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Can biogas digesters help to reduce deforestation in Africa?

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ABSTRACT

Biogas digesters could help to reduce deforestation in Sub-Saharan Africa by providing a source of energy that would otherwise be provided by woodfuel. However, the link between deforestation and use of woodfuel at global level is weak because fuel is often obtained from fallen wood or from sources felled for construction or land clearance. This paper examines the link between deforestation and use of woodfuel, and evaluates whether biogas digesters are likely to help reduce deforestation in Africa. Woodfuel production and consumption in Africa are increasing over time. Of the deforestation observed in 2010, we estimated that 70(±42)% can be attributed to woodfuel demand. Uncertainties in this figure arise from uncertainty in efficiency of energy use in different designs of wood-burning stoves, and the percentage of energy obtained from woodfuel in rural and urban populations. The contribution of woodfuel demand to deforestation is predicted to increase by 2030 to up to 83(±50)%. This is due to an increasing population requiring more woodfuel and so contributing to a higher proportion of total deforestation. Biogas production has the potential to reduce deforestation due to woodfuel demand by between 6 and 36% in 2010 and between 4 and 26% in 2030. This is equivalent to 10–40% of total deforestation in 2010, and 9–35% of total deforestation in 2030. The highest contribution to biogas production is likely to be from cattle manure, and the uncertainty in the potential of biogas to reduce deforestation is mainly associated with uncertainties in the amount of biogas produced per animal.

1. Introduction

Despite a marked shift in the type of energy use in developing countries from biomass-based fuel to more sophisticated energy delivery, such as gas and electricity [1], the majority of people in developing countries still rely on traditional fuels such as fuelwood, charcoal and dung cakes [2]. In this paper, we define *fuelwood* as the wood that is burnt directly as fuel; and we define *woodfuel* as the sum of the wood used both

Abbreviations: SSA, Sub-Saharan Africa; GDP, gross domestic product.

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directly as fuel and indirectly for making charcoal. Historical trends indicate that the use of both fuelwood and charcoal for cooking is increasing [3,4]. Population increase in recent years has contributed to the increased demand for energy, including woodfuel, which is evidenced by collection of woodfuel remaining one of the most important and time consuming household chores in Sub-Saharan Africa (SSA) [5,6]. After the development of the use of fossil fuels and electrical energy, people with high income, mainly living in and around cities, are increasingly attracted towards using these more sophisticated, but expensive, energy types [7]. Charcoal is also very popular and widely used for cooking in most African cities [2,8]. However, for people with low income and living in rural areas, fuelwood is still the primary source of heat energy. In this context, the environmental perspective of woodfuel consumption is one of the areas of interest of this paper.

Different activities and approaches have been used to alleviate the problem of deforestation. In order to reduce over-reliance on woodfuel energy for cooking and heating, alternative sources of energy need to be investigated. Biogas energy could be a suitable alternative for cooking and heating energy and therefore is proposed as one of the approaches to reduce deforestation, particularly deforestation resulting from woodfuel consumption. By providing an alternative energy source that would otherwise be obtained from fuelwood or charcoal, it is widely assumed that biogas digesters could help to reduce the rate of deforestation in SSA [9–12]. However, the link between deforestation and the use of fuelwood and charcoal at global level is weak because fire wood is often obtained from fallen wood or from sources that would already be felled for construction or land clearance [13].

In order to establish the potential impact of biogas on deforestation, the impact of woodfuel demand on deforestation must first be established. Arnold et al. [14] reviewed woodfuel requirements and impacts on forests during the 1980s and found that, globally, there is a very weak link between woodfuel demand and deforestation. However, much has changed since then. The population has increased substantially [15], both the number and size of urban areas have increased [16], and the average gross national income per capita has increased more than threefold [17]. These trends are likely to have modified the 1980 scenario of consumption, demand and choice of fuel. In the developing world, any such changes could have significant effects on forest resources, as woodfuel is the main source of fuel for cooking and heating. It is timely therefore to revisit the issue of the impact of woodfuel consumption on deforestation.

This paper examines the link between deforestation and the use of fuelwood and charcoal in SSA, and determines whether biogas digesters are likely to help reduce deforestation in Africa. Statistical data have been collated from FAO, UNDP, World Bank and other sources. Some additional data have been obtained from the wider literature. As far as possible, national data have been collected for all countries in SSA. The available data have been used to describe the current situation and to provide future scenarios that have been analysed using the projected figures.

2. Impact of present day energy demand on the forests of Africa

2.1. *Amount of wood required to meet present day energy demand*

The amount of wood needed to supply current energy demand, W_{dem} (Mt y^{-1}), was calculated from the total energy demand from woodfuel, $E_{dem,\ wood}$ (GJ y^{-1}), the gross heat of combustion, $\Delta H_{combustion}$ (GJ t^{-1}), and the efficiency of energy use, $P_{eff,\ wood}$ (energy released/total energy content of the fuel, %);

$$W_{dem} = \frac{E_{dem,wood}}{10^2 \times P_{eff,wood} \times \Delta H_{combustion}} \quad (1)$$

The gross heat of combustion, $\Delta H_{combustion}$, was assumed to be 15.5 GJ t^{-1} after Jensen [18]. The efficiency and design of commonly used stove types in SSA are particularly variable due to limitations in available materials, cultural differences and financial restrictions, so it is difficult to assign an accurate value to the efficiency of energy use ($P_{eff,\ wood}$). For the five most popular types of stove used, the efficiency for wood burning was measured to be between 14% for an open fire stove [19] and 44% for a rocket stove [20]. Excluding the losses of charcoal production, burning charcoal is more efficient than burning wood. Therefore, for these calculations, $P_{eff,\ wood}$ is assumed to be 44%. The total national energy demand from woodfuel ($E_{dem,\ wood}$) was calculated from the energy demand per capita, E_{dem} (GJ caput^{-1} y^{-1}), the population, n_{pop} (caput), and the percentage of the total energy demand that is supplied by woodfuel at national level, P_{wood} (%);

$$E_{dem,wood} = \frac{E_{dem} \times n_{pop} \times P_{wood}}{10^5} \quad (2)$$

This was calculated separately for the urban and rural populations because the energy demand is different in rural and urban areas. The energy demand (E_{dem}) was assumed to be 9.26 GJ caput^{-1} for the rural population, and 6.13 GJ caput^{-1} for the urban population [7,21]. Data for the per capita energy demand in different countries are available from the International Energy Agency Key World Energy Statistics 2012 (data for 2010) [22]. However, numbers are available for less than half of the countries included in the analysis, and the countries with figures given tend to be the richer countries with higher per capita energy demand resulting in an average energy demand across all countries of 32.62 GJ caput^{-1}. Therefore, in order to provide a consistent approach across countries, the more general values provided by Barnes et al. [7] were assumed. The size of the urban and rural populations ($n_{pop,\ urban}$ and $n_{pop,\ rural}$) was obtained from United Nations, Department of Economic and Social Affairs, Population Division [15]. The percentage of the total energy demand that is supplied by woodfuel (P_{wood}) was calculated for the urban and rural populations assuming that 100% of the rural population and 75% of the urban population use woodfuel for cooking [8];

$$P_{wood} = \frac{\left(n_{pop,rural} + \left(0.75 \times n_{pop,urban}\right)\right)}{\left(n_{pop,urban} + n_{pop,rural}\right)} \quad (3)$$