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Prospects for forest-based ecosystem services in forest-coffee mosaics as forest loss continues in southwestern Ethiopia

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A B S T R A C T

When natural ecosystems are degraded owing to land-use changes, humans will increasingly rely on managed landscapes for biodiversity and ecosystem services. In landscapes with ongoing forest–agriculture transitions and agricultural intensification, we need to understand the impact of land-use changes on ecosystem service provisioning and the relative roles of remnant forests and managed landscapes in ecosystem service delivery. Using socio-ecological surveys in southwest Ethiopian agroecosystems, we assessed the impact of land-use changes on forest-based ecosystem services and livelihoods, and the prospects for coffee agroforests to provide complementary forest-based ecosystem services. We found that over 67% of provisioning and <50% of cultural and regulating forest-based services can be provided by semi-forest and garden coffee systems. Most forest-based cultural, regulating and supporting services cannot be substituted in coffee agroforests since these services are largely concentrated in the forest remnants. The extent to which people substitute or complement those losses in coffee agroforests depends on the livelihood strategies and socio-cultural practices of local people, management intensity, and policy and demographic factors that affect agroecosystem intensification.

Introduction

Tropical deforestation and conversion into agricultural landscapes degrade rich biodiversity and ecosystem services vital to livelihoods. Ecosystem services are products of ecosystem functions and processes in natural and managed ecosystems through which biodiversity and human life are sustained (Costanza et al., 1997; Millennium Assessment, MEA, 2005). Forest-based ecosystem services are directly available as products derived from and within forests and those that indirectly support other production landscapes. The direct services provided by forests include provisioning services (timber, fiber, bioenergy, grazing, clean water, and traditional medicines) and socio-cultural benefits (ritual services, esthetic, and ecotourism). Other forest services include regulating and supporting services. Regulating services include erosion and landslide control and regulation of water, air, drought, disease, and climate. Supporting services from forests include pollination, nutrient cycling, and sources of propagules for shade and agroforestry trees, biocontrol of agricultural pests, carbon sequestration and biodiversity conservation (Jose, 2009; Power, 2010).

Human activities such as logging, deforestation and land-use changes are diminishing biodiversity and ecosystem services globally (Foley et al., 2005; Tengberg et al., 2012). When forest ecosystem services decrease following deforestation, people will inevitably rely more on goods and services from working landscapes such as coffee agroforests, home-gardens, and plantations (Jose, 2009; de Beenhouwer, Aerts, & Honnay, 2013). Agroforests that are managed to allow natural regeneration of species can support biodiversity and other tree-based ecosystem services such as fiber, fodder, nutrient cycling, and pollination (Jose, 2009; Pfund et al., 2011; Scales & Marsden, 2008). Ecosystem services from agroforests (agroecosystem services) can reduce overexploitation of forest resources or serve as complementary sources for forest services (Porter et al., 2009). People can promote agroecosystem services through management that increases native species diversity, or through substitution of lost forest services with new ecosystem service providers in their managed lands (Cerdan et al., 2012; Jose, 2009; Power, 2010; Swift, Izac, & van Noordwijk, 2004).

Southwest Ethiopian forests are home to various ecosystem services including forest coffee, honey, spices, construction materials, and ritual services. Intimate human–forest interactions occur

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due to the high degree of dependence on these forest-based ecosystem services. These forests are believed to be the origin and primary center of diversity of Arabica coffee where coffee is still grown in the wild and contains a highly diverse gene pool (Aerts et al., 2013). However, many of these forests have already been converted to agricultural landscapes, or the remnant forests are managed to produce semi-forest coffee, and a more intensive garden and plantation coffee systems (Table 1; Senbeta & Denich, 2006; Tadesse, Zavaleta, & Shennan, 2014; Wiersum, 2008). The semi-forest and smallholder coffee are cultivated under native forest canopies through planting coffee seedlings and allowing natural regeneration of coffee plants and clearing the understory vegetation (Hundera et al., 2013; Senbeta & Denich, 2006). The plantation coffee has been managed by state enterprise, and more recently small-scale investors intensively managed to increase yield of coffee and other agricultural products (Tadesse, 2013). We consider plantation coffee as more intensified due to reduced shade tree species diversity and cover, use of agrochemicals, and intensive management of understory shrubby and herbaceous vegetation in these plantations. In this region, woody species richness declines by about 34% if forests are converted into semi-forest coffee and by an additional 37% or more if semi-forest coffee systems are intensified into plantation coffee systems (Tadesse, Zavaleta, & Shennan, 2014).

Globally, the role of managed landscapes for providing ecosystem services has been given less attention despite growing interest in supporting biodiversity in agricultural landscapes (Calvet-Mir, Gomez-Baggethun, & Reyes-Garcia, 2012; Power, 2010). Apart from actual agricultural production in managed landscapes, there has been little examination on the ability of these landscapes to provide other ecosystem services formerly provided by natural ecosystems (Melo et al., 2013).

Although the impact of converting southwest Ethiopian forests into semi-forest coffee, and further intensification into plantation coffee systems has recently been studied (Hundera et al., 2013; Senbeta & Denich, 2006; Tadesse et al., 2014), little is known about the impact of such land-use changes on the availability of various ecosystem services. Thus, we need to address important questions about how well coffee agroforests can support human well-being either instead of or in addition to natural forests. To assess the potential of production landscapes for delivering different ecosystem services, we studied coffee-forest mosaics of southwest Ethiopia that maintain few of the last remaining biodiversity-rich natural forests of the nation, and that represent the last remaining major global wild habitat for *Arabica* coffee (Senbeta & Denich, 2006).

The assessment, planning and sustainable management of ecosystem services require identifying specific biodiversity components and associated ecosystem services vulnerable to land-use change and intensification (Vihervaara, Rönkä, & Walls, 2010). Some biodiversity components and associated ecosystem services can be more affected by land-use changes than others (see Metzger et al., 2006). Given continuing deforestation, we hypothesize that local people in southwest Ethiopia increasingly rely on traditional shade coffee agroforests for various forest-based ecosystem services although availability of these services vary in coffee agroforests depending on management and the type of ecosystem service in question. Here, we examined the potentials and limitations of coffee agroforests in sustaining forest-based ecosystem services in southwest Ethiopia.

Finally, the loss of forest-based ecosystem services following land-use changes may have variable impact on local people as a function of their degree of dependence on such goods and services. In southwest Ethiopia, we assume such dependence to correlate with the socioeconomic and cultural backgrounds of local people. We examined if specific socioeconomic groups (e.g. indigenous minorities, women, and the landless) were more vulnerable to the effects of deforestation and agroforest intensification than settlers and indigenous majorities.

Table 1
Deforestation and expansion of agricultural lands and plantations in Yeki and Decha regions between 1973 and 2010 (Tadesse et al., in press)

Area (ha)	Yeki		Decha	
	1973	2010	1973	2010
Forests	40981	19973	76491	54834
Cultivated/settlements	11012	18531	62668	77775
Coffee farms	9769	20709		2650
Coffee/tea plantations		2450		2600
Eucalyptus plantations		100		1300

Methods

Study area

Our study area included two regions with contrasting degrees forest and agroforest covers namely Yeki (604 km^2) and Decha (1390 km^2) (Fig. 1). Yeki district has more coffee plantations, less wild coffee forests, and less forest cover than Decha district. The Yeki district is found at 7.2° N, 35.3° E latitude and longitude respectively with population density of 236 persons/km^2. The population is composed of (1) settlers (42% of the total population) who came from other parts of Ethiopia mainly after the 1980s and who practice intensive cereal and garden coffee production, and (2) diverse indigenous groups who used to practice shifting cultivation and hunting-gathering in the past but currently adopted intensive cereal and coffee cultivation with the use of various non-timber products. Decha district and its surrounds are found between 6.15° and 8.8° N and 35.3° and 36.5° E latitudes and longitudes. The population of Decha with a density of 77 people/km^2 is 92.6% rural with more indigenous people (87% of total population) who harvest more forest products such as forest and semi-forest coffee, forest apiculture, and wild spices. The rates of forest cover losses in Yeki have been higher than in Decha between 1973 and 2010. Consequently, such deforestation resulted in the loss of 52% of Yeki forests and 29% of Decha forests (Table 1; Fig. 1).

Sampling villages, focus groups and households

In 2009–2011, we convened ten focus group discussions (FGD) in 10 villages with 6 villages in Yeki (25% of total) and 4 villages in Decha (13% of total). We selected villages to sample representative degrees of forest and agroforest cover around those villages. In each village, a focus group was composed of 10–15 key informants with varying gender, age group, and socio-cultural composition. Using systematic random samples of 105 households from indigenous and settler groups across the villages neighborhoods and selecting houses encountered to the left and right of our transects using semi-structured questionnaires (Martin, 1995, 268 pp.). The questionnaires were used to generate information about the forest-based ecosystem services, the purpose of collection, quantity collected in locally known units per year, land-cover type where it was collected, and distance traveled to collect. Households were asked to compare the current state of ecosystem services with the past which spanned from 15 to 40 years ago as long as the household can remember. We also collected coping strategies to mitigate any shortage of ecosystem services and associated income losses that resulted from the land-use changes.