'Sustainable Bioenergy Solutions for Tomorrow (BEST) – Case India: Madhya Pradesh, Maharashtra and Tamil Nadu

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A technical report on:

Agriculture Biomass Economics and Farmers' Willingness to Participate in Biomass-to-Energy Business Model in Three Selected Indian States

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Executive Summary

- An extensive data has been collected from approximately 471 rural farmers from three selected Indian states. In each state, two districts with roughly 10 villages in each district were surveyed. The aims of this survey-based study were mainly to evaluate the surplus biomass potentials among rural farmers, assess the current socio-economics of biomassfor farmers, and finally investigate the farmers' perceptions and willingness to participate in a new and modern waste-to-energy (W-2-E) business model in their region. The following key results are reported:
- **In Maharashtra state:** Around one-third of the surveyed farmers possess up to 5 acres of cropland, 36% hold from 5 to 10 acres, and 30% possess over 10 acres of cropland. Approximately 65-80% of the surveyed farmers produce from about one ton up to 5 tons of crop residues annually. Sugarcane is the key crop planted by the farmers who participated in this study. The study shows that 62% of the farmers in Pune district would like to sell their biomass in a price range of 3000-6000 rupees per ton (36-73 euros) and 22% would like to sell their biomass in a price range (6000-9000 rupees per ton (36-110 euros) and 6% wish to sell it through a community-based association. (1 euro= 81.50 rupees as of 18.08.2014 exchange rate). In Thane district 34% of the farmers wish to sell their biomass in a price range of 3000-6000 rupees and 37% wish to sell their surplus biomass through established community-based association in their village. As a result of the prices outlook, the majority of the famers surveyed in this study seek to make from 1000 rupees up to 10000 rupees total annual income from selling all their surplus biomass. Regarding their perceptions of WtE business model, the surveyed farmers in Pune and Thane districts showed explicit and high willingness to sell their surplus biomass *directly* to an energy producer and without a middleman involvement. They believe WtE concept generate extra income and guarantee many employment opportunities in their area. However, logistics, such as transportation, remain key hurdle to biomassmanagement. Regarding the biomass pricing scheme and policymaking, the famers (90%) in Thane and Pune are in favor for a community-based association and less favoring (40-60%) a governmental role in setting the prices.
- **In Madhya Pradesh.** One-third of the surveyed farmers possess up to five acres of cropland, 32% from 5 to 10 acres, and 34% hold 10 acres or more. Almost 75% of the surveyed farmers produce from about one ton up to 5 tons of crop residues annually. Approximately 54% of farmers in Indore district wish to sell their biomass from about 1000 up to 3000 Rupees per ton (RPT) or 12-37 Euros while 34% of farmers wish to sell their biomass between (3000-6000) or 37-72 euros

per ton. In Bhopal district 58% of the farmers would like to sell their surplus biomass in a price range of 1000-3000 RPT or 12-36 euros and 31% would like to sell it with a price range 3000-6000 RPT or 36-72 euros. About 60% of the farmers seek to make from 1000 up to 10000 rupees total income annually from selling their surplus biomass. Over 90% of surveyed farmers in Madhya Pradesh state showed explicit and high willingness to sell their surplus biomass to an energy producer however only 40% of them are able to supply biomass throughout the year. Furthermore, 71% of the surveyed farmers wish not to spend resources in collecting and mobilizing their crop residues and 84% wish not to have a middleman involved in the procurement process but rather selling it directly to an energy producer. The farmers also see benefits, such as getting electricity from nearby power plant, however they indicated that lack of labor and unreliable transportation logistics are some key challenges to W-2-E business model. The farmers in Indore and Bhopal districts have shown support to both governmental role and community-based association in setting and regulating the biomass prices and market.

- **In Tamil Nadu.** Over half (53%) of the surveyed farmers possess up to 5 acres of land, 33% from 5 to 10 acres, and 14% hold 10 or more acres of cropland. Over 61% of the farmers produce from less than a ton up to 5 tons of biomass per year. In Kanchipuram district 61% of farmers would like to sell their surplus biomass from less than 1000 up to 3000 Rupees per ton (RPT) or 12-37 Euros and 25% of the farmers would like to sell their biomass from 3000-6000 RPT or (37-72) euros. In Coimbatore district 63% the farmers wish to sell their surplus biomass from 1000-3000 RPT and 16% wish to sell it with a price range of 3000-6000 RPT or 37-72 euros). Similar to other states the farmers showed high willingness to sell their surplus biomass to an energy producer with approximately 83% of the surveyed farmers are able to supply biomass throughout the year.

  In the biomass procurement process 40% of the surveyed farmers wish not to invest extra resources in collecting and mobilizing their crop residues and 62% wish not to have a middleman involved in this process however they seek to sell their biomass directly to and energy producer with 70% of them are willing to have contractual obligation with an energy producer. Famers also believe that WtE model generate extra income and provide opportunity to have access to electricity from a nearby power plant. About 15% of the surveyed farmers expressed concerns regarding possible environmental pollution from a nearby power plant and 90% of them believe that currently there are no obstacles to WtE business mode in their area. Similar to farmers in Maharashtra state, the farmers in Tamil Nadu are in favor for community-based association in setting and regulating biomass prices and market and favoring less governmental role.

Recommendations

- Promote the concept of community-based associations in selected villages which will create a collaborative business opportunity thus guarantee the flow of continuous and reliable amounts of biomass needed to run a power plant in the region.
- Quantities and prices of biomass varies considerably among the villages in the surveyed districts due to varying sizes of croplands, crop types, climate variabilities, and lack of clear pricing mechanism in each district. While in some districts the pricing mechanism is mainly linked to middleman however the farmers probably sell their biomassdepending on the seasonal productivity and biomasstypes and surplus quantities.
- Farmers expressed concerns regarding the logistics and biomasstransportation since no reliable and modern fleet exists to transport larger quantities of biomass from their land. Therefore, the investment in establishing power plant may involve designated fleet to collect biomass or hiring local trucks to transport biomass from farmers' land on regular and reliable basis.
- Farmers showed willingness to receive benefits from power plant such as power supply, and gas for cooking. It might be attractive to provide the farmers with access to electricity as a part of the value chain.
- An outreach campaigns are needed to elevate farmers' awareness about the benefits of establishing a power plant in their nearby region and also to avoid future public grievance or opposition.
- Political orientation and degree of political trust (between farmers and their local government) in the prospect region to establish power plant is unequivocal to understand the nature of policy planning and policy making since farmer's needs and voices provide direct access to voting boxes.
- Considerable quantities of biomass are still burnt on site in some villages, other is used for feeding livestock, and a share must be left on-site to maintain soil fertility, aeration, and organic content. Therefore it is recommended to buy only a designated share of biomass from farmers to maintain health agricultural and cultural systems. Manu studies suggest that one-third of the total biomass must be left on site to maintain soil fertility and proper aeration.
- Better understanding of local NGOs and municipalities' perceptions of biomass-based power plant would help in to develop suitable incentive mechanism to ensure business success and profitability.
- Farmless people are key stakeholders who heavily reliant on biomass for their energy needs and this consumption category shall be an important part of the future policy action.
- Farmers' willingness to use alternatives to biomass for cooking is a key issues such as the use of solar cooker or the use of LPG is also worth considering.
- The prospects of utilizing wastelands for energy-dedicated crop are also a key issue in the biomass supply chain, particularly where power plants are envisioned to be installed and commissioned.

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1. Introduction

The Indian economy and population are growing rapidly. The population of India is estimated to be growing 18 million every year (China 10 million) which will surpass China's population with a record of 1.5 billion by 2028. Indeed by 2015 some Indian cities will experience the largest population boom with Delhi reaching 24 million, Mumbai 22 million, and Calcutta 17 million (Seitz and Hite, 2012). Besides the population boom, energy independence and rural electrification remain some of the key challenge to the Indian government together with the post-harvest losses in the agriculture sector particularly in rural India. The agriculture sector in India is considered as the backbone of the country contributing approximately 17% of the country's total GDP and providing substances for approximately 60% of the rural population (Hiloidhari et al., 2014).

While the country is endowed with considerable fossil fuel reserves (US Energy Information Administration [EIA], 2014), however, renewable energy potentials exceed the current national conventional fossil fuels resources. The Ministry of New and Renewable Energy (MNRE) made estimates of the wind, solar, and small hydropower capacity that would largely enable the transition to a more clean energy production, encourage energy independence, and navigate the pathway towards rural electrification. In 2013 India invested approximately US$ 6 billion in renewable energy of which US$ 600 million new investment in biomass & waste-to-energy projects (Bloomberg New Energy Investment, 2014). As per the MNRE, a total of 288 biomass power and cogeneration projects aggregating to 2665MWe capacity have been installed in the country for feeding power to the grid (Hiloidhari et al., 2014).

Of great importance are the surplus crop residues potentials readily accessible for small scale or family-size biogas installation, large scale cogeneration, and considerable potentials for second generation biofuels production particularly from agriculture and forestry wastes, municipal solid and liquid wastes, and industrial by-products such as molasses from sugar industry. For instance, India is the second largest sugarcane producer with 17% of the world production in the last decade. Plantations are located mainly in Uttar Pradesh (north India) and Tamil Nadu (south India) and more than 90% of them are irrigated. A number of studies have estimated the gross biomass potentials and the respective surplus potentials in India varies greatly due to state-wise variations in cropping areas, productivity, and also the competing uses of biomasses (Hiloidhari et al., 2014). Overall, India produces 686 million tones (MT) gross crop residue biomass on annual basis, of which 234 MT (34% of gross) are estimated as surplus for bioenergy generation which is equivalent to 17% of India's total primary energy consumption (Hiloidhari et al., 2014). Amongst all the crops, sugarcane produces the highest amount of surplus residue followed by rice. Other studies provided estimates of biomass at about 565 million tons per annum of which 189 million tons of surplus biomass can be used either to fully substitute the nations' needs for transportation fuels (Indian Renewable Energy Status Report, 2010) or correspond to a potential of 18,000 MWe of power generation. Another one million tons of non-edible oils are annually available for producing biodiesel needs for the diesel-based railway network (Indian Renewable Energy Status Report, 2010).

Globally, bioenergy is receiving robust policy impetus to mainly revalorize the undervalued biomass/biomass resources to deliver energy services to people on a low income, not just for household use but to earn a living: the so-called 'productive uses' of energy (Best, 2014). In rural India agricultural biomass serve as alternative tool for clean cooking facilities, lightening, and better livelihoods for millions (Srinidhi and Mendoza, 2014; IEA bioenergy, 2012). This of particular importance in the Indian context since 33% of India's population has no access to grid-based electricity (National Census, 2011). Approximately 70% of India's population (nearly 830 million) lives in rural areas. Over 85% of these rural households use cattle dung, agricultural waste and fuel wood as the primary cooking fuel. Rural housewives are at 10-20 times higher health risks from inhaling the smoke fumes and fire dust (Srinidhi and Mendoza, 2014). Since its adoption of the Green Revolution in mid-60s, which received extensive support from various influential interests (Swain and Mehta, 2014), Indian farmers have enjoyed heavily subsidized (almost free) electricity through their organized lobbying, and emerging regional political parties who responded favorably to the farmers' wishes and maintained and fuelled intensification of subsidies over time (Dubash and Rajan, 2001; Gulati and Narayanan, 2003; Birner et al., 2007). Nevertheless agricultural electricity subsidies in India are closely linked with food security, poverty mitigation, state finance, water scarcity and, increasingly, climate change (Swain and Mehta, 2014). The availability of cheap electricity promotes overuse of electricity and water in Indian agriculture (Swain and Mehta, 2014; Badiani & Jessoe, 2011) and is a factor for both India's groundwater and electricity crises (Swain and Mehta, 2014). While agriculture consumes about one quarter of total electricity, its revenue contribution is as low as 7 per cent, leaving the utilities in financial distress (Swain and Mehta, 2014; Power Finance Corporation, 2013). Indian farmers today are seeking continuous supply and quality electricity to maintain their agricultural activities especially those who uses groundwater electric pumps (Swain and Mehta, 2014).

Since technologies do not operate on their own, but rather embedded in a wider political, economic and social framework, which are likely to govern both how they develop and what consequences they bring in (Giddens, 2011). In this framework, we look at the social aspect of technology deployment by investigating the perceptions of rural farmers. A closer look at the value chain of biomass valorization requires the involvement of farmers, as key stakeholders, into the process of biomass-to-energy modern technological processes. Farmers' perceptions and viewpoints regarding biomass procurement process will reveal key issues for the sake of developing a successful business model for all interest groups especially potential foreign investors. In this regard, Bioenergy Solutions for Tomorrow (BEST) – India is a collaborative research project of Cluster for Energy and Environment (CLEEN) and Finnish Bio-economy Cluster (FIBIC) to foster new and sustainable bioenergy business opportunities, lucid know-how transfer, and ultimately upgrade biomass uses through modern technologies developed and crafted in Finland.

Therefore the key and overall objective of this survey study is to primarily investigate the perceptions of the local farmers and their willingness to participate in a new business model for converting biomass useful forms of energy. The study also provides approximate estimates of the available biomass (crop residues) and analyzes the current pricing schemes as suggested by the farmers. The study further investigates the possible benefits, potential impacts, and any sort of barriers to the establishment of a biomass-based power plant in the nearby area from the farmers' point of view.

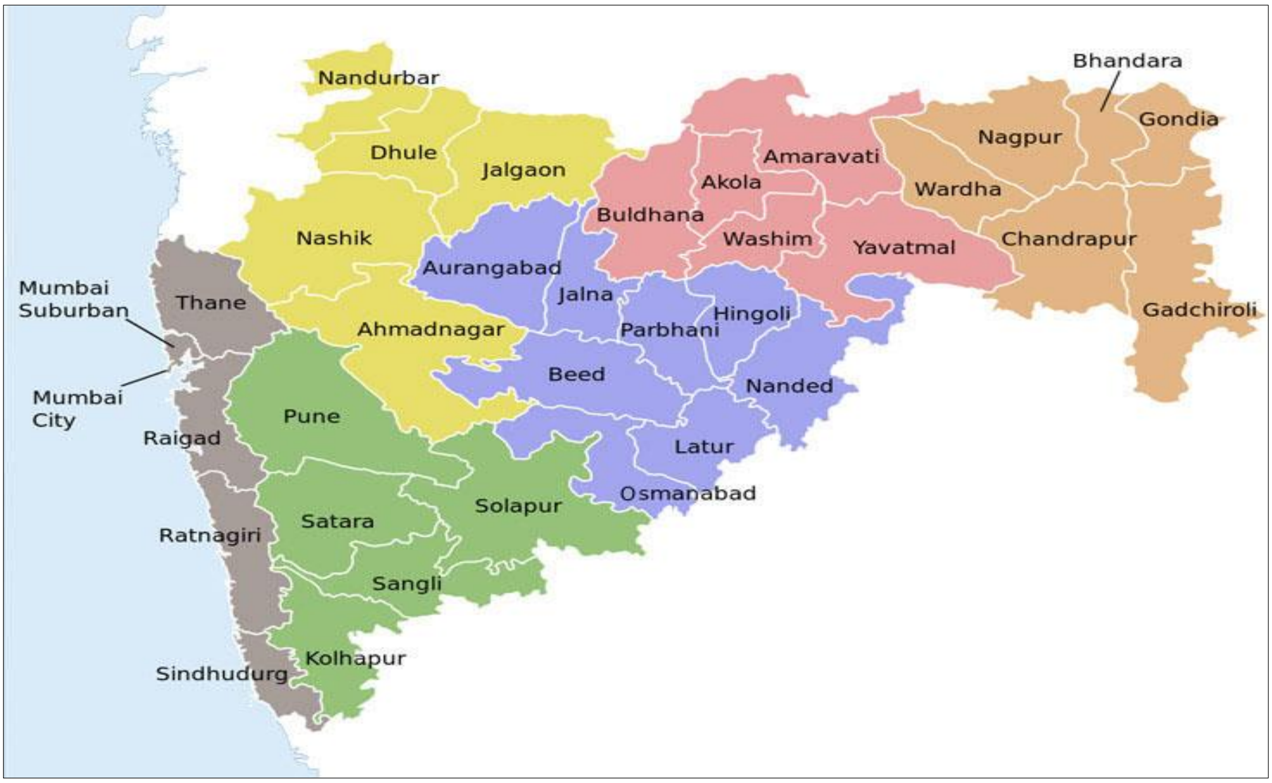
2. Methodology

The results of this social survey study are based on a set of data collected from three different Indian states (Maharashtra, Madhya Pradesh, and Tamil Nadu). The targeted population was rural farmers who cultivate various types of crops on varying sizes of rainfed/irrigated agriculture lands. Two districts were selected from each state. In Maharashtra Pune and Thane districts were selected for the survey study, Bhopal and Indore districts were selected in Madhya Pradesh, and Coimbatore and Kanchipuram districts from Tamil Nadu. Semi- structured questionnaires were developed and later were translated into Hindi, Marathi and Tamil to conduct the pen-paper survey. In each state, bilingual tools were used for the survey. Field teams consisting of six members each were constituted to conduct survey in the selected districts. Each field team consisted of five investigators and one Supervisor. SIGMA India has been assigned on collecting data from the field and data coding and entry while UEF team and TERI colleagues helped develop the survey tools, conduct field interviews, data analysis, and results reporting. The farmers' survey consisted of three main sections. The first section's heading was: *Farmer's perception for biomass production and* *marketing*, which was represented by 10 statements with 4 possible answers *(yes, no, don't know, and remarks).* The second part of the survey aimed at assessing the potential quantities of crop residues the farmers are able to sell throughout the year and analysis of biomass prices per ton suggested by the farmers to provide a glance on the traditional biomass procurement chain in the selected and surveyed Indian states. This section was organized by a figure-sheet consisted of 4 columns. These columns help to indicate the (*type of biomass/crop residues the farmer produces*), (*the average annual production [tons/per]*), *(the expected selling price at the farm gate [Rubes/Kg])*, and any *remarks* if the farmer wish to add. The final section of this study consisted of 3 open-ended questions. The first question aimed at identifying the major obstacles the farmers might experience during the supply of biomass to an energy company, the second questions addressed the benefits the farmers might get from selling biomass to an energy company, and finally the possible impacts of a nearby biomass-based power plants on the famer's livelihood and his community. The complete questionnaire is added as an annex to this report (Annex 1). The results are organized as per state. The report is concluded with a set of recommendations administered to potential foreign investor to maximize the quantities of biomass retrieved from farmers and leapfrog the barriers may be encountered during the process of establishing biomass-based power plant in the close-to-farmer region.

3. Key figures from Surveyed States

3.1. Maharashtra State

Maharashtra is the third largest state in India with large tribal population. Mumbai is the capital of Maharashtra. It has 35 districts divided into six divisions (see map). Maharashtra state is a highly urbanized state with 45% of the population residing in urban areas. Maharashtra is the wealthiest state in India, contributing 15% of the country's industrial output and 13% of its GDP. Maharashtra encompasses an area of 30.77 million hectare and as per the 2011 census; it has a population of 112.3 million. More than 60% of the people of Maharashtra are employed in agriculture and associated activities. Rice is the second important crop after Jowar (sorghum) in Maharashtra State. In Maharashtra rice is the second important crop of the people, which is grown over an area of 15 thousand hectares with an annual rough rice production of 32.37 thousand tones. The average productivity of the state is 2.01 t/ha. Maharashtra ranks 13th place in rice production in country (Thaware et al., 2011). According to Hiloidhari et al. (2014) Maharashtra has an annual surplus biomass potential of 31 million tons equivalent to 563 PJ. The state has also substantial production of sugarcane, maize, wheat, grams, and many other horticultural crops.



Map 1. Map of Maharashtra: source www.maharashtra.gov.in

3.1.1. Pune District

Pune is one of the most economically developed districts. Youth in Pune district are assumed to *have greater access to education, employment opportunities, modern consumer goods, new ideas* and modern lifestyles than those in most other districts of the state Maharashtra. The landscape of Pune district is distributed triangularly in western Maharashtra at the foothills of the Sahyadri Mountains and is divided into three parts: "Ghatmatha", "Maval" and "Desh". Pune district forms a part of the tropical monsoon land and therefore shows a significant seasonal variation in temperature as well as rainfall conditions. Climate of the western region of Pune is cool whereas the eastern part is hot and dry. The total population size of Pune district is about 9.43 million population (60% reside in urban areas) distributed across 14 sub-districts, 35 towns, and 1877 villages.

3.1.2. Thane District

As per census of 2011, Thane District houses roughly 12 million citizens. Thane district is divided into three parts known as coastal zone, hilly track and urban zone. Thane district is well known for highest revenue collection. There are 4 Members of Parliament and 24 Members of Maharashtra Legislative Assembly. Last 3-4 years, district is known for Turmeric and Taser silk production. The Maharashtra Industrial Development Corporation has developed 10 industrial areas in the district.

In Thane there exist three national highways and three railway tracks for transportation. Average rainfall in Thane is 2,576 mm with total cultivable land approximately 4.3 million hectares with over 12 million domestic livestock.

3.2. Crops and biomass residues in Pune and Thane districts

Eleven villages were surveyed in Pune district and ten villages in Thane district for crop and biomass types and their estimated quantities. **Figure 3.2.1** presents the villages surveyed in each district and number of respondents in each village. In Pune district sugar cane is the key crop followed by pearl millet and sorghum. There are many other crops being planted however on smaller scale such as rice, various vegetables crops, grams, and legumes (lentil and chickpea) **(Figure 3.2.2)**. On village level basis the number of crops being planted over one-year cycle may range from two crops such in Dhalewadi (Kharkhanapata) village and up to 16 crops in Pargaon village. **Figure 3.2.3** demonstrates the estimated biomass quantities produced per farmer in the surveyed villages in Pune District. It appears that most farmers (60-80%) in these villages produce from about than one ton up to five tons of crop residues (biomass) per year. The figure also shows that some farmers (10-15 %) are capable of producing over 5 tons year. Depending on the biomass type (husk, stems, combs) the biomass quantities are substantially higher for stem biomass (e.g. 1.5 Residues Ratio for maize) and rather less for husk (0.5 for maize).

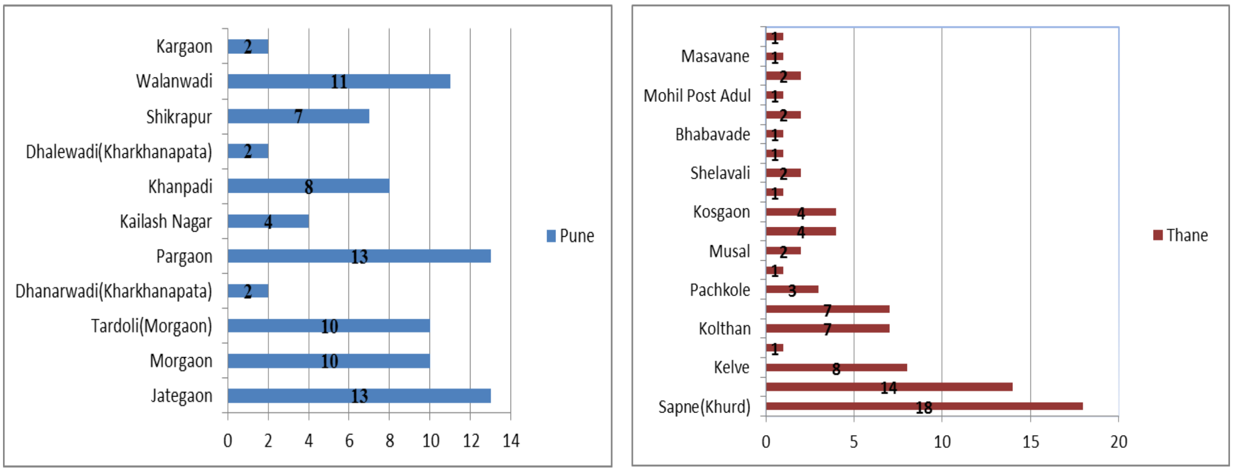


Figure 3.2.1. Village names and number of respondents in Pune and Thane districts (N=163)

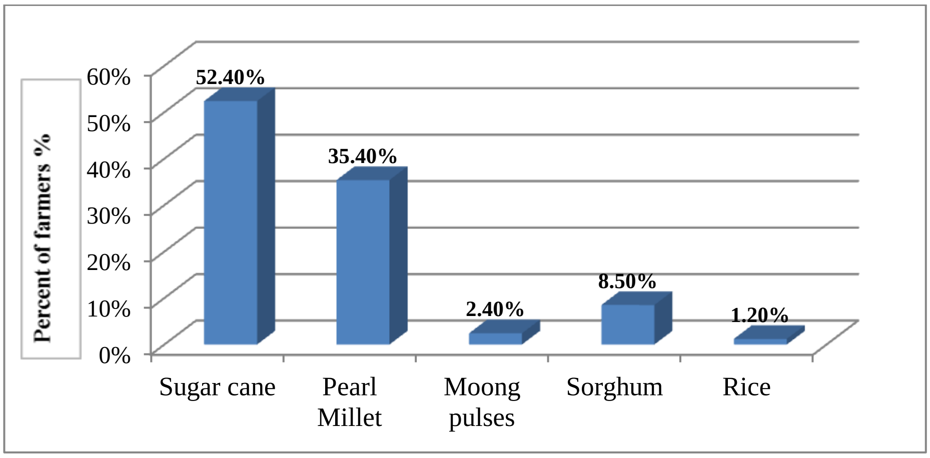


Figure 3.1.2. Common crops planted in Pune District and in the surveyed villages

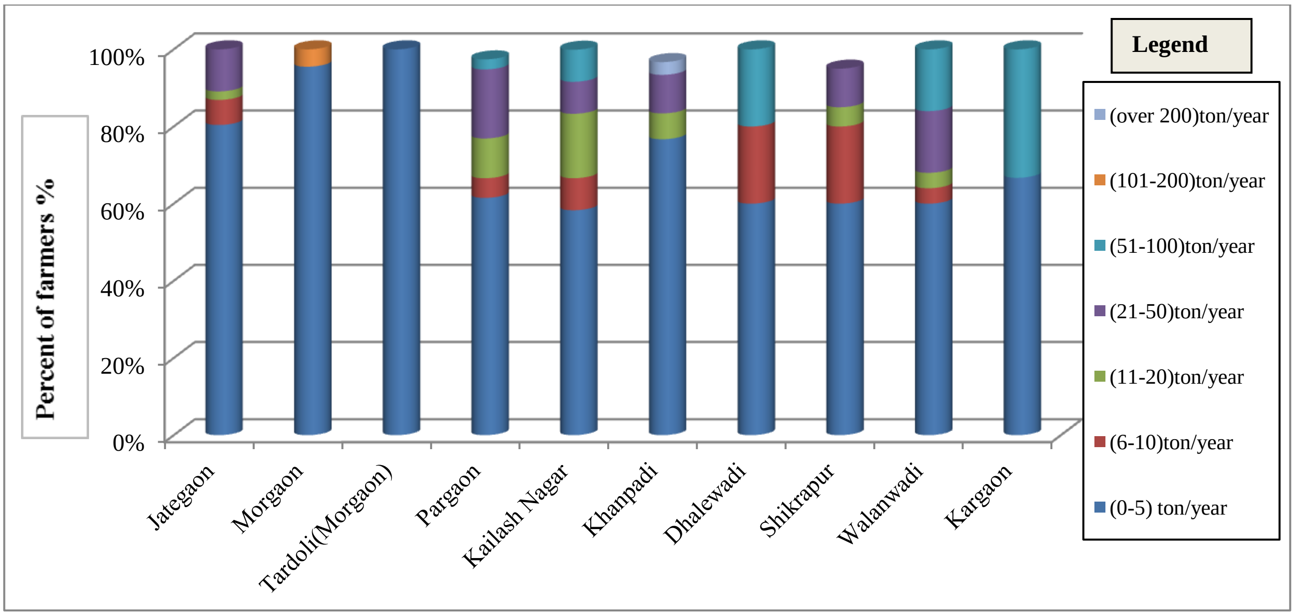


Figure 3.2.3. Average biomass quantities (ton/year) farmers produce in the surveyed villages of Pune District

In Thane district the crops outlook is different where rice is prominent crop planted by the surveyed farmers. The data show that over 90% of the farmers grow rice as their first and main crop annually. Other crops also planted in Thane include red gram, bengal gram, coconut, wheat, legumes, and various types of vegetables. With Musquo village as an exception, most of the villages in Thane also produce less than a ton and up to 5 tons of biomassper year **(Figure 3.2.5).** In Musquo village farmers generate from 6 up to 10 tons of biomass annually.

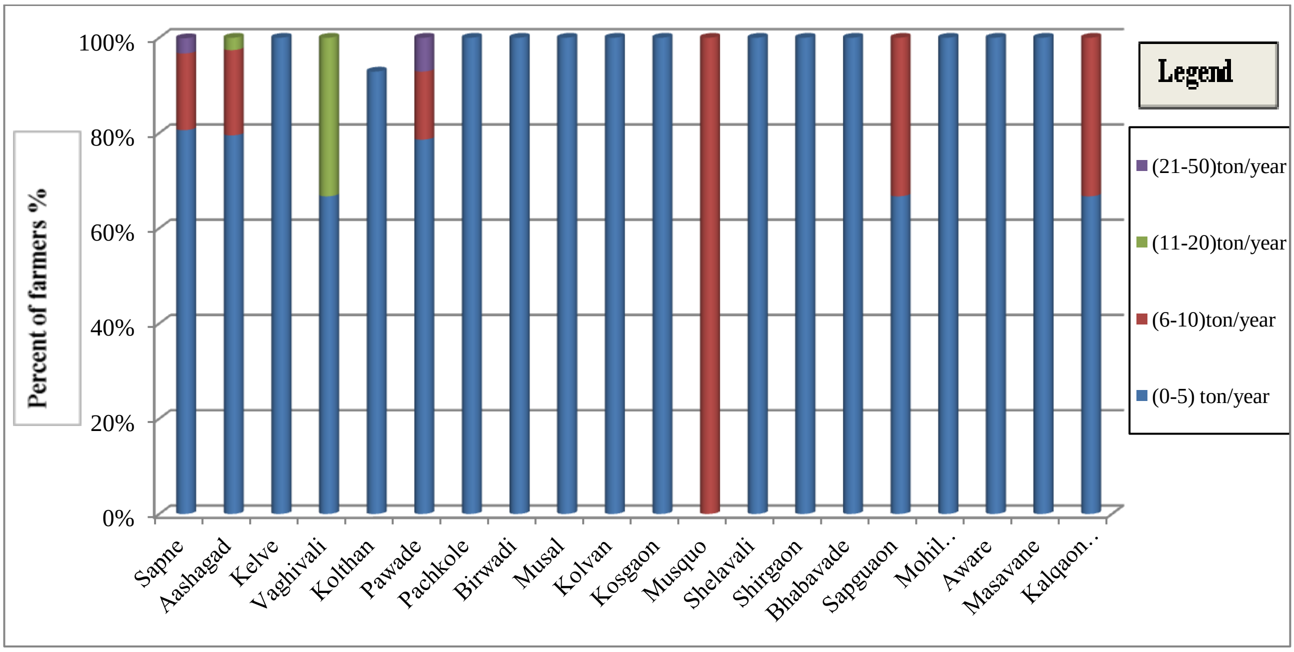


Figure 3.2.4. Average biomass quantities (ton/year) farmers produce in the surveyed villages of Thane District

The analysis show that there are many crop types being planted in Pune and Thane districts and farmers possess various cropland sizes. As a result, each farmer produces various amounts of biowastes. Biomass/crop residues in these two districts are being used for various activities including mainly feed for livestock, cooking, and brick making. Approximately 10% of the biomass is being burned in-site and vegetables wastes are left in site for nutrient recycling.

3.3. Economics of biomass wastes in Thane and Pune Districts

In Pune district, approximately 60%-70% of farmers in the surveyed villages wish to sell their biomass on average 3000-6000 rupees (equivalent to 37-72 Euros). Some 20-30% of the surveyed farmers would like to sell their biomass with higher prices (6000-9000 rupees). The farmers also wish to sell their surplus biomass through community-based association however to lesser degree **(Figure 3.3.1)**. In Thane district however farmers in seven villages appeared more eager to sell their surplus biomass through community-based association. In some other villages such as (Musquo, Shelavali, Bhabavade, Masavane) farmers would like to sell their biomass with a price range (37-72 euros). Biomass are found the cheapest in Vaghivali village and relatively expensive in Kelve, Kalqaon Post Alyani, Kolvan) villages **(Figure 3.3.2)**. The figure also shows that some farmers wish to sell their surplus biomass with over 10000 rupees per ton. This is unusually high price and never existed; probably the farmers referred to the price of all their surplus biomass quantities. It was also found that different crop biomass is sold with different prices. For instance if the demand on biomass is high, prices also increase. On average price of kg biomass is estimated between 2-3 Rupees in normal market condition. The variations in cropped area, cropping pattern, yield, and surplus fraction of residue are some of the major factors resulting in variations in surplus residue potential and hence related bioenergy potential amongst the states.

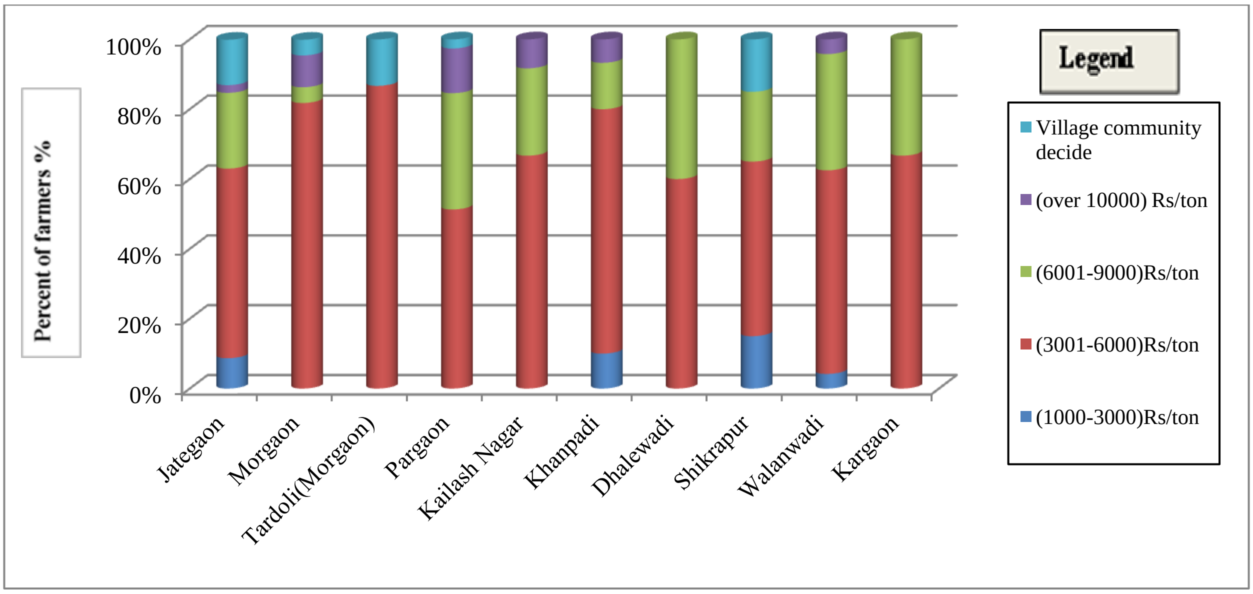


Figure 3.3.1. Average biomass prices (Rupees/ton) farmers willing to sell in Pune District

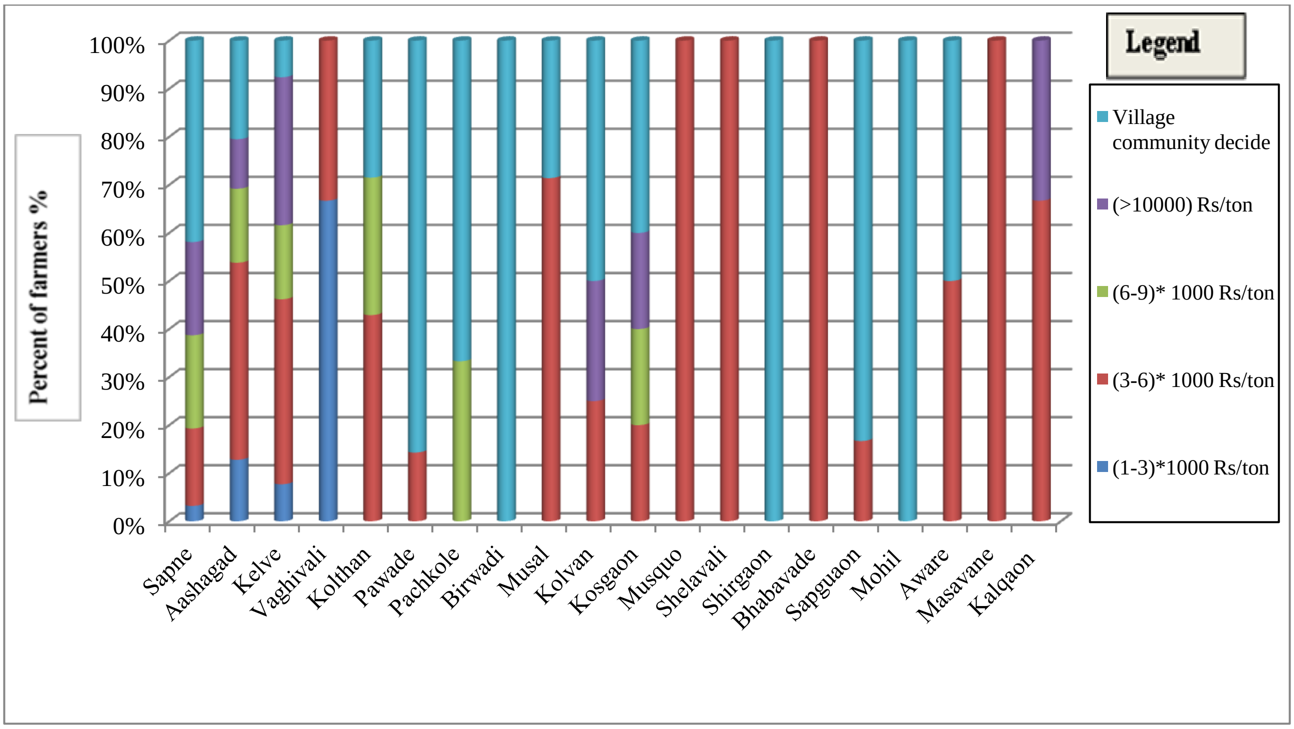


Figure 3.3.2. Average biomass prices (Rupees/ton) farmers willing to sell in Thane District

To gain insights about the farmers' income from selling their biomass we cross tabulated the average biomass quantities generated per year against the average selling prices per ton. In Pune district the majority of farmers in the surveyed villages would make from around 1000 up to 10000 rupees (12-120 euros) extra income per year **(Figure 3.3.4).** Similar findings are also reported for farmers in the Thane district. When excluding the community association role in setting prices, the average extra income farmers would make fall between the 1000 and 10000 rupees or (12-120 euros) per year **(Figure 3.3.5).** It was assumed that the farmers wish to sell their surplus biomass excluding the quantities for own uses.

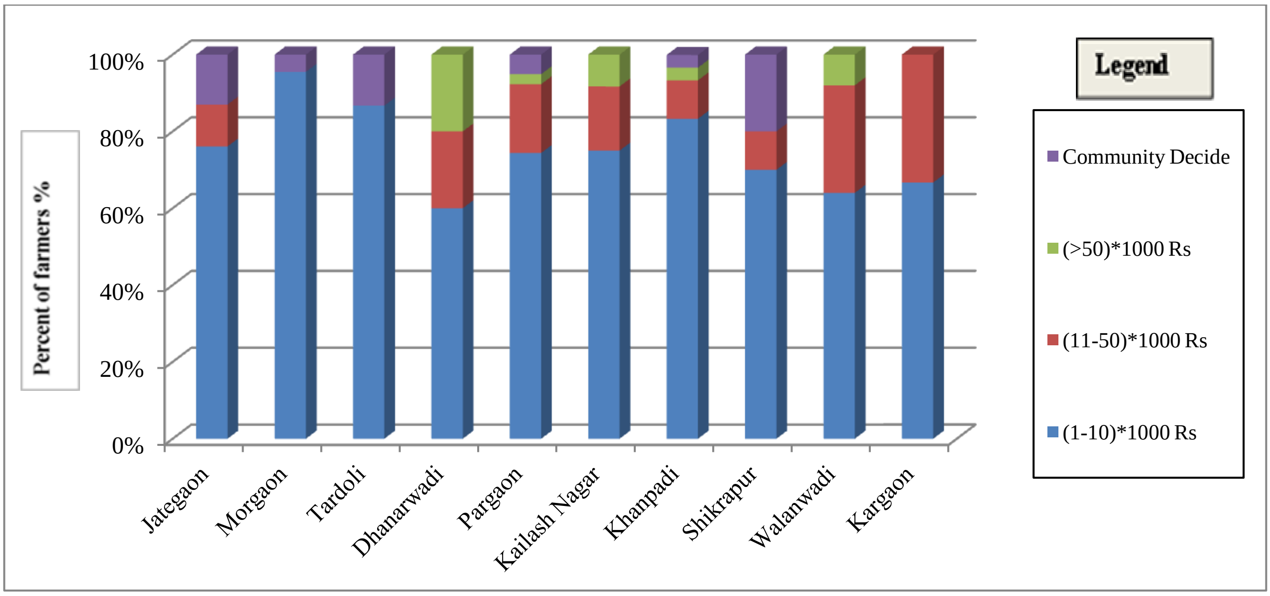


Figure 3.3.4. Average total income (Rs) farmers would make from selling biomass in Pune District (village-wise)

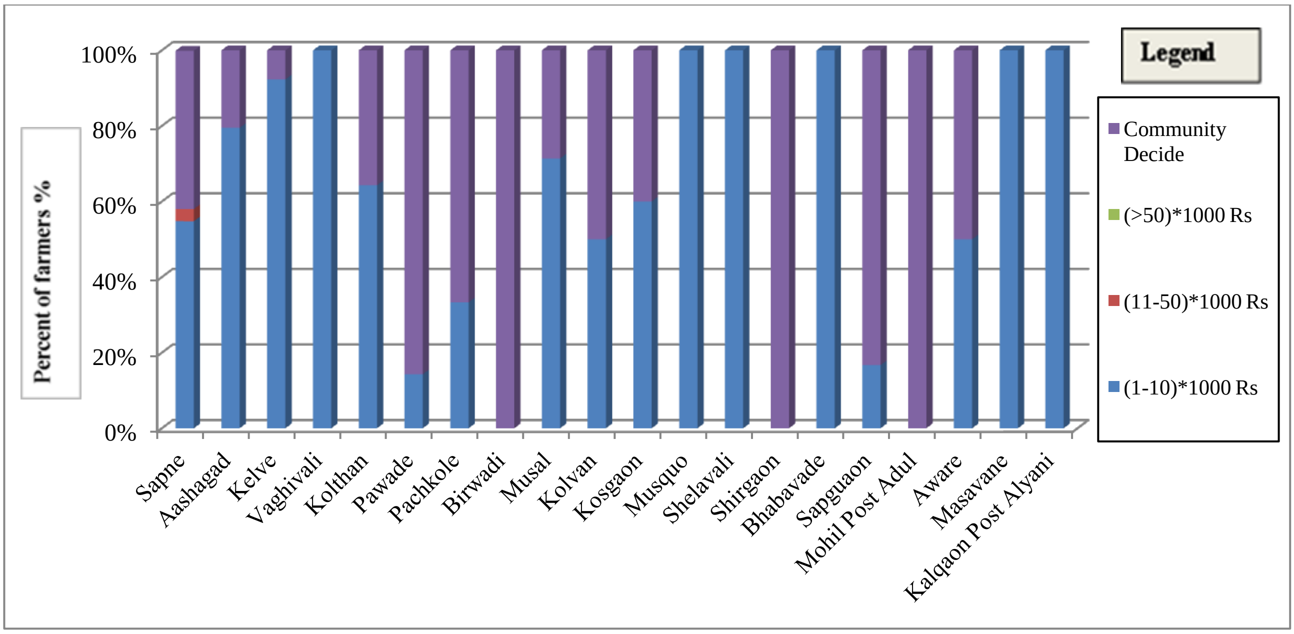


Figure 3.3.5. Average total income (Rs) farmers would make from selling biomass in Thane District (village-wise)

4. Key figures from Surveyed States

4.1. Madhya Pradesh

Madhya Pradesh (MP) is located in the heart of the India. MP is about 9.4% of geographic area of India. Madhya Pradesh is divided into 10 divisions and 50 districts for administrative purpose. The capital of the state is Bhopal. The economy of the state mainly depends on agriculture with more than 70% of the population involved in agricultural activities. Madhya Pradesh has a subtropical climate. It has a hot dry summer (April–June), followed by monsoon rains (July–September) and a cool and relatively dry winter. The average rainfall is about 1,370 mm (53.9 in). The total population of MP is about 74 million inhabitants with two third living in rural areas. **Map 2** shows the selected districts for surveying and the selected villages in those districts. Madhya Pradesh has annual surplus biomass potential equivalent to 207 PJ (Hiloidhari et al. 2014).

4.1.1. Indore District

Indore is the most populous city in the central India, with an estimated 2.2 million residents as of 2011census. It covers 3.9 million km^2 with 624 inhabited villages and 4 forest villages. It has 14% forest cover, 3% cultivable waste land, and about 68% is net sown agricultural land with average 2.4 hectare land holding size and an average use of fertilizer per hectare of about 78 kg/hectare. Over 90% of its citizens have access to drinkable water and electricity (Madhya Pradesh Human Development Report, 2007).

4.1.2. Bhopal District

Bhopal is one of the fastest growing cities in the country at rate of 3.2% annually. Currently it has a population of 2.38 million inhabitants. Bhopal district is almost 80% urbanized with most people living in the city of Bhopal while 37% are below poverty line. As the principal city of the region, it serves all towns and districts around, the nearest large city of Indore about 180 km. away to the West. The city of Bhopal is of strategic importance, it an important link between north–south and east– west rail and road routes across the country (Madhya Pradesh Human Development Report, 2007). The total number of respondents (farmers) was 161 from both districts (80 from Bhopal and 81 from Indore). See **figure 4.1.1** for name of villages and number of respondents.

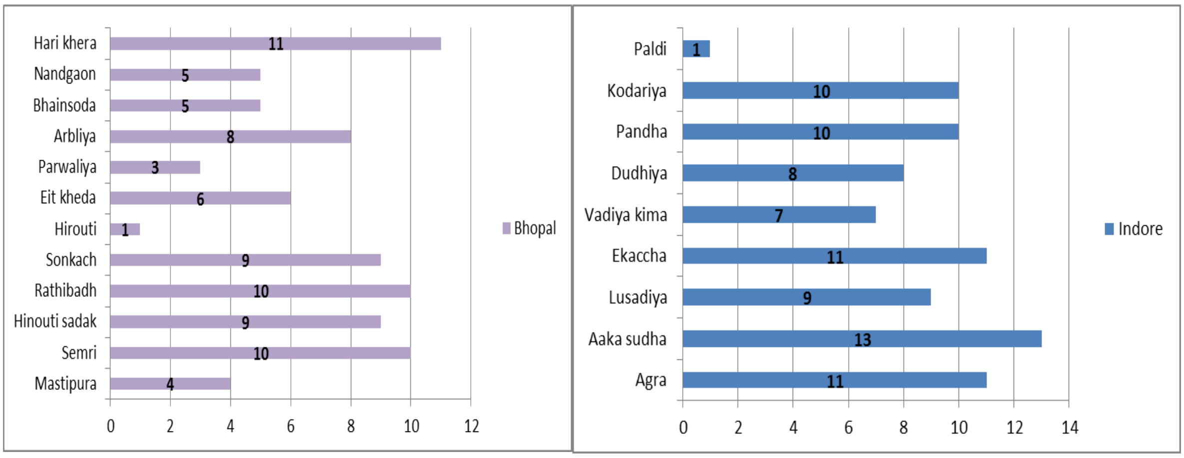
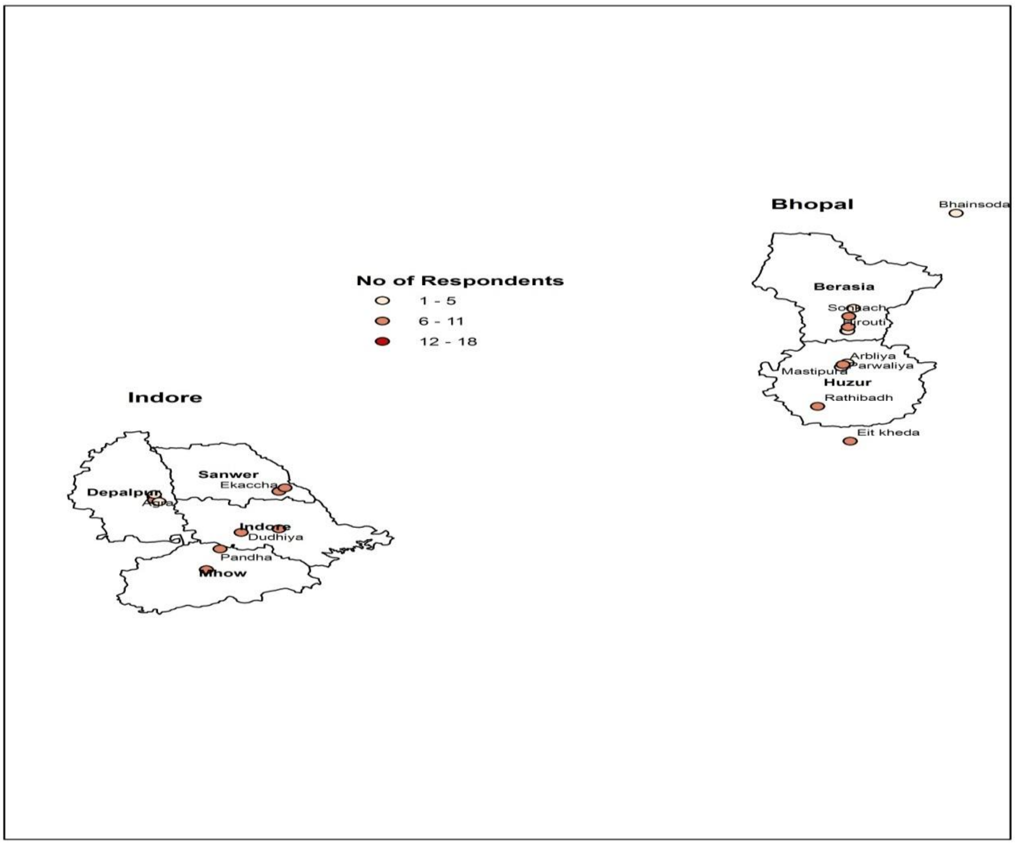


Figure 4.1.1. Number of participants and surveyed villages in Bhopal and Indore Districts



Map 2. Location of Indore and Bhopal Districts/ Madhya Pradesh

4.2. Crops and biomass residues in Indore and Bhopal districts with a village-level analysis

Wheat (*Triticum durum*) is the most commonly planted crop by farmers who participated in this study. Other common crop planted in these districts includes soybean, corn, potato, and other vegetables. Stalk or straw has crop residues value of 1.5 and it has a heating value 17.15 Mega Joule per kg (MJ/Kg). Wheat straw is mainly used as (Bhusa) - mechanically threshed to be more palatable- for animal feed in the wheat-growing areas. Use of wheat straw as animal feed is also reported to be common in the Trans-Gangetic plains to Bihar sub- regions of India. Wheat straw burning is not common in Madhya Pradesh however about 10% of wheat straw are burned in-situ in Uttar Pradesh (Hiloidhari et al. 2014).

Regarding the biowastes/residues produced in the selected districts and surveyed villages **figure 4.2.3 and figure 4.2.4** presents the average quantities as per village in Indore and Bhopal districts. In Indore, most of the farmers (75%) in the surveyed villages produce on average from less than a ton and up to 5 tons of biomass except for Paldi village. About 10-15% of the farmers produce on average from 6 to 10 tons of wheat-based residues. The variations are due to the size of the farmers' cropland and productivity per hectare. Similar biomass quantification is also reported for Bhopal district, where the majority of the surveyed farmers (74%) produce also from less than a ton and up to 5 tons of biomass on annual basis. In Bhopal however considerable volumes of biomass (11-20 tons) are also produced even though on smaller scale (5-10%) of the farmers in some villages.

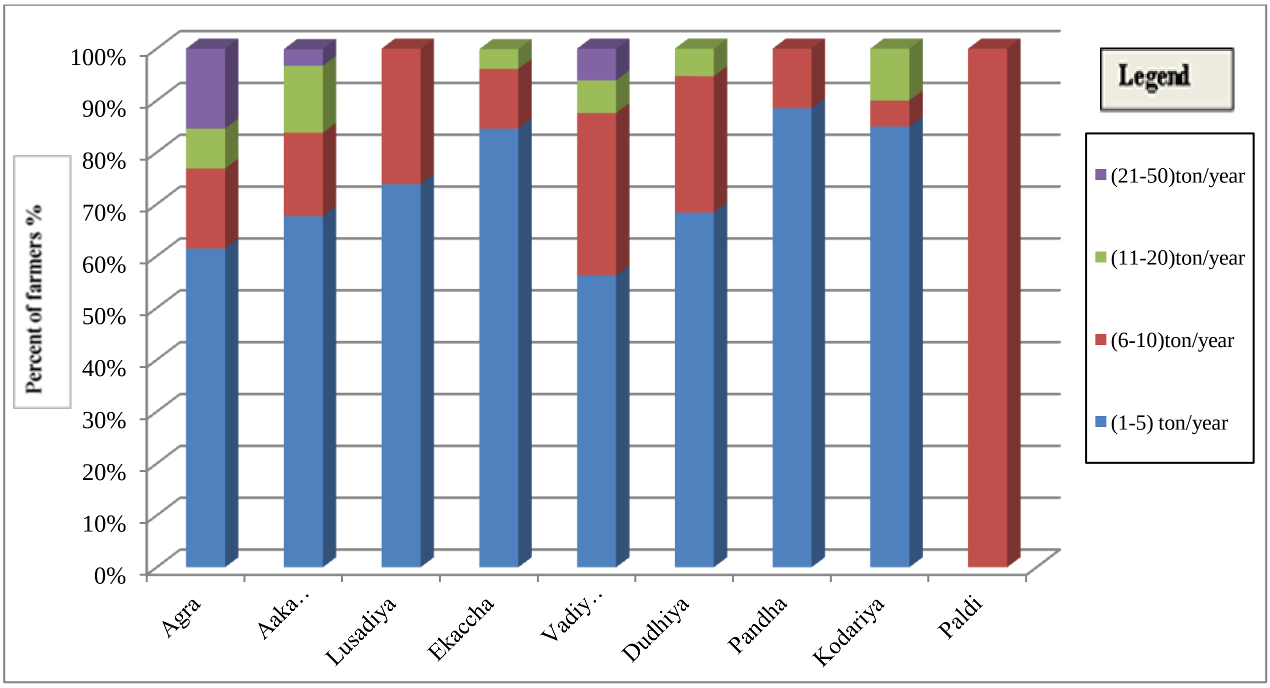


Figure 4.2.3. Average biomass quantities (ton/year) farmers produce in the surveyed villages of Indore District

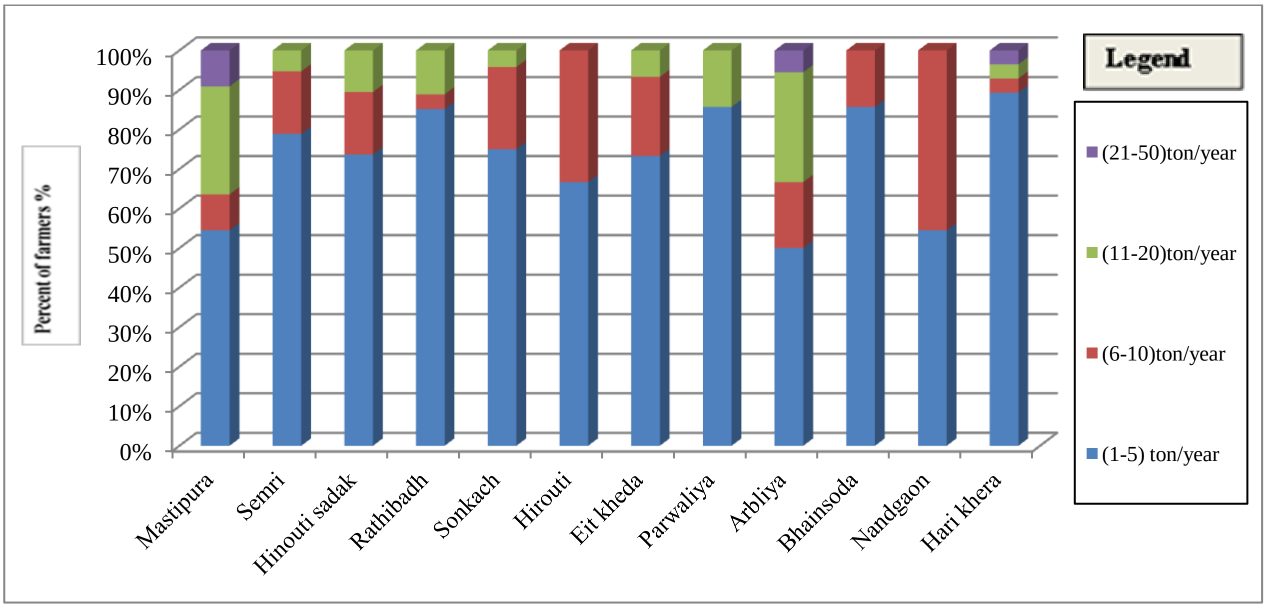


Figure 4.2.4. Average biomass quantities (ton/year) farmers produce in the surveyed villages of Bhopal District

4.3. Economics of biomass wastes in Indore and Bhopal Districts

The selling prices per ton biomass are presented in **figure 4.3.1 and figure 4.3.2** below. In Indore district 60% of the surveyed farmers would like to sell their biomass between 1000 to 3000 rupees per ton and 35% wish to sell it between 3000 and 6000 rupees per ton. In **Paldi** village it appears odd since all quantities of biomass are wished to be sold with relatively high prices (over 10000 rupees). It might be that the proposed price refers to selling all biomass quantity-not per ton. In Bhopal district the price outlook is reported slightly different. Approximately 80% of the surveyed farmers wish to sell their biomass between 1000 to 3000 rupees per ton, 12% wish to sell their biomass between 3000-6000 rupees per ton, and about 6% of the farmers would like to sell their biomass with a price over 6000 rupees per ton.

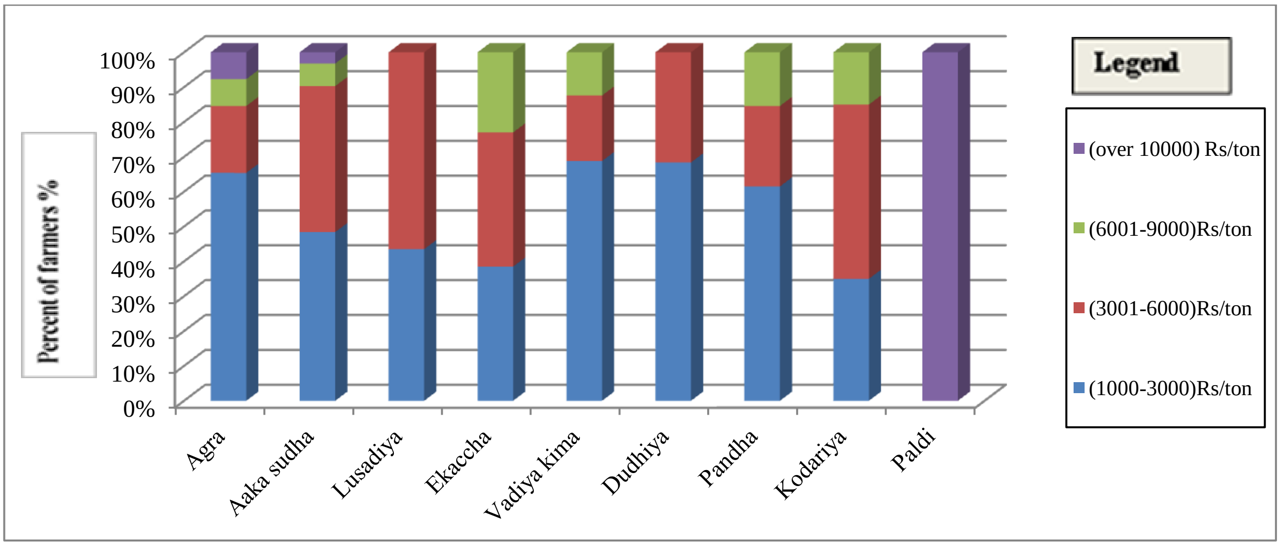


Figure 4.3.1. Average biomass prices (Rupees/ton) farmers willing to selling in Indore District (village-wise)

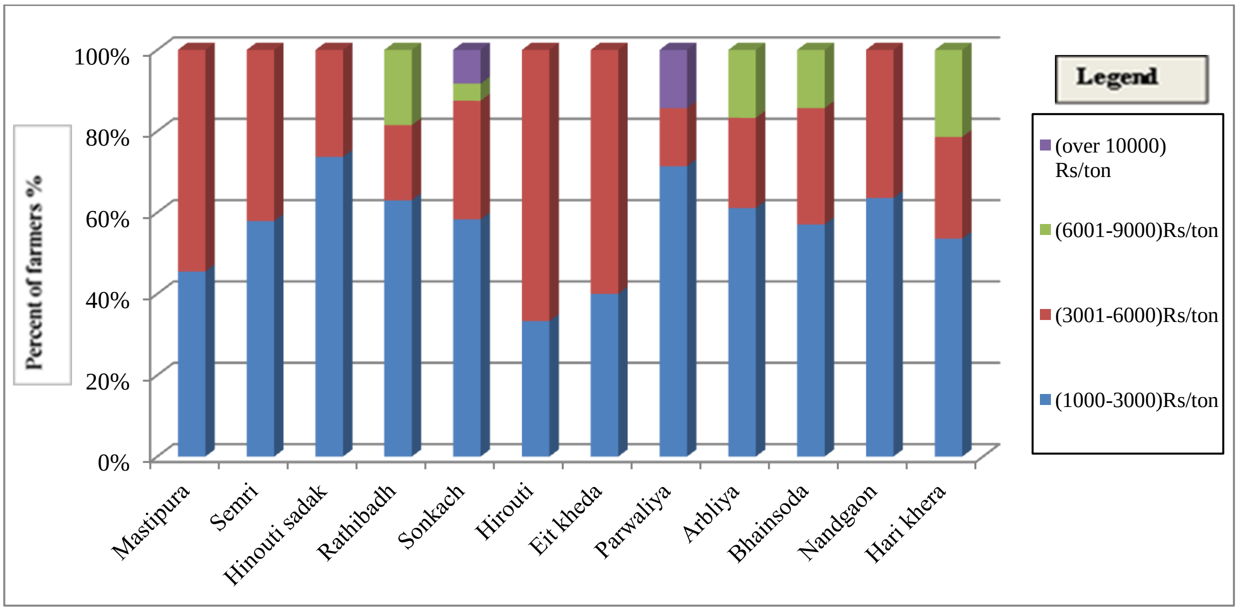


Figure 4.3.2. Average biomass prices (Rupees/ton) farmers willing to selling in Bhopal District (village-wise)

The income prospects from selling biomass were cross tabulated across the villages in Indore and Bhopal districts **(Figure 4.3.3)**. In Indore district, about 57% of the farmers would make about 1000 to 10000 (12-120 euros) rupees extra income annually from selling their surplus biomass with the price they indicated and about 35% of the farmers would make from 11000 up to 50000 rupees (130-600 euros) annually. In Bhopal district 60% of the surveyed farmers would make 1000-10000 rupees extra income and 31% would make 11000 to 50000 rupees extra income from selling surplus crop residues annually. The variations in income are related to the size of quantities sold, the type of biomass sold, and also which parts of the crop residues are sold (straw, husk, combs, and stems…etc). It is also a matter of the selling price the farmers wish to sell by.

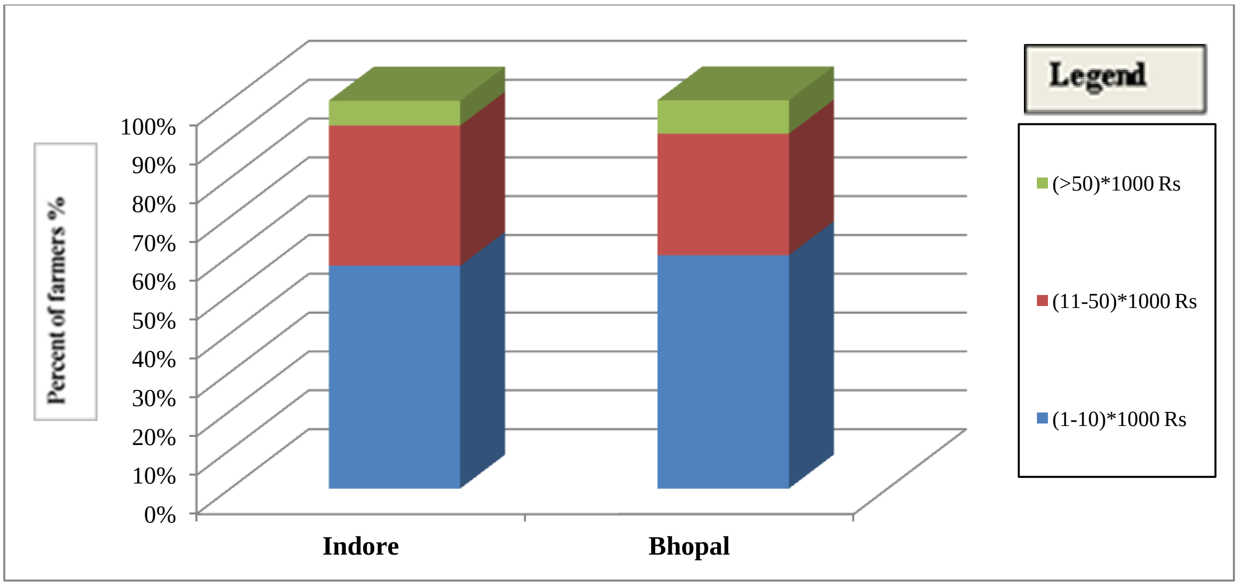


Figure 4.3.3. Average total income farmers would make from selling biomass in Indore and Bhopal Districts

5. Key figures from Surveyed States: Tamil Nadu

5.1. Tamil Nadu

The state of Tamil Nadu is located at southern part of India. The population of Tamil Nadu, according to the 2011 census, stands at about 72 million. Tamil Nadu has 32 districts and 208 sub-districts and the capital of the state is Chennai. It is India's second most industrialized state. The economy of the state is dominated by service sector and manufacturing. Agriculture has been the mainstay of the State's economy since independence with more than 65% of the population relies on this sector for a living. The agriculture sector of the state contributes about 21% of the state GDP. Tamil Nadu's climate is mainly tropical. The two districts selected for study in the state of Tamil Nadu include – Kanchipuram and Coimbatore.

5.1.1. Kanchipuram district

Kanchipuram district is situated on the northern East Coast of Tamil Nadu and is adjacent by Bay of Bengal and Chennai city and is bounded in the west by Vellore and Thiruvannamalai district, in the north by Thiruvallur district and Chennai district, in the south by Villuppuram district in the east by Bay of Bangal. The district has a total geographical area of 4393.37 km^2 and coastline of 57 km^2. For development reasons, it is divided into 13 development blocks with 648 Village Panchayats. The population of Kanchipuram is about 3.4 million. The pre-monsoon rainfall is almost uniform throughout the district. The coastal taluks get more rains rather than the interior regions. This district is mainly depending on the seasonal rains, the distress conditions prevail in the event of the failure of rains. Northeast and Southwest monsoon are the major donors with 54% and 36% contribution each to the total annual rainfall. Agriculture is the main occupation of the people with 47% of the population engaged in it. Paddy is the major crop cultivated in this district. Groundnuts, Sugarcane, Cereals & Millets and Pulses are the other major crops. The total forest area in the district is 24 thousand hectare (http://www.kanchi.nic.in/district_profile_pro.html)

5.1.2. Coimbatore district

Coimbatore is also known as "the Manchester of South India". It is the third largest city in Tamil Nadu and houses numerous textile mills and small scale engineering units. According to 2011 census, Coimbatore had a population of 1,050,721. Coimbatore is a Municipal corporation as well as the headquarters of the Coimbatore District. The city is divided into five administrative zones – East, West, North, South and Central, each further subdivided into 20 wards. **Figure 5.1.1** shows the selected districts and the selected villages with the number of respondents and name of surveyed villages. Total number of respondents (farmers) was 147.

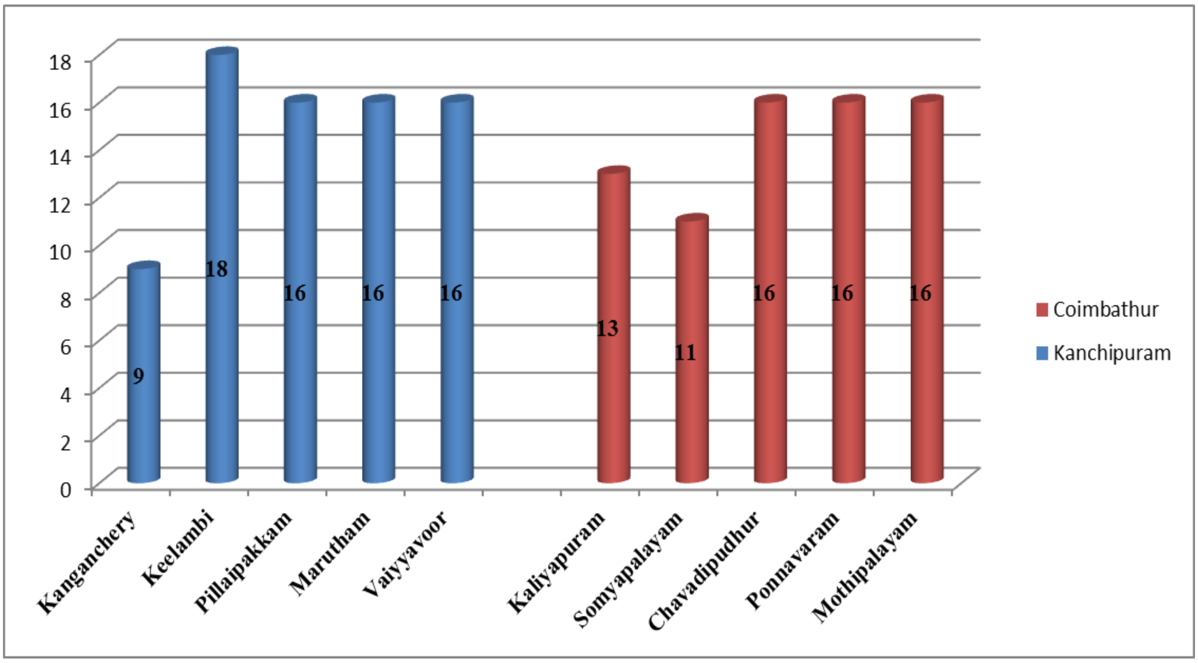


Figure 5.1.1. Number of respondents and name of surveyed villages in the surveyed districts

5.2. Crops and biomass residues in Kanchipuram and Coimbatore districts

Of the 74 farmers surveyed in Kanchipuram district 72 (97%) are mainly planting rice. The rest of the farmers are planting chilly and Bengal gram (Chickpea). Other crops planted on smaller scale include Gingelly (sesame), sugar cane, ground nut, peanut, lentil, and wheat. In Coimbatore district the majority (51%) of the surveyed farmers plant corn and 30% plant tomato and banana **(Figure 5.2.1)**.

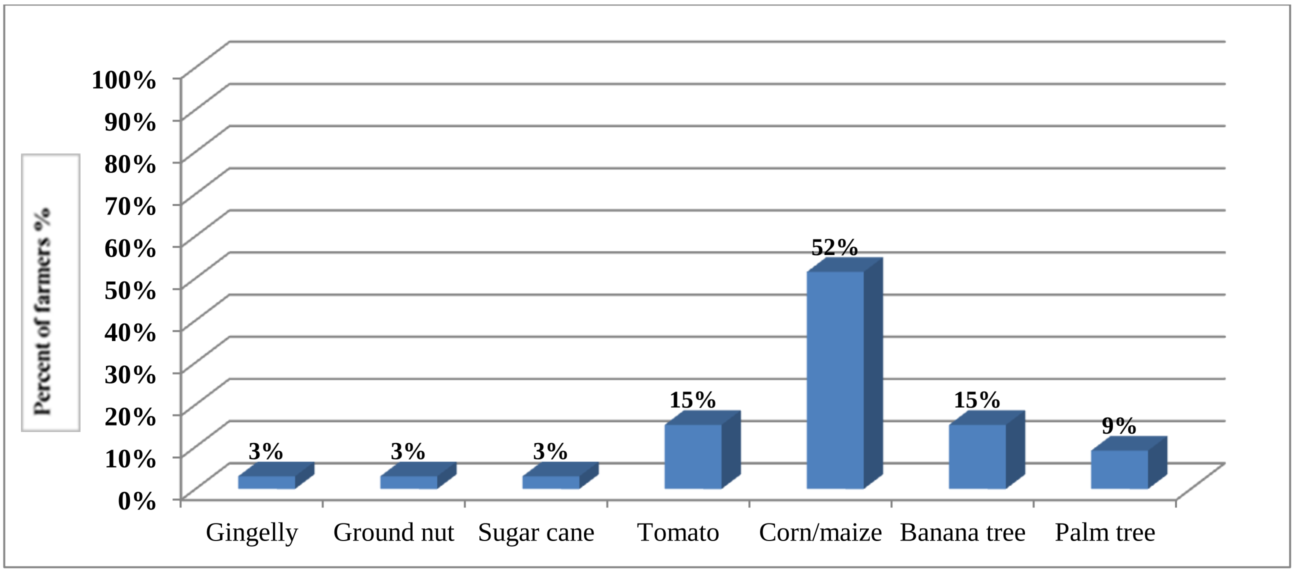


Figure 5.2.1. Crops planted in surveyed villages in Coimbatore district

In Kanchipuram districts most of the farmers (70-80%) in the surveyed villages produce from one ton and up to 5 tons of crop residues annually, the rest (20-30%) produces from 6 and up to 20 tons of crop residues annually. In Coimbatore district approximately 65-85% the farmers produce about one ton and up to 5 tons annually **(Figure 5.2.2)**. There are however farmers who also produces higher quantities such in Mothipalayam, Chavadipudhur, and Kaliyapuram villages **(Figure 5.2.2)**. Crop residues from corn, wheat, and rice constitute the highest biomassquantities in these two districts.

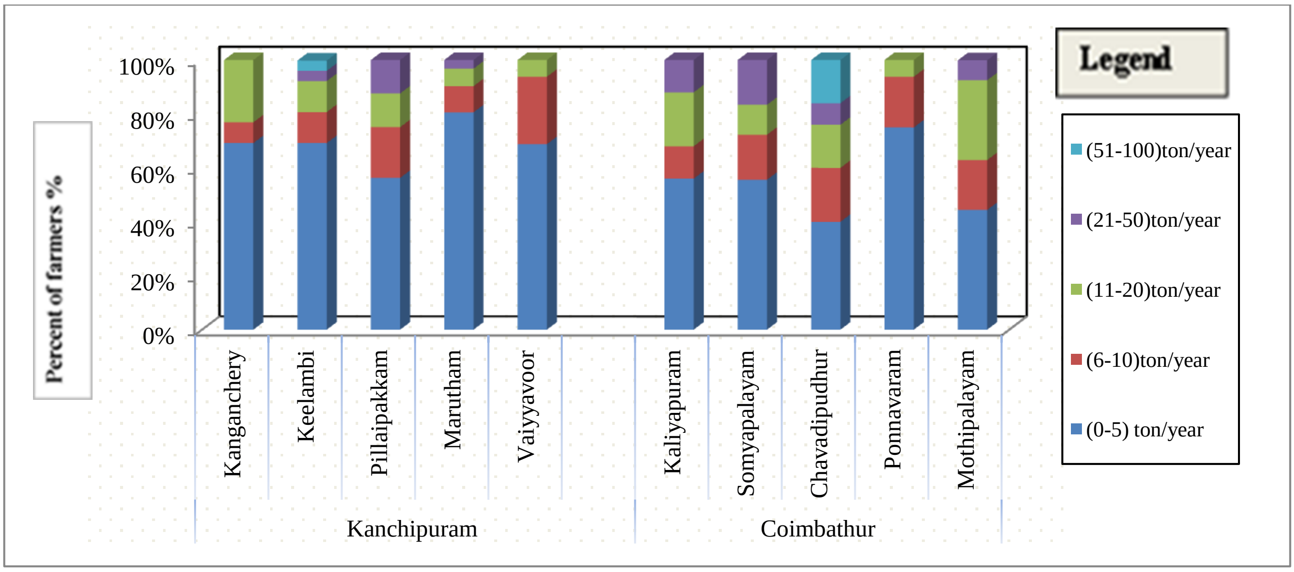


Figure 5.2.2. Average biomass quantities (ton/year) farmers produce in Kanchipuram and Coimbatore (villages)

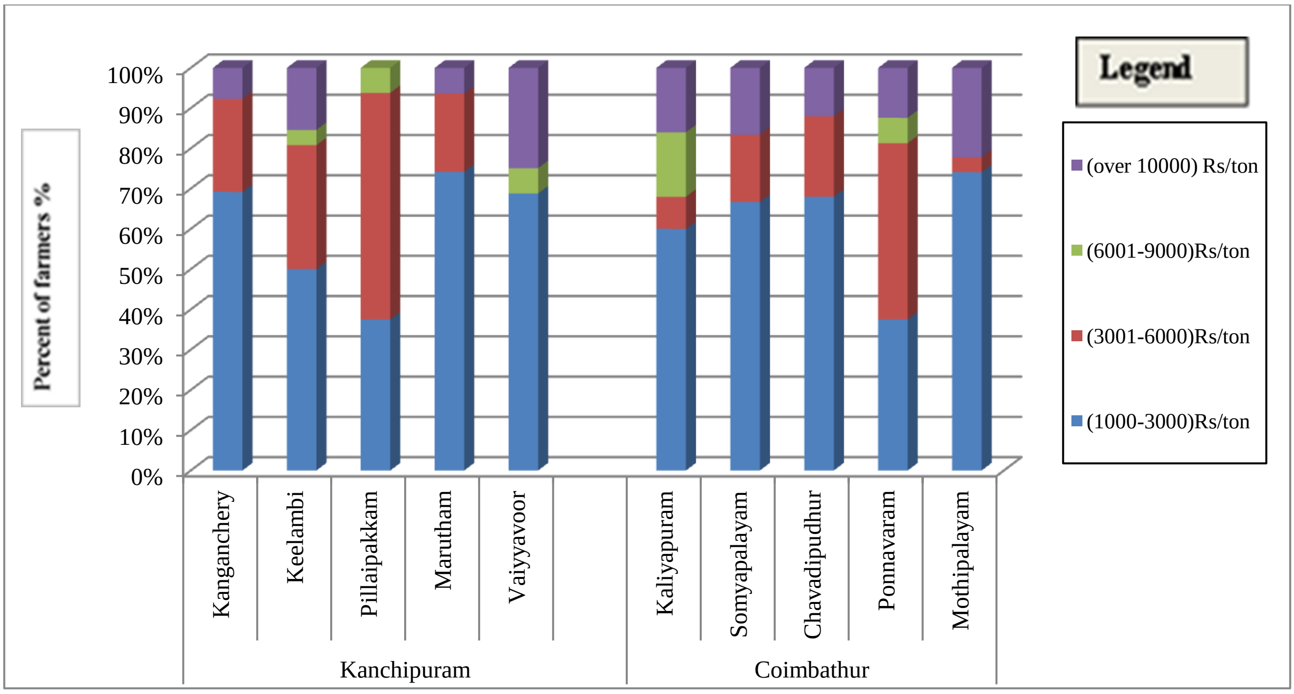


Figure 5.2.3. Average biomass prices (Rupees/ton) farmers willing to sell in Kanchipuram and Coimbatore (TN)

Prices per ton biomass are also presented in **figure 5.2.3.** The data shows that the majority of the surveyed farmers (80-90%), and in both districts, would like to sell their surplus crops residues in the range of 1000 up to 6000 rupees (12-75 euros) per ton. However, and on average, 65% of the farmers wish to sell their surplus crop residues around 1000-3000 rupees per ton (10-35 euros). The final part of this economic analysis aimed at investigating the annual average income the farmers in Tamil Nadu state would earn from selling their surplus crop residues. The income has been recoded into three main categories as presented in **figure 5.2.4** below.

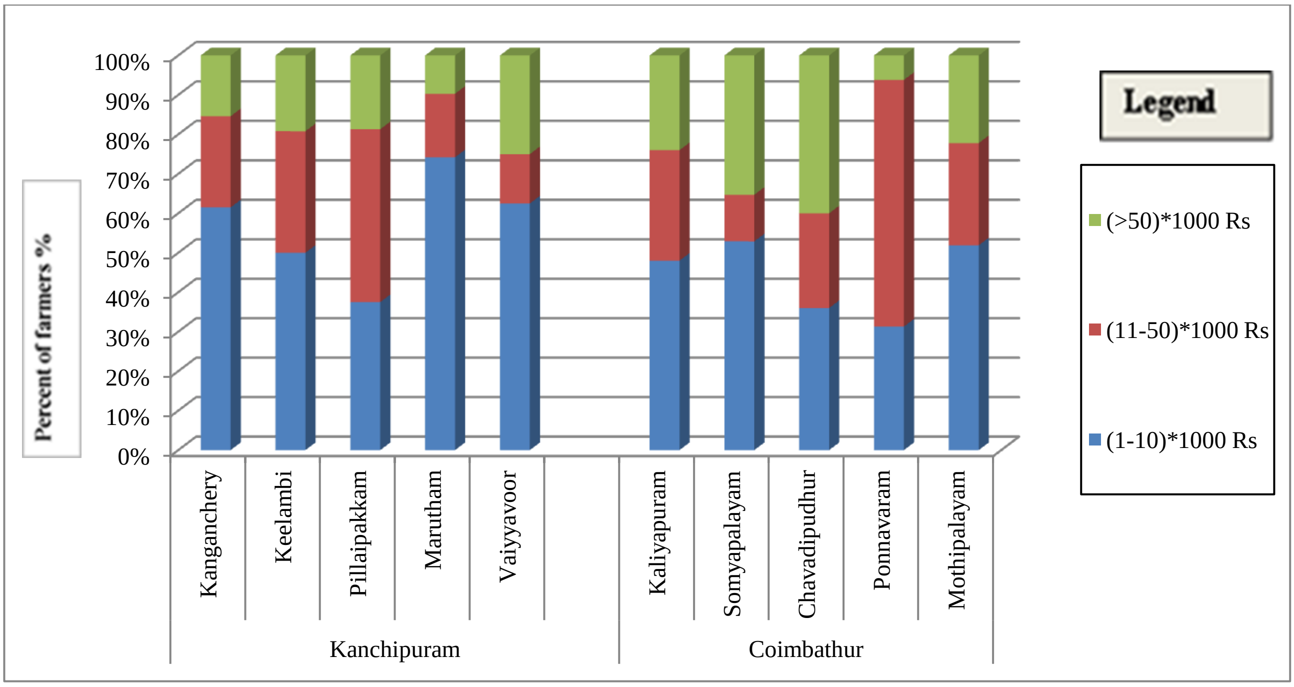


Figure 5.2.4. Average farmer income from selling prices in the surveyed districts in Tamil Nadu state.

In Kanchipuram district and in surveyed villages 50-70% of farmers would make from about 1000 rupees annually and up to 10000 rupees. Some 10-30% of the farmers would make more than 10000 rupees up to 50000 rupees annually- those farmers produce the highest quantities of crop residues in their village. Approximately, the remaining 10% of the famers would make over 50000 rupees per year. On the other hand, the number of farmers in Coimbatore who makes over 50000 rupees is much higher than the other state. This analysis shows that there exists considerable biomass potential in the selected Indian states. The study show that biomass quantities and pricing varies considerably among the surveyed districts within the three selected states. Many factors are influencing the status of cropping and their crop residues. The size of the cropping land, drought forecasting, market supply and demand, and type of crop planted influence the crop residues quantities. High demand for crop residues for various uses may also influence the biomass prices. For instance in drought periods the quantities of crop residues available for livestock may drop drastically thus drives the prices high up. To be able to develop an efficient biomass procurement method, a market-based method must be applied and to be fairly accepted by all farmers. It is also noteworthy to mention that the farmers in this survey study may have overestimated and/or overpriced their biomass.

6. Farmers' perceptions of and willingness to participate in biomass-based new and sustainable energy model in their region

6.1. Results from Maharashtra State

Figure 6.1.1 and 6.1.2 presents the results of the farmers' willingness to sell their biomass to an energy company and the extent of biomass availability throughout the year and from other farmers in Thane and Pune district. As clearly indicated, farmers in both districts show high and explicit willingness to sell their biomass with a strongly believe that selling their surplus biomasses would generate extra income for them. About 93% of farmers in Thane are very much able to supply biomass throughout the year compared to 80% in Pune district. Over 80% of the farmers in both districts suggest that other farmers in their area are capable of supplying biomass to an energy company. See **Annex 1** for the complete statements.

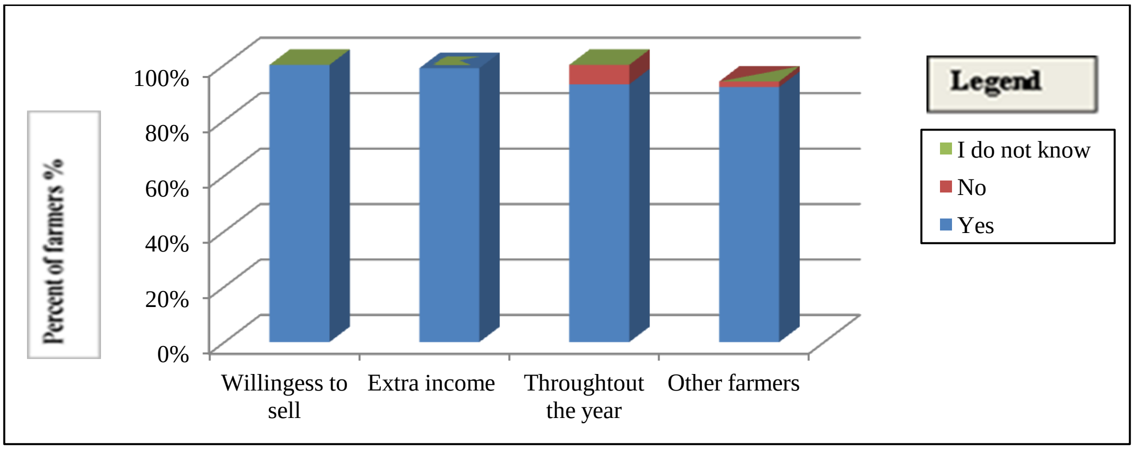


Figure 6.1.1. Farmers' willingness to sell their biomass in Thane District

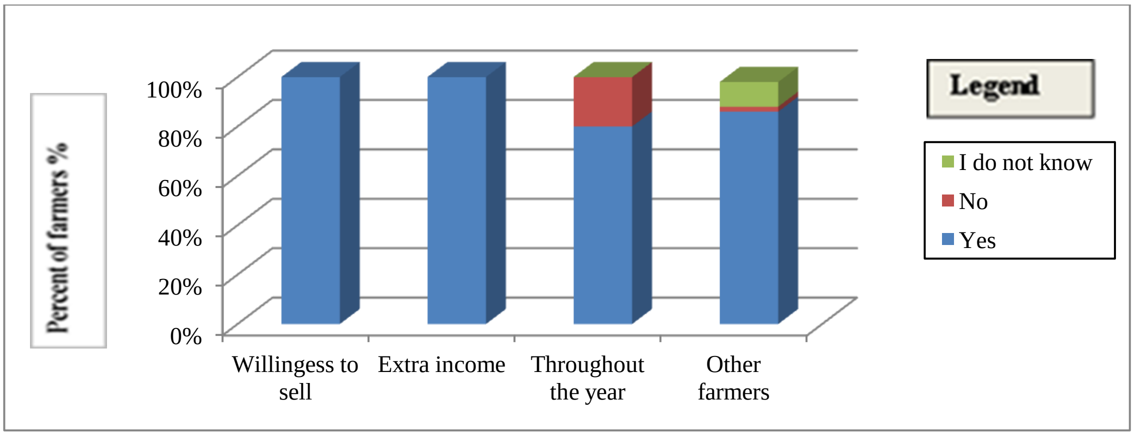


Figure 6.1.2. Farmers' willingness to sell their biomass in Pune District

Figure 6.1.3 and Figure 6.1.4 explores the farmers' preferences to selected biomass procurement methods in Thane and Pune districts respectively.

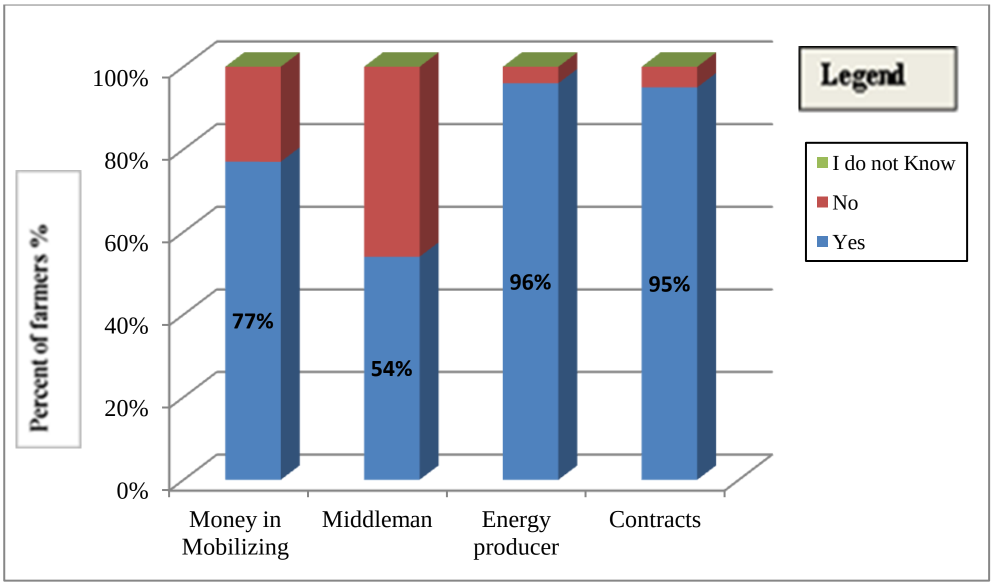


Figure 6.1.3. Farmers' preferences to biomass procurement methods in Thane District

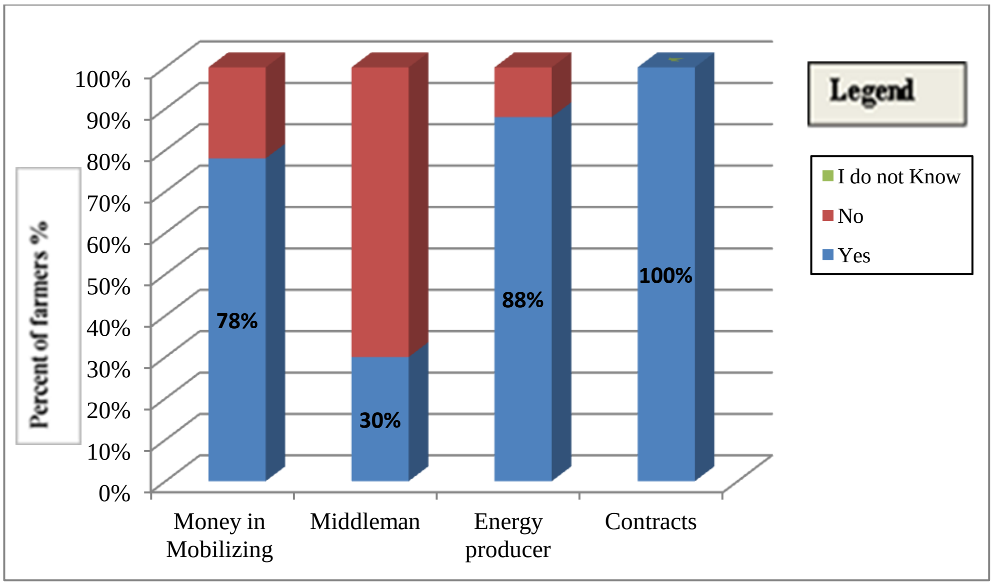
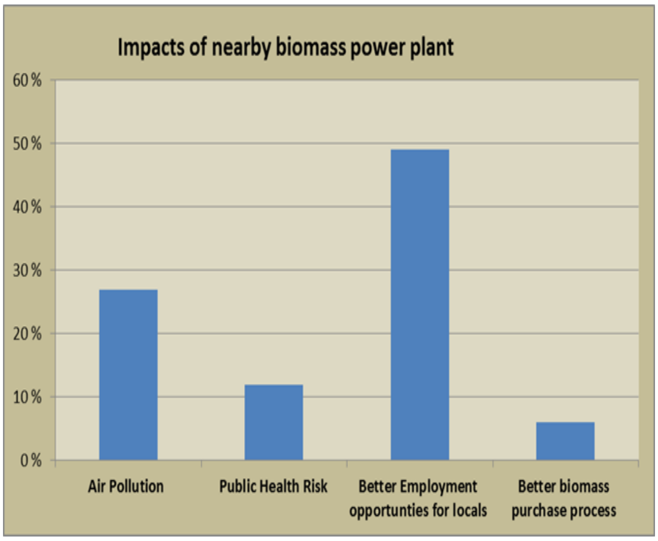


Figure 6.1.4. Farmers' preferences to biomass procurement methods in Pune District

In both Thane and Pune district around 77% of the farmers showed interest in spending money to collect and mobilize their biomass if there is a demand from an energy company. It is probably not surprising since the farmers need to clean their fields for the next crop rotation, or they already spend some resources to collect the crop residues for feeding their livestock through hiring seasonal workers. Three possible purchase methods were proposed to farmers. Some ~50% of the farmers in Thane and 70% in Pune showed clear unwillingness to involve a middleman in the biomass procurement process however they showed explicit interest (96%) in Thane and (88%) in Pune to sell their biomass directly to energy company, and even with higher tendency (95%) in Thane and 100% in Pune to be involved in the biomass procurement process through purchase contracts made with energy company. Farmers' perceptions of biomass pricing mechanism were investigated through asking the farmers whether the government should regulate the prices or through a community-based cooperation. The results show that even though 46% of the farmers in Thane district agree to have a governmental intervention however they fully (100%) support the idea of community-based biomass procurement cooperation. In Pune district more farmers are in favor for the governmental role (61%), yet again, 92% of them support the community-based cooperation to sell biomass. Community-based renewable energy micro projects, with high levels of public participation, are more likely to be accepted by the public than top-down development of large-scale schemes and may bring additional benefits such as increased engagement with sustainable energy issues (Rogers et al. 2012). It seems that the farmers innately acknowledge the benefits of selling their surplus biomass to energy corporate and it further demonstrates the confidence the farmers put in energy producers rather than the traditional biomass trading at the community level with a middleman involved. It is therefore imperative for any energy company to present the investment as a win-win model for both energy producers and farmers as key suppliers of biomass and cultivate their willingness to sell surplus biomass.

The other parameter of this survey study looks into the benefits, impacts, and possible barriers to biomass-supply chain to energy producers. The inputs from farmers were categorized and coded for an explicit results presentation. When the farmers were asked about the benefits of selling their biomass to energy producer almost 95% of them pinpointed the **extra income** associated with selling the crop residues. Other benefits included employment opportunities to the locals. A number of key obstacles to biomass supply were pointed-to by the farmers of which the transportation logistics and costs seem the key barrier **(Figure 6.1.5)**. Farmers alluded to the unreliability of transportation trucks in their region, unavailability, and the relatively high costs to collect and transport the biomass from their fields. They have also referred to weaknesses in the traditional biomass procurement process in which middleman unreliability and delay in paying the farmers are also noteworthy barriers. Regarding the possible impacts of a nearby biomass-based power plant the farmers see new employment opportunities in the region and overall enhancing the biomass purchase process. Farmers (almost 40%), on the other hand, perceive the biomass-based power plant with negative impacts on the environment (air pollution) and also affecting the public health. It is not well-known why such perceptions arose, however, tradition biomass incineration in the field may have evoked such negativity. An outreach approach is probably needed to elevate public awareness of the modern biomass technologies.



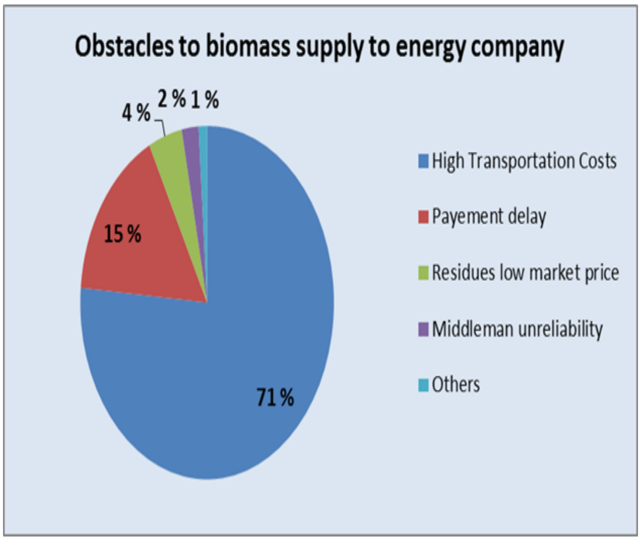


Figure 6.1.5: key obstacles to biomass supply chain in Maharashtra state (right) and possible impacts of a nearby biomass based power plant (left)

6.2. Results from Madhya Pradesh State

Similar to Maharashtra state, 90% of the farmers in Indore and Bhopal districts showed high willingness to sell their surplus crop residues to energy producer **(Figure 6.2.1) and (Figure 6.2.2)**. However, only 50% of the farmers reported possible supply of biomass throughout the year. This probably due to the nature of crop rotation in the state of Madhya Pradesh or time gaps between cultivation, which only allow the partial use of the land for certain crops through certain period of the year. As clearly indicated by **figure 6.2.3 and 6.2.4**, about 65-70% of the famers are *unwilling* to spend money in collecting and mobilizing biomass for energy use and almost 74-84% of them do not wish to have a *middleman* involved in the biomass purchase process in both districts. As reported in Maharashtra state, the famers show high interest in selling biomass directly to energy producer and particularly through contractual obligation with the energy enterprise.

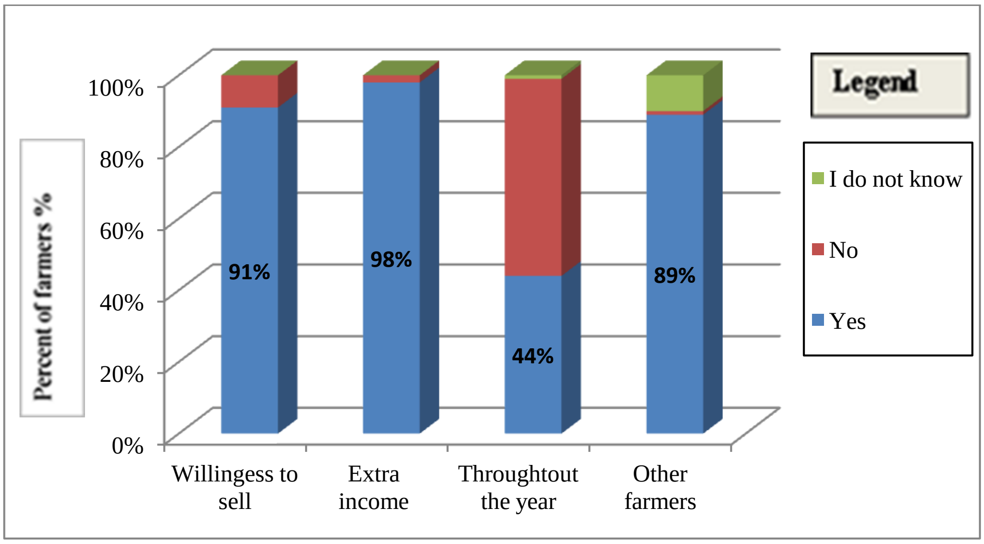


Figure 6.2.1. Farmers' willingness to sell their surplus biomass in Indore District

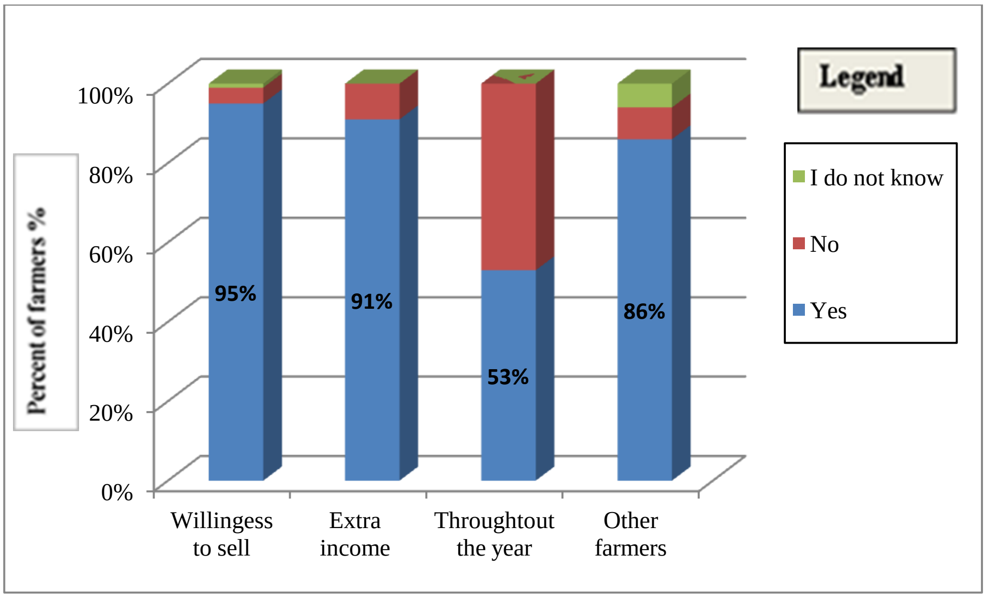


Figure 6.2.2. Farmers' willingness to sell their surplus biomass in Bhopal District

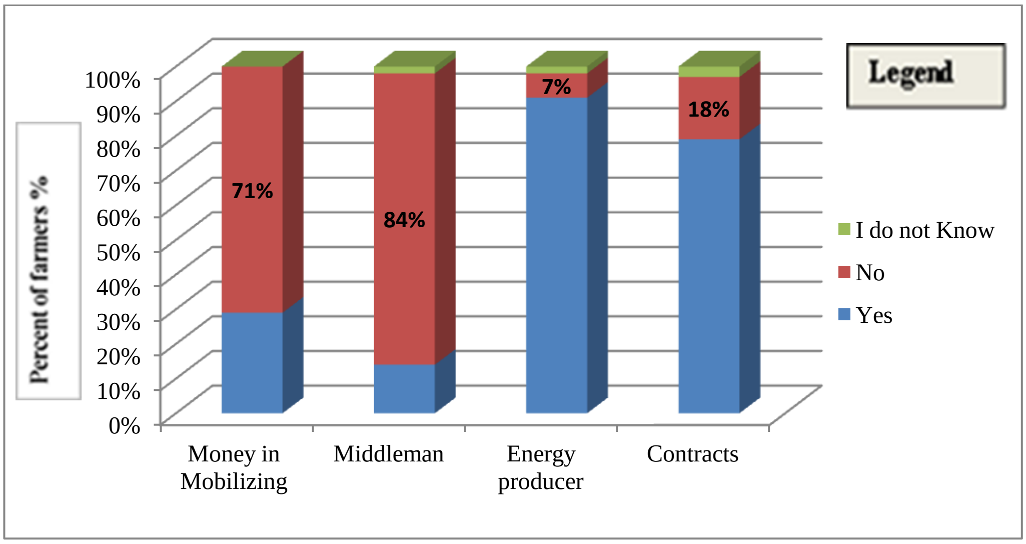


Figure 6.2.3. Farmers' preferences to biomass procurement methods in Indore District

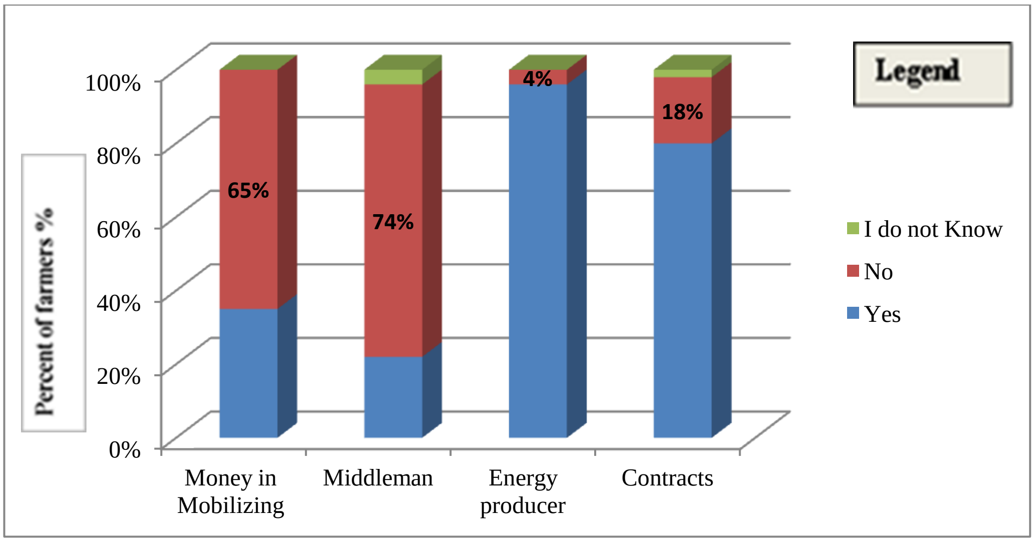
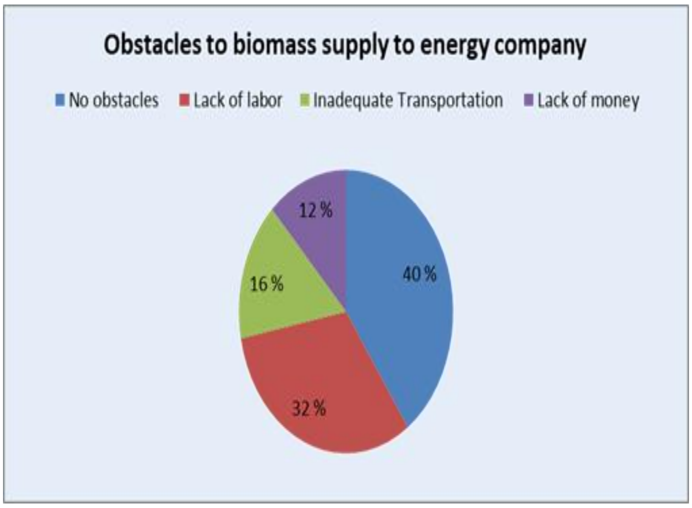


Figure 6.2.4. Farmers' preferences to biomass procurement methods in Indore District

In **Both Indore and Bhopal** districts farmers showed almost equal yet high support to both state-approach and village-based cooperative to regulate the biomass prices. While the support to a community-based approach is understandable, however, the degree of political trust in Madhya Pradesh and the ruling party might have an influence on the farmer's perceptions. Previous experiences in India have shown that political parties that tend to publically support and favor the farmers' needs will harvest the majority of the farmers' votes while a governor with otherwise intentions may not get re-elected (Ashwini and Mehta, 2014). Regarding the obstacles to biomass supply, 40% of the farmers see no immediate concerns while approximately 62% of the farmers consider the lack of labor, inadequate transportation logistics, and lack of financial resources as key barriers to biomass supply chain **(Figure 6.2.5, left)**. Furthermore, and unlike Maharashtra state, the famers in Madhya Pradesh only see positive impacts (employment and electricity source) of a nearby biomass based power plant **(Figure 6.2.5, right)** and various positive benefits from selling biomass to an energy producer **(Figure 6.2.6).**



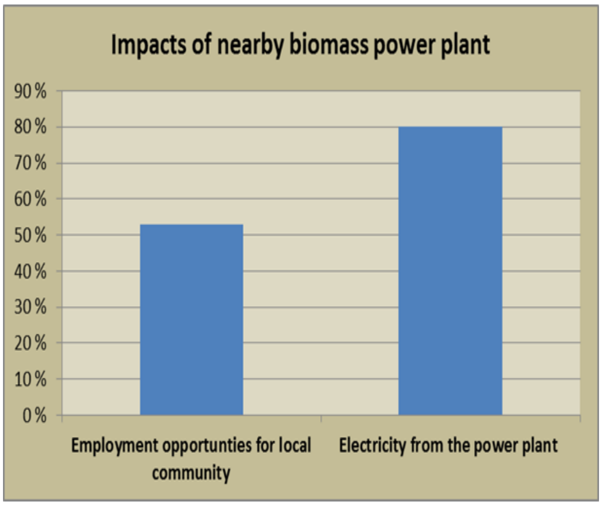


Figure 6.2.5: key obstacles to biomass supply chain in Madhya Pradesh (left) and possible impacts of a nearby biomass based power plant (right).

In this context, generating extra income is largely perceived (80%) as the key benefit of selling biomass to energy producer. Furthermore, the farmers anticipate receiving reliable, stable, and hopefully affordable electricity from a nearby biomass-based power plant accompanied by more and more employment opportunities to the locals. An investigation of possible electricity distribution to the farmers using the existing or through new grids would be of great importance to a complete and successful biomass-to-energy business model.

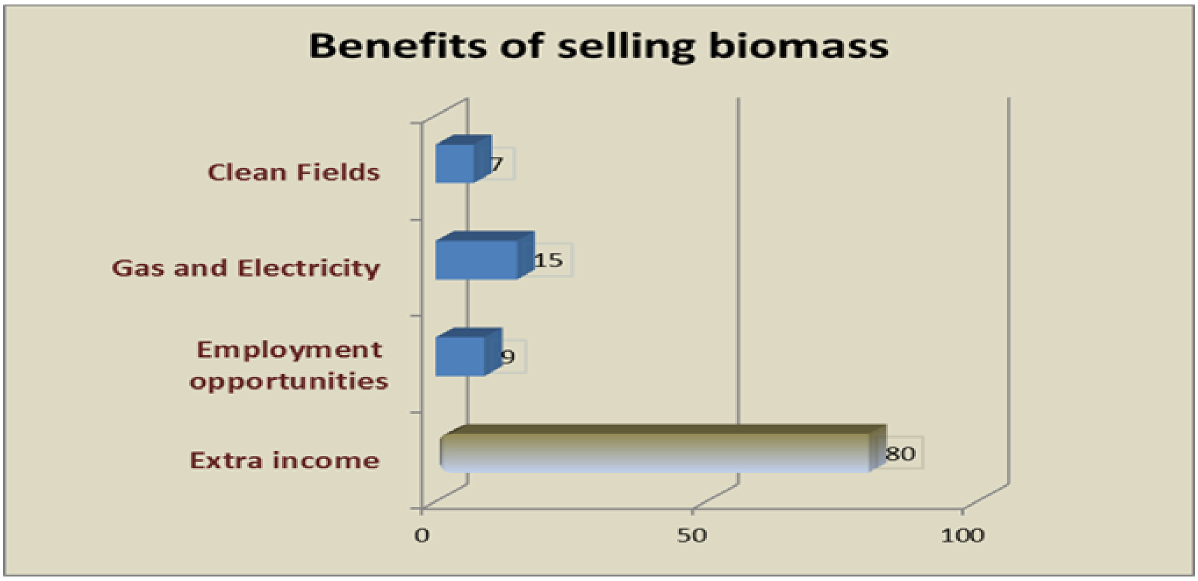


Figure 6.2.6. Key benefits of the farmers gain from selling biomassto an energy company in MP state.

6.3. Results from Tamil Nadu State

Similar high farmers' willingness (95-100%) to sell their biomass to an energy producer was also reported in Tamil Nadu state **(Figure 6.3.1 and Figure 6.3.2)**. Almost all the surveyed farmers indicated that selling their surplus biomass would generate extra income for them. Approximately 85% of the farmers are able to sell biomass throughout the year compared to only 50% in Madhya Pradesh state. Over 90% of the farmers also suggest that there are other farmers in there are who are also able to supply biomass for an energy producer. In the next section, the farmers' perceptions of suggested procurement methods were investigated and presented in **Figure 6.3.3** and **Figure 6.3.4** below.

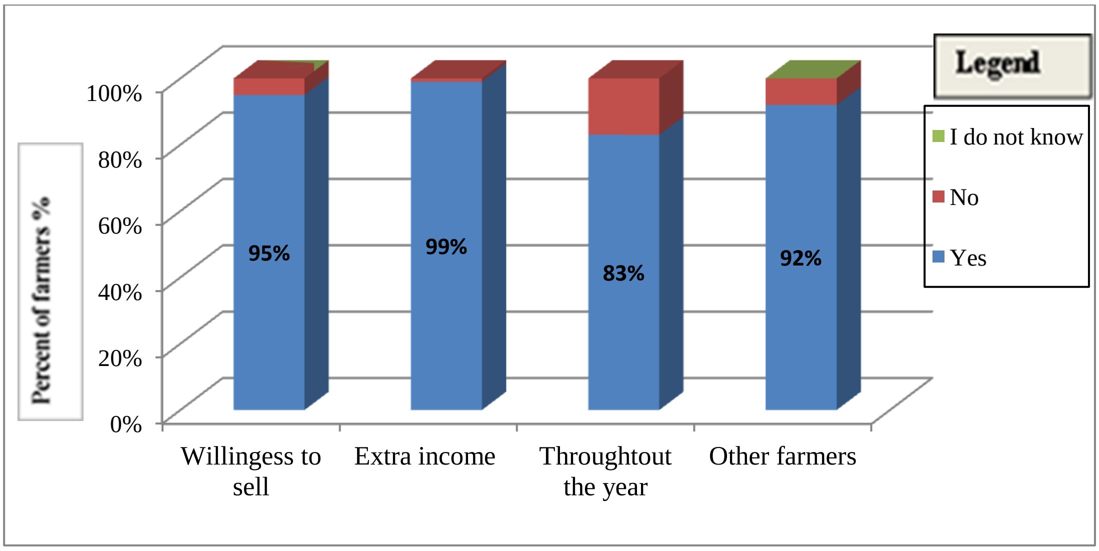


Figure 6.3.1. Farmers' willingness to sell their biomass in Kanchipuram District

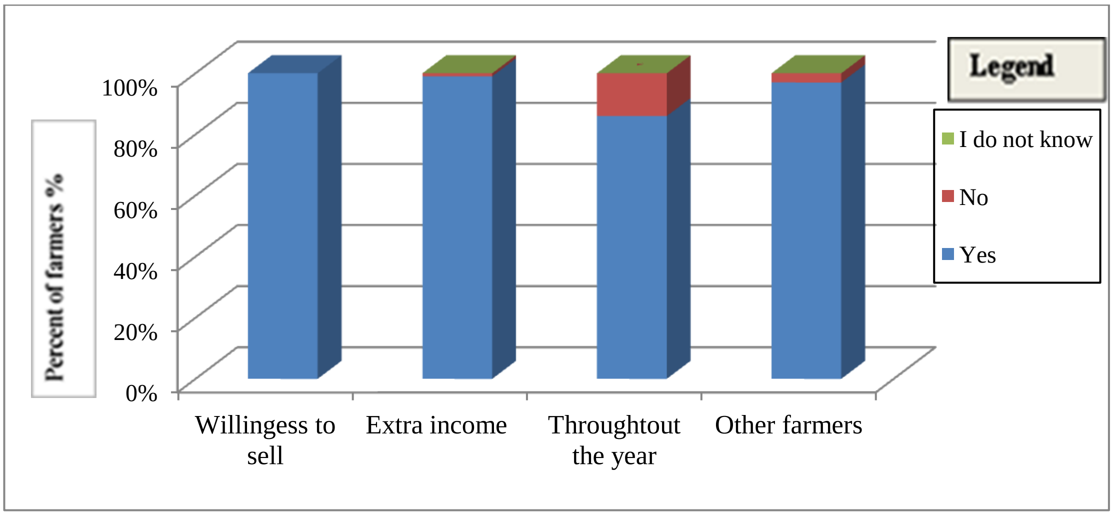


Figure 6.3.2. Farmers' willingness to sell their biomass in Coimbatore District

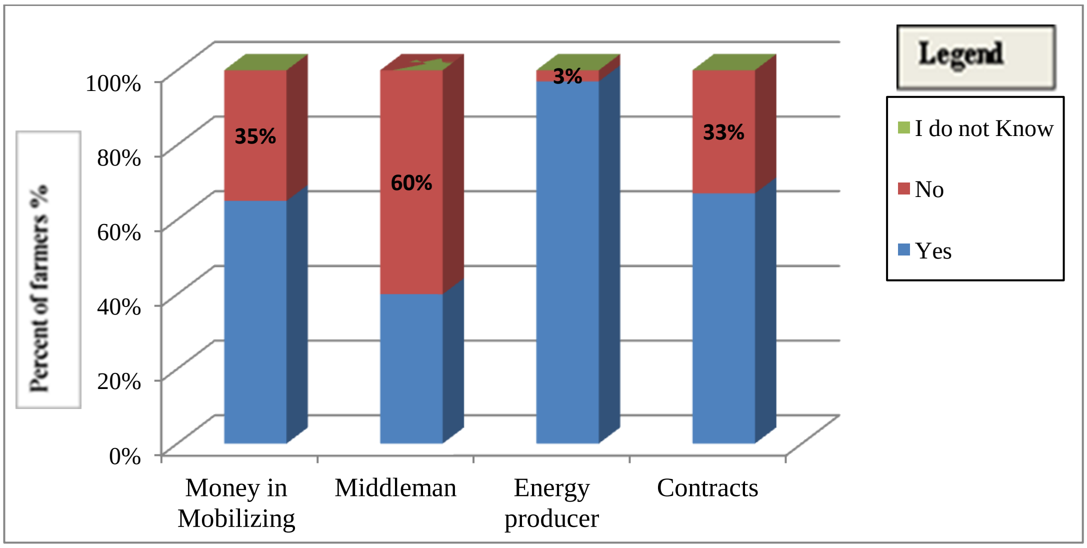


Figure 6.3.3. Farmers' preferences to biomass procurement methods in Kanchipuram District

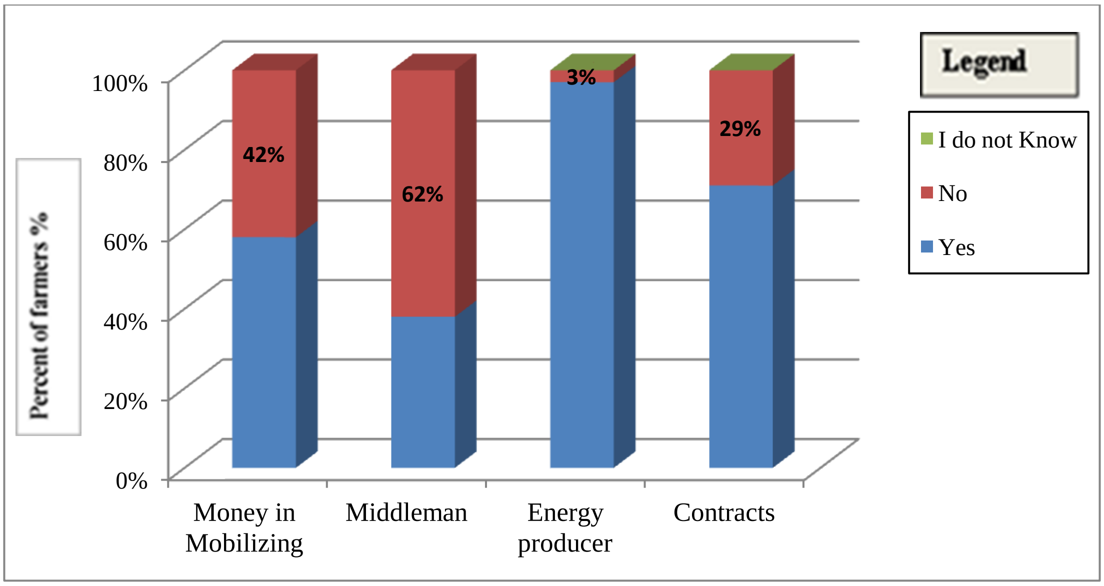
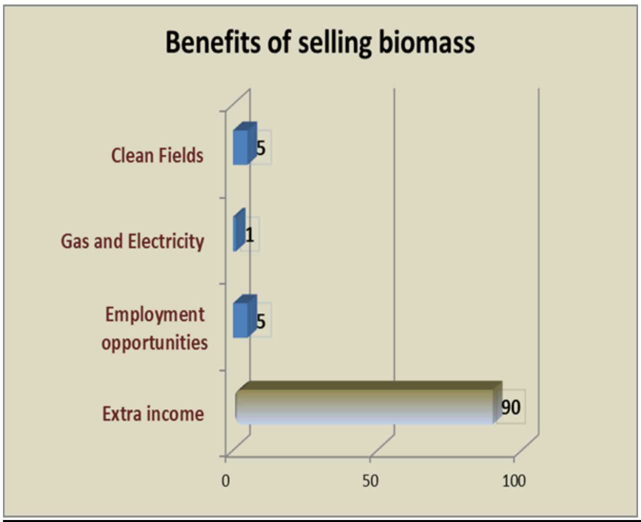


Figure 6.3.4. Farmers' preferences to biomass procurement methods in Coimbatore District

About 35%-42% of the surveyed farmers in both districts farmers are not in a position to spend money in mobilizing the biomass and 60% of the farmers in both districts wish to have no middleman. However, the farmers (98%) seem very much willing to sell their biomass directly to energy producer and to a lesser extent (70%) through contractual obligation. The farmers may have not fully understood the nature of such proposed contracts therefore took a step-back. It is therefore imperative to clearly provide the farmers with easy-to-digest information regarding the contractual deals and also adopt and softly bend to the farmers' capabilities and needs in supplying biomass. Furthermore, almost all of the surveyed farmers in Tamil Nadu are in favor for a village-based cooperative body to maintain and set the biomass prices with less favor of a governmental-oriented approach (55%).



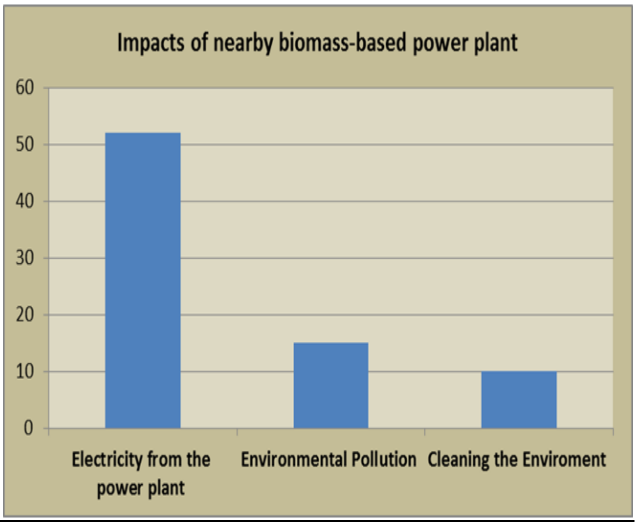


Figure 6.3.5. Benefits of selling biomass to energy producer (left) and impacts of a nearby biomass-based power plant

Regarding the benefits of selling biomass to energy producer generating extra income seems the most immediate benefit for the local farmers in Tamil Nadu **(Figure 6.3.5, left)**. The farmers (~15%) however expressed concerns over the introduction of a biomass-based power plant with possible environmental pollution; however, the majority (~60%) of the farmers perceives the biomass-based power plant as a tool for cleaning the environment, and an alternative source to acquire electricity for their own use (over 50%) **(Figure 6.3.4, right)**. As mentioned previously, a business-model that may offer electricity- or even upgraded biogas and biofertilizers- to farmers may accelerate the biomass acquisition process and lead to a better biomass-value chain, which is a win-win approach. Misconceptions regarding biomass incineration and the associated pollution must be addressed at the community level through outreach campaigns or tailored farmers-oriented workshops to eradicate such misconceptions. In Tamil Nadu state most of the farmers (90%) expressed no concerns or obstacles in supplying biomass for a prospect energy company in the nearby area. Yet again, concerns regarding biomass transportation and logistics are a concern for some 10% of the local farmers.

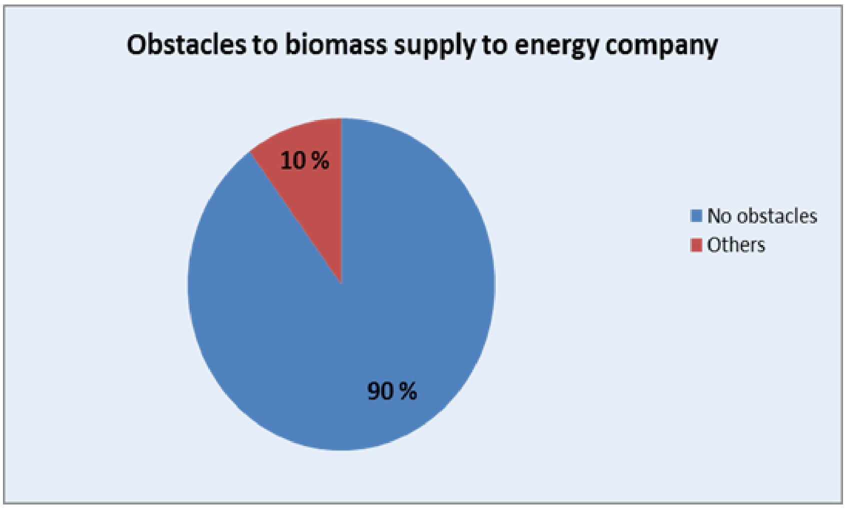


Figure 6.3.5. Obstacles to biomass supply to energy producer in Tamil Nadu

7. Summary of findings

It seems clear that the farmers exhibit a high willingness to sell their biomass to an energy producer and mostly throughout the year except for Madhya Pradesh state (only 50% of farmers can do so). The second clear attitude among the farmers is that they are grudgingly willing to spend [extra] money to collect or transfer their biomass from their fields to a terminal point, and clearly in all states the farmers wish not to have a middleman involved in the biomass procurement process. A noteworthy finding is that the farmers in all states wish to sell their biomass directly to energy producer and especially through contractual obligation with the energy enterprise. In terms of price regulation and governance, the farmers in Maharashtra and Tamil Nadu states are in favor for a community or village-based cooperative body to maintain and set the biomass prices whilst in Madhya Pradesh state the farmers are also in favor for governmental approach to maintain the prices. The political nature of the ruling parties play pivotal role in shaping the farmers attitudes toward the governmental institutions and, for instance, biomass-associated laws and regulations in that specific context and region. While in Tamil Nadu there seem no obstacles to supply biomass for energy producer, however, in Maharashtra state and Madhya Pradesh state transportation logistics and reliability and lack of labor rendered key obstacles to biomass supply. Moreover, the key benefits of selling biomass, according to the farmers' perceptions, are the extra income associated with selling the biomass and in all the surveyed states. The farmers in all states perceive the impacts of establishing a biomass-based power plant mainly positively. More employment opportunities, a tool for faster cleaning of fields for next rotation, and better biomass value chain and use (valorization). Furthermore, the farmers expressed their willingness to acquire electricity from the power plant at affordable rates and stable supply given the brownouts and blackouts they experience on daily basis. Most of the farmers are capable of providing from less than a ton up to 5 tons of biomass yearly at 12-37 euros per ton. It seems that small farmers, with limited financial resources, are voluntarily selling their biomass fairly cheap to avoid the burden of spending their own resources in collecting biomass from their fields.

Further research-based investigation is needed to address few more issues in developing successful waste-to-energy business model in the three selected Indian states. The political orientation of the farmers and the degree of political trust they exhibit for the ruling political party in their state is very fundamental to energy strategic planning in the specific context since political trust and orientation in India is very crucial in maintaining for instance agricultural subsidies for electricity and water. Farmers in India have long enjoyed almost free electricity thus changing the farmers' attitudes toward subsidies, elevating their awareness, and introducing new agricultural techniques and methods, modern machinery will increase the farmers' capacities and productivity. The second important issue is whether verbal obligation meets the actual obligations.

The resource assessment also showed that land productivity varies greatly hence biomass production also varies every year due to variabilities in precipitation and the crop selected for crop rotation. Biomass also has various uses and demand on biomass for household use and industry may influence the market-driven prices. According to Gregory and Stern, (2014) "rural energy choices are constrained not only by low incomes, but also by thin markets for commercial fuels and equipment. Often, local availability constrains energy use more than either household budget limitations or woodfuel prices". A closer cooperation with the local farmers association is required to understand the farmer's needs and better business planning in terms of biomass availability and costs since these two elements are crucial for developing net-profit investment with greater positive impact on the local livelihoods.

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Annex 1

Social Survey tool used to collect data regarding biomass quantities among rural farmers and their willingness to participate in biomass-to-energy business model

C.1. Farmer's perception for biomass production and marketing (Please ✓)

S. No.	Particulars	Yes	No	Don't know	Remarks (If any)
1	Are you willing to supply crop biomass/residues from your land to energy producers?				
2	Do you think supplying crop residues from your land could give you an extra income?				
3	Do you think you could supply crop residues from your land throughout the year?				
4	Are you willing to spend money in mobilizing crop biomass /residues from your land to mitigate the demand of energy producers?				
5	Are you willing to sell crop biomass residues to middle-men / supplier supplying biomass to energy producers?				
6	Are you willing to sell crop residues directly to energy producers?				
7	Are you willing to go for a contractual obligation with energy producers for supplying the crop residues from your land?				
8	Do you think there are other farmers in your area who are willing to supply crop residues for energy production?				
9	Do you want government to regulate the price (MSP) of crop biomass residues for energy production?				
10	Are you in favor of a village-level cooperative body/ society that shall be involved in regulating the supply of crop biomass/ residues to the energy producers?				

C.2. What is the expected selling price of crop biomass produced from their own land, selling to energy company/producers?

S. No.	Type of Biomass/ Crop residues	Average Annual Production (tons/ year)	Expected Selling Price at Farm land (Rs. Kg)	Remarks (If any)

S. No.	Type of Biomass/ Crop residues	Average Annual Production (tons/ year)	Expected Selling Price at Farm land (Rs. Kg)	Remarks (If any)

C.3 In your opinion what are the major obstacles could be experienced for supplying crop residues from your land to the energy producers?

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C.4 In your opinion what are the important benefits that you can get from supplying crop residues from your land to the energy producers?

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C.5 In your opinion what are the possible impacts that may happen if there is a biomass-based power plant would be established nearby your area?

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