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Ecosystem services trade-offs from high fuelwood use for traditional shea butter processing in semi-arid Ghana

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ABSTRACT

Traditional production of shea (*Vitellaria paradoxa*) butter uses large amounts of fuelwood. This study examines the effects of shea production on the environment by identifying the ecosystem service trade-offs due to the high fuelwood consumption. Fuelwood species inventories for different land use types and on-site plot-based standing biomass measured. We estimate greenhouse gas (GHG) emissions and changes in carbon stocks for different shea products in rural and urban settings. Results suggest that, processing of shea can cause a significant change of carbon stocks in the four study villages and result in the loss of carbon sequestration ecosystem services. For GHG emissions, rural shea butter processors emit 3.14–3.31 kg CO_2 eq/kg shea butter, while urban processors emit slightly less (2.29–2.54 kg CO_2 eq/kg shea butter). We identify trade-offs with several other provisioning (woodland products), regulating (erosion control) and cultural ecosystem services (religious and spiritual values). Such findings can initiate discussions about the hidden environmental and socioeconomic costs of current shea production practices. Potential strategies to enhance the sustainability of shea production include the adoption of improved stoves, sustainable fuelwood harvesting practices, parkland management, alternative fuels, and product pricing premiums to fund the adoption of cleaner shea processing technologies.

1. Introduction

The importance of traditional biomass fuels such as fuelwood and charcoal in meeting the energy needs of most rural households in developing countries cannot be overemphasized (Food and Agriculture Orgaganizxation (FAO), 2016; Zulu and Richardson, 2013). Fuelwood also contributes greatly to food preservation and livelihood activities in rural and urban settings (FAO, 2010). For example, more than 2.2 million families in Ghana (40% of the total population) depend on fuelwood for cooking and heating (Peprah, 2010). At least 280,000 of these households also use fuelwood for livelihood activities such as smoking fish, making gari (cassava grits fried into small granules and then eaten directly or processed), brewing pito (alcohol made from fermented millet), firing pottery, and extracting oil (from oil palm, coconuts, groundnuts, and shea) (Kwarteng, 2015).

At the same time, deforestation due to growing fuelwood and charcoal use can be a major threat to biodiversity and the provision of ecosystem services, especially in semi-arid landscapes (Adkins et al., 2010; Peprah, 2010; Chidumayo and Gumbo, 2013). Greenhouse gas (GHG) emissions related to deforestation can be as much as 20% of anthropogenic emissions (Gullison et al., 2007; Smith et al., 2014).

Ghana currently experiences a high rate of deforestation possibly having lost as much as 1.99–2.19 % of forest cover annually over the past decades, even though these numbers can be uncertain (Pouliot et al., 2012; Hansen et al., 2009). However, forest loss continues unabated every year despite promoting re-afforestation policies, planting new forests, and creating forest reserves (Oppong-Anane, 2006; Oduro et al., 2015). Additionally, timber exports are high, fuelwood consumption practices are highly inefficient, and ever-harsher weather conditions cause poor forest regrowth and regeneration (Powell et al., 2010; Hawthorne et al., 2011). These contributed singinficantly to Ghana not being able to meet Millennium Development Goal 7 (MDG7) on environmental sustainability (UNDP, 2015).

Reducing fuelwood and charcoal-driven deforestation is a particularly intractable issue in poor rural contexts, where populations are highly dependant on ecosystem services for their

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livelihoods (Adkins et al., 2010; Ros-Tonen and Wiersum, 2005; Wunder et al., 2014; Belcher, 2014; Woollen et al., 2016). This can be a particularly important challenge for Ghana given the ongoing importance of forest resources to most rural households (Appiah et al., 2009; Pouliot and Treue, 2013). However, the direct and indirect environmental impact of fuelwood/charcoal demand for value-added processing of non timber forest products (NTFPs) has rarely been explored in developing countries (Ros-Tonen et al., 2014).

The shea fruit (*Vitellaria paradoxa*) is such a NTFP that depends on fuelwood for its transformation into value-added products such as food (shea butter), edible oil, and raw materials for cosmetics and pharmaceuticals (Lovett and Haq, 2000; Carette et al., 2009; Elias and Carney, 2007). The export of raw shea kernel and shea butter ("*karite*" in French) to international markets in Europe, Asia, and the United States has increased in recent years (Elias, 2015; Jasaw et al., 2015; Ghana Export Promotion Authority [GEPA], 2014; Bello-Bravo et al., 2015). Countries who import shea products subsequently process them into a wide range of food products (including chocolate) and cosmetics (Schreckenberg et al., 2006).

For these reasons, the shea tree is highly valued by rural households in Western and Central Africa. It currently grows throughout northern Ghana (CRIG, 2007; Naughton et al., 2015), with almost every rural household in the region engaging in shea fruit picking, and processing into shea kernels (shea nuts) and/or shea butter. Therefore, shea trees are selectively managed and protected on farmlands, which has resulted in nearly homogenous shea tree stands (Bello-Bravo et al., 2015). Shea is considered a "female crop" as women predominately collect shea fruits (Elias and Carney, 2007; Boffa, 2015). As a result, most of the shea-related research focuses on how shea production alleviates poverty for rural women, generates employment, and commands a high export value (Chalfin, 2004; Elias and Carney, 2007; Lovett, 2010; Pouliot, 2012; Boffa, 2015; Bello-Bravo et al., 2015).

When it comes to environmental impact, Glew and Lovett (2014) argue that shea is less harmful compared to other vegetable oils such as oil palm. However, few empirical studies have examined the environmental effects of resource consumption during shea processing (Jibreel et al., 2003; Lovett, 2010; Naughton et al., 2017). In particular the high fuelwood consumption during shea processing has been shown to account for at least 74.5% of the carbon footprint of shea butter in cosmetics sold in the United Kingdom (Glew and Lovett, 2014). Recent studies in northern Ghana show that approximately 1.7–2 kg of fuelwood is needed to produce 1 kg of shea butter from raw kernels (Mohammed and Heijndermans, 2013; Jasaw et al., 2015).

However, high fuelwood input for the production of shea butter could have implications beyond direct GHG emissions (Glew and Lovett, 2014). For example, the extraction of fuelwood species from savanna landscapes could exacerbate the high rate of land degradation and desertification already witnessed in the area (Naughton et al., 2017). Fuelwood extraction for shea processing could also exacerbate the loss of habitat, biodiversity, and ecosystem services such as nutrient and micro-climate regulation in areas that already experience such trends (Tom-Dery et al., 2014; Lolig et al., 2014).

The aim of this study is to identify the main ecosystem service trade-offs of shea production in order to facilitate a better understanding of its effects on the environment and rural livelihoods. We mainly focus on how fuelwood use throughout the shea processing chain can affect carbon sequestration. We also quantify the direct GHG emissions of shea processing and provide a rapid assessment on potential effects to other ecosystem services. We focus in rural northern Ghana to illustrate the main effects of high fuelwood consumption in a setting with highly degraded biomass resources and a low regeneration potential for key fuelwood species.

2. Methodology

2.1. Study location

Shea production in Ghana is concentrated in the Upper West, Upper East, and Northern regions. These regions are located within the Guinea Savannah Ecological region, which is dominated by grass and tree species including the shea tree (*V. paradoxa*), various species of acacia (*Acacia farnesiana*), baobabs (*Adansonia digitata*), mahogany (*Khaya senegalensis*), neem (*Azadirachta indica*), mango (*Magnifera indica*), and various fire-resistant tree species. There is a marked change in the plant life of this vegetation zone between the two main seasons of the year (average annual rainfall = 900–1100 mm) (McSweeney et al., 2010). The area is verdant during the rainy season, but the grass dries and most of the deciduous trees shed their leaves during the dry season (harmattan). The dry season also marks harsher weather conditions and rampant bushfires.

Study sites were selected in both urban and rural settings considering their different resource requirements for shea kernel/butter production (Jasaw et al., 2015) (Fig. 1). Urban sites were the major cities of the region, Tamale (Northern Region) and Wa (Upper West Region). Rural sites were the villages of Kpalgun and Zagua (Tolon District, Northern region), and Zowayeli and Baleufili in (West District, Upper West Region). These specific villages were selected because they engage in typical shea processing activities prevalent throughout the shea growing regions of Ghana.

Subsistence farming is the principal livelihood activity in the four study villages. Agroforestry parks and forests outside forest reserves (usually sacred groves) are mostly common pool resources used for the unrestricted harvesting of timber for fuelwood and NTFPs such as shea fruit. Females from every household in the study villages are engaged in shea activities during the shea season (May–August).

Finally, land degradation in all four villages is widespread as only a few dispersed, selectively preserved trees remain. Increased land degradation in the study sites has been attributed in recent years to climate and ecosystem change (Kusakari et al., 2014). Other livelihood activities such as firewood harvesting, charcoal production, farm clearing, stone quarrying, and construction have further modified and degraded the landscape.

2.2. Data collection and analysis

2.2.1. Overall approach

The overall methodology consists of eight different but interrelated steps. These involve land use classification (Step 1–2) (Section 2.2.2), carbon stock estimation (Step 3–4) (Section 2.2.3), quantification of fuelwood use for shea activities (Step 5) and its impact in terms of carbon stock change (Step 6), GHG emissions (Step 7) and trade-offs with other ecosystem services (Step 8) (Section 2.2.4). For Step 1–6, we used the IPCC principles to estimate carbon stock change and GHG emissions from land use and cover change (IPCC, 2014), modified where necessary to fit the specific context of our study. Primary data was collected in 2014 (May–June) and 2015 (February, and July–August) (see Sections 2.2.2–2.2.4 for more details on type and method of data collection).

The results were synthesized using the conceptual framework of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015). In this framework fuelwood harvesting for shea production can be considered as a direct driver