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Composting, anaerobic digestion and biochar production in Ghana. Environmental–economic assessment in the context of voluntary carbon markets

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ABSTRACT

In some areas of Sub-Saharan Africa appropriate organic waste management technology could address development issues such as soil degradation, unemployment and energy scarcity, while at the same time reducing emissions of greenhouse gases. This paper investigates the role that carbon markets could have in facilitating the implementation of composting, anaerobic digestion and biochar production, in the city of Tamale, in the North of Ghana. Through a life cycle assessment of implementation scenarios for low-tech, small scale variants of the above mentioned three technologies, the potential contribution they could give to climate change mitigation was assessed. Furthermore an economic assessment was carried out to study their viability and the impact thereon of accessing carbon markets. It was found that substantial climate benefits can be achieved by avoiding landfilling of organic waste, producing electricity and substituting the use of chemical fertilizer. Biochar production could result in a net carbon sequestration. These technologies were however found not to be economically viable without external subsidies, and access to carbon markets at the considered carbon price of 7 EUR/ton of carbon would not change the situation significantly. Carbon markets could help the realization of the considered composting and anaerobic digestion systems only if the carbon price will rise above 75–84 EUR/t of carbon (respectively for anaerobic digestion and composting). Biochar production could achieve large climate benefits and, if approved as a land based climate mitigation mechanism in carbon markets, it would become economically viable at the lower carbon price of 30 EUR/t of carbon.

1. Introduction

This paper presents a research into the economic viability of composting, biochar production and anaerobic digestion (AD) in an African context. Organic waste can be a resource for energy production, nutrient recycling and soil restoration. However it is also a source of greenhouse gases (GHG) harmful to the global climate, if left to decompose anaerobically in non sanitary landfills. In Sub Saharan Africa the decomposition of organic waste in open landfills is estimated to be responsible for 6.8% of Africa's GHG emissions, and expected to keep rising with the economic development of the region, although various technologies can be used to process organic waste and reduce these emissions (Barton et al., 2008; Couth and Trois, 2010a). This paper discusses the environmental impacts of three organic waste management systems and their benefits from a life cycle perspective. Furthermore it aims at evaluating how the access to finance from carbon trading can support their implementation. The research is based on a case study from the peri-urban area of the rapidly growing city of Tamale in Ghana, an area where soil degradation is a major development issue (Al-Hassan and Poulton, 2009; Alfsen et al., 1997; Cofie et al., 2009; Derbile, 2010; Quaye, 2008; Songsore, 1996) and energy scarcity leads to daily blackouts.

1.1. Composting and AD for sustainable MSW management

Most of the research on waste management in Sub Saharan Africa advocates composting as an appropriate technology for management of the organic fraction of municipal solid waste (MSW) in Africa, for its GHG abatement potential, low technical complexity and low capital requirements (Barton et al., 2008; Couth and Trois, 2010b; Couth and Trois, 2012). AD is also

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considered a particularly suited technology for the African context for the same reasons (Boyd, 2012; Mohammed et al., 2013a). Furthermore composting has been identified as an especially beneficial solution for the North of Ghana, where Tamale is located, because of its potential contribution to nutrient cycling (Cofie et al., 2009; Drechsel and Kunze, 2001) and soil restoration (Blench, 2007; Derbile, 2010) and many have suggested AD as a feasible renewable energy technology with high GHG abatement potential in Ghana (Arthur et al., 2011; Mohammed et al., 2013b; Ofori-Boateng et al., 2013; Wikner, 2009).

However the real benefits for climate change mitigation of these technologies must be evaluated from a life cycle perspective, looking at indirect impacts caused by their implementation in a pre-determined geographical context. The net GHG abatement potential of composting and AD has in fact been found to be influenced to a large extent by site specific factors like transportation distances (Lundie and Peters, 2005; Peters and Rowley, 2009), final use of the compost (Boldrin et al., 2009; Couth and Trois, 2012a), alternative sources of energy (Friedrich and Trois, 2011; Sonesson et al., 2000) and process energy use and process emissions (Butler and Hooper, 2010; Edelmann et al., 2000; Peters and Rowley, 2009). Just a handful of studies nonetheless assess the benefits for GHG abatement of composting and AD referring specifically to the context of developing countries (Aye and Widjaya, 2006; Barton et al., 2008; Boyd, 2012; Friedrich and Trois, 2011, 2013; Nzila et al., 2012; Salum and Hodes, 2009). No Ghanaian case study has been found in peer-reviewed literature, although in gray literature Wikner (2009) does provide an extensive GHG footprint of alternative waste management options for the city of Kumasi in Ghana. Following the indication by Barton et al. (2008) and Friedrich and Trois (2011) that more studies are required to evaluate these benefits in specific African urban areas, this paper aims to quantify GHG reductions from composting and AD in Ghana and specifically in Tamale.

The economic viability of these two technologies varies according to local conditions, too, i.e. land cost, distances to be covered by waste and fertilizer transportation, compost demand and electricity price. Different studies have found them to be viable in developing countries (Aye and Widjaya, 2006; Zurbrugg et al., 2002) or barely feasible, depending on revenues from carbon markets and feed-in tariffs (Couth and Trois, 2012b; Salum and Hodes, 2009). Danso et al. (2006) assessed the willingness of Ghanaian farmers in different cities to pay for compost from MSW and found that based on production and transport costs only farmers in the range of 35 km from a composting station would be able to benefit from it, and that the willingness to pay in Tamale was on average 10 times higher than in other Ghanaian cities. Nonetheless their research shows that compost production would require subsidies to be viable. To our knowledge no other study presents a detailed economic assessment of composting and/or AD in Ghana.

1.2. Biochar production

Biochar is another technology in the field of organic waste management that shows potential for agriculture and climate change mitigation. Biochar is charcoal, produced with pyrolysis of biomass. It is at the same time an extremely stable way of sequestering carbon and, in certain conditions, a powerful soil ameliorant (Lehmann et al., 2006; Woolf et al., 2010), so it could be a very effective way of using farmland as carbon sink, while at the same time improving its productivity.

The production of biochar was included in the environmental and economic assessment of organic waste management system in Tamale because of the high potential of biochar in tropical sandy acidic soils (Duku et al., 2011; Maraseni, 2010), like those of Northern Ghana, and in order to evaluate whether co-producing biochar and compost, two organic soil amendments with the same market, could create economies of scale through logistic and management synergies and improve the economic performance of both. Biochar is already being tested in the region by NGOs reporting very positive impact on crop yields (Abokobi Society Switzerland, 2013).

Although pyrolysis is suited for producing energy and fuel from MSW (Li et al., 1999; Malkow, 2004; Yufeng et al., 2003) no literature sources have been found reporting agricultural tests of biochar produced from MSW. Only one study (Ibarrola et al., 2012) explored its GHG footprint with an LCA focused on the U.K. context. In this research biochar is therefore considered to be produced from rice husks, the currently unused waste of Tamale's rice mill, as many studies have suggested the technical feasibility and agricultural benefits of biochar production from this feedstock (Haefele et al., 2011; Islam and Ani, 2000; Lehmann et al., 2006; Ogawa and Okimori, 2010; Shackley et al., 2012a; Woolf et al., 2010). The only economic assessment of biochar focusing on the African context is found in Scholz et al. (2014), who analyzes two scenarios from Senegal and Kenya also from an LCA perspective. Sparrevik et al performed an LCA of biochar based in Zambia (2013) and another one based in Indonesia, together with a societal cost benefit analysis (2014). Shackley et al. (2012b) performed an economic and GHG assessment of biochar production from rice husks in Cambodia, while all other studies focus on industrialized countries (Field et al., 2013; Galinato et al., 2011; Gaunt and Lehmann, 2008; Ibarrola et al., 2012; Roberts et al., 2010). In general GHG balances of biochar systems show high potential for carbon sequestration, although the extent of the net benefit depends on a number of case-specific factors, such as considered baseline (Ibarrola et al., 2012; Roberts et al., 2010; Shackley et al., 2012b), type of feedstock used (Roberts et al., 2010) especially in developing countries, technology used (Field et al., 2013; Sparrevik et al., 2013). For biochar, even more than for composting and AD, economic viability seem to require the access to revenues from the sales of carbon credits in developing (Pratt and Moran, 2010; Shackley et al., 2012b; Scholz et al., 2014) as much as developed countries (Field et al., 2013; Galinato et al., 2011; Roberts et al., 2010).

1.3. Carbon markets and organic waste management

Composting, AD and biochar production can abate GHG emissions in a number of ways: by avoiding methane formation in landfills, by producing renewable energy, by avoiding the use of mineral fertilizer and by sequestering carbon in agricultural soil, in the form of organic matter (organic carbon) or biochar (elemental, or black, carbon). Not all these benefits can however qualify to be financially rewarded by carbon trading mechanisms, as accounting methodologies have only been approved so far for the former two (UNFCCC, 2010, 2011). The inclusion of soil carbon sequestration in carbon trading is being advocated for by a part of the scientific community (Whitman and Lehmann, 2009; Woolf et al., 2010 for biochar, Lal, 2004; Ringius, 2002; Vagen et al., 2005 for organic soil carbon sequestration) and do exist in some specific carbon markets outside the CDM (American Carbon Registry, 2013; Australian DoE, 2013; Verified Carbon Standard, 2013). Nowhere to our best knowledge can carbon offsets be generated for recycling of nutrients by producing organic fertilizer from waste (Couth and Trois, 2012a). In this study, besides methane avoidance and renewable energy, the economic assessment also considers carbon credits for biochar sequestration. Biochar projects do not yet qualify for carbon crediting under any scheme, although the American Carbon Registry is currently working on a methodology for this kind of intervention (ACR, 2013).