Final Report

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

Supported by / Prepared for
The Gujarat Electricity Regulatory Commission



The Energy and Resources Institute
...towards global sustainable development

Suggested format for citation

T E R I. 2017
Consultancy Services to Assess the Biomass Availability and Determination of Biomass Price in the six Districts of Gujarat
New Delhi: The Energy and Resources Institute. 168 pp.

For more information

Project Monitoring Cell
T E R I
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail pmc@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delhi (0)11

Table of contents

List of Figures:

List of Tables:

Abbreviations

APY	: Area Production Yield
CRR	: Crop to Residue Ratio
DGVCL	: Dakshin Gujarat Vij Company 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 Company Ltd
NODP	: National Oilseed Development Programme
PGVCL	: Paschim Gujarat Vij Company Ltd
SEZs	: Special Economic Zones
SHG	: Self-Help Group
SNA	: State Nodal Agency
UGVCL	: Uttar Gujarat Vij Company 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. 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.

We would like to thank Mr Anand Kumar, Chairman, GERC, Mr K M Shringarpure, Member Finance, GERC; Mr. P J Thakkar, Member Technical GERC; Mr Roopwant Singh, Secretary, GERC; Mr S R Pandey, Legal Advisor, GERC; Mr P J Jani, Deputy Director, GERC; and Mr D R Parmar, Joint Director, GERC for their overall support and guidance in the completion of the study including providing linkages with SNAs and arranging logistics during our field visits.

We would like to thank Mr Sunil Dhingra, Project Advisor, TERI and Mr Shirish Garud, Director, Renewal Energy and Technology Application (RETA) division of TERI, for their insightful guidance and advice during the course of this study and in the project review meetings.

We would like to thank Dr V P Chauvatia, Director of Research, JAU; Dr Khanpara, Research Scientist, JAU; Mr Bhavesh Pataudia, Assistant Professor, JAU; and Mr Bhavesh Vasvelia, PGVCL for their kind support during field visits and a freelance survey of Junagadh district.

We would like to thank Mr B B Patel and Mr Vimal Upadhay from PGVCL for their kind support during our field visits in Amreli district.

We would also like to thank Mr P J Kuverani and Mr Milan Bhai from PGVCL for their support during our visits to Bhavnagar district.

We would also like to thank Dr Bharat Mehta, Senior Scientist and Head, KVK Vadodara, Dr C R Patel, Subject Matter Specialist, KVK Vadodara, and Mr Pinakin Patel, MGVCL for their kind support during field visits and freelance survey of Vadodara District.

We would also like to thank Mr M D Choudhari and Mr Desai from DGVCL (Gujarat Electricity Board) for their kind support during our field visit in Bharuch District.

We would also like to thank Mr I R Patel, Mr R B Sadhu, and Mr B K Vaghela from UGVCL for their support during our visit to Sabarkantha District.

A round of thanks is due to members of the local community at various sites for patiently answering our questions during the survey and actively participating in our interactive sessions and interview.

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 tons of biomass (including forest and agro-residues) annually, of which 120–150 million metric tons 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 stalk, groundnut stalk, 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 3.61 lakh tons in Junagadh. In addition, about 1.96 lakh tons 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 tons and 29,400 tons, respectively. In case of Bhavnagar, current annual production of cotton stalk and groundnut shell is estimated to be around 8.01 lakh tons and 34,120 tons, 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. 3,316–3,947 per ton. 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. 2,563–3,156 per ton. The estimated weighted average of fuel in all the districts lies in the range of Rs. 2,933–3,463 per ton. 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 and rice. Major sources of generating biomass are sugarcane bagasse, stalks of cotton, castor, maize, pigeon pea 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 3.11 lakh tons in Bharuch. In addition, about 4.18 lakh tons sugarcane bagasse is generated annually at two sugar mills located in Bharuch district. 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 tons, 1.02 lakh tons and 43.76 thousand tons, respectively. In the case of Sabarkantha, the current annual production of cotton stalk and castor stalk is estimated to be around 2.81 lakh tons and 2.98 lakh tons, 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. 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 have 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 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.

Team of professionals

Mr Shirish Garud, Internal Advisor

Mr Sunil Dhingra, Internal Advisor

Mr Abhishek Agrawal, Principal Investigator

Mr Sarvesh Devraj, Team Member

Ms Astha Gupta, Team Member

Mr Avishek Goel, Team Member

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 metric ton 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.

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

Calculation for biomass costing

The cost details of different types of crop residues were obtained from farmers, industries and other relevant local sources in each district. The cost details such as loading, unloading and transportation were obtained from relevant sources. Based on these input cost, the estimated price of various crop residues type were obtained.

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. 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].

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 taluka. Figure 1.1 shows the political map of Gujarat.

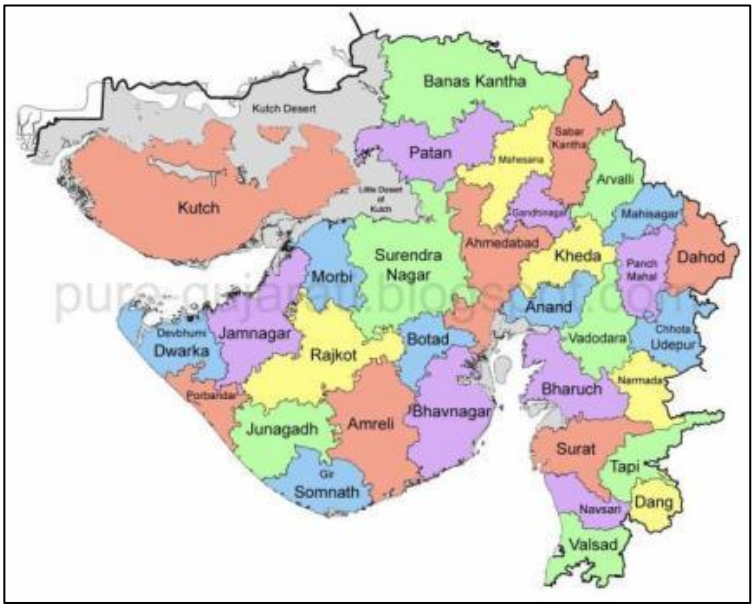


Figure 1.1: Political map of Gujarat

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

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

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.

1.4 Biomass energy potential

Gujarat Energy Development Agency (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 as published by GEDA.

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 tons of biomass which can sustain power generation to the order of 15,000 MW

Source: GEDA website

GEDA has also provided 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

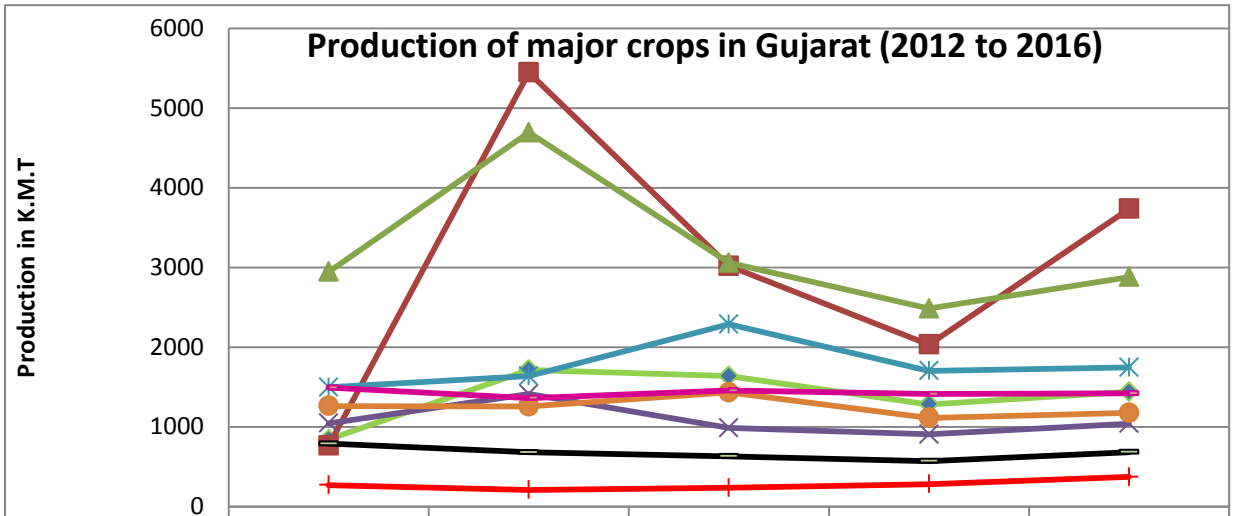
Two-thirds of the population are engaged in agricultural activities from which they earn their living. Agriculture is the main source of employment in rural areas. The total geographical area of Gujarat is 19,602,400 hectares, of which crops take up 10,630,700 hectares. The average rainfall in the state varies widely from 250 mm to 1,500 mm across various zones[3]. 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.

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

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 castor production) in the country. Area under castor production is 7.15 lakh hectares with production of 14.56 lakh metric tons. The state produces 30.18 lakh metric tons 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 2012-13 to 2016-17. 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	842	1715	1636	1282	1440
Groundnut	763	5446	3018	2032	3736
Wheat	2944	4694	3059	2484	2879
Bajra	1045	1413	987	906	1041
Rice	1497	1636	2287	1703	1745
Sugarcane	1261	1255	1433	1112	1176
Pigeon Pea	270	209	235	282	371
Castor	1493	1361	1456	1413	1420
Maize	791	681	631	571	684

Source: Directorate of Agriculture, Gujarat State, Gandhinagar

Figure 1.2: Production of major crops in Gujarat (2012-13 to 2016-17) [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.

[4] Directorate of agriculture, Gujarat State, Gandhinagar

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	Bajra	June–July	September–October
4	Cotton	May–June	October–December
5	Sugarcane	June–October	October–January
6	Rice	June–July	October–November
7	Pigeon Pea	June–July	November–January
8	Castor	July–August	January–February
9	Maize	November-March	June- September

Table 1.3: District-wise biomass generation (K.M.T) for 2014–15

S.No	District	Cotton			Groundnut		Wheat		Bajra			Sugarcane		Rice			Pigeon Pea	Castor	Maize		Total
		Stalk	Husk	Boll Shell	Shell	Stalk	Stalk	Pod	Stalk	Husk	Cob	Bagasse	Tops & leaves	Husk	Straw	Stalk	Stalk	Stalk	Stalk	Cob	
1	KUTCH	215.40	54.27	54.27	22.52	150.14	76.22	15.24	10.88	1.63	1.80	0.00	0.00	0.00	0.00	0.00	0.00	371.39	0.35	0.05	**974.16**
2	BANASKANTHA	157.29	32.67	32.67	36.73	244.90	400.30	80.06	646.21	96.93	106.62	0.00	0.00	0.00	0.00	0.00	2.38	532.66	27.69	4.15	**2401.26**
3	PATAN	212.32	34.92	34.92	0.04	0.29	146.30	29.26	43.14	6.47	7.12	0.00	0.00	0.00	0.00	0.00	0.00	402.60	0.00	0.00	**917.38**
4	MAHESANA	223.61	42.37	42.37	5.73	38.19	301.67	60.33	92.14	13.82	15.20	0.00	0.00	5.41	40.56	40.56	0.00	310.61	1.02	0.15	**1233.74**
5	ARAVALLI	248.65	40.15	40.15	11.80	78.69	223.74	44.75	19.37	2.91	3.20	0.00	0.00	0.18	1.33	1.33	18.25	87.20	107.71	16.16	**945.57**
6	SABARKANTHA	281.75	48.15	48.15	36.44	242.95	359.45	71.89	37.74	5.66	6.23	0.00	0.00	2.68	20.09	20.09	16.44	298.04	50.92	7.64	**1554.31**
7	GANDHINAGAR	104.10	19.95	19.95	4.07	27.13	155.49	31.10	67.86	10.18	11.20	0.00	0.00	68.50	513.72	513.72	0.74	117.22	0.00	0.00	**1664.93**
8	AHMEDABAD	489.85	45.43	45.43	0.04	0.29	575.70	115.14	6.08	0.91	1.00	0.00	0.00	88.40	662.97	662.97	1.85	185.59	0.00	0.00	**2881.65**
9	ANAND	25.03	6.06	6.06	0.00	0.00	290.71	58.14	185.01	27.75	30.53	0.00	0.00	77.82	583.62	583.62	1.86	9.34	1.15	0.17	**1886.87**
10	KHEDA	93.69	19.22	19.22	0.35	2.32	224.84	44.97	145.66	21.85	24.03	0.00	0.00	72.01	540.09	540.09	1.62	50.43	0.76	0.11	**1801.26**
11	PANCHMAHAL	45.77	9.84	9.84	0.47	3.13	64.61	12.92	7.85	1.18	1.30	0.00	0.00	9.11	68.35	68.35	82.93	0.11	236.83	35.52	**658.11**
12	CHOTA UDEPURA	269.20	66.11	66.11	2.12	14.15	2.66	0.53	0.00	0.00	0.00	0.00	0.00	5.10	38.23	38.23	75.15	2.85	259.17	38.88	**878.49**
13	MAHISAGAR	39.73	6.85	6.85	0.81	5.39	155.50	31.10	12.23	1.83	2.02	0.00	0.00	15.29	114.68	114.68	30.23	4.68	187.86	28.18	**757.91**
14	DAHOD	3.99	0.72	0.72	0.82	5.43	157.90	31.58	0.00	0.00	0.00	0.00	0.00	6.50	48.78	48.78	34.14	0.07	286.62	42.99	**669.04**
15	VADODARA	409.90	67.27	67.27	0.00	0.00	83.11	16.62	20.64	3.10	3.41	8.14	1.23	12.64	94.82	94.82	43.76	101.89	12.45	1.87	**1042.94**
16	SURENDRANAGAR	1246.03	203.61	203.61	21.83	145.54	149.58	29.92	11.88	1.78	1.96	0.00	0.00	4.13	30.97	30.97	0.00	130.06	0.00	0.00	**2211.87**
17	RAJKOT	873.53	120.40	120.40	89.25	595.02	71.35	14.27	0.82	0.12	0.13	0.00	0.00	0.00	0.00	0.00	0.88	37.32	0.36	0.05	**1923.90**
18	JAMNAGAR	684.29	119.52	119.52	89.96	599.73	6.97	1.39	0.27	0.04	0.04	0.00	0.00	0.00	0.00	0.00	1.83	39.06	0.00	0.00	**1662.62**
19	PORBANDAR	80.71	17.55	17.55	40.51	270.04	86.11	17.22	0.24	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	4.34	0.00	0.00	**534.35**
20	GIR SOMNATH	131.16	19.40	19.40	79.93	532.85	483.06	96.61	29.24	4.39	4.82	27.44	4.16	0.00	0.00	0.00	0.10	22.12	0.00	0.00	**1454.68**
21	MORBI	612.86	124.36	124.36	34.09	227.25	79.87	15.97	0.54	0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.00	51.06	0.14	0.02	**1270.69**
22	BOTAD	645.67	75.32	75.32	0.10	0.64	21.34	4.27	0.27	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.17	0.82	0.00	0.00	**824.00**
23	DEVBHUMI DWARKA	169.20	42.88	42.88	74.20	494.69	11.26	2.25	0.30	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	5.44	0.00	0.00	**843.19**
24	JUNAGADH	360.56	77.49	77.49	195.86	1305.74	449.66	89.93	5.26	0.79	0.87	0.00	0.00	0.00	0.00	0.00	0.55	3.64	0.00	0.00	**2567.84**
25	AMRELI	1569.22	150.52	150.52	29.49	196.59	22.21	4.44	0.95	0.14	0.16	0.00	0.00	0.00	0.00	0.00	2.66	15.06	0.00	0.00	**2141.96**
26	BHAVANAGAR	800.91	102.71	102.71	34.12	227.48	41.84	8.37	19.95	2.99	3.29	0.22	0.03	0.00	0.00	0.00	1.39	4.11	3.49	0.52	**1354.13**
27	SURAT	25.53	4.55	4.55	0.44	2.94	23.89	4.78	0.00	0.00	0.00	221.25	33.52	31.30	234.74	234.74	27.01	0.32	2.52	0.38	**852.46**
28	NARMADA	177.84	21.13	21.13	0.26	1.75	4.45	0.89	2.41	0.36	0.40	16.77	2.54	2.21	16.58	16.58	51.51	2.12	18.73	2.81	**360.47**
29	BHARUCH	310.73	42.67	42.67	0.29	1.95	73.22	14.64	1.47	0.22	0.24	82.81	12.55	5.17	38.80	38.80	136.11	67.20	2.20	0.33	**872.07**
30	DANG	0.00	0.00	0.00	1.28	8.53	6.28	1.26	26.13	3.92	4.31	0.41	0.06	8.92	66.94	66.94	6.87	0.00	9.73	1.46	**213.04**
31	NAVASARI	0.00	0.00	0.00	0.00	0.00	0.72	0.14	0.14	0.02	0.02	41.36	6.27	52.85	396.40	396.40	2.24	0.00	0.00	0.00	**896.56**
32	VALSAD	0.00	0.00	0.00	0.15	0.97	0.00	0.00	8.07	1.21	1.33	13.64	2.07	49.18	368.82	368.82	8.74	0.00	0.00	0.00	**823.00**
33	TAPI	31.94	3.69	3.69	4.04	26.91	16.00	3.20	0.00	0.00	0.00	50.33	7.63	41.20	309.00	309.00	41.10	3.66	4.70	0.71	**856.80**
GUJARAT STATE TOTAL		**10540.46**	**1619.78**	**1619.78**	**817.74**	**5451.62**	**4766.01**	**953.18**	**1402.75**	**210.40**	**231.45**	**462.37**	**70.06**	**558.60**	**4189.49**	**4189.49**	**590.51**	**2861.01**	**1214.40**	**182.15**	**41931.25**

Source: Directorate of Agriculture, Gujarat, Gandhinagar

Table 1.3 clearly indicates that the biomass generation from the major crops in the year 2014–15 is as follows: cotton stalk (10.54 million tons) has the highest production and is followed by groundnut stalk (5.45 million tons) and wheat stalk (4.76 million tons).

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.

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

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.

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
	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	784,330	Persons	2011
		b) Female	741,275	Persons	2011
		Total population	1,525,605	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 8% 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 39% of total farmers in have small land holding, 35% farmers have other land holding, while 26% farmers have marginal 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	Land Area (in hectares)	No. of Farmers	Total Area (in hectares)
1	Marginal	<1	44,444 (26%)*	29,110
2	Small	1 - 2	65,736 (39%)*	96,273
3	Others	>2	58,436 (35%)*	222,267
		Total	**168,616**	**347,650**

Source: District statistical book, Junagadh

* Figure in bracket shows the percentage of different category of farmers

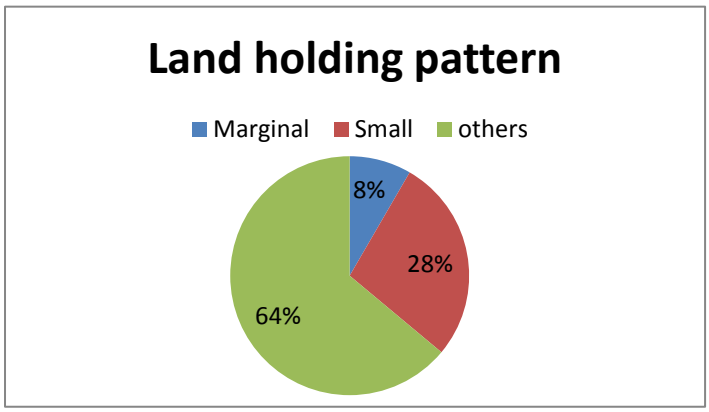


Figure 2.2: Percentage share of different land holdings

2.2.2 Land use pattern

The total geographical area of the district is 586 kilo hectares out of which nearly 507 kilo hectare (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 2.3 shows the percentage share of different land use patterns.

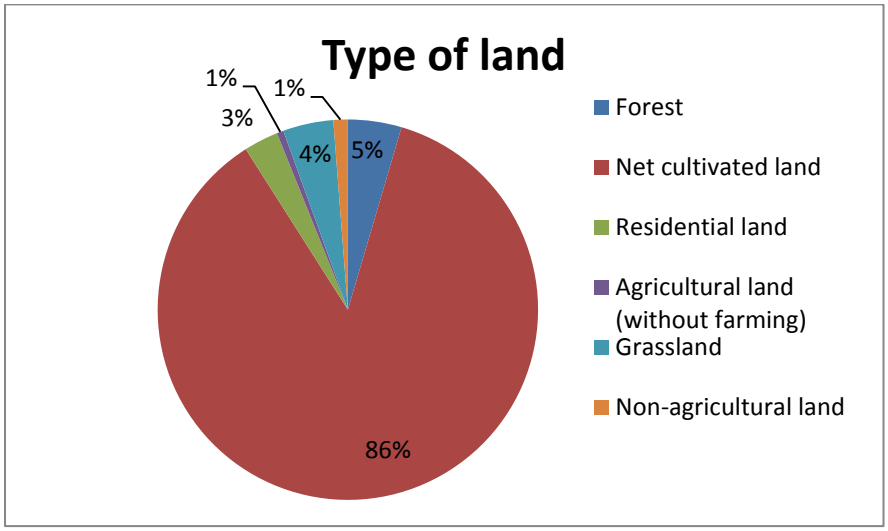


Figure 2.3: Land use pattern

2.2.3 Production pattern of different crops

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 652.87 K.M.T which was the highest in the state. Figure 2.4 (a) and Figure 2.4 (b) shows the year-wise crop production data for major and minor crops of Junagadh district for last three years[6]. It can be seen from the figure below that there is a large variation in the production of groundnut in all the years. Figure 2.5 (a) and Figure 2.5 (b) shows the area under crop production for major and minor crops for the last three years[7]. The area under groundnut production is the highest every year.

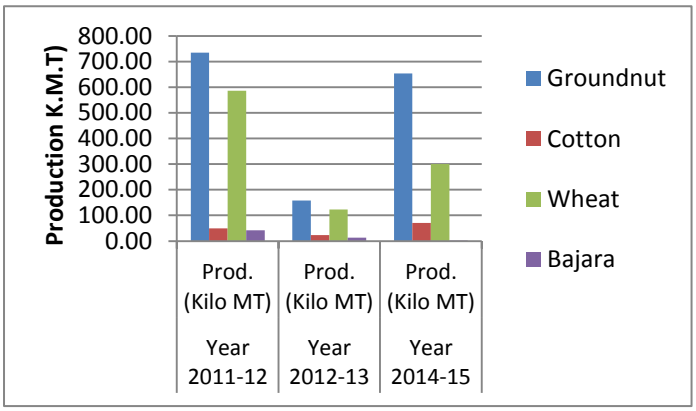


Figure 2.4(a): Year wise production trend of major crops

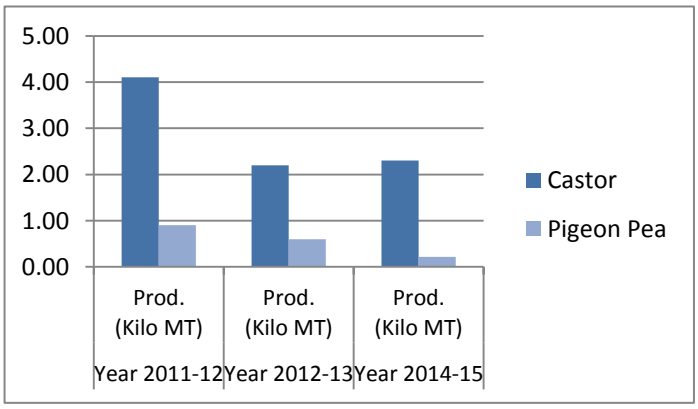


Figure 2.4(b): Year wise production trends of minor crops

[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

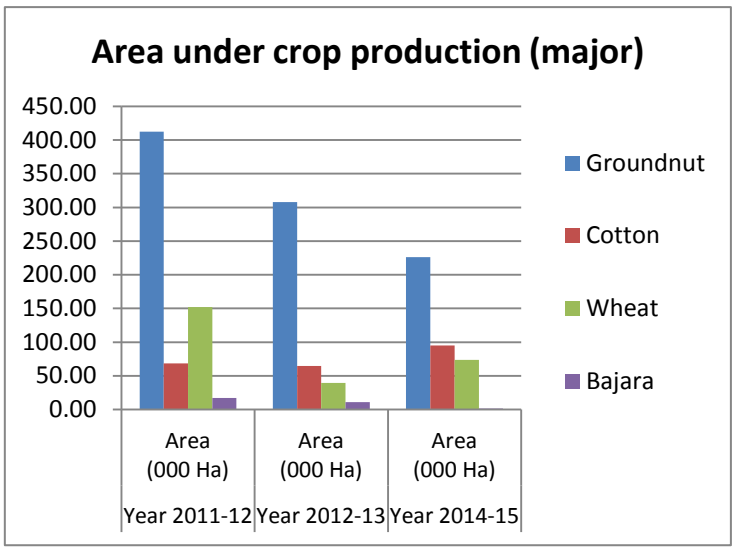


Figure 2.5(a): Area under major crop production

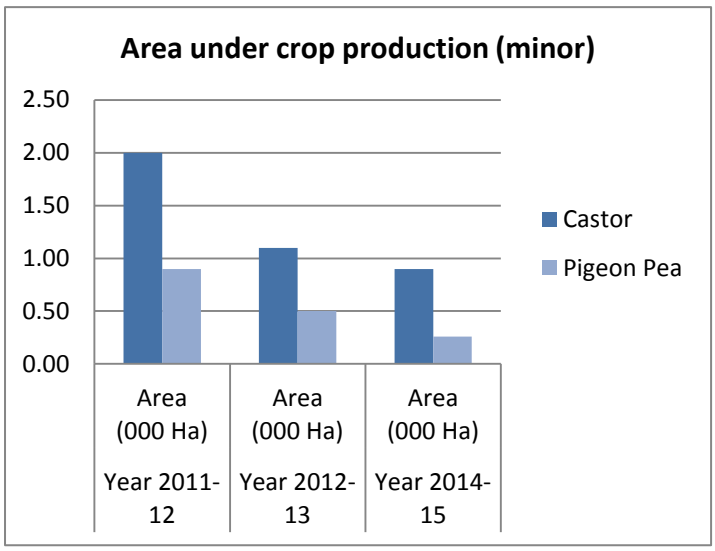


Figure 2.5(b): Area under minor crop productions

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 K.M.T. 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. (K.M.T)	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	Bajra	1.70	2.63	1.55
5	Castor	0.90	2.30	2.56
6	Pigeon pea	0.26	0.22	0.85
7.	Others (Onion, garlic and vegetables)	109.05	-	-

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. The main crops of the district are groundnut followed by cotton, wheat, onion, isabgul etc.

As shown in pie chart in Figure 2.6, out of the total crop produced, 44.6% area is for groundnut cultivation only. Others include vegetables, such as onion, garlic, etc.

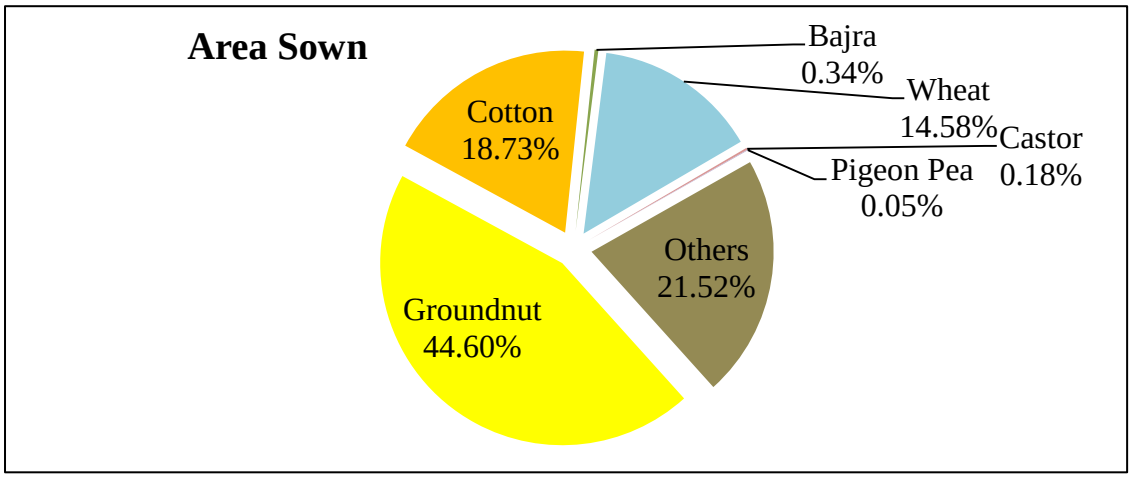


Figure 2.6: Per cent share of area of different crops sown in the district

2.3 Biomass resource analyses

The biomass of identified crops has been calculated with the formula mentioned in methodology. Table 2.4 shows the quantity of crop residue generated from different crops in the district.

Table 2.4: Crop residue generated in the district (2014–15)

Crop Residue	Quantity (in K.M.T)
Groundnut shell	195.86
Groundnut stalk	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	3.64
Pigeon pea stalk	0.55
Total	**2567.84**

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 (cotton stalk and groundnut shell) in the district is 556.42 K.M.T.

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 bajra. 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 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 ton.

Wheat stalk and groundnut stalk is completely used as fodder residues and hence not available for energy purpose. Other residues, such as pigeon pea stalks, castor stalks and bajra stalks are produced in less quantity and hence not considered.

As per interaction with APMC, about 20% total groundnut produced can be estimated to be used as a food commodity. Therefore, 20% of groundnut shell lost while eating groundnut.

A summary of the farmers' interviews have been shown in Table 2.5. The details of interviews have been given in Annexure X.

Table 2.5: Summary of the farmers' interviews

Name of the crop	Type of residue	Current usage of crop residues	Crop Selling price (Rs./20 kg)
Cotton	Stalk	Burnt in field, Domestic cooking and heating	800–1000
Groundnut	Shell	For captive use in Oil mills, bio coal industries	600–800
	Stalk	Fodder	100–200
Wheat	Stalk	Fodder and manure	250–300
Pigeon Pea	Stalk	For HHs cooking	600–800

Figure 2.7: Cotton field

Figure 2.8: Processed cotton in APMC

Figure 2.9: 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 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 product to APMC. As per the survey, the average residue generation in the form of shells from groundnuts is around 25%.

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 tons of groundnuts per day out of which 2.5 to 5 tons of shells are produced. The self-consumption of groundnut shells by oil mill is 0.5 to 1 ton 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 2.10). One kg of groundnut contains 700 grams of seed which is separated by the oil mills itself. The seed contains 60% of the oil content (Figure 2.11). 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. Hence **total annual groundnut shell consumption by all oil mills in the district are estimated to be 13.50 K.M.T** as average groundnut shell consumed by an oil mill is 0.75 (average of 0.5 and 1) tons per day.

Figure 2.10: Bio coal fire in an oil mill boiler

Figure 2.11: 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 shell and 10% other local fuels including cotton stalk. The capacity of the machine in the plant was 1.5 ton per hour. Hence, total groundnut shell consumed in bio-coal unit is 1.35 tons/hr. These units are operated 8 hours/day and 250 days in a year. Therefore, **estimated annual groundnut shell consumption in bio-coal industries in Junagadh district is 54 K.M.T**. All these plants are based on piston press technology. The production cost was found to be Rs. 0.6 to 1.00 per kg including labour, electricity, and maintenance. The cost of raw material varies from Rs. 3.5 per kg to Rs. 4.0 per kg depending upon the seasonal availability and production of groundnut. Transportation cost of bio coal is Rs. 15–20/km/ton. The selling price of bio-coal ranges from Rs. 5 to 6 per 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 2.12 shows the bio-coal unit in Junagadh.

Figure 2.12: 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 75% is disposed in fields by burning 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 use around 5% cotton stalk for blending with groundnut shell. The entire openly burnt cotton stalk can be estimated as a surplus. Table 2.6 shows the per cent consumption of cotton stalk as per the current practices. Table 2.7 shows the annual estimated surplus cotton stalk.

Table 2.6: Percentage wise consumption of cotton stalk in different sectors in the district

Cooking and other domestic uses (%)	Bio-coal industries (%)	Open field burning (%)
20	5	75

Source: Interview with farmers

Table 2.7: Estimated surplus cotton stalk in the district

A	**Total cotton stalk generated in the district (K.M.T)**	**360.56**
B	Estimated demand of cotton stalk in domestic cooking and other works (K.M.T)	72.11
C	Estimated demand of cotton stalk in Bio coal industries (K.M.T)	18.03
D	Total annual demand of cotton stalk (K.M.T) [B+C]	90.14
E	Estimated net surplus cotton stalk (K.M.T) [A – D]	270.42

2.4.3.2 Groundnut shell consumption and surplus

As per the industrial survey, it has been found that groundnut shell is produced in oil mills. Groundnut shells are majorly consumed by bio-coal industries. Table 2.8 shows the consumption and surplus of groundnut shell.

Table 2.8: Estimated surplus of groundnut shell in the district

A	**Total groundnut shell generated in the district (K.M.T)**	**195.86**
B	Total groundnut shell consumed by bio coal industries (K.M.T)*	54.00
C	Estimated annual groundnut shell consumed by oil mills (K.M.T)**	13.50
D	Estimated annual groundnut shell lost while groundnut eating (K.M.T)***	39.17
E	Total annual consumption of groundnut shell (K.M.T) [B+C+D]	106.67
F	Estimated surplus groundnut shell (K.M.T) [A-E]	89.19
G	Potential surplus of groundnut shell (K.M.T) [A-C-D]****	143.19

* Explained in section 2.4.2.2

** Explained in section 2.4.2.1

*** Described in section 2.4.1

**** Potential surplus includes the quantity of groundnut shell which is currently consumed by bio coal industries but can be potentially available for alternate competitive use.

As per the survey and calculations, around 2.7 lakh tons of cotton stalk and 1.43 lakh tons 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 concrete 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 demand of biomass for institutional cooking is nil. Table 2.9 shows the institutional demand of crop residue in the district

Table 2.9 Institutional demand of crop residue in the district

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 (production), 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 25.67 lakh tons out of which residue generated from the considered crop residues, that is, cotton stalk and groundnut shell are 5.56 lakh tons

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

Type of crop residue	Generation	Consumption/Demand HH/Bio-coal	Surplus
Cotton stalk	360.56	90.14	270.42
Groundnut shell	195.86	52.67	143.19

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 ton of cotton stalk collection from the field requires four to five 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. 800 to Rs. 1,000 per ton 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 ton 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 tons. 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: Estimated cost of cotton stalk

Particulars	Average cost (Rs/Ton)	Reference
Farmer's remuneration*	350 (200-500)**	farmer's interview
Labor charges for uprooting, bundling and loading[8]	900 (800-1,000)**	farmer's interview
Shredding cost	350	farmer's interview
Transportation cost (0–25 km)	350	Local source
Unloading cost	100	Local source
Av. Landed cost	**2,050**	

*Assumed numbers

** Figures in brackets give the price range during the year

Table 2.12: Cost of groundnut shell

Particulars	Average cost (Rs/Ton)	Reference
Cost of groundnut shell charged by oil mill	3,100 (2,800–3,400)*	From oil mill
Loading and Unloading	200	From oil mill
Transportation cost (0 – 50 km)[9]	450	From oil mill
Av. Landed cost	**3,750**	

* Figures in brackets give the price range during the year

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 needs consideration. In case of groundnut shell, 5% loss in weight due to moisture and dust/sand/stone has 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 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[10]		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		
Groundnut Shell	3,750	5*	50	-	-	50	3,947
Cotton Stalk	2,050	15	150	5	50	200	2,563

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

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

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. 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. 3,463 per ton** at corresponding weighted average GCV of **4,370 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. 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 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[11]. 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 headquarters in Amreli itself. Taluka wise demographic profile of Amreli district is given in

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

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**		
i)	Latitude	20.45 to 22.15 North	Degree
ii)	Longitude	70.13 to 71.45 East	Degree
B	**Administrative units**		
i)	Sub Division	05	Nos
ii)	Tehsil	11	Nos
iii)	Sub-Tehsil	--	Nos
iv)	Patwar Circle	15	Nos
v)	Panchayat Samitis	09	Nos
vi)	Nagar Nigams	--	Nos
vii)	Nagar Palika	09	Nos
viii)	Gram Panchayats	596	Nos
ix)	Revenue villages	626	Nos
x)	Assembly areas	05	Nos
2	**Population**		
i)	Male	770,651	Persons
ii)	Female	742,963	Persons

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

3.2 Agricultural scenario of Amreli District

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 720,690 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. as expressed in Table 3.2. Figure 3.2 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.

Table 3.2: Land use pattern in Amreli District

S. No.	Type of land use pattern	Area (hectares)
1	Forest	35,965
2	Barren and Uncultivable land	24,515
3	Area under non-Agriculture use	46,569
4	Permanent Pasture and Grazing land	51,090
5	Cultivable Fallow land	8,768
6	Current Fallow	7,975
7	Fallow land other than current fallow	1,765
8	Net area sown	544,043
9	**Aggregate**	**720,690**

Source: District Statistical book (2014-15)

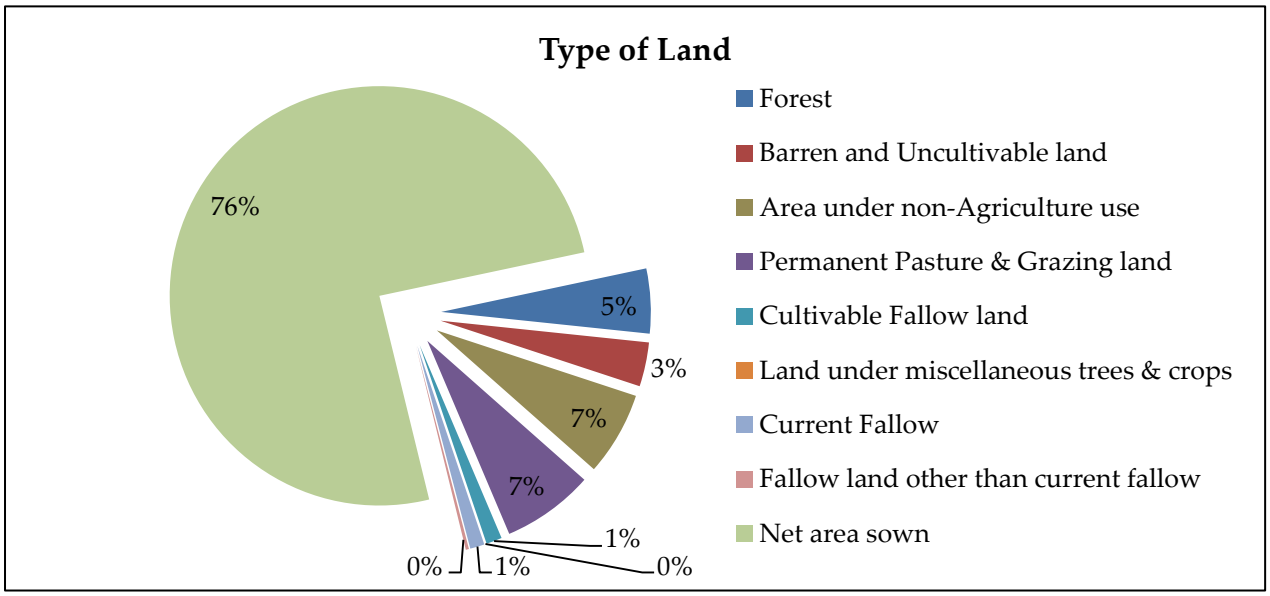


Figure 3.2: Land use pattern in Amreli district

3.2.2 Land holding pattern

As per the data obtained from the District Statistical Office, Amreli, there are total 249,104 farmers with a total land area of 590,425 hectares in the district. Percentage share of different land holdings shown in Figure 3.3 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. Taluka-wise land holding pattern and number of farmers are given in Annexure V.

Table 3.3: No. of farmers and area based on their land holdings[12]

S.No	Type	Land Area (in hectares)	Number of Farmers	Total area (in hectares)
1	Marginal	<1	52,891	32,672
2	Small	1-2	89,756	132,332
3	Others	>2	106,457	425,421
	Total		249,104	590,425

Source: District Statistical Office, Amreli (2014–15)

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

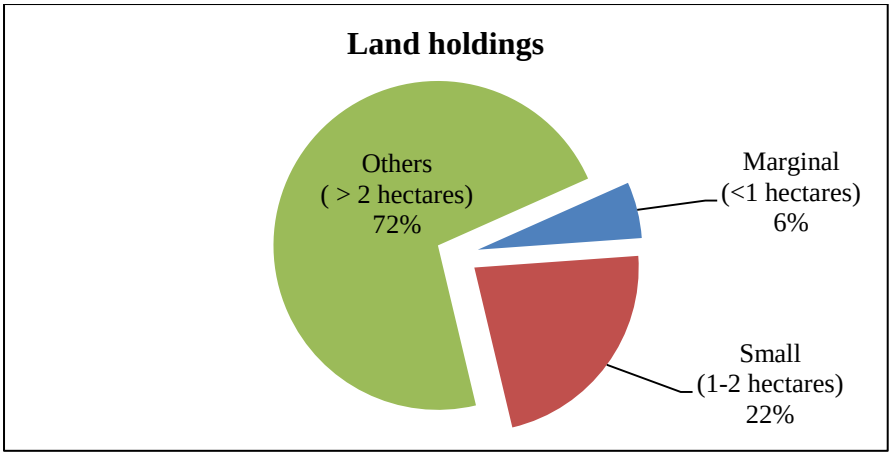


Figure 3.3: Percentage share of different land holdings

3.2.3 Production pattern of different crops

The main crops of the district are cotton followed by groundnut, wheat, castor, pigeon pea, onion, etc. Cropping pattern in Amreli is mostly cotton and groundnut. 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 3.4 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. Others in the figure 3.4 refer to the crops grown in the district such as gram, udad, fruits and vegetables etc. Year wise Area, production and yield data of selected crops for three years is given in Annexure IV.

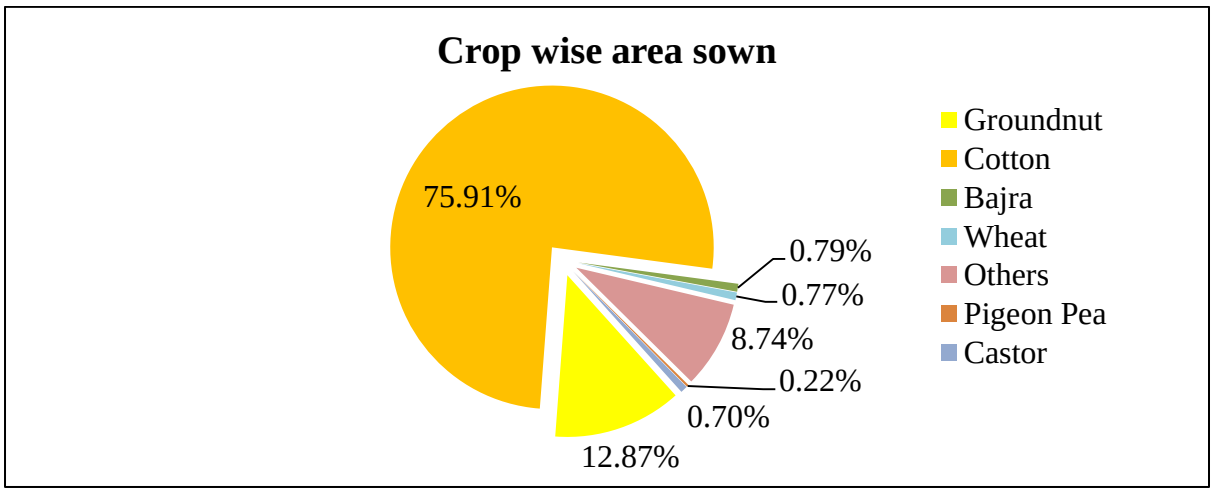


Figure 3.4: Percentage share of different crops sown in the Amreli district

Figure 3.5(a, b) and 3.6(a, b) gives the trend of the area under cultivation and production respectively for different crops. From 2011-12 to 2014-15, the area under cultivation for groundnut and wheat has decreased in the past years. The data for 2013–14 is not included

during the analysis as the data set obtained from the agricultural department was incomplete. Table 3.4 shows the area production yield data for the year 2014-15.

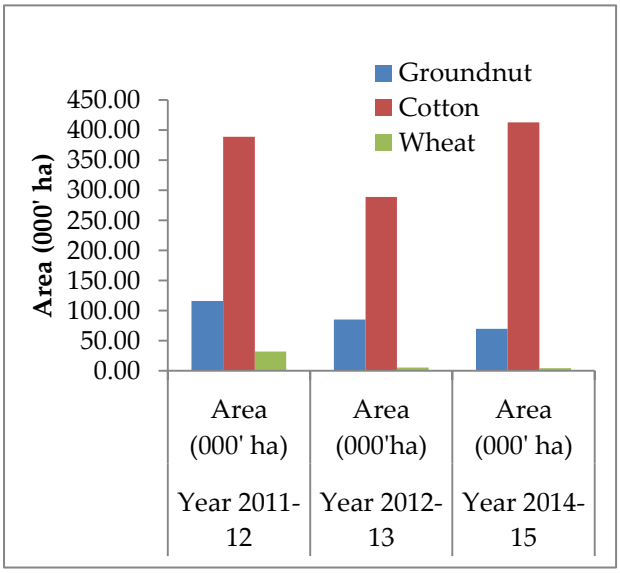


Figure 3.5 (a): Area under Major Crop Production

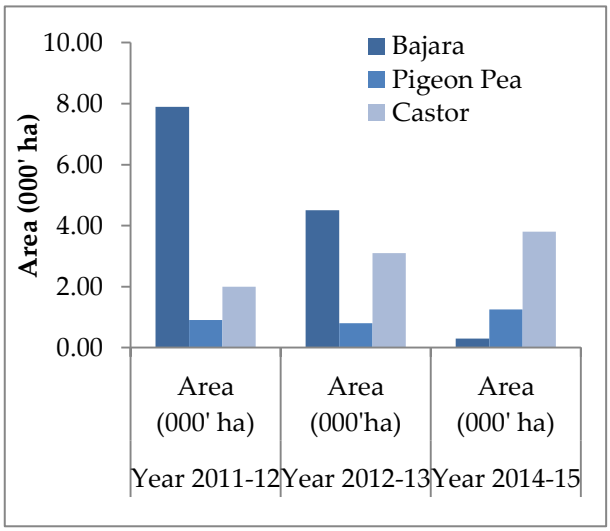


Figure 3.5 (b): Area under Minor Crop Production

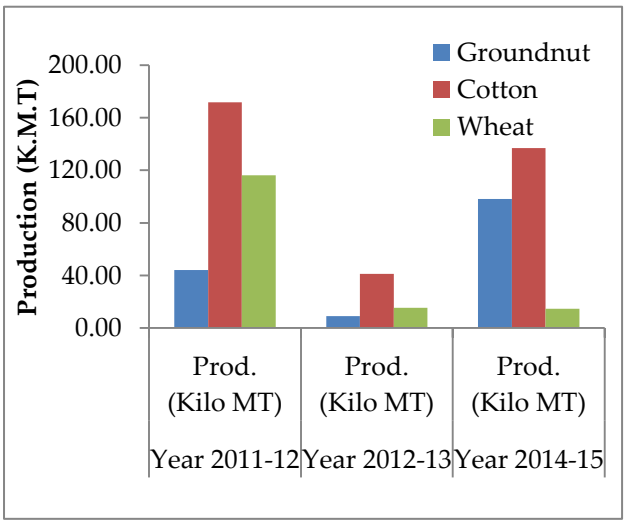


Figure 3.6 (a): Year wise production trend of major crops

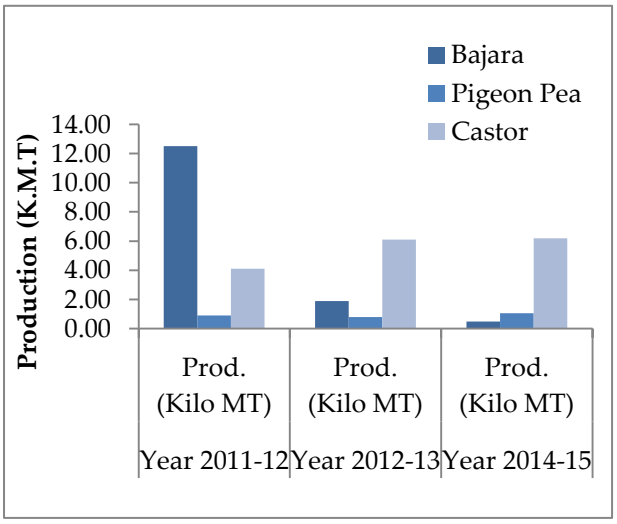


Figure 3.6 (b): Year wise production trend of minor crops

Table 3.4: APY data of selected crops

S No.	Name of the Crop	Year 2014-15		
		Area (000' Ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Groundnut	70.00	98.30	1.40
2	Cotton	413.00	136.83	0.33
3	Wheat	4.20	14.81	3.53
4	Bajra	0.30	0.48	1.60
5	Pigeon Pea	1.25	1.06	0.85
6	Castor	3.80	6.20	1.63
7	Others	51.49	-	-

Source: APY Tentative Data (2014-15), Directorate of Agriculture, Gandhinagar

3.3 Primary data collection

A team of two person accompanied by an executive officer from PGVCL visited the farmer groups and industries during February 28 to March 4, 2017 in Amreli district. To understand the utilisation of crop residue 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 taluka for farmer interviews was 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 taluka thus selected were Bagasara, Amreli, and Savarkundla. A total of 15 farmers were surveyed as shown in table 3.5. The details of interviewed farmers are given in Annexure X.

Table 3.5: List of number of farmers surveyed

Name of Taluka	Number of farmers surveyed
Bagasara	4
Amreli	6
Savarkundla	5
Total	**15**

Figure 3.7: Interview with farmers in three blocks of Amreli District

Table 3.6 presents a summary of details gathered from farmers which were essentially interviewed during the team visit to Amreli.

Table 3.6: The summary of the farmers' interviews conducted in Amreli District

Name of the Crop	Type of crop residues	Current usage of crop residues
Cotton	Stalk	Burnt in field and for domestic cooking
Groundnut	Shell	Given to Oil mills/ Traders/ APMC
	Stalk	Fodder
Wheat	Stalk	Fodder and Manure
Pigeon Pea	Stalk	Used for cooking purpose
Chana	Straw	Fodder

Bajra	Stalk	Used for cooking purpose
Castor	Stalk	Used for cooking purpose

Source: Interview with farmers

As per interaction with farmers, the major crops grown in Amreli District are groundnut and cotton. Other than this they also grow wheat, 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 upon rainfall.

3.4 Observations

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

Cotton stalk: According to the farmers, currently around 20% 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 trader, APMC and oil mills. Around 20% of groundnut shell is lost while eating groundnut.

Other residues: According to the farmers, wheat stalk, groundnut stalk goes to fodder. Other residues, such as pigeon pea stalks, chana straw, and bajra 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 ton. 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.

3.4.1 Industrial survey

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

3.4.1.1 Oil mills

Farmers in Amreli District sell their entire produce of groundnut to APMC. Amreli District has around 30 oil mills as discussed with the visited mills. The team visited two oil mills (one small and one medium) in the district. As per the survey, around 80% 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 tons per day (small) to 40 tons (medium) per day.
- Average groundnut shell generated at each mill is 4.5 tons per day. These mills are operation around 180 days in a year. Hence total groundnut shell generated in the district from oil mills will be 24.3 K.M.T.
- 10% of groundnut is used by oil mills for their captive use. Hence, **annual groundnut shell consumed by oil mills in the district is 2.43 K.M.T.** Remaining shells are sold to bio-coal industries for bio-coal making.
- APMC sell groundnut at a price of Rs. 40–50 per kg. Oil mill separates groundnut shells from the seeds during the oil extraction process.
- Price for groundnut shell varies from Rs 2.50 per kg to Rs 3.00 per kg depending on the season as shown in Table 3.7.

Table 3.7: Cost 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)
40–50	2.50 to 3.00

Source: Interview from oil mills

Figure 3.8: Visit to oil mill industries in Amreli District

3.4.1.2 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 as shown in Figure 3.9. 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. The groundnut shell was procured directly from the oil mills. Table 3.8 shows the details of three bio-coal industries visited in the Amreli district. The following observations were made after the interaction with the industries:

- The range of capacity of three plants visited is 5,000–7,000 tons/year
- The production cost was found Rs 600 per ton to Rs 700 per 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.
- Selling price of bio-coal is given in Table 3.8 and it varies with the price of raw material. Details 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 Ankleshwar.

Table 3.8: Cost details 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)	2.00–2.50	3.00–3.50	3.00–3.50
Transportation cost of raw material included in purchasing price (Rs/ kg)			0.30 to 0.50
Selling price of bio-coal (Rs./ kg)	4.00-6.00	4.00-4.50	4.00-4.50

Source: Interview with bio-coal industries in Amreli district

Figure 3.9: Visit to bio-coal industries in Amreli District

3.4.2 Institutions

In Amreli there are total of 815 mid-day meal institutions (Table 3.9) 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 crop residue for cooking is nil.

Table 3.9: Information related to the mid-day meal scheme in Amreli District

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

Source: Mid-day Meal Collectorate, Gandhinagar

3.5 Crop residue resource analysis

3.5.1 Total crop residue generated and its use

As per the formula described in the methodology section, crop residue or crop residue of the major crops has been calculated. Table 3.10 shows the values of major crop residue generated from different crops in the district. The total crop residue generated from the major crops in the district is around 21.42 lakh tons in 2014–15.

Table 3.10: Crop residue generated in the district (2014-15)

Crop Residue	Quantity (in K.M.T)
Groundnut Shell	29.49
Groundnut stalk	196.59
Cotton Stalk	1,569.22
Cotton Husk	150.52
Cotton Boll Shell	150.52
Wheat Stalk	22.21
Wheat Pod	4.44
Bajra Stalk	0.95
Bajra Husk	0.14
Bajra Cob	0.16
Pigeon pea stalk	2.66
Castor stalk	15.06
Aggregate	**2,141.96**

Out of this generated crop residue,

a) Eighty per cent of the cotton stalk (1,255.38 K.M.T) 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) Out of 29.49 K.M.T of groundnut shell around 23.6 K.M.T is used in oil mills and bio-coal industries and rest shells are lost while eating groundnut.

c) Other crop residue (543.25 K.M.T) such as groundnut stalk, bajra, stalk, and wheat stalk etc. is self-consumed by the farmers either for fodder, manure, and domestic cooking.

3.5.2 Crop residue 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% of the cotton stalk is used as a fuel for domestic cooking and rest 80% is disposed of in fields by burning them. A crop residue-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 3.11

shows the per cent consumption of cotton stalk as per current practices. Table 3.12 shows the estimated annual surplus of cotton stalk in Amreli District.

Table 3.11: Percentage wise consumption of cotton stalk in different sectors in the district

District	Current practices with Cotton Stalk[13]	
	Cooking and heating (%)	Open field burning (%)
Amreli	20	80

Source: Interview with farmers

Table 3.12: Estimated surplus cotton stalk in the district

A	Cotton stalk generated in Amreli (K.M.T)	1,569.22
B	Estimated demand of cotton stalk in domestic cooking and other works (K.M.T)	313.84
C	**Estimated net surplus cotton stalk (K.M.T) [A-B]**	**1,255.38**

3.5.2.2 Groundnut shell consumption and surplus

It has already been seen that groundnut shells are mostly produced in oil mills. The total shell produced from oil mills has been estimated as 24,300 tons per annum. Table 3.13 gives the estimated surplus of groundnut shell in the district after being consumed by the oil mills.

Table 3.13: Estimated surplus of groundnut shell in the district

A	**Groundnut shell produced in the district (K.M.T)**	**29.49**
B	Ground nut shell used by oil mills for their captive use (K.M.T)*	2.43
C	Ground nut shell lost while eating groundnut (K.M.T)**	5.89
D	Groundnut shell consumed by bio coal industries (K.M.T)***	17.00
E	Estimated potential surplus groundnut shell (K.M.T) [A-B-C]****	21.17

* Explained in section 3.4.1.1
** Described in section 3.4
*** From Table 3.8
**** Although all the surplus groundnut shells are currently consumed by bio-coal industries but it can be considered as potential surplus as it can be utilised for other competitive use.

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 and heating purposes while remaining stalks are left in the field. Cropping of pigeon pea and castor is very limited in Amreli District. There is limited information about pigeon pea stalk and castor stalk is achieved during survey. Although as per interaction with farmers, they used to burn the pigeon pea stalk in the field itself.

3.6 Crop residue 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 is high; as a result the farmers are not interested in selling the stalk. However,

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

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 per ton. 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 3.14 and Table 3.15 give the estimated cost of cotton stalk and groundnut shell prevailing in the district.

Table 3.14: Estimated cost of cotton stalk

Particulars	Average cost (Rs./Ton)	Reference
Farmers Remuneration*	400 (300–500)**	farmers' interview
Collection cost (Labour charges for uprooting, bundling and loading)[14]	900 (800–1,000)**	farmers' interview
Transportation cost 0–25 km.	400 (300–500)**	local source
Unloading cost	200	from farmers
Processing cost (Shredding cost)	350	farmers' interview
Average landed cost	2,250	

*Farmers were not aware of remuneration

**Figures in brackets give the price range during the year

Table 3.15: Estimated cost of groundnut shell

Particulars	Average cost (Rs./Ton)	Reference
Crop residue cost from oil mills (including loading and unloading)	2,750 (2,500–3,000)*	from oil mills
Transportation 0–50 km.[15]	400	from oil mills
Average landed cost	3,150	

* Figures in brackets give the price range during the year

Therefore, the cotton stalk will be priced at Rs 2,250 per ton for its use (including labour charges, farmer remuneration, shredding and transportation); however, groundnut being a more commercial crop with a high demand will be priced at Rs 3,150 per ton.

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 and dust/sand/stone while in case of cotton stalk, 15% loss in weight due to moisture and 5% loss in weight due to dust/sand/stone is considered. Table 3.16 shows the crop residue price per ton considering moisture and dust/sand losses.

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

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

Table 3.16: Final cost of groundnut shell and cotton stalk considering losses

Description	Crop residue Price/ton	Moisture[16]		Dust/sand/stone		Total Weight losses per unit	Crop residue Price Per ton 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. So, it is assumed that the cotton stalk is feasibly available for four months in a year while groundnut shell 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 ton** at corresponding weighted average GCV of **4,370 kcal/kg**.

[16] 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 *taluka*: 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 around 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

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

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

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 holdings. A *taluka*-wise land holding pattern and the number of farmers is given in Annexure V.

Table 4.2: No. of farmers and their land holdings

S.no	Type	Scale (in hectares)	No. of Farmers	Area (in hectares)
1	Marginal	<1	51,753	34,562
2	Small	1 - 2	70,876	103,169
3	Others	>2	66,084	277,238
		Total	**188,713**	**414,969**

Source: District Agriculture Office, Bhavnagar

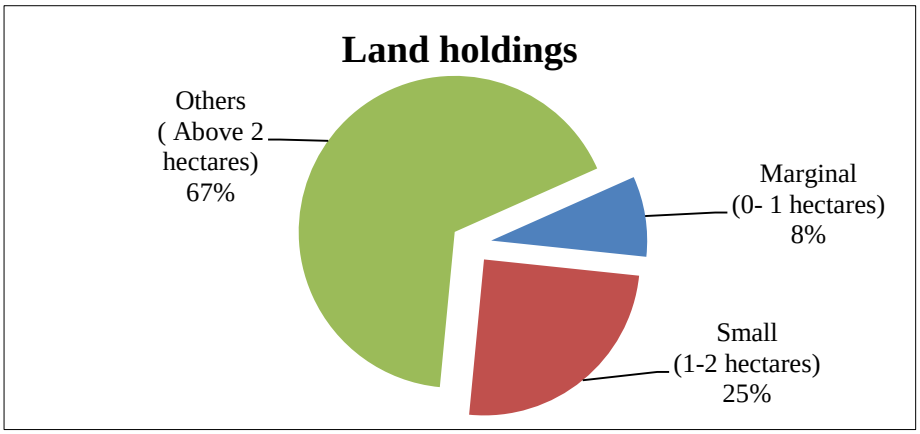


Figure 4.2: Percentage share of different land holdings

4.2.2 Land use pattern

The total reported area for the purpose of land use is 658,407 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. Table 4.3 shows the area of land use pattern while Figure 4.3 shows the percentage share of land use patterns.

Table 4.3: Land use pattern in Bhavnagar district

S.N.	Type of Land	Area (Ha)
1	Forest	77,981
2	Barren and Uncultivable land	65,601
3	Area under non-Agriculture use	21,455
4	Permanent Pasture & Grazing land	47,815
5	Cultivable Fallow land	35,906
6	Land under miscellaneous trees & crops	3,938
7	Current Fallow	13,684
8	Fallow land other than current fallow	23,305
9	Net area sown	368,722
Total		658,407

Source: District Statistical Book (2014-15)

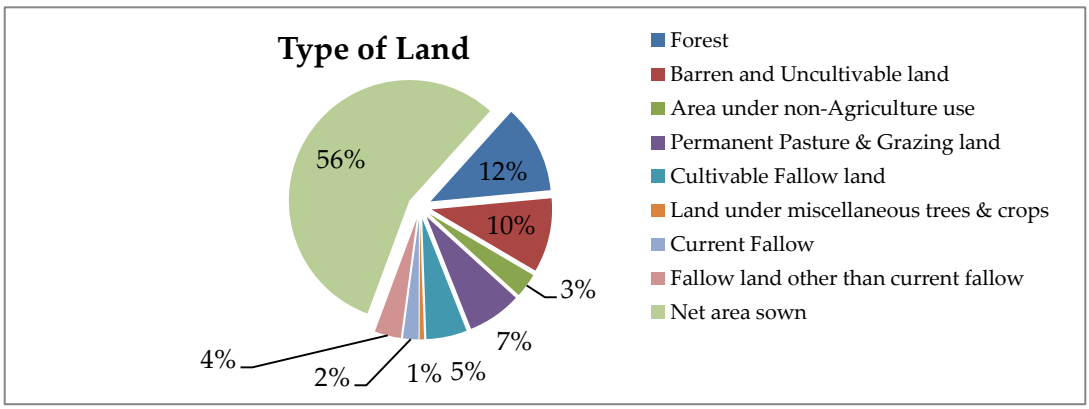


Figure 4.3 Land use pattern

4.2.3 Production pattern of different crops

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 tons. 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, wheat and garlic. The total production of cotton in Bhavnagar in 2014–15 was 93.37 K.M.T. In the present report, we consider only four major crops and three minor crops in our study including groundnut, cotton, wheat, bajra, Castor, Pigeon Pea and Maize.

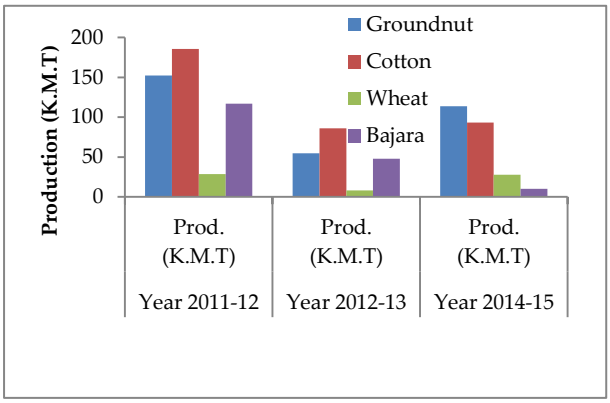


Figure 4.4(a): Year-wise production trend of major crops

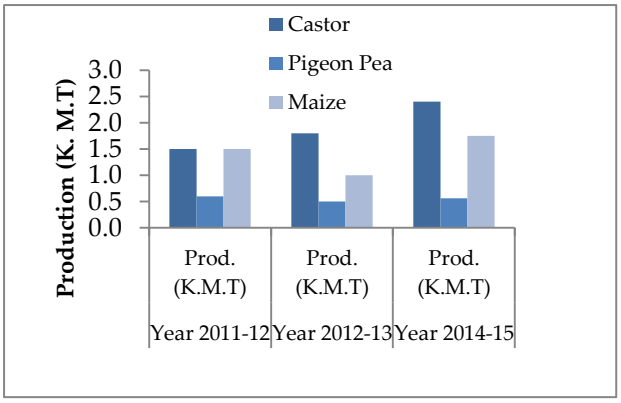


Figure 4.4(b): Year-wise production trend of minor crops

Figure 4.4 (a) and figure 4.4(b) shows the year-wise crop production data of Bhavnagar District for the last three years.

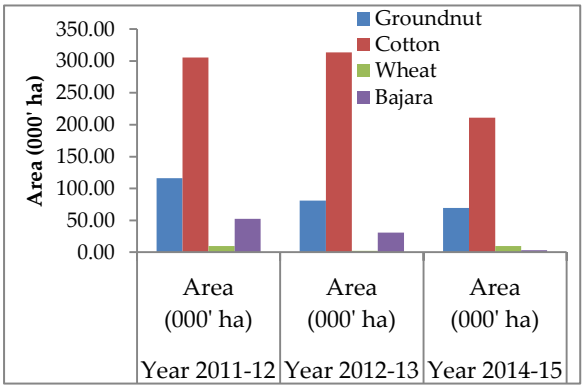


Figure 4.5(a): Year-wise land under cultivation for major crops

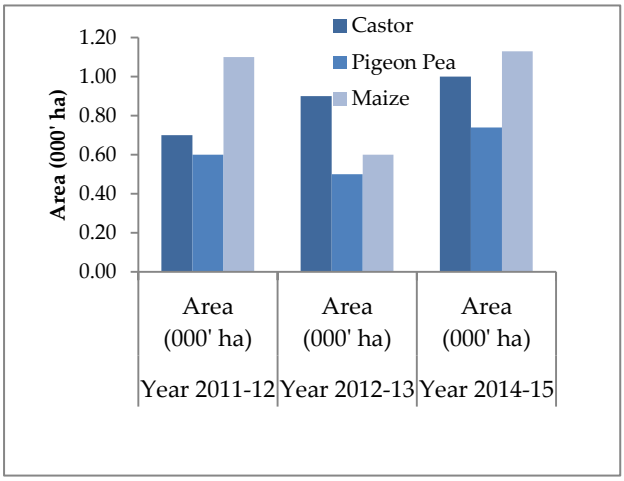


Figure 4.5(b): Year-wise land under cultivation for minor crops

Figure 4.5 (a) and Figure 4.5 (b) depicts the area under cultivation for three years.

Table 4.4 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 113.74 K.M.T followed by cotton (93.37 K.M.T) and Wheat (27.89 K.M.T). All of the others crops includes vegetable crops.

Table 4.4: APY data of selected crops for 2014–15

Sr. No.	Name of the Crop	Year 2014–15		
		Area (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Groundnut	69.55	113.74	1.64
2	Cotton	210.77	93.37	0.44
3	Wheat	9.70	27.89	2.87
4	Bajara	3.30	9.98	3.02
5	Castor	1.00	2.40	2.40
6	Pigeon pea	0.74	0.56	0.76
7	Maize	1.13	1.75	1.55
8	Others	138.47	-	-

Source: Tentative APY data, Directorate of Agriculture

4.2.4 Cropping pattern

The cropping pattern in Bhavnagar is mostly groundnut, 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 sown. The dominating crops area wise during the rabi season is wheat. The main crops of the district are groundnut followed by cotton, wheat, bajra, garlic, onion, castor, pigeon pea etc. Year wise 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 4.6, out of the total crop produced 48.49% area is under cultivation for cotton. Groundnut covers around 16% of total area sown.

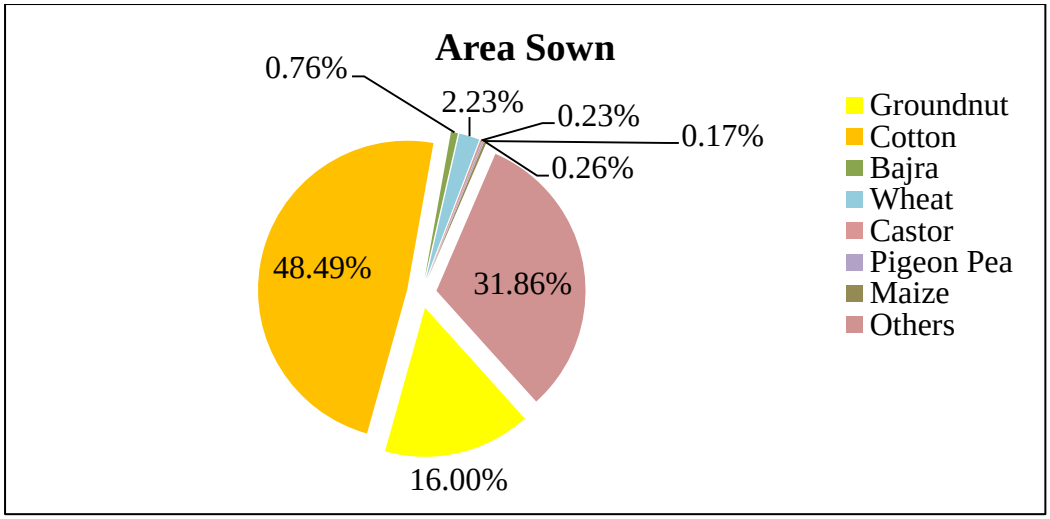


Figure 4.6: Per cent share of different crops sown in the district[17]

4.3 Crop residue resource analysis

4.3.1 Total Crop residue generated

As per the formula described in the methodology section, crop residue of identified crops has been calculated. Table 4.5 shows the values of major crop residue generated from different crops in the district of the year 2014–15.

Table 4.5: Major crop residue generated in the district

Crop Residue	Quantity (in K.M.T)
Cotton Stalk	800.91
Cotton Husk	102.71
Cotton Boll Shell	102.71
Groundnut Shell	34.12
Groundnut stalk	227.48
Castor Stalk	4.11
Pigeon pea Stalk	1.39
Wheat Stalk	41.84
Wheat Pod	8.37
Bajra Husk	2.99
Bajra Stalk	19.95
Bajra Cob	3.29
Maize Stalk	3.49
Maize cob	0.52
Sugarcane bagasse	0.22
Sugarcane tops and leaves	0.03
Total	**1,354.13**

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

17 District Agriculture Office

In 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 and industries in Bhavnagar. Since in year 2013 two *talukas* Ghadhada and Botad were removed from Bhavnagar district and became a part of new district named as Botad. Because of this, there are few variations in the data.

4.4.1. Farmers' survey

4.4.1.1 Farmers' information

Selection of *taluka* 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 *taluka* thus selected were Mahuwa, Sihor, Palitana, and Jesar. A total of 9 farmers were surveyed. The details of the interviewed farmers are given in Annexure X.

Table 4.6: Indicative list of farmers surveyed

Name of Taluka	Number of farmers surveyed
Mahuwa	3
Palitana	3
Shihor	2
Jesar	1

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

4.4.1.2 Data collection

Table 4.7 presents a summary of details gathered from farmers who were interviewed during the team visit to Bhavnagar.

Table 4.7: The summary of farmer interviews conducted in Bhavnagar District

Name of the crop	Crop residue generated	Usage of crop residues	Crop selling price(Rs./ 20 kg)
Cotton	Stalk	Burnt in field Used for domestic cooking	700–1,000
Groundnut	Shell	Sold to Oil mills/APMC	600–900
	Stalk	Fodder	
Wheat	Stalk	Fodder and Manure	350–600
Pigeon Pea	Stalk	Used for cooking purposes	600–800
Bajra	Stalk	-	400
Castor	Stalk	Used for cooking purposes	-

Source: Interview with farmers

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, castor 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.

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 used in 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.

Groundnut shell: According to the farmers, the entire groundnut is purchased from the farmers at the market price by the traders, APMC/oil mills. About 20% total groundnut produced can be estimated to be used for local consumption purposes.

Other residues: According to the farmers, wheat stalk and groundnut stalk goes to fodder. Other residues, such as pigeon pea stalks and bajra 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 1100 per ton. This is primarily the cost of labour involved in uprooting the stalk from the field and loading it on to trucks and tractors. Other than this, farmer remuneration of Rs 300 to Rs 500 per ton is considered.

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

4.4.3 Industrial survey

In Bhavnagar District, major Crop residue-related industries are oil mills, chemical, dehydrating and bio-coal industries. These industries are mostly based on 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 APMC traders/oil mills. Bhavnagar District has around 15 oil mills with average crushing capacity of 15 tons 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. These oil mills are operational 7 months in a year. **Hence total shell consumed by oil mills is 2.83 K.M.T**. The team visited one of the oil mills in the district.

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.
- The capacity of groundnut crushing ranges from 2.5 tons per day (small) to 20 tons (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.
- The price for groundnut shell varies from 2.5 Rs/kg to 3 Rs/kg depending on the season which is sold to bio coal industries from the mills as shown in the following table.

Table 4.8: Prices of groundnut 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 bio-coal, and agro-industries (Rs/kg)
35-50	2.5 to 3

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 shell (100%) as a primary fuel and the other unit uses a combination of groundnut shell (major), cotton stalk, jeera husk, and chana stalk. The groundnut shell was procured either directly from the oil mills, whereas cotton stalk was purchased from the farmers and jeera husk and chana stalk are purchased from the nearby districts. Average capacity of plant is 1.25 tons/hour. They use 90% of groundnut shell (1.125 tons/hr) as raw material to produce bio-coal. Machines are operated 10 hours per day and are operational for 300 days in a year. Hence, **annual groundnut shell consumed by bio-coal industries in the district comes out to be 10.13 K.M.T**. Cost analysis of both ground nut shell and cotton stalk is given in Tables 4.9 and 4.10. The following observations were made after interacting with the industries:

- The capacity of the two plants visited is 1-1.5 tons/day. 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 analysis of raw materials and their bio-coal are given in Table 4.9 and Table 4.10. The price of raw material is low during the months of October to January and high during the months of July to September.
- The selling price of bio-coal varies with the price of raw material. Details as obtained from the industry are mentioned in Annexure IX. These bio-coals are used in chemical industries.

Table 4.9: Cost analysis of groundnut shell and its bio-coal in Bhavnagar District

Bio coal units	
Parameters	**Unit 1**
Purchasing price of raw material (Rs/kg)	2–2.5
Transportation cost of raw material (Rs/kg)	0.3–0.5
Selling price bio-coal (Rs/kg)	4–5.5

Table 4.10: Cost analysis of cotton stalk and its bio-coal in Bhavnagar District.

Bio coal unit	
Parameters	**Unit 2**
Purchasing price of raw material (Rs/kg)	2–3
Transportation + chipping cost of raw material (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. A data of chemical industry is given in Table 4.11. The idea to visit this company was because this was the only industry in Bhavnagar which uses Crop residue 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 Crop residue also depends upon the pricing of the Crop residue available.

Table 4.11: Details of the chemical industry

Chemical Unit	
Parameters	**Unit**
Capacity (tons/year)	25,740
Purchasing price of Crop residue (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 dehydrating industries with an average capacity of 5–8 tons/day[18]. 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 Crop residue as a backup fuel. Cotton stalk and groundnut shell are the Crop residue in practice. The total requirement of Crop residue is given in Table 4.12:

Table 4.12: Dehydrating industry in Bhavnagar

Drying capacity (Ton/day)	**Onion-5** **Garlic-2**
Crop residue consumption (Ton/monthly) (Optional)	Groundnut shell -15 Cotton stalk -15

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 4.13. Hence, the demand of Crop residue for institutional cooking is nil.

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

Table 4.13: 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

Source: Mid-day Meal Collectorate, Gandhinagar

4.5 Crop residue 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 burning it, and 5% goes into the bio-coal industries. A Crop residue-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 4.14: Percentage wise consumption of cotton stalk in different sectors in Bhavnagar District

District	Current practices with Cotton Stalk[19]		
	Cooking and heating (%)	Open-field burning (%)	Bio-coal (%)
Bhavnagar	25	70	5

Source: Interview with farmers

Table 4.15: Estimated availability of cotton stalk in Bhavnagar District for year 2014–15

A	Cotton stalk generated in Bhavnagar (K.M.T)	800.91
B	Estimated demand of cotton stalk in domestic cooking (K.M.T)	200.23
C	Estimated demand of cotton stalk in Bio-coal industries (K.M.T)	40.04
D	Total annual demand of cotton stalk (K.M.T) (B+C)	240.27
E	Estimated net surplus cotton (K.M.T.) (A-D)	560.64

4.5.2 Consumption and surplus of castor stalk and pigeon pea stalk

In Bhavnagar District the production of castor is low and castor stalk is left in the fields and the rest is utilized for cooking purposes.

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

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

4.5.3 Consumption and surplus of groundnut shell

As per the above observations, it has already been seen that groundnut shells are mostly produced in the oil mills. Groundnut shells are majorly consumed by bio-coal industries. Table 4.16 shows the consumption and net surplus of groundnut shell in the district

Table 4.16: Estimated surplus of groundnut shell

A	**Total Generation of groundnut shell in Bhavnagar district (K.M.T)**	**34.12**
B	Total estimated annual groundnut shell consumption in bio-coal industries (K.M.T)*	10.13
C	Total estimated annual groundnut shell consumption for local consumptions (K.M.T)**	6.82
D	Ground nut shell consumed by oil mills (K.M.T)***	2.83
E	Total annual utilization of groundnut shell (K.M.T) [B+C+D]	19.78
F	Net availability of groundnut shell (K.M.T) [A-E]	14.34
G	Potential availability of groundnut shell in the district (K.M.T) [A-C-D]****	24.47

* Explained in section 4.4.3.2

** Explained in section 4.4.2

*** Explained in section 4.4.3.1

**** Potential availability includes groundnut shell consumption in bio-coal industries. Although, it is consumed in bio-coal industries but it is potentially available for competitive uses if other competitive demand exist in future.

4.5.4 Summary of Crop residue generation, consumption, and surplus

Table 4.17 shows the generation, consumption, and surplus of the Crop residue available. In this study, Crop residue consumption doesn't include burning it in the open fields. The total generated quantity of the crop residues in the district is 13.54 lakh tons out of which the residue generated from the considered crop residues, that is, cotton stalk and groundnut shell are 8.35 lakh tons.

Table 4.17: Crop residue generation, consumption, and surplus (K.M.T/annum)

Type of crop residue	Production	Demand	Potential Surplus
Cotton stalk	800.91	240.27	560.64
Groundnut shell	34.12	9.65	24.47

4.6 Crop residue 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. Normally, one ton of residue collection from the field requires four to six man-days. The cost of man-day is around Rs 200. Though at present the farmers are not expecting any remuneration apart from labour cost, in actual terms they might demand an additional amount if the demand in the market builds up for cotton stalk (for example in power plants). Based on observations in the fields, the estimated labour cost will be around Rs 800–1,200 per ton for cotton stalk apart from shredding and transportation.

However, the groundnut is directly purchased by the APMC traders from the farmers at the market price that is 35–50 Rs/ton. 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 4.18 and table 4.19 give the estimated cost of cotton stalk and groundnut shell prevailing in the district.

Table 4.18: Estimated price of cotton stalk

Particulars	Average Cost (Rs/Ton)	Reference
Farmer's remuneration*	400 (300-500)**	Interaction from farmer
Labor charges for uprooting, bundling and loading[20]	1,000 (800-1,200)**	Farmer's interview
Shredding cost	350	Farmer's interview
Transportation cost (0–25 km)	500	Local source
Unloading cost	100	From farmers
Av. Landed cost	**2,350**	

Source: Interview with farmers and local sources

*Farmers were not aware of remuneration

** Figure in brackets gives the price range during the year

Table 4.19: Estimated cost of groundnut shell

Particulars	Average Cost (Rs./Ton)	Reference
Cost of groundnut shell charged by oil mill	2,750 (2,500-3,000)*	From oil mill
Loading and unloading cost	200	From oil mill
Transportation (0–50 km)[21]	450	From oil mill
Average Landed cost	**3,400**	

* Figure in brackets gives the price range during the year

4.6.1 Cost of fuels including losses

After getting the landed cost of fuels, loss in weight due to moisture and dust/sand/stone present in the fuel from the oil mills/farmer's field has to be considered. In the case of groundnut shell, 5% loss in weight due to moisture and 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 4.20 shows the Crop residue price per ton considering moisture and dust/sand losses.

[20] The collective cost of uprooting and labour cost was obtained with the interaction from the farmers
[21] This information was collected from the oil mills and interaction with transport person was not done

Table 4.20: The final cost of groundnut shell and cotton stalk considering losses

Description	Crop residue Price/ton	Moisture[22]		Dust/sand/stone		Total Weight losses per unit	Crop residue 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%.

4.6.2 Weighted average

In case of Bhavnagar, potential surplus of groundnut shell is 24.47 K.M.T, which is around 35% of the total crop residue demand of 200 tons/day for a 10 MW power plant.

Therefore, 35% weightage is taken for groundnut shell while 65% weightage is considered in the case of cotton stalk while calculating the weighted average of fuel cost. So, the weighted average cost of fuel comes out to be **Rs. 3,162 per ton** at corresponding weighted average GCV of **4,417kcal/kg.**

[22] In case of cotton stalk and groundnut shell, moisture values were assumed from literature and project developers. Experimental value needs to be assessed

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 21.30–22.00 latitude and 72.45–73.15 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 662 revenue 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 585,582 respectively (a *taluka*-wise population is mentioned in Annexure III).[23] The district is mostly rural and around 66% of the population resides in the rural area. The district has eight

[23] Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), District Irrigation Plan (2016–2020)

talukas, with Bharuch as its headquarters. Table 5.1 shows the different particulars of Bharuch District, such as geographical data, administrative set up, population etc.

Table 5.1: Bharuch District at a glance

S. No	Particulars	Statistics	Units
1	**Geographical features**		
(A)	**Geographical data**		
i)	Latitude	21.30^0 to 22.00^0	Degree
ii)	Longitude	72.45^0 to 73.15^0	Degree
iii)	Geographical Area	524,385	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	633,875	Nos
ii)	Female	585,582	Nos

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

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*, 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.[24]

[24] 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 330,478 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. Table 5.2 shows the land use pattern in Bharuch district and 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.

Table 5.2: Land use pattern of Bharuch District

S. No	Type of land use pattern	Area (ha)
1	Forest	24,506
2	Barren and Uncultivable land	19,825
3	Area under non-Agriculture use	72,455
4	Permanent Pasture and Grazing land	16,321
5	Cultivable Fallow land	35,458
6	Current Fallow	25,316
7	Fallow land other than current fallow	26
8	Net area sown	330,478
9	**Aggregate**	**5,24,385**

Source: District Statistical Book (2014-15)

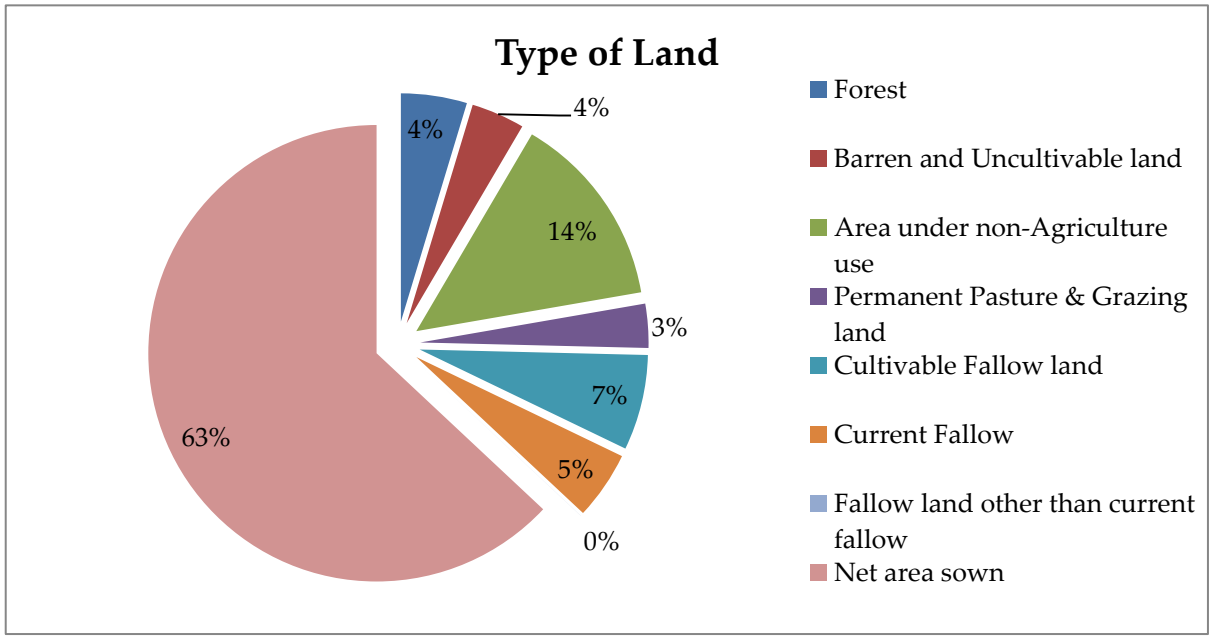


Figure 5.2: Land use pattern of Bharuch District

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 5.3 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 5.3: Number of farmers based on their land holdings[25]

S.no	Type	Scale (in hectares)	Number of Farmers	Area (in hectares)
1	Marginal	<1	45,936	22,976
2	Small	1–2	7,114	10,347
3	Others	>2	47,404	215,627
Aggregate			**100,454**	**248,950**

Source: District Statistical Book (2014-15)

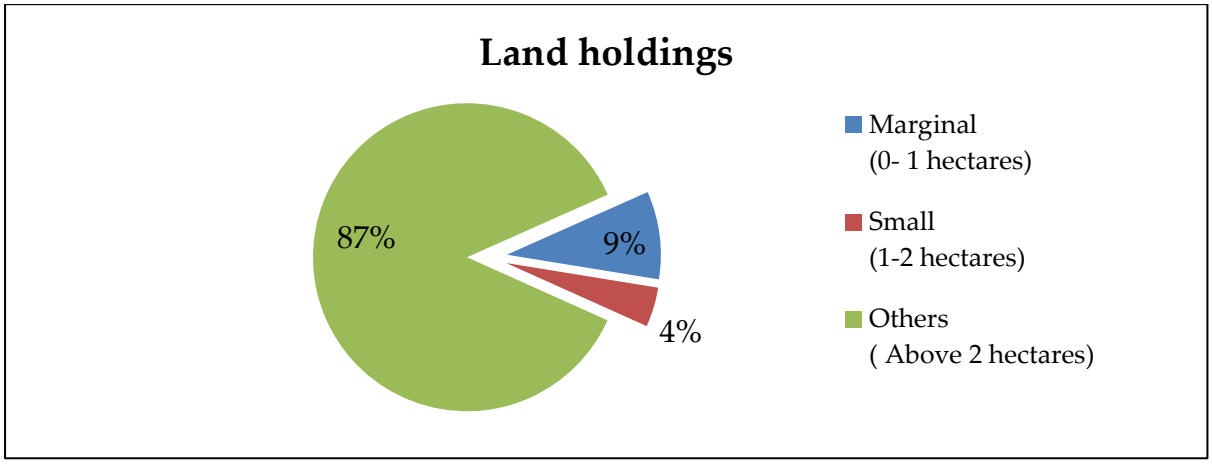


Figure 5.3: Percentage share of different land holdings

5.2.3 Production pattern of different crops

The main crops of the district are sugarcane followed by pigeon pea, wheat, cotton, castor and rice 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 (330.48 thousand hectares), around 11.01% area under cultivation is allocated for sugarcane (36.4 thousand hectares). Cotton (81.77 thousand hectares) is also a major crop in the district an approximate of 24.74% area under production. Others in the figure 5.4 refer to the crops grown in the district such as gram, *udad*, fruits and vegetables crops to name a few. Year wise area, production and yield data of selected crops for last three years is given in Annexure IV.

[25] DAO, Bharuch

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 high yield as compared to cotton.

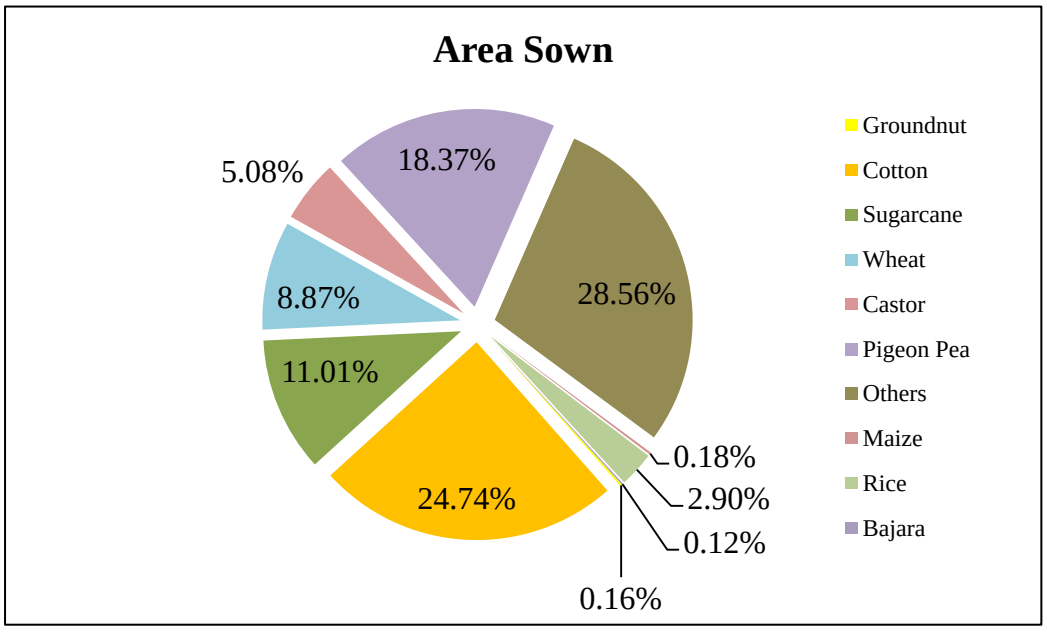


Figure 5.4: Percentage share of different crops sown in Bharuch District

Figure 5.5(a, b) and 5.6(a, b) gives the trend of the area under cultivation and production respectively for crops, such as sugarcane, cotton, wheat, castor, pigeon pea, groundnut, maize and rice. 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.

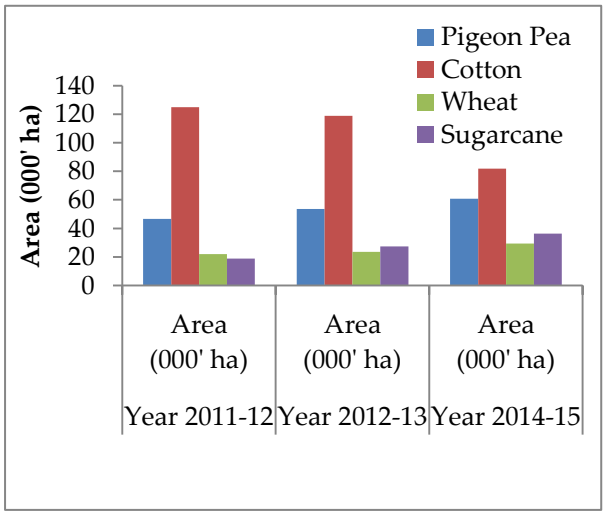


Figure 5.5 (a): Area under major crop production

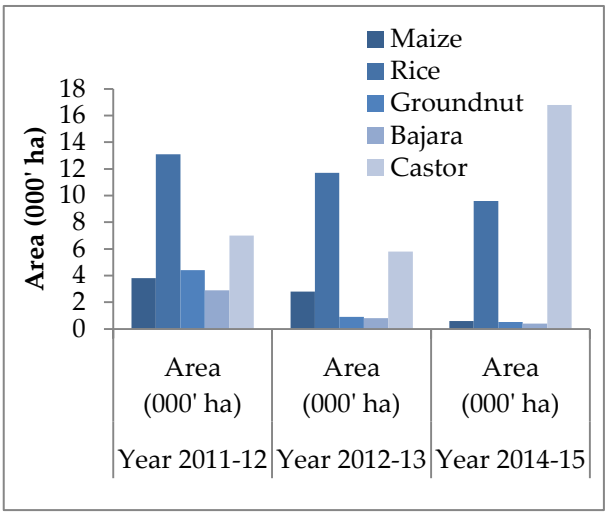


Figure 5.5 (b): Area under minor crop production

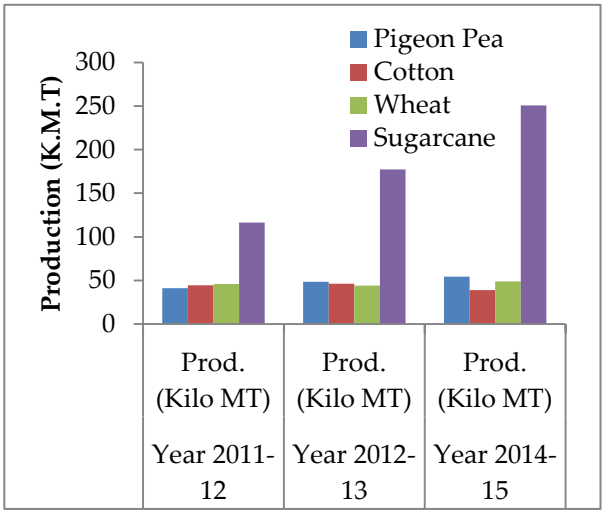


Figure 5.6 (a): Year wise production trend of major crops

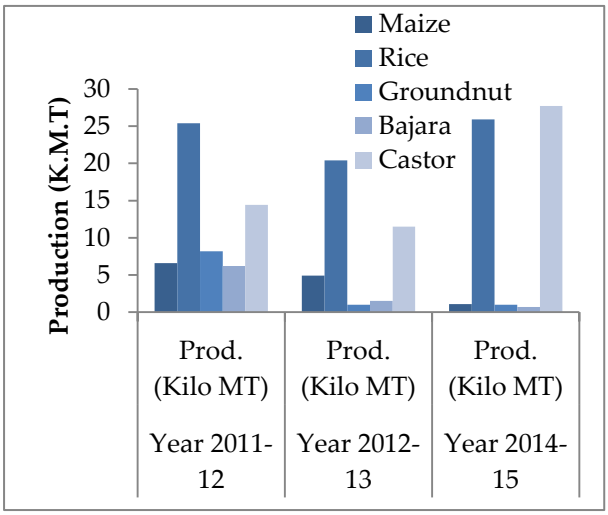


Figure 5.6 (b): Year wise production trends of minor crops

Table 5.4: APY data of selected crops

Sr. No.	Name of the Crop	Year 2014-15		
		Area (000′ Ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Pigeon Pea	60.70	54.40	0.90
2	Cotton	81.77	38.79	0.47
3	Wheat	29.30	48.82	1.67
4	Sugarcane	36.40	250.94	6.89
5	Maize	0.60	1.10	1.83
6	Rice	9.60	25.90	2.70
7	Groundnut	0.53	0.98	1.85
8	Bajara	0.40	0.70	1.75
9	Castor	16.80	27.70	1.65
10	Others	94.38	-	-

Source: Tentative APY data, Directorate of Agriculture

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 *taluka* 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 and 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 *taluka*. Table 5.5 shows the number of farmers that were interviewed in the two *taluka*. A total of eight farmers were surveyed the details of them are given in Annexure X.

Table 5.5: An indicative list of surveyed farmers in Bharuch District

Name of Taluka	Number of farmers surveyed
Valia	6
Hansot	2


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

Table 5.6: A summary of farmer interviews conducted in Bharuch District

Name of the crop	Type of residue	Current usage
Cotton	Cotton stalk	It is partially used as a fuel for cooking purposes and the remaining is ploughed back into the field using a rotavator
Sugarcane	Sugarcane leaves	Burnt immediately and very small amount given as fodder
Wheat	Wheat stalk	Mostly ploughed back into the field using a rotavator and the remaining is used for cooking
Pigeon Pea	Pigeon pea stalk	Used for cooking purposes
Castor	Castor stalk	Used for cooking.
Rice	Rice straw	Used as cattle feed; sold at a price of Rs 1–1.75 per kg

Source: Interview with farmers

As per Table 5.6, the major crops grown by farmers in Bharuch District are sugarcane, cotton, wheat, castor, rice 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. In case of sugarcane, one labour can harvest one ton 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 rotavator. Some farmers rented a rotavator 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 rotavator 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 *taluka*. After interacting with these officers, the team concluded that 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 rotavator.

It was also brought to the team's knowledge that 4–5 people are required for two days to uproot 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 80-100 per ton.

Other residues: As already mentioned in the Table 5.6, pigeon pea stalk is used in domestic cooking and heating purposes. In case of wheat stalk, it is majorly ploughed back into the field in the form of manure (~80%). In case of castor stalk, it is 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 ton and Rs 3,578 per ton 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 in Table 5.7 below:

Table 5.7: 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 (tons 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 (tons per day)	4,000	4,000
Bagasse generated (tons per day)	1,040–1,200 (26%–30% of the cane crushed)	1,200 (30% of the cane crushed)
Power generation capacity	Plant 1: 6 MW Plant 2: 1.5 MW (standby)	Plant: 3 MW
Bagasse Consumption (tons per day)	850 tons per day	750 tons per day
Steam requirement	70 tons per hour	63 tons per hour
Steam usage (tons per hour)	Power generation: 42–43 Mill turbines: 22–23 Distillery: 4–5 Process: 3–4	Power generation: 27 Mill turbines: 30–31 Distillery: 4–5
Surplus bagasse	190-350 tons per day	450 tons per day
	Loose MC: 50% Price: Rs 1,600 per ton (excl. transport) CV: 2,240 kcal/kg	Loose MC: 48%–50% Price: Rs 1,900 per ton (excl. transport) CV: 2,000 kcal/kg
Sugarcane purchase cost (per ton)	Rs 3,500 per ton (MC: 70%)	Rs 3,578 (MC: 70%)

Source: Interview with sugar industry officials

General observations other than the information mentioned in Table 5.7 are 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 tons bagasse to start their operations in the next season.

Table 5.8: Summary table of prices for sugarcane and its bagasse in Bharuch District

Purchasing price of sugarcane (from farmers to sugar industry) (Rs/ton)	Selling price of loose sugarcane bagasse (from sugar industry to particle board, paper industry, etc.) (Rs/ton)
3,500–3,578	1,600–1,900

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 stalk, saw dust, and jeera husk were also being used in smaller quantities. Figure 5.9 and Table 5.9 summarizes the team's visit to the three bio-coal industries.

a. 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 5.9: 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 (tons per annum)	3500			1,700–1,800 (140–50 tons per month)					1,800 (150 tons per month)				
Residue used	Bagasse	Castor stalk	Jeera husk	Bagasse	Saw dust	Bagasse	Castor stalk	Saw dust	Bagasse	Saw dust	Bagasse	Castor stalk	Saw dust
Percentage share in bio-coal	70	15	15	65	35	50	15	35	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 ton (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 ton (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 ton to nearby areas Rs 900–1,000 per MT to Maharashtra					Rs 250–300 per ton to nearby areas Rs 800–1,000 per MT to Maharashtra				

Source: Interview with bio-coal industry officials

General observations other than those that have been mentioned in Table 5.9 have been listed below:

- Majorly, sugarcane bagasse is procured from sugar industries in the district, whereas castor stalk 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 Unjha 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 tons 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 crop residue being transported. A truck with 10 ton capacity truck could effectively carry around 6–7 tons depending on the type of crop residue.
- 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 ton. The labour cost for loading and unloading is approximated to be around Rs 100 per ton.

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 crop residues. These numbers have been given below:

- GIDC Ankleshwar: 20–25
- 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 crop residue 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 5.10 and Figure 5.10.

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

Table 5.10: 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 tons per hour	Flow rate: 120 m^3/hr Temp req: 150–180 °C	-	1 ton per hour Temp. required: 90 °C (approx.)	-	2 tons 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 bio coal: 50%–55% Furnace Oil: 25%–40% Gas: 10%–20%	Groundnut shell bio coal	Bio coal (groundnut shell, bagasse) and wood	Groundnut shell bio coal	Groundnut shell bio coal	Bio coal: Groundnut Shell, Sugarcane bagasse, Sawdust, Castor Stalk
Bio-coal usage (tons per day)	34	13	Bio coal: 2.5 Wood: 2	1	1	3
Storage capacity (tons)	150	100	25–30	20	17	150

Bio-coal source	Junagadh (5–6 industries)	Saurashtra region	Rajkot (GN shell) Surat: bagasse	Amreli (Paradise bio-coal industry)	Junagadh (1 supplier)	Kasol, Gondal, Balsar, Vadodara, Rajpipla, Bharuch, Surat, Balsa, Swarashtra
Price of bio-coal in Rs. per ton (incl. transport)	5,000–5,800	5,200–6,200	Bio-coal: 4,500–500 Wood: 2,500	4,800–7,000	5,500–7,000	5,200–6,500 (GN Shell) 4,500–5,200 (bagasse) 5,000–7,000 (saw dust)

Source: Interview with chemical and pharmaceutical industry officials

Observations other than the information mentioned in table 5.10 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 ton 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 ton.
- 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 ton 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 ton when transported from Surat District.

5.5 Crop residue resource analysis

5.5.1 Total crop residue generated and its use

As per the formula, described in the methodology section, crop residue has been calculated. Table 5.11 shows the values of crop residue generated from different crops.

Table 5.11: Major crop residue generated in Bharuch District

Crop Residue	Quantity (K.M.T)	Consumption (K.M.T)				Net surplus (K.M.T)
		Household Cooking	Fodder	Industry	Manure	
Cotton Husk	42.67	-	-	-	42.67	-
Cotton Boll Shell	42.67	-	-	-	42.67	-
Groundnut Shell	0.29	-	-	-	0.00	0.29
Groundnut stalk	1.95	-	1.95	-	-	-
Wheat Pod	14.64	-	-	-	14.64	-
Bajra Stalk	1.47	1.47	-	-	-	-
Bajra Husk	0.22	-	-	-	0.22	-
Bajra Cob	0.24	-	-	-	0.24	-
Sugarcane bagasse*	82.81	-	-	82.81	-	-
Sugarcane tops & leaves	12.55	-	-	-	-	12.55

Rice Straw	38.80	-	38.80	-	-	-
Rice Stalk	38.80				38.80	
Rice Husk	5.17	-	-	5.17	-	-
Maize Stalk	2.20	-	2.20	-	-	-
Maize Cob	0.33	-	0.33	-	-	-
Cotton Stalk	310.73	48.47**	-	-	93.22***	386.99
Castor Stalk	67.20		-	-	-	
Pigeon Pea Stalk	136.11		-	-	-	
Wheat Stalk	73.22		-	-	58.58***	
Aggregate	**872.07**	**49.94**	**43.28**	**87.98**	**291.04**	**399.83**

* 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 is different from the total bagasse generated using crop residue ratio and has been explained in Table 5.12. Sugarcane consumption and surplus analysis has been explained in detail in section 5.5.2.1.

* *Explained in table 5.15
*** explained in table 5.14

Table 5.12: Total crop residue generation of bagasse in Bharuch District

Sugar Industry	Bagasse generated (tons per day)	No. of days the industry is functional in a year	Total Bagasse generated at each unit (K.M.T)
Shree Ganesh Khand Udyog Sahakari Mandli Ltd.	1,120	180	201.60
Shree Khedut Sahakari Khand Udyog Mandli Ltd.	1,200	180	216.00
Aggregate			**417.60**

Source: Interview with Sugar Industry representatives

5.5.2 Crop residue consumption and surplus analysis

5.5.2.1 Sugarcane bagasse consumption and surplus

As already discussed, a total of 417,600 tons 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 25%–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 5.13 below shows the consumption and estimated surplus of sugarcane bagasse in Bharuch district.

Table 5.13: Consumption and estimated surplus analysis for sugarcane bagasse in Bharuch District

Sugar Industry	Bagasse generated (tons/day)	Bagasse used by sugar industry (tons/day)	Surplus bagasse (tons/day)	No. of days industry is functional in a year	Surplus bagasse (K.M.T)
Shree Ganesh Khand Udyog Sahakari Mandli Ltd.	1,120	850	270	180	48.60
Shree Khedut Sahakari Khand Udyog Mandli Ltd.	1,200	750	450	180	81.00
Aggregate					**129.60**

Therefore, it can be concluded that a total **of 4.17 lakh tons of bagasse gets generated** in the district out of which nearly **1.29 lakh tons of potential surplus bagasse** is available in the district. 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 5.14.

Table 5.14: Generation of different stalks in the district

Different stalks	Total generation (K.M.T)	Stalk ploughed back into the field (K.M.T)	Remaining stalk (K.M.T)
Cotton Stalk	310.73	93.22 @ 30%	217.51
Wheat Stalk	73.22	58.58 @ 80%	14.64
Pigeon pea stalk	136.11	-	136.11
Castor stalk	67.20	-	67.20
Aggregate	**587.26**	**151.80**	**435.46**

As per the 2011 census 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 5.15 shows the total estimated annual crop residue consumption for cooking in Bharuch District from secondary sources.

Table 5.15: Estimated annual crop residue cooking consumption and surplus in District

A	Particulars	Values
B	Remaining stalk after ploughing back (K.M.T)*	435.46
C	Total household in Bharuch District	335,098
D	Households using crop residue as a fuel for cooking[26]	22,134
E	Per day per household cooking requirement (kg)	6
F	Estimated annual crop residue demand for cooking in Bharuch District (K.M.T)	48.47
G	**Estimated surplus stalk in the district (K.M.T) [B-F]**	**386.99**

* From table 5.14

Therefore, it can be concluded that though 5.87 lakh tons of stalks (cotton, wheat, pigeon pea and castor) gets generated in Bharuch district and out of which nearly 3.87 lakh tons of estimated 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 demand of crop residue for institutional cooking is nil.

Table 5.16: 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

Source: Mid-day Meal Collectorate, Gandhinagar

5.6 Crop residue cost analysis

In case of sugarcane bagasse, it has commercial value and, therefore, has an established supply chain as it is utilized by paper mills, particle board, and bio-coal industries. In case of stalks, it does not hold much commercial value and hence do 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 5.17 and Table 5.18 give the estimated cost of sugarcane bagasse and cotton stalk in the district.

Table 5.17: Estimated cost of sugarcane bagasse in Bharuch District

Particulars	Average Cost (Rs/Ton)	Reference
Material cost of bagasse purchased from Sugar industries	1,750 (1,600–1,900)*	Sugar industries
Transportation 0–50 km.	350 (300–400)*	Bio-coal industries
Loading and unloading	200 (160–240)*	Bio-coal industries
Trader's margin	200	Bio-coal industries
Average landed cost	**2,500**	

Source: Interview with sugar and bio-coal industries officials

* Figures in brackets give the price range during the year

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

Table 5.18: Estimated cost of cotton stalk in Bharuch District

Particulars	Average Cost (Rs/Ton)	Reference
Farmers Remuneration*	500	Farmers
Uprooting and bundling cost	775 (750–800)**	Agricultural officers in extension offices
Loading cost	90 (80–100)**	Agricultural officers in extension offices
Transportation cost 0 – 25 Kms.	400	Bio-coal industries
Unloading cost	90 (80–100)**	Agricultural officers in extension offices
Processing cost (Shredding)	350	Local source
Average landed cost	**2,205**	

Source: Interview with farmers and officers in the agricultural offices

*Farmers are not aware about the fluctuation in price due to moisture loss
** Figures in brackets give the price range during the year

Therefore, the average landed cost of sugarcane bagasse comes out to be **Rs 2,500 per ton** at **GCV of 2,250 Kcal/kg** (50% moisture), whereas cotton stalk will be priced around **Rs 2,205 per ton** at **GCV of 4,472 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 sugar 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 stalks of considered crop residues, 15% loss in weight due to moisture and 5% loss in weight due to dust/sand/stone have been considered. Table 5.19 shows the crop residue price per ton considering moisture and dust/sand losses.

Table 5.19: Final cost of sugarcane bagasse and stalks considering losses

Description	Crop residue Price/ton	Moisture[27]		Dust/sand/stone		Total Weight losses per unit	Crop residue Price Per ton considering losses
		% loss	Weight loss in kg per unit tons	% loss	Weight loss in kg per unit ton		
Sugarcane bagasse	2,500	25	250	5	50	300	3,571[28]
Cotton stalk	2,205	15	150	5	50	200	2,756

[27] 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
[28] 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 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 20° 49′ to 22° 49′ north latitude and 72° 51′ to 74° 17′ east longitude[29]. 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-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

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

population less than 50. 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%.

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 names 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

Particulars	Statistics	Unit
Geographical data		
a) Latitude	$20^0$49' to $22^0$49' North	Degree
b) Longitude	$72^0$51 to $74^0$17' East	Degree
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	
Population		
a) Male	2,153,736	Persons
b) Female	2,011,890	Persons
Total population	4,165,626	Persons
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 marginal, small, and other holding. Figure 6.3 show that 28% of the total farmers in Vadodara District have small land holdings while 42% have marginal 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	Marginal	<1	64,184	33,979
2	Small	1 – 2	41,666	60,074
3	Others	>2	45,388	200,270
	Total		**151,238**	**294,323**

Source: District statistical book, Vadodara

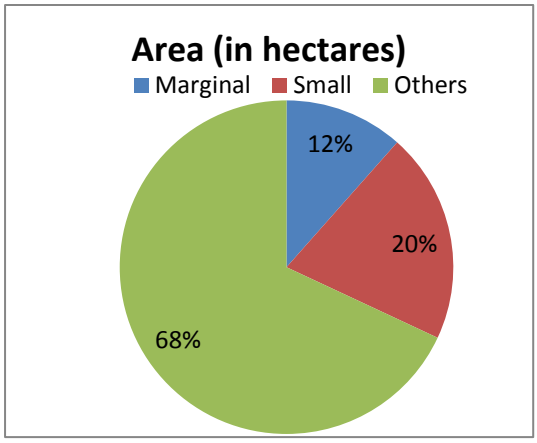


Figure 6.2: Percentage share of different land holdings

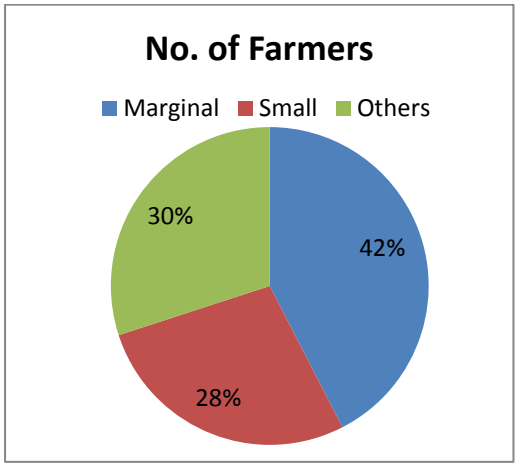


Figure 6.3: Number of farmers belongs to a different scale of land holding

6.2.2 Land use pattern

The total geographical area of the district is 508 kilo hectares out of which nearly 302 kilo hectare (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 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.

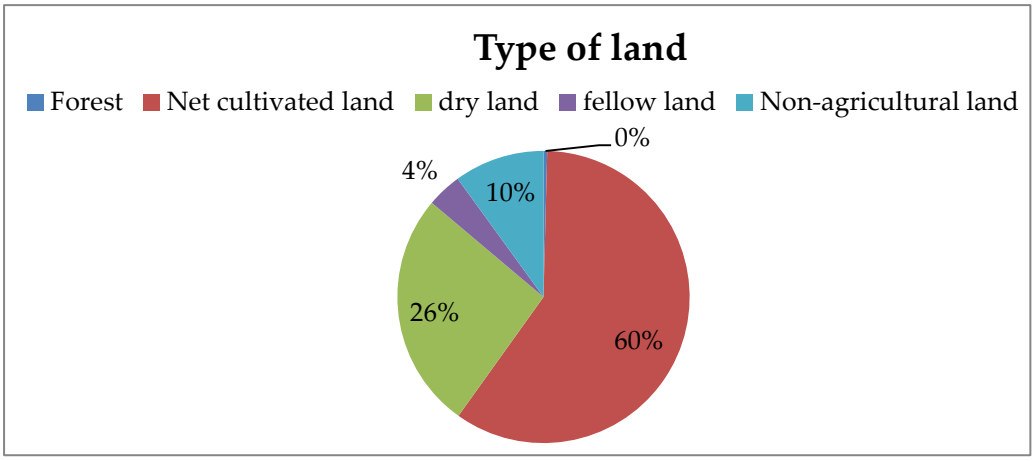


Figure 6.4: Land use pattern

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 wheat, paddy, cotton, castor and sugarcane etc. In the present report, we considered 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[30]. Figure 6.6 shows the area under crop production for last 3 years[31]. Table 6.4 shows the season-wise crops grown in Vadodara District.

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

Table 6.4: Season-wise crops grown

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

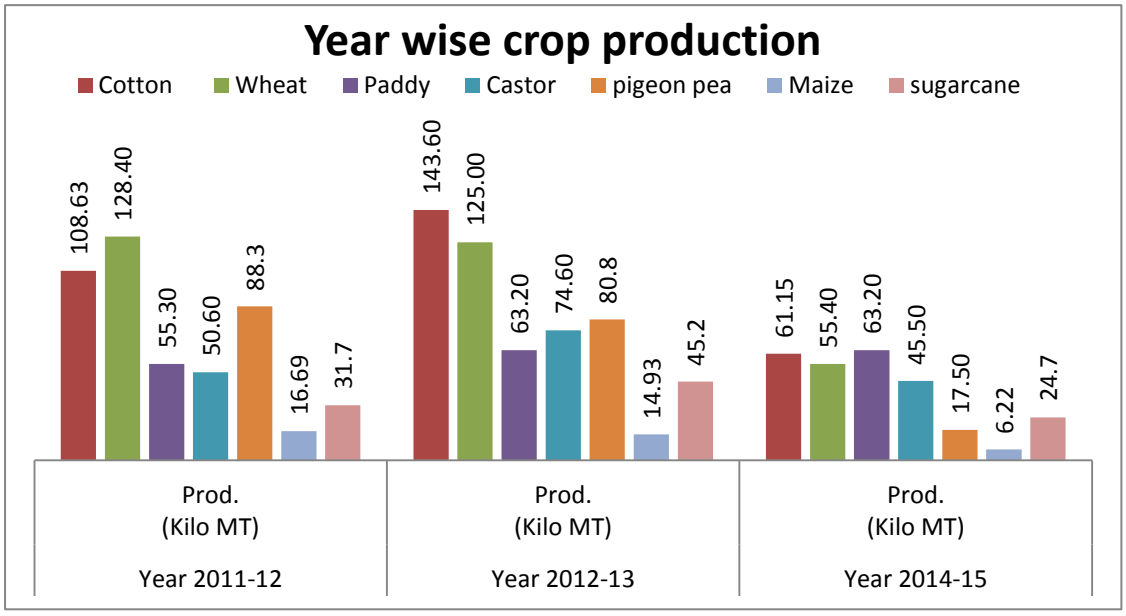


Figure 6.5: year-wise crop production data of Vadodara District

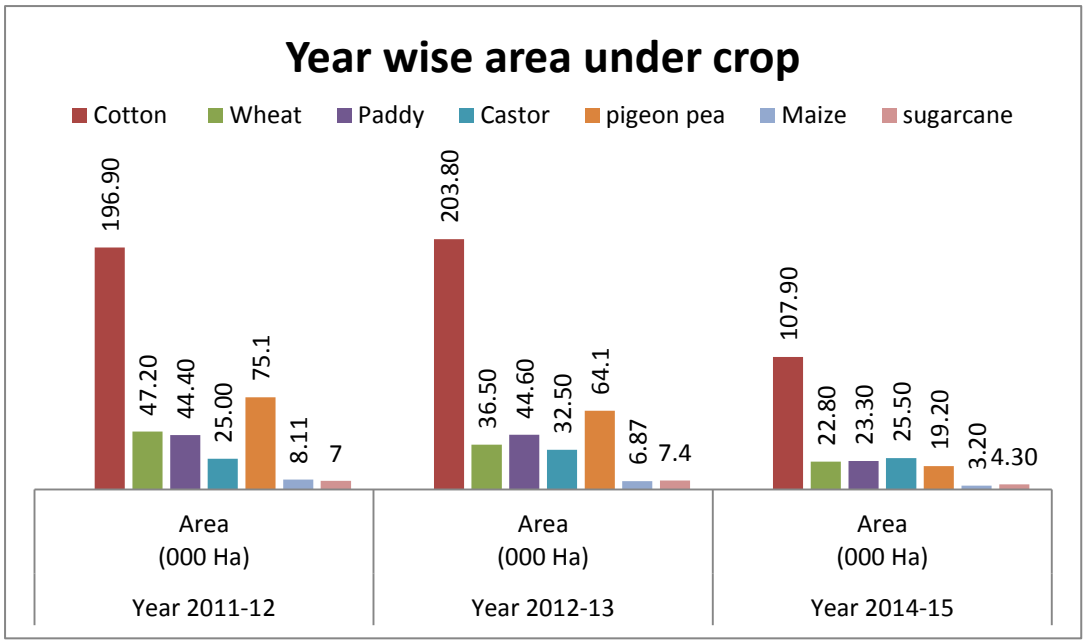


Figure 6.6: Year-wise land under crop production for different crops

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 K.M.T. 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. (K.M.T)	Yield (Tons/Ha)
1	Cotton	107.90	61.15	0.57
2	Wheat	42.80	55.4	1.29
3	Paddy	23.30	63.20	2.71
4	Castor	25.50	45.50	1.78
5	Pigeon pea	19.2	17.50	0.91
6	Maize	3.2	6.22	1.95
7	Sugarcane	4.3	24.7	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 specialized commodity marketing, namely, APMC at district level and sub yards at taluka level. Mainly cotton, wheat, castor, 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, 46.88% area under cultivation is for cotton followed by wheat whose area is 18.6%.

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	Cotton	107.90
2	Wheat	42.80
3	Paddy	23.30
4	Castor	25.50
5	Pigeon pea	19.20
6	Maize	7.16
7	Sugarcane	4.30
	Aggregate	**230.16**

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

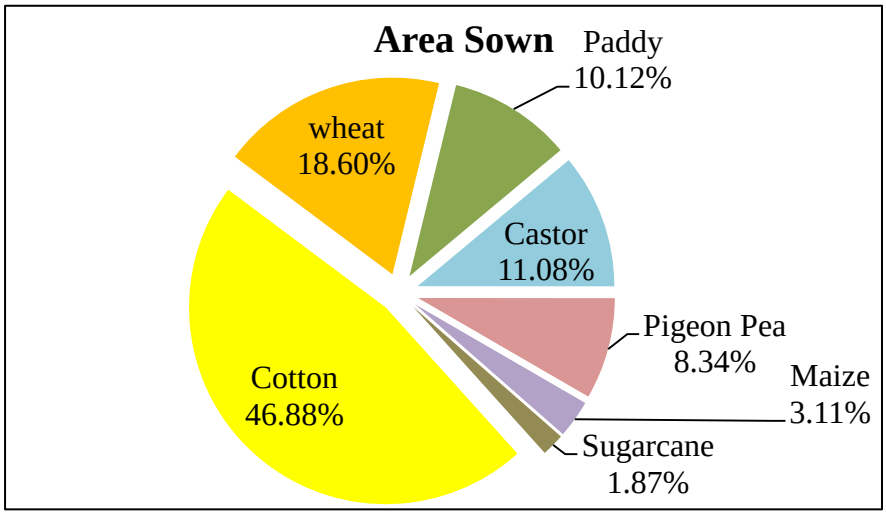


Figure 6.7: Per cent share of area of different crops sown in the district

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.

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

Crop Residue	2014-15 (in K.M.T)	Consumption (in K.M.T)				Net surplus
		Domestic cooking	Fodder	Fertiliser	Industries	
Cotton Stalk	409.90	116	-	167	-	272.55
Castor stalk	101.89					
Pigeon pea stalk	43.76					
Cotton Husk	67.27	-	-	67.27	-	-
Cotton ball shell	67.27	-	-	67.27	-	-
Wheat Stalk	83.11	-	83.11	-	-	-
Wheat Pod	16.62	-	16.62	-	-	-
Bajra stalk	20.64			20.64		-
Bajra husk	3.10		3.10			-
Bajra cob	3.41		3.41			-
Rice Husk	12.64	-	-	-	12.64	-
Paddy Stalk	94.82	-	-	94.82	-	-
Paddy straw	94.82	-	94.82	-	-	-
Maize cob	1.87	-	1.87	-	-	-
Maize stalk	12.45	-	12.45	-	-	-
Sugarcane Bagasse	8.14	-	-	-	8.14	-
Sugarcane Top and leaves	1.23	-	1.23	-	-	-
Total	**1042.94**	**116**	**216.61**	**417**	**20.78**	**272.55**

Out of this generated biomass, cotton stalk, paddy husk 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, 1.04 million tons, the total available quantity of the considered crop residues (stalks of cotton, castor, pigeon pea and rice husk) is 0.57 million tons.

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). 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, paddy and castor. 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 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, 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. Although some amount of the stalk is used for domestic cooking by marginal farmers and labors while rest is either ploughed back or burnt in the fields.

Maximum availability of cotton stalk is during the months of January to March. The price of this mixture is around Rs 1/kg. Maize cobs and paddy straw are used wholly as fodder. 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	Biomass	Uses
Cotton	Cotton stalk	• Burnt in fields • Used for domestic cooking
Maize	Maize cobs, leaves and waste	Goes to fodder at Rs 1,000 to 1,500/ ton
Pigeon Pea	Stalk	Left in the fields or used for cooking
Castor	Stalk	Castor stalk left in field
Paddy	Stalk, straw and husk	Stalk and straw goes to fodder, husk goes to brick kilns from rice mills at Rs 1,000–2,000/ ton

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 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 tons per day. 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 ton of wood is used in boiler to process 50 tons of maize grains for oil production. Cost of wood is Rs 2–2.25/kg. Though these units do not consume biomass residue, they 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 ton/hour. The major residues used are sawdust and groundnut shell. Almost all the groundnut shell in Vadodara District comes from the Saurashtra region. All of these plants are based on piston press technology. The production cost was found to be around Rs 510/ton including labour and electricity charges. The cost of raw material varies from Rs 3,000 to 3,200 per ton for saw dust and Rs 4,000 to 4,200 per ton for groundnut depending upon the seasonal availability of groundnut. These machines are operational for 8 hours/day. The selling price of briquette ranges from Rs 5,500 to 5,600 per ton. These briquettes are generally used in chemical industries.

Figure 6.9: Bio-coal unit in Vadodara

- 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/ton).
- 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

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 tons/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 ton including the processing cost (Rs 1.5/kg), labour cost (Rs 0.9/kg), and transportation cost is around Rs 400/ton as transportation cost within 25 km is Rs 2,500–3,000 (for 6–7 tons). 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 Bodeli taluka in Vadodara. The average price of sugarcane is around Rs 2,600/ton. Currently, the mill is closed due to cane shortage. The mill's maximum cane-crushing capacity is 2,500 tons/day. However; its actual cane-crushing capacity is only 500–600 tons/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 around 80% 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. This bagasse has 50% moisture and remaining bagasse is sold to other industries at a cost of Rs 1,600–2,000 per ton. Bagasse price includes loading cost (Rs 125/ton), unloading cost (Rs 125/ton), and transportation cost (Rs 400/ton 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 and estimated availability 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 cooking consumption and availability of all stalks in district

A	**Total Stalks (cotton, castor and pigeon pea) generated in the district (K.M.T)**	**555.55**
B	Total household in Vadodara district	418,851
C	Households using crop residue as a fuel for cooking[32]	53,126
D	Per day per household cooking requirement (kg)	6
E	Estimated annual consumption of stalks for cooking (K.M.T)	116.34
F	Estimated amount of stalks ploughed back into the field (K.M.T) (30%)	166.67
G	Estimated available stalks of cotton, castor and pigeon pea (K.M.T) [A -E-F]	272.54

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 K.MT.

6.4.3.3 Consumption and surplus of sugarcane bagasse

The total bagasse generated from the sugar mills in Vadodara District is 8.14 K.M.T which is almost completely used by sugar mills and other industries. Hence, there is no surplus bagasse generated in the district.

6.4.4 Institutions

In Vadodara District, there are a total of 1,297 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 of 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	1,297	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. The total generated quantity of the crop residues in the district is 10.42 lakh tons out of which residue generated from the considered crop residues, that is, cotton stalk, castor stalk, pigeon pea, sugarcane bagasse and paddy husk 5.76 lakh tons. The current consumption of the selected crop residues is estimated at 3.03 lakh tons. So, potentially the surplus quantity of the available biomass is 2.85 lakh tons.

32 http://www.censusindia.gov.in/DigitalLibrary/MFTableSeries.aspx

Table 6.11: Biomass generation, consumption, and available (K.M.T/annum)

Biomass	Generation	Consumption	Available
Stalks of cotton, castor and pigeon pea	555.55	283.01	272.54
Paddy husk	12.64	12.64	12.64*
Sugarcane bagasse	8.14	8.14	0
Total	**576.33**	**303.79**	**285.18**

*currently consumed in brick kilns but potentially available for competitive use

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 ton 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 ton 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 500 per ton 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 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	1,100 (1,000-1,200)*[33]
Shredding cost	350
Farmer's remuneration**	500
Transportation cost (0-25 Kms)[34]	450
Unloading cost	125
Av. Landed cost	**2,525**

* Figure in bracket shows price range
**Farmers are not aware about the fluctuation in price due to moisture loss

[33] The collective cost of uprooting and labor cost was obtained from farmers interaction
[34] This information was collected from bio coal and interaction with transport person was not done.

Table 6.13: Cost of Paddy husk

Particulars	Paddy husk (Rs/Ton)	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 sugar 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[35]		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		
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 as compared to the available quantity of paddy straw. So, based on assumption 90% weightage (30% for each 3 stalks) 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 ton** at corresponding weighted average GCV of **4,220 kCal/kg.**

[35] 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 taluka: Himatnagar, Idar, Khedbrahma, Poshina, Prantij, Talod, Vadali, and Vijaynagar, and the political map of Sabarkantha District is shown in Figure 7.1.[36]

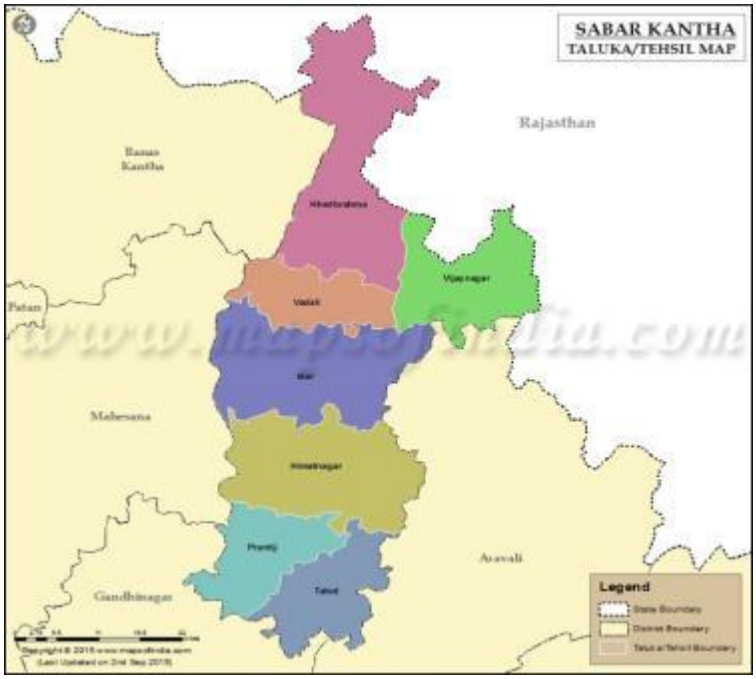


Figure 7.1: Political map of Sabarkantha District

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 the district such as wheat, groundnut, cotton, maize, castor, pigeon pea etc. The average rainfall of the district is found to be around 575 mm.

[36] 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 The district has a moderate literacy rate of 75.79%. The basic information of the district has been given in Table 7.1. The demographic profile of the district is shown in Annexure III.

Table 7.1: District at a glance[37]

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

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 marginal, small and others. A *taluka*-wise land holding pattern and the number of farmers per holding have been given in Annexure V.

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

Table 7.2: Number of farmers based on their land holdings[38]

S.no	Type	Scale (in hectares)	Number of Farmers	Area (in hectares)
1	Marginal	<1	43,909	63,116
2	Small	1 - 2	74,051	33,959
3	Others	>2	35,233	155,669
	Aggregate		**153,193**	**252,744**

Source: District Statistical Department

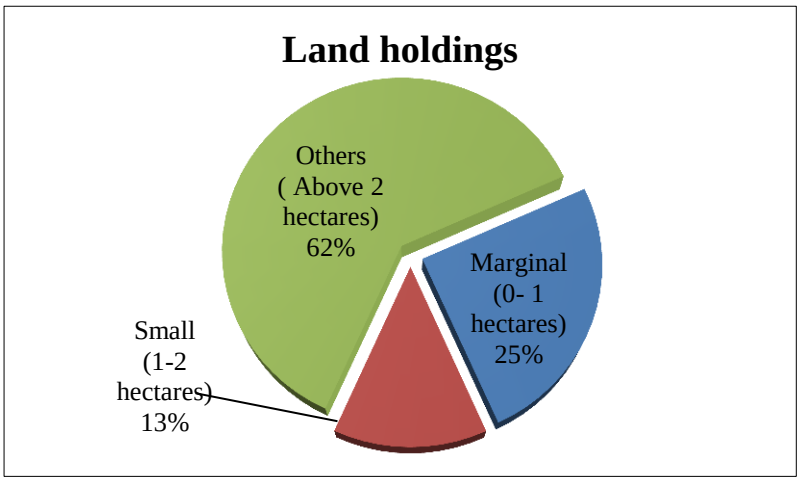


Figure 7.2: Percentage share of different land holdings

7.2.2 Land use pattern

The total reported area for the purpose of land use is 404,359 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.

Table 7.3: Land use pattern of Sabarkantha District

S. No	Type of land use pattern	Area (ha)
1	Forest	75,644
2	Barren and Uncultivable land	24,122
3	Area under non-Agriculture use	24,608
4	Permanent Pasture and Grazing land	17,750
5	Cultivable Fallow land	6,632
6	Current Fallow	15,323
7	Net area sown	240,280
8	**Aggregate**	**404,359**

Source: District Statistical Book (2014-15)

[38] DAO, Sabarkantha

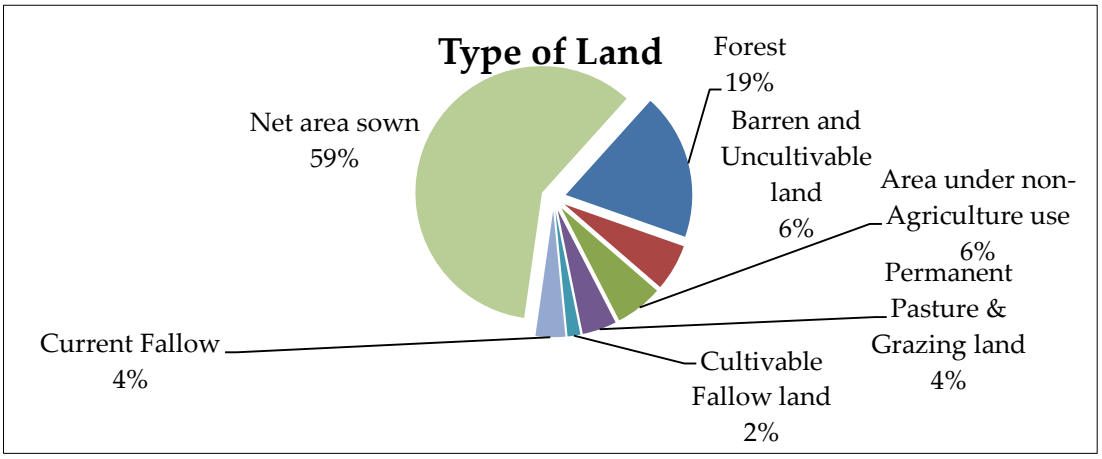


Figure 7.3 Land use pattern

7.2.3 Production pattern of different crops

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 24.85 K.M.T and 43.77 K.M.T respectively

In the present report, we have considered only eight crops in our study including groundnut, cotton, wheat, pigeon pea, castor, Bajara, rice and maize. Figure 7.4 (a) and figure 7.4 (b) 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 2013–14 is not included due to its unavailability.

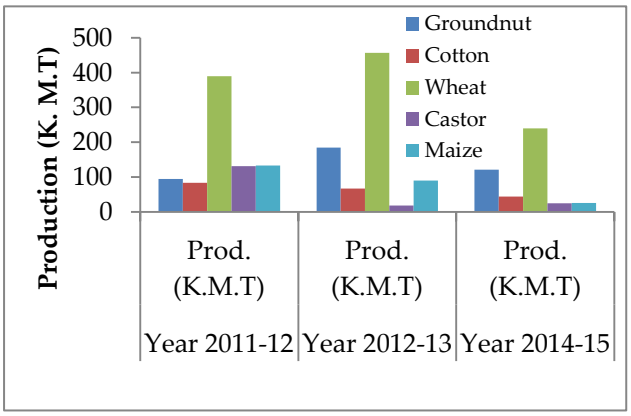


Figure 7.4 (a): Year-wise production trend of major crops

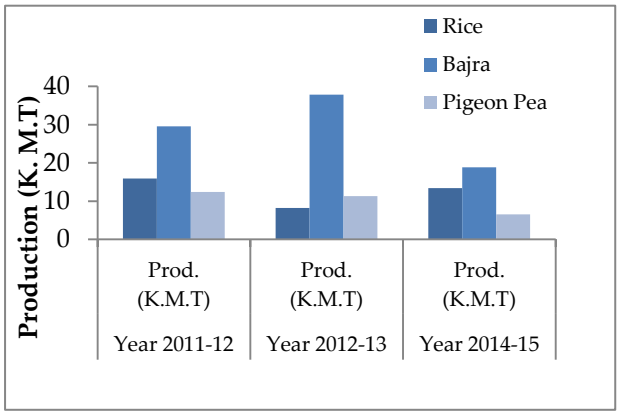


Figure 7.4 (b): Year-wise production trend of minor crops

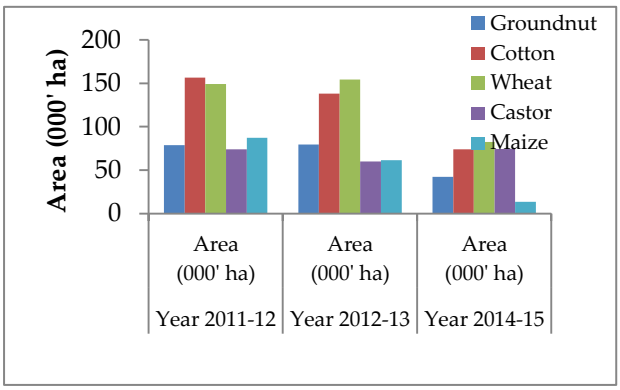


Figure 7.5 (a): Area under production for major crops

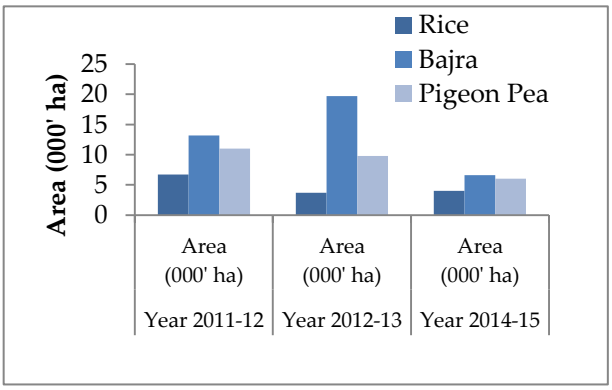


Figure 7.5 (b): Area under production for minor crops

Figure 7.5 (a) and figure 7.5 (b) 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.

Table 7.4 shows the area, production, and yield data of the selected crops for the year 2014–15. It can be easily being seen from the table that Wheat is the major crop with a production of 239.63 K.M.T followed by groundnut (121.48 K.M.T) and cotton (43.77 K.M.T)

Table 7.4: APY data of selected crops[39]

Sr. No.	Name of the Crop	Year 2014-2015		
		Area (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Groundnut	42.30	121.48	2.87
2	Cotton	74.14	43.77	0.59
3	Wheat	82.30	239.63	2.91
4	Pigeon Pea	6.00	6.58	1.10
5	Castor	74.51	24.85	0.33
6	Maize	13.50	25.46	1.89
7	Rice	3.98	13.39	3.36
8	Bajra	6.60	18.87	2.86
9	Others	224.29	-	-

Source: Tentative APY data, Directorate of Agriculture.

7.2.4 Cropping pattern

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

Sabarkantha is one of the leaders in oil seed production. Under irrigated conditions oilseed crops are cultivated in most blocks. 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 15.60% area under cultivation is for wheat. Castor is the second-major crop grown in the district with around 14.12% area under production whereas cotton stands in the third place with 14.05%. Area sown for vegetable crops (Others) is huge (42.51%).

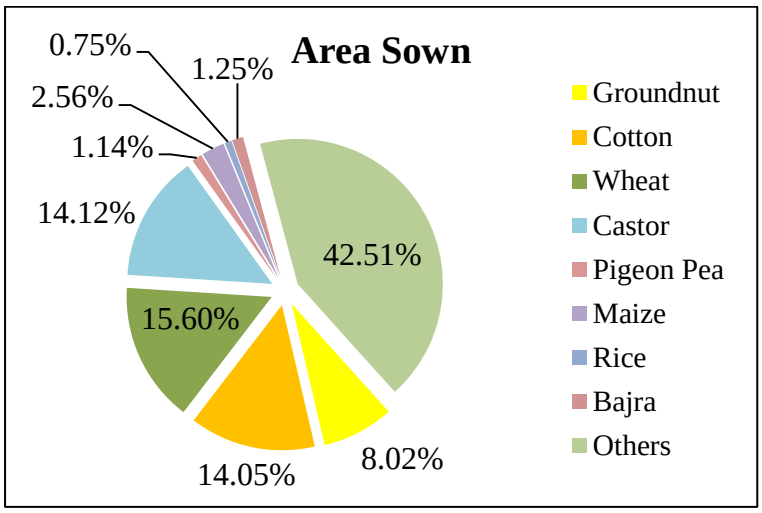


Figure 7.6: Precent share of area under different crops sown in the district

[39] Directorate of Agriculture, Gandhinagar

7.3 Crop residue analysis

7.3.1 Total crop residue generated

As per the formula described in the methodology section, crop residue or biomass of the identified crops has been calculated. Table 7.5 shows the values of major crop residue generated from different crops in the district for the year 2014–15.

Table 7.5: Crop residue generation and consumption in the district

Crop Residue	Quantity (in K.M.T)	Consumption (K.M.T)				Net surplus (K.M.T)
		Household Cooking	Fodder/ Eating	Industry	Manure	
Groundnut Shell	36.44	0	7.29* (eating)	4.5*	0	24.65*
Groundnut stalk	242.95	0	242.95	0	0	0
Cotton Husk	48.15	0	0	0	48.15	0
Cotton Boll Shell	48.15	0	0	0	48.15	0
Wheat Pod	71.89	0	0	0	71.89	0
Maize cob	7.64	0	7.64	0	0	0
Maize stalk	50.92	0	50.92	0	0	0
Cotton Stalk	281.75	151.16**	0	57.98**	173.94**	196.71**
Castor Stalk	298.04					
Pigeon Pea Stalk	16.44	0	16.44	0	0	0
Wheat Stalk	359.45	0	359.45	0	0	0
Bajra Husk	5.66	0	0	0	5.66	0
Bajra stalk	37.74	37.74	0	0	0	0
Bajra Cob	6.23	0	0	0	6.23	0
Rice Husk	2.68	0	0	2.68	0	0
Rice Straw	20.09	0	20.09	0	0	0
Rice Stalk	20.09	0	0	0	20.09	0
Aggregate	**1554.31**	**188.90**	**704.78**	**65.16**	**374.11**	**221.36**

*Explained in table 7.14 (b)
** Explained in section 7.5.1

Out of this generated crop residue, 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 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 centers 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

The selection of taluka was done on the basis of a potential of major crops grown in the district. The information was gathered from secondary sources and in consultation with DAO at Sabarkantha; the four taluka thus selected were Talod, Idar, Khedbrahma, and Prantij. A total of 13 farmers were surveyed, the details of the interviewed farmers are given in Annexure X.

Table 7.6: Indicative of a list of farmers surveyed

Name of Taluka	Number of farmers surveyed
Idar	2
Khedbrahma	3
Prantij	4
Talod	4

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

7.4.1.2 Data collection

Table 7.7 presents a summary of farmers' interviewed during the team's visit to Sabarkantha District.

Table 7.7: The summary of farmers' interviews conducted in Sabarkantha District

Name of the crop	Type of crop residues	Current usage of crop residues	Crop selling price (Rs./20 kg)
Cotton	Stalk	Burnt in fields Converted to manure in fields and for household usages	900–1,000
Groundnut	Shell	Given to oil mills/ traders/ APMC	600–900
	Stalk	Fodder	-
Wheat	Stalk	Fodder and manure	350–500
Pigeon pea	Stalk	Used for cooking purposes	800–1,000
Maize	Maize cob	Goes in fodder	250–300
Castor	Stalk	Used for cooking purposes, bio-coal industries	500–600
Bajra	Stalk	Information is not available	_

Source: Interview with farmers

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. 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 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, 10% stalk is diverted into bio-coal industries, 30% is ploughed back in the field 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, Khedbrahma, 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. Approximately 20% of the groundnut is used for eating purposes in the district. Hence, 20% of the groundnut shell gets lost while eating.

Other residues: According to the farmers, wheat stalk, maize stalks and its cobs and groundnut stalk goes to fodder.

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 ton rather than burn it in the open fields. This is majorly the cost of labor involved in uprooting the stalks from the field and loading it onto trucks/tractors. Farmer remuneration is assumed Rs 500/ton based on interaction and discussion

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, decorticating and bio-coal industries. These industries are mostly based on 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 to APMC traders. 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 tons/day out of which around 30% of groundnut shell is produced. The team visited both the oil mills in the district. In case of oil mills, groundnut shells are separated from nuts. The following are the key observations from the oil mills:

- There are two groundnut based oil mills in the district with capacities of 5 and 35 tons per day respectively. Therefore, average handling capacity of groundnut is 20 tons per day.
- As per interaction with the oil mills, the average outcome of shells is 30% of the groundnut. Hence, average capacity of ground shell produced by oil mills is 6 tons/day. These are operational 300 days in the district. They consume on an average 12.5% of the groundnut shell for their captive use. **Hence, around 0.45 K.M.T of groundnut shell is being self-consumed by the oil mills.**
- Price for groundnut shell (including loading, unloading and transportation) varies from 2.5 Rs/kg to 4 Rs/kg depending on the season.

Price of the groundnut shell sold to industries from the mills is shown in the table 7.8

Table 7.8: 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 bio-coal and agro-industries (Rs/kg)
35–45	2.5 to 4

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 were using saw dust as its major ingredient followed by castor stalk, groundnut shell, and cotton stalk. The ratio of combination is as follows: stalk of castor and cotton 10%, groundnut shell 30%, and saw dust 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 from Saurashtra region and from local 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:

- There are 2 bio-coal industries in the district with capacities of 4,800 and 9,000 tons per year and they run for around 9 hours per day for a period of 300 days in a year. Hence, the average capacity of the two industries comes out to be 2.5 tons per hour (approximately). 30% of groundnut is used as raw material. **Therefore, estimated annual groundnut shell consumption in bio-coal industries in Sabarkantha district is 4.05 K.M.T.**
- All these plants are based on piston press technology. The production cost was found to be Rs 600 to 750 Rs/ton including labour, electricity, and maintenance.
- The cost analysis of raw materials and its bio-coal is shown in Table 7.9 and Table 7.10. The selling price of bio-coal is 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 7.9: Cost analysis of groundnut shell and its bio-coal in Sabarkantha District

Bio coal units	
Parameters	**Unit 1**
Capacity (tons/ 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 (.475)
Cost of raw material excluding transport (Rs/ kg)	2.725-3.025
Selling price bio-coal (Rs/ kg)	4–6

Table 7.10: Cost analysis of stalks and its bio-coal in Sabarkantha District

Bio coal unit	
Parameters	**Unit 2**
Capacity (tons/ year)	9,000
Purchasing price of raw material including transportation and chipping(Rs/ kg)	2–2.5
Selling price bio-coal (Rs/ kg)	3.5–4

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

7.4.4.3 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 ton/hr pellet fired boilers. During a visit, it was found that the dairy currently uses saw dust pellets, which are brought from Kutch and Saurashtra regions. Details of the dairy is given in Table 7.11

Table 7.11: Details of Sabar Dairy

Dairy Unit	
Parameters	**Unit**
Pallets demand (tons/ 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

7.4.4.4. 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 7.12.

Table 7.12: Details of PVC leather industry in Sabarkantha

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

Figure 7.11: Visit to PVC leather-manufacturing unit

7.4.4.5. Groundnut shell decorticating industry

Decorticating industries are well established in Sabarkantha District. The decorticating 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 decorticating industries in Sabarkantha. The team visited one of the industries in Himatnagar for which the details are mentioned in Table 7.13.

Table 7.13: Details of a decorticating industry in Himatnagar, Sabarkantha

Total groundnut handling capacity (tons/day)	**10**
Season of groundnut availability	September–December and April–June
Groundnut shell produced (ton/ day)	2
No. of operational days	120
Total shell produced (ton/ year)	240

7.5 Crop residue 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 much commercial use in Sabarkantha District. Stalks are often disposed of by burning it in the agricultural fields or are ploughed back into the soil. The other uses of stalks 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 7.14 (a, b) shows the total estimated annual crop residue consumption in Sabarkantha District from secondary sources.

Table 7.14 (a): Total estimated annual stalks consumption in Sabarkantha District

A	**Stalks of castor and cotton generated in Sabarkantha (K.M.T)**	**579.79**
B	Total no of households using crops residue as cooking fuel	69,022
C	Per day per household fuel consumption (Kg)	6
D	Annual demand of stalks for cooking (K.M.T)	151.16
E	Amount of stalks ploughed back into the field (K.M.T) [30% of A]	173.94
F	Demand of stalks in bio-coal industries (K.M.T) [10% of A]	57.98*
G	Total annual demand of stalks [D+E+F]	383.08
H	**Estimated surplus stalks (K.M.T)** [A-G]	**196.71**

*mentioned in section 7.4.3.2

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 decorticating industries. The total shell produced has been estimated as 36.44 K.M.T per annum. Groundnut shells are consumed by bio-coal industries, oil mills as well as lost during eating. There is no clear picture of the total groundnut based

oil mills, but as per the interaction with district industrial centre, there are only two groundnut-based oil mills in the region.

Table 7.14 (b): Total estimated annual groundnut shell consumption in Sabarkantha District

A	**Total groundnut shell generated in the district (K.M.T)**	**36.44**
B	Total groundnut shell consumed by bio coal industries (K.M.T)*	4.05
C	Estimated annual groundnut shell consumed by oil mills (K.M.T)**	0.45
D	Estimated annual groundnut shell lost while groundnut eating (K.M.T)***	7.29
E	Total annual consumption of groundnut shell (K.M.T) [B+C+D]	11.79
F	Estimated surplus groundnut shell (K.M.T) [A-E]	24.65
G	Potential surplus of groundnut shell (K.M.T) [A-C-D]****	28.70

*Explained in section 7.4.3.2

**Explained in section 7.4.3.1

***Explained in section 7.4.2

**** Potential surplus includes the quantity of groundnut shell which is currently consumed by bio-coal industries because this quantity can be potentially available for alternate competitive use.

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 7.15. Hence, the demand of biomass for institutional cooking is nil.

Table 7.15: 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 crop residue generation, consumption, and surplus

Table 7.16 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 1,554.31 K.M.T out of which the residue generated from the considered crops, that is, cotton stalk and castor stalk are 579.79 K.M.T as well as groundnut shell is 36.44 K.M.T.

Table 7.16: Crop residue generation, demand, and surplus (K.M.T/annum)

Type of crop residue	Generation	Demand	Potential Surplus
Stalks of cotton & castor	579.79	383.08	196.71
Groundnut shell	36.44	7.74	28.70

7.6 Crop residue 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, one ton 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 800–1,000 per ton apart from handling charges.

Castor stalk is generally purchased by bio-coal industries and the estimated cost for castor stalk is around Rs 600–800/ton. As already mentioned, groundnut shell is majorly being consumed by 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 7.17, 7.18 and 7.19 gives the estimated cost of cotton stalk, castor stalk and groundnut shell prevailing in the district.

Table 7.17: Cost of Cotton stalk

Particulars	Cotton stalk (Rs/Ton)	Reference
Farmer's remuneration	500*	From farmer
Labor charges for uprooting, bundling and loading[40]	9,00 (800-1,000)**	From farmers
Shredding cost	350	From farmers
Transportation cost (0-25 Kms)	500	Local sources
Unloading cost	100	From farmers
Av. Landed cost	**2,350**	

*Farmers were not aware about the fluctuation in price due to moisture loss
**Figures in brackets give the price range during the year

Table 7.18: Cost of Castor stalk

Particulars	Castor stalk (Rs/Ton)	Reference
Farmers' remuneration	500*	From farmers
Labour charges for uprooting, bundling, and loading[41]	700 (600-800)**	From farmers
Shredding cost	350	From farmers
Transportation cost (0–25 km)	500	From farmers
Unloading cost	100	From farmers
Av. Landed cost	**2,150**	

*Farmers were not aware about the fluctuation in price due to moisture loss
**Figures in brackets give the price range during the year

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

Table 7.19: Cost of groundnut shell

Particulars	Average cost (Rs/Ton)	Reference
Cost of groundnut shell*	2,875(2,725-3,025)**	From oil mill
Loading and Unloading	200	From oil mill
Transportation cost (0 – 50 km)[42]	475(450-500)**	From oil mill
Av. Landed cost	**3,550**	

*From table 7.9

** Figures in brackets give the price range during the year

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 has to be considered. Table 7.20 shows the biomass price per ton considering moisture and dust/sand losses.

Table 7.20: Final cost of cotton stalk, castor stalk and groundnut shell considering losses

Description	Biomass Price/ton	Moisture[43]		Dust/sand/stone		Total Weight losses per unit	Biomass Price Per ton considering losses
		%	Weight loss per unit	%	Weight loss per unit		
Cotton Stalk	2,350	15	150	5	50	200	2,938
Castor Stalk	2,150	15	150	5	50	200	2,688
Groundnut shell	3,550	5*	50	-	-	50	3,737

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

7.6.2 Weighted average

As the net availability of stalks of cotton and castor is 196.71 K.M.T and groundnut shell is 28.70 K.M.T, therefore these are considered in the ratio of 87 to 13 respectively. Therefore, in calculating weighted averages, 87% weightage is taken for stalks (cotton and castor) while 13% weightage is considered in case of groundnut shell. So, the weighted average cost of fuel comes out to be **Rs 2,933 per ton** at corresponding weighted average GCV of **4,192 Kcal/kg**.

[42] This information was collected from the oil mills and the interaction with transport person was not done.
[43] 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 selected crop residues

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	4,472	7.78
Groundnut shell	4,315	6.03
Sugarcane	2,250[44]	50
Pigeon pea stalk	4,473	6.34
Castor stalk	3,876	7.47
Paddy husk	3,737	5.17

[44] 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 P J Thakkar, Member Mr D R Parmar, Joint Director Mr S R Pandey, Legal advisor Mr P J Jani, Deputy Director, Legal	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 [45]

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		

[45] 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

Taluka	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[46]

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
Gariadhar	58,669	56,218	114,887
Palitana	107,424	103,142	210,566

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

Name of Taluka		Population	
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

Taluka	Population		
	M	F	Total
Jambusar	79,981	73,713	1,53,694
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 Vadodara District

Taluka	Population		
	Male	Female	Children
Savali	92976	86626	19884
Vadodara	1076085	988183	23079
Vaghodia	77251	72451	15567
Dabhoi	93335	87183	14394
Padara	114380	104861	27287
Karjan	70698	66476	15775
Shinor	33912	31528	6505
Desar	39208	36199	9682
Total	**1597845**	**1473507**	**132173**

Table A3.6 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

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 (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)	Area (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)	Area (000 ha)	Prod. (K.M.T)	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 (000 ha)	Prod. (Kilo MT)	Yield (Tons/ Ha)	Area (000 ha)	Prod. (Kilo MT)	Yield (Tons/ Ha)	Area (000 ha)	Prod. (Kilo MT)	Yield (Tons/ Ha)
1	Groundnut	116	44	0.4	85	9	0.1	70	98.30	1.40
2	Cotton	389	172	0.4	289	41	0.1	413	136.83	0.33
3	Wheat	32	116	3.6	5	15	2.9	4.20	14.81	3.53
4	Bajara	8	13	1.6	5	2	0.4	0.3	0.48	1.60
5	Castor	2	4.1	2.05	3.1	6.1	1.97	3.8	6.20	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 2012–13			Year 2014–15		
		Area (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)	Area (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)	Area (000 ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
1	Groundnut	116.40	152.10	1.31	81.14	54.78	0.7	69.55	113.74	1.64
2	Cotton	305.20	185.74	0.61	313.50	85.94	0.3	210.77	93.37	0.44
3	Wheat	9.70	28.70	2.96	2.40	7.90	3.3	9.70	27.89	2.87
4	Bajara	52.30	116.80	2.23	31.00	47.90	1.5	3.3	9.98	3.02
5	Castor	0.7	1.5	2.14	0.9	1.8	2.00	1	2.40	2.40
6	Pigeon Pea	0.6	0.60	1.00	0.5	0.5	1.000	0.74	0.56	0.76
7	Maize	1.10	1.50	1.36	0.60	1.00	1.67	1.13	1.75	1.55

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.M.T)	Yield (Tons/ Ha)	Area (000' ha)	Prod. (K. M.T)	Yield (Tons/ Ha)	Area (000' ha)	Prod. (K. M.T)	Yield (Tons/ Ha)
Groundnut	4.4	8.20	1.86	0.90	1.00	1.10	0.53	0.98	1.85
Cotton	125.10	45.04	0.36	118.90	46.91	0.39	81.77	38.79	0.47
Wheat	22	45.80	2.08	23.50	44.10	1.88	29.30	48.82	1.67
Sugarcane	18.80	116.30	6.19	27.50	177.40	6.46	36.40	250.94	6.89
Castor	7.00	14.40	2.14	5.8	11.5	1.99	16.80	27.70	1.65
Pigeon Pea	46.60	40.90	0.88	53.50	48.50	0.91	60.70	54.40	0.90
Maize	3.80	6.60	1.74	2.80	4.90	1.73	0.60	1.10	1.83
Paddy	13.10	25.40	1.94	11.70	20.40	1.74	9.60	25.90	2.70
Bajra	2.90	6.20	2.14	0.80	1.50	1.90	0.40	0.70	1.75

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. (K.M.T)	Yield (Tons/ Ha)	Area (000 Ha)	Prod. (K.M.T)	Yield (Tons/ Ha)	Area (000 Ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
Cotton	196.90	108.63	0.55	203.80	143.66	0.70	107.90	61.15	0.57
Wheat	47.20	128.40	2.72	36.50	125.00	3.42	42.80	55.40	1.29
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	8.11	16.69	2.06	6.87	14.93	2.17	3.2	6.22	1.95
sugarcane	7	31.7	4.53	7.4	45.2	6.11	4.3	27.3	6.35

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. (K.M.T)	Yield (Tons/ Ha)	Area (000' ha)	Prod. (K.M.T)	Yield (Tons/ Ha)	Area (000' ha)	Prod. (K.M.T)	Yield (Tons/ Ha)
Groundnut	78.90	94.50	1.20	79.50	184.95	2.33	42.30	121.48	2.87
Cotton	156.60	83.22	0.53	138.30	67.32	0.49	74.14	43.77	0.59
Wheat	149.20	389.40	2.61	154.30	456.40	2.96	82.30	239.63	2.91
Pigeon pea	11.00	12.40	1.13	9.80	11.30	1.15	6.00	6.58	1.10
Castor	74.00	131.50	1.76	60.10	18.27	0.30	74.51	24.85	0.33
Maize	87.10	132.80	1.52	61.28	89.50	1.46	13.50	25.46	1.89
Bajra	13.20	29.60	2.24	19.70	37.90	1.92	6.60	18.87	2.86
Rice	6.70	15.90	2.37	3.70	8.20	2.22	3.98	13.39	3.36

Source: District Agricultural Office, Sabarkantha

AnnexureV: Taluka-wise land holding pattern

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

		Marginal (0-–1 hectares)		Small (1–2 hectares)		Others(Above 2 hectares)	
S.No.	Taluka	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
2	Vanthali	4,001	2,711	5,731	8,343	5,223	20,027
3	Junagadh	4,264	2,803	6,809	10,023	6,220	23,424
4	Bhesana	2,742	1,802	5,844	8,707	6,329	24,216
5	Visavadar	4,429	2,976	9,234	13,746	9,834	37,950
6	Mendarda	2,517	1,754	4,890	7,196	3,636	13,203
7	Keshod	6,334	4,313	9,289	13,534	7,355	27,563
8	Mangrol	8,565	5,113	7,920	11,359	6,592	2,5552
9	Maliya	6,527	4,106	7,072	10,244	5,360	20,117
	Whole district	**44,444**	**29,110**	**65,736**	**96,273**	**58,436**	**222,267**

Source: Agriculture census 2010–11

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

S.no	Taluka	Marginal (0-–1 hectares)		Small (1–2 hectares)		Others (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	Marginal (0–-1 hectares)		Small (1–2 hectares)		Others(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
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
Aggregate		**51,753**	**34,562**	**70,876**	**103,169**	**66,084**	**277,238**

Table A5.4 Talukawise land holding pattern in Bharuch District

S.no	Taluka	Marginal (0–-1 hectares)		Small (1–2 hectares)		Others(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	Marginal holding		Small holding		Other 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	Marginal (0-–1 hectares)		Small (1–2 hectares)		Others(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 Unculti vable land	Area under non-Agriculture use	Permanent Pasture and Grazing land	Cultiv able Fallo w land	Current Fallow	Fallow land other than current fallow	Net area sown
1	Amreli	0	393	504	4,000	1,653	0	290	70,984
2	Babra	1,923	7,547	3,634	5,899	383	1,200	0	55,886
3	Dhari	18,626	1,580	7,580	4,705	730	350	213	66,640
4	Jafrabad	277	3,394	3,183	3,057	65	790	126	23,498
5	Khambha	8,753	1,411	2,740	6,200	1,750	1,635	263	36,341
6	Bagasara	71	396	1,802	2,900	150	1,256	408	26,579
7	Kunkavav	21	800	2,109	3,500	176	577	210	47,984
8	Lathi	291	2,434	5,612	3,655	522	0	0	53,570
9	Liliya	135	668	2,070	3,641	114	72	53	32,225
10	Rajula	1,068	3,011	4,535	3,955	1,685	1,132	70	46,488
11	Savarkundla	4,800	2,881	12,800	9,578	1,540	963	132	83,848
Aggregate		**35,965**	**24,515**	**46,569**	**51,090**	**8,768**	**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
Savali	0	10,154	1,838	3,532	60,031
Vadodara	0	12,400	124,405	11,452	36,951
Vaghodia	1,055	10,438	1,556	411	37,852
Dabhoi	0	4,192	2,559	721	52,020
Padara	1,029	6,303	1,364	1,181	41,987
karjana	0	5,120	143	2,269	49,950
shinor	0	2,255	1,779	50	23,879
Total	**2,084**	**50,862**	**133,644**	**19,616**	**302,670**

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**

Annexure VII: 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[47]	4**
Pigeon pea	stalk	2.5
Sugarcane	Bagasse	0.33
	Top leaves	0.05
Maize	Cob	0.3
	Stalk	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 tons per hectare.

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

47 http://biomasspower.gov.in/document/Reports/Rajasthan%20biomass%20fuel%20supply%20study%202015%20(1).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 tons 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 ton of groundnut contains 700 kg of seed.

1 ton 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 tons/ hr each	groundnut	Oil mills at Rs 3.5/ kg	Rs 5/ kg Chemical, ceramic and dairy industry
Powertek Bio-Coal	Junagadh	1.5 tons/ hr	groundnut	Oil mills at Rs 3-4.5/ kg	5–6 Boiler, Ankleshwar, Baroda
Anand Fuel Pvt. Ltd.	Keshod	4 tons/ 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 tons per day	20%	25%	Bio-coal industries Dairy industries Power plants	2.5 to 4
Kirti oil mill	Savar Kundla	2.5 tons per day	20%	100%	Not sold	

Other details include:

- Groundnut purchased from APMC at 40 to 50 Rs/ kg.
- One ton 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**
Vihaan industries	Amreli	7,000	Oil mills, seed selling (traders) at 3–3.5	4–4.5 Chemical industry
Paradise industry	Amreli	5,000	Oil mills at 2–2.5	4–6 Chemical industry Ankleshwar
Deep Industries	Amreli	5,000	Oil mills at 3–3.5	4–4.5 Chemical, rolling mills and pharmaceutical in Vadodara

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 tons per day	20%	25%	Bio-coal industries Dairy industries Power plants	2.5 to 3

Other details include:

- Groundnut purchased from APMC at 40 to 50 Rs/ kg.
- 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/ manufacturers

Name of the Bio coal	Taluka	Purchasing source and price Rs/kg	Bio-coal selling price Rs/kg
Royal Bio-Coal	Bhavnagar	Oil mills, seed selling (traders) at 3–3.5	4–4.5 Chemical industry
Jiya Eco Products Ltd.	Bhavnagar	Farmers	3–4

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 ton/ hr		
Working period	9 months in a year; closed during the rainy season; 8 hours/ day		
Total capacity (tons 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/ ton, electricity: Rs 300/ ton		

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/ ton).
- 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.
- Biocoal/ 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 tons per day
Storage Capacity(tons)	300
Bio-coal source	Saurashtra region
Price of bio-coal in Rs per ton (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 ton/ day (maximum), 500–600 ton/ day (actual)
Bagasse generated	25%
Power generation capacity	3 MW (captive use)
Bagasse Consumption (tons per day)	80%
Steam usage (tons per hour)	Power generation, mill turbines, distillery, process
Usage of surplus bagasse	Bales MC: 50% Price: Rs 1,600–2,000 per ton CV: 2250 kcal/ kg
Sugarcane purchase cost	Rs 3,500 per ton

Miscellaneous:

- Ash is sent back to the fields
- The average price of sugarcane was Rs 2,600 per ton
- 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 tons rice processed/day
Working period	2–3 months in a year (November–January) [70 days]
Total capacity (tons per annum)	280
husk produced	15%–20%
Residue prices in Rs Per ton (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 tons/ 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 tons). Hence transportation cost is approximately Rs 400/ ton

Table A9.4.5: Survey of oil mills 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 tons per day corn processing	100 tons per day corn processing
Working period	300 days/ 24 hours	
Total capacity (tons per annum)	15,000	
Product	Maize oil (20%–25%), Maize oil feed (75%–80%)	
Fuel consumption	1.6 tons/ 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 stalk-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 stalk 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 stalk - fodder groundnut shell - traders
4	Mahesh Bhai	Bagasara	4	Cotton (200–300) Groundnut	800–1,000 600–700 700–800	Cotton stalk burnt in fields Groundnut shell -

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
				(200–300) Wheat (500–600)		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 stalk- fodder
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 stalk- 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 stalk- 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 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/ ton (inclusive of uprooting and labour costs)
- Most of the farmers use groundnut stalk 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 stalk - 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 Chana Pigeon Pea	800–1,000 700–800 700–800	Cotton stalk burnt in fields
7	Navin Bhai	Palitana	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 stalk - manure

Table A10.4 Farmers' survey of Bharuch District

S. No.	Name of farmer	Taluka	Land holdings (acre)	Crop production (ton/acre)	Crop selling price Rs per ton
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 ton cobs is produced from 1 acre. Price

Name of farmer	Taluka	Land holdings (acre)	Crop production (ton/acre)	Observations
				of maize cobs is Rs 1/ kg ➢ Rice straw goes for fodder ➢ stalks of cotton, pigeon pea, and castor stalk 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 (ton/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

S. No.	Name of farmer	Taluka	Land holdings (acre)	Crop production (ton/acre)	Crop selling price Rs per ton
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 (February 17, 2012)[48]

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:

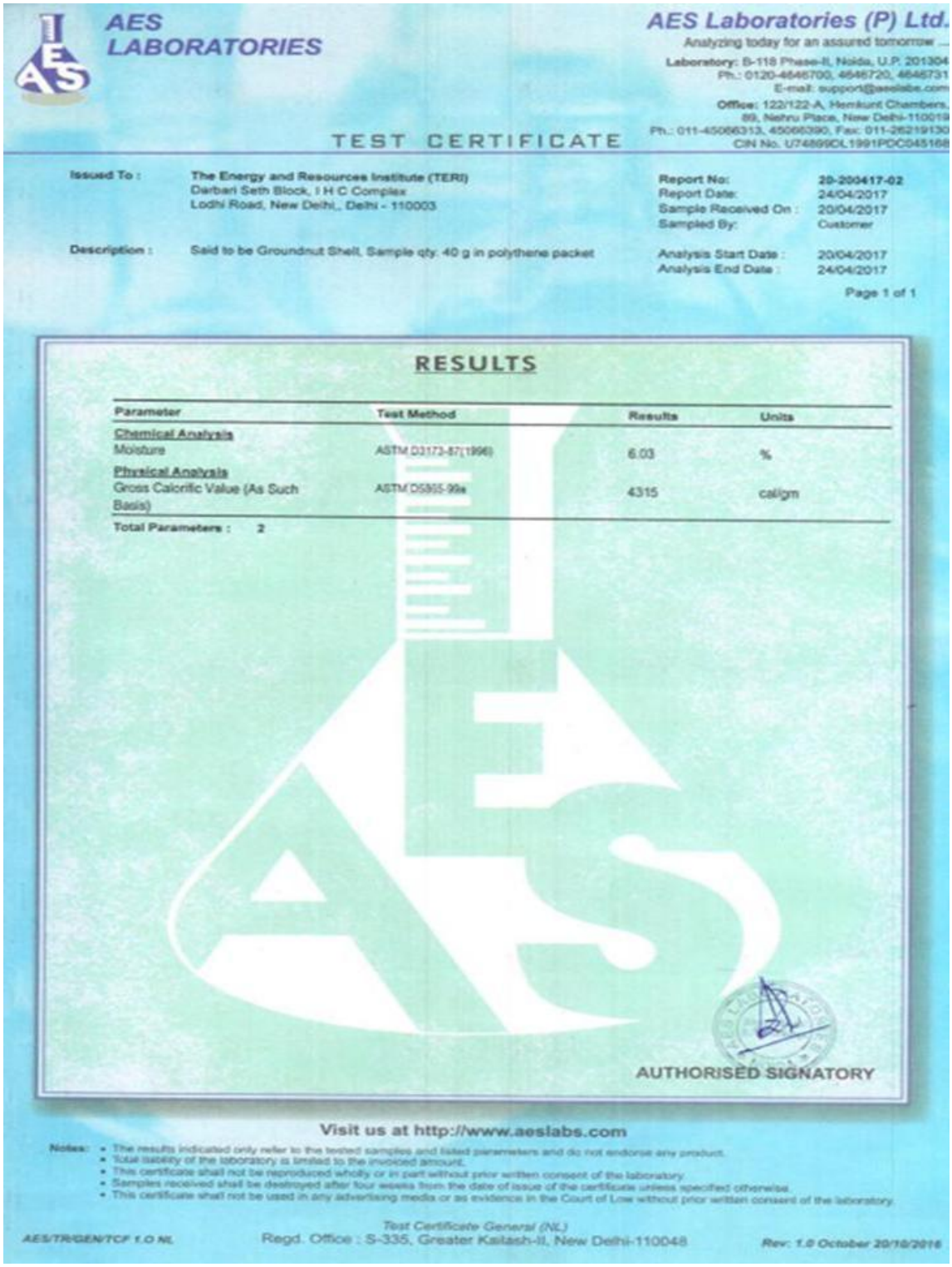
- The cost is for the standing biomass in field and the crop residues retain about 60% moisture content (in case of cotton stalk/ turver stalk) while the desirable moisture range is 30%. Hence, the cost of biomass (cotton stalk/ tuver stalk) may be considered 30% more on and above the shown prices (namely, Rs 1,300/ ton instead of Rs 1,000/ per ton in case of cotton/ tuver stalk).
- Transportation cost is at Rs 560/ ton (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/ ton.
- Chipping cost: being the biomass of a vivid type based on seasonal crop variation, the procured biomass needs to be shipped off to avoid the density-variation effect biomass. Chipping cost practically experience is approximately Rs 200/ ton.

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

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

Annexure XII: Lab report for GCV calculation of different crop residues

GCV of Groundnut shell



AES LABORATORIES

AES Laboratories (P) Ltd.
Analyzing today for an assured tomorrow ...
Laboratory: B-118 Phase-II, Noida, U.P. 201304
Ph.: 0120-4646700, 4646720, 4646731
E-mail: support@aeslabs.com
Office: 122/122-A, Hemkunt Chambers,
89, Nehru Place, New Delhi-110019
Ph.: 011-45066313, 45066390, Fax: 011-26219130
CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

Issued To : The Energy and Resources Institute (TERI)
Darbari Seth Block, I H C Complex
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

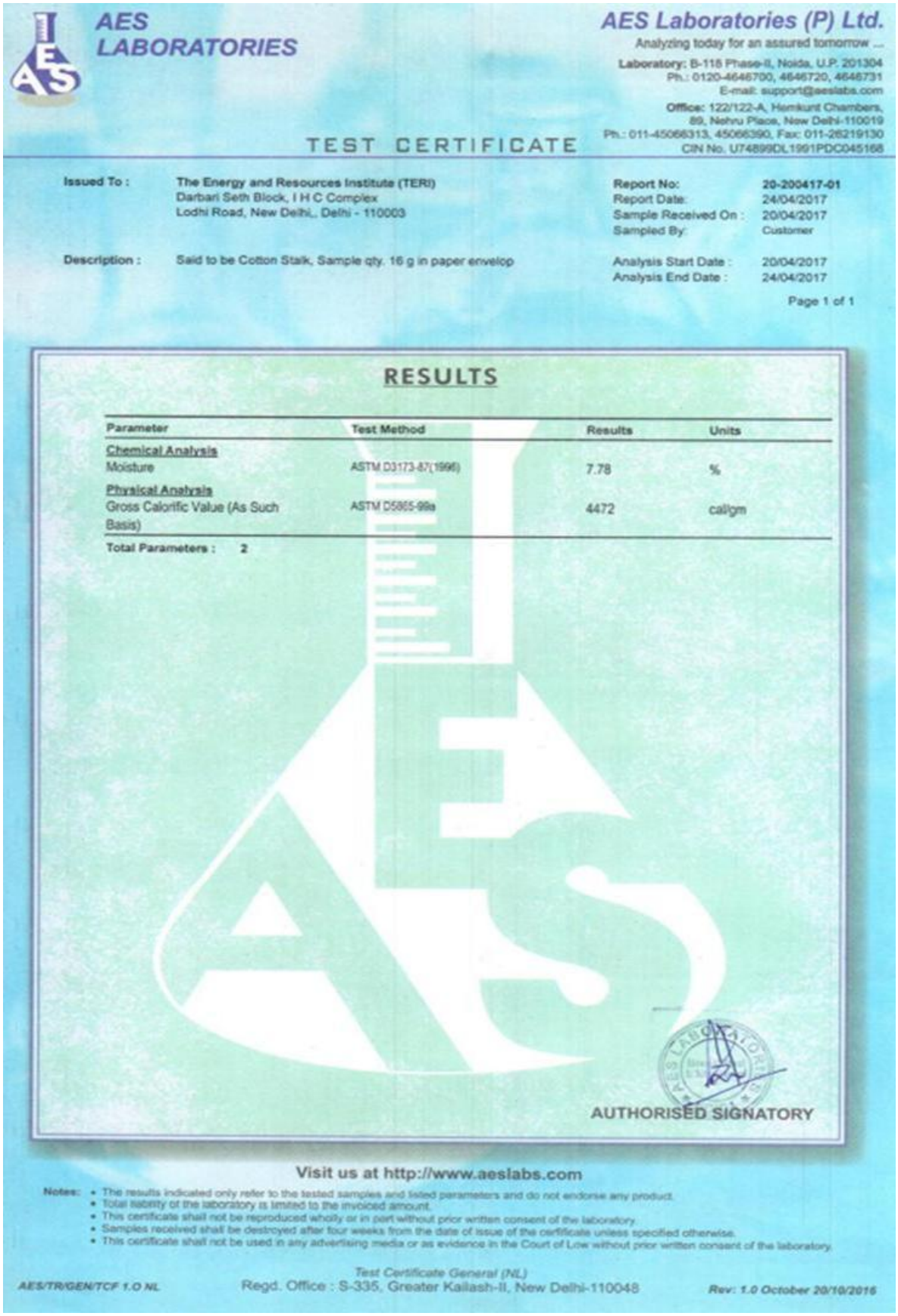
AUTHORISED SIGNATORY

Visit us at http://www.aeslabs.com

Notes:
- The results indicated only refer to the tested samples and listed parameters and do not endorse any product.
- Total liability of the laboratory is limited to the invoiced amount.
- This certificate shall not be reproduced wholly or in part without prior written consent of the laboratory.
- Samples received shall be destroyed after four weeks from the date of issue of the certificate unless specified otherwise.
- This certificate shall not be used in any advertising media or as evidence in the Court of Law without prior written consent of the laboratory.

Test Certificate General (NL)
AES/TR/GEN/TCF 1.0 NL
Regd. Office : S-335, Greater Kailash-II, New Delhi-110048
Rev: 1.0 October 20/10/2016

GCV of Cotton stalk



AES LABORATORIES

AES Laboratories (P) Ltd.
Analyzing today for an assured tomorrow ...
Laboratory: B-118 Phase-II, Noida, U.P. 201304
Ph.: 0120-4646700, 4646720, 4646731
E-mail: support@aeslabs.com
Office: 122/122-A, Hemkunt Chambers, 89, Nehru Place, New Delhi-110019
Ph.: 011-45066313, 45066390, Fax: 011-26219130
CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

Issued To : The Energy and Resources Institute (TERI)
Darbari Seth Block, I H C Complex
Lodhi Road, New Delhi,, Delhi - 110003

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

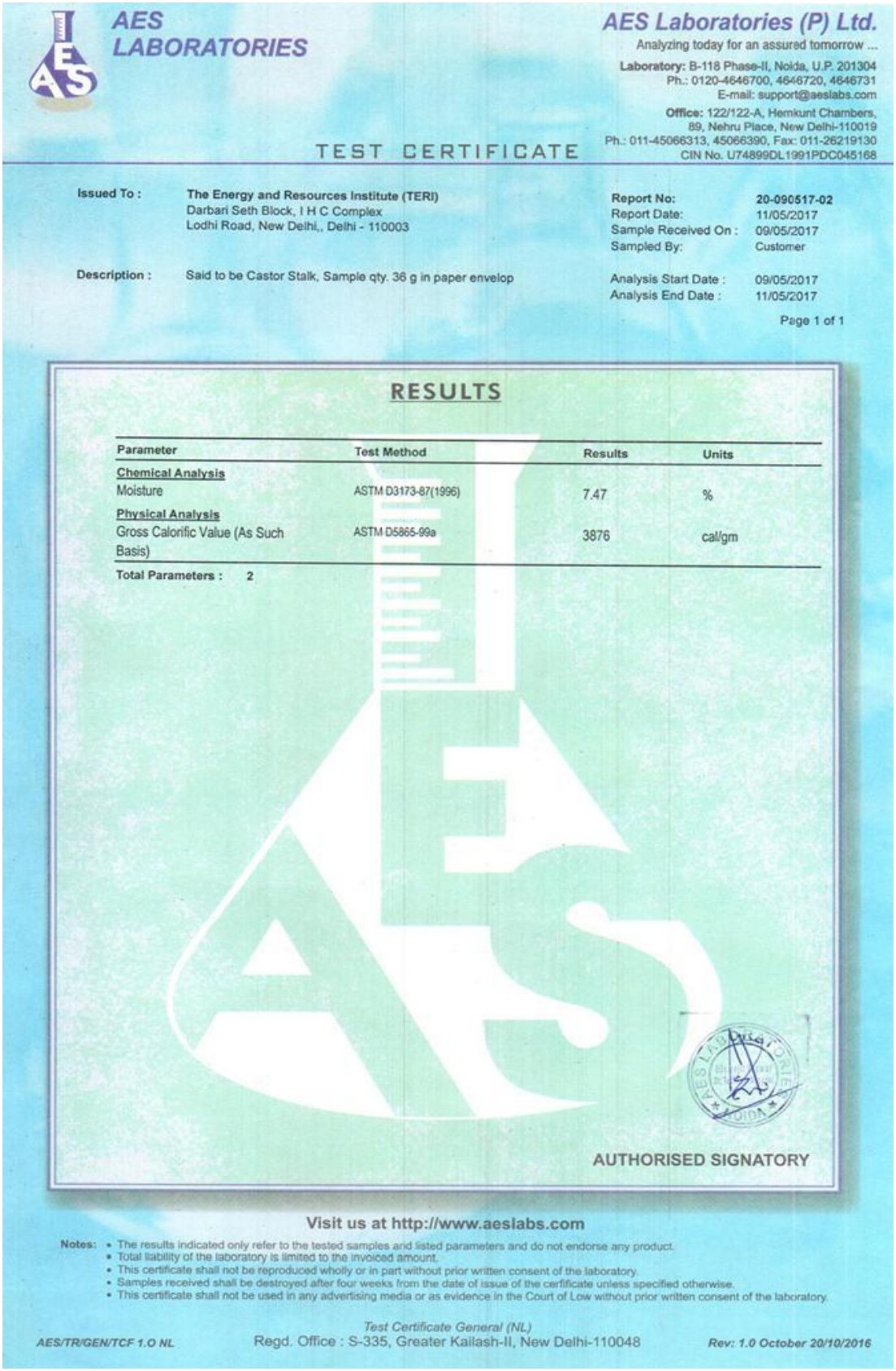
AUTHORISED SIGNATORY

Visit us at http://www.aeslabs.com

Notes:
- The results indicated only refer to the tested samples and listed parameters and do not endorse any product.
- Total liability of the laboratory is limited to the invoiced amount.
- This certificate shall not be reproduced wholly or in part without prior written consent of the laboratory.
- Samples received shall be destroyed after four weeks from the date of issue of the certificate unless specified otherwise.
- This certificate shall not be used in any advertising media or as evidence in the Court of Law without prior written consent of the laboratory.

Test Certificate General (NL)
AES/TR/GEN/TCF 1.0 NL
Regd. Office : S-335, Greater Kailash-II, New Delhi-110048
Rev: 1.0 October 20/10/2016

Test report for GCV and moisture value of castor stalk



AES LABORATORIES

AES Laboratories (P) Ltd.
Analyzing today for an assured tomorrow ...
Laboratory: B-118 Phase-II, Noida, U.P. 201304
Ph.: 0120-4646700, 4646720, 4646731
E-mail: support@aeslabs.com
Office: 122/122-A, Hemkunt Chambers, 89, Nehru Place, New Delhi-110019
Ph.: 011-45066313, 45066390, Fax: 011-26219130
CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

Issued To : The Energy and Resources Institute (TERI)
Darbari Seth Block, I H C Complex
Lodhi Road, New Delhi,, Delhi - 110003

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

Report No: 20-090517-02
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

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

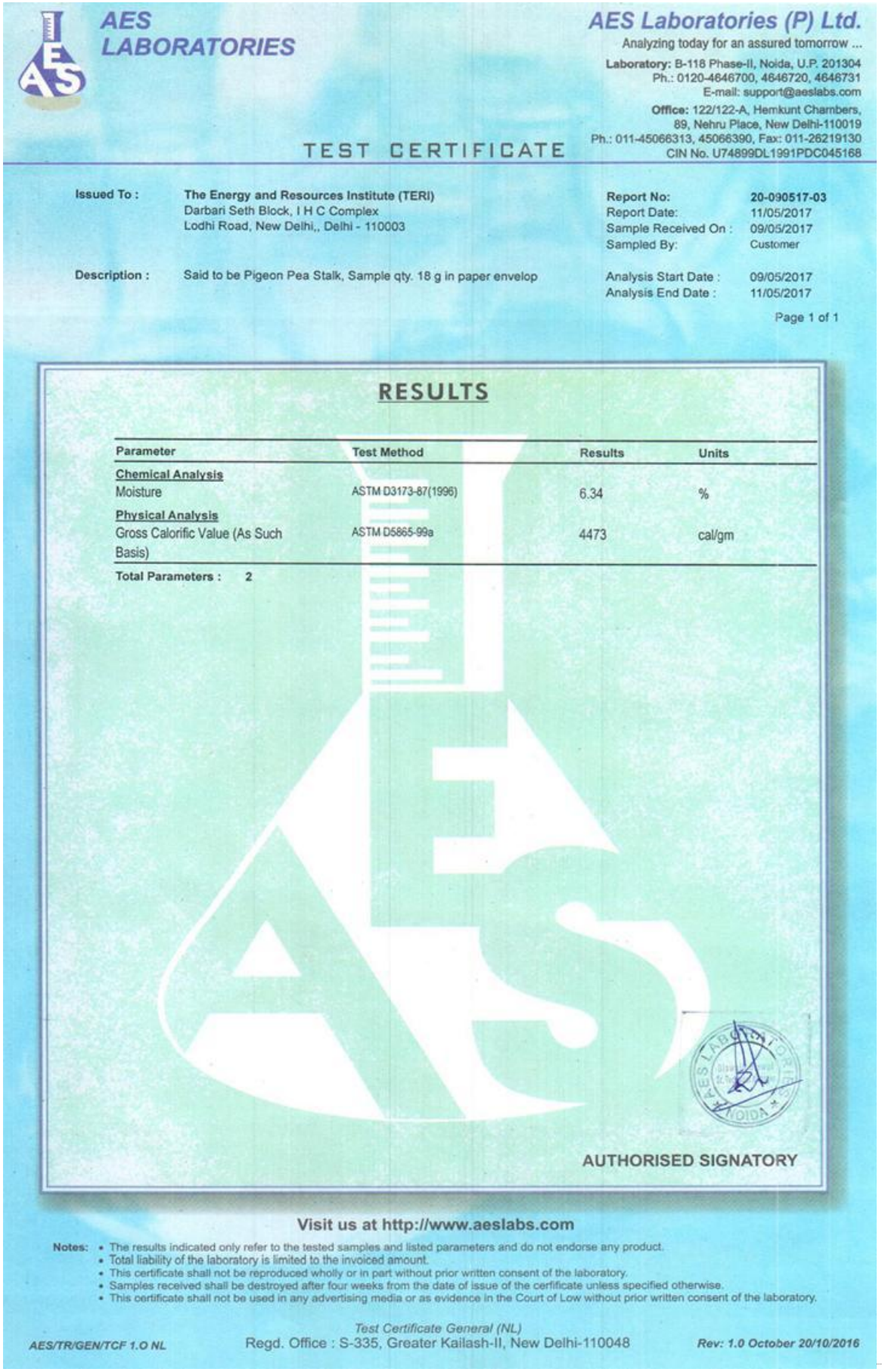
AUTHORISED SIGNATORY

Visit us at http://www.aeslabs.com

Notes:
- The results indicated only refer to the tested samples and listed parameters and do not endorse any product.
- Total liability of the laboratory is limited to the invoiced amount.
- This certificate shall not be reproduced wholly or in part without prior written consent of the laboratory.
- Samples received shall be destroyed after four weeks from the date of issue of the certificate unless specified otherwise.
- This certificate shall not be used in any advertising media or as evidence in the Court of Law without prior written consent of the laboratory.

Test Certificate General (NL)
AES/TR/GEN/TCF 1.0 NL
Regd. Office : S-335, Greater Kailash-II, New Delhi-110048
Rev: 1.0 October 20/10/2016

Test report for GCV and moisture value of pigeon pea stalk



AES LABORATORIES

AES Laboratories (P) Ltd.
Analyzing today for an assured tomorrow ...
Laboratory: B-118 Phase-II, Noida, U.P. 201304
Ph.: 0120-4646700, 4646720, 4646731
E-mail: support@aeslabs.com
Office: 122/122-A, Hemkunt Chambers,
89, Nehru Place, New Delhi-110019
Ph.: 011-45066313, 45066390, Fax: 011-26219130
CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

Issued To : The Energy and Resources Institute (TERI)
Darbari Seth Block, I H C Complex
Lodhi Road, New Delhi,, Delhi - 110003

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

Report No: 20-090517-03
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

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

AUTHORISED SIGNATORY

Visit us at http://www.aeslabs.com

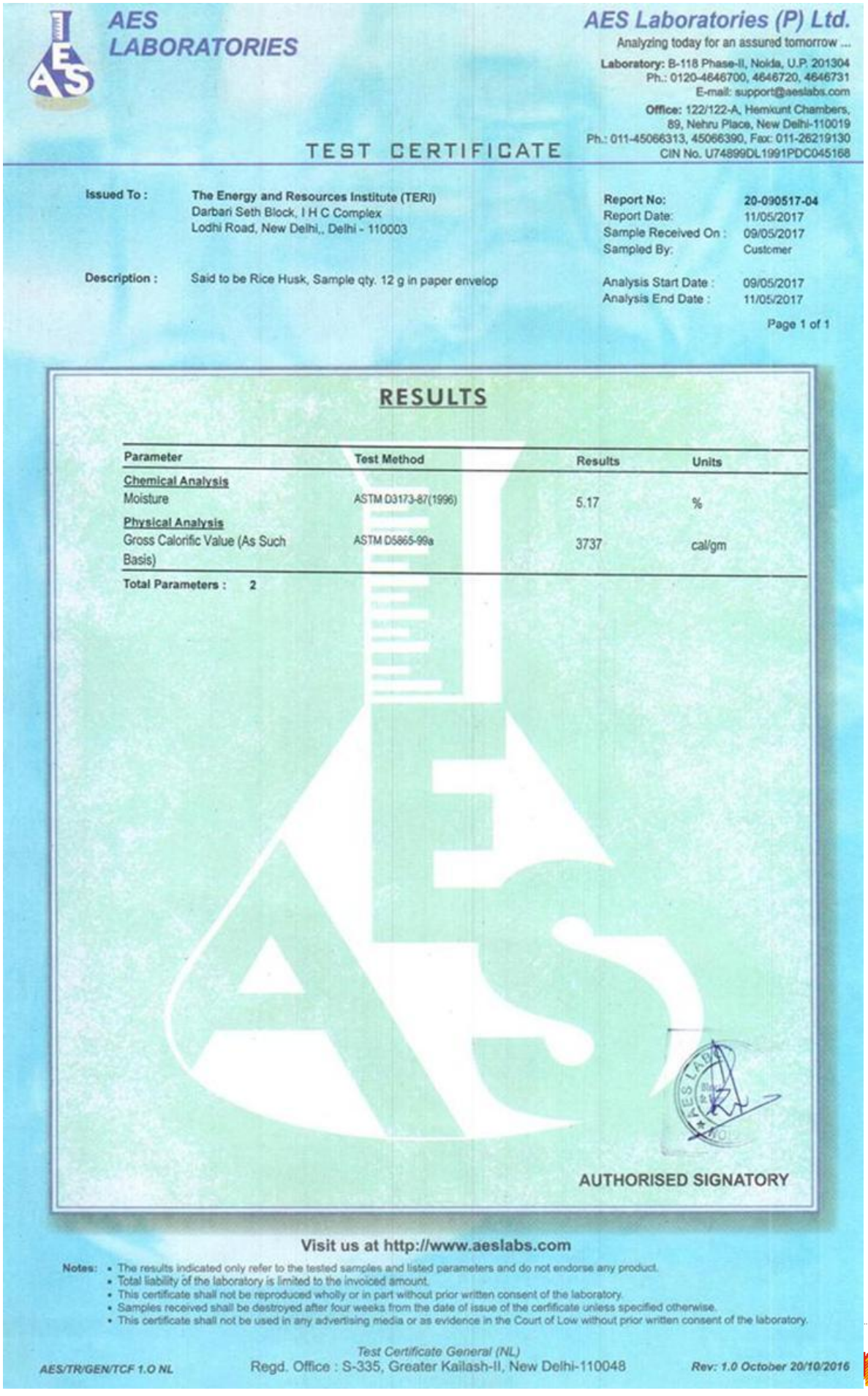
Notes:
- The results indicated only refer to the tested samples and listed parameters and do not endorse any product.
- Total liability of the laboratory is limited to the invoiced amount.
- This certificate shall not be reproduced wholly or in part without prior written consent of the laboratory.
- Samples received shall be destroyed after four weeks from the date of issue of the certificate unless specified otherwise.
- This certificate shall not be used in any advertising media or as evidence in the Court of Low without prior written consent of the laboratory.

AES/TR/GEN/TCF 1.O NL

Test Certificate General (NL)
Regd. Office : S-335, Greater Kailash-II, New Delhi-110048

Rev: 1.0 October 20/10/2016

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



AES LABORATORIES

AES Laboratories (P) Ltd.
Analyzing today for an assured tomorrow ....
Laboratory: B-118 Phase-II, Noida, U.P. 201304
Ph.: 0120-4646700, 4646720, 4646731
E-mail: support@aeslabs.com
Office: 122/122-A, Hemkunt Chambers,
89, Nehru Place, New Delhi-110019
Ph.: 011-45066313, 45066390, Fax: 011-26219130
CIN No. U74899DL1991PDC045168

TEST CERTIFICATE

Issued To : The Energy and Resources Institute (TERI)
Darbari Seth Block, I H C Complex
Lodhi Road, New Delhi,, Delhi - 110003

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

Page 1 of 1

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

AUTHORISED SIGNATORY

Visit us at http://www.aeslabs.com

Notes:
- The results indicated only refer to the tested samples and listed parameters and do not endorse any product.
- Total liability of the laboratory is limited to the invoiced amount.
- This certificate shall not be reproduced wholly or in part without prior written consent of the laboratory.
- Samples received shall be destroyed after four weeks from the date of issue of the certificate unless specified otherwise.
- This certificate shall not be used in any advertising media or as evidence in the Court of Law without prior written consent of the laboratory.

Test Certificate General (NL)
AES/TR/GEN/TCF 1.0 NL
Regd. Office : S-335, Greater Kailash-II, New Delhi-110048
Rev: 1.0 October 20/10/2016