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Review

Forests, water and food security in the northwestern highlands of Ethiopia: Knowledge synthesis

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ABSTRACT

This paper synthesizes the spatial and temporal relationship between forest cover and water, as well as its implications for food security in the northwestern highlands of Ethiopia. Different studies addressing the topic of land cover and hydrology have been reviewed. Analyses of 20–40 year long time series showed little and inconsistent relationships between forest cover change and hydrology on meso-scale (100–1000 km^2) watersheds. Spatial studies, however, showed stronger relationships between land cover and low flow features such as grasslands and woodlands. Interviews with local communities suggested land cover change impacts are more pronounced at smaller scale (<100 km^2) watersheds; which is consistent with observational studies on small scale watersheds and farm level plots. The stronger relationships between forests and hydrology at smaller scales suggests land management policies should be oriented to farm level conditions, where water is vital for the food security of subsistence farmers who comprise 86% of the population in the highlands.

1. Introduction

Land degradation and seasonality of rainfall are critical water management challenges for influencing the food security status (FAO, 2011) in areas like the highlands of Ethiopia. Land degradation has been intensifying because of the inappropriate land use practices and the seasonality of the rainfall. Eighty-two percent of the annual rainfall falls during 3–4 months of the year (Conway, 2000), which can create erosive runoff. Farming activities, on steep slopes accompanied with the highly seasonal rainfall, has been exacerbating soil erosion (Haile et al., 2011). Annual soil loss in the highlands of the country is estimated to be 32 tons ha^{-1} yr^{-1} (Berry, 2003). In turn, decades of soil degradation has amplified the magnitude of seasonality in the water available for food production and reduced the fertility of the soil that is critical for the subsistence agricultural activity of a rapidly growing

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population (Zeleke and Hurni, 2001). Degraded soils are less forgiving for sub-optimal timing of the start – but especially the end of the rains (Mellander et al., 2013). The variability of the rainfall has been affecting the productivity of crops negatively for decades (Bewket, 2009).

The northwestern highlands of Ethiopia (Fig. 1) are supporting the livelihood of about 25 million people, who are predominantly agrarian (Population Census Commission, 2008). Water flow during the dry season is a critical constraint for both local water supply and subsistence agriculture. In the dry season, supplementary agriculture has been impaired because of lack of available water. The available water, which is governed by seasonality, is critical to the food security. Farmers can produce two or three times a year if water is sufficient throughout the year with both rain-fed and dry season irrigation practice. Otherwise, the production remains once a year being only rain-fed, which is also dependent on the intensity and pattern of the rainfall.

Not only the subsistence agriculture but also water resources at the transboundary level are influenced by the seasonal and spatial variability of available water (Bewket, 2009; Betrie et al., 2011; Mellander et al., 2013). Three large rivers (Abbay, Tekeze and Baro-Akobo) from the northwestern highlands are flowing toward Sudan to join the Nile proper. The Abbay River alone contributes more than 60% of the Nile water reaching Egypt. The Abbay and the other two rivers (Baro-Akobo and Tekeze) contribute about 85% of the water in the Nile at Aswan. Because of the high contribution of water to the Nile, this area has been the focus of negotiation between the Nile riparian countries. Changes in the river flows of this region, such as those attributed to forest cover are thus of great international interest.

Forest cover change could influence both river flows and soil water (Giambelluca, 2002). The northwestern Ethiopia has been experiencing forest cover change for centuries in the

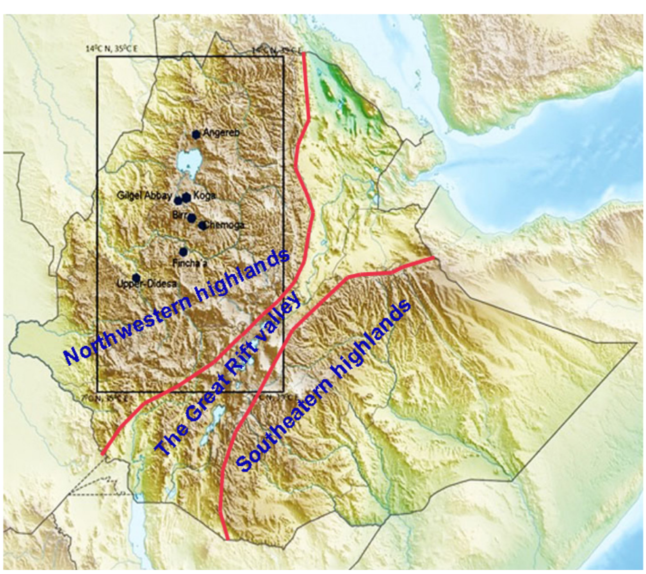

Fig. 1 – Location of the northwestern highlands of Ethiopia (rectangle) and the 7 gauge stations for watersheds where both forest cover change and hydrological change studies have been conducted simultaneously (dark dotted).

form of deforestation and new plantation (Darbyshire et al., 2003; Gebrehiwot et al., 2014b). There is an interest in increasing forest cover not only for the sake of ecosystems services, but also for economic value of the trees (FDRE, 2011). It is therefore important to be able to analyze and predict the impact of forests on the water regime.

Forests are seen as a tool for better management of the water resources which can counteract land degradation and seasonality of available water. Such views are the basis for some of the integrated water resources management policies of the country (Ministry of Water Resources, 2001). This view is backed by the belief that deforestation has contributed to reduction of low flow (Gebrehiwot et al., 2010). However, the variability and differences at the scale of watersheds, rainfall, geology, soil, vegetation and anthropogenic influences do not allow the simple conclusion that afforestation will help in sustaining available water (Bruijnzeel, 2004; Ellison et al., 2012). Scale of watersheds, differences in forest management, species composition and type of forest changes are factors contributing to a relationship between forests and water resources that is anything but simple (Giambelluca, 2002).

There are a number of different reviews and studies on the relationship between forest and water from different parts of the world, including the tropics (Hibbert, 1967; Bosch and Hewlett, 1982; Bruijnzeel, 1993, 2004; McCulloch and Robinson, 1993; Andreassian, 2004). The common conclusion from these studies is that there is often an increase of water yield after forest harvest which attenuates over the course of several years as the vegetation cover is re-established (both in temperate and tropical areas). An increase in the frequency of high flows after harvest is also commonly reported. Forest cover change effect is less predictable when the change is different from clear cutting (harvest); like forest degradation, logging or selective thinning. There is also a hysteresis to be considered when forests are re-established. The length of time without forest cover has been identified as particularly important due to the influences of soil properties (Malmer et al., 2010). In addition, effects on total flow and high flow are better understood than low flows (Eisenbies et al., 2007; Cui et al., 2012). Part of the difficulty in predicting low flows is the low accuracy of low flow measurement (Ratto et al., 2007), which could contribute to the complexity of the observed responses. High flows are also difficult to measure, but it is important to remember that it is the frequency of high flows which increases, with less certainty about the magnitude of the highest flows. These studies also indicated that forest development can augment baseflows in degraded areas; where forests help the development of organic matter and by then increasing the water storage capacity of the soil (Roberts et al., 2005). So, there is difficulty in generalizing about the specifics of forest cover influences on the hydrological regime, and thus the need to gather regional data.

The goal of this knowledge synthesis is to summarize both what is known and key knowledge gaps; with a focus on the situation for forests, water and food security in northwestern highlands of Ethiopia. The most detailed review comes from three different meso-scale watersheds (Figs. 1, 3) – Gilgel Abbay, Birr and Upper-Didesa. Studies from other watersheds – Angereb, Maybar, Anjeni, Koga, Ribb, Gumera, Guder, Muger, Fincha, and Chemoga are also synthesized. Observational