Renewable and Sustainable Energy Reviews 61 (2016) 202–212

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Lignocellulosic residues for production of electricity, biogas or second generation biofuel: A case study of technical and sustainable potential of rice straw in Mali

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ARTICLE INFO

Article history:
Received 4 June 2015
Received in revised form
25 January 2016
Accepted 4 March 2016
Available online 7 April 2016

Keywords:
Biomass resources
Rice straw
Lignocellulosic residues
Second generation biofuel
Renewable energy
Mali

ABSTRACT

Biomass from agricultural residues, especially lignocellulosic biomass, is not only seen as a sustainable biomass source for the production of electricity, but increasingly as a resource for the production of biogas and second generation biofuel in developing countries. Based on empirical research in an irrigated rice-growing area, Office du Niger, in Mali, this article builds scenarios for the sustainable potential of rice straw. The paper concludes that there is great uncertainty regarding the size of the sustainable resources of rice straw available for energy, but that the most likely scenario estimates a resource of about 120,000 t, which would permit up to three 5 MW_{el} rice straw-fuelled power plants. Based on the findings from the empirical studies, the article further suggests that recently published research on the potential of rice straw in a number of African countries seems first to underestimate the uncertainty of resource assessments, and secondly to overestimate the resources available for energy production, mainly due to optimistic residue-to-product ratios and availability factors.

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http://dx.doi.org/10.1016/j.rser.2016.03.023
1364-0321/

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1. Introduction

Biomass from agricultural residues, especially lignocellulosic biomass, is not only seen as a sustainable biomass source for the production of electricity [1–3] but increasingly as the resource for the production of biogas and second generation biofuel in developing countries [4,5]. In this regard, a number of studies of available biomass for energy have been produced at the global level [6,7], for Europe (see e.g. [8], and for the African continent [9,10]. Common to the global and EU studies is the fact that methodologies are difficult to compare and that the results vary significantly from low to high predictions.

With regard to the African continent, a number of country studies of biomass potential have recently been published [11–18]. These studies generally report on a number of different biomass types selected according to their importance in terms of availability. Often the analyses comprise all available biomass residues and waste streams [11,13,16,19], while in a number of cases they provide only partial analyses, mainly concentrating on agricultural residues [12,14,17], agriculture and forestry residues [15], or dedicated energy crops [18]. While global studies and EU studies often look forward to 2030 or 2050, national studies in Africa in general provide only static analyses based on FAO crop-production statistics, global residue-to-product ratios and global assumptions regarding available shares of the resource.

To refine and consolidate the parameters for global and regional studies, there is a need for localised, empirically based studies which take into account the spatial distribution and competing use of biomass resources, as well as providing scenarios for future prospects. The current case study from Mali contributes to fill this gap by providing a first estimate of the potential sustainable resources of rice straw in Office du Niger in Mali. It addresses the methodological challenges involved in assessing the technical and the sustainable resources of lignocellulosic biomass, as well as the uncertainties of biomass resource estimates.

The article starts by briefly describing the farming practices in the case study area. Section 3 describes the methodology used in the study, including the conceptual framework and the assumptions behind the scenarios defined. The results of the study are presented in Section 4, and the uncertainties and limitations of the study are discussed in Section 5. Before providing a conclusion in Section 7, Section 6 discusses the potential implications of the findings for interpreting existing research and provides recommendations for future research.

2. Farming practices in Office du Niger

In this article, Office du Niger (ON) is used as a case study for the assessment of sustainable resources of rice straw in Mali because it is the most important rice-cultivating area in Mali and the area with the highest concentration of rice straw. This section will provide the context for the study, including the historical background to rice production in ON and a short description of current agricultural practices.

ON was founded in 1932 as a colonial-owned entity based on forced labour with the objective of supplying the French colonial power with cotton. Plans were ambitious, aiming to develop almost one million hectares (ha) [20]. ON started by producing cotton, but this was gradually abandoned in 1965–1970 when rice was introduced. However, already by the end of the 1970s, the production of rice was decreasing and the equipment and infrastructure had fallen into decay, whereupon the World Bank and a wide group of donors engaged in a large rehabilitation programme [21]. Dramatic economic and institutional changes accompanied technical and financial support for the rehabilitation of infrastructure such as canals, drainage systems etc.,. In the years from 1986 to 1994, ON's trade monopoly on rice and fertilizer was abolished, village associations were made responsible for water management, and central threshing and hulling were gradually replaced by decentralised and privatised threshing and hulling. The effects were impressive: in the period from 1979 to 1994 the yield of rice increased by 300%, a development that is continuing, as will be further explained below [22]. ON is currently a dynamic agricultural development area in Mali, which is still attracting a high level of donor intervention and recently also large-scale private investment [23,24].

In spite of recent developments, however, the production of rice is still based on a high level of manual labour input. The rice is harvested by sickle and left in the field to dry. From there it is manually transported to the dikes, where it is stored in piles until it is threshed by mobile threshers. Due to problems with water management and drainage, the rice fields are often still wet during the harvest, making the mechanisation of harvesting and the transport of straw from the fields difficult [25]. Currently the stubble left in the fields is partly burned, partly incorporated into the soil and partly used to feed grazing animals.

The number of cattle in the ON is high, but statistical information is currently not available. In 1998 there were about 300,000 head of cattle (including 43,000 draught oxen) and about 16,000 donkeys for transport [26]. According to extension officers in the area, the number of cattle has increased since 1998. During the rainy season most of the cattle are on transhumance in the pastoral zones around the irrigated areas in ON, but the animals return to these areas during the dry season from December to May/June. During this period they graze stubble in the fields and feed on piles of threshed straw [26].

The cattle in the ON do not only belong to the farmers themselves. During the dry season the relative abundance of feed stock in the inland delta has traditionally attracted transhumant herders from the regions north of ON. The increasing pressure on fodder, partly due to decreases in rainfall, but mainly to increases in the number of cattle, means that the large irrigated area in ON is an attractive destination for transhumant herders with their cattle.