MODELLING THE POTENTIAL BIOENERGY PRODUCTION FROM AGRO-FORESTRY CROPS AND RESIDUES IN ANGOLA

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ABSTRACT: The aim of this work is to make an assessment of the biomass resources potential for bioenergy in the province of Huíla, in Angola, namely from crop residues. Huíla province has an area of 79,023 square kilometres (more than the area of Netherlands and Belgium) and a population of 2,354,398 (2014 census). Lubango is the capital of the province. Agricultural residues included especially those generated from maize, sorghum and millet. The preliminary analysis to the data shows that circa 500 000 tonnes of agroforest biomass could be logistically collected and sorted, and *circa* 9 PJ could be produced. The characteristics of the different crop residues are presented in the study and different scenarios for the exploitation of this biomass were taken into account. In Scenario 1, it was considered *business as usual*; in scenario 2, it was considered the use of biomass for heat production only. For the different scenarios, the environmental impacts derived from the implementation of the biosystems were discussed, namely in terms of greenhouse gas (GHG) emissions and non-renewable energy use. Considering Scenario 1, *circa* 1.8 PJ only can be produced, with several environmental impacts associated. Considering Scenario 2, *circa* 2.27 PJ of energy can be produced. Yet, different biomass processing options can be considered given the characteristics of the different biomasses. A discussion of the logistics of collection and transportation of the biomass was carried out to evaluate the effect of field cover factor and crop yield.
Keywords: bioenergy, agricultural residues, sustainability, environmental impact, Angola

1 INTRODUCTION

Energy is a vital commodity. It is commonly recognized that access to energy is linked with development and economic well-being [1]. Alleviating energy poverty is vital for development in low-income countries and is a prerequisite to fulfil the development goals [2]. Biomass is the major energy source in Angola contributing to 65% of the country's primary energy supply and 80% of Angolans rely on biomass for most of their energy needs, especially in rural areas [3]. Nevertheless, in Angola, only 30% of the population has access to electricity, although Angola has extensive hydroelectric power resources that far exceed its present needs and crude oil production in Angola ranks second in sub-Saharan Africa [4]. Moreover, the combustion of biomass using inefficient technologies and appliances can be deleterious to health and may result in wastage of biomass resources, which may lead, in the long term, to negative impacts on the environment such as extensive deforestation, declining soil fertility and diminished and polluted water resources [4, 5].

In 2011, the Inter-ministerial Commission for Energy Security has established principles to guide the formulation of future energy strategies and policies within the country: to establish energy as a main driver of economic development; to develop infrastructure in order to provide affordable energy to the entire population; to encourage efficient operation and the financial stability of the energy sector; and to promote balanced development of Angolan economy and society, reducing social and geographical disparities and increasing energy security and environmental sustainability [6].

Therefore, an assessment of the biomass resources potential for bioenergy in the province of Huíla, in Angola, is being conducted. Huíla province has an area of 79,023 square kilometres (more than the area of Netherlands and Belgium) and a population of 2,354,398 (2014 census). The province is divided into 14 municipalities and 52 comunas. Lubango is the capital of the province. Electricity is the highest source of energy for lighting and wood is the highest source of energy for cooking, heating and cooling. Sixty percent of the population uses stoves, 92% uses a fire-pan and 35% uses a community stove (data obtained from an enquiry [7]).

More specifically, in the project, the amount and types of sustainable agroforest residues and dedicated crops to energy and their provincial distribution is being determined. Agricultural residues included those generated from sugarcane, maize, rice, sorghum and millet, and other cereals, roots and tubers (cassava, sweet potato), pulses and oil crops, and fruits processing [8]. Yet, the most significant crops in this province, in terms of area and biomass are maize, sorghum and millet.

2 MATERIALS AND METHODS

Key target of the work is the assessment of the crop residues in the region. Major agricultural crop residues for bioenergy production were determined based on the availability and production rate: maize, sorghum and millet. The agricultural systems that generate food, feed, fiber, and fuels need to be also efficient and sustainable (economically, environmentally and socially). The methodology applied to evaluate the amount of crops available for bioenergy was determined following the methodology presented by Cativa and Fernando [9].

Regarding those major crops being produced in the Huíla province, the potential sustainable crop residue for bioenergy production can be estimated by using the residue to product ratio (RPR):

$$\text{RPR} = \text{Residue production/Crop production} \quad (1)$$

Residue production and crop production, represent the amount of total residue and crop (Mg) being produced in a certain field area. To meet the challenges of the sustainable production of bioenergy, with a focus on the environmental criteria, the environmental impacts derived from the implementation of the biosystems were discussed. Greenhouse gas (GHG) emissions and non-renewable energy use were considered in this assessment. A discussion of the logistics of collection and transportation of the biomass, including the effect of field cover factor and crop yield, was considered in the assessment. The characteristics of the different crop residues were determined also. At the end of each growing season, the crops residues were harvested and the available biomass per area was monitored. The quality of the biomass was analysed taking in consideration the following parameters: ash content, nitrogen content and phosphorus content. The chemical analyses were performed according to the following procedures: a) ash content: by calcination at 550ºC for two hours, in a muffler furnace; b) nitrogen: by the kjeldahl method.

In the study different scenarios for the exploitation of this biomass are taken into account. In Scenario 1, it was considered *business as usual*; in scenario 2, it was considered the use of biomass for heat production only; Yet, different biomass processing options can be considered given the characteristics of the different biomasses.

3 RESULTS AND DISCUSSION

3.1 Crop residues yields

The arable cultivated land of Huíla Province is 5458 km^2 (7.4% of the area of Huíla) and the forest area is 6174 km^2 (7.8% of the area of Huíla).

Figure 1 presents maize residues yields obtained in the Huíla Province.

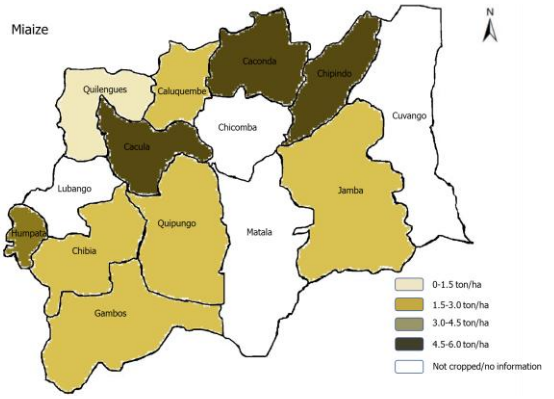

Figure 1: Maize residues yields obtained in the Huíla Province.

According to the results presented, the municipalities that present the highest amount of residues are Humpata, Cacula, Caconda and Chipindo. In some municipalities it was still noy possible to obtain data (Lubango, Chicomba, Matala, Cuvango).

Figure 2 presents sorghum residues yields obtained in the Huíla Province.

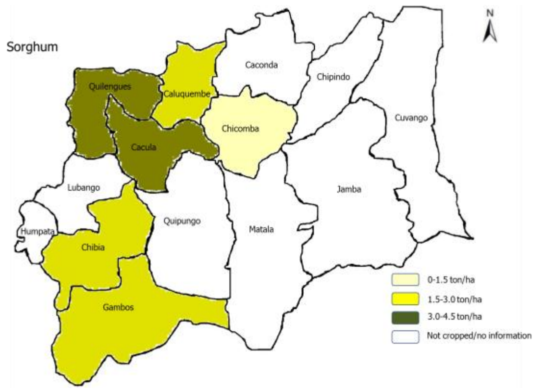

Figure 2: Sorghum residues yields obtained in the Huíla Province.

According to the results presented, the municipalities that present the highest amount of residues are Quilengues and Cacula. In some municipalities it was still not possible to obtain data or the crop is not being cultivated (Lubango, Humpata, Chicomba, Quipungo, Caconda, Matala, Chipindo. Jamba and Cuvango).

Figure 3 presents millet residues yields obtained in the Huíla Province.

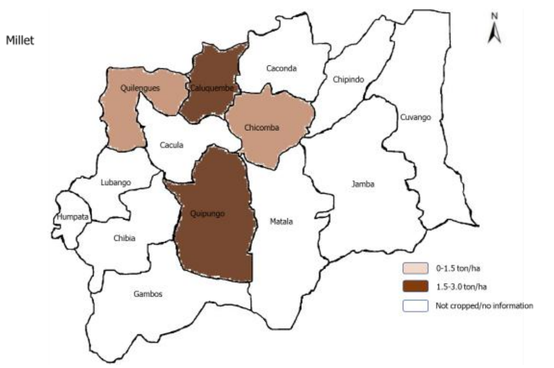

Figure 3: Millet residues yields obtained in the Huíla Province.

According to the results presented, the municipalities that present the highest amount of residues are Quipungo and Caluquembe. In the majority of the municipalities it was still not possible to obtain data or the crop is not being cultivated.

3.2 Biomass quality

Considering that these wastes are usually used for bioenergy production in combustion furnaces, ash content and nitrogen content of the biomass was assessed in order to evaluate the biomass quality. In the processing and use stage, ash content of the substrate mix should be lower than 5 g per 100 g of dried substrate in order not to increase the amount of residues derived from the combustion of this biomass and also, to avoid the occurrence of slagging processes, lowering the lifetime of those sort of equipment's [10]. The same is applicable to the nitrogen content of the residues to be exploited. In the mix, the amount should be lower than 1 g per 100 g [10]. The lower the nitrogen absorbed by the biomass, the lower the N emissions, that will contribute to the GHG emissions. Maize presented 8% of ash, Sorghum circa 7% and millet 8 %. According to Gomes et al. [10], ash content is higher than the result recommended. Maize presented 1.3 % of nitrogen, Sorghum, 1.5% and millet 1.6 %. Results presented in terms of nitrogen are also higher than the amount recommended. Mixing substrates with higher ash/nitrogen content with those with lower ash/nitrogen content will result in a product with less technical/environmental constraints.

3.3 Modelling the exploitation of crops residues to bioenergy

Considering that the amount of residues that should be left in the ground are *circa* 2-4 ton/ha [11], to control soil erosion and to enrich soil with organic matter and nutrients, the value of 2 ton/ha was chosen as the most promising. Therefore, taking into consideration this aspect, total biomass that can be collected is *circa* 13063046 ton. However, not all this biomass can be collected and sorted. The amount of biomass that can be logistically sorted and collected is 522521 ton (especially when considering the existence of roads, and the location of conversion units – such as a biomass power plant). The energy potential in this amount of biomass collected is around 9.1 PJ.

Different scenarios for the exploitation of this biomass are taken into account. In Scenario 1, business as usual, it was considered the use of the biomass from crop residues of the major crops (Maize, sorghum and millet). Preliminary data indicates that a total of 1.8 PJ could be produced. However, there are a lot of environmental impacts derived from the exploitation of biowastes as considered in Scenerio 1. In fact, the use of fire-pan or community stove present very low efficiency and risks to humans, and can be highly improved. On the other hand, the collection of residues can be improved. Figures 4 and 5 show the constraints associated with biomass collection and use.

Figure 4: Biomass collection process in the Province of Huíla, Angola.

Figure 5: Biomass use in the Province of Huíla, Angola.

In Scenario 2 it was considered the improvement of the collection systems, the improvement of the transportation systems and the improvement of the stoves efficiency. Preliminary data show that the amount of energy that can be produced is 2.27 PJ. With the improvement of the named systems, GHG emissions from the inputs will be reduced and the potential GHG emissions reduction is improved.

4 CONCLUSIONS

In the province of Huíla, Angola, biomass is the major source of energy. However, its production is low efficient and presents several environmental impacts. Those running systems can be improved and this will improve the rural economy, the environmental impacts and the social dimension. Investment is needed but the municipality is focusing on this issue.

A sensitivity analysis is needed to evaluate the effect of field cover factor, crop yield, and well-to-wheel GHG emission on collectable residue, biofuel production, and GHG emissions. In the assessment, different biomass processing options can be also considered, based on the characteristics of the residues.

5 ACKNOWLEDGEMENTS

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