing price of raw material (Rs/ kg)	2–2.5	3–3.5	3–3.5
Transportation cost of raw material included in purchasing price (Rs/ kg)	0.3 to 0.5		
Selling price of bio-coal (Rs./ kg)	4-6	4-4.5	4-4.5

Figure 3.8: Visit to bio-coal industries in Amreli District

3.4.3 Institutions

In Amreli there are total of 815 mid-day meal institutions serving a total of 39,463 students under the mid-day meal scheme. All these institutions use LPG to cook food. Hence, the institutional demand of biomass for cooking is nil.

Table 3.7: Information related to the mid-day meal scheme in Amreli District

Sl. No.	District	Total no. of Institutions	Mode of cooking (No. of Schools)			
			LPG	Solar Cooker	Fire wood	Others
1	Amreli	815	1,512	0	0	0

3.5 Biomass resource analysis

3.5.1 Total biomass generated and its use

As per the formula described in the methodology section, crop residue or biomass of the major crops has been calculated. Table 3.8 shows the values of major crop residue generated from different crops in the district. The total biomass generated from the major crops in the district is 21.44 lakh tonnes in 2014–15.

Table 3.8: Major crop residue generated in the district

Crop Residue	Generation in 2014-15 (Kilo MT)	Usage
Groundnut Shell	29.49	Oil mill and bio-coal industry
Groundnut Husk	196.60	Fodder
Cotton Stalk	1,569.40	Field burning and domestic cooking
Cotton Husk	150.52	Field burning
Cotton Boll Shell	150.52	Field burning
Wheat Straw	22.20	Fodder and manure
Wheat Pod	4.44	-
Bajra Husk	2.43	-
Bajra Stalk	16.20	Domestic cooking
Bajra Cob	2.67	-
Aggregate	**2,144.57**	

Out of this generated biomass,

a) Eighty percent of the cotton stalk (**1,255 Kilo MT**) is burnt in the fields. Cotton stalk is removed from the field within 7–10 days after harvesting and for preparation of field for next crop season.

b) Around **30 Kilo MT** of groundnut shell is majorly used in oil mills and bio-coal industries.

c) Other biomass **(a total of around 549 Kilo MT),** such as groundnut husk, bajra, stalk, and wheat straw is self-consumed by the farmers either for fodder, manure, and domestic cooking.

3.5.2 Biomass consumption and surplus analysis

3.5.2.1 Cotton stalk consumption and surplus

Cotton stalk does not have much commercial use in Amreli District. Cotton stalks are often disposed of by burning it in the agricultural field or ploughed back into the soil. The other uses of cotton stalk include cooking and heating purpose. As per the survey, about 20%–25% of the cotton stalk is used as a fuel for domestic cooking and rest 75%–80% is disposed of in fields by burning them. A biomass-based power plant of capacity of 10 MW has already been commissioned in Savarkundla block of Amreli District but it is non-operational as of now. Information gathered from the power plant has been provided in Annexure II. Table 3.9 shows the per cent consumption of cotton stalk as per current practices. Table 3.10 shows the estimated annual availability of cotton stalk in Amreli District.

Table 3.9: Percentage consumption of cotton stalk considered for Amreli District

District	**Current practices with Cotton Stalk**[17]	
	Cooking and heating (%)	Open field burning (%)
Amreli	20–25	75–80

Table 3.10: Estimated availability of cotton stalk in Amreli District

Average cotton stalk generated in Amreli (Kilo M.T.)	**1569.40**
Estimated utilization of cotton stalk in domestic cooking and other works (Kilo M.T.)	314
Estimated cotton stalk left for open burning (Kilo M.T.)	1255

3.5.2.2 Groundnut consumption and surplus

As per the observation mentioned in the tables, it has already been seen that groundnut shells are mostly produced in oil mills (Table 3.11). The total shell produced from oil mills has been estimated as 24,000 tonnes per annum. Groundnut shells are mostly consumed by bio-coal industries and the remaining by the dairy industries and power plants. About 20% (6000 tons) total groundnut produced is sold in the local markets.

Table 3.11: Consumption of groundnut shell generated

Average groundnut produced in the district (tons)	**98,000**
Average groundnut shell produced in the district (which is 0.3 of total groundnut) (tons)	30,000
Total oil mills in Amreli district	30
Average groundnut shell generated at each mill per day (tons)	4.5
No. of days Oil mill run	180
Total groundnut shell generated from oil mills (tons)	24,000
Ground nut shell used by oil mills for their captive use (~10%) (tons)	Approx. 2,400
Sold to local market (tons)	6000
Potential surplus groundnut shell (tons)	Approx. 21,600

3.5.2.3 Consumption and surplus of castor stalk and pigeon pea stalk

As per the interaction with the farmers, it was found that castor stalk is used for cooking; it is used for heating purposes in a very small quantity due to its hollowness; castor stalks are of low density than cotton stalks and emit lot of smoke when used as a fuel and most of the stalk is left in the field for decaying. Cropping of pigeon pea and castor is very limited in Amreli District. There is limited information about pigeon pea stalk and castor has been achieved during survey. Although as per interaction with farmers, they used to burn the pigeon pea stalk in the field itself.

[17] The information and approximate percentages on utilization of cotton stalk for different purposes was obtained from the farmers' survey

3.6. Biomass cost analysis

As per the interactions with farmers, at present there is no transaction with respect to crop residues. In the case of cotton stalk, there is low demand for residue and the cost of uprooting it is high; as a result the farmers are not interested in selling the stalk. However, when asked during the survey, farmers have opined that if at all they sell crop residue, they would consider factors, such as farmer's remuneration, labour cost for collecting residues from field, and storing them in proper places before being transported.

However, the groundnut is directly purchased by the APMC traders from the farmers at the market price that is Rs 40–50 Rs/ tonne. Groundnut shell that has been separated from groundnut has a high market price due to its promising demand with oil mills and bio-coal industries.

During the survey, an approximate cost for various components, such as shredding, uprooting, loading, unloading, and transportation was obtained from farmers, traders, and industries. Table 3.12 and table 3.13 give the estimated cost of cotton stalk and groundnut shell prevailing in the district.

Table 3.12: Estimated cost of cotton stalk residues

Particulars	Cotton stalk (Rs/Ton)	Reference
Farmers Remuneration	300–500*	From farmers
Collection cost (Labour charges for uprooting, bundling and loading on to trucks including material cost)[18]	800–1000	From farmers
Transportation cost 0–25 km.	300–500	From farmers
Unloading cost	200	From farmers
Processing cost (Shredding cost)	350	From farmer
Average landed cost	**2,250**	

* Farmers were not aware about the fluctuation in price due to loss of moisture

Table 3.13: Estimated cost of groundnut shell

Particulars	Groundnut shell(Rs/Ton)	Reference
Biomass cost from oil mills (including loading and unloading)	2,500–3,000	From oil mills
Transportation 0–50 km.[19]	400	From oil mills
Average landed cost	**3,150**	

Therefore, the cotton stalk will be priced at 2,250 Rs/ tonne for its use (including uprooting, shredding, and transportation); however, groundnut being a more commercial crop with a high demand will be priced at 3150 Rs/ tonne.

3.6.1 Cost of fuels including losses

After getting the landed cost of fuels, losses in weight due to moisture and dust/ sand/ stone present in the fuel from oil mills/ farmer's field has to be considered. In case of groundnut shell, 5% loss in weight has been considered due to moisture as well as dust/ sand/ stone has been considered; while in case of cotton stalk, 15% loss in weight due to moisture and 5%

[18] The collective cost of uprooting and labour cost was obtained from interaction with the farmers

[19] This information was collected from oil mills and interaction with the person in charge of transportation was not done.

loss in weight due to dust/ sand/ stone has been considered. Table 3.14 shows the biomass price per tonne considering moisture and dust/ sand losses.

Table 3.14: Final cost of groundnut shell and cotton stalk considering losses

Description	Biomass Price/tonne	Moisture[20]		Dust/sand/stone		Total Weight losses per unit	Biomass Price Per tonne considering losses
		%	Weight loss per unit	%	Weight loss per unit		
GN Shell	3,150	5*	50	-	-	50	3,316
Cotton Stalk	2,250	15	150	5	50	200	2,813

* In case of GN shell, the moisture and handling losses have together been considered at 5%.

3.6.2 Weighted average

Weighted average of the fuel cost has been calculated based on the fact that cotton stalk is available during the harvesting season, that is, October to December and maintaining inventory of cotton stalk for more than a month is difficult as long-term storage has its own problems of safety and deterioration in quality due to degradation. Other than this it has a self-heating property if stored in large piles because of temperature development due to high-moisture content. So, it is assumed that the cotton stalk is feasibly available for four months in a year while groundnut can be available in the remaining eight months in a year. Hence, 35% weightage is taken for cotton stalk while 65% weightage is considered in case of groundnut shell while calculating the weighted average of fuel cost. So, weighted average cost of fuel comes out to be **Rs 3,140 per tonne** at corresponding weighted average GCV of 4370 kcal/ kg.

[20] In case of cotton stalk and groundnut shell moisture values were assumed from literature and project developer. Experimental value need to be assessed

Chapter 4 Bhavnagar District

4.1 Brief profile of Bhavnagar District

4.1.1 Location and geographical area

Bhavnagar District is positioned in the south-east corner of the Saurashtra peninsula of Gujarat. It is surrounded by Surendranagar and Ahmedabad districts on the north, Rajkot and Amreli districts on the west, the Arabian Sea on the south and the Gulf of Cambay on its east. It has a coastline of about 152 km. The total geographical area of district is 9,971 Sq. km.

Bhavnagar has 10 blocks or *talukas*: Bhavnagar, Sihor, Umarana, Gariadhar, Palitana, Mahuva, Talaja, Ghogha, Vallbhipur, and Jesar. The district headquarters and main industrial zones are in Bhavnagar *taluka*. There are close to 800 villages in this district and the political map of Bhavnagar District is shown in Figure 4.1.

Figure 4.1: Political map of Bhavnagar District

4.1.2 Climate and rainfall

The district falls under agro-climatic zones. The average climate of the Bhavnagar District is hot and humid due its coastal geography, whereas winters are relatively cold. The temperature range of the district is a maximum 44°C in summer and a minimum of 9.0°C in winter. The average rainfall of the district found to be around 732 mms due to south-west wind in the rainy seasons. According to Gujarat Government data, the average rainfall in the district headquarter was measured at 732 mms. The entire district receives an equal rainfall except Gariadhar and Umrana *taluka*, which receives less than the average rainfall in the district.

4.1.3 Administrative set-up and demography

According to the 2011 census, total population of the district was 2,877,961, out of which the rural and urban population of district were 1,697,808 and 1,180,153, respectively. The socio-demographic data of Bhavnagar District shows that the population density is 288 persons per sq. km. The district has a moderate literacy rate of 76.84% wherein rural and urban, both populations account for more than 70% literacy rate. The brief information about district has been given in table 4.1. Taluka wise demographic profile of Bhavnagar district is given in Annexure III.

Table 4.1: District at a glance[21]

S No	Particulars	Statistics	Unit
1	**Geographical features**		
A	**Geographical data**		
	d) Latitude	21.05° to 22.10°North	Degree
	e) Longitude	71.03° to 72.09°East	Degree
	f) Geographical area	997,100	Hectares
B	**Administrative units**		
	i) Sub Division	06	
	j) Tehsil	12	Numbers
	k) Patwar Circle	15	
	l) Panchayat Samitis	775	
	m) Nagar Nigams	01	Numbers
	n) Nagar Palika	8	Numbers
	o) Gram Panchayats	775	Numbers
	p) Revenue villages	824	Numbers
	q) Assembly areas	09	Numbers
2	**Population (Census 2011)**		
	c) Male	1,490,465	Persons
	d) Female	1,387,496	Persons
	Total population	2,877,961	Persons
5	**Education(2013–2014)**		
	e) Primary schools	1,063	Numbers
	f) Secondary and senior secondary schools	177	Numbers
	g) Middle schools	498	Numbers
	h) Colleges	98	Numbers

4.2. Agricultural scenario of Bhavnagar District

4.2.1 Agricultural land holding pattern

There are total of 188,713 farmers with a total land area of 414,969 hectares in Bhavnagar District. Percentage share of different land holdings shown in Figure 4.4 indicate that approximately 8% land holding are less than one hectare, 25% are between 1 to 2 hectares, and 67% are above 2 hectares. Table 4.2 shows the number of farmers with a different scale of land including small, medium, and large holdings. A *taluka*-wise land holding pattern and the number of farmers are given in Annexure V.

[21] District industrial potentiality survey report of Bhavnagar district [2016–17]

Table 4.2: No. of farmers based on their land holdings[22]

S.no	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Small	0–1	51,753	34,562
2	Medium	1-2	70,876	103,169
3	Large	Above 2	66,084	277,238
Aggregate			**188,713**	**414,969**

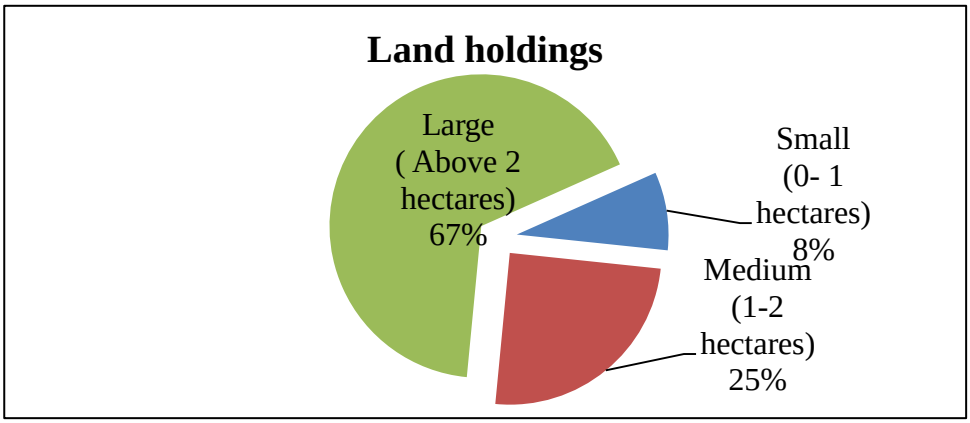


Figure 4.2: Percentage share of different land holdings

4.2.2 Land use pattern

The total reported area for the purpose of land use is 570,867 hectares of which nearly 368,722 hectares (or 56%) is the net-sown area. Other than the net-sown area, land is classified under different categories, such as permanent pasture and grazing land, cultivable fallow land, forest land, land under non-agricultural use, barren and uncultivable land, etc. A *taluka*-wise land use pattern including the area under forest, non-agricultural land, grassland, and net cultivated land is given in Annexure VI. Figure 4.5 shows the percentage share of land use patterns.

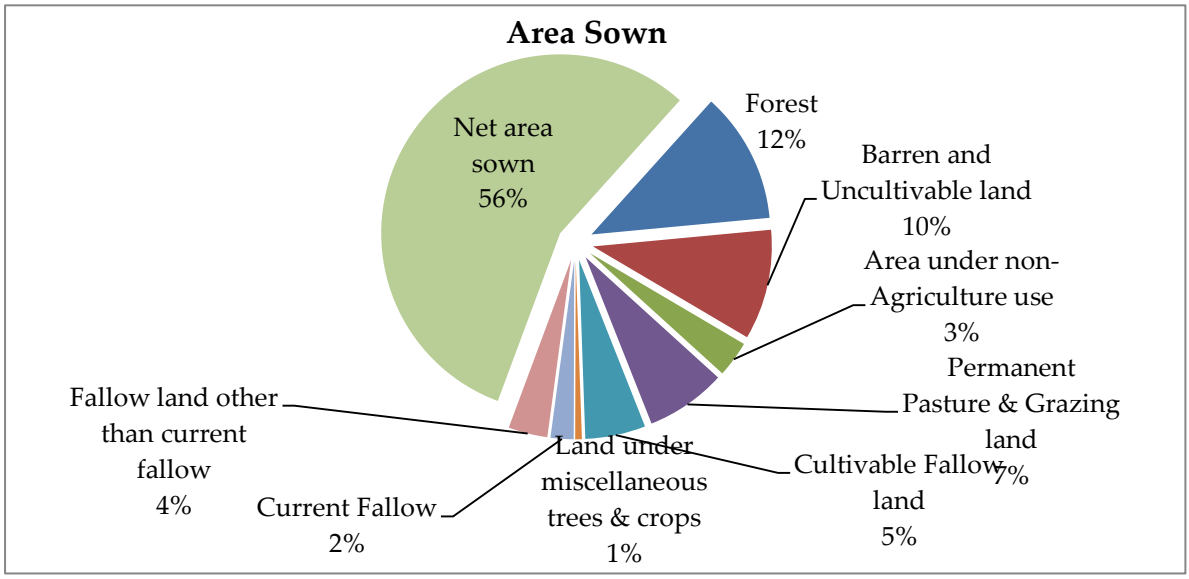


Figure 4.3 Land use pattern

[22] District Agriculture Office

4.2.3 Year-wise area production and yield pattern

Agriculture is the principal source of livelihood generation in the district. The major businesses of Bhavnagar District includes, polishing units, salt and marine chemicals, plastics, shipbuilding, and ship-breaking industries. Bhavnagar is the largest producer of salts and minerals with approximate annual production capacity of 35,000 tonnes. The Alang ship breaking yard is the biggest in the world recycling about 50% of the salvaged ships globally. In an agricultural aspect, Bhavnagar mainly produces cotton, groundnut, and garlic. The total production of cotton in Bhavnagar in 2014–15 was 93 K.M.T. In the present report, we consider only four major crops in our study including groundnut, cotton, wheat, and bajra. Figure 4.3 shows the year-wise crop production data of Bhavnagar District for the last three years. It can be easily seen from the figure that there is a large variation in production of groundnut in all the years.

Figure 4.4: Year-wise crop production trend

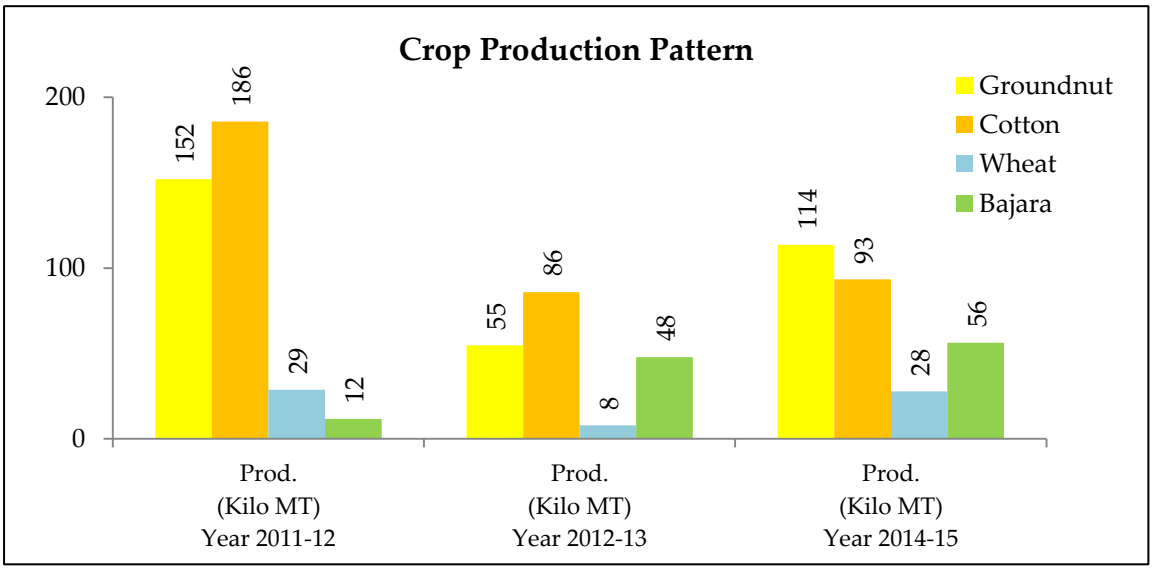


Figure 4.5 depicts the area under cultivation for three years; the figures shows that during year 2011–2 the area under crop is high for all crops , whereas in year 2012–13 and 2014–2015 it sees as subsequently decreasing.

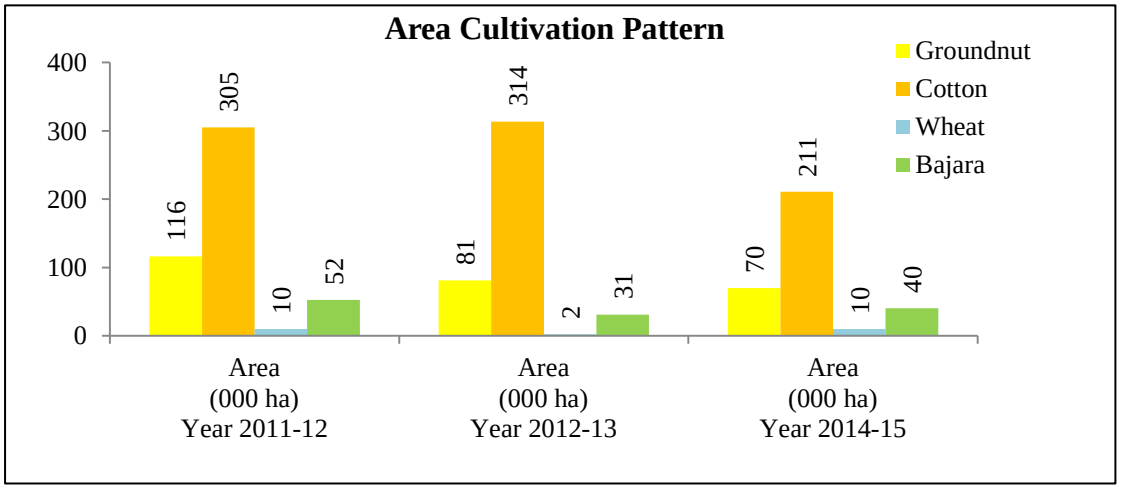


Figure 4.5: Year-wise land under cultivation for different crops

Table 4.3 shows the area, production, and yield data of the selected crops for the year 2014–15. It can be easily seen from the table that groundnut is the major crop with a production of 114 KMT followed by cotton (93 KMT) and Bajra (56 KMT).

Table 4.3: APY data of selected crops[23] for 2014–15

Sr. No.	Name of the Crop	Year 2014–15		
		Area (Kha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Groundnut	70	114	2
2	Cotton	211	93	0
3	Wheat	10	28	3
4	Bajara	40	56	1

4.2.4 Cropping pattern

The cropping pattern in Bhavnagar is mostly groundnut-wheat, cotton-wheat, and horticulture based under irrigated conditions. The cropping pattern is mostly uniform in all the blocks. Under irrigated conditions, oilseed crops are cultivated in most blocks. During the kharif season, cotton is sown in major area, while groundnut occupies the second-highest place in term of area shown. The dominating crops area wise during the rabi season is wheat which is followed by groundnut during the summer months. The main crops of the district are cotton followed by groundnut, bajra, wheat, onion, castor, pigeon pea, etc. Year wise area, production and yield of identified crops for the last three years is given in Annexure IV

As shown in the pie chart in Figure 4.6, out of the total crop produced around 48.50% area that under cultivation is only reserved for cotton. Groundnut is the second-major crop in the district with around 16.01% area under production; wheat stands in the third place with a 9.29%.

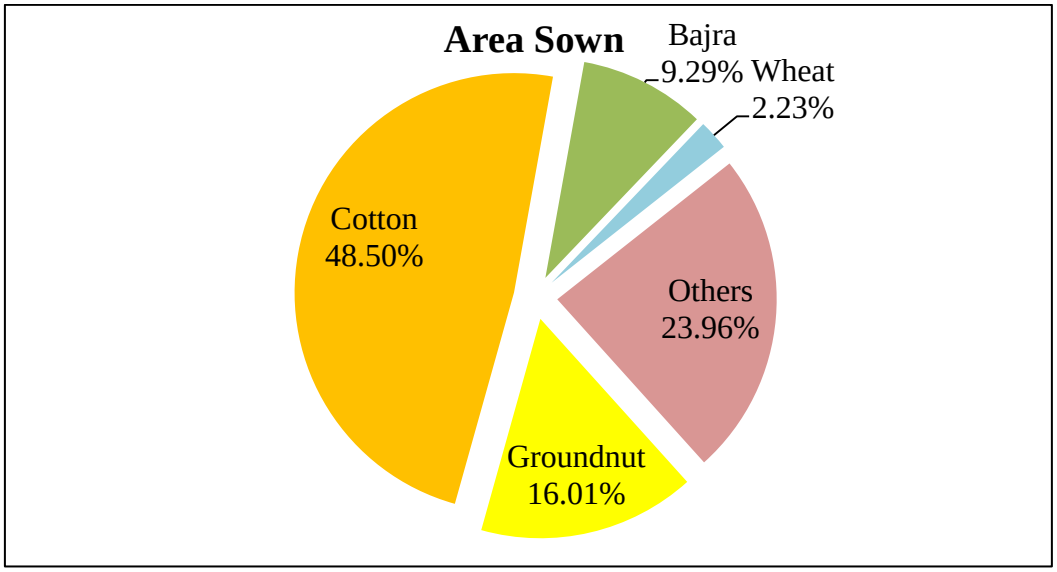


Figure 4.6: Per cent share of different crops sown in the district[24]

[23] Directorate of Agriculture

4.3 Biomass resource analysis

4.3.1 Total biomass generated

As per the formula described in the methodology section, crop residue or biomass of identified crops has been calculated. Table 4.4 shows the values of major crop residue generated from different crops in the district of the year 2014–15.

Table 4.4: Major crop residue generated in the district

Crop Residue	KMT
Groundnut Shell	34.11
Groundnut Husk	227.40
Cotton Stalk	801.04
Cotton Husk	102.70
Cotton Boll Shell	102.70
Wheat Stalk	41.85
Wheat Pod	8.37
Bajra Husk	16.89
Bajra Stalk	112.60
Bajra Cob	18.58
Total	**1466**

Out of this generated biomass, the majority of the cotton stalk is burnt in fields and groundnut shell is majorly used in bio-coal industries. Other biomass is self-consumed by the farmers either for fodder or for other domestic applications, such as cooking, heating, etc.

In the case of groundnut, stalks along with seed pods are harvested and separated at fields/ household levels. Shells are separated from groundnuts at the industrial level, that is, groundnut decorticators/ oil mills at a later stage are used for seed or oil extraction purposes.

In the case of cotton, lint along with seed is picked from the standing crops and stalks are left drying at the fields. Cotton stalks are removed from the field only after a gap of 15 to 30 days from its last picking in order for the field to be prepared for the next season.

4.4. Primary data collection

Interactions were carried out at the district level with district government departments. Contacts of farmer groups and industries were provided by the agricultural and industrial centres, respectively. A team of two persons accompanied by an executive officer from PGVCL visited the farmers groups, traders, and industries over a period of 4 days in Bhavnagar. Since in year 2013 district's two *talukas* Gdhada and Botad were removed from Bhavnagar district and made a new district-Botad. Because of this, there are few variations in the data.

24 District Agriculture Office

4.4.1. Farmers' survey

4.4.1.1 Farmers' information

Selection of *talukas* were done on the basis of the production potential of two major crops (cotton and groundnut) in the district from secondary information and in consultation with the district agricultural officer at Bhavnagar. The four *talukas* thus selected were Mahuwa, Sihor, Palitana, and Jesar. A total of 11 farmers were surveyed that included farmers with small, medium, and large land holdings.

Table 4.5: Indicative list of farmers surveyed

Name of Taluka	Number of farmers surveyed	Range of land holdings (hectares)
Mahuwa	3	1.5 to 16
Palitana	3	0.8 to 3.23
Shihor	2	1.6 to 16
Jesar	1	0.8 to 5

Figure 4.7: Interview with farmers in four blocks of Bhavnagar District

4.4.1.2 Data collection

Table 4.6 presents a summary of farmers who were interviewed during the team visit to Bhavnagar.

Table 4.6: The summary of farmer interviews conducted in Bhavnagar District

Crop	Crop production (Tons/Hectare)	Crop selling price (Amount in rupees per 20 kg)	Biomass residue from crops	Uses
Cotton	1.2–2	700–1,000	Cotton Stalk	Burnt in field Converted to manure in field
Groundnut	0.75–2.5	600–900	Groundnut Shell	Given to Oil mills/ Traders/ APMC
			Groundnut husk	100% fodder
Wheat	2–3.5	350–600	Wheat Straw	50%–60% fodder and 50%–40% manure
Pigeon Pea	0.5	600–800	Pigeon Pea Stalk	Used for cooking purposes
Bajra	1.5	400	Bajra Stalk	-
Castor	-	-	Castor Stalk	Used for cooking purposes

As per this table, the major crops grown by farmers in Bhavnagar District are cotton, groundnut, and wheat. Other than this they also grow, bajra, and pigeon pea but in limited quantities. As per the interaction with the farmers, it was found that the crop yield range vary from year to year depending upon rainfall.

Based on the source of generation, crop residues generated from agriculture activities at the field and/ or household levels are identified as field-level residues. Field-level residues (stalks and straw) are left after the harvesting of agricultural crops.

4.4.2 Observations

During interaction with farmer groups, the following observations were made:

Cotton stalk: According to the farmers, currently only 25% of the total cotton stalk is used as a fuel for domestic cooking purposes, 5% cotton stalk is directed towards the bio-coal industries, and the rest is burnt in open fields. This is done after a week from the harvesting season. The reasons stated for burning the stalk in the fields is due to the cost involved in the uprooting of the stalk from the fields with no alternative use of the stalk thereafter. However, a few farmers in the Shihor and Palitana *talukas* have now started purchasing/ renting shredder machines for chipping the cotton stalk and thereafter using it as manure in their agricultural fields.

Groundnut shell: According to the farmers, the entire groundnut is purchased from the farmers at the market price by the traders, APMC/ oil mills.

Other residues: According to the farmers, wheat straw and groundnut husk goes to fodder. Other residues, such as pigeon pea stalks and bajara stalks are produced less in quantity and are used for fodder purposes.

Therefore, it can be inferred from the field survey that cotton stalk is available as field residue which is available in large quantities. The farmers are ready to sell the cotton stalk rather than burn it in the open fields. They are willing to sell the cotton stalk at a very low price ranging from Rs 900 to Rs 1000 per tonnes. This is primarily the cost of labour involved in uprooting the stalk from the field and loading it on to trucks and tractors.

Detailed information regarding the farmer visits has been shared in the Annexure X.

4.4.3 Industrial survey

In Bhavnagar District, major biomass-related industries are oil mills, chemical, dehydrating, and bio-coal industries. These industries are mostly based on groundnut, groundnut shell, and cotton stalk. The details regarding the conducted industrial survey have been listed below.

4.4.3.1 Oil mills

Farmers in Bhavnagar District sell their entire produce of groundnut to traders. Some traders are involved in the processing of the groundnut (oil mills) whereas some directly sell the produce in the market. Bhavnagar District has around 15 oil mills with average crushing capacity of 15 tonnes per day. Out of which 30% is the shell production. Out of total generated shell 20% is self-consumed by oil mills in their boilers. Hence total shell consumed by oil mills is 2835 tonne. The team visited one of the oil mills in the district. As per the survey, around 75%–80% of the total groundnut crop produced in the district is used for crushing in the oil mills and the remaining 20%–25% of the groundnut is sold in the local markets.

In the case of oil mills, groundnut shells are separated from the nuts. The following are the key observations from the oil mills:

- The operating seasons of these units are between October to January and July to September. But more than 80% is processed during the months of October to January.
- The capacity of groundnut crushing ranges from 2.5 tonnes per day (small) to 20 tonnes (medium) per day.
- APMC or traders sell the groundnut at a price of Rs 35–50 per kg. Oil mills separate groundnut shells from the seeds during the oil extraction process.
- Of the total, some oil mills use around 20% of the groundnut shells as fuel for the boiler, while the remaining 80% is supplied either to the bio-coal industries or other agro-based industries outside the district or to the power plants. However, some oil mills use 100% groundnut shells as fuel in the boiler.
- The price for groundnut shell varies from 2.5 Rs/ kg (October–December) to 4 Rs/ kg (July–September) depending on the season.
- The price of the groundnut shell sold to power plants from the mills ranges from 2.5 to 4 Rs/ kg and there is an increase in the price, around 0.5 Rs/ kg, if sold through a contractor as has been shown in the following table.

Table 4.7: Prices of ground and its shell in Bhavnagar

Selling price of groundnut from APMC to oil mills (Rs/kg)	**Selling price of groundnut shell from oil mills to power plant, bio-coal, and agro-industries (Rs/kg)**	**Selling price of groundnut shell at a power plant via a contractor**
350-50	2.5 to 4	3 to 4.5

Considering the total oil mills in the district is 15.The total shell produced from oil mills is estimated as 9,000 tonnes per annum.

Figure 4.8: Visit to an oil mill industry in Bhavnagar District

4.4.3.2. Bio-coal industries

As per the survey, there are three bio-coal industries in Bhavnagar District, and the two industries were visited by the team for data collection. Out of two, one uses groundnut (100%) as a primary fuel and the other unit uses a combination of cotton stalk (40%), jeera husk (30%), and chana stalk (30%). The groundnut shell was procured either directly from the traders or from the oil mills, whereas cotton stalk was purchased from the farmers and jeera husk and chana stalk from the nearby districts. The following observations were made after interacting with the industries:

- The range of capacity of the two plants visited is 3,600–6,000 tonnes/ year
- These plants are based on piston press technology. The production cost was found 600 to 750 Rs/ ton including labour, electricity, and maintenance.
- The cost of raw material varies as per Table 4.8 depending upon the seasonal availability and is inclusive of transportation cost. The price of raw material is high during the months of October to January and less during the months of July to September.
- The selling price of bio-coal is given in Table 4.9 and it varies with the price of raw material. Chemical properties of bio-coal as obtained from the industry are mentioned in Annexure IX. These bio-coals are used in chemical industries, pharmaceutical industries, rolling mills, etc. based in cities, such as Vadodara, Ankleshwar, and Sabarkantha.

Table 4.8: Cost analysis of groundnut shell and its bio-coal in Bhavnagar District

Bio coal units	
Parameters	**Unit 1**
Capacity (tonnes/ year)	3,600
Purchasing price of raw material (Rs/ kg)	2–2.5
Transportation cost of raw material included in purchasing price (Rs/ kg)	0.3–0.5
Selling price bio-coal (Rs/ kg)	4–5.5

Table 4.9: Cost analysis of cotton stalk and its bio-coal in Bhavnagar District.

Bio coal unit	
Parameters	**Unit 2**
Capacity (tonnes/ year)	6,000
Purchasing price of raw material (Rs/ kg)	2–3
(Transportation + chipping) cost of raw material included in purchasing price (Rs/ kg)	0.6–0.7
Selling price bio-coal (Rs/ kg)	3–4


Figure 4.9: Visit to a bio-coal industry in Bhavnagar District

4.4.3.3. Chemical/ salt industry

Bhavnagar is rich in salt production. Our survey team visited an agro-based chemical industry which produces carbonate minerals for pharmaceutical industries. The idea to visit this company was because this was the only industry in Bhavnagar which uses biomass to some extent for limited days. At the time the company was using groundnut bio-coal and cotton stalk for meeting its heating requirements. During interactions with company's head, it was found that the utilization of biomass also depends upon the pricing of the biomass available.

Table 4.10: Details of the chemical industry

Chemical Unit	
Parameters	**Unit**
Capacity (tonnes/ year)	25,740
Purchasing price of biomass (Rs/ kg)	2–2.5

Figure 4.10: Boiler used at the chemical industry

4.4.3.4. Dehydrating industry

Mahuwa *taluka* has around 10–15[25] dehydrating industries with an average capacity of 5–8 tonnes/ day. The team also visited an onion- and garlic-drying unit in Bhavnagar. The factory requires the total average fuel of 15 Tons/ day to meet their heating requirements. Currently, the industry is using coal as the primary fuel and biomass as a backup fuel. Cotton stalk and groundnut shell are the biomass in practice. The total requirement of biomass has given in Table 4.11:

Table 4.11: Dehydrating industry in Bhavnagar.

Drying capacity (Ton/day)	**Onion-5** **Garlic-2**
Biomass consumption (Ton/ monthly)	Groundnut-15 Cotton stalk-15
Price of biomass purchase (Rs/ kg)	2.5-3

4.4.4 Institutions

In Bhavnagar there are a total of 1,142 mid-day meal institutions serving a total of 77,896 students under the mid-day meal scheme. All these institutions use LPG for cooking purposes which has been clearly charted in Table 4.12. Hence, the institutional demand of biomass for cooking is nil.

Table 4.12: Information related to the mid-day meal scheme in Bhavnagar District

District	**Total no. of Institutions**	**Mode of cooking (No. of Schools)**			
		LPG	**Solar Cooker**	**Fire wood**	**Others**
Bhavnagar	1,142	1,142	0	0	0

[25] As per the interaction with the dehydrating industry that was visited

4.5 Biomass consumption and surplus analysis

4.5.1 Cotton stalk consumption and surplus

Cotton stalk does not have much commercial use in Bhavnagar District. Cotton stalks are often disposed of by burning it in the agricultural fields or are even ploughed back into the soil. The other uses of cotton stalk include cooking and heating. As per the survey, about 25% of the cotton stalk is used as a fuel for cooking practices. Around 70% is disposed of in fields by burying it, and 5% goes into the bio-coal industries. A biomass-based power plant with a capacity of 10 MW has already been commissioned in Sihor block of Bhavnagar District but it is non-operational as of now. Information gathered from the power plants have been provided in Annexure-II. Table 4.14 shows the per cent consumption of cotton stalk as per the current practices. Table 4.15 shows the estimated annual availability of cotton stalk in Bhavnagar District.

Table 4.13: Percentage consumption of cotton stalk as has been considered for Bhavnagar District

District	**Current practices with Cotton Stalk**[26]		
	Cooking and heating, (%)	Open-field burning (%)	Bio-coal (%)
Bhavnagar	25	70	5

Table 4.14: Estimated availability of cotton stalk in Bhavnagar District for year 2014–15

Cotton stalk generated in Bhavnagar (KMT)	**801**
Estimated utilization of cotton stalk in domestic cooking and other works (KMT)	200.0
Estimated utilisation of cotton stalk in Bio-coal industries (KMT)	40.0
Total annual utilization of cotton stalk (KMT)	240
Estimated cotton stalk left for open burning (KMT.)	561

4.5.2 Consumption and surplus of castor stalk and pigeon pea stalk

In Bhavnagar District the production of castor and is low but mostly castor stalk is left in the fields to be used as manure and the rest is utilized for cooking purposes.

In context of pigeon pea stalk, there was little information available.

4.5.3 Groundnut consumption and surplus

As per the above observations, it has already been seen that groundnut shells are mostly produced in the oil mills. The total shell produced from oil mills has been estimated as 900 tonnes per annum. Groundnut shells are majorly consumed by bio-coal industries. A total of 90% of the fuel consumed in bio-coal industries is groundnut shell. About 20% total groundnut produced can be estimated to be used for local consumption purposes.

[26] The information and approximate percentages on the utilization of cotton stalk for different purposes was obtained from the farmers' survey

Table 4.15: Percentage consumption of groundnut shell

Total Generation of groundnut shell in Bhavnagar district (Kilo MT)	**34.1**
Total bio coal industries in Bhavnagar district	3
Average capacity of a plant (tonnes/ hour)	1.25
Groundnut consumption (tonnes/ hour)	1.125
Av. No. of hours of operation/ day	10
Total numbers of days of operation/ year	300
Total estimated annual groundnut shell consumption in bio-coal industries (Kilo MT)	10.1
Total estimated annual groundnut shell consumption for local consumptions (Kilo MT)	6.8
Ground nut shell consumed by oil mills (Kilo MT)	2.8
Total annual utilization of groundnut shell (Kilo MT)	19.7
Net availability of groundnut shell (Kilo MT)	14.4

As per the survey and calculations, around 561 KMT of cotton stalk and 14.4 KMT of groundnut shell will be potentially available in a year from Bhavnagar District.

4.5.4 Summary of biomass generation, consumption, and surplus

Table 4.13 shows the generation, consumption, and surplus of the biomass available. In this study, biomass consumption doesn't include burning it in the open fields. The total generated quantity of the crop residues in the district is 14.66 lakh tonnes out of which the residue generated from the considered crop residues, that is, cotton stalk and groundnut shell are 8.3 lakh tonnes.

Table 4.16: Biomass generation, consumption, and surplus (kilo MT/ annum)

Biomass	**Generation**	**Consumption**	**Available**
Cotton stalk	801	240	561
Groundnut shell	34.1	19.7	14.4

4.6. Biomass cost analysis

As per interactions with the farmers, at present there is no transaction with respect to crop residues. In the case of cotton stalk, there is low demand of the residue and a high cost involved in the uprooting of the cotton stalk; the farmers are, therefore, currently not selling the stalk. However, when asked during the survey, farmers have opined that if at all they sell crop residue; they would consider factors, such as labour cost for collecting residues from the fields and storing them in a proper place before being transported to other places. Normally, a tonne of residue collection from the field requires five to six man-days. The cost of man-day is around Rs 200. Though at present the farmers are not expecting any consideration apart from labour cost, in actual terms they might demand an additional amount if the demand in the market builds up for cotton stalk (an example is the case of power plants). Based on observations in the fields, the estimated price will be around Rs 900–1,100 per tonne for all the field-level crop residues apart from handling charges and transportation.

However, the groundnut is directly purchased by the APMC traders from the farmers at the market price that is 35–50 Rs/ tonne. The groundnut shell separated from groundnut has a market price due to its high demand with the oil mills and within the bio-coal industries.

During the survey, an approximate cost for various components, such as shredding, uprooting, loading, unloading, and transportation was obtained from the farmers, traders, and industries. Table 4.17 and table 4.18 give the estimated cost of cotton stalk and groundnut shell prevailing in the district.

Table 4.17: Cost of identified surplus residues

Particulars	Cotton stalk (Rs/Tonne)	Reference
Farmer's remuneration	400*	Interaction from farmer
Labor charges for uprooting, bundling and loading[27]	900-1,100	From farmers
Shredding cost	350	From farmers
Transportation cost (0–25 km)	500	From farmers
Loading cost	100	From farmers
Av. Landed cost	**2,350**	

*The farmer is not aware about the fluctuation in price due to moisture loss

Table 4.18: Estimated cost of groundnut shell

Particulars	Groundnut Shell (Rs/Ton)	Reference
Cost of groundnut shell charged by oil mill	2,750	From oil mill
Loading and unloading cost	200	From oil mill
Transportation (0–50 km)[28]	450	From oil mill
Av. Landed cost	**3,400**	

The table describes the total landed cost of cotton stalk and groundnut shell. The estimated average landed cost for cotton stalk and groundnut was calculated at Rs. 2,350 and Rs 3,400, respectively.

4.6.1 Cost of fuels including losses

After getting the landed cost of fuels, losses in weight due to moisture and dust/ sand/ stone present in the fuel from the oil mills/ farmer's field have to be considered. In the case of groundnut shell, 5% loss in weight due to moisture due to dust/ sand/ stone has been considered while in the case of cotton stalk, 15% loss in weight due to moisture and 5% loss in weight due to dust/ sand/ stone has been considered. Table 4.19 shows the biomass price per tonne considering moisture and dust/ sand losses.

Table 4.19: The final cost of groundnut shell and cotton stalk considering losses

Description	Biomass Price/ton	Moisture[29]		Dust/sand/stone		Total Weight losses per unit	Biomass Price Per ton considering losses
		%	Weight loss per unit	%	Weight loss per unit		
GN Shell	3,400	5*	50	-	-	50	3,579
Cotton Stalk	2,350	15	150	5	50	200	2,938

*In case of GN shell, the moisture and handling losses have together been considered at 5%.

[27] The collective cost of uprooting and labour cost was obtained with the interaction from the farmers
[28] This information was collected from the oil mills and interaction with transport person was not done
[29] In case of cotton stalk and groundnut shell, moisture values were assumed from literature and project developers. Experimental value needs to be assessed

4.6.2 Weighted average

The weighted average of the fuel cost has been calculated based on considering the fact that cotton stalk is available during the harvesting season, that is, October to December and in maintaining the inventory of cotton stalk for more than a month is difficult as a long-term storage has its own problems of safety and deterioration in quality due to degradation. Other than this it has a self-heating property if stored in large piles because of temperature development due to high-moisture content. In case of Bhavnagar, the total availability of groundnut shell is 17.1 KMT, which is around 20% of the total biomass demand of 200 tonne/ day for an ideal 10 MW power plant.

Hence, 80% weightage is taken for cotton stalk while 20% weightage is considered in the case of groundnut shell while calculating the weighted average of fuel cost. So, the weighted average cost of fuel comes out to be **Rs. 3,066 per tonne** at corresponding weighted average GCV of 4441kcal/ kg.

Chapter 5 Bharuch District

5.1. Brief profile of Bharuch District

5.1.1 Location and geographical area

Bharuch District has an area of 5,253 sq. km and is located between 21.24–22 latitude and 72–73.15 longitude. The district is surrounded by Vadodara in the north, Surat in the south, Narmada in the east, and the Gulf of Khambhat in the west. Bharuch District is subdivided into eight *talukas*: (1) Ankleshwar, (2) Bharuch, (3) Jambusar, (4) Vagra, (5) Aamod, (6) Hansot, (7) Jhagadia, and (8) Valia. These eight *talukas* have around 657 villages. The district consists of 543 *panchayats* among which 76 are group gram panchayats. Figure 5.1 shows the political map of Bharuch District.

Figure 5.1: Map of Bharuch District

5.1.2 Climate and rainfall

The climate of Bharuch is tropical. The average minimum temperature in the district is 10.7 °C and the maximum temperature 41.4 °C. The district enjoys moderate climate with greater humidity on its coastal side. The district receives its rainfall through the south-west winds resulting in monsoon showers that begin in the middle of July and continue till September and are the months of heavy rainfall. The average rainfall varies from 900 mm to 1,100 mm.

5.1.3 Administrative set up and demography

As per the district industrial potentiality survey report 2016–17, the total population of the district is 1,219,457 of which the male and female population count is 633,875 and 144,262, respectively (a *taluka*-wise population is mentioned in Annexure III).[30] The district is mostly rural and around 66% of the population resides in the rural area. The district has eight *talukas*, with Bharuch as its headquarters. Table 5.1 shows the different particulars of Bharuch District, such as geographical data, administrative set up, population, agriculture, forest, etc.

30 Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), District Irrigation Plan (2016–2020)

Table 5.1: Bharuch District at a glance

S. No		Particulars		Statistics	Units
1		**Geographical features**			
(A)		**Geographical data**			
i)		Latitude		21.30" to 22.00"	Degree
ii)		Longitude		72.45" to 73.15"	Degree
iii)		Geographical Area		525,330	Hectares
(B)		**Administrative Units**			
i)		Sub Divisions		04	Nos
ii)		Tehsils		08	Nos
iii)		Sub-Tehsil		-	Nos
iv)		Patwar Circle		-	Nos
v)		Panchayat Simitis		18	Nos
vi)		Nagar Nigam		-	Nos
vii)		Nagar Palika		04	Nos
viii)		Gram Panchayats		543	Nos
ix)		Revenue Villages		662	Nos
x)		Assembly Area		05	Nos
2		**Population**			
i)		Male		805,707	Nos
ii)		Female		745,312	Nos
iii)		Urban		524,959	Nos
iv)		Rural		1,026,060	Nos

5.2 Agricultural scenario of Bharuch District

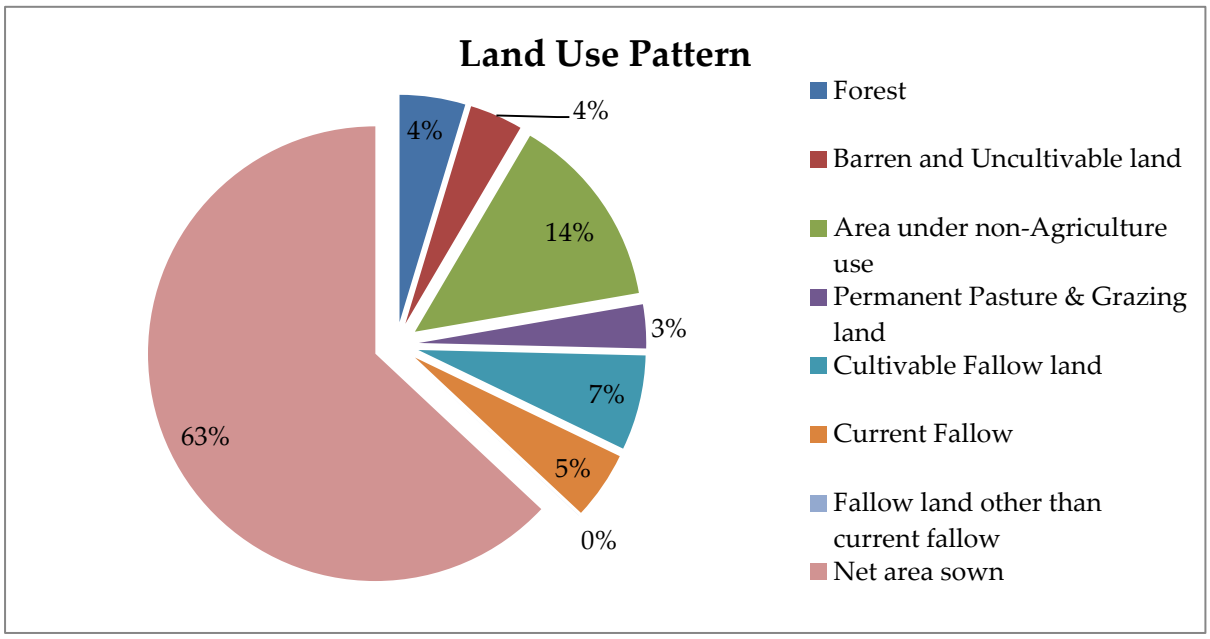
Agriculture is the main occupation in the district as the majority of its population is involved in agricultural and its allied activities. During kharif season crops, such as cotton, rice, *tur*, *adad* (kindly bean), millet, sesame, maize, etc. are cultivated in the district. Whereas during rabi season crops, such as wheat, *jowar*, *gram*, *mag*, green gram, sugarcane, and vegetables are cultivated, and during summers groundnut, rice, maize, *mag*, sugarcane, vegetable are cultivated.[31]

[31] https://bharuchdp.gujarat.gov.in/Bharuch/english/<Last accessed on May 1, 2017>

5.2.1 Land use pattern

As per the data obtained from the DAO, Bharuch, the total reported area for the purpose of land use is nearly 524,385 hectares, of which close to 334,078 hectares (or 63%) is the net sown area. Other than the net sown area, land is classified under different categories, such as permanent pasture and grazing land, cultivable fallow land, forest land, land under non-agricultural use, barren and uncultivable land, etc. Figure 5.2 shows the percentage share of different land use pattern. *Taluka*-wise land use pattern, including the area under forest, non-agricultural land, grassland, and net cultivated land, is given in Annexure VI.

Figure 5.2: Land use pattern of Bharuch District



5.2.2 Land holding pattern

As per the data obtained from the DAO, Bharuch, there are a total of 100,454 farmers with a total land area of 248,950 hectares in Bharuch District. A percentage share of different land holdings shown in Figure 5.3 indicates that approximately 9% land holding are less than one hectare, 4% are between 1 to 2 hectares, and 87% are above 2 hectares. Table 5.2 shows the number of farmers with different land holdings. A *taluka*-wise land holding pattern and the number of farmers are given in Annexure V.

Table 5.2: Information on farmers and area based on their land holdings in Bharuch District[32]

S.no	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Small	0–1	45,936	22,976
2	Medium	1–2	7,114	10,347
3	Large	Above 2	47,404	215,627
Aggregate			**100,454**	**248,950**

[32] DAO, Bharuch

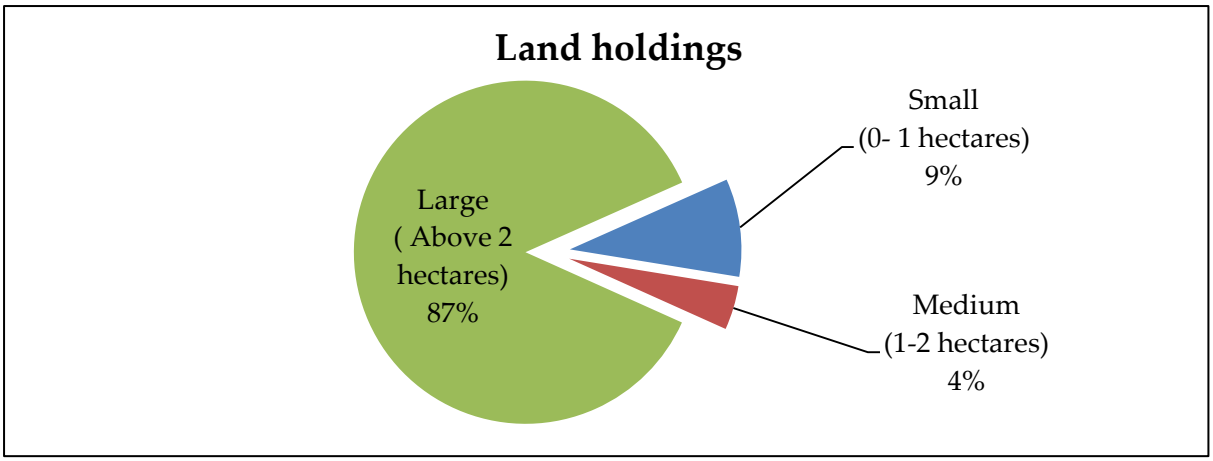


Figure 5.3: Percentage share of different land holdings

5.2.3 Cropping pattern, area, and production of major crops

The main crops of the district are sugarcane followed by cotton, *bajra*, wheat, castor, pigeon pea, etc.

As per the data obtained from the Directorate of Agriculture, Figure 5.4 shows a crop-wise area sown in the district. Out of the total net area sown (330 thousand hectares), around 11.01% area under cultivation is allocated for sugarcane (36.4 thousand hectares). Cotton (82 thousand hectares) is also a major crop in the district an approximate of 24.74% area under production. Year wise area, production and yield data of selected crops for last three years is given in Annexure IV.

Though the area under cotton cultivation is more than that of sugarcane, the production of sugarcane in the district is the highest due to its highest yield (6.9 tonnes/ hectare) as compared to cotton (0.5 tonnes/ hectare).

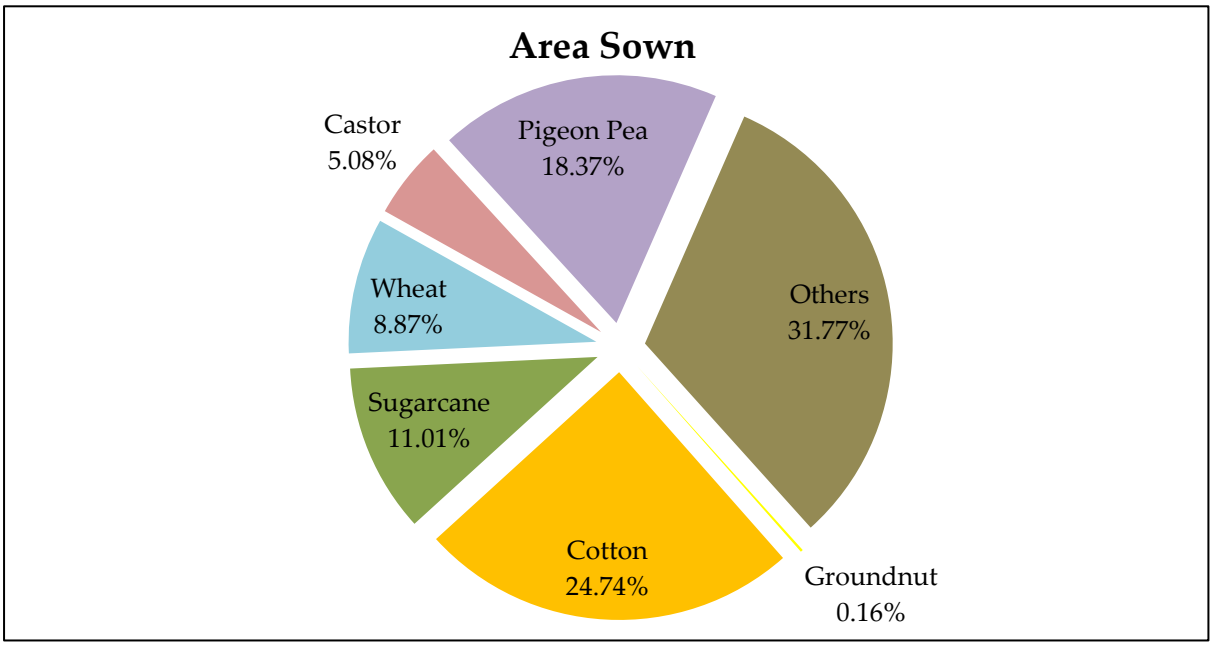


Figure 5.4: Percentage share of different crops sown in Bharuch District

Figure 5.5 gives the trend of the area under cultivation for crops, such as sugarcane, cotton, wheat, castor, pigeon pea, and groundnut. It can be concluded from the graph that the area

under cultivation for cotton has decreased whereas the area under cultivation for crops, such as sugarcane and pigeon pea has increased in these past years. The data for 2013–14 was not included during the analysis as the data set obtained from the agricultural department was incomplete.

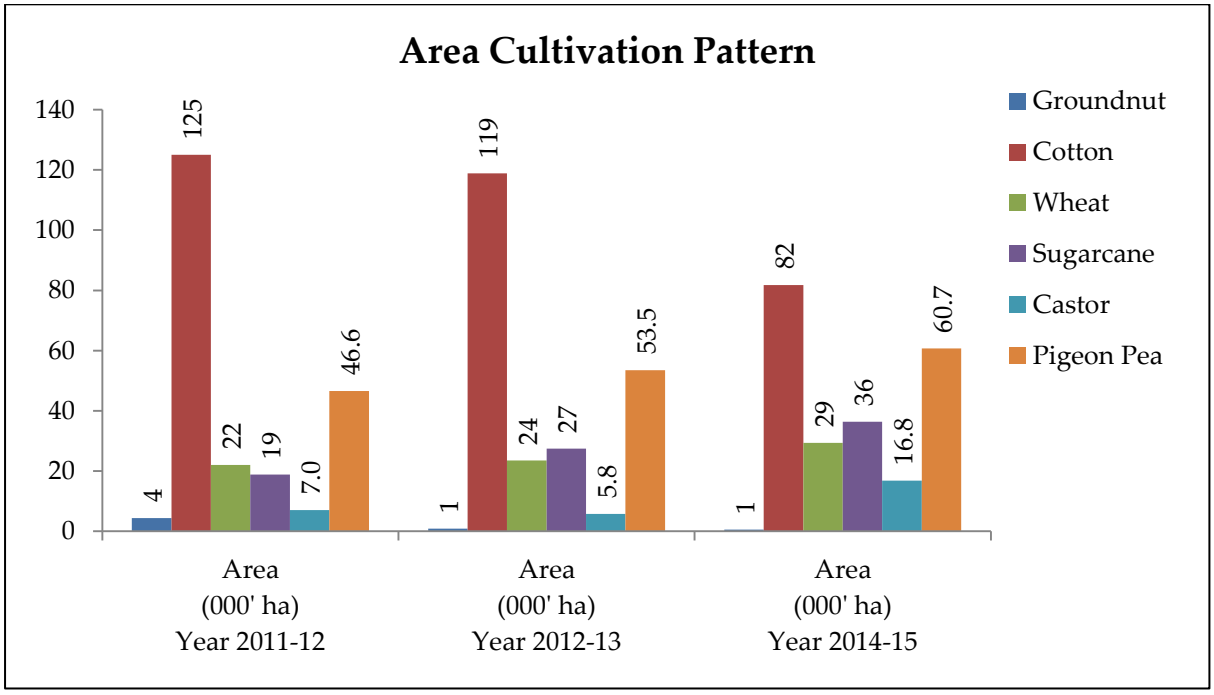


Figure 5.5: Year-wise land under cultivation for the different crops in Bharuch District

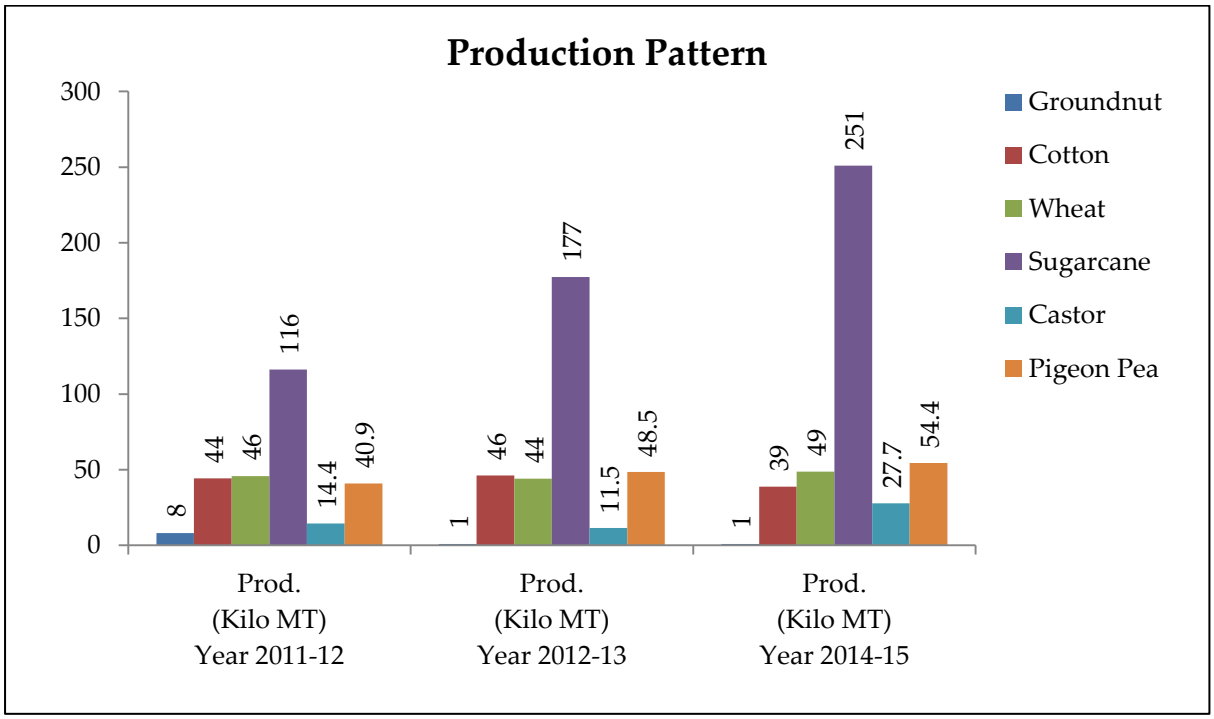


Figure 5.6: Year-wise crop production trend in Bharuch District

5.3 Primary data collection

A team member from TERI was accompanied by an executive officer from DGVCL for visiting farmer groups and industries in Bharuch starting from April 9 till April 13, 2017. The aim of visiting the farmers and various types of industries was to understand the availability, utilization, and pricing of different crop residues available in the district. Industry contacts and farmer groups were provided by the DAO and the DIC, respectively. Representatives from DGVCL also facilitated meetings with the involved industries and farmers.

5.3.1. Farmers survey

The selection of *talukas* for farmer interviews was done on the basis of potential production of major crops, such as sugarcane, cotton, etc. in the district which was obtained from secondary information which was also carried out in consultation with the DAO in Bharuch. The two *talukas* where the interviews were held are Valia and Hansot *taluka*. The two sugar industries of Bharuch District are also located in the above-mentioned *talukas*. Table 5.3 shows the number of farmers that were interviewed in the two *talukas* and their land holdings. A total of eight farmers were surveyed that included farmers with small, medium, and large land holdings collectively.

Table 5.3: An indicative list of surveyed farmers in Bharuch District

Name of Taluka	Number of farmers surveyed	Range of land holdings under different crops (hectares)
Valia	5	0.5 to 12.5
Hansot	3	2 to 5

Figure 5.7: Meeting/ Interview with the farmers in the two *talukas* of Bharuch District

Table 5.4: A summary of farmer interviews conducted in Bharuch District

Crop	Crop production (Tons/Hectare)	Biomass residue from crops	Uses
Cotton	0.45–1.00	Cotton stalk	It is partially used as a fuel for cooking purposes and the remaining is ploughed back into the field using a rotaveter
Sugarcane	12.50–31.00	Sugarcane leaves	Burnt immediately and very small amount given as fodder to cowsheds
Wheat	1.00–1.50	Wheat stalk	Mostly ploughed back into the field using a rotaveter and the remaining is used for cooking
Pigeon Pea	0.01–0.30	Pigeon pea stalk	Used for cooking purposes
		Pigeon pea husk	Used as cattle feed; sold at a price of Rs 3–7.5 per kg
Castor	0.10–0.75	Castor stalk and shell	Ploughed back into the field as well as used for cooking.
Rice	2.00–3.00	Rice straw	Used as cattle feed; sold at a price of Rs 1–1.75 per kg

As per Table 5.4, the major crops grown by farmers in Bharuch District are sugarcane, cotton, wheat, castor, and pigeon pea. As per the interaction with farmers, it was also found that the crop yield varies from year to year depending upon rainfall and availability of water (such as irrigated and un-irrigated fields).

5.4 Observations

During interaction with farmer groups, the following observations were made:

Sugarcane leaves: After interacting with farmers in both the *talukas* it was concluded that almost all the farmers burn the sugarcane leaves as the cost involved in separating them from the stem is high and involves a lot of workforce and time. However, some farmers were separating the leaves from the sugarcane (a very small quantity though) and giving it as fodder to cowsheds. In case of sugarcane, one labour can harvest one tonne of sugarcane per day and the cost of labour comes out to be Rs 280 per person.

Cotton stalk: During interaction with farmers, the team was told that the cotton stalk which is left after harvesting is partially used as a fuel for cooking and the remaining is ploughed back into the field using a rotaveter. Some farmers rented a rotaveter at a cost of Rs 600 per hour while others owned a rotavator which is priced at around Rs 80,000–85,000. As mentioned by the farmers, a rotaveter has the capacity to plough back cotton stalk at a rate of 0.2–0.3 hectares per hour.

The team also had a detailed discussion with the local agricultural officer in the extension office as well as Gram Sewak in the two *talukas*. After interacting with these officers, the team concluded that nearly some portion of the cotton stalk in the field is used by farmers in their houses while the remaining amount (~ 30%) is ploughed back into the field using a rotaveter.

It was also brought to the team's knowledge that 4–5 people are required for two days to uproot and bundle the cotton stalk for one acre of land and the cost of labour is Rs 150 per labour per day. The team was also told that if farmers transport the cotton stalk to their homes, the cost comes out to be Rs 500 per tractor which can carry cotton stalk generated on 5 acres of land. In case of loading and unloading, cost of labour is around Rs 100 and it required 2–4 labours to load and unload the cotton stalk from the tractor.

Other residues: As has already been mentioned in the Table 5.4, pigeon pea stalk is used in domestic cooking and heating purposes whereas its husk is used as fodder and sold within a price range of Rs 3–7.5 per kg. In case of wheat stalk, it is majorly ploughed back into the field in the form of manure (~ 80%). In case of castor stalk and shell, farmers plough them back into the field using a rotaveter and some amount is also used for cooking.

Apart from using crop residues as a cooking fuel, the local households also use kerosene which is available at a cost of Rs 22 per litre (approximately).

Annexure X carries a detailed account of the farmer visits.

5.4.1 Industrial survey

Bharuch District is the hub of chemical and pharmaceutical industries. As the district has the highest production of sugarcane among all its major crops, therefore, it has two sugar mills for processing the sugarcane harvested. Apart from this there are three bio-coal industries and six chemical and pharmaceutical industries which were surveyed during the team visit.

5.4.1.1 Sugar industry

Sugarcane is sold to the two sugar mills in the district, that is, Shree Ganesh Khand Udyog Sahakari Mandli Ltd. in Valia (*taluka*) and Shree Khedut Sahakari Khand Udyog Mandli Ltd. in Hansot (*taluka*). There is no trader involved in the chain of selling sugarcane to the sugar industries. Farmers bring their produce directly to the sugar industry in tractors, trucks, etc. Every year the selling price for sugarcane is fixed before the season (October–April) sets in and this year the selling price was fixed at Rs 3,500 per tonne and Rs 3,578 per tonne at the respective sugar industry.

The team visited both the sugar industries which are located in the district. Key observations from both the industry have been mentioned below:

Table 5.5: The summary of sugar industries visited in Bharuch District

Name of the Company	Shree Ganesh Khand Udyog Sahakari Mandli Ltd.	Shree Khedut Sahakari Khand Udyog Mandli Ltd.
Taluka	Valia, Bharuch	Hansot, Bharuch
Total boilers	4	2
Boiler usage	Generation of steam	Generation of steam
Boiler Capacity (tonnes per hour)	Boiler 1: 25 Boiler 2: 25 Boiler 3: 38 Boiler 4: 15 (standby)	Boiler 1: 35 Boiler 2: 35
Working period	6 months (October–April) 24 hours in a day	6 months (October–April) 24 hours in a day
Sugarcane crushing capacity (tonnes per day)	4,000	4,000
Bagasse generated (tonnes per day)	1,040–1,200 (26%–30% of the cane crushed)	1,200 (30% of the cane crushed)
Power generation capacity	Plant 1: 6MW Plant 2: 1.5 MW (standby)	Plant: 3MW
Bagasse Consumption (tonnes per day)	850 tonnes per day	750 tonnes per day
Steam requirement	70 tonnes per hour	63 tonnes per hour

Name of the Company	Shree Ganesh Khand Udyog Sahakari Mandli Ltd.	Shree Khedut Sahakari Khand Udyog Mandli Ltd.
Steam usage (tonnes per hour)	Power generation: 42–3 Mill turbines: 22–3 Distillery: 4–5 Process: 3–4	Power generation: 27 Mill turbines: 30–1 Distillery: 4–5
Surplus bagasse	360–80 tonnes per day	450 tonnes per day
Usage of surplus bagasse	Bales Moisture Content: 50% Price: Rs 1700–50 per tonne (excl. transport) CV: 2240 kcal/ kg	Bales Moisture Content: 48%–50% Price: Rs 2,000 per tonne (excl. transport) CV: 2,000 kcal/ kg
	Loose MC: 50% Price: Rs 1,600 per tonne (excl. transport) CV: 2,240 kcal/ kg	Loose MC: 48%–50% Price: Rs 1,900 per tonne (excl. transport) CV: 2,000 kcal/ kg
Sugarcane purchase cost (per tonne)	Rs 3,500 per ton (MC: 70%)	Rs 3,578 (MC: 70%)

General observations other than the information mentioned in the Table 5.5 have been listed below:

- Ash produced (1%–1.5% of the bagasse is burnt) in the boiler is sent back to the fields.
- Loose bagasse and bagasse in the form of bales is sold to paper mills, particle board, bio-coal industries, etc.
- Shree Khedut Sahakari Khand Udyog Mandli Ltd. retains 1,000 tonnes bagasse to start their operations in the next season.

Table 5.6: Summary table of prices for sugarcane and its bagasse in Bharuch District

Purchasing price of sugarcane (from farmers to sugar industry) (Rs/tonne)	Selling price of loose sugarcane bagasse (from sugar industry to particle board, paper industry, etc.) (Rs/tonne)	Selling price of sugarcane bagasse in the form of bales (from sugar industry to particle board, paper industry, etc.) (Rs/tonne)
3,500–3,578	1,600–1,900	1,700–2,000

Figure 5.8: Visit to two sugar industries in Bharuch District

5.4.1.2. Bio-coal Industries

As per the survey, there are three functional bio-coal industries in Bharuch District and all of these were visited by the team. All the three industries were using sugarcane bagasse as the major residue for bio-coal production, whereas castor shell, saw dust, and jeera husk were also being used in smaller quantities. Figure 5.9 and Table 5.7 summarizes the team's visit to the three bio-coal industries.

a. Castor shell and sugarcane bagasse

b. Drying of bagasse in the field

c. Bio-coal making machine

d. Bio-coal

Figure 5.9: Visit to bio-coal industries in Bharuch District

Table 5.7: Analysis of bio-coal industries in Bharuch District

Name of the Company	**Fine Energy Coal**			**Narmada Bio fuel**					**Shree Padma Hari**				
Location (*Taluka*)	Valia			Valia					Jhagadia				
Working period	365 days 10 hours per day			12 months					12 months				
Total capacity (tonnes per annum)	3500			1,700–1,800 (140–50 tonnes per month)					1,800 (150 tonnes per month)				
Residue used	Bagasse	Castor shell	Jeera husk	Bagasse	Saw dust	Bagasse	Castor shell	Saw dust	Bagasse	Saw dust	Bagasse	Castor shell	Saw dust
Percentage share in bio-coal	70	15	15	65	35	40–5	15–20	35–40	60	40	40	20	40
Seasonal Availability of Raw material	Dec–Apr	Mar–Apr	Whole year	Oct–Apr		Feb–Mar			Oct–Apr		Feb–Mar		
Residue prices in Rs per tonne (incl. transport)	2,000	2,900	2,200	2,500	3,500	2,400–2,500	2,600	3,400–3,500	2,500	3,500	2,500	2,700	3,500
Moisture content of residue (%)	30	2-3	1-2	40	10	40	5	10	40	10	40	5	10
Briquette price in Rs per tonne (incl. transport)	4,500–7,000			4,000–5,700					4,000–5,400				
Transport price of bio-coal	Rs 100 per ton to chemical industries in Ankleshwar			Rs 300 per tonne to nearby areas Rs 900–1,000 per MT to Maharashtra					Rs 250–300 per tonne to nearby areas Rs 800–1,000 per MT to Maharashtra				

General observations other than those that have been mentioned in Table 5.7 have been listed below:

- Majorly, sugarcane bagasse is procured from sugar industries in the district, whereas castor shell, saw dust, and jeera husk is procured from farmers, wood industry, and jeera-making industries, respectively. In case of saw dust and jeera husk, it is transported from the nearby districts and Unja in northern Gujarat, respectively.
- Bagasse received by bio-coal industries contains nearly 30%–40% moisture and hence is sun dried for 2–3 days to bring the MC down to 10% before being fed into briquette-manufacturing machines.
- Generally, these industries store bio-coal for nearly six months and dispatch them during the rainy season. These industries have a storage capacity of 200–600 tonnes approximately.
- Calorific value of all the different kinds of bio-coal mentioned above is nearly 4,200 kcal/ kg.
- As per the interactions, it was found that bio-coal was costliest during the rainy season.
- As said by the bio-coal industries, nearly 80% of the bio-coal consumed by the chemical and pharmaceutical industries is transported from Saurashtra region in Gujarat.
- After discussions with the bio-coal industries, it was found that the approximate cost of transportation is Rs 300–400 per ton (for a distance of up to 40 km) depending upon different biomass being transported. A truck with 10-tonne capacity truck could effectively carry around 6–7 tonnes depending on the type of biomass.
- It was brought to the knowledge of the team that traders are involved in the process of transportation of raw materials to bio-coal units and they have a fixed margin of nearly Rs 200 per tonne. The labour cost for loading and unloading is approximated to be around Rs 100 per tonne.

5.4.1.3 Chemical and pharmaceutical industries

Bharuch District has got four major industrial centers known as Gujarat Industrial Development Corporation (GIDC), which are located in Ankleshwar, Panoli, Dahej, and Jhagadia, respectively. As per the interaction with the officials of Gujarat Pollution Control Board, there are a total of 1,426 chemical and pharmaceutical industries in the district.
While interacting with the owners of several bio-coal industries, chemical industries, etc. the team was able to approximate the number of chemical and pharmaceutical industries in the district using biomass. These numbers have been given below:

- GIDC Ankleshwar: 20–5
- GIDC Panoli: 15–20
- GIDC Dahej: 10–15
- GIDC Jhagadia: 4–5

Therefore, there are a total of 49–65 (approx.) chemical and pharmaceutical industries in the district which are using biomass for their boiler operations.
The team visited a total of six chemical and pharmaceutical industries in GIDC Panoli and GIDC Ankleshwar region of the district. Details about these industries have been summarized in Table 5.8 and Figure 5.10.

Figure 5.10: Visit to different Chemical and Pharmaceutical industries in Bharuch District

Table 5.8: Summary of chemical and pharmaceutical industries visited in Bharuch District

Name of the Company	Sun Pharmaceutical	Ginni Filament	Dalmia Chemical	Prudent Pharma	Reine Lifescience	Sunshine Velvet
Location	GIDC, Panoli	GIDC, Panoli	GIDC, Panoli	GIDC, Ankleshwar	GIDC, Ankleshwar	GIDC, Ankleshwar
Total boilers	1	2 (1 working +1 standby)	1	1	1	1
Boiler usage	Generation of steam	Thermofluid heating	Generation of steam	Generation of steam	Generation of steam	Generation of steam
Boiler capacity	10 tonnes per hour	Flow rate: 120 cu.m. per hour Temp req: 150–180 °C	-	1 tonne per hour Temp. required: 90 °C (approx.)	-	2 tonnes per hour
Working period	12 months 24 hours per day	12 months 24 hours per day	12 months 24 hours per day	12 months 24 hours per day	12 months 24 hours per day	12 months 24 hours per day
Fuel used	Groundnut shell briquette: 50%–55% Furnace Oil: 25%–40% Gas: 10%–20%	Groundnut shell briquette	Briquette (groundnut shell, bagasse+wheat husk) and wood	Groundnut shell briquette	Groundnut shell briquette	Briquette 1: Groundnut Shell Briquette 2: Sugarcane bagasse Briquette 3: (GNS = 60%) + (Sawdust + CS = 40%)
Bio-coal usage (tonnes per day)	34	13	Briquette: 2.5 Wood: 2	1	1	3

Name of the Company	Sun Pharmaceutical	Ginni Filament	Dalmia Chemical	Prudent Pharma	Reine Lifescience	Sunshine Velvet
Storage capacity (tonnes)	150	100	25–30	20	17	150
Bio-coal source	Junagadh (5–6 industries)	Saurashtra region	Rajkot (GN shell) Surat: bagasse + wheat husk	Amreli (Paradise bio-coal industry)	Junagadh (1 supplier)	Briquette 1: Junagadh, Kasol, Gondal, Balsar Briquette 2: Vadodara, Rajpipla, Bharuch, Surat, Balsar Briquette 3: Swarashtra
Price of bio-coal in Rs. per ton (incl. transport)	5,000–5,800	5,200–6,200	Briquette: 4,500–500 Wood: 2,500	4,800–7,000	5,500–7,000	Briquette 1: 5,200–6,500 Briquette 2: 4,500–5,200 Briquette 3: 5,000–7,000

Observations other than the information mentioned in table 5.8 have been listed below:

- Higher prices of bio-coal are usually found during the rainy season, that is, June–September. Prices of bio-coal could be as high as Rs 7,000 per tonne during the rainy season.
- Maintenance period of boiler is generally found to be once every fortnight.
- Moisture content of bio-coal is nearly 6%–10%.
- Chemical and pharmaceutical industries mostly use bio-coal with higher groundnut shell content due to its better burning properties.
- Steam generation cost in boilers using bio-coal was estimated to be around Rs 1,100–1,500 per tonne.
- Calorific values of bio-coal were found out to be 3,700–4,200 kcal/ kg depending on the different residues being used.
- Transportation cost of bio-coal was approximately Rs 700–1,100 per tonne from the Saurashtra region (depending on distance of the districts in the region and seasonal variation). Transportation cost of bio-coal was nearly Rs 250–300 per tonne when transported from Surat District

5.5 Biomass resource analysis

5.5.1 Total biomass generated and its use

As per the formula, described in the methodology section, crop residue or biomass of the major crops has been calculated. Table 5.9 shows the values of major crop residue generated from different crops.

Table 5.9: Major crop residue generated in Bharuch District

Crop Residue	Generation in 2014-15 (kilo MT)	Consumption (kilo MT)				Potential surplus (kilo MT)
		Household Cooking	Fodder	Industry	Manure	
Groundnut Shell	0.29	0	0	0.29	0	0
Groundnut Husk	1.96	0	1.96	-	0	0
Cotton Husk	42.67	-	-	-	-	-
Cotton Boll Shell	42.67	0	0	0	42.67	0
Wheat Pod	14.65	-	-	-	-	-
Sugarcane Bagasse**	417.6	0	0	417.6	0	129.6*
Sugarcane top & leaves	12.55	0	0	0	0	12.55
Pigeon Pea Husk	16.32	0	16.32	0	0	0
Cotton Stalk	310.73	48.4	0	0	93.22	435.3
Castor Stalk	67.20		0	0	0	
Pigeon Pea Stalk	136.00		0	0	0	
Wheat Stalk	73.23		0	0	58.6	
Aggregate	**1135.87**	**48.4**	**18.28**	**417.89**	**194.49**	**865.45**

* Potential surplus calculations have been explained in section 5.5.2.1

** In Bharuch district, bagasse is mostly generated at the two sugar industries mentioned above. These two sugar industries can only buy sugarcane from the farmers within a radius of 30 km and because of their location; farmers from nearby districts also sell their produce to these two sugar industries. Hence, a different methodology has been used in calculating the total bagasse generated in the district which has been described in Table 5.10:

Table 5.10: Total biomass generation of bagasse in Bharuch District

Sugar Industry	Bagasse generated (tonnes per day)	No. of days the industry is functional every year	Total Bagasse generated at each unit (tonnes)
Shree Ganesh Khand Udyog Sahakari Mandli Ltd.	1,120	180	201,600
Shree Khedut Sahakari Khand Udyog Mandli Ltd.	1,200	180	216,000
Aggregate (tonnes per annum)			**417,600**

5.5.2 Biomass consumption and surplus analysis

5.5.2.1 Sugarcane bagasse consumption and surplus

As already discussed, a total of 417,600 tonnes of bagasse is generated from the two sugar industries in the district. As per the interaction with the officials of the sugar industry, it was observed that nearly 26%–30% bagasse gets generated by crushing sugarcane. Nearly 65%–75% of the bagasse generated is used by the sugar industries in their own mills and the remaining is being sold to paper, bio-coal, and particle board industries in the form of bales as well as loose bagasse.

Table 5.11: Consumption and estimated surplus analysis for sugarcane bagasse in Bharuch District

Sugar Industry	Bagasse generated (tonnes per day)	Bagasse used by sugar industry (tonnes per day)	Surplus bagasse (tonnes per day)	No. of days the industry is functional every year	Surplus bagasse
Shree Ganesh Khand Udyog Sahakari Mandli Ltd.	1,120	850	270	180	48,600
Shree Khedut Sahakari Khand Udyog Mandli Ltd.	1,200	750	450	180	81,000
Aggregate (tonnes per annum)					**129,600**

Therefore, it can be concluded that a total **of 4.2 lakh tonnes of bagasse gets generated** in the district out of which nearly **1.3 lakh tonnes of potential surplus bagasse** is available in the district which is currently being consumed by paper mills, particle board, and bio-coal industries, to name few. As the availability of bagasse in the district is very high, therefore, sugar mills can explore the possibility of cogeneration plants under separate tariff schemes suitable for bagasse cogeneration plants. Hence, in the present study, bagasse is not considered in calculating the weighted average of fuel cost.

5.5.2.2 Stalk consumption and surplus

As already mentioned, stalks of cotton, pigeon pea, castor, and wheat does not hold much commercial value in the district and are either ploughed back or used for cooking. Therefore, a different methodology has been used in estimating the surplus amount of stalks in the district which has been mentioned in Table 5.12.

Table 5.12: Generation of different stalks in the district

Different stalks	Total generation (KMT)	Stalk ploughed back into the field (KMT)	Remaining stalk (KMT)
Cotton Stalk	310.73	93.22 @30%	217.5
Wheat Stalk	73.23	58.6 @80%	14.6
Pigeon pea stalk	136	-	136
Castor stalk	67.20	-	67.20
Aggregate	**587.16**	**151.82**	**435.3**

As per the 2011census data, the total number of households in Bharuch Districts is 335,098. The total number of households using crop residues is 22,134. As per the interaction with farmers, nearly 6 kg of crop residue is being consumed per day per household (considering a family of five members). Table 5.13 shows the total estimated annual crop residue consumption for cooking in Bharuch District from secondary sources.

Table 5.13: Estimated annual crop residue cooking consumption and surplus in Bharuch District

Particulars	**Values**
Total household in Bharuch District	335,098
Households using crop residue as a fuel for cooking[33]	22,134
Per day per household cooking requirement (kg)	6
Estimated annual crop residue consumption for cooking in Bharuch District, considering crop residue used for 365 days(kilo MT)	48.4
Remaining stalk after ploughing back (kilo MT)	435.3
Estimated surplus stalk in the district (kilo MT)	**386.9**

Therefore, it can be concluded that though 5.87 lakh tons of stalks gets generated in Bharuch district and out of which nearly 4.4 lakh tons of potential surplus stalks is available in the district.

5.5.3 Institutions

In Bharuch, there are total of 1,026 midday meal institutions serving a total of 36,186 students under the midday meal scheme. All these institutions cook their food based out of LPG. Hence, the institutional demand of biomass for cooking is nil.

Table 5.14: Information related to the midday meal scheme in Bharuch District

District	**Total no. of Institutions**	**Mode of cooking (No. of Schools)**			
		LPG	**Solar Cooker**	**Fire wood**	**Others**
Bharuch	1,026	1,026	0	0	0

5.6 Biomass cost analysis

In case of sugarcane bagasse, it does hold some commercial value and, therefore, has an established supply chain as it is utilized by paper mills, particle board, and bio-coal industries, to list a few. In case of cotton stalk, it does not hold much commercial value and hence does not have an established supply chain.

During the survey, an approximate cost for various components in the supply chain, such as shredding, uprooting, loading, unloading, and transportation was obtained from farmers and its relevant industries. Table 5.15 and Table 5.16 give the estimated cost of sugarcane bagasse and cotton stalk prevailing in the district.

[33] http://www.censusindia.gov.in/DigitalLibrary/MFTableSeries.aspx<Last accessed on May 2, 2017>

Table 5.15: Estimated cost of sugarcane bagasse in Bharuch District

Particulars		**Sugarcane bagasse (Rs/Tonne)**	**Reference**
Material cost of bagasse purchased from Sugar industries	Loose form @50% MC	1,600–1,900	Sugar industries
	Bales form @50% MC	1,700–2,000	Sugar industries
Transportation 0–50 km.		300–400	Bio-coal industries
Loading and unloading		160–240	Bio-coal industries
Trader's margin		200	Bio-coal industries
Average landed cost		**2500**	

Table 5.16: Estimated cost of cotton stalk in Bharuch District

Particulars	**Cotton stalk (Rs/Tonne)**	**Reference**
Farmers Remuneration	500*	Farmers
Uprooting cost	750–800	Agricultural officers in extension offices
Loading cost	80–100	Agricultural officers in extension offices
Transportation cost 0 – 25 Kms.	400	Bio-coal industries
Unloading cost	80–100	Agricultural officers in extension offices
Processing cost (Shredding)	350	Farmers
Average landed cost	**2,205**	

*Farmers are not aware about the fluctuation in price due to moisture loss

Therefore, the average landed cost of sugarcane bagasse comes out to be **Rs 2,500 per tonne** at GCV of 2250 Kcal/ kg (50% moisture), whereas cotton stalk will be priced around **Rs 2,205 per tonne** at GCV of 4472 Kcal/ kg (7.78% moisture).

5.6.1 Cost of fuels including losses

After getting the landed cost of fuels, losses in weight due to moisture and dust/ sand/ stone present in the fuel from oil mills/ farmer's field has to be considered. In case of sugarcane bagasse, 25% loss in weight due to moisture and 5% loss in weight due to dust/ sand/ stone have been considered while in case of cotton stalk, 15% loss in weight due to moisture and 5% loss in weight due to dust/ sand/ stone have been considered. Table 5.17 shows the biomass price per tonne considering moisture and dust/ sand losses.

Table 5.17: Final cost of Groundnut shell and cotton stalk considering losses

Description	**Biomass Price/ton**	**Moisture**[34]		**Dust/sand/stone**		**Total Weight losses per unit**	**Biomass Price Per ton considering losses**
		% loss	**Weight loss in kg per unit tons**	**% loss**	**Weight loss in kg per unit ton**		
Sugarcane bagasse	2500	25	250	5	50	300	3571[35]
Cotton Stalk	2205	15	150	5	50	200	2756

[34] In case of cotton stalk and sugarcane bagasse moisture values were assumed from literature and sugar & bio-coal industries. Experimental value need to be assessed

[35] Bagasse price has been calculated considering 25% moisture loss.

Chapter 6 Vadodara District

6.1 Brief profile of Vadodara District

6.1.1 Location and geographical area

Vadodara is one of the most cosmopolitan cities in India and is located to the south-east of Ahmedabad along the bank of the river Vishwamitri. The district is known as "Sanskar Nagri" (City of Culture) due to its rich cultural traditions. It is famous for its palaces, parks, temples, and museums. It is also famous as a "Gateway to the Golden Corridor", as all the rail and road arteries that link Delhi, Mumbai, and Ahmedabad pass thorough Vadodara including Delhi–Mumbai Industrial Corridor (DMIC). Vadodara, also known as Baroda, is the third-largest city in the Indian State of Gujarat after Ahmedabad and Surat. As of 2011, it is the third, most-populous district of Gujarat, after Ahmadabad and Surat. The Vadodara district in middle Gujarat falls under the agro-climatic zone-III of the Gujarat state. Geographically, Vadodara District is lies between 21° 49' to 22° 49' north latitude and 72° 51' to 74° 17' east longitude. The total area of the district is 7,77,000 hectares out of which 5 37,653 hectares area is cultivable. The district consists of eight *talukas*.[36] Figure 6.1 shows the political map of Vadodara District.

Figure 6.1: Political map of Vadodara district

6.1.2 Demography

Vadodara covers 3.85% of the total area of Gujarat state. The population density of Vadodara District is the ninth highest and is 552 per sq. km. Vadodara District is the third-

[36] http://kvkvadodara.org/district-profile/ <L ast accessed on May 2, 2017>

most populated district in the state. In Vadodara District, sub-district Vadodara has the highest population (2,064,268). As per the 2011 census, there are nine villages with a population less than 50. Vadodara District has a sex ratio of 934 (number of females per 1,000 males). Among sub-districts, Karjan has the highest sex ratio of 940 and Padra has the lowest sex ratio of 917. Vadodara has a child sex ratio of 897. Vadodara District also has a literacy rate of 78.92 % with a female literacy rate of 72.03%.The total number of household in the district stands at 873,369. The total population of the district is 4,223,568 of which the male population constitutes about 2,150,229 and the female population stands at 2,073,339.

6.1.3 Administrative set up

The district of Vadodara has been recently bifurcated and a new district, namely, Chhotaudepur with its five blocks—Naswadi, Chhotaudepur, Kawant, Pavi Jetpur, and Sankheda—has been carved out of the erstwhile Vadodara District that had twelve blocks and is now left with seven. The name of remaining seven blocks are: Savali, Vadodara, Waghodia, Dhaboi, Padara, Karjan, and Shinor. Table 6.1 shows the district at a glance.

Table 6.1 District at a glance

S No	Particulars	Statistics	Unit
1	**Geographical features**		
A	**Geographical data**		
	a) Latitude	20.49 to 22.49 North	Degree
	b) Longitude	72.51 to 74.17 East	Degree
	c) Geographical area	409170	Hectares
B	**Administrative units**		
	a) Talukas	07	
	b) Patwar Circle	NA	
	c) Panchayat Samitis	10	
	d) Nagar Nigams	01	
	e) Nagar Palika	5	
	f) Gram Panchayats	866	
	g) Revenue villages	NA	
	h) Assembly areas	12	
2	**Population**		
	a) Male	2,150,229	Persons
	b) Female	2,073,339	Persons
	Total population	4,223,568	Persons
3	**Forest**		
	a) Forest	77,788	Hectares
4	**Education**		
	a) Primary schools	2,432	Numbers
	b) Middle school	307	Numbers
	c) Secondary and senior secondary schools	191	Numbers
	d) Colleges	54	Numbers
	e) Technical university	1	Number

Source: District Industrial Potentiality Survey Report of Vadodara District (2016-17)

6.2 Agricultural scenario of Vadodara District

6.2.1 Agricultural land holding pattern

There are a total of 151,238 farmers with a total land area of 294,323 hectares in Vadodara District. The percentage share of different land Holdings shown in Figure 6.2 indicates that 12% land holding are less than one hectare, 20% are between 1 to 2 hectares, and 68% are above 2 hectares. Table 6.2 shows the number of farmers with a different scale of land holding including small, medium, and large holding. Figure 6.3 shows that 28% of the total farmers in Vadodara District have medium-scale land holdings, 30 % have large-scale land holdings, while 42% have small-scale land holdings. A *taluka*-wise land holding pattern and number of farmers are given in Annexure V.

Table 6.2: Number of farmers based on their land holdings

S.No.	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Small	Below 1 Hectare	64,184	33,979
2	Medium	1 to 2 Hectares	41,666	60,074
3	Large	Above 2 Hectare	45,388	200,270
Aggregate			**151,238**	**294,323**

Source: District statistical book, Vadodara

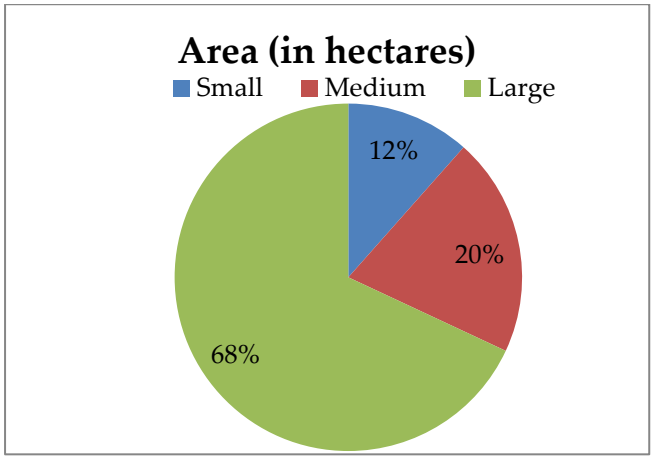


Figure 6.2: Percentage share of different land holdings

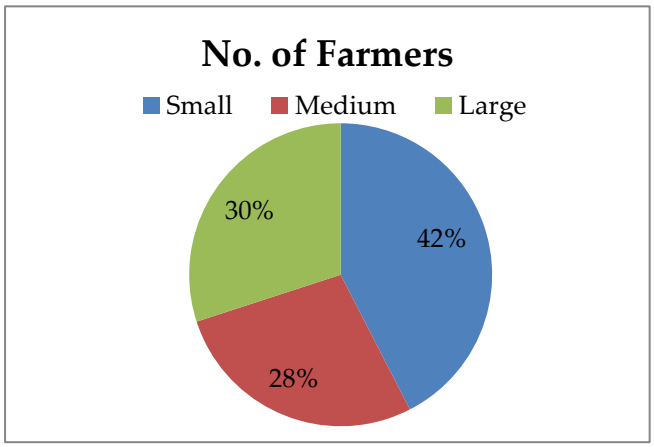


Figure 6.3: Number of farmers belongs to a different scale of land holding

6.2.2 Land use pattern

The total geographical area of the district is 508 kilo/ hectares out of which nearly 302 kilo/ hectare (or 60%) is under cultivation. Another area of the land is under other uses including non-agricultural uses, dry land, and fallow land and land under miscellaneous uses. Figure 6.4 shows the percentage share of *taluka*-wise different land use patterns. A *taluka* wise land use pattern including areas under forest, non-agricultural land, grassland, and net cultivated land is given in Annexure VI.

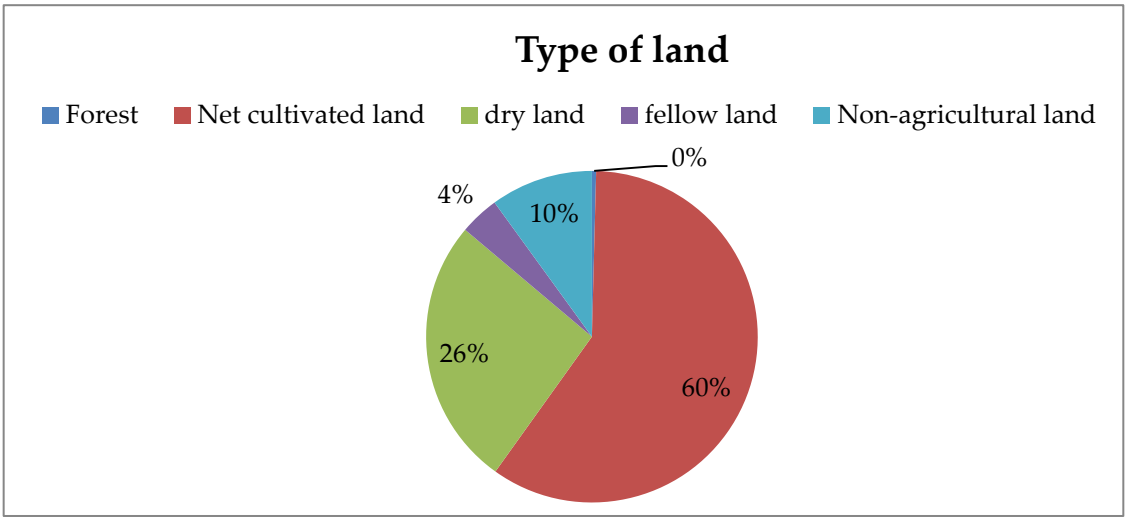


Figure 6.4: Land use pattern

6.2.3 Agro-ecological situations

Based on important features of agro-climatic zone and other important aspects, such as edaphic factors (soil texture, structure, and depth), sources of irrigation, climatic factors at the micro level (rainfall, temperature variation, relative humidity), and existing farming system, the entire district is divided into two agro-ecological situations (AES). Table 6.3 shows the agro-ecological situation of Vadodara District

Table 6.3 Agro-ecological situations

Name of AES	Situation	Crop grown	Taluka/Mandal covered
AES-I	Sandy loam soil with high rainfall	Predominately maize, cotton , tur, tobacco, vegetables, and horticulture crops	Vadodara, Savli, Padara, Vaghodia, and a part of Dabhoi
AES-IX	Deep black soil with high rainfall	Major banana, cotton, vegetables, and sugarcane	Karjan, a part of Dabhoi, and Shinor

6.2.4 Year-wise area production and yield pattern

The major crops in the district are cotton, pigeon pea, castor, wheat, and maize. In the present report, we consider eight crops in our study including groundnut, cotton, wheat, maize, sugarcane, pigeon pea, castor, and paddy. Figure 6.5 shows the year-wise crop production data of Vadodara District for the last three years.[37] It can easily be seen from the figure below that cotton is the major crop. Figure 6.6 shows the area under crop production

[37] Data for year 2013–14 has been excluded due to anomalous figures of area and crop production

for last 3 years.[38] Area under cotton production is highest every year. Table 6.4 shows the season-wise crops grown in Vadodara District.

Table 6.4: Season-wise crops grown

Sr.	Kharif	Rabi	Summer
1	Paddy	Wheat	Bajara
2	Tobacco	Potato	Paddy
3	Bajara	Rustica Tobacco	Vegetables
4	Banana	Mustard	Green gram
5	Castor	Vegetables	Groundnut
6	Vegetables	Gram	
7	Cotton	Forage	
8	Pigeon pea		

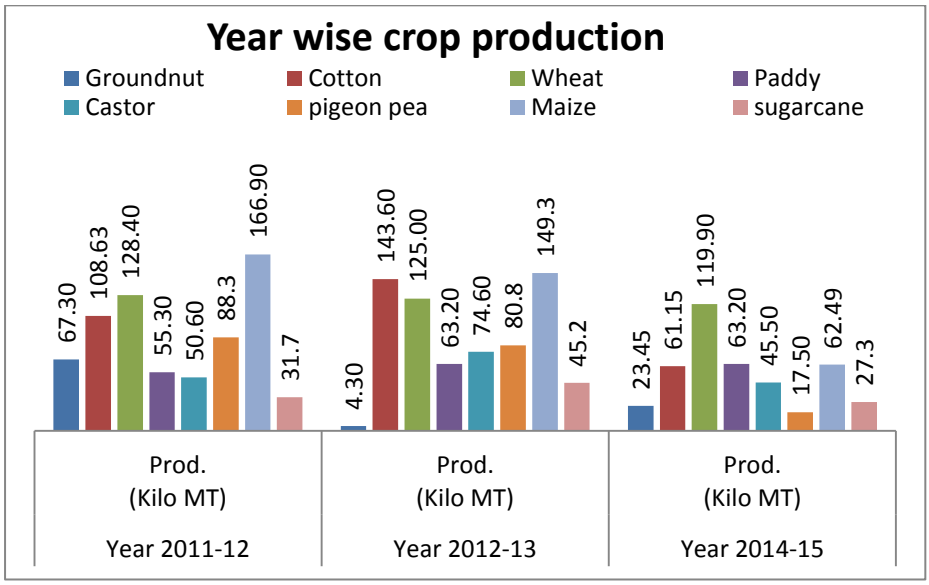


Figure 6.5: Year-wise crop production trend[39]

[38] Data for year 2013–14 has been excluded due to anomalous figures of area and crop production
[39] Data for year 2013-14 has been excluded due to anomalous figures of area and crop production

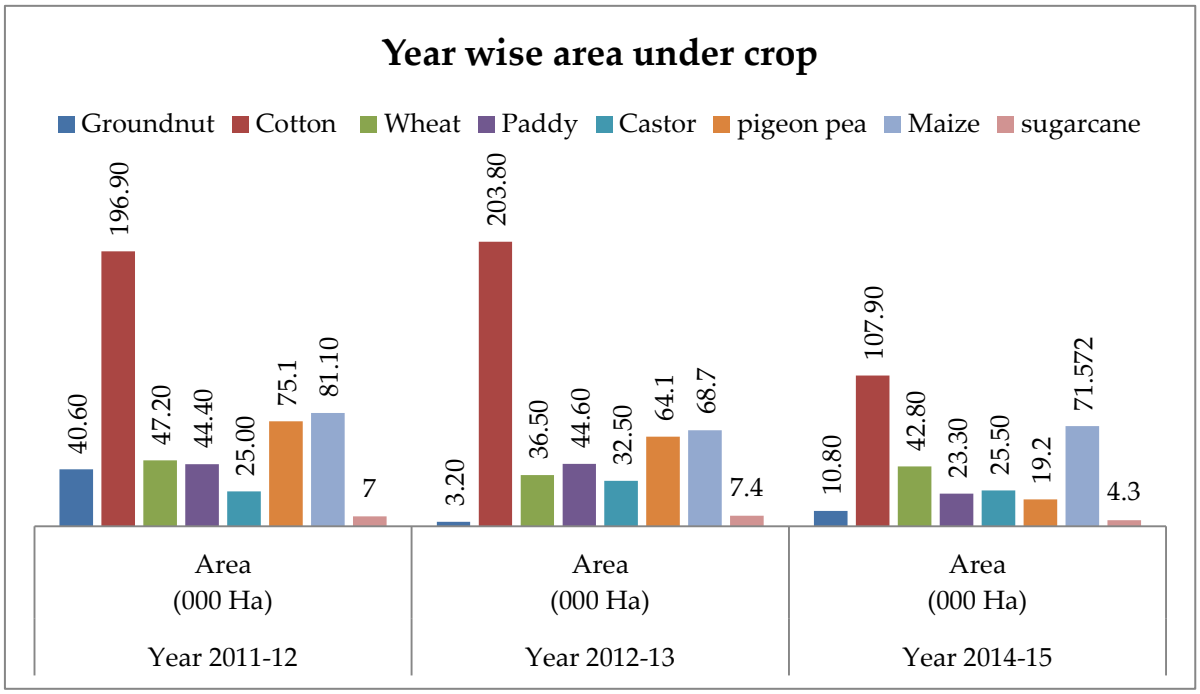


Figure 6.6: Year-wise land under crop production for different crops

Table 6.5 shows the area, production, and yield data of selected crops for the year 2014–15. It can be easily seen from the table that cotton is one of the major crop with a production of 61.15 KMT. Groundnut is usually cultivated both in kharif and summer seasons. The usual area under groundnut cultivation during summer season is a mere 5%. A year-wise area, production, and yield of major crops in Vadodara District are given in Annexure IV.

Table 6.5: APY data of selected crops

Sr. No.	Name of the Crop	Year 2014–15		
		Area (000 Ha)	Prod. (Kilo MT)	Yield (Tonnes/ Ha)
1	Groundnut	10.80	23.45	2.17
2	Cotton	107.90	61.15	0.57
3	Wheat	42.80	119.90	2.80
4	Paddy	23.30	63.20	2.71
5	Castor	25.50	45.50	1.78
6	pigeon pea	19.2	17.50	0.91
7	Maize	71.572	62.49	0.87
8	sugarcane	4.3	27.3	6.35

Source: Directorate of Agriculture

6.2.5 Cropping pattern

There is a change in the cropped area due to partition of Vadodara District; at present, it is well understood that a well-developed marketing system is crucial for the growth of agricultural sectors. The principal marketing channels in the district specializes in commodity marketing, general purpose marketing, private traders, and contractors.

The specialized commodity marketing, namely, APMC at district level and sub yards at *taluka* level. Mainly groundnut, cotton, wheat, castor, sesamum, jowar/ sorghum, bajari, garlic, etc. are selling through APMC and block level co-operative. They also generally lead with fruit crops at the block level, namely, Padara, Dabhoi, Savali, and Karjan.

Table 6.6 shows the area under crop production for identified crops for year 2014–15 in the district. As shown in the pie chart in Figure 6.7, out of the total crop produced, 35% area under cultivation is for cotton followed by maize whose area is 23%.

Table 6.6: Area under production for the crops in each district for the year 2014–15

Sr. No	Types of crop sown	Area (in kilo hectares)
1	Groundnut	10.80
2	Cotton	107.90
3	wheat	42.80
4	Paddy	23.30
5	Castor	25.50
6	Pigeon pea	19.20
7	Maize	71.57
8	Sugarcane	4.30
	Aggregate	**305.37**

Source: District Statistical Book, Vadodara (UPDATED-2015–16)

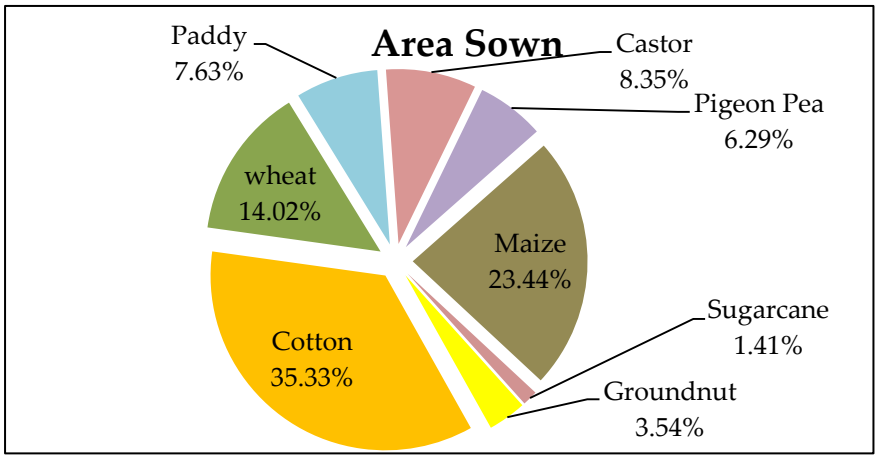


Figure 6.7: Per cent share of area of different crops sown in the district

6.3 Biomass resource analyses

The biomass of identified crops has been calculated with the formula mentioned in Methodology. Table 6.7 shows the major crop residue generated from different crops in the district.

Crop Residue	2014-15 (in Kilo MT)	Consumption (in Kilo MT)				Potential surplus
		Domestic cooking	Fodder	Fertiliser	Industries	
Groundnut Shell	7.0	-	-	-	7.0	7.0
Groundnut husk	46.90	-	46.90	-	-	

Cotton Stalk	410	116*	-	167*	-	273*
Castor stalk	102					
Pigeon pea stalk	43.75					
Cotton Husk	67.3	-	-	67.3	-	
Cotton ball shell	67.3	-	-	67.3	-	
Wheat Stalk	179.84	-	179.84	-	-	
Wheat Pod	35.97	-	-	-	-	
Paddy Husk	12.64	-	-	-	12.64*	12.64*
Paddy Stalk	94.80	-	-	94.8	-	
Paddy straw	94.80	-	94.8	-	-	
Pigeon Pea Husk	5.25	-	5.25	-	-	
Maize cob	18.75	-	18.75	-	-	
Maize stalk	125	-	125	-	-	
Sugarcane Bagasse	9.0	-	-	-	9	0
Sugarcane Top and leaves	1.4	-	1.4	-	-	
Total	**1321**	**116**	**472**	**396**	**28.64**	**292.64**

Table 6.7: Major crop residue generated in the district for year 2014–15

Out of this generated biomass, cotton stalk, paddy husk, sugarcane bagasse, groundnut shell, and stalks of castor and pigeon pea are taken into consideration. Other biomass is either used by the farmers as fodder, compost, and other domestic applications, such as cooking or is available in a very small quantity. Out of the total crop residue generated, that is, 1.3 million tonnes, the total available quantity of the considered crop residues in the district is 0.57 million tonnes.

In case of groundnut crop, husk along with seed pods are harvested and separated at the farmers' fields. Shells are separated from groundnuts at the agro-industrial level, that is, oil mills at a later stage for seed or oil extraction purposes.

In respect of cotton, lint along with seed is picked from standing crops and stalks are left drying at fields. Cotton stalks are removed from the field only after a gap of 15 to 30 days from its last picking in order to prepare the fields for the next season of crops.

6.4. Primary data collection

Primary data includes farmers as well as industrial visits. The types of crops grown in the districts are noted along with their physical verifications. In case of Vadodara District, variations in the data have been observed because the district has been divided into two (Vadodara and Chhota Udaipur). Once the survey was completed, classification of the crops into major or minor crops was done. The yield of crop at the field was gathered from land owners and was compared with the yield given by the agricultural department.

Thus, the district-level survey and the verification of biomass-residue generation at the fields were carried out.

However, it cannot be said that this will represent the true picture of the surplus availability. On completion of the field-level survey, other tasks, such as cost at source and trend, availability and transportation cost, etc. were also gathered.

6.4.1 Farmers and KVK survey

The major crops grown by farmers in Vadodara District are cotton, wheat, pigeon pea, castor, and maize. Other than this, they also grow onion, garlic, and other vegetable crops. The main aim was to interact with the farmers in order to get a holistic view of the agricultural scenario of the region along with their personal viewpoints. Crop yields vary from year to year and place to place depending upon rainfall, soil conditions, and farm-management practices.

Based on the source of generation, crop residues generated from agriculture activities at the field/ household level are identified as field-level residues (stalks, straw) which are the leftover of agriculture crops after harvesting and are either found at agriculture fields or with the farmers in their habitations.

As observed during the field survey, only crops that generate a substantial quantity of residue and have a surplus are considered for assessment. Residue generated from crops, such as pulse stalks, maize stalks, and bajra stalks are not considered for assessment since the crop residues are either entirely used for fodder purposes or their generation is widely dispersed in small quantities.

At the field level, predominantly, the stalks are residues of cotton, castor, maize, and pigeon pea. As per the interaction with KVK officials, cotton is grown in both kharif and rabi seasons, but majorly grown during the Kharif season. The current practice of disposing cotton stalk is shifted from composting to open burning. This is due to fact that while disposing the cotton stalk after shredding it in the field itself results in destroying the cotton ball and lint due to the “pink ball worm” present in the cotton stalk. Therefore, farmers cogently have to burn the cotton stalk in the field. As in Vadodara District, 50% farmers has small land holdings. Hence, they all consume the cotton stalk produced for their domestic cooking and heating. Therefore, some amount of the stalk is used for domestic cooking and the rest is burnt in the fields. Maximum availability of cotton stalk is during the months of January to March.

Pigeon pea stalk and leaves are mixed together after threshing and is used as fodder. The price of this mixture is around Rs 1/ kg. Maize cobs and paddy straw are used wholly as fodder. The area under castor production is decreasing significantly from the last three years due to destruction of crops by wild animals.

Maize grains are the major food for poultry. Almost 50% of the total maize grains go to poultry and oil mills at a prize of Rs 13–18/ kg.

The summary of farmers’ interviews is shown in Table 6.8. The details of farmers’ interview are given in Annexure X. In Gujarat, 4 *bigha* is roughly equal to 1 hectare.

Table 6.8: Summary of farmers’ interviews

Crop	Yield (Tons/Hec)	Biomass	Uses
Cotton	4	Cotton stalk	• Burnt in fields • Used for domestic cooking
Maize	8	Maize cobs, leaves and waste	Goes to fodder at Rs 1,000 to 1,500/ tonne

Crop	Yield (Tons/Hec)	Biomass	Uses
Pigeon Pea	2	Stalk	Left in the fields and used for cooking
Castor	2	Stalk and shells	Castor shell goes to brick kilns at Rs 2,000/ tonne
Paddy		Stalk, straw and husk	Stalk and straw goes to fodder, husk goes to brick kilns from rice mills at Rs 2,000–4,000/ tonne

Figure 6.8: Meeting with farmers and KVK officials

6.4.2 Industrial survey

In Vadodara District, the major biomass-related industries are chemical industries, rice mills, maize oil mills, and bio-coal (briquetting) industries. During the survey, two maize oil mills, one rice mill, one bio-coal industry, one sugar mill, and one chemical industry have been surveyed to know the biomass supply and demand scenario in Vadodara District. Other than this, a biomass based power plant was also visited which is wood based. The details of the industrial interviews have been given in Annexure IX.

6.4.2.1 Maize corn oil mills

Maize is the major crop used for oil production in Vadodara District. In this regard, two maize oil mills were surveyed. Maize grains are purchased by oil mills at Rs 13–18/ kg from APMC. The maize-processing capacity of the oil mills visited was 50 and 100 TPD. Wood is used as a fuel in the boiler. Oil mills produce 20%–25% of maize oil which is used for human consumption while the rest is oil feed which is used in animal husbandry. Based on the interaction with oil mill owners, 1.6 tonne of wood is used in boiler to process 50 tonnes of maize grains for oil production. Cost of wood is Rs 2–2.25/ kg. Though these units do not produce biomass residue, we nevertheless use wood as a boiler fuel.

6.4.2.2. Bio-coal industries

As per the survey, there are around 5–6 bio-coal industries in Vadodara District, out of which one was visited based on the interest shown by owner. The capacity of the machine is 1 tonne/ hour. The major residues used are sawdust and groundnut shell. Almost all the groundnut shell in Vadodara District comes from the Shaurashtra region. All of these plants are based on piston press technology. The production cost was found to be around Rs 510/ tonne including labour and electricity charges. The cost of raw material varies from Rs 3,000 to 3,200 per tonne for saw dust and Rs 4,000 to 4,200 per tonne for groundnut depending upon the seasonal availability of groundnut. These machines are operational for 8 hours/ day. Transportation cost of briquettes is Rs 15–20/ km/ tonne. The selling price of briquette ranges from Rs 5,500 to 5,600 per tonne. These briquettes are used in chemical and boiler industries.

- There are only 5–6 bio-coal industries in the district. Most of them have shifted their business from bio-coal to something else due to unfavourable market reception of bio-coal as the price of wood in Vadodara District is less (Rs 2,000–2,500/ tonne).
- Eighty per cent of the bio-coal used in the district comes from Saurashtra region.
- Industries in Vadodara are reluctant to use biomass and bio-coal as wood and coal prices are exceptionally low (Rs 2–2.5/ kg for wood and Rs 5/ kg for coal). This is the main reason for a limited and unsuccessful business of bio-coal in Vadodara

Figure 6.9: Bio-coal unit in Vadodara

6.4.2.3 Rice mill

There are only 8–10 rice mills in the district. The capacity range of these rice mills are approximately 4–10 tonnes/ day. These mills are operational seasonally from November to January. In the process of milling, 15-20% husk is produced. Most of the rice mills are located in Dabhoi District. The cost of rice husk is approximately Rs 3,000 to 4,000 per tonne including the processing cost (Rs 1.5/ kg), labour cost (Rs 0.9/ kg), and transportation cost is around Rs 400/ tonne as transportation cost within 25 km is Rs 2,500–3,000 (for 6–7 tonnes). The major consumers of rice husk are brick kilns.

6.4.2.4 Sugar mill

There is only one sugar mill in the district Sitaram Sugars Allied Industries Ltd situated in the *taluk* Bodeli in Vadodara. The average price of sugarcane is around Rs 2,600/ tonne. Currently, the mill is closed due to cane shortage. The mill's maximum cane-crushing capacity is 2,500 tonnes/ day. However; its actual cane-crushing capacity is only 500–600 tonnes/ day. The total sugar recovery from this, that is, the cane crushing, is merely 10%. 25% bagasse is generated from the mills out of which more than 20% is used by the mill to generate steam for power production through bagasse-fired boilers. A total 3MW of power is generated which is fully consumed by the sugar mills for their captive use. The mill is functional during the months of November to March. Surplus bagasse generated is 30–5 tonnes/ day. This bagasse has 50% moisture and is sold to other boiler industries at a cost of Rs 1,600–2,000 per tonne. Bagasse price includes loading cost (Rs 125/ tonne), unloading cost (Rs 125/ tonne), and transportation cost (Rs 400/ tonne for 80–90 km). The calorific value of generated bagasse is 2,250 kCal/ kg.

6.4.3 Observations and analysis

6.4.3.1 Stalk consumption and surplus

The stalks of cotton, pigeon pea, and castor do not have much commercial use in the Vadodara Districts. The stalks are often ploughed back into the soil or are disposed of by burning in the agricultural fields itself. The stalks (the thicker stems) are also partially used for domestic cooking by small farmers and labours. As per the 2011 census data, the total number of households in the Vadodara Districts is 880,121 out of which 418,851 are rural households. The total number of households using crop residues is 53,126. As per the interaction with the farmers, per day per household consumption of crop residue for cooking is around 6 kg, assuming there are five members in every household. Table 6.9 shows the total estimated annual crop residue consumption for cooking in Vadodara District from secondary sources. As per the interaction with farmers, roughly 30% of the total stalks are ploughed back into field.

Table 6.9: Estimated annual crop residue consumption for cooking in Vadodara District

Total household in Vadodara district	**418,851**
Households using crop residue as a fuel for cooking[40]	53,126
Per day per household cooking requirement (kg)	6
Estimated annual consumption of stalks for cooking (KMT)	116
Estimated amount of stalks ploughed back into the field (KMT)	167
Total annual consumption of stalks in cooking and ploughing back into the field (KMT)	283
Estimated potentially available stalks of cotton, castor and pigeon pea (KMT)	273

[40] http://www.censusindia.gov.in/DigitalLibrary/MFTableSeries.aspx

6.4.3.2 Consumption and surplus of rice husk

As per the interaction with rice mill owners, the paddy husk that is produced goes to the brick kilns. Hence, the entire rice husk is potentially available for other competitive use such as biomass power generation. Therefore, the total potential availability of rice husk is 12.64 kilo MT.

6.4.3.3 Consumption and surplus of groundnut shell and sugarcane bagasse

In Vadodara District, the production of groundnut is rather limited (23 KMT). The demand of the groundnut shell required for industries using boiler is mostly fulfilled by the districts of the Saurashtra region. The potential surplus of groundnut shell is 7 KMT which is currently consumed either by bio-coal industries or by boiler industries.

The total bagasse generated from the sugar mills in Vadodara District is 9 KMT out of which 95 to 100% is used by the boiler. Hence, there is no surplus bagasse generated in the district.

6.4.4 Institutions

In Vadodara District, there are a total of 861 midday meal-serving institutions through which a total of 53,828 students are served with midday meals. These midday meal-serving institutions cook their food using only LPG. There is no single institution in the whole district which is based on fuel other than LPG. Hence, the institutional demand of biomass for cooking is zero.

Table 6.10: Data regarding the midday meal cooking pattern

District	Total no. of Institutions	Mode of cooking (No. of Schools)			
		LPG	Solar Cooker	Fire wood	Others
Vadodara	1,297	1297	0	0	0

Source: MDM office, Gandhinagar

6.4.5 Summary of biomass generation, consumption, and surplus

Table 6.11 shows the generation, consumption, and surplus of the available biomass. In this study, biomass consumption does not include burn in open field. The total generated quantity of the crop residues in the district is 13.2 lakh tonnes out of which residue generated from the considered crop residues, that is, cotton stalk, groundnut shell, castor stalk, pigeon pea , paddy straw, and sugarcane bagasse are 5.9 lakh tonnes. The current consumption of the selected crop residues is estimated at 3.11 lakh tonnes. So, potentially the surplus quantity of the available biomass is 2.92 lakh tonnes.

Table 6.11: Biomass generation, consumption, and surplus (KMT/ annum)

Biomass	Generation	Consumption	Available
Stalks of cotton, castor and pigeon pea	556	283	273
Groundnut shell	7	7	7
Paddy husk	12	0	12
Sugarcane bagasse	9	12	0
Total	**584**	**311**	**292**

6.5. Biomass cost analysis

As per the interactions with the farmers; at present there are no transactions with respect to crop residues. However, when asked during the survey, farmers have opined that if at all they sell crop residue, they would consider factors, such as labour cost for collecting residues from the field before it is transported to other places. In case of cotton stalk, a tonne of cotton stalk collection from a field requires five to six man days. The cost of each man day is around Rs 200. Hence, the cost works out between Rs 1,000/ - to Rs 1,200/ - per tonne of the residues. Though, at present, the farmers are not expecting any consideration apart from labour costs, in actual terms they might demand an additional amount. Based on observations in the field, remuneration to farmers is assumed to be Rs 200 to 500 per tonne for cotton stalk apart from the handling charges and transportation. In case of castor and pigeon pea stalk, farmers have no knowledge of the costs involved in the uprooting, bundling, and labour charges (as it is not the current practice at commercial scale in the district). As per the interaction with the farmers, the team got to know that the cost economy of castor and pigeon pea stalk—which includes uprooting, bundling, loading, unloading, etc.—may be similar to the cost economics of cotton stalk. Therefore, the costing of castor and pigeon pea is assumed to be similar to that of cotton stalk.

As groundnut is not the major crop in the district, shell generation in the district is rather less. Moreover, all the requirement of groundnut shell by industries is fulfilled by exporting from the districts of the Saurashtra region (Bhavnagar, Junagadh, Amreli, and Rajkot). Hence, the costing of groundnut shell is not considered while calculating the weighted average of fuel cost for Vadodara District. As availability of stalks is high and uniform in the district, therefore, it is assumed it can be made available within a radius of 0–25km, while in the case of rice husk, transportation is considered in the range of 0–50 km.

Tables 6.12 and 6.13 show the estimated total cost of cotton, castor, pigeon pea stalks as well as paddy straw, respectively.

Table 6.12: Cost of stalks of cotton, castor, and pigeon pea

Particulars	**Stalks of cotton, castor and pigeon pea (Rs/Ton)**
Labor charges for uprooting, bundling and loading	1000-1200[41]
Shredding cost	350
Farmer's remuneration	500*
Transportation cost (0-25 Kms)[42]	450
Unloading cost	125
Av. Landed cost	**2525**

*Farmers are not aware about the fluctuation in price due to moisture loss

[41] The collective cost of uprooting and labor cost was obtained from farmers interaction

[42] This information was collected from bio coal and interaction with transport person was not done.

Table 6.13: Cost of Paddy straw

Particulars	Paddy husk (Rs/Tonne)	References
Processing cost	1,500	From rice mill owner
Loading, unloading and packing cost	900	From rice mill owner
Transportation (0-50 km)	800	From rice mill owner
Av. Landed cost	**3,200**	

6.5.1 Cost of fuels including losses

After getting the landed cost of fuels, losses in weight due to moisture and dust/ sand/ stone present in the fuel from oil mills/ farmers' fields/ rice mill has to be considered. In case of stalks of cotton, castor, and pigeon pea 15% loss in weight is due to moisture and a 5% loss in weight due to dust/ sand/ stone has been considered. In case of paddy husk, handling losses is considered as 5% each Table 6.14 shows the biomass price per ton considering moisture and dust/ sand losses.

Table 6.14: Final cost of paddy husk and cotton stalk considering losses

Description	Biomass Price/ton	Moisture[43]		Dust/sand/stone		Total Weight losses in kg per ton	Biomass Price Per tonne considering losses
		%	Weight loss in kg per tonne	%	Weight loss in kg per tonne		
Stalk of cotton, castor and pigeon pea	2,525	15	150	5	50	200	3,156
Paddy husk	3,200	-	-	5	50	50	3,368

6.5.2 Weighted average

Weighted average of the fuel cost has been calculated based on the consideration that stalks of cotton, castor, and pigeon pea are available in more quantity (126 KMT) as compared to the available quantity of paddy straw (12.64 KMT, respectively) So, it is assumed that 90% cotton stalks, castor, and pigeon pea are available, while the remaining 10% is paddy husk. Hence, 90% weightage is taken for stalks of cotton, castor, and pigeon pea, while 10% weightage is considered for paddy husk for calculating the weighted average of fuel cost. So, weighted average cost of fuel comes out to be **Rs 3,177 per tonne** at corresponding weighted average moisture of 4220 kCal/ kg.

[43] In case of stalks of cotton, castor, and pigeon pea, moisture values were assumed from literature and the respective project developers. Experimental value need to be assessed

Chapter 7 Sabarkantha District

7.1 Brief profile of Sabarkantha District

7.1.1 Location and geographical area

Sabarkantha is a north-eastern district of Gujarat and its prominent district offices and headquarters are located in Himatnagar. The district is infolded by Rajasthan to its north-east, Banaskantha and Mehsana districts to its west, Gandhinagar to its south, and the Aravalli District to its south-west. In the year 2013, Aravalli district has been separated from Sabarkantha district. The north-eastern part of the district is covered by the hills of Aravalli and Sabarmati, Hathmati, and Harnav are the three rivers that flow in the Sabarkantha region. Sabarmati River flows on the western border of the district. The total area of the district is 5,390 sq. km.

Sabarkantha District incorporates eight blocks or *talukas*: Himatnagar, Idar, Khedbrahma, Poshina, Prantij, Talod, Vadali, and Vijaynagar, and the political map of Sabarkantha District is shown in Figure 7.1.[44]

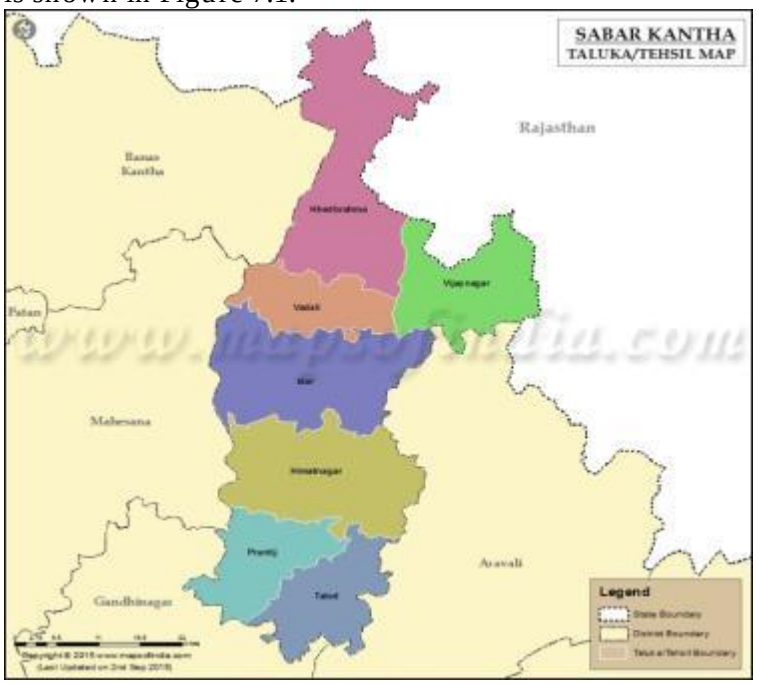


Figure 7.1: Political map of Sabarkantha District

7.1.2 Climate and rainfall

The Tropic of Cancer passes through Sabarkantha District, hence mercury is at an all-time high—44.4 °C—in these regions and in winters, the minimum temperature is around 10.2 °C. The district has low natural vegetation; however, numerous crops are grown in Sabarkantha. Of these, the main crops are: cotton, groundnut, maize, castor, pigeon pea, among a few other vegetables. The average rainfall of the district is found to be around 575 mms.

[44] Source: http://www.mapsofindia.com/maps/gujarat/tehsil/sabarkantha.html <Last accessed on May 2, 2017>

7.1.3 Administrative set up and demography

According to the 2011 census, the total population of the district was 1,388,671, out of which the female and male population were 676,826 and 711,845, respectively. The major population, that is, 82.92% of district, lives in rural area. The socio-demographic data of Sabarkantha District shows that the population density is 328 persons per sq. km. The district has a moderate literacy rate of 75.79%. The basic specks of the district have been given in Table 7.1. The demographic profile of the district is shown in Annexure III.

Table 7.1: District at a glance[45]

S No	Particulars	Statistics	Unit
1	**Geographical features**		
A	**Geographical data**		
	a) Latitude	23.03° to 24.30° North	Degree
	b) Longitude	74.43° to 73.39° East	Degree
	c) Geographical area	539,000	Hectares
B	**Administrative units**		
	a) Sub Division	01	
	b) Tehsil	8	Numbers
	c) Panchayat Samitis	13	
	d) Nagar Palika	8	Numbers
	e) Gram Panchayats	436	Numbers
	f) Revenue villages	692	Numbers
	g) Assembly areas	01	Numbers
2	**Population (Census 2011)**		
	a) Male	711,845	Persons
	b) Female	676,826	Persons
	Total population	1,388,671	Persons
3	**Education (2013-2014)**		
	a) Primary schools	2,855	Numbers
	b) Secondary and senior secondary schools	569	Numbers
	c) Middle schools	-	Numbers
	d) Colleges	32	Numbers

[45] District industrial potentiality survey report of Sabarkantha District (2016–17)

7.2. Agricultural scenario of Sabarkantha District

7.2.1 Agricultural land holding pattern

There are a total of 153,193 farmers with a total land area of 252,744 hectares in Sabarkantha District. The percentage share of different land holdings as shown in Figure 7.2 indicates that approximately 25% land holdings are less than one hectare, 13% are between 1 to 2 hectares, and 62% are above 2 hectares. Table 7.2 shows the number of farmers with a different scale of land including small, medium, and large holdings. A *taluka*-wise land holding pattern and the number of farmers per holding have been given in Annexure V.

Table 7.2: No. of farmers based on their land holdings[46]

S.no	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Small	0–1	43,909	63,116
2	Medium	1–2	74,051	33,959
3	Large	Above 2	35,233	155,669
Aggregate			**153,193**	**252,744**

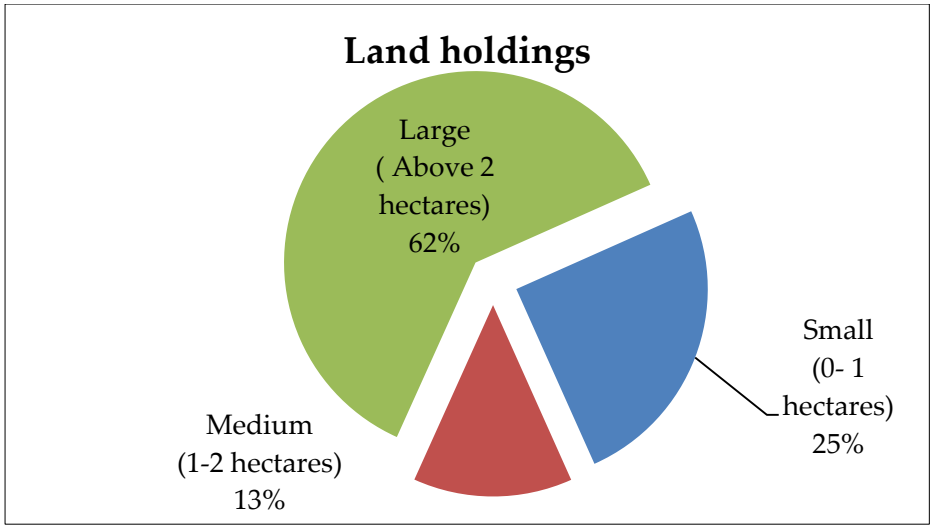


Figure 7.2: Percentage share of different land holdings

7.2.2 Land use pattern

The total reported area for the purpose of land use is 729,828 hectares, of which nearly 240,280 hectares (or 59%) is the net sown area. Other than the net sown area, land is classified under different categories, such as permanent pasture and grazing land, cultivable fallow land, forest land, land under non-agricultural use, barren, and uncultivable land, etc. A *taluka* wise land use pattern including areas under forest, non-agricultural land, grassland, and net cultivated land is given in Annexure VI. Figure 7.3 shows the percentage share of land use patterns.

[46] DAO, Sabarkantha

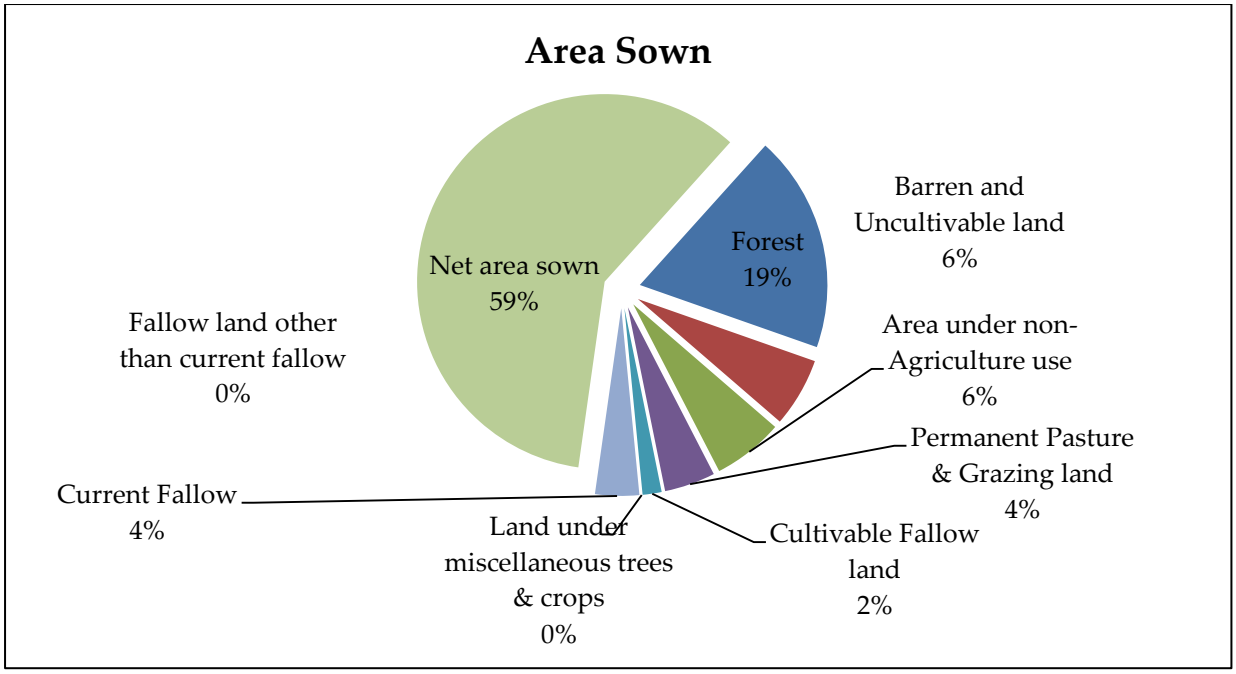


Figure 7.3 Land use pattern

7.2.3 Year-wise area production and yield pattern

Agriculture is the main source of income in the Sabarkantha District. There are various crops grown in the district based on climate conditions but the majority of cultivable land is occupied by cotton, castor, maize, groundnut, pigeon pea, wheat, and a few vegetables. Depending upon the rainfall, a slight shift in the cropping pattern is clearly observed due to less monsoon showers resulting in a huge reduction in crops that are water dependent.

The focus of the industry sectors are agricultural-based industry, ceramics, chemicals, and milk processing units. The important raw materials, such as groundnut, cotton, clay, oilseeds, and tobacco are abundantly present in Sabarkantha. The total production of castor and cotton in Sabarkantha District in 2014–15 was 298 KMT and 280 KMT.

In the present report, we have considered only six major crops in our study including groundnut, cotton, wheat, pigeon pea, castor, and maize. Figure 7.4 shows the year-wise crop production data of Sabarkantha District for the last three years. It can easily be deduced that there is a large variation in production of all the crops in the mentioned years. Data for year 2013–15 has not included due to its unavailability.

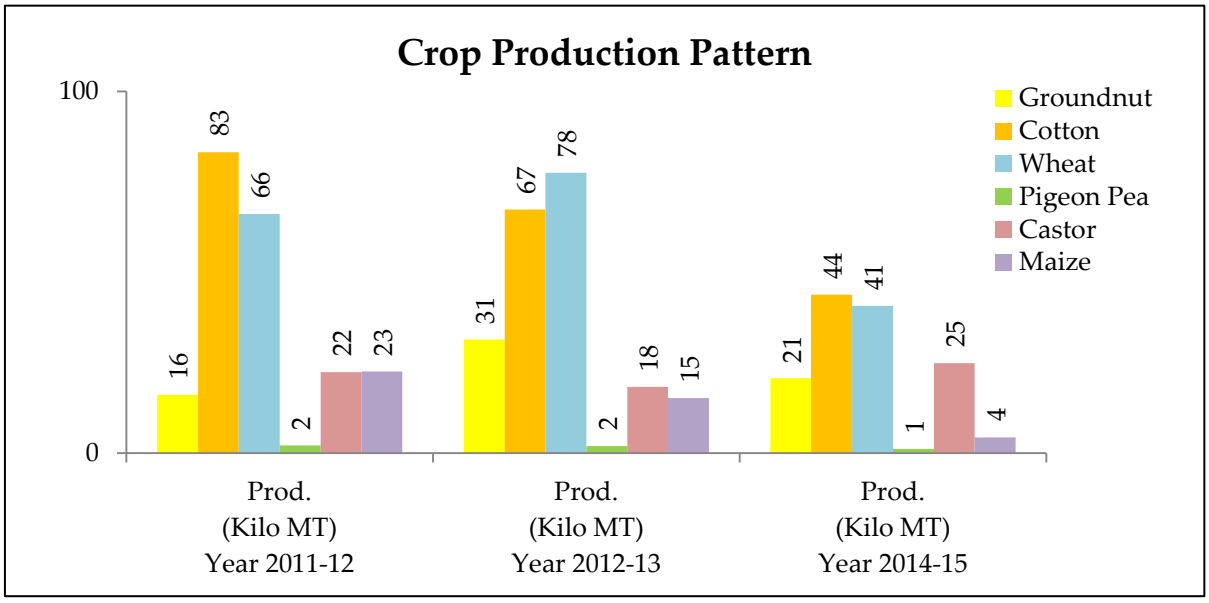


Figure7.4: Year-wise crop production trend

Figure 7.5 depicts the area under cultivation for three years; the figures show that during year 2011–12, the area under crop is high for groundnut and pigeon pea, whereas in the year 2012–13 and 2014–15 the area under cultivation has drastically reduced.

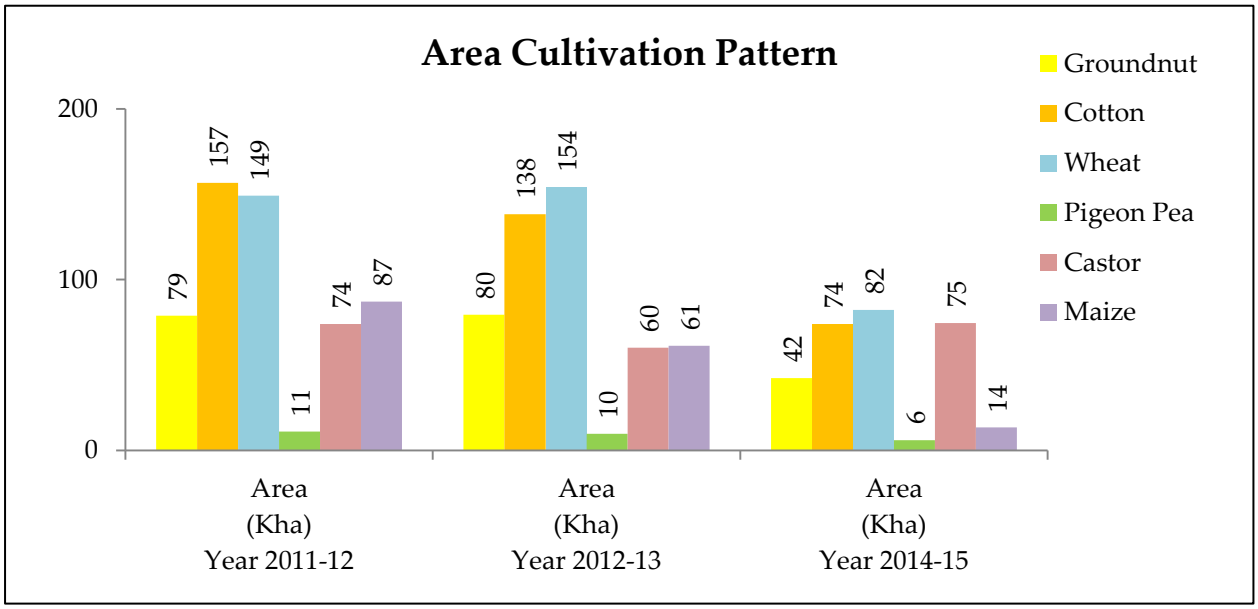


Figure 7.5: Year-wise land under cultivation for different crops

Table 7.3 shows the area, production, and yield data of the selected crops for the year 2014–15. It can be easily be seen from the table that cotton is the major crop with a production of 44 KMT followed by wheat (41 KMT) and Castor (25 KMT).

Table 7.3: APY data of selected crops for 2014–15[47]

Sr. No.	Name of the Crop	Year 2014-2015		
		Area (Kha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Groundnut	42	21	0.5
2	Cotton	74	44	0.6
3	Castor	75	25	0.3
4	Wheat	82	41	0.5
5	Pigeon pea	6	1	0.2
6	Maize	14	4	0.3

7.2.4 Cropping pattern

Cropping pattern in Sabarkantha is mostly maize-wheat, cotton-groundnut-wheat, castor, maize-pigeon pea, and horticulture-based under-irrigated conditions.

There is a significant increase in cotton production after adopting modified species of cotton, that is, Bt. Cotton. Also, Sabarkantha is one of the leaders in oil seed production. Under irrigated conditions, oilseed crops are cultivated in most blocks. During kharif season, cotton is sown in major areas, while castor occupies the second-highest place in terms of the area sown. An area, production, and yield of identified crops for the last three years are given in Annexure IV. As shown in the pie chart in Figure 7.6, out of the total crop produced, around 15.20% area under cultivation is for wheat. Caster is the second-major crop grown in the district with around 13.76% area under production, whereas cotton stands in the third place with 13.68 %.

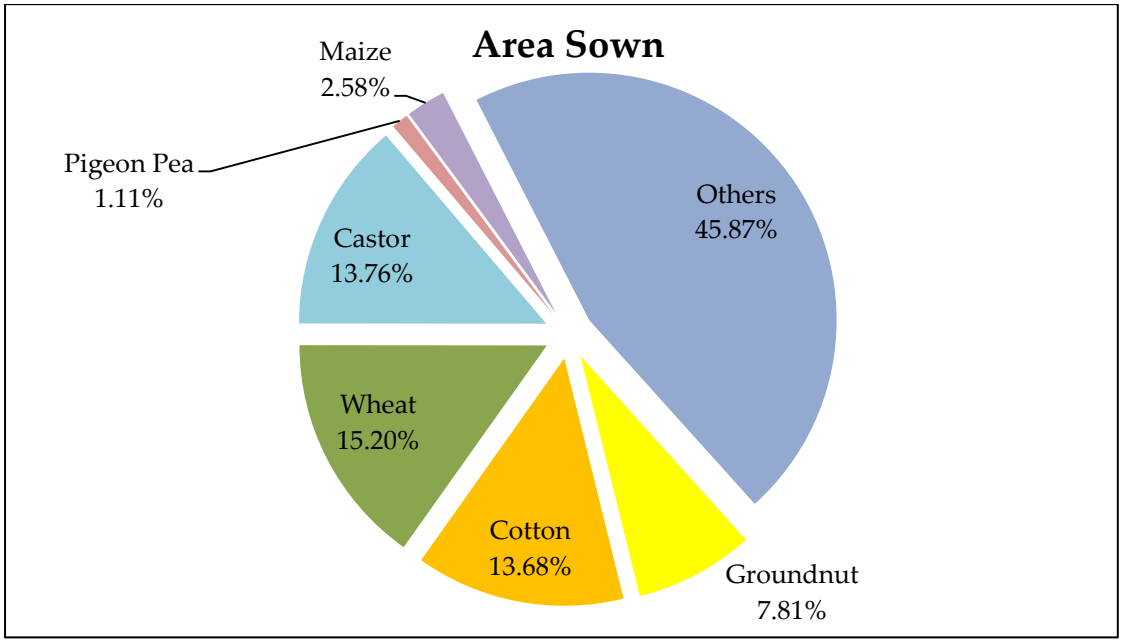


Figure 7.6: Precent share of area under different crops sown in the district

[47] Directorate of Agriculture, Gandhinagar

7.3 Biomass resource analysis

7.3.1 Total biomass generated

As per the formula described in the methodology section, crop residue or biomass of the identified crops has been calculated. Table 7.4 shows the values of major crop residue generated from different crops in the district for the year 2014–15.

Table 7.4: Major crop residue generated in the district

Crop Residue	Generation in 2014-15 (kilo MT)	Consumption (kilo MT)				Potential surplus (kilo MT)
		Household Cooking	Fodder	Industry	Manure	
Groundnut Shell	6	0	0	3	0	3
Groundnut Husk	41	0	41	0	0	0
Cotton Husk	82	0	0	0	82	0
Cotton Boll Shell	82	0	0	0	82	0
Wheat Pod	12	0	12	0	0	0
Maize cob	1	0	1	0	0	0
Maize stalk	9	0	9	0	0	0
Pigeon Pea Husk	0.3	0	0.3	0	0	0
Cotton Stalk	280	151*	0	58*	173*	196*
Castor Stalk	298					
Pigeon Pea Stalk	3	0	3	0	0	0
Wheat Stalk	61	0	61	0	0	0
Aggregate	**875.3**	**151**	**127.3**	**61**	**337**	**199**

*Explained in section 7.5.1

Out of this generated biomass, a majority of the cotton and castor stalk are burnt in fields and groundnut shell is majorly used in bio-coal industries. Other biomass is used by the farmers either for fodder or for other domestic applications, such as cooking, heating, etc.

In case of groundnut crop, stalks along with seed pods are harvested and separated at the fields/ household level. Shells are separated from groundnuts at the industrial level, that is, groundnut decorticators/ oil mills at a later stage for seed or oil-extraction purposes.

In case of cotton, lint along with seed is picked from standing crops and stalks are left drying at the fields. Cotton stalks are removed from the field only after a gap of 15 to 30 days from its last picking in order to prepare the field for the next season.

In case of caster, seeds are picked from the standing crops and the stalks are left to dry. Castor seeds are removed at the fields itself; the stalks are removed after 10–20 days from the last picking.

7.4 Primary data collection

Interactions were carried out at the district level with district government departments. Contacts of farmer groups and industries were provided by the agricultural and industrial centres, respectively. A team of two persons accompanied by an executive officer from UGVCL visited the farmers' groups, traders, and industries over duration of 5 days in

Sabarkantha. Since in year 2013, the district was bifurcated into two separate districts; it is for this reason that a data discrepancy has been observed. .

7.4.1. Farmers survey

7.4.1.1 Farmers' information

A selection of *talukas* was done on the basis of a potential for three major crops (cotton, castor, and groundnut) grown in the district. The information was gathered from secondary sources and in consultation with DAO at Sabarkantha; the four talukas thus selected were Talod, Idar, Khedbrahma, and Prantij. A total of 12 farmers were surveyed that included farmers with small, medium, and large land holdings.

Table 7.5: Indicative of a list of farmers surveyed

Name of Taluka	Number of farmers surveyed	Range of land holdings (hectares)
Idar	2	2.2 to 16
Khedbrahma	2	3 to 7
Prantij	4	2.5 to 10
Talod	4	3.2 to 28

Figure 7.7: Interview with farmers in the four blocks of Sabarkantha District

7.4.1.2 Data collection

Table 7.6 presents a summary of farmers who were interviewed during the team's visit to Sabarkantha District.

Table 7.6: The summary of farmer interviews conducted in Sabarkantha District

Crop	Crop production (Tons/Hectare)	Crop selling price (Amount in rupees per 20 kg)	Biomass residue from crops	Uses
Cotton	1.7-2.5	900–1,000	Cotton stalk	Burnt in fields Converted to manure in fields and for household usages
Groundnut	0.5-2	600–900	Groundnut shell	Given to oil mills/ traders/ APMC
			Groundnut husk	100% fodder
Wheat	2-3.5	350–500	Wheat straw	50%–60% fodder and 50%–40% manure
Pigeon pea	0.7	800–1,000	Pigeon pea stalk	Used for cooking purposes
Maize	1.7	250–300	Maize cob	Goes in fodder
Castor	1-1.5	500–600	Castor stalk	Used for cooking purposes, bio-coal industries

As per the given table, the major crops grown by farmers in Sabarkantha District are cotton, castor, groundnut, and wheat. Other than this, they also grow pigeon pea and maize but in limited quantities. As per the interaction with farmers, it was found that the crop yield range varies from year to year depending upon rainfall.

Based on the source of generation, crop residues generated from agricultural activities at the fields/ household levels are identified as field-level residues. Field-level residues (stalks, straw) are left after the harvesting of agricultural crops.

7.4.2 Observations

During the interaction with various farmer groups, the following observations were made:

Stalks of cotton, castor, and pigeon pea: According to the farmers, currently, some quantity of stalks are being used as fuel for domestic cooking, 5% cotton stalk is diverted into bio-coal industries, and the rest is burnt/ buried in the fields. This is done after a week from the harvesting season. The reasons stated for burning the stalk in the field are due to the costs involved in the uprooting of the stalk from the field with no alternative use of the stalk thereafter. However, farmers in the Idar, Khedbrhma, and Talod *talukas* have now started purchasing/ renting shredder machines for ploughing the stalks and thereafter using it as manure in their agricultural fields. The shredder machines charged on an hourly basis—Rs 600–700/ hour.

Groundnut shell: According to the farmers, the entire groundnut produce is purchased from the farmers at market price by the traders/ APMC/ oil mills.

Other residues: According to the farmers, wheat straw and groundnut husk goes to fodder. Other residues such as maize stalks and its cobs are produced less in quantity and are used for fodder purposes.

Therefore, it can be inferred from the field survey that stalks are available as field residue which is available in a rather large quantity. The farmers are ready to sell the stalks at a price ranging from Rs 900 to 1,100 per tonne rather than burn it in the open fields. This is majorly the cost of labour involved in uprooting the stalks form the field and loading it onto trucks/ tractors.

Detailed information regarding the farmer visits has been shared in the Annexure X.

7.4.3 Industrial survey

In Sabarkantha District, major biomass-related industries are oil mills, chemical, dairy, decorating, and bio-coal industries. These industries are mostly based on groundnut and groundnut shell, cotton stalk, saw dust, and castor stalk. The details about the conducted industrial survey have been listed below.

7.4.3.1 Oil mills

Farmers in Sabarkantha District sell their entire groundnut produce to traders. Some traders are involved in processing the groundnut (oil mills), whereas some directly sell the produce in the market. Mostly, Sabarkantha has mustard oil-based oil mills; the total number is 10 that include all types. The two oil mills based on groundnut shell were found with a crushing capacity of 5 and 35 tonnes/ day. The team visited both the oil mills in the district. As per the survey, around 70%–75% of the total groundnut crop produced in the district is used for crushing in the oil mills and the rest 25%–30% of the groundnut is sold in the local market.

In case of oil mills, groundnut shells are separated from nuts. The following are the key observations from the oil mills:

- The operating season of these units are between the months of October to January and July to September. But more than 80% is processed during the months of October to January.
- The capacity of groundnut crushing ranges from 5 tonnes per day (small) to 35 tonnes (medium) per day.
- APMC or traders sell groundnut at a price of Rs 35–45 per kg. Oil mills separate groundnut shells from the seeds during the oil extraction process.
- Some oil mills use around 20% of the total groundnut shells as a fuel in the boiler while the remaining 80% is supplied either to the bio-coal industries or other agro-based industries outside the district or even to the power plants. However, some oil mills use 100% groundnut shell as fuel in the boiler.
- Price for groundnut shell varies from 2.5 Rs/ kg (October–December) to 4 Rs/ kg (July–September) depending on the season.
- Price of the groundnut shell sold to power plants from the mills ranges from 2.5 to 4 Rs / kg and, if sold through a contractor, there is an increase in the price to around 0.5 Rs/ kg. This has been shown in the following table. .

Table 7.7: Prices of ground and its shell in Sabarkantha

Selling price of groundnut from APMC to oil mill (Rs/kg)	Selling price of groundnut shell from oil mill to power plant, bio-coal and agro-industries (Rs/kg)	Selling price of groundnut shell at power plants via a contractor
35–45	2.5 to 4	3 to 4.5

Considering the total number of oil mills in the district is five, the total shell produced from the oil mills can be estimated as 3,000 tonnes per annum.

Figure 7.8: Visit to oil mill industries in Sabarkantha District

7.4.3.2. Bio-coal industries

As per the survey, there are two bio-coal industries in Sabarkantha District, and the two industries were visited by the team for data collection. Both bio-coal industries using saw dust as its major ingredient is followed by castor stalk, groundnut shell, and cotton stalk. The ratio of combination is as follows: castor 10%–20%, groundnut shell 30%, and saw dust 50%–60%. Sometimes, jeera husk is also used as a bio-coal constituent in a minor fraction. Saw dust is purchased from nearby districts. The groundnut shell was procured either directly from the traders or from the oil mills, whereas cotton stalk was purchased from farmers and jeera husk from Talod *taluka*. The following observations were made after interacting with the industries:

- The range of capacity of two plants visited is 4,800 and 9,000 tonnes/ year, respectively.
- All these plants are based on piston press technology. The production cost was found to be Rs 600 to 750 Rs/ tonne including labour, electricity, and maintenance.
- The cost of raw material varies as shown in Table 7.8 depending upon the seasonal availability, and its inclusive transportation cost. The price of raw material is high during the months of October to January and less during the months of July to September.
- The selling price of bio-coal is given in Table 7.9 and it varies with the price of raw materials. These bio-coals are used in chemical industries, pharmaceutical industries, rolling mills, etc. based in cities, such as Vadodara, Ankleshwar, and Sabarkantha.

Table 7.8: Cost analysis of groundnut shell and its bio-coal in Sabarkantha District

Bio coal units	
Parameters	**Unit 1**
Capacity (tonnes/ year)	4,800
Purchasing price of raw material (Rs/ kg)	3.2–3.5
Transportation cost of raw material included in purchasing price (Rs/ kg)	0.45–0.5
Selling price bio-coal (Rs/ kg)	4–6

Table 7.9: Cost analysis of castor stalk and its bio-coal in Sabarkantha District

Bio coal unit	
Parameters	**Unit 2**
Capacity (tonnes/ year)	9,000
Purchasing price of raw material (Rs/ kg)	2–2.5
(Transportation + chipping) cost of raw material included in purchasing price (Rs/ kg)	0.2–0.45
Selling price bio-coal (Rs/ kg)	3.5–4

Figure 7.9: Visit to bio-coal industries in Sabarkantha District

7.3.4.3. Dairy industry

The Sabarkantha District Co-operative Milk Producers' Union Ltd (Sabar Dairy), Himatnagar, is the only dairy in the district. It handles around 25 lakh litres of milk per day. The basic milk pasteurization and other heating requirements are met by a 12 tonne/ hr pallet fired boilers. During a visit, it was found that the dairy currently uses saw dust pallets, which are brought from Kutch and Saurashtra regions. Details of the dairy is given in Table 7.10

Table 7.10: Details of Sabar Dairy

Dairy Unit	
Parameters	**Unit**
Pallets demand (tonnes/ year)	10,500
Purchasing price of biomass (Rs/ kg)	7 (fixed for whole year)
Average working days	300

Figure 7.10: Visit of Sabar dairy, Himatnagar

7.3.4.4. PVC leather manufacturing industry

In Prantij *taluka*, there is a big PVC leather manufacturing unit. The main product is rexene and this unit is the only such unit in Gujarat. The total production capacity of the plant is 12,000–14,000 metres/ day. Currently, the heat required for the various processes are being met by the two bio-coal fired boilers with a capacity of 6 KL/ hr. The total requirements of biomass are given in Table 7.11:

Table 7.11: Details of PVC leather industry in Sabarkantha

Production capacity (meter)	**12,000–14,000**
Bio-coal consumption (tonne/ day)	Groundnut 7
No. of operational days	260
Total consumption of bio-coal (tonne/ year)	1,820
Price of bio-coal purchase (Rs/ kg)	4–5

Figure 7.11: Visit to PVC leather-manufacturing unit

7.3.4.5. Groundnut shell-decorating industry

Decorating industries are well established in Sabarkantha District. The decorating industries purchase groundnut directly from the farmers and separate the shell. These groundnut seeds are then sold to international and national markets. There are around five decorating industries in Sabarkantha District with an average capacity of 4–10 tonnes/ day. The team visited one of the industries in Himatnagar for which the details are mentioned in Table 7.12.

Table 7.12: Details of a decorating industry in Himatnagar, Sabarkantha

Total groundnut handling capacity (tonnes/ day)	10
Season of groundnut availability	September–December and April–June
Groundnut shell produced (tonne/ day)	2 (20 % groundnut shell , 80% groundnut seeds)
No. of operational days	120
Total shell produced (tonne/ year)	240
Price of groundnut purchase (Rs/ kg)	4.5–5
Sell price of groundnut shell (Rs/ kg)	2–2.5

7.5 Biomass consumption and surplus analysis

7.5.1 Consumption and surplus of stalks of cotton and castor

The stalks of castor and cotton do not have commercial use in Sabarkantha District. Cotton stalks are often disposed of by burning it in the agricultural fields or are ploughed back into the soil. The other uses of cotton stalk include cooking and heating. As per the 2011 census, the total number of households in Sabarkantha Districts is 478,497. The total number of households using crop residues is 69,022. As per the interaction with farmers, per day per household consumption of crop residue for cooking is around 6 kg assuming there are five members in a household. As per the interaction with farmers, roughly 30% of the total stalks are ploughed back in to the field. Around 10% stalks of cotton and castor go to bio-coal industries. Table 7.13 shows the total estimated annual crop residue consumption for cooking in Sabarkantha District from secondary sources.

Table 7.13: Total estimated annual stalks consumption for cooking in Sabarkantha District

Stalks of castor and cotton generated in Sabarkantha(KMT)	578
Total no of households using crops residue as cooking fuel	69022
Per day per household fuel consumption (Kg)	6
Annual utilization of cotton stalk for cooking (K.M.T)	151
Amount of stalks ploughed back into the field (K.M.T)	173
Utilisation of stalks in bio-coal industries (K.M.T)	58
Total annual utilisation of stalks	382
Estimated cotton stalk left for open burning (K.M.T.)	**196**

7.5.2 Groundnut consumption and surplus

As per the above-mentioned observations, it has already been seen that groundnut shells are mostly produced in oil mills and decorating industries. The total shell produced from oil mills has been estimated as 3 KMT per annum. Groundnut shells are majorly consumed by bio-coal industries. Ninety per cent of the total fuel consumed in bio-coal industries comprises groundnut shell. About 20% of the total groundnut produced can be estimated to be used for local consumptions. There is no clear picture of the total groundnut-based oil mills, but as per the interaction with district industry centres, there are only two groundnut-based oil mills in the region.

7.5.3 Institutions

In Sabarkantha there are a total of 1,399 midday meal institutions under the midday meal scheme. All these institutions cook their food using only LPG, which is clearly charted in Table 7.14. Hence, the institutional demand of biomass for cooking is nil.

Table 7.14: Information related to the midday meal scheme in Sabarkantha District

Sl. No.	District	Total no. of Institutions	Mode of cooking (No. of Schools)			
			LPG	Solar Cooker	Fire wood	Others
1	Sabarkantha	1,399	1,399	0	0	0

7.5.4 Summary of biomass generation, consumption, and surplus

Table 7.15 shows the generation, consumption, and surplus of the biomass available. In this study, biomass consumption does not include burning it in the open fields. The total generated quantity of the crop residues in the district is 877 KMT out of which the residue generated from the considered crops, that is, cotton stalk and castor stalk are 578 KMT. The total available crop residue of the above-mentioned three crops is 254 KMT.

Table 7.15: Biomass generation, consumption, and surplus (KMT/ annum)

Biomass	Generation	Consumption	Available
Stalks of cotton & castor	578	382	196
Total	**578**	**382**	**196**

7.6. Biomass cost analysis

As per the interactions with farmers, at present there are no transactions with respect to crop residues. In case of cotton stalk—a low demand of the residue and high costs involved in uprooting of the cotton stalk—farmers are currently not inclined towards selling the stalk. However, when asked during the survey, farmers have opined that if at all they sell crop residue, they would consider factors, such as labour cost for collecting residues from the fields and storing them in a proper place before being transported to other places. Usually, a tonne of residue collection from fields requires four to five man-days. The cost of a man-day is around Rs 200. Though at present, apart from labour cost, the farmers are not expecting any considerations and in actual terms might demand an additional amount if the demand in the market increases for cotton stalk (example in case of power plants). Based on observations in the field, the estimated price for uprooting and bundling cotton stalk will be around Rs 900–1,100 per tonne for all the field-level crop residues apart from handling charges and transportation.

Castor stalk is generally purchased by bio-coal industries and the estimated cost for castor stalk is around Rs 600–700/ tonne. During the survey, an approximate cost for various components, such as shredding, uprooting, loading, unloading, and transportation was obtained from farmers, traders and industries. Table 7.16 and 7.17 give the estimated cost of cotton stalk and castor stalk prevailing in the district. As per this information, it was concluded that the cost economies of both cotton and castor stalks are similar.

Table 7.16: Cost of identified surplus residues

Particulars	Cotton stalk (Rs/Ton)	Reference
Farmer's remuneration	500*	From farmer
Labor charges for uprooting, bundling and loading[48]	900-1100	From farmers
Shredding cost	350	From farmers
Transportation cost (0-25 Kms)	500	From farmers
Loading cost	100	From farmers
Av. Landed cost	**2450**	

*Farmers were not aware about the fluctuation in price due to moisture loss

[48] The collective cost of uprooting and labor cost was obtained from farmers interaction

Table 7.17: Cost of identified surplus residues

Particulars	Castor stalk (Rs/Tonne)	Reference
Farmers' remuneration	500*	From farmers
Labour charges for uprooting, bundling, and loading[49]	600–700	From farmers
Shredding cost	350	From farmers
Transportation cost (0–25 km)	500	From farmers
Loading cost	100	From farmers
Av. Landed cost	**2,150**	

*Farmers were not aware about the fluctuation in price due to moisture loss

The above-mentioned table describes the total landed cost of cotton and castor stalk. The estimated average landed cost for cotton stalk and castor stalk were calculated as Rs 2,450 and Rs 2,150, respectively.

7.6.1 Cost of fuels including losses

After getting the landed cost of fuels, losses in weight due to moisture and dust/ sand/ stone present in the fuel from the farmers' fields have to be considered. In case of cotton, there is a 15% loss in weight due to moisture and factors such as dust/ sand/ stone have to be considered; also, in case of castor stalk, there is a 15% loss in weight due to moisture and this, too, has to be considered. Table 7.18 shows the biomass price per tonne considering moisture and dust/ sand losses.

Table 7.18: Final cost of castor stalk and cotton stalk considering losses

Description	Biomass Price/tonne	Moisture[50]		Dust/sand/stone		Total Weight losses per unit	Biomass Price Per tonne considering losses
		%	Weight loss per unit	%	Weight loss per unit		
Cotton Stalk	2,450	15	150	5	50	200	3,063
Castor Stalk	2,150	15	150	5	50	200	2,688

7.6.2 Weighted average

The weighted average of the fuel cost has been calculated by considering the fact that cotton and castor stalk are available during the harvesting season, that is, October to December. Furthermore, maintaining inventory of cotton stalk for more than a month is difficult as long-term storage has its own problems of safety and deterioration in quality due to degradation is largely unavoidable. Other than this it has a self-heating property if stored in large piles because of temperature development due to high-moisture content. As the net availability of cotton stalk and castor stalk is nearly in the ratio of 55 to 45. Therefore, in calculating weighted averages, 55% weightage is taken for cotton stalk while 45% weightage is considered in case of castor stalk. So, the weighted average cost of fuel comes out to be Rs 2,893 per ton at corresponding weighted average GCV of 4205 Kcal/ kg.

[49] The collective cost of uprooting and labour cost was obtained from interaction with farmers

[50] In case of cotton stalk and castor stalk, moisture values were assumed from literature and project developer. Experimental value need to be assessed.

Characteristics of biomass

Gross calorific value obtained from the samples of biomass collected from field is given in Table below. Lab report for GCV and moisture are given in Annexure XII

Table: GCV of field samples collected

Sample details	Gross Calorific value (Cal/gm.)	Moisture content (%)
Cotton stalk	4472	7.78
Groundnut shell	4315	6.03
Sugarcane	2,240[51]	50
Pigeon pea stalk	4,473	6.34
Castor stalk	3,876	7.47
Paddy husk	3,737	5.17

[51] From a sugar mill

Annexure I: Meeting details to various SNAs and stakeholders

Table A1.1 Meetings at the state level

Office	Name of contact person/contact number	Purpose of Visit/ Information obtained
GERC	Mr D R Parmar, Joint Director Mr S R Pandey, Legal advisor	To brief overall project progress and tour plan
Directorate of Agriculture	Mr S J Solanki, Jt. Director of Agriculture	To collect the district-wise agriculture data over the last three years
Collectorate, MDM	R G Trivedi, IAS (Ms Unnati)	District-wise MDM-related data
GEDA	Mr S J Ruparel, Senior Project Executive	Policies and existing biomass initiatives by GEDA
IC	Mr D R Parmar, Deputy Commissioner of Industries, Contact: 9724171192, 7096958566	List and contacts of industries operating in six districts.
Directorate of Economics and Statistics (DES)	Mr H R Khanger, Deputy Director, DES	District statistics, socio-demographic profile of districts

Table A1.2 Stakeholders' meeting, Junagadh District

Name of Stakeholder	Office	Data collected
Mr R M Gambhir	DPO, DSO	District Statistical Plan Handbook (2013–14, 2014–15, and 2015–16)
Mr N D Babaria	DAO	Crop production data of Junagadh District (last six years)
Ms Hetal Joshi	Deputy collector, MDM	Taluka-wise MDM data
Mr K L Gamit	DIC	Industries (MSMEs) information of Junagadh District)
Dr V P Chovatia Dr I V Dhruj	JAU, Junagadh	Information about agriculture scenario in Junagadh District

Table A1.3 Stakeholders' meeting, Amreli District

Name of Stakeholder	Office	Data collected
Mr K K Patel	DAO	Area under production data of Amreli District (last three years), facilitated meetings with farmer groups
Mr Nitin Choprani	DPO/ DSO	District Statistical Plan Handouts (2014–15 and 2015–16)
Mr P D Patel	DIC	Industries (MSMEs) information of Amreli District and facilitated meetings with bio-coal industries
Mr Sujeet Kumar	DDO	Facilitated meeting with DAO and DSO and also gave a few contacts of oil mills

Table A1.4 Stakeholders' meeting, Bhavnagar District

Name of Stakeholder	Office	Data collected
Mr Brijesh Joshi	DPO, DSO	District Statistical Plan Handbook (2013–14, 2014–15, and 2015–16)
Mr Kausambi	DAO	Area under production data of Bhavnagar District (last three years), facilitated meetings with farmer groups
Mr R K Vasava	DIC	Industries (MSMEs) information of Bhavnagar District and facilitated meetings with bio-coal industries.
Mr Ayush Oak Mr S J Chavda	DDO/ Deputy DDO , Bhavnagar	Information about the agricultural scenario in Bhavnagar District

Table A1.5 Stakeholders meeting, Bharuch District

Name of Stakeholder	Office	Data collected
Shri. Harish Lalwani	DAO	District agricultural data (last three years), facilitated meetings with farmer groups
Mr Yadav	Director of Agriculture	
Mr B P Sangod	DIC	Industries (MSMEs) information of Bharuch District and facilitated meetings with industries, such as chemical, pharmaceutical, bio-coal, etc.
Mr Anand B Patel	DDO	Facilitated meeting with DAO and gave a brief idea about the whole district

Table A1.6 Stakeholders meeting, Vadodara District

Name of Stakeholder	Office	Data collected
Shri J H Suthar	DAO	District agricultural data
Mr H N Mevada	DIC	No data provided
Mr Jay C Rawal	DSO	Provided a district statistical handbook and gave a brief idea about the whole district

Table A1.7 Stakeholders meeting, Sabarkantha District

Name of Stakeholder	Office	Data collected
Shri V K Patel	DAO	District agricultural data (last three years), facilitated meetings with farmer groups
Mr G P Zala	DIC	Industries (MSMEs) information of Sabarkantha District and facilitated meetings with industries, such as chemical, pharmaceutical, bio-coal, etc.
Mr H J Vyas	DDO	Facilitated meeting with DSO and gave a brief idea about the whole district
Shri Jaswant Chavda	DSO	Statistical data of the district

Annexure II: Power plant details

Table A2.1 Biomass-based power projects installed till December 31, 2012 [52]

Sr. No.	Name and address of developer	Location	Installed Capacity in MW	Month of commissioning (year wise)	Biomass is being used
1	M/ s. Amreli Power Projects Ltd. 4th Floor, My Home Plaza, 10-5 6/ B, Masab Tank, Hyderabad - 500 028. Andhra Pradesh	Village: Savarsampadar, Taluka: Savarkundla, Dist: Amreli	10	01.03.2011	Cotton Stalk, Groundnut shell, and Prosopis juliflora
2	Junagadh Power Projects (P) Limited, Flat No. 502, Emerald Block, Lumbini Rock Dale Compound, Somjiguda, Hyderabad – 500 080	Village: Khokharda, Taluka: Vanthali, Dist: Junagadh	10	22.05.2011	Cotton stalk, groundnut shell, and Prosopis juliflora
3	M/ s. Bhavnagar Biomass Power Projects Pvt. Ltd., 25-35/ 10/ 2, MallikarjunaNagar, Mumbai Highway, R. C. Puram, Hyderabad – 382 017.	Village: Vavadi(Gajabhai), Taluka: Shihor, Dist: Bhavnagar	10	19.03.2012	Cotton stalk, Groundnut shell, and Prosopis juliflora
4	M/ s. Ankur Scientific Energy Technologies Pvt. Limited, Near: Navrahana School, Sama. Vadodara – 390 024	Village: Sankheda, Taluka: Sankheda, Dist: Vadodara	1.2 (Gasification Route)	20.10.2011	Prosopis juliflora and Woody biomass
Total			31.2 MW		

[52] https://geda.gujarat.gov.in/news_single.php?news=59 <Last accessed on May 11, 2017>

Annexure III: Demographic profiles

TableA3.1 Demographic profile of Junagadh District

Name of Taluka	No. of villages covered	Population		
		M	F	Total
Manavadar	55	68,702	64,128	132,830
Vanthali	46	50,481	46,708	97,189
Junagad	70	225,794	213,626	439,420
Bhesan	46	40,711	39,001	79,712
Visavadar	103	71,822	68,201	140,023
Mendarda	48	35,440	33,091	68,531
Keshod	53	100,239	94,507	194,746
Mangrol	63	109,066	103,907	212,973
Malia	63	82,075	78,106	160,181
Total		**784,330**	**741,275**	**1,525,605**

http://pmksy.gov.in/mis/Uploads/2016/20160816044104401-1.pdf<Last accessed on 02-May-2017>

Table A3.2 Demographic profile of Amreli District

Name of	Population		
	M	F	Total
Amreli	122,893	118,386	241,279
Savar Kundla	121,965	117,307	239,272
Rajula	89,454	86,239	175,693
Babra	71,923	68,598	140,521
Dhari	71,281	68,526	139,807
Lathi	67,654	65,260	132,914
Jafrabad	55,238	52,764	108,002
Kunkavav	50,438	49,356	99,794
Khambha	47,214	46,217	93,431
Bagasara	42,469	40,585	83,054
Lilia	30,520	29,903	60,423
Total	**771,049**	**743,141**	**1,514,190**

Table A3.3 Demographic profile of Bhavnagar District[53]

Name of Taluka	Population		
	M	F	Total
Vallabhipur	41,335	38,857	80,192
Umrala	44,391	41,932	86,323
Bhavnagar	409,978	377,341	787,319
Gogha	51,861	49,116	100,977
Sihor	110,343	101,893	212,236

[53] http://pmksy.gov.in/mis/Uploads/2016/20160816041116779-1.pdf <Last accessed on 5 May 2017>

Name of Taluka		Population	
Gariadhar	58,669	56,218	114,887
Palitana	107,424	103,142	210,566
Talaja	174,482	151,185	325,667
Mahuva	206,965	200,294	407,259
Jesar	43,222	41,563	84,785
Total	**1,248,670**	**1,161,541**	**2,410,211**

Table A3.4 Demographic profile of Bharuch District

Name of		Population	
	M	**F**	**Total**
Amod	40,587	37,995	78,582
Vagara	53,489	46,555	100,044
Bharuch	144,160	136,018	280,178
Jhagadia	95,085	90,252	185,337
Ankleshwar	115,366	100,677	216,043
Hansot	31,713	29,555	61,268
Valia	73,494	70,817	144,311
Total	**633,875**	**585,582**	**1,219,457**

Table A3.5 Demographic profile of Sabarkantha District

Name of Taluka		Population	
	M	**F**	**Total**
Himatnagar	168,924	156,745	325,669
Idar	132,488	125,416	257,904
Khedbrahma and Poshina	147,996	145,147	293,143
Prantij	83,566	77,713	161,279
Talod	79,739	74,685	154,424
Vadali	47,170	45,187	92,357
Vijaynagar	51,962	51,933	103,895
Total	**711,845**	**676,826**	**138,8671**

Source http://pmksy.gov.in/mis/Uploads/2016/20160816051410660-1.pdf <Last accessed on May 2, 2017>

Annexure IV: Year-wise area, production, and yield of major crops

Table A 4.1 Year-wise area, production, and yield of major crops in Junagadh District

S. No	Name of the Crop	Year 2011–12			Year 2012–13			Year 2014–15		
		Area (Kha)	Prod. (Kilo MT)	Yield (Tons/ Ha)	Area (Kha)	Prod. (Kilo MT)	Yield (Tons/ Ha)	Area (Kha)	Prod. (Kilo MT)	Yield (Tons/ Ha)
1	Groundnut	412.50	735.00	1.78	307.94	158.57	0.51	225.99	652.87	2.89
2	Cotton	68.60	49.11	0.72	64.50	22.87	0.35	94.88	70.45	0.74
3	Wheat	152.30	585.50	3.84	39.70	122.60	3.09	73.90	299.78	4.06
4	Bajara	17.30	41.70	2.41	11.20	13.50	1.21	1.70	2.63	1.55
5	Castor	2.00	4.10	2.05	1.10	2.20	2.00	0.90	2.30	2.56
6	Pigeon Pea	0.90	0.90	1.00	0.5	0.6	1.20	0.26	0.22	0.85

Table A4.2 Year-wise area, production, and yield of major crops in Amreli District

Sr. No.	Name of the Crop	Year 2011–12			Year 2012–13			Year 2014–15		
		Area (Kha)	Prod. (Kilo MT)	Yield (Tons/ Ha)	Area (Kha)	Prod. (Kilo MT)	Yield (Tons/ Ha)	Area (Kha)	Prod. (Kilo MT)	Yield (Tons/ Ha)
1	Groundnut	116	44	0.4	85	9	0.1	70	98	1.4
2	Cotton	389	172	0.4	289	41	0.1	413	137	0.3
3	Wheat	32	116	3.6	5	15	2.9	4	15	3.5
4	Bajara	8	13	1.6	5	2	0.4	4	8	1.9
5	Castor	2	4.1	2.05	3.1	6.1	1.97	3.8	6.2	1.63
6	Pigeon Pea	0.9	0.9	1.00	0.8	0.8	1.000	1.25	1.06	0.85

Table A4.3 Year-wise area, production, and yield of major crops in Bhavnagar District

Sr. No.	Name of the Crop	Year 2011–12	Year 2011–12	Year 2011–12	Year 2012–13	Year 2012–13	Year 2012–13	Year 2014–15	Year 2014–15	Year 2014–15
		Area (Kha)	**Prod. (Kilo MT)**	**Yield (Tons/ Ha)**	**Area (Kha)**	**Prod. (Kilo MT)**	**Yield (Tons/ Ha)**	**Area (Kha)**	**Prod. (Kilo MT)**	**Yield (Tons/ Ha)**
1	Groundnut	116.40	152.10	1.31	81.20	54.80	0.7	69.60	113.70	1.6
2	Cotton	305.20	185.74	0.61	313.50	85.94	0.3	210.80	93.36	0.4
3	Wheat	9.70	28.70	2.96	2.40	7.90	3.3	9.70	27.90	2.9
4	Bajara	52.30	11.70	0.22	31.00	47.90	1.5	40.40	56.30	1.4
5	Castor	0.7	1.5	2.14	0.9	1.8	2.00	1	2.4	2.40
6	Pigeon Pea	0.6	0.6	1.00	0.5	0.5	1.000	0.7	0.6	0.86

Table A4.4 Year-wise area, production, and yield of major crops in Bharuch District

Name of the Crop	Year 2011–12			Year 2012–13			Year 2014-15		
	Area (000' ha)	Prod. (K MT)	Yield (Tonnes/ Ha)	Area (000' ha)	Prod. (K MT)	Yield (Tonnes/ Ha)	Area (000' ha)	Prod. (K MT)	Yield (Tonnes/ Ha)
Groundnut	4	8	1.9	1	1	1.1	1	1	1.8
Cotton	125	44	0.4	119	46	0.4	82	39	0.5
Wheat	22	46	2.1	24	44	1.9	29	49	1.7
Sugarcane	19	116	6.2	27	177	6.5	36	251	6.9
Castor	7.0	14.4	2.1	5.8	11.5	2.0	16.8	27.7	1.6
Pigeon Pea	46.6	40.9	0.9	53.5	48.5	0.9	60.7	54.4	0.9

Source: District Agricultural Office, Bharuch

Table A4.5 Year-wise area, production, and yield of major crops in Vadodara District

Name of the Crop	Year 2011–12			Year 2012–13			Year 2014–15		
	Area (000 Ha)	Prod. (KMT)	Yield (Tonnes / Ha)	Area (000 Ha)	Prod. (KMT)	Yield (Tonnes / Ha)	Area (000 Ha)	Prod. (KMT)	Yield (Tonnes / Ha)
Groundnut	40.60	67.30	1.66	3.20	4.30	1.34	10.80	23.45	2.17
Cotton	196.90	639.00	0.55	203.80	844.70	0.70	107.90	359.70	0.57
Wheat	47.20	128.40	2.72	36.50	125.00	3.42	42.80	119.90	2.80
Paddy	44.40	55.30	1.25	44.60	63.20	1.42	23.30	63.20	2.71
Castor	25.00	50.60	2.02	32.50	74.60	2.30	25.50	45.50	1.78
pigeon pea	75.1	88.3	1.18	64.1	80.8	1.26	19.2	17.50	0.91
Maize	81.10	166.90	2.06	68.7	149.3	2.17	71.572	62.49	0.87
sugarcane	7	31.7	4.53	7.4	45.2	6.11	4.3	27.3	6.35

Source: http:/ / pmksy.gov.in/ mis/ Uploads/ 2016/ 20160816051410660-1.pdf <Last accessed on May 2, 2017>

Table A4.6 Year-wise area, production, and yield of major crops in Sabarkantha District

Name of the Crop	Year 2011–12			Year 2012–13			Year 2014–15		
	Area (000' ha)	Prod. (KMT)	Yield (Tonnes/ Ha)	Area (000' ha)	Prod. (Kilo)	Yield (Tonnes/ Ha)	Area (000' ha)	Prod. (Kilo)	Yield (Tonnes/ Ha)
Groundnut	79	16	0.20	80	31	0.4	42	21	0.5
Cotton	157	83	0.53	138	67	0.5	74	44	0.6
Wheat	149	66	0.44	154	78	0.5	82	41	0.5
Pigeon pea	11	2	0.19	10	2	0.2	6	1	0.2
Castor	74	22	0.30	60	18	0.30	75	25	0.33
Maize	87	23	0.26	61	15	0.248	14	4	0.32

Source: District Agricultural Office, Sabarkantha

AnnexureV: *Taluka*-wise land holding pattern

Table A 5.1 *Taluka*-wise land holding pattern in Junagadh District

		Small holding (Below 1 Hectare)		Medium holding (1 to 2 Hectare)		Large holding (Above 2 Hectare)		Total	
S.No.	Taluka	No. of farmers	Land holding	No. of farmers	Land holding	No. of farmers	Land holding	No. of farmers	Land holding
1	Manavadar	5,065	3,532	8,947	13,121	7,887	30,215	21,899	46,868
2	Vanthali	4,001	2,711	5,731	8,343	5,223	20,027	14,955	31,081
3	Junagadh	4,264	2,803	6,809	10,023	6,220	23,424	17,293	36,250
4	Bhesana	2,742	1,802	5,844	8,707	6,329	24,216	14,915	34,725
5	Visavadar	4,429	2,976	9,234	13,746	9,834	37,950	23,497	54,672
6	Mendarda	2,517	1,754	4,890	7,196	3,636	13,203	11,043	22,153
7	Keshod	6,334	4,313	9,289	13,534	7,355	27,563	22,978	45,410
8	Mangrol	8,565	5,113	7,920	11,359	6,592	2,5552	23,077	42,024
9	Maliya	6,527	4,106	7,072	10,244	5,360	20,117	18,959	34,467
	Whole district	44,444	29,110	65,736	96,273	58,436	222,267	168,616	34,7650

Source: Agriculture census 2010–11

Table A5.2 *Taluka*-wise land holding pattern of Amreli District

S. no	Taluka	Small (0–1 hectares)		Medium (1–2 hectares)		Large (Above 2 hectares)	
		No. of farmers	Total land	No. of farmers	Total land	No. of farmers	Total land
1	Amreli	6,466	4,263	11,448	16,655	11,939	45,528
2	Babra	5,067	2,891	8,937	13,321	11,650	43,915
3	Dhari	4,507	2,652	8,612	12,696	11,701	47,091
4	Jafrabad	2,832	1,756	3,594	5,261	4,205	18,007
5	Khambha	2,630	1,825	5,728	8,447	7,341	42,096
6	Savarkundla	8,525	6,038	14,526	21,302	14,647	54,058
7	Kunkavav	5,688	2,668	7,340	11,015	9,363	34,241
8	Bagasara	5,067	2,891	8,937	13,321	11,650	43,915
9	Lathi	3,898	2,498	7,445	10,997	9,907	37,676
10	Liliya	3,084	1,865	5,371	7,930	6,062	22,192
11	Rajula	5,127	3,325	7,818	11,387	7,992	36,702
Aggregate		52,891	32,672	89,756	132,332	106,457	425,421

Source: Agriculture census 2010–11

Table A5.3 *Taluka*-wise land holding pattern of Bhavnagar District

S.No	Taluka	Small (0–1 hectares)		Medium (1–2 hectares)		Large (Above 2 hectares)	
		No. of farmers	Total land	No. of farmers	Total land	No. of farmers	Total land
1	Bhavnagar	4,706	3,114	5,114	7,404	5,362	23,420
2	Sihor	6,716	4,454	9,064	13,162	6,911	28,296
3	Umrana	2,948	1,890	5,086	7,466	6,220	23,424

S.No	Taluka	Small (0–1 hectares)		Medium (1–2 hectares)		Large (Above 2 hectares)	
4	Vallabhipur	1,810	1,184	4,157	6,202	7,084	31,167
5	Talaja	10,069	6,666	11,579	16,686	9,507	36,294
6	Mahuwa	11,913	8,182	16,051	23,302	13,638	67,041
7	Paalitana	6,608	4,331	8,714	12,641	6,042	22,696
8	Gariyadhar	4,489	3,047	7,560	11,133	6,786	23,306
9	Ghogha	2,494	1,694	3,551	5,173	4,534	21,594
10	Jesar*						
Aggregate		51,753	34,562	70,876	103,169	66,084	277,238

Table A5.4 *Taluka*wise land holding pattern in Bharuch District

S.no	Taluka	Small (0–1 hectares)		Medium (1–2 hectares)		Large (Above 2 hectares)	
		No. of farmers	Total land	No. of farmers	Total land	No. of farmers	Total land
1	Bharuch	10,861	5,061	571	783	6,279	24,892
2	Ankleshwar	5,024	2,820	749	1,086	4,456	29,156
3	Hansot	3,685	1,761	305	432	3,619	14,508
4	Vagra	2,778	1,453	549	779	6,505	32,081
5	Jambusar	8,292	4,290	535	786	9,436	39,595
6	Amod	5,278	2,664	374	525	5,752	24,656
7	Jhagadia	6,750	3,361	2,521	3,696	6,012	24,642
8	Valia	3,268	1,566	1,510	2,260	5,345	26,097
Aggregate		**45,936**	**22,976**	**7,114**	**10,347**	**47,404**	**215,627**

Source: District Agricultural Office, Bharuch

Table A5.5 *Taluka*-wise land holding pattern in Vadodara District

Taluka	Small holding		Medium holding		Large holding	
	No. of farmers	Land holding	No. of farmers	Land holding	No. of farmers	Land holding
Savali	13,740	7,078	8,363	12,003	9,895	40,343
Vadodara	11,760	5,986	5,715	8,086	4	21,932
Vaghodia	5,472	2,932	4,398	6,436	7,288	31,206
Dabhoi	7,621	4,336	6,352	9,298	9,176	34,670
Padara	13,691	6,976	6,635	9,478	6,039	22,280
Karjana	7,645	4,245	6,871	9,919	8,980	34,644
Shinor	4,255	2,426	3,332	4,854	4,006	15,195
Total	**64,184**	**33,979**	**41,666**	**60,074**	**45,388**	**200,270**

Source: District statistical handbook, Vadodara District

Table A5.6 *Taluka*-wise land holding pattern in Sabarkantha District

Taluka	**Small (0-–1 hectares)**		**Medium (1–2 hectares)**		**Large (Above 2 hectares)**	
	No. of farmers	**Total land**	**No. of farmers**	**Total land**	**No. of farmers**	**Total land**
Himatnagar	9,219	13,197	17,747	8,087	7,307	33,680
Prantij	5,211	7,387	9,417	4,842	4,101	18,653
Talod	4,713	6,756	7,877	3,888	4,939	23,431
Idar	10,797	15,628	17,804	7,940	7,702	33,262
Vadali	4,639	6,732	5,957	2,849	3,357	17,919
Khedbrahma	6,060	8,763	9,854	3,714	5,902	22,411
Poshina						
Vijaynagar	3,270	4,653	5,395	2,639	1,925	6,313
Aggregate	**43,909**	**63,116**	**74,051**	**33,959**	**35,233**	**155,669**

Source: District Agricultural Office, Sabarkantha

Annexure VI: *Taluka*-wise land use pattern

Table A6.1 *Taluka*-wise land use pattern in Junagadh District

S.N.	Taluka	Land Area	Forest	Non-agricultural land	Residential land	Agricultural land (without farming)	Grassland	Non use land	Net cultivated land (2015-16)
1	Manavadar	67,735	659	758	4,415	10	3,520	391	51,748
2	Vanthali	40,741	45	869	40	54	4,000	483	42,356
3	Junagadh	66,080	17,965	658	6,525	20	3,609	62	42,841
4	Bhesana	55,502	0	735	0	532	0	0	36,001
5	Visavadar	99,186	0	745	0	2,036	0	0	58,879
6	Mendarda	47,658	6,510	991	1,280	244	1,680	669	30,797
7	Keshod	52,913	234	987	2,663	105	5,894	1,017	55,494
8	Mangrol	48,715	1,296	786	2,286	270	6,445	1,331	46,290
9	Maliya	35,363	0	658	0	55	0	0	63,890
	Total	**513,893**	**26,709**	**7,187**	**17,209**	**3,326**	**25,148**	**3,953**	**428,296**

Table A6.2 Taluka-wise land use pattern in Amreli District

S. No	*Taluka*	Forest	Barren and Uncultivable land	Area under non-Agriculture use	Permanent Pasture and Grazing land	Cultivable Fallow land	Land under miscellaneous trees and crops	Current Fallow	Fallow land other than current fallow	Net area sown
1	Amreli	0	393	504	4,000	1,653	0	0	290	70,984
2	Babra	1,923	7,547	3,634	5,899	383	0	1,200	0	55,886
3	Dhari	18,626	1,580	7,580	4,705	730	0	350	213	66,640
4	Jafrabad	277	3,394	3,183	3,057	65	0	790	126	23,498
5	Khambha	8,753	1,411	2,740	6,200	1,750	0	1,635	263	36,341
6	Bagasara	71	396	1,802	2,900	150	0	1,256	408	26,579
7	Kunkavav	21	800	2,109	3,500	176	0	577	210	47,984
8	Lathi	291	2,434	5,612	3,655	522	0	0	0	53,570
9	Liliya	135	668	2,070	3,641	114	0	72	53	32,225
10	Rajula	1,068	3,011	4,535	3,955	1,685	0	1,132	70	46,488
11	Savarkundla	4,800	2,881	12,800	9,578	1,540	0	963	132	83,848
Aggregate		35,965	24,515	46,569	51,090	8,768	0	7,975	1,765	544,043

Source: District Statistical book 2014-15

Table A6.3 *Taluka*-wise land use pattern in Bhavnagar District

S. No	Taluka	Forest	Barren and Uncultivable land	Area under non-Agriculture use	Permanent Pasture & Grazing land	Cultivable Fallow land	Land under miscellaneous trees & crops	Current Fallow	Fallow land other than current fallow	Net area sown
1	Vallabhipur	1,119	4,028	396	2,947	2,057	115	773	836	40,551
2	Jesar*	6,967	2,879	1,359	2,692	6,348	0	1,768	2,532	24,446
3	Umrana	93	0	271	2,620	10	0	546	1,541	32,317
4	Bhavnagar	8,471	25,736	7,752	3,498	5,613	624	4,468	4,746	27,783
5	Ghogha	1,234	4,242	3,436	3,342	458	0	266	1,341	29,291
6	Sihor	21,026	6,286	2,330	6,972	2,825	1,543	2,396	2,865	41,050
7	Gariyadhar	45	631	472	3,650	2,137	5	1,005	1,521	34,360
8	Paalitana	26,581	16,564	1,167	6,146	2,502	484	495	2,460	27,146
9	Talaja	5,109	2,472	1,460	6,575	5,949	403	1,143	995	43,671
10	Mahuwa	7,336	2,763	2,812	9,373	8,007	764	824	4,468	68,107
Aggregate		77,981	65,601	21,455	47,815	35,906	3,938	13,684	23,305	368,722

Table A6.4 *Taluka*-wise land use pattern in Bharuch District

S. No	Taluka	Forest	Barren and Uncultivable land	Area under non-Agriculture use	Permanent Pasture and Grazing land	Cultivable Fallow land	Current Fallow	Fallow land other than current fallow	Net area sown
1	Jambusar	0	6,119	31,755	2,759	883	2,541	0	65,769
2	Amod	0	2,600	4,845	809	78	2,474	0	35,700
3	Vagra	5,781	580	5,075	1,957	22,593	6,709	0	45,353
4	Bharuch	2	1,103	7,967	1,735	2,220	3,633	0	46,765
5	Jhagadia	14,596	6,984	4,601	3,681	3,095	1,379	0	46,503
6	Ankleshwar	91	717	7,001	1,500	1,779	4,820	0	28,540
7	Hansot	983	694	7,859	1,821	4,779	1,494	26	22,222
8	Valia	3,053	1,028	3,352	2,059	31	2,266	0	39,626
Aggregate		**24,506**	**19,825**	**72,455**	**16,321**	**35,458**	**25,316**	**26**	**330,478**

Table A6.5 *Taluka*-wise land use pattern in Vadodara District

Taluka	Forest	Non-agricultural land	Dry land	Fellow land	Net cultivated land	Total land area
Savali	0	10,154	1,838	3,532	60,031	165,360
Vadodara	0	12,400	124,405	11,452	36,951	258,249
Vaghodia	1,055	10,438	1,556	411	37,852	117,756
Dabhoi	0	4,192	2,559	721	52,020	66,902
Padara	1,029	6,303	1,364	1,181	41,987	111,822
karjana	0	5,120	143	2,269	49,950	121,443
shinor	0	2,255	1,779	50	23,879	58,878
Total	2,084	50,862	133,644	19,616	302,670	900,410

Source: District statistical book 2015–16

Table A6.6 *Taluka*-wise land use pattern in Sabarkantha District

S.No	Taluka	Forest	Barren and Uncultivable land	Area under non-Agriculture use	Permanent Pasture and Grazing land	Cultivable Fallow land	Current Fallow	Net area sown
1	Himatnagar	8,803	4,799	3,111	4,062	1,383	1,105	55,236
2	Prantij	0	3,536	2,555	2,862	337	1,482	30,120
3	Talod	237	3,935	2,950	3,145	400	3,493	29,856
4	Idar	4,666	3,579	4,400	3,341	793	5,356	56,325
5	Vadali	1,560	2,225	2,415	2,674	588	521	23,523
6	Khedbrahma	31,687	4,623	7,576	1,538	22,49	3,052	32,522
7	Vijaynagar	28,691	1,425	1,601	128	882	314	12,698
Aggregate		**75,644**	**24,122**	**24,608**	**17,750**	**6,632**	**15,323**	**240,280**

AnnexureVII: District-wise number of registered MSMEs

Sr No	District name	Total Units
1.	Ahmedabad	93,655
2.	Amreli	1,468
3.	Anand	3,267
4.	Aravalli	22
5.	Banaskantha	2,970
6.	Bharuch	7,185
7.	Bhavnagar	7,520
8.	Botad	146
9.	Chhota Udaipur	12
10.	Dahod	587
11.	Dang	8
12.	Devbhumi Dwarka	27
13.	Gandhinagar	3,539
14.	Gir Somnath	14
15.	Jamnagar	6,642
16.	Junagadh	1,658
17.	Kachchh	2,265
18.	Kheda	1,134
19.	Mahisagar	5
20.	Mehsana	2,887
21.	Morabi	2
22.	Morbi	203
23.	Narmada	960
24.	Navsari	2,838
25.	Panchmahal	1,508
26.	Patan	1,272
27.	Porbandar	806
28.	Rajkot	31,109
29.	Sabarkantha	2,232
30.	Surat	173,008
31.	Surendranagar	4,807
32.	Tapi	574
33.	Vadodara	16,379
34.	Valsad	5,448
	Total :	**376,357**

Source: Industries commissionerate, Ahemadabad

Annexure VIII: CRR values of different biomass of identified crops

Table A 8: Biomass produced CRR value of identified crops

Name of crop	Biomass	CRR
Cotton	Husk	1.1
	Stalk	3.8*
	Boll shell	1.1
Groundnut	shell	0.3
	stalk	2
wheat	stalk	1.5
	Pod	0.3
Bajara	Husk	0.3
	Stalk	2
	Cobs	0.33
Castor	stalk[54]	12**
Pigeon pea	Husk	0.3
	stalk	2.5
Sugarcane	Bagasse Top leaves	0.33 0.05
Maize	Cob stalk	0.3 2
Paddy	Husk	0.2
	Stalk	1.5
	Straw	1.5

Source: Combustion Gasification and Propulsion Laboratory (CGPL), IISc, Bangalore INDIA

*Due to the reason that the residue generation of cotton stalks is not proportional to the cotto n crop, its residue yield is given in tonnes per hectare.

** Castor residue has been taken in tonnes per hectare.

[54] http://ndpublisher.in/admin/issues/IJAEBV8N2m.pdf

Annexure IX: Industries' interviews

Table A9.1 Data collection in Junagadh District

Name of the oil mill	*Taluka*	Capacity of groundnut crushed	Groundnut shell generated	Groundnut shell used in mill	Groundnut shell sold to industries	Groundnut shell selling price(Rs/kg)
Pooja Oil Mill	Junagadh	40 tonnes per day	30%	25%	Bio-coal industries; dairy industries; power plants	3 to 4

Other details include:

Groundnut purchased from APMC at 40 to 45 Rs/ kg.

1 tonne of groundnut contains 700–50 kg of seed.

1 tonne of groundnut shell produces approximately 350 kg of oil.

Crushed groundnut produces approximately 50% cake and approximately 50% oil.

Selling price of groundnut oil is Rs 100/ kg.

Selling price of oil cake is Rs 23.5/ kg.

Name of the bio coal industry	*Taluka*	Capacity of groundnut shell used tons /hr	Biomass	Purchasing source and price Rs./kg	Bio-coal selling price Rs/kg
Pooja	Junagadh	2 machine of 1.5 tonnes/ hr each	groundnut	Oil mills at Rs 3.5/ kg	Rs 5/ kg Chemical, ceramic and dairy industry
Powertek Bio-Coal	Junagadh	1.5 tonnes/ hr	groundnut	Oil mills at Rs 3-4.5/ kg	5–6 Boiler, Ankleshwar, Baroda
Anand Fuel Pvt. Ltd.	Keshod	4 tonnes/ hr	Groundnut and cotton stalk	Oil mills and Farmers At Rs 2.5-5/ kg (lump sum)	4.5–5 Brick kilns of Punjab and Ceramic industries of Morbi

Table A9.2 Data collection in Amreli District

Name of the oil mill	*Taluka*	Capacity of groundnut crushed	Groundnut shell generated	Groundnut shell used in mill	Groundnut shell sold to industries	Groundnut shell selling price(Rs/kg)
Vivek oil mill	Amreli	40 tonnes per day	20%	25%	Bio-coal industries Dairy industries Power plants	2.5 to 4
Kirti oil mill	Savar Kundla	2.5 tonnes per day	20%	100%	Not sold	

Other details include:

- Groundnut purchased from APMC at 40 to 50 Rs/ kg.
- One tonne groundnut shell produces approximately 360 kg of oil.
- Crushed groundnut produces approximately 50% cake and approximately 50% oil.
- Selling price of groundnut oil is Rs 95/ kg
- Selling price of oil cake is Rs 24/ kg. Cake is sold to biscuit industries, fisheries, and the rubber industry.

Name of the bio coal industry	***Taluka***	**Capacity of groundnut shell used tones/year**	**Purchasing source and price Rs/kg**	**Bio-coal selling price Rs/kg**	**Use of castor shell**
Vihaan industries	Amreli	7,000	Oil mills, seed selling (traders) at 3–3.5	4–4.5 Chemical industry	No
Paradise industry	Amreli	5,000	Oil mills at 2–2.5	4–6 Chemical industry Ankleshwar	10%–15%
Deep Industries	Amreli	5,000	Oil mills at 3–3.5	4–4.5 Chemical, rolling mills and pharmaceutical in Vadodara	10%

Table A9.3 Data collection In Bhavnagar district

Name of the oil mill	***Taluka***	**Capacity of groundnut crushed**	**Groundnut shell generated**	**Groundnut shell used in mills**	**Groundnut shell sold to industries**	**Groundnut shell selling price(Rs/kg)**
Krishna Industries	Bhavnagar	20 tonnes per day	20%	25%	Bio-coal industries Dairy industries Power plants	2.5 to 4

Other details include:

- Groundnut purchased from APMC at 40 to 50 Rs/ kg.
- One tonne groundnut shell produces approximately 360 kg of oil.
- Groundnut crushed produces approximately 50% cake and approximately 50% oil.
- Selling price of groundnut oil is Rs 95/ kg.
- Selling price of oil cake is Rs 24/ kg. Cake is sold to biscuit industries, fisheries, and the rubber industry.

Data collection from bio-coal industries/ Briquette manufacturers

Name of the Bio coal	Taluka	Capacity of groundnut shell/cotton stalk used tonnes /year	Purchasing source and price Rs/kg	Bio-coal selling price Rs/kg	Use of castor shell
Royal Bio-Coal	Bhavnagar	7,000	Oil mills, seed selling (traders) at 3–3.5	4–4.5 Chemical industry	No
Jiya Eco Products Ltd.	Bhavnagar	5,000	Farmers	3–4	No

Table A9.4.1 Bio-coal industry survey of Vadodara District

Name of the Company	**Basil bio-coal,**		
Name of the contact person	Thakurbhai 9879301223		
Address	Mahuwad, Padra		
Capacity	1 tonne/ hr		
Working period	9 months in a year; closed during the rainy season; 8 hours/ day		
Total capacity (tonnes per annum)	2,000		
Bio-coal type	Saw dust, groundnut shell		
Residue used	Saw dust	groundnut shell	other wastes
Percentage share in bio-coal	50	50	_
Seasonal Availability of Raw material	round the year	April–July	Whole year
Residue prices in Rs. Per ton (incl. transport)	3,000-3,200	4,000–4,200	800–2,000
Source of residue	Saw mills and traders	from Saurashtra region	local sources

bio coal price in Rs. per ton (incl. transport)	5,500–5,600
Storage Capacity (tons)	300
production cost price	labour charges: Rs 210/ tonne, electricity: Rs 300/ tonne

Summary:

- There are only 5–6 bio-coal industries in the district. Most of them have shifted their business from bio-coal to some other business because of the uneconomic market conditions related to bio-coal as the price of wood in Vadodara District is rather less (Rs 2,000–2,500/ tonne).
- Eighty per cent of the bio-coal used in the district comes from the Saurashtra region.
- Industries in Vadodara are reluctant to use biomass and bio-coal as wood and coal prices are exceptionally low (Rs 2–2.5/ kg for wood and Rs 5/ kg for coal). This is the main reason for the limited and unsuccessful business of bio-coal in Vadodara.
- Briquettes go to chemical industries, such as sterlin, transpick, and mayor.

Table A9.4.2 Chemical industry survey in Vadodara District

Name of the Company	**Sterlin**
Name of the contact person	-
Address	Baser, Padra
Total boilers	1
Boiler usage	Generation of steam
Boiler Capacity	10 kg/ cm^2
Fuel used	Bio-coal
Bio-coal usage	50–60 tonnes per day
Storage Capacity(tons)	300
Bio-coal source	Saurashtra region
Price of bio-coal in Rs per tonne (including transport)	4,800–5,400

Miscellaneous:

- The given information has been collected through telephonic conversations as the team could not personally visit the plants. The industry personnel very reluctant to provide information.
- Coal rates are very low in Vadodara. High-quality coal is available at Rs 5–6/ kg. This is the main reason for the low interest of industries in using bio-coal and other resides.

Table A9.4.3 Sugar mill survey in Vadodara District

Name of the Company	**Sitaram sugar mill (closed), Ladhod**
Name of the contact person	S N Thakre, 7219061010
Address	Ladhod, Vadodara
Total boilers	4 (bagasse fired)
Boiler usage	Generation of steam
Boiler capacity	35–40 kg/ cm2
Working period	5 months (November–March), 24 hours
Sugarcane crushing capacity	2,500 tonnes/ day (maximum), 500–600 tonnes/ day (actual)
Bagasse generated	25%
Power generation capacity	3 MW (captive use)
Bagasse Consumption (tonnes per day)	20%
Steam usage (tonnes per hour)	Power generation, mill turbines, distillery, process
Surplus bagasse	30–5 tonnes per day
Usage of surplus bagasse	Bales MC: 50% Price: Rs 1,600–2,000 per tonne CV: 2250 kcal/ kg
Sugarcane purchase cost	Rs 3,500 per tonne

Miscellaneous:

- Ash is sent back to the fields
- The average price of sugarcane was Rs 2,600 per tonne
- Bagasse goes to other boiler industries
- Sugar mill is closed due to cane shortage
- Sugar recover is 10% of cane crushing
- There is only one sugar mill in new Vadodara District

Table A9.4.4: Survey of rice mill in Vadodara District

Name of the Company	**Nima rice mill**
Address	Dabhoi
Capacity	4 tonnes rice processed/day
Working period	2–3 months in a year (November–January) [70 days]
Total capacity (tonnes per annum)	280
husk produced	15%–20%
Residue prices in Rs Per tonne (including transport)	Rs 2–4/kg

Miscellaneous

- There are only 8–10 rice mills in the district
- Capacity range of these rice mills are in the range of 4–10 tonnes/ day
- Cost of rice husk includes processing cost (Rs 1.5/ kg) and labour cost (Rs 0.9/ kg)
- Rice husk goes to brick kilns
- Transportation cost within 25 km is Rs 2,500–3,000 (for 6–7 tonnes). Hence transportation cost is approximately Rs 400/ tonne

Table A9.4.5: Survey of an oil mill in Vadodara District

Name of the Company	**Shri neel pawan oil mill**		**Ashwin Vanaspati**
Name of the contact person	Abhishek Patel		Hardik bhai (7990350242)
Address	Savali		Savali
Capacity	50 tonnes per day corn processing		100 tonnes per day corn processing
Working period	300 days/ 24 hours		
Total capacity (tonnes per annum)	15,000		
product	Maize oil (20%–25%),	Maize oil feed (75%–80%)	
Fuel consumption	1.6 tonnes/ day (wood in boiler)		

Miscellaneous:

Maize oil is used as food oil for human consumption while maize oil feed goes to animal husbandry; cost of maize seed is Rs 13–18/ kg, while the cost of wood is Rs 2–2.25/ kg

Annexure X: Farmers' Interviews

Table A10.1 Farmers' survey of Junagadh District

S. No.	Name of farmer	*Taluka*	Land holdings (Hectare)	Crops grown and production (tons/hectare)	Crop selling price Rs. Per kg	Residue produced and used
1	Maheshbhai Gokul bhai Undhad (9429215376)	Bhesan	2.88	Cotton: 2.1	55–80	Cotton stalk- burnt in field
2	Sayibhai gobanbhai (9913087110)	Visavadar	2	Cotton: 3.62	57	Cotton stalk- use as manure
3	Mansukhbhai (09913944142)	Bheshan	2	Groundnut: 1	35-43	Groundnut husk- fodder groundnut shell- traders
4	Ramji bhai Vagasia (09428953949)	Bheshan	2.5	Cotton: 1 Groundnut: 1	40-52 35-40	Cotton stalk- burnt in field groundnut shell- traders
5	Mansukh dirubhai	Bheshan	1.52	Cotton: 1.8	50-60	Cotton stalk burnt in a week's time
6	Mansukh bhai (9427925996)	Visavadar	2.5	castor: 4 Groundnut: 2	30-35 30-40	Groundnut husk sell at Rs. 4–5/ kg to cattle holders

Table A10.2 Farmers' survey for Amreli District

S. No.	Name of farmer	Taluka	Land holdings acre	Crops grown and production (kg/acre)	Crop selling price Rs. Per 20kg	Residue produced and used
1	Dilip Bhai	Bagasara	3	Cotton (400–500) Groundnut (60–600) Pigeon pea	1,100 750–800 700–1,000	Cotton stalk- burnt in fields Groundnut shell sold to traders
2	Valla Bhai	Bagasara	20	Cotton (300) Pigeon pea (200)	800–1,000 800	Cotton stalk- burnt in fields
3	Ramesh Bhai	Bagasara	32	Cotton (400–500) Groundnut (60–600) Wheat (500–600)	800–1,000 600–700 700–800	Cotton stalk- burnt in fields Groundnut husk - fodder groundnut shell - traders
4	Mahesh Bhai	Bagasara	4	Cotton (200–300) Groundnut (200–300) Wheat (500–600)	800–1,000 600–700 700–800	Cotton stalk burnt in fields Groundnut

S. No.	Name of farmer	Taluka	Land holdings acre	Crops grown and production (kg/acre)	Crop selling price Rs. Per 20kg	Residue produced and used
						shell -traders
5	Harish Bhai	Amreli	4	Cotton (500) Pigeon Pea (	1,100–1,200	Cotton stalk burnt in a week's time
6	Teda Bhai	Amreli	2.5	Cotton (500) Groundnut (800) Wheat Chana Pigeon Pea	800–1000 700–800 700–800	Cotton stalk burnt in fields
7	Atul Bhai	Amreli	12	Cotton (1,400) Groundnut (800) Bajra (600) Jeera (400)	1,100 700–800 400 1,500–1,700	Cotton stalk 60% used in domestic cooking and 40% burnt
8	Jignesh Bhai	Amreli	9	Cotton (500) Wheat (1,000)	900–1,100	
9	Arvind Bhai	Amreli	17	Cotton (1,000) Wheat (2,400) Chana (600)	800–1,100 700–800	Cotton stalk-burnt Chana straw-fodder Wheat straw-manure
10	Vinod Bhai	Amreli	10	Cotton (1,200) Groundnut (800) Wheat (2,000)	800–1,000	Cotton stalk-burnt
11	Mukesh Bhai	Savar kundla	2	Cotton (800) Groundnut (1,000) Wheat (1,400)	800–1,000 700–800 700–800	Cotton stalk burnt in fields after 25%–30 % use in domestic cooking Wheat straw-60% fodder and 40% manure
12	Dharmesh Bhai	Savar kundla	25	Cotton (1,200) Groundnut (1,000)	800–1000 700–800	Cotton stalk is shredded and used in the field as manure Groundnut husk - Fodder
13	Gajipara Jitu Bhai	Savar kundla	4	Cotton (400)	800–1000	Cotton stalk-Partially shredded and partially used for domestic cooking
14	Dilip Patel	Savar kundla	3.5	Cotton (500) Groundnut (350)	800–1000 700-800	Cotton stalk-Used in

S. No.	Name of farmer	Taluka	Land holdings acre	Crops grown and production (kg/acre)	Crop selling price Rs. Per 20kg	Residue produced and used
						manure
15	Shailesh Bhai	Savar kundla	2	Groundnut (400) Wheat (800)	800 700–800	

Other details:

- Shredder cost: Cost of the shredding machine is 1.58 lakh.
- The renting cost for shredder is 700–800 Rs/ hour for shredding a 1.5 acre of cotton production.
- Farmers were willing to sell the cotton stalk at 800 to 100 Rs/ tonne (inclusive of uprooting and labour costs).
- Most of the farmers use groundnut husk for fodder and some sell it at a cost of 100–200 Rs/ 20kg to other farmers.

Table A10.3 Farmers' survey for Bhavnagar District

S. No.	Name of farmer	*Taluka*	Land holdings acre	Crops grown and production (kg/acre)	Crop selling price Rs. Per 20kg	Residue produced and used
1	Khoda Bhai	Jesar	12	Cotton (800) Groundnut (100–485)	700–1,000 600–900	Cotton stalk - burnt in fields Groundnut shell sold to traders
2	Madhu Bhai	Mahuwa	7	Cotton (200) Groundnut (400)	800 800	Cotton stalk - burnt in field
3	Shyamji Bhai	Mahuwa	40	Cotton (400–500) Groundnut (60–600) Wheat (350–450) Bajra (500)	800–900 800 300–400 250–350	Cotton stalk - burnt in field Groundnut husk - fodder Groundnut shell - traders
4	Nanji Bhai	Mahuwa	2.5	Cotton (400) Groundnut (200–300) Wheat (500–600)	600–800 600–700 300	Cotton stalk- burnt in fields Groundnut shell - Traders
5	Ashok Bhai	Palitana	8	Cotton (500) Pigeon Pea (	1,100–1,200	Cotton stalk burnt in a week's time
6	Kesu Bhai	Palitana	2	Cotton (500) Groundnut (800) Wheat	800–1,000 700–800 700–800	Cotton stalk burnt in fields

S. No.	Name of farmer	*Taluka*	Land holdings acre	Crops grown and production (kg/acre)	Crop selling price Rs. Per 20kg	Residue produced and used
				Chana Pigeon Pea		
7	Navin Bhai	Plitana	10	Cotton (1400) Groundnut (800) Bajra (600) Jeera (400)	1,100 700–800 400 1,500–1,700	Cotton stalk 60% used in domestic cooking and 40% burnt
8	Narayan Bhai	Sihor	15	Cotton (500) Wheat (1,000) Pigeon pea	900–1,100	
9	Kalu Bhai	Sihor	13	Cotton (1,000) Wheat (2,400) Chana (600)	800–1,100 700–800	Cotton stalk - burnt Chana straw - fodder Wheat straw - manure

Table A10.4 Farmers' survey of Bharuch District

S. No.	Name of farmer	Taluka	Land holdings (acre)	Crop production (tonne/acre)	Crop selling price Rs per tonne
1	Mahendra Singh Rana Singh	Desad, Valia	Sugarcane: 20 Cotton: 18 Wheat: 2 Castor: 10	Sugarcane: 25–50 Cotton: 2 Wheat: 2–3 Castor: 1–1.5	Sugarcane: 3,500 Cotton: 50,000 Wheat: 22,000 Castor: 50,000
2	Rajendra Singh Man Singh	Luna, Valia	Sugarcane: 20	Sugarcane: 30–40	Sugarcane: 3,500
3	Dharmesh bhai	Bharadia, Valia	Sugarcane: 11 Pigeon pea: 10 Castor: 12	Sugarcane: 25–30 Pigeon pea: 0.02–0.03 (un-irrigated) Castor: 0.2	Sugarcane: 3,500 Pigeon pea: 51,000 Castor: 50,000
4	Mahipal Singh	Valia	Sugarcane: 7 Pigeon pea: 3	Sugarcane: 40 Pigeon pea: 0.6	Sugarcane: 3,500 Pigeon pea: 50,500
5	Rakesh Kumar	Luna, Valia	Sugarcane: 7–8 Cotton: 25 Pigeon pea: 1–2 Castor: 5–6	Sugarcane: 25–30 Cotton: 0.9–1 Pigeon pea: 0.4–0.5 Castor: 1–1.5	Sugarcane: 3,500 Cotton: 50,000 Pigeon pea: 50,500 Castor: 51,000
6	Suninder Singh	Mangrol, Amod	Sugarcane: 4 Rice: 2	Sugarcane: 37.5–62.5 Rice: 4–6	Sugarcane: 3,578 Rice: 15,000
7	Ranjit	Kala, Valia	Sugarcane: 4–5	Sugarcane: 35–50	Sugarcane: 3,578
8	Kalpesh M. Patel	Nagal, Ankleshwar	Sugarcane: 8–10	Sugarcane: 35–40	Sugarcane: 3,578

Table A10.5 Farmers survey of Vadodara District

Name of farmer	Taluka	Land holdings (acre)	Crop production (ton/acre)	Observations
Gopal	Vadia, Savli, 9824047447	Sugarcane: 200	Sugarcane: 100–50	➢ Sugarcane leaves are burnt in fields and goes to fodder ➢ Biggest sugarcane farmer, sugarcane goes to jiggery and sugar mills, farmers are reluctant to grow cotton due to pink ball worm
Syed Nisar Ali	Kamalpura, Savali, 9979216314	Cotton: 5 Pigeon pea: 7 Maize: 20 Castor: 12 Rice: 6	Cotton: 2 Pigeon pea: 0.8 Maize: 4 Castor: 1	➢ Rs 1 to 1.5/ kg is labour cost to clean the cotton field ➢ Pigeon pea stalk is given to labour for cooking for free ➢ Maize cob and leaves ➢ Leaves goes to fodder at Rs 1.5/ kg, 1.2 tonne cobs is produced from 1 acre. Price of maize cobs is Rs 1/ kg ➢ 0.5 tonne of castor shell is produced from 1 acre Castor shell goes to brick kilns at Rs 2/ kg, castor stalk given to labour for cooking for free ➢ Rice straw goes for fodder ➢ stalks of cotton, pigeon pea, and castor is used for domestic cooking by small labourers
Devji bhai+4	Kathmandava, Dabhoi	2	Pigeon pea: 0.02–0.03 (un-irrigated) rice: 3.5	➢ Cotton and pigeon pea stalk is used for domestic heating ➢ maize stalk is used as fodder; maize cobs are sold to businessman who cut it into small pieces and use as fodder at Rs 0.7–0.8/ kg ➢ Maize grains are the major food for poultry. Almost 50% of maize grains go to poultry at Rs 13–14/ kg. The farmer group has the same view and information regarding crops. All the farmers in the whole village are small with a land area in the range of 1 to 3 acres.
Parvad bhai+4	Kathmandava, Dabhoi	1	Maize: 4.8	There are 70–80 farmers in the entire village; all are small farmers with a land area in the range of 1–3 acres/ farmers. There aren't any proper crop growing patterns. They grow crops as per the market and demand and this subject to change every year; additionally, they also grow vegetables

Table A10.6 Farmers' survey of Sabarkantha District

S. No.	Name of farmer	Taluka	Land holdings (acre)	Crop production (tonne/acre)	Crop selling price Rs per ton
1	Ajit H Patel	Diyoli, Idar	Groundnut: 4 Cotton: 2 Wheat: 5 Castor: 20 Maize: 5	Groundnut: 15–25 Cotton: 1.5 Wheat: 2.2 Castor: 1–1.5	Groundnut: 30,000–35,000 Cotton: 50,000 Wheat: 19,000 Castor: 40,000
2	Balwant Singh Rathore	Diyoli, Idar	Groundnut:1 Wheat: 4	Groundnut: 4 Wheat: 1.4	Groundnut: 35,000 Wheat: 17,000
3	Parsottam bhai	Jagganathpur, Khedbrahma	Cotton: 7 Pigeon pea: 6 Wheat: 5 Maize: 7	Cotton: 20–5 Pigeon pea: 8 Wheat: 3 Maize: 5	Cotton: 45,000 Pigeon pea: 50,000 Wheat: 20,000 Maize: 13,570
4	Chand bhai	Kalol kampa, Khedbrahma	Maize: 3.6 Wheat: 3.6	Maize: 4 Wheat: 2	Maize: 15,000 Wheat: 15,000
5	Hasmukh bhai	Vishnupur kampa, Khedbrahma	Cotton: 1.6 Pigeon pea: 1.6 Castor: 2	Cotton: 2 Pigeon pea: 1.4 Castor: 0.8	Cotton: 50,000 Pigeon pea: 25,000 Castor: 30,000
6	Ramesh Patel	Vadvasa, Prantij	Castor: 4 Rice: 2	Castor: 1.5 Rice: 1.4–2	Castor: 35,000 Rice: 15,000
7	Kanti Bhai	Balisana, Prantij	Groundnut: 2.8 Wheat: 0.8 Rice: 1.6 Maize: 8	Groundnut: 5 Wheat: 0.8 Rice: 1.6 Maize: 7	Groundnut: 55,000 Wheat: 20,000 Rice: 16,000 Maize: 15,000
8	Manu Bhai	Vadrad, Prantij	Groundnut: 1 Wheat: 1.6 Bajara: 1 Castor: 2 Rice: 1.6	Groundnut: 0.6 Wheat: 1 Bajara: 1.2 Castor: 3 Rice: 1.6	Groundnut:55,000 Wheat:19,000 Bajara:10,000 Castor: 30,000 Rice: 15,000
9	Ramji Bhai	Jainpur, Prantij	Castor: 8 Groundnut: 8 Wheat: 2	Castor: 2.5 Groundnut: 1 Wheat: 1.5	Castor:31,000 Groundnut: 50,000 Wheat: 20,000
10	Balu Singh	Talod	Castor: 2 Groundnut: 2 Wheat: 2	Castor: 1.5 Groundnut: 2 Wheat: 1.5	Castor: 30,000 Groundnut: 53,000 Wheat: 20,000
11	Jala Gulab Singh	Jasajini, Talod	Castor: 0.5 Maize: 0.5 Cotton: 0.5 Groundnut: 0.5	Castor: 1.5 Maize: 3.5 Cotton: 1.5 Groundnut: 2	Castor: 30,000 Maize: 15,000 Cotton:50,000 Groundnut: 50,000
12	Sajjan Singh	Rupal, Talod	Groundnut:12 Rice: 4 Castor: 20	Groundnut: 6 Rice: 2 Castor: 2.5	Groundnut: 55,000 Rice: 15,000 Castor: 30,000
13	Jawan Singh	Jasajini, Talod	Cotton: 8 Castor: 6 Groundnut: 2	Cotton:2 Castor:1.5 Groundnut:2	Cotton: 50,000 Castor:30,000 Groundnut: 50,000

Annexure XI: Cost of biomass available in open market (Dated February 17, 2012)[55]

S. NO.	Type of Biomas	Basic cost of Biomss at Agri.field location (in Rs.)		
		Bhavnagar	**Junagadh**	**Amreli**
1	Cotton Stalk with 60% moisture	**900–1,000**	**1,000**	**750**
2	Tuver Stalk with 60% moisture	**900–1,000**	**-**	**-**
3	Groundnut shell	**2,200–2,500**	**-**	**5,000**
4	Prosopis juliflora	**2,800–3,200**	**2,500–3,000**	**-**

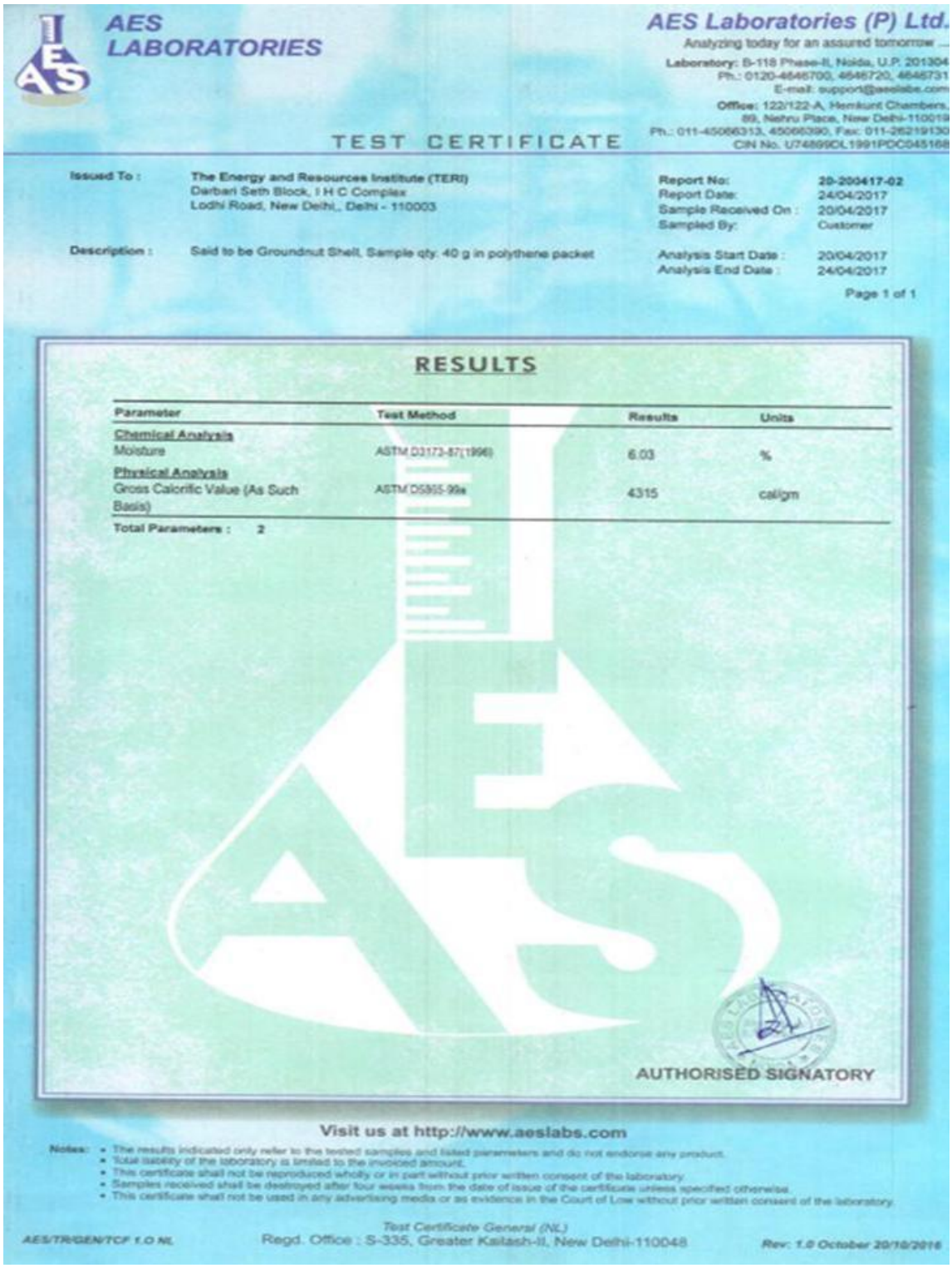
In addition to the shown cost, the following logistics can also be considered:

- The cost is for the standing biomass in field and the crop residues retain about 60% moisture content (in case of cotton stalk/ turver stalk) while the desirable moisture range is 30%. Hence, the cost of biomass (cotton stalk/ tuver stalk) may be considered 30% more on and above the shown prices (namely, Rs 1,300/ tonne instead of Rs 1,000/ per tonne in case of cotton/ tuver stalk).
- Transportation cost is at Rs 560/ tonne (covering a distance of about 15–20 km from the fields to biomass collection centres and biomass collection centres to biomass storage location at the plant site.
- Biomass loading and unloading: on average, not more than two labours are involved for biomass handling during the transit period. Hence, the total labor charges are Rs 300/ tonne.
- Chipping cost: being the biomass of a vivid type based on seasonal crop variation, the procured biomass needs to be chipped off to avoid the density-variation effect biomass. Chipping cost practically experience is approximately Rs 200/ tonne.

With considering the above-mentioned logistics, (taking the example of cotton stalk) biomass cost works out to be Rs 2,360 per tonne.

[55] GEDA/DIR/GERC/BM, as on February 28, 2014

Annexure XII: Lab report for GCV calculation of Cotton stalk and groundnut shell



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Ph.: 011-45066313, 45066390, Fax: 011-26219130
CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

Issued To : The Energy and Resources Institute (TERI)
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Lodhi Road, New Delhi,, Delhi - 110003

Description : Said to be Groundnut Shell, Sample qty. 40 g in polythene packet

Report No: 20-200417-02
Report Date: 24/04/2017
Sample Received On : 20/04/2017
Sampled By: Customer
Analysis Start Date : 20/04/2017
Analysis End Date : 24/04/2017

Page 1 of 1

RESULTS

Parameter	Test Method	Results	Units
Chemical Analysis			
Moisture	ASTM D3173-87(1996)	6.03	%
Physical Analysis			
Gross Calorific Value (As Such Basis)	ASTM D5865-99a	4315	cal/gm

Total Parameters : 2

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Figure A.12.1 GCV of Groundnut shell

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Report No: 20-200417-01
Report Date: 24/04/2017
Sample Received On : 20/04/2017
Sampled By: Customer

Description : Said to be Cotton Stalk, Sample qty. 16 g in paper envelop

Analysis Start Date : 20/04/2017
Analysis End Date : 24/04/2017

Page 1 of 1

RESULTS

Parameter	Test Method	Results	Units
Chemical Analysis			
Moisture	ASTM D3173-87(1996)	7.78	%
Physical Analysis			
Gross Calorific Value (As Such Basis)	ASTM D5865-99a	4472	cal/gm

Total Parameters : 2

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Figure A.12.2 GCV of Cotton stalk

Test report for GCV and moisture value of castor stalk

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Report No: **20-090517-02**
Report Date: 11/05/2017
Sample Received On : 09/05/2017
Sampled By: Customer

Description : Said to be Castor Stalk, Sample qty. 36 g in paper envelop

Analysis Start Date : 09/05/2017
Analysis End Date : 11/05/2017

Page 1 of 1

RESULTS

Parameter	Test Method	Results	Units
Chemical Analysis			
Moisture	ASTM D3173-87(1996)	7.47	%
Physical Analysis			
Gross Calorific Value (As Such Basis)	ASTM D5865-99a	3876	cal/gm

Total Parameters : 2

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Test report for GCV and moisture value of pigeon pea stalk

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Report No: **20-090517-03**
Report Date: 11/05/2017
Sample Received On : 09/05/2017
Sampled By: Customer

Description : Said to be Pigeon Pea Stalk, Sample qty. 18 g in paper envelop

Analysis Start Date : 09/05/2017
Analysis End Date : 11/05/2017

Page 1 of 1

RESULTS

Parameter	Test Method	Results	Units
Chemical Analysis			
Moisture	ASTM D3173-87(1996)	6.34	%
Physical Analysis			
Gross Calorific Value (As Such Basis)	ASTM D5865-99a	4473	cal/gm

Total Parameters : 2

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CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

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Description : Said to be Rice Husk, Sample qty. 12 g in paper envelop

Report No: **20-090517-04**
Report Date: 11/05/2017
Sample Received On : 09/05/2017
Sampled By: Customer

Analysis Start Date : 09/05/2017
Analysis End Date : 11/05/2017

RESULTS

Parameter	Test Method	Results	Units
Chemical Analysis			
Moisture	ASTM D3173-87(1996)	5.17	%
Physical Analysis			
Gross Calorific Value (As Such Basis)	ASTM D5865-99a	3737	cal/gm

Total Parameters : 2

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Test report for GCV and moisture value of rice/ paddy husk