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Case Study RRJoDST

Biomass Resource Assessment and Management of Amritsar District of Punjab: A Case Study

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Abstract

The biomass resource assessment and management of Amritsar district in Punjab highlights the intricate balance between biomass generation and consumption, with significant implications for various sectors including dairy farming. Through meticulous evaluation of agricultural residue, animal waste, and forestry biomass, the study unveils the potential for bioenergy production within the region. Key findings indicate a substantial surplus of biomass, primarily derived from agricultural activities, alongside seasonal variations in availability. For the dairy sector, this surplus biomass presents an opportunity for sustainable energy generation and improved waste management practices. Given the substantial population of cattle and buffaloes in the district, the utilization of surplus agricultural residue and animal dung for biogas production could offer a renewable energy source for dairy farms. Moreover, the study underscores the importance of optimizing biomass collection mechanisms to ensure consistent fuel supply throughout the year, aligning with the continuous demand of dairy operations. However, challenges such as alternate uses of biomass and transportation costs must be addressed to maximize the potential of bioenergy in the dairy sector. By strategically integrating biomass resources into dairy farm operations, there exists a pathway towards achieving energy self-sufficiency, reducing environmental impact, and enhancing sustainability in the dairy industry of Amritsar district. Furthermore, the assessment emphasizes the economic viability of biomass utilization, with market rates indicating potential cost savings for dairy farmers. By leveraging locally available biomass resources, dairy operations can mitigate dependence on conventional energy sources, thereby enhancing resilience and long-term viability in an increasingly dynamic agricultural landscape.

Keywords: Biomass resource, agricultural residue, animal waste, forestry biomass, biogas production, bioenergy

INTRODUCTION

Estimating the availability of biomass for energy generation is a critical endeavor that requires comprehensive data collection and analysis from diverse sources. This process involves collaboration with specialized departments and experts across various fields to ensure accurate estimations. One significant aspect of this estimation is recognizing that the surplus agricultural residue available for energy production is often considerably lower than the total residue production. This discrepancy arises due to factors such as collection efficiency and alternate uses of agricultural residue.

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Estimation of Animal Waste Biomass

In addition to crop residues, animal waste, particularly in the form of dung, constitutes a significant biomass resource for energy generation.

The calculation of biomass production from animal dung involves understanding the population of specific animals and their corresponding productivity factors for dung production.

DAIRY SCIENCE AND BIOMASS PRODUCTION

Dairy farming represents a significant aspect of agriculture worldwide, contributing to both food production and biomass generation. In the context of biomass production, dairy science plays a crucial role in understanding the dynamics of milk production and the management of dairy cattle. Additionally, dairy farming generates substantial amounts of animal waste in the form of dung, which can be utilized for energy production.

Factors influencing dung production in dairy farming include the breed of cattle, their diet, and management practices. For instance, high-yielding dairy breeds tend to produce more dung compared to traditional or dual-purpose breeds. Moreover, the composition of the diet, including the proportion of forage and concentrates, can influence the quantity and quality of dung produced. Effective management practices, such as housing systems and waste management strategies, also impact dung production and collection efficiency.

By integrating insights from dairy science into biomass estimation frameworks, more accurate assessments of biomass availability for energy generation can be achieved. This interdisciplinary approach ensures that factors specific to dairy farming, such as cattle population dynamics and management practices, are appropriately accounted for in biomass estimation models.

In conclusion, estimating the surplus agricultural residue available for energy generation requires a multifaceted approach that considers various factors, including collection efficiency, alternate uses of residue, and animal waste biomass. Incorporating insights from dairy science enhances the accuracy of biomass estimations, particularly concerning dung production from dairy cattle. This collaborative effort between agricultural experts, energy specialists, and dairy scientists is essential for developing sustainable biomass energy solutions.

ASSESSMENT TECHNIQUE

Estimating the amount of biomass available for energy generation necessitates gathering and analyzing extensive data from various sources, requiring collaboration with specialized departments and experts in relevant fields (Table 1).

Agricultural Crop Residue Assessment

For agriculture residue biomass, following formula is used:

Residue production (R, t/year) = Grain production (t/year) × RPR (residue-product ratio)

The previous section contains a formula detailing the residue-product ratio or CRR (Crop Residue Ratio) for several common Indian crops. Given the numerous facors influencing crop yield and residue production, such as seed variety, soil quality, irrigation, and weather conditions, it may be advisable to validate these values through direct field measurements as a best practice.

Table 1. Specialized fields and their corresponding biomass estimates.

Specialized field employed	Biomass estimated
Forestry and remote-sensing	Woody biomass and tree based oil seeds
Agriculture	Agricultural residues
Animal husbandry	Animal wastes
Municipal bodies	Municipal wastes
Industries	Industrial waste

Generally, surplus agricultural residue available for energy production is much lower when compared to the total amount of residue production because:

1. *Collection efficiency factor (C):* It is common that not all agricultural residue can be fully collected, with some inevitably lost during the collection process. Thus, we need to define a collection efficiency factor (ranging from 0 to 1).
2. *Alternate uses (X):* Agro-residues are employed for various other uses such as animal feed mulching, roof thatch etc.

Surplus agriculture residue available for energy production (A)=R×C–X

Estimation of Animal Waste Biomass

The calculation of biomass production in the form of animal dung for a specific region can be achieved by understanding the population of a particular animal and its corresponding productivity factor for dung.

Potential animal dung (kg/day on dry basis, AD) = number of animals × dung productivity (kg/head/day on dry basis)

Dung production varies across different regions of the country due to differences in animal size, weight, and feed intake. The average dung production of animals in the Indian Subcontinent is as follows (Table 2).

The quantity of dung suitable for biogas production might be notably less than initially estimated. Two key factors impact the availability of excess dung for biogas production:

1. *Collection efficiency factor (C):* Complete collection of dung is often hindered because in numerous regions, cattle are not confined to stalls but allowed to roam freely in fields for grazing, posing challenges in dung collection. Therefore, again collection efficiency factor (ranging from 0 to 1) is required.
2. *Alternate uses of dung (X):* In India, dung is dried and utilized as a fuel, either mixed with clay for plastering walls and floors of houses, or employed as a fertilizer.

Surplus dung available for energy production (SD) = AD×C–X

Hence, we can conclude that biomass availability in this case could be increased by improving the collection efficiency and also decreasing the alternate use.

Forestry Biomass Estimation Technique

Estimation of woody biomass is a two-step process:

Step 1. Map creation involves delineating the spatial distribution of different ground cover types and estimating biomass. Techniques utilized for map creation encompass the use of satellite imagery.

  i. *Low spatial resolution imagery*: They provide overview data with low level of accuracy for ground cover typing and broad vegetation types.
  ii. *High spatial resolution imagery:* Fine details could be studied by using satellite imagery with higher spatial resolution or aerial photography.

Table 2. Average dung production in Indian Subcontinent.

Animal	Dung production (kg/head/day, dry weight)	Volatile substance (kg/head/day)
Dairy cattle	2.87	2.64
Non-dairy cattle	1.50	1.38
Buffalo	2.65	2.43

Table 3. Productivity of some forest plantations.

Plant species	Productivity (m^3/ha)
Eucalyptus grandis	15–50
Acacia mearnsii	14–25
Pinus radiate	12–35
Pinus caribaea	20–50

Source: Yokoyama and Matsumura (2015) [7].

Step 2. Ground inventory preparation sample areas are selected representing various ground cover types and primary measurements are taken to calculate sustainable woody biomass yield in t/year. For estimation of annual sustainable yield, following formula is used:

$ASY=2\times GS/R$

Where, ASY is Annual Sustainable Yield in t/year.
GS is Growing Stock in tons and formula for its calculation is given below:

$GS=$ *Area of the forest (ha)* $\times$ *Productivity (m^3 of biomass/ha)* $\times$ *Density of biomass (t/m^3)*

R is rotation age for various trees (2–3 years for fast growing agroforestry trees to 60–100 years for high forest trees). Productivity of some forest plantations in tropical countries is given in Table 3.

The actual annual sustainable yield from the forests may not be fully realized due to various factors like lack of accessibility, machine efficiency etc. Therefore, we need to define a collection efficiency factor (C, ranging from 0 to 1) to calculate extractable sustainable yield (ESY).

$ESY=C\times ASY$

In order to calculate the surplus woody biomass available for energy production, we have to estimate the present alternate uses of biomass (X) in t/year. Biomass has several other usages, primarily as timber and construction material.

Surplus woody biomass availability (F, tons/year) = ESY–X

CASE STUDY: BIOMASS AVAILABILITY AND ASSESSMENT OF AMRITSAR DISTRICT OF PUNJAB

Amritsar lies in North-West part of Punjab with a geographical area of 516,700 ha and land use pattern is as shown in Figure 1.

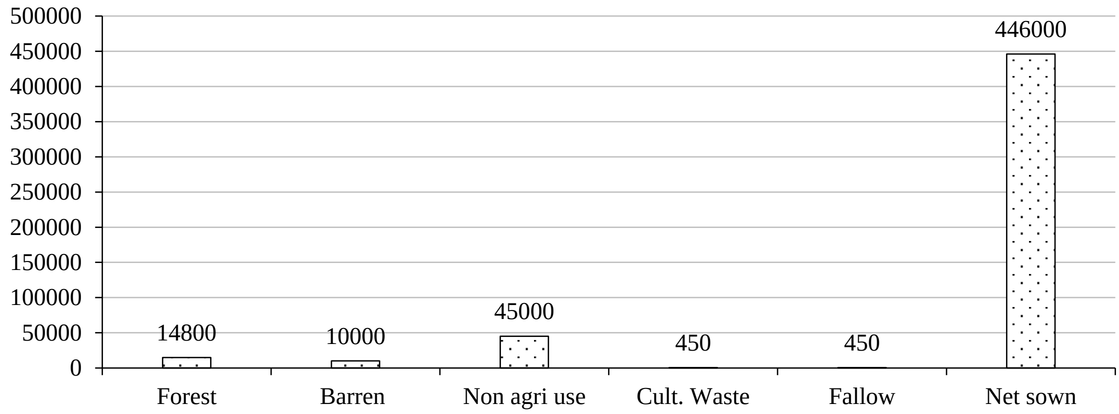

Figure 1. Land use pattern in Amritsar (in ha).
Source: Biomass Resource Assessment and Management, PAU, 2006.

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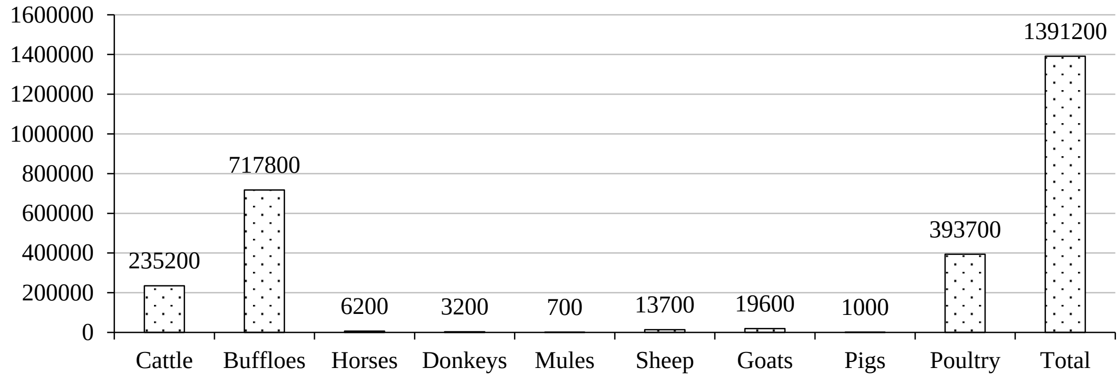

Figure 2. Livestock population in Amritsar.

From Figure 1, we can infer:

1. Almost 85% of land is sown and hence considerable volume of agro-residue is available.
2. 2.86% of land is under forest cover categorized as state forest and private forest but biomass generation from state forest is not considered for power generation.
3. Since only a small area of land has been marked as barren or fallow, the biomass availability from non-agricultural lands is insignificant, and at times, fodder demand exceeds availability.

The livestock population in the district is as shown in Figure 2. Figure 2 shows that cattle, buffaloes and poultry constitute major livestock population in the district.

Biomass Generation in the District

- *Agro-residue based:* The large land area put to agriculture leads to high grain production by the state. Table 4 shows area under crop in '000 ha (A, in blue), production in 000' Mt (P in brown) for 2004–2006. The table clearly shows that wheat contributes almost 50% of total production, whereas 47% is contribution of paddy and rest other crops account for remaining 3%. Biomass from paddy is of three major types i.e. straw, husk and bran where husk and bran are considered under agro-industrial category and only straw is included under crop residue. Sugarcane biomass can be also categorized in, tops and leaves along with trash are taken as crop residues and bagasse is in agro-industry category. Graphical representation of cropping pattern of major crops in Amritsar is shown in Figure 3. The crop residues generally have a moisture content of 20%. Figure 4 provides Crop Residue Ratio (CRR) for various crops for 20% moisture content. Crop wise biomass generation can be calculated as through the Table 4.

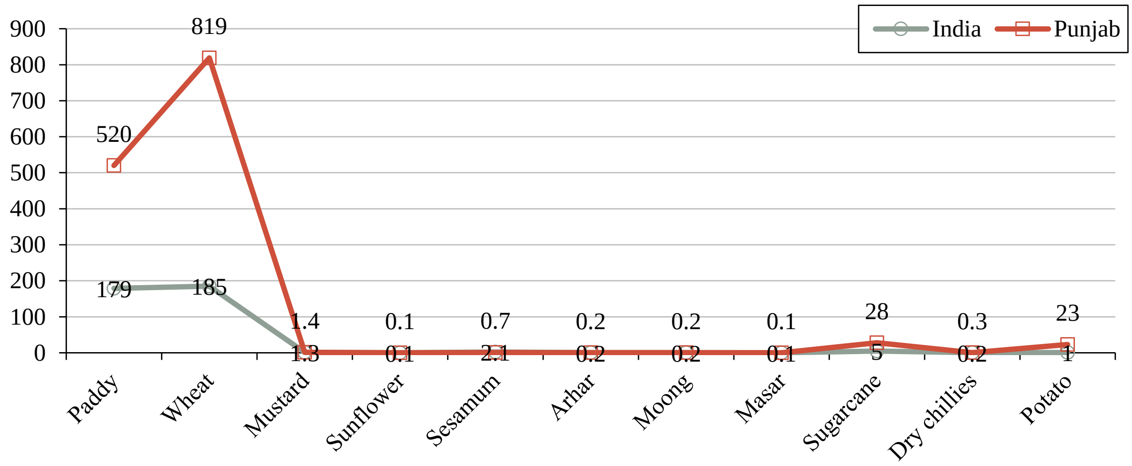

Figure 3. Cropping pattern of major crops in Amritsar [8].

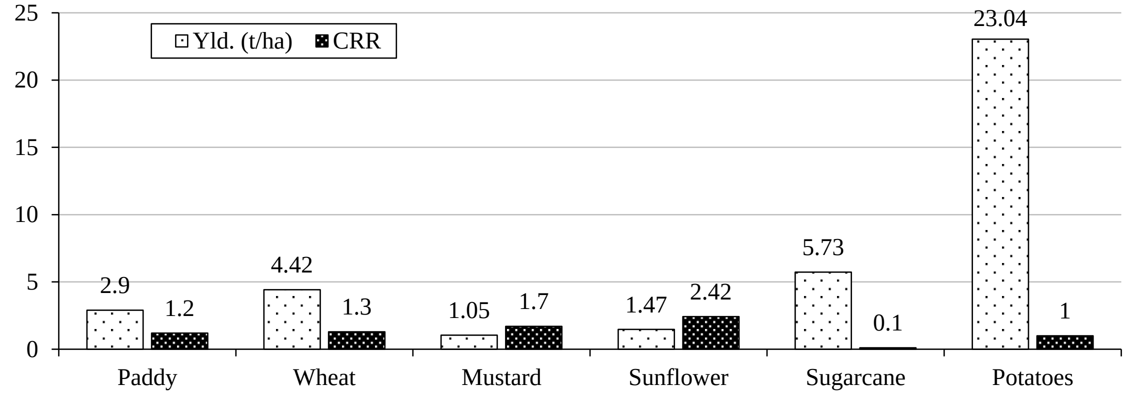

Figure 4. Crop residue ratio of crops and yield (t/ha) of various crops isn the district.

Table 4. Crop wise residue generated in the district.

Crop	Area (ha)	Production (Mt)	Biomass (Mt)	Biomass type
Paddy	179	520353	624424	Straw
Wheat	185	819365	1065175	Straw
Mustard	1.3	1366	2323	Stalks
Sunflower	0.1	147	356	Stalks
Sugarcane	5	28685	2869	Trash
Potato	1	23040	23040	Straw
Total		1392957	1718186	

Source: Biomass Resource Assessment and Management, PAU, 2006.

- *Forest and other lands:* Although 2.86% of total geographical area is covered by state forest yet biomass from forest is not calculated in the present study because there is complete ban on tree felling under this category of land (Table 5). Besides state forest and private forest farm bunds and waste lands are there in the district. During the survey, farmers revealed that 0.843 Mt was produced annually from farm bundhs, whereas 1.5 Mt was produced every year from the wastelands including grazing land, permanent pastures and barren non-cultivatable land. Total biomass generation in the district is depicted in Figure 5.

Table 5. Forest based biomass generated in the district [8].

Land type	Area (ha)	Yield (Mt/year)	Biomass generated (Mt/year)
Private forest	97	10	970000
Waste land	55.9	1.5	83850
Farm Bunds	446	0.844	376424

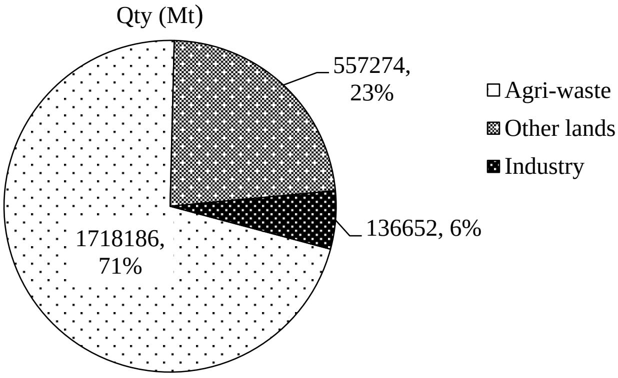

Figure 5. Total biomass generation from various sources in the district [8].

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Biomass Consumption in The District

Domestic Sector

1. *Fodder for livestock*: Major livestock in this district is constituted by cattle and buffaloes and therefore only they were considered in the study accounting to total population of 95300. The Figure 6 shows total fodder requirement of 1524800 Mt/year. and break-up ratio of the same, Use of biomass as fodder in the district is depicted in Figure 6.
2. *Domestic fuel*: In the state of Punjab, due to higher income, the rural population only uses biomass for lighting their chulhas thereby reducing the per capita consumption of wood and residue. Total biomass used as domestic fuel is 188247 Mt/year.

   Wood: forest or other lands

   - Annual consumption: 188247 Mt/year.
   - Per capita consumption: 101 kg/year.

   Crop residues

   - Annual consumption: 26569 Mt/year.
   - Per capita consumption: 17.5 kg/year.

3. *Thatching:* Most of the houses are pucca in the state thereby reducing use of biomass in thatching, therefore only 2% of households use it leading to use of 1750716 Mt/year (Figure 7).

Biomass Consumption in Industry

Industrial sector also consumes some of the generated biomass and the Table 7 clearly shows the type of biomass used industry along with its source and utilized quantity (Table 7 and Figure 8).

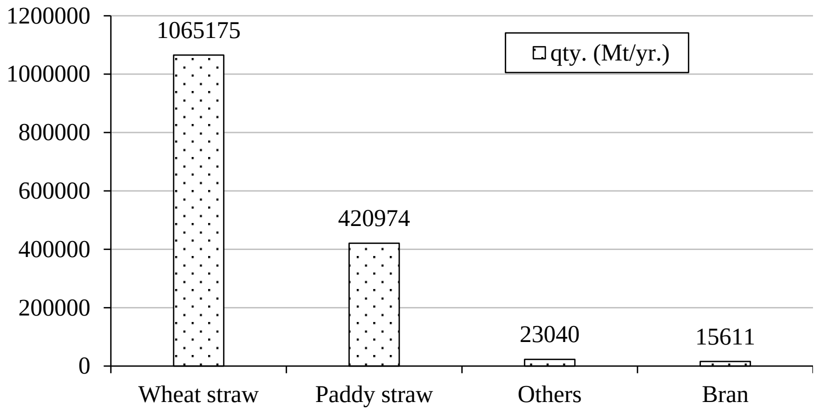

Figure 6. Use of biomass as fodder in the district.

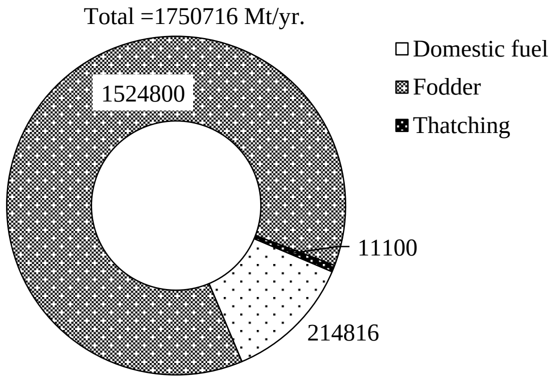

Figure 7. Total biomass consumption for food, fodder and housing in the district [8].

Table 7. Consumption of biomass in industry.

Industry	**Source**	**Biomass type**	**Quantity (Mt/year)**
Sugar mill	Farm bunds	Wood	438
Saw mill	Farm bunds	Wood	18750
Brick kilns	Rice mill Saw mill	Husk Wood chips, Saw dust	721215625.938
Industries	Rice mills	Husk	42357
	Total		140229

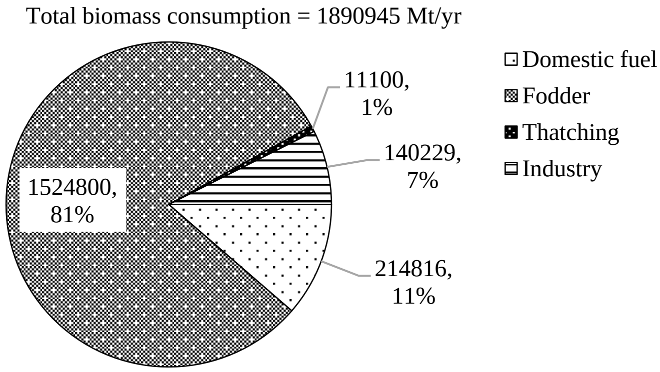

Figure 8. Total biomass consumption in the district including industrial use.

The chart in Figure 8 shows that a major portion of biomass is used as fodder for the livestock which is 81% and remaining 19% is used for other purposes. Since the district is industrially developed, industrial activities account for 7% of biomass consumption, whereas dominance of LPG equipped population reduces the use of biomass for cooking activities. Further, we can see that existence of concrete building has reduced the volume of biomass consumption to only 7%.

Surplus Biomass in The District

To calculate the surplus amount of Biomass remaining in the district, the amount of total Biomass generated and total amount of the consumed proportions, we can deduce from the discussion above that out of 2412112 Mt of biomass generated, major portion of it, 1890945 Mt, was consumed and the biomass surplus in nature which could be used for power generation is only 521167 Mt (22%) of total biomass. Hence to successfully replace the fossil fuels by biofuels, the remaining 78% of biomass which is used in allied spheres should be brought down with addressing the need for fodder fuel and housing material (Figure 9).

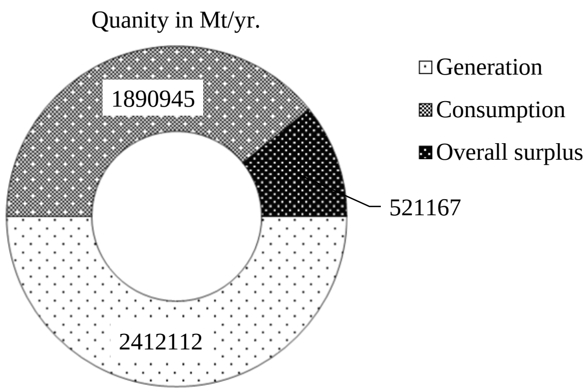

Figure 9. Surplus biomass generated in the district [8].

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BIOMASS COLLECTION MECHANISM

Table 9 clearly shows that paddy and wheat being major crops grown produce significant amount of residue too, but that is available for short duration of only 3 months, i.e. October to December for rice and March to May for wheat. Similarly, maize and mustard are also available for period of 3 and 4 months respectively. Sugarcane provides two different categories of residue whose seasonal availability is also variable. As far as seasonal availability is concerned, firewood and tree Biomass can be harnessed all the year round, thereby could be very helpful to maintain continuous fuel supply. Graphical representation of the rate of various biomass in the market has been depicted in Figure 10.

For transportation of biomass, generally, tractor trolleys are used. The cost of transportation depends on number of rounds that a trolley has to make irrespective of the weight of the biomass, but in general, in a single trip, it carries 4–5 Mt depending upon type of biomass. In general, each trip costs around Rs. 400–500. Average cost of biomass landing is around Rs. 1600/t.

Table 9. Seasonal availability of various biomass across the district.

	Month											
	Jan	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Paddy straw										■	■	■
Wheat straw			■	■	■	■				■	■	■
Maize cobs										■	■	■
Mustard stalks									■	■	■	■
Sugarcane trash	■	■	■							■	■	■
Sugarcane tree and leaves										■	■	■
Sesamum stalk			■	■						■	■	■
Firewood	■	■	■	■	■	■	■	■	■	■	■	■
Tree biomass	■	■	■	■	■	■	■	■	■	■	■	■

Source: Biomass Resource Assessment and Management, PAU, 2006.

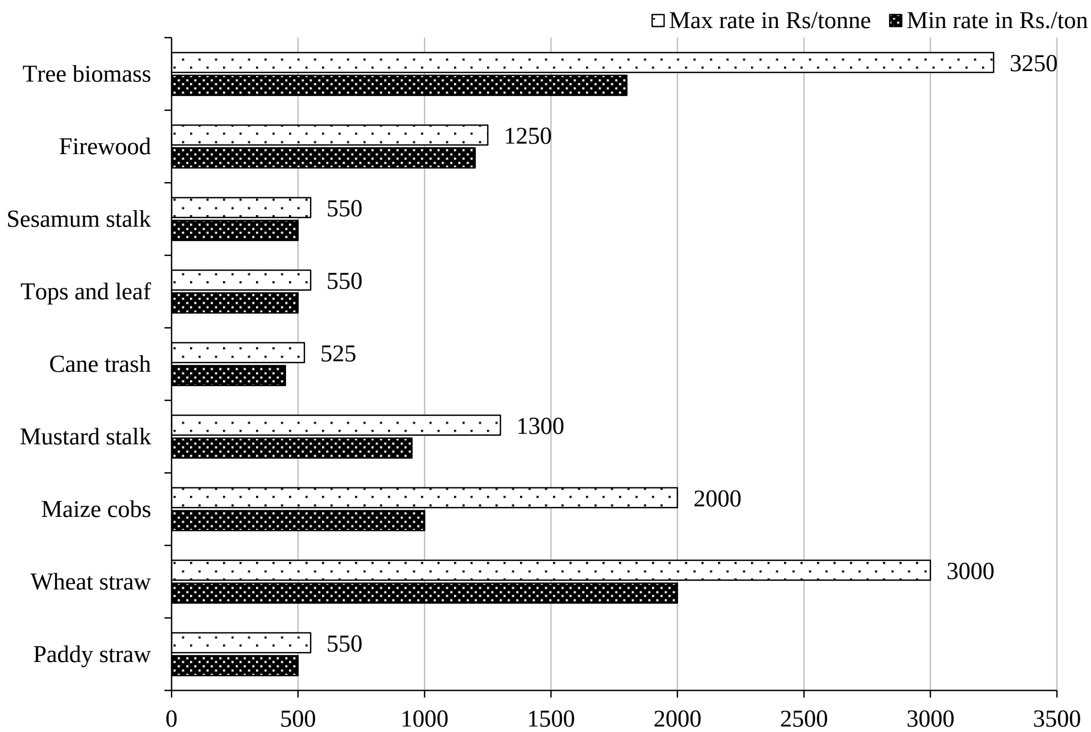

Figure 10. Rate of various biomass in the market (2006) [8].

CONCLUSION

In conclusion, the biomass resource assessment of Amritsar district underscores the significant potential for sustainable energy production, particularly within the dairy sector. By harnessing surplus agricultural residue and animal waste, dairy farmers can achieve energy self-sufficiency while reducing environmental impact. However, effective management strategies and infrastructure improvements are essential to optimize biomass utilization and overcome existing challenges. Through strategic integration of biomass resources, Amritsar's dairy industry can transition towards a more sustainable and resilient future, contributing to both economic prosperity and environmental stewardship in the region.

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