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The Environmental Challenges of Biomass Utilisation for Combined Heat and Power Generation in a Paper Mill in Tanzania

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Abstract

Biomass-driven, combined heat and power (CHP) also known as co-generation plants are said to provide reliable, efficient, clean power and heat worldwide. However, it is known that the use of biomass for energy applications may lead to land use competition, environmental degradation and food in-security. This study was therefore carried out at a Paper Mill and the seven surrounding villages with the aim of assessing the environmental challenge of wood biomass utilisation for CHP generation.

Data were collected by interviewing technical staff at the paper mill, Sao Hill Plantation, Government officials from Ministry of energy and other energy regulatory bodies. A questionnaire was used to collect data from seven villages surrounding the paper mill while a check list was used to collect information on environmental management aspect within the paper mill departments. Descriptive Statistics was used in assessing environmental challenge of biomass use at the Paper Mill while a chi square was used also to establish the relationship and association between variables.

Findings revealed that there were negative impacts on air quality, land use and water. The chi square test revealed that there was no significant difference (χ^2=0.253 and $p > 0.05$) in having environmental problems and distance from Paper Mill. It was also observed that arable land which was needed to grow trees was becoming scarce affecting the sustainable supply of raw materials.

Keywords: Wood biomass resources; Cogeneration of electricity; Pulp and paper mill; Forestry; Environmental management

Introduction

Biomass is a versatile raw material that can be used for production of heat, power, transport fuels, and bio-products. When generated and used on a sustainable basis, it is a carbon-neutral carrier that can make a large contribution to reducing greenhouse gas emissions. Currently, biomass accounts for about 10% of the total primary energy consumption in the world [1]. Despite the fact that traditional biomass in the form of wood fuel still remains a major source of bio energy; liquid biofuel and processed biomass production have shown rapid growth during the last decade [2].

Several studies including Dasappa et al., Smeets et al., Smeets et al. and Marrison et al. [3-6] have highlighted the potential for bio-energy production on the African continent. In Tanzania for example several studies [7-9], have been conducted on the use of sisal, charcoal, animal sludge and bagasse as raw materials for energy use and generation of electricity, But at the country level, the use of wood biomass residue have not received high attention in the context of specific assessments, associated environmental impacts as well as awareness on electricity generated despite the fact that wood biomass is currently contributing more than 11 MW of electricity to the national grid [10].

The Tanzanian energy demand is estimated at 22 million tonnes of oil equivalent (TOE) per annum or 0.7 TOE per capita. According to MEM-2013 [11], the quantitative distributions of the different energy sources to the energy balance were biomass fuels 90%, Petroleum 8%, electricity 1.2% and others less than 1% (including coal and renewable energy sources). These percentages show low per capita consumption of commercial energy (petroleum, coal and electricity) and relatively high dependence on biomass fuels in Tanzania. According to MFA-2011 [12], only 14% of the population had access to electricity (approximately 2% of rural population where 80% of country's population live and 37% of urban population) despite the fact that the country had very huge potential of renewable energy sources especially wood biomass.

Tanzanian industries using wood or agricultural feedstock (e.g., sugar, tannin, and sisal) have been generating their own power from waste biomass materials. It is estimated that about 58 MW of such generation is taking place [11]. According to Gwang'ombe [9], the estimated co-generation potential in Tanzania was more than 315 GWh per year. This was 10.5% of the national electricity generation. Songela [7] asserts that the energy generation potential from excess bagasse in sugar mills was about 99 GWh per year which was 3.5% of the national electricity generation; Private sector has been leading in utilizing biomass to generate heat and power.

The Paper Mill Combined Heat and Power Capacity

The paper mill has two product lines; Line 1 for manufacturing 30,000 tons per annum of industrial packaging grades, Line 2 for manufacturing 30,000 tons per annum of graphic paper grades; newsprint, mechanical printing and wood free printing paper grades.

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The production lines are integrated with a Chemical Pulp Mill (Kraft) with a designed capacity to produce 150 tons per day of unbleached chemical pulp, 80 tons per day of mechanical pulp; Chemical Recovery Plant for handling 320 tons per day dry black liquor solids and supplying 640 m^3/day white Liquor to the Kraft Pulp Mill.

Process heat and part of the electrical energy requirement are met through a captive co-generation plant comprising one (1) 10.5 MWe Extraction-Back Pressure Turbine, one (1) 60 Tonnes Per Hour (TPH), 45 bar of pressure, temperature of 450˚C, coal/Wood biomass fired Steam Boiler and one (1) 40 TPH, 45 bar, 450˚C Chemical Recovery Boiler firing the dissolved organics from the Kraft Mill Spent Chemicals. The total electrical energy demand at optimum operating levels is at 25 MW, out of which, approximately 9.0 MW is met from the co-generation plant and the balance 16 MW drawn from the grid; TANESCO [13].

The objective of this study was to examine the environmental impacts of biomass utilisation for heat and power generation at a Paper Mill and also to identify available environmental management programmes.

Paper Mill Raw Material Requirements

Information collected from Paper Mills on their current wood raw material are as follows:

Sufficiency of Wood Raw Material Requirements for Paper Mill Medium and Long Term Requirements

Data collected from the paper mill indicated that, with first level upgrades on Paper Machine No.1, It had increased the installed rated capacity of Paper Machine No.1 of 30,000 FTPA, to a new level capacity of 54,545.50 FTPA from Year 2010/2011.

Increase in the mill capacity means increase demand in the raw materials for both power plant and paper making. Paper Mill current projections on raw materials stands at.

Materials and Methods

This study was carried out at a paper mill and in the seven surrounding villages in southern highlands of Tanzania. The following sample determination formula based on Kothari [14] was used to generate a sample size to be used in this study.

$$n = \frac{z^2 pq}{d^2} \quad (1)$$

Where:

n =sample size in the study area when population > 10 000.

z = Standard normal deviation, set at 1.96 (2.0 approximate) corresponding to the 95% confidence interval level.

p = Proportion of the target population (50% if population is not known).

q = 1.0 – p (1-50) (1-0.5) = 0.5

d = degree of accuracy desired, (set at the 95% equivalent to 0.05)

Based on the above formula, the sample size for this study was supposed to be 384 respondents, but due to number of households which were at a distance of less than 30km from the paper mill 28% of the cases were selected for this study. Therefore, 106 respondents were selected to participate in the study, based on the fact that a sample of 30 respondents, according to Bailey [15] irrespective of the population size is the bare minimum for a study in which statistical analysis is to be done while, Kumar [16], observes that a sample size of between 80 and 120 respondents is suitable for rigorous statistical analysis.

Purposive sampling of the seven surrounding villages was done based on accessibility and proximity to the Mufindi Paper Mill site [17] as well as the wood plantations within a radius of 30 kilometres. Systematic sampling technique was used to select the required 106 households and from each, a household head or spouse to the household head was enumerated. A survey of the seven villages was conducted to determine the geographical location of the village as well as household distribution; therefore data was collected from every 5th household in each of the seven villages.

Primary data were collected using structured questionnaire containing both open and closed-ended questions on biomass utilization from the selected villages. Key informant interview was used to collect data from government officials and other stakeholders; these included Ministry of Energy and Minerals (MEM), National Environmental Management Council (NEMC), Rufiji Water Basin Authority - Iringa, Rural Energy Agency (REA), Tanzania forest services (TFS), Energy and Water Regulatory Authority (EWURA),Tanzania Traditional Energy Development and Environment Organization *(TaTEDO*) and Tanzania Renewable energy Association (TAREA) and a checklist was used to collect data during Focus group discussion from various departments at the Paper mill.

Quantitative data were analysed using Statistical Package for Social Sciences (SPSS), while chi-square test was used to establish the relationship between socio-demographic characteristics of the respondents and their awareness of the cogeneration activities at the paper mill as well as environmental impacts.

Results and Discussion

Size of land owned by the villagers

The size of land owned by respondents varied from one village to another and from one household to another, the study indicated that 70% of the respondents owned ≤ 10 hectares of land, 19.8% of the respondents owned 11-20 hectares while the remaining 9.4% of the respondents owned ≥ 21 hectares (Table 2). Land ownership was one of the crucial factors as the bigger the land the household possesses the more the income derived from agricultural activities and tree plantations. However, the presence of larger tree plantations and increase in tree product prices had led to not only increased land prices but, also land scarcity and land use related-conflicts [18] had argued that Sub-Saharan Africa, including Tanzania, would witness an a 8% increase in the total land use for wood fuel cultivation, offset by fall, incomes decline, and their ability to access food depreciate roughly 3.4% decrease in forested land and a 4.5% reduction in pastureland. In a rural area, like the study area, having the larger percentage of people owning less than 10 hectares of land is a typical sign that most of land is now under wood cultivation by larger companies.

The findings also showed that due to increasing lack of sufficient land, the available natural forest had been encroached upon in opening new farms. Also, there had been frequently burning of existing larger plantations and this was associated with the increasing scarcity in land ownership by the villagers. The same argument had been canvassed by Narain et al. [19] who found that households with less land tend to perceive conservation programmes as a limitation to their subsistence needs and therefore are likely to have negative attitude toward conservation. Masozera [20], Reardon and Vostii [21] furthermore,

S. N	Area	Unit	Conversion formula	Total wood	Remarks
1	Paper production	54,545.50 FTPA	5.5 m^3 tonne of FTPA	300,000 m^3	
2	Biomass for power generation and power boiler	292,000 tonnes/a (800t/d*365 days)	575 kg/m^3	167,900 m^3	About 44.6 (35.6+9.0) MW will be generated.
Total wood requirement				467,900 m^3	

Table 1: Paper mill wood requirement.

argued that households with less land tend to be poor in off-farm capital and therefore cannot afford to continue sustainable agriculture.

Size of land used for tree plantation

About 84% of the respondents used ≤ 10 ha for tree planting, 11.3% used 11-20 ha, while 2.8% used ≥ 21 hectares for tree planting. There was a noticeable shift from growing of food crops to cash crops, especially tree planting. The shift was motivated by the increasing prices of wood products especially timber and the huge market for electricity poles and wood fuel at the Paper Mill. At the time of this study, there were already cases of food price increases. Despite the fact that many respondents believed that this might have been caused by increased demand from the number of people who were working at the mill, another reason could be due to the decline in the number of farmers who were involved in growing food crops. These results correlate the findings of ABN-2007 [22] who reported that in Zambia, farmers were persuaded by agribusinesses to grow cotton instead of maize only to see market prices.

Wood waste utilization

Fuel wood used at the Paper Mill for electrical power generation was in form of wood waste. The researcher wanted to know what the respondents did with the wood waste after they had harvested their trees. The findings indicated that 71.7% of the respondents had no idea of what they would do with such wood waste after harvesting. This was perhaps because 78.3% of the respondents had not yet harvested their trees. However 13.2% of the respondentsleft their wood waste on the farm after harvesting, 12.3% used as firewood, while 2.8% were burning it on the field as a means of land clearing for the next planting season. The researcher also observed that even Paper Mills left most of the waste at the field after harvesting trees (Figure 1). When asked why they were leaving the tree branches and roots while they could be used as fuel at the cogeneration plant the harvesting manager said:

"The branches and roots are the smallest parts and for now we don't have any mechanism to transfer them to the mill. Also we have a lot of raw materials in forms of wood chips from other supplies and from our sister company".

Environmental problems resulting from wood biomass use at paper mill

Data collected from the field indicated that 78.3% of the respondents believed that there were environmental impacts associated with Mufindi paper mill, while 21.7% believe that there were no environmental impacts. From such finding it is clear that the majority of the respondents believed that the mill operation caused environmental problems.

The mill had different levels of impact environmental impacts across the villages (Figure 2), of all the respondents, 31.1% mentioned air pollution in form of smoke, bad smell and ashes from the Paper Mills, 25.5% mentioned bad smell only, while 20.8% reported that there had not been any significant environmental impact. Less than 10% mentioned smoke from the power Plant, dust pollution especially that which was caused by moving cars carrying tree logs from harvesting sites to the paper mill.

These findings corroborate those by WWF-2006 which argued that plantations and biomass use have negatively impact on biodiversity, water resources, soil quality, and air pollution. An environmental impact assessment done at Mufindi Paper Mill by Nzalalila et al. [23] also indicated that, the likely key environmental issues relating to mill operations included generation of solid, liquid, heat, and gaseous wastes which, if not properly disposed could lead to environmental pollution. The same source also asserted that solid wastes can result in abnormal piling of debris and emission of noxious and malodorous gases and that sometimes fire may result, dust might lead to breathing and lung problems.

Again the type of environmental problems mentioned differed depending on the distance of the village from the Paper Mill. Air pollution by ashes from the power generation plant was recorded only at the distances greater than 17 km. Dust had environmental impact at 6-17 km or more (Figure 3).

This is because most of these villages are close to the main road heading to the paper mill. Hence, there was higher vehicle traffic especially during the transportation of both raw materials from the forest to the paper mill, and the paper products to Dar es Salaam.

When the distance from the paper mill and the associated environmental problem was statistically tested, however there was no significant association between the two variables (Table 3). Therefore the null hypothesis was accepted. This means that despite the change in distance from the paper mill, most villages experienced the same type of environmental problems. This could be due to the height of the smoke chimney of the paper mill.

Effects of environmental pollution on human health, physical facilities and biodiversity

About 34% of the respondents opined that the pollution caused by the paper mill led to frequent coughing, 14.2% reported being diagnosed with chest diseases as the result of inhaling the polluted air from the paper mill while 6.6% reported food contamination by ashes coming from the paper mill. About 4% reported death of fishes as the result of discharge of untreated effluent from the Paper mill to the nearby river. About 32.2% of the respondents were not aware of any environmental impact resulting from operation of the paper mill. These respondents believed that further scientific studies should be carried out to identify the likelihood of any impact as some of the impacts might take years to identify. The remaining 6.6% believe that the environmental pollution problems had led to iron sheet rusting, flue and coughing (Table 4).

Availability of environmental management programmes

From the findings, about 82.2% of the respondents reported that there were environmental management programmes and activities being undertaken. Also this study indicated that there were several types of environmental programmes mostly aimed at mitigating the

Where	Upto 2012		2015-2020		2025 And Beyond	
Paper Machine I/Ii	300'000 m^3	45,000-54,545.50	495000 m^3	90,000 FTPA	900,000 m^3	180,000 FTPA
Biomass Powered Power Plant	167'900 m^3	44.6MW	167900 m^3	44.6 MW	167,000 m^3	44.6 MW
Total	467-500,000 m^3		662,900 m^3		1,157,900 m^3	

Table 2: Short and long term paper mill wood requirements.

Figure 1: Paper Mill harvesting site and typical type of waste left at the site.

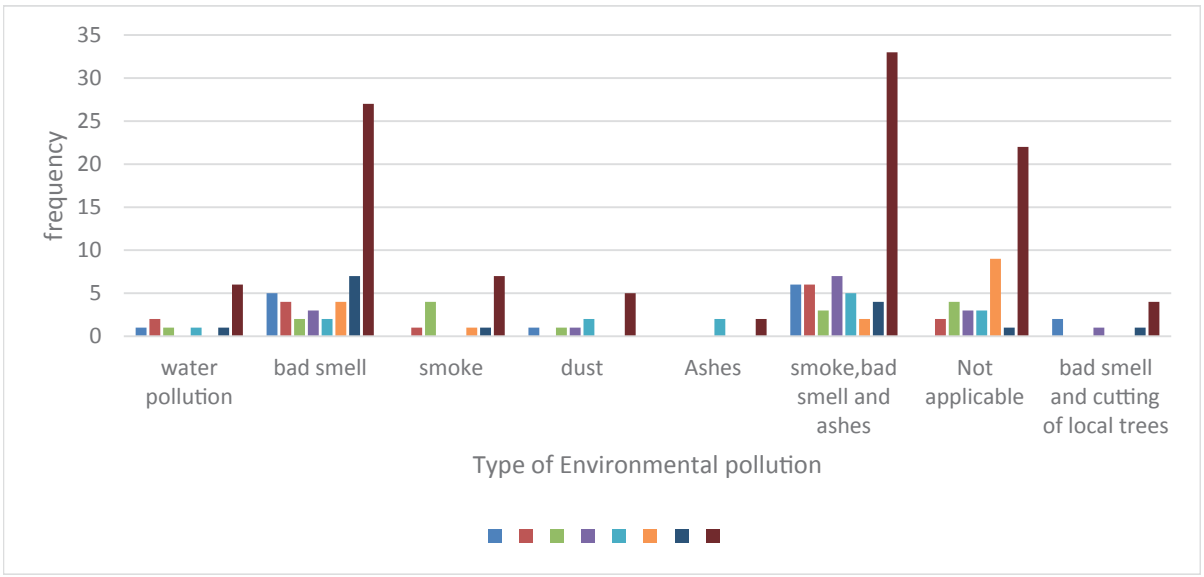

Figure 2: Environmental impacts per each village.

impact of climate change and controlling unsustainable use of natural resources. About 17.9% of these environmental management activities were in the form of fire burning control. 17% on tree planting activities and 20.8% on tree planting, water sources management and bush burning control. About 17.9% of the respondents were not aware of any environmental management programme, activity or campaign at the study area (Figure 4).

Effectiveness of the available environmental programmes

Findings showed that the available environmental management programmes had been effective at different levels. About 28.3% of the respondents believed that the available environmental management programmes had led to an increase in tree planting activities, 22%, believed that awareness towards environment management had led to decrease in forest fires. The decrease in forest burning activities was

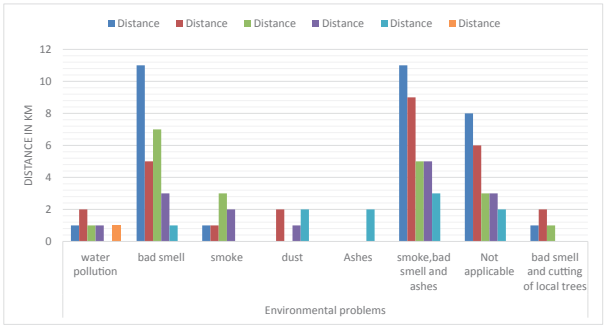

Figure 3: Effect of distance from the paper mill on environmental impact

Size of Land	Frequency (N)	Percent (%)
≤ 10 hectares	75	70.8
11- 20hectres	21	19.8
≥ 21 Hectares	10	9.4
Total	106	100

Table 3: Size of land owned.

Distance from Mufindi paper mill	Environmental problems				Chi-square value (x^2)	P-value
	Yes	%	No	%		
< 6 km	25	75.8%	8	24.2%	0.253	0.881
6-17 km	37	80.4%	9	19.4%		
> 17 km	21	77.8%	6	22.2%		

Table 4: Chi-square test of association between having environmental problems and distance from Mufindi Paper Mill.

associated with the increased environmental management programmes as confirmed by 19% of all respondents (Figure 5). Despite these achievements there is still much to be done on improving the quality of the environment as well as solving the land use conflicts.

Conclusion

The focus of this paper was on the environmental challenge of wood biomass utilisation for energy cogeneration in one of the paper mill in Tanzania. The sustainability of wood biomass cogeneration will mostly depend on the awareness of the people; this is because majority of villagers where this study was conducted were not aware of electricity generation at the mill. this lack of awareness in a way affected the raw material supply to the mill due to the fact that people are mostly planting trees for other uses than wood fuel such as for timber which takes up to 15 years before harvesting while if they were to plant for fuel purposes it would take them up to only 5 years and also increasing their income. The study also found that there are environmental problems being caused by Paper Mill, with direct impacts on the air quality, land use and water .Although some cases might need technical evaluation, numerous complaints from various stakeholders signifies the extent of the problem. Despite the presence of environmental programmes at the study area, their effectiveness is also a matter of concern. In villages like Kitasengwa where fire prevention education has been preached every day and despite the presence of Sao hill plantation division office, fire cases have been occurring repeatedly. Also due to the fact that most programs at village have been championed by the villagers themselves the financial and technical operation has always been a problem.

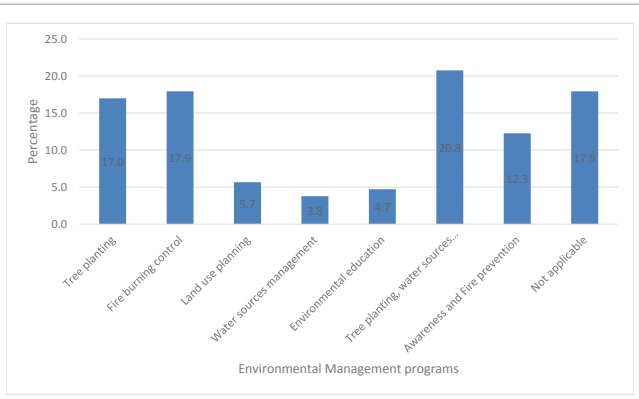

Figure 4: Environmental management programs.

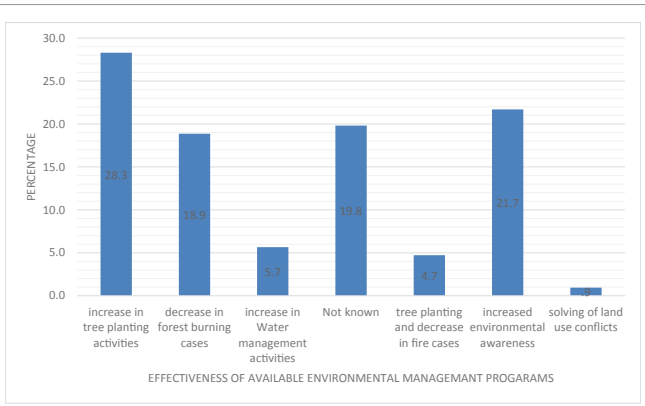

Figure 5: Effectiveness of available environmental management programs.

Coughing of residents near the industry	36	34.0
Chest diseases	15	14.2
Dying of fish	4	3.8
Crop diseases 'burning'	3	2.8
Food contamination	7	6.6
Not known	34	32.1
Iron sheet rust, flue and coughing	4	3.8
burning of crops, dust, coughing	3	2.8
Total	**106**	**100.0**

Table 5: Effects of the environmental problems at the study area.

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