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System wide impacts of fuel usage patterns in the Ethiopian highlands: Potentials for breaking the negative reinforcing feedback cycles

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ABSTRACT

Due to scarcity of firewood, farmers in rural Ethiopia are forced to use cattle dung as a complementary energy source. By looking at patterns of firewood and cattle dung use for energy generation and their implications for food crop production, forest regeneration and community level emission reduction potentials, this study explores system interactions using a community living next to the Menagesha Suba state forest in Ethiopia as a case study. Mixed methods were used including household surveys, nutrient content analyses of firewood and cattle dung, and calculations of fuel and emission reductions for four cooking energy efficiency scenarios. It was found that the community and surrounding environment is stuck in a negative feedback cycle. Therefore shifts in current practices and systems are needed to break this cycle, for example by enhancing firewood supply, improving soil fertility, improving energy efficiency and enabling access to carbon financing for emissions reduced.

Introduction

Nearly three-fourths of Ethiopia's population, which is now around 87 million (UN, 2013), depends on biomass fuels (MoFED, 2007). The dependency on biomass fuels among the rural population is as high as 90% (Kumie et al., 2009). This high dependency is largely due to limited access to other alternative energy technologies in rural Ethiopia (Wolde-Ghiorgis, 2002) and the low cost of traditional biomass, often being one of the cheapest fuels available per unit energy in developing countries (Ryan, 1994) and collected for free in many areas (Schlag and Zuzarte, 2008).

Although forests are one of the main sources of firewood in Ethiopia they have receded severely over the past number of decades (Reusing, 1999). According to the Ethiopian Forestry Action Programme (EFAP) (1994), forests covered around 16% of the country in the 1950s dropping down to 2.7% in 1989 (prior to the 1950s estimates for forest cover have been much higher, up to around 65%, but with no specific reference year for these estimates (Berry, 2003)). The highland areas have particularly been affected with their forest cover reduced to as low as 5.6% from about 20% in 1950s (Berry, 2003). The major driver behind this drastic decline has mostly been attributed to human impact (Reusing, 1999). With a national population growth rate of 2.68% (calculated between 2005 and 2010; UN, 2013), more than twice the global rate of 1.20% over the same period (UN, 2013), population continues to grow at a steady rate. This combined with limited firewood availability is resulting in increased pressures on both land and forest resources.

Firewood resource availability in Ethiopia has been an ongoing challenge for many decades. To address this, in the 1890s efforts were made by the emperor in power at that time to reduce firewood scarcity by introducing and promoting the species *Eucalyptus globulus* Labill and *Eucalyptus camaldulensis* Dehnh to be planted by farmers in plantations (Ayana et al., 2013). This initiative gained significant traction due to the resulting increased firewood supply with plantations being grown across many parts of the country. Though the planting of the two above-mentioned fast growing tree species significantly reduced firewood scarcity, farmers have now been discouraged from planting them, especially in and around their farmlands, due to the perceived negative impacts of the trees on crop yield through potential allelopathic effects (Kidanu et al., 2004; Lisanework and Michelsen, 1993). This government initiative to stop eucalyptus planting was implemented with no provision for alternative plantation species resulting in decreased firewood supply with limited amounts of eucalyptus planting continuing only at farm borders (Kidanu et al., 2004) and on degraded lands. The reduction of planting the above-mentioned species combined

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with the lack of substitute species for the farmers has aggravated the firewood scarcity among rural communities.

The decline in forested areas is mainly caused by the conversion of forests into farmlands (Fig. 1). As land gets scarce, agricultural activities on farming parcels increase leading to severe land degradation (Tadesse, 2001) due to lack of fallowing. This then creates pressure to cultivate more areas. One strategy to address such degradation, which is being used by many local communities in different parts of Ethiopia, is the use of animal waste and crop residues as fertilizer. However, in the central highlands, animal waste (mostly cattle dung) is instead used for energy, whereas crop residues are used for animal feed and mud wall construction. To address the strong deficiency of nitrogen (N) and phosphorus (P) minerals in the soils of the highlands of Ethiopia farmers are obliged to use chemical fertilizers like Urea (containing 46% N) and DAP (*Diammonium phosphate*; containing 18% N and 46% P) to fertilize farmlands to boost crop production. At times, when there are supply shortages of these chemical fertilizers or farmers lack the financial capital to purchase them, crop yield declines and food shortages become more severe, while communities burn nutrient rich cattle dung due to firewood scarcity. The linkages between resource use, forests, energy supply and demand, and food production are outlined in Fig. 1. Resulting impacts on climate change are also included.

The extreme forest reduction and impacts on energy supply due to limited firewood availability have been the subject of many academic inquiries (e.g. Beyene and Koch, 2013; Guta, 2011; Mekonnen, 1999). Discussion about firewood in Ethiopia has mostly revolved around its energy potential and impacts on energy availability due to land conversion (e.g. Wolde-Ghiorgis, 2002) with some efforts also focusing on interventions for greenhouse gas emission reductions (e.g. ADP, 2012; Beyene and Koch, 2013; Mekonnen, 1999), yet the links between firewood scarcity and crop productivity has remained unexplored. To address this gap, this study explores interacting system dynamics by looking at firewood and cattle dung use for energy generation and the implications for food crop production, forest regeneration and community level carbon dioxide (CO_2) reduction potentials using a community living next to the Menagesha Suba state forest in Ethiopia as a case study. To examine these interactions this study explores the following questions:

1. What are the fuel use patterns in the study community, especially with regard to the farmer proximity to the state forest?
2. What implications do fuel collection patterns combined with fuel demand have for nutrient cycling, and thereby forest regeneration and crop productivity?
3. What are the potential fuel and CO_2 emission reductions that could occur using stoves with improved efficiencies or renewable energy sources, under four hypothetical scenarios and what are these interventions' potential impacts on nutrient cycling and energy availability?

By exploring these questions a more detailed picture of the interacting systems in the central Ethiopian highlands emerges with implications for fuel supply, food security and climate change mitigation.

Materials and methods

The study was conducted in the Menagesha Suba area located in central Ethiopia (Fig. 2). It is situated between 8°56′–9°00′ N and 38°31′–38°35′ E and has an average altitude of 2330 m above sea level. A state forest covering 3530 ha composed of both natural (~70%) and plantation (~30%) forests is located in the area. The community living in and outside the state forest has relied on the forest for centuries for various forest products (e.g. construction wood, firewood, fencing materials and traditional medicines). Except for the state forest, there are no other forests or woodlands in the area.

Farm households in the area were classified into three categories: insider farmers (A), border farmers (B) and far outsider farmers (C) (hereafter insiders, border farmers and far outsiders, respectively) depending on their proximity to the state forest (Fig. 3). Insiders live inside the area delineated as the state forest; border farmers live adjacent to the forest boundary up to 1.7 km distance from it; and far outsiders are those residing between a 1.7 and 3.4 km distance from the forest boundary. Insiders are temporary workers of the state forest and solely rely on the state forest for provision of natural resources as they own no land. Both border farmers and far outsiders can legally collect fallen branches from the forest which have not been previously harvested by insiders or the forest managers. Due to greater transport distances far outsiders do

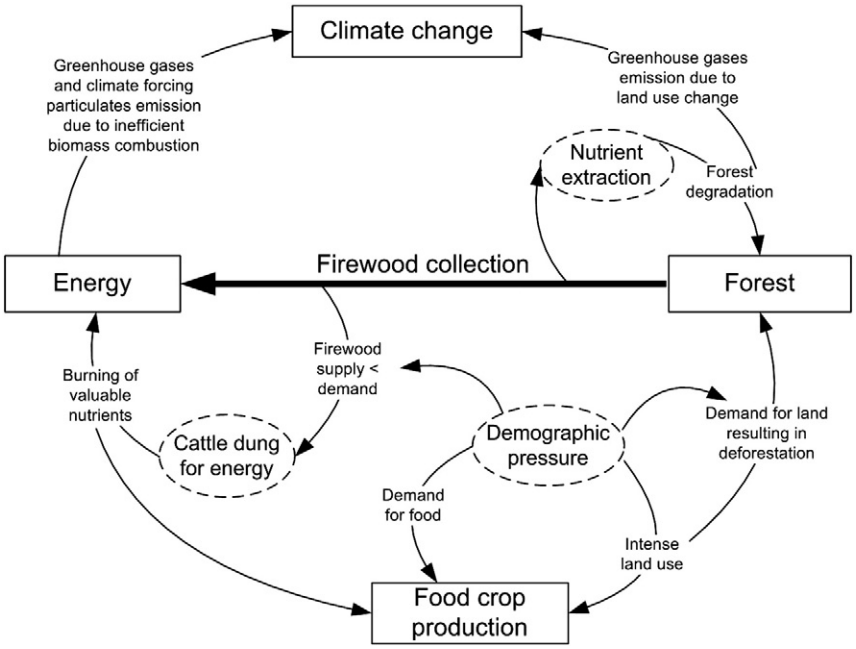

Fig. 1. System interactions in the Menagesha Suba area focusing on the links between forest, energy needs, food crop production and climate change.