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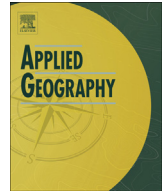
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Prospects for forest-based ecosystem services in forest-coffee mosaics as forest loss continues in southwestern Ethiopia



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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.

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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 over-exploitation 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.

Methods

Study area

Our study area included two regions with contrasting degrees forest and agroforest covers namely Yeki (604 km²) and Decha (1390 km²) (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/km². 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/km² 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.

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

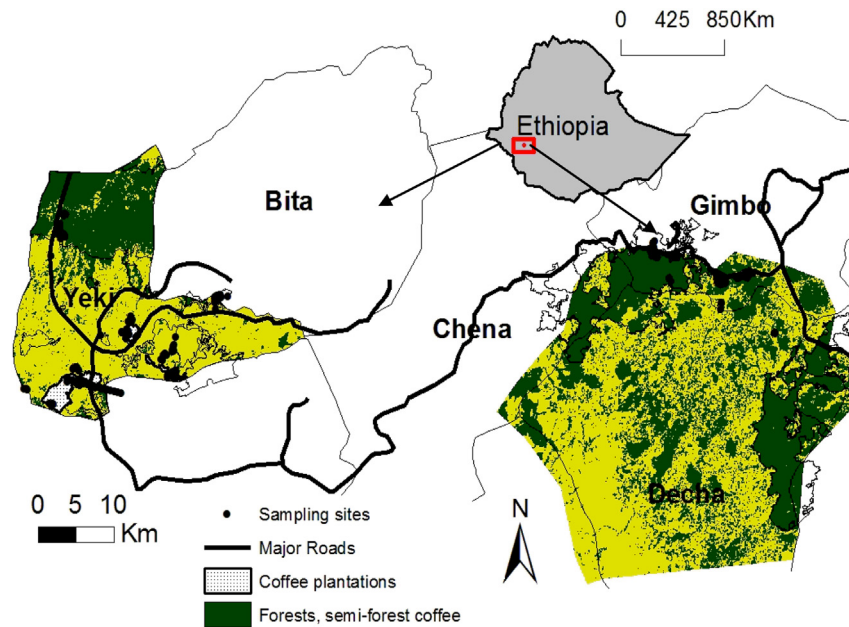


Fig. 1. Map of the study area in Yeki (left) and Decha (right) districts with non-forested areas (gray shaded) and forested areas (dark shaded).

The land-cover types were classified as (1) forests (unmanaged vegetation of >3 ha with trees above 5 m in height and canopy cover of more than 10%); (2) semi-coffee forests where coffee is cultivated under native forest canopies through planting coffee seedlings and allowing natural regeneration of coffee plants and by clearing the understory vegetation (Senbeta & Denich, 2006); and (3) garden coffee systems where naturally regenerating and nursery coffee plants are grown with other crops under native shade tree species (Wiersum et al., 2008), (4) plantation coffee. We also gathered field data reported by informants about ecosystem services from home-gardens, crop fields, grasslands and wetlands using field surveys.

In addition to the data from interviews and focus group discussions, we also recorded the availability and abundance of ecosystem services based on field ecological studies from 114 (20 m by 20 m) plots in 16 forests fragments and 79 (20 m by 20 m) plots in small-scale coffee agroforests and plantations. In each plot, we recorded the abundance of ecosystem services or their providers, mainly for wild/semi-wild coffee, spices, construction lianas, honeybee hives in the forests and coffee agroforests.

We used *F*-tests to compare the economic values of major ecosystem services between wild forests and coffee agroforests. We calculated ecosystem service use diversity from major land-use types using richness (*S*) and Shannon's diversity (*H'*) indices (Magurran, 1988) representing the number and diversity of distinct categories of ecosystem services described by local people. We used chi-square tests to compare ecosystem service use between land-use types and between the two districts.

Results

Forest fragments in southwest Ethiopia have higher ecosystem service richness where 85% of all forest-based ecosystem services described by local people were found in the landscape (richness, *S* = 44; diversity, *H'* = 3.0) (Table 2). Most of the fuel (74%), lianas (90%), and wild fruits and vegetables (65%) and 51% of the major marketed ecosystem services (coffee, honey and spices) were collected from forest fragments in the region (Fig. 2).

Coffee farms sustained about 40% of the main marketed forest-based ecosystem services, 67% of provisioning and <50% of cultural and regulating services found in forest fragments. According to the household survey, coffee farms were particularly major sources for coffee (91%), medicinal plants (55%), mushroom (50%), and oils and condiments (80%) (Fig. 3). Coffee farms and forests were sources for 46% and 49% of the honey produced in 2010 and both did not vary in the per hectare density of traditional beehives ($F_{1,10} = 0.36$, $p = 0.56$).

Household consumption and sale from ecosystem services varied with the source land-cover type ($\chi^2_{25} = 104.6$, $p < 0.001$) and between the two districts. About 75% of Decha households depended on forests for forest-based ecosystem services compared to only 32% of Yeki households who relied on forests ($\chi^2_4 = 37.2$, $p < 0.001$). Lianas, forest spices, wild and semi-wild coffee, medicinal plants, wild meat, and wild fruits were particularly collected from forests and used more in Decha than in Yeki ($\chi^2_{19} = 51.3$, $p < 0.001$). Mean (\pm SE) income from ecosystem service sales in Decha (\$823 \pm 62) was relatively higher than in Yeki (\$604 \pm 33). Similarly, for native households, about 50% of the sources for marketed ecosystem services were forest fragments compared to 15% of settlers who mainly depended on working landscapes (75%; $\chi^2 = 13.6$, $p < 0.001$) (Fig. 4B). 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).

Most people in the region reported that land-use changes and deforestation (1) diminished ecosystem service providers including cultural and ritual resources, (2) increased the time needed by household to collect forest-based ecosystem services, and (3) reduced income from sale of forest-based services (Fig. 5). People specifically reported that lianas, wild animals, and regulating services such as erosion control, water purification and climate regulation were reported to have been disappearing first due to deforestation. Honey productivity has been reportedly declined due to deforestation, and trunk honey or *Holqa* disappeared. Generally people reported that cultural and regulating services were more affected than provisioning services. Some socio-economic groups (indigenous Manjo and Majanger people, women)

Table 2
Forest-based ecosystem service diversity indices of reported goods and services from six different land-use/cover types

Indices	Forests	Semi-forest coffee	Home-gardens	Annual crop fields	Grassland	Wetlands and rivers
Richness (<i>S</i>)	44	27	5	8	4	7
Diversity (<i>H'</i>)	3.0	1.9	1.5	1.7	1.4	1.6

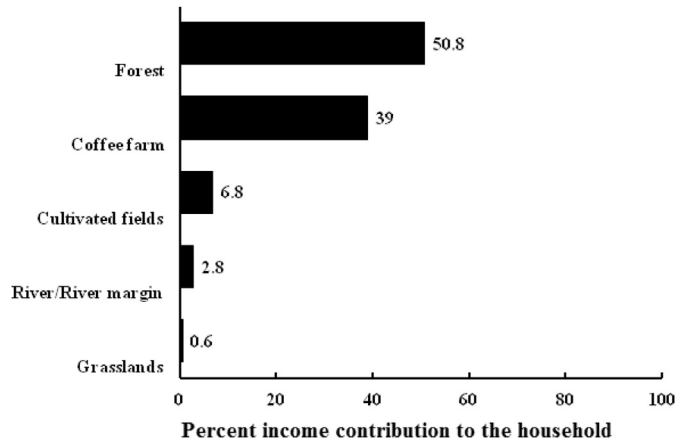


Fig. 2. Potential of land-use types based on their contribution in marketable and forest-based ecosystem services

who heavily relied on forest-based ecosystem services for income were reported as the most affected due to ecosystem service losses following deforestation.

The average time needed by a household member to collect a particular ecosystem service in relatively forested Decha landscape (2.8 ± 1.6 h) was shorter compared to the more deforested Yeki district (4.2 ± 3.7 h). According to informants, land-cover changes over the last 30 years reduced accessibility of forest-services to people in Yeki and Decha increasing the mean distance (mean hour \pm SE) needed to collect forest goods by 2 ± 1.5 h more ($F_{1,19} = 4.1, p < 0.001$). More households in Yeki depended on coffee

farms for semi-wild and garden coffee, honey, charcoal, and fuel than in Decha who used more forest-based services such as wild coffee, lianas, spices and vegetables ($\chi^2_4 = 36.4, p < 0.001$) (Fig. 4A). Due to the loss of forests, the average time (hours \pm SE) needed to collect forest-based goods from coffee farms and cultivated fields was (0.7 ± 0.16 h) and (0.7 ± 0.4 h) respectively, compared to forests (1.4 ± 0.7 h). Among some ecosystem services, lianas (3.3 ± 0.4), and fuel (3.5 ± 0.6) took longer compared to timber (0.7 ± 0.4 h), coffee and spices (0.9 ± 0.2 h) and honey (1 ± 0.8 h). People reported to hunt easily in 1980s, but now they had to travel several hours to days for a successful hunting (G. Tadesse pers. comm.).

Landscape changes decreased the average number of traditional beehives owned by a household by 15 compared to the period before mid-1980s ($t = -3.37, p = 0.005$). People reported that land-use changes decreased the amount of forest honey produced in the mid-80s by one-third. The cause of honey loss was reported by the informants due to (1) loss of native bee forage and beehive-supporting tree and shrub species, (2) the growing use of exotic plant species and agrochemicals that are toxic to honey bees, and (3) increased fire frequency associated with decreased honeybee populations. Following land-use changes, informants recognized that following (*Guya*) decreased *Vernonia* and other shrub species that were used for bee forage and medicinal honey sources. The loss of these shrubs also created shortage in fodder and shrub cover that used to regenerate soil organic matter.

Land-use changes and deforestation were blamed for decreased income from sales of lianas, construction tools made from wood and fiber, fuel, honey and hunting (Fig. 5). People also reported that land-use changes aggravated erosion and decreased the quality and volume of perennial springs with declining soil fertility and increased soil acidity in some villages.

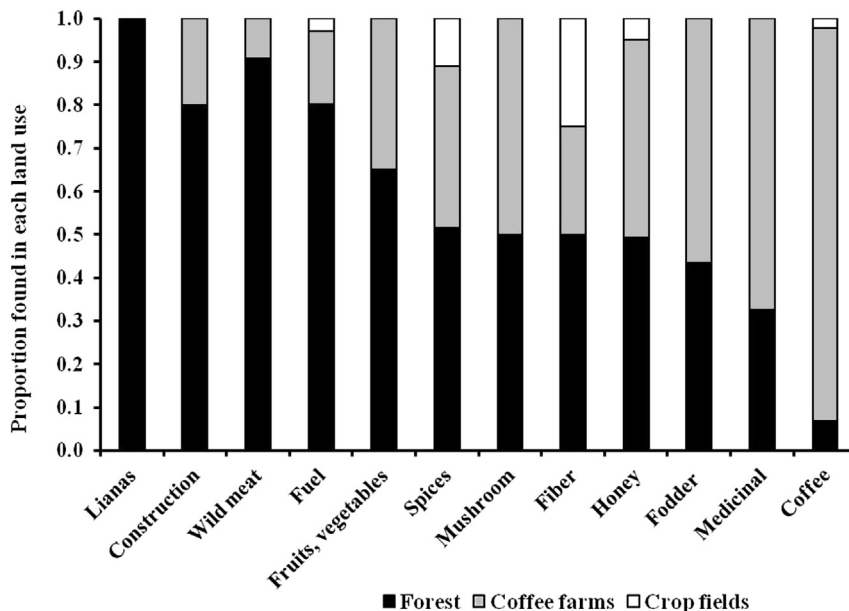


Fig. 3. Ecosystem services important to household consumption and income collected from forests, coffee farms, and all other cultivated lands.

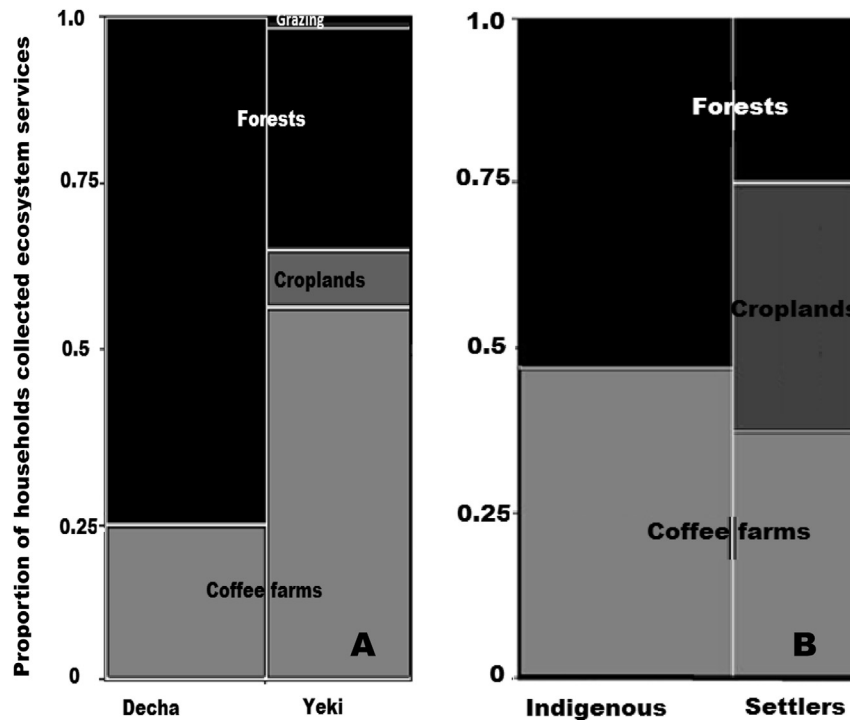


Fig. 4. Proportion of (A) households depending on ecosystem services in more forested Decha and less forested Yeki districts, and (B) indigenous and settler households from both districts who depended on coffee farms and forests for ecosystem services.

As part of coping strategies of diminishing forest goods, households also reported a shift from use of forest products to use of imported plastics, reliance from forests to exotic plantations and modern inputs, from selling fuel to selling coffee and cereals and fruits, from hunting to fishing and livestock production.

Discussion

Southwest Ethiopian coffee agroecosystems sustain high biodiversity with a range of ecosystem services on which millions of subsistence farmers highly depend. Ecosystem service availability and use varied from place to place partly as a function of variability in forest cover in the landscape. Most of the ecosystem services including the cultural, regulating, and supporting services were provided by forest remnants. People value and conserve forests mainly in areas where they obtain more benefits from forest ecosystem services. With the loss of more than 50% forests over the last 37 years in southwest Ethiopia (Tadesse et al., in press), the associated ecosystem services have been either lost or degraded as confirmed by local communities during our surveys. Consequently, people in the region increasingly relied on coffee agroforests for forest-based ecosystem services although the latter are also facing further intensification and conversion into other production landscapes.

Prospects for forest-based ecosystem services in coffee systems

Next to natural forests, coffee agroforests in southwest Ethiopia maintain unique biodiversity and forest-based ecosystem services similar to agroforestry systems described by Pfund et al. (2011). These include timber and non-timber forest products, soil enrichment, erosion control, carbon sequestration, and the regulation of soil, water and drought. We found that coffee agroforests are important sources of forest-based provisioning services. The average time needed by a southwest Ethiopian household to collect

some goods such as coffee and honey did not increase significantly despite deforestation since these services were available in the agroforests.

Human–forest and agroforest interactions in southwest Ethiopia for ecosystem services might have contributed to the conservation of forest fragments and to the maintenance of diverse native species in coffee agroforests (Hylander et al., 2013). In southwest Ethiopia, small-scale farmers largely shaped and influenced their landscapes for their ecosystem service needs including cultural benefits. The cultural services of conservation significance include traditional apiculture in forest plots (*Kobbos*), ritual services in forests (*Guddos*), and big sacred trees (*Adbar*) around settlements. The role of traditional beliefs in forest conservation has also been observed in other parts of Africa such as Zimbabwe (Byers, Cunliffe, & Hudak, 2001) and Mozambique (Virtanen, 2002). Globally, the positive role of sacred groves in the conservation of biodiversity and forests has been reported by Bhagwat and Rutte (2006).

Traditional coffee agroforests have been established mostly from the original forest vegetation through minimal management (understory clearings), or by active management and eventual diversification of shade tree species (Hylander et al., 2013; Senbeta & Denich, 2006; Tadesse et al., 2014). Therefore, traditional coffee systems managed by smallholder farmers have high species and functional group diversity and structure comparable to the surrounding native forests than large-scale coffee farms, monoculture plantations or other agricultural lands (Aerts et al., 2011; Tadesse et al., 2014).

Local farmers have multiple and varied ecosystem service needs that should be provided by various shade-trees and associated biodiversity in their coffee farms from which most of the forest-based ecosystem services in coffee systems were provided. Traditional coffee farmers reported that they encouraged or planted a set of multipurpose tree species for coffee-shade, fodder, timber, fuel wood, beehive support, bee forage, soil fertility, and microclimate

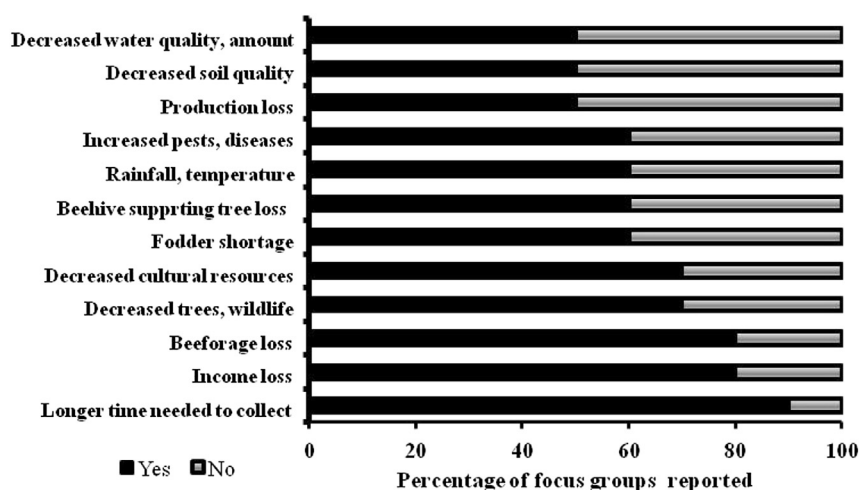


Fig. 5. Proportion of focus groups who reported the major effects of land-use changes on various ecosystem services in the two districts.

regulation. Integration of such diverse trees in the form of eco-agriculture for various ecosystem services including non-timber forest products (Jose, 2009; Scherr & McNeely, 2008), and for drought and climate regulation has also been reported elsewhere including in drier parts of Ethiopia and other African countries (de Beenhouwer et al., 2013; Kristjanson et al., 2012; Sherr & McNeely, 2008). Smallholder coffee systems are better in maintaining more biodiversity and ecosystem services than large-scale coffee systems in our study region (Tadesse et al., 2014) which has also been documented in central America (Mendez et al., 2010).

On-farm diversification and management of ecosystem service providers can enhance the services provided to and from agricultural landscapes (Jose, 2009; Power, 2010) besides their role in buffering overexploitation of forest ecosystem service providers. Empirical studies show that high species and functional group richness is often linked to high ecosystem functioning and services (Balvanera et al., 2006; Diaz & Cabido, 2009; Hooper et al., 2005; Thompson et al., 2011). Forest-based ecosystem services have been described as important to coffee production in other regions; e.g. coffee yields increased by 20% due to adjacent forest-based pollinators in Costa Rica (Ricketts et al., 2004) which was also confirmed by coffee growers in our study region who reported substantial declines in coffee yield in the absence of shade tree species.

Challenges to forest-based ecosystem services in coffee systems

Agroforest intensification is a major driver of ecosystem service declines in coffee, cacao, and other agricultural systems globally (see de Beenhouwer et al., 2013; Foley et al., 2005; Rice, 2008; Tscharrntke et al., 2005). Deforestation and agricultural intensification are ongoing threats to biodiversity, ecosystem services and traditional livelihoods in southwest Ethiopia (Senbeta & Denich, 2006; Tadesse et al., in press). Although farmers in the past maintained high shade tree diversity for multiple needs, currently these landscapes are facing rapid deforestation and agricultural intensification, i.e., reduced shade tree richness and stem density, and replacement of native shade species by exotic shade trees (Tadesse et al., 2014). The intensification of coffee agro-forests and other agricultural systems in the region have been driven by population growth, changes in land-tenure and agricultural development policies, socio-cultural transformation, and market drivers (Tadesse et al., in press). The level of intensification of these coffee farms depended on the availability of land to coffee growers, the scale of production, and the location of the farm in the landscape. We

observed that intensification increased in coffee gardens around homesteads and into large-scale farms. The use of these forest-based ecosystem services have been diminished in areas where deforestation and cultural transformation have been higher, and where land-tenure changes affected customary forest use rights (Tadesse et al., in press).

Current trends of converting forests and wetlands into tea, *Eucalyptus*, and oil-palm plantations, and into crop lands (Tadesse et al., in press) will not only reduce biodiversity but also the actual and potential economic benefits from forest-based ecosystem services, as reported in other parts of Africa (Pfund et al., 2011). Given the current land-use trajectory, most of the ecosystem services will be degraded or lost in the foreseeable future. This illustrates the challenges of traditional coffee agroforestry systems in ecosystem service provisioning, and the need to develop incentives for the forest-based ecosystem services provided in working landscapes.

Generally, our discussion with the focus groups and field observations signifies that the prospects for ecosystem services in coffee landscapes depends on the intensity of management that often varied with the livelihood strategies, production practices, and the needs of coffee growers. Coffee agroforests can maintain a significant portion of forests-based ecosystem services if they are not (1) greatly intensified either in the form of reduced shade tree cover and reduced species richness or through the use of agrochemicals and high yielding coffee cultivars that do not require more shade trees, and (2) converted into tea and oil-palm plantations or annual croplands (Tadesse et al., in press). Our results show that ecosystem service availability in coffee landscapes depends on management and the degree of intensification that varies with (1) knowledge, skills and background of coffee growers, (2) proximity to forests since establishment of native shade trees in these farms depends on propagule dispersal from source populations and species that provide various ecosystem services.

Sustainable use of the forest fragments in the region will have greater ecosystem service values than short-term logging and overharvesting. Melca (2006) estimated that the annual value of a traditionally managed Sheka forest in southwest Ethiopia to be \$1260 ha⁻¹ while the maximum cost of converting those forests into perennial crop plantation, in terms of carbon release was \$1240 ha⁻¹. The benefit from managing forests more sustainably often exceeds the value associated with the conversion of forests through farming and other uses (MEA, 2005). Balmford et al. (2002) reported an 18% greater total economic value (TEV) in sustainable forestry than small-scale farming in Cameroon (~\$2570 compared

with $\sim \$2110 \text{ ha}^{-1}$) which implies a negative TEV when forests are converted to plantations.

Due to their high reliance on ecosystem services, people in southwest Ethiopia are more vulnerable to ecosystem service degradation following land-use changes. In particular, indigenous minorities were more vulnerable to ecosystem service losses since they were more dependent on forest products, hunting, and the sale of fuel wood. Others, mainly dominant indigenous groups and settlers, depend on coffee in highly managed coffee agroforests in addition to other cultivated crops and livestock. Management, shifts to working landscapes and other coping strategies can partially mitigate ecosystem service losses following deforestation. Many farmers started planting multipurpose species around their homesteads and coffee farms to substitute for ecosystem service losses due to deforestation and overexploitation of forest tree species.

Although there is some potential for shifting practices to accommodate the loss of forest-based ecosystem services, those mostly found in the forest remnants (construction lianas, wild meat, and ritual services) could not be substituted or adequately supplemented with those found in non-forested landscapes.

Conclusion and conservation implications

The forest-coffee mosaics in southwest Ethiopia will continue providing ecosystem services if (1) forest conversion and coffee intensification are reduced and if both forests and coffee agroforests are integrated in conservation, and (2) cultural diversity associated with the use and management of forest-based ecosystem services is maintained, and traditional and local conservation institutions are strengthened. Preventing further forest loss or reducing intensification of traditional coffee agroforests cannot be effective if separated from the promotion of both provisioning and socio-cultural ecosystem services. Ecosystem service provisioning in coffee agroforests depends strongly on which ecosystem service we need to conserve, and on the presence of adjacent forest fragments which are vital sources for propagule dispersal and ecosystem service flows.

Local people may substitute for the loss of forest-based ecosystem services following deforestation particularly in smallholder traditional agroforests but the extent to which people adapt and substitute forest-based ecosystem service losses depends on their socio-cultural practices, economic needs, and policy and demographic drivers that affect agricultural intensification. Deforestation will affect socio-cultural ecosystem services and indigenous people more than settlers and provisioning services implying the need to involve socioeconomic groups who are largely dependent on forest-based ecosystem services but often blamed for deforestation.

Smallholder and traditionally diverse coffee agroforestry systems will be sustained mainly for their income beyond the sale of conventional products (Idol, Hagger, & Cox, 2011). These involve promoting premium ecosystem markets and other incentives such as the REDD+ (Reducing Emissions from Deforestation and Degradation) project, coffee certification programs, and eco(agro)-tourism which can alleviate poverty and reduce the ongoing challenges of deforestation and intensification in the region while encouraging ~ 15 million coffee growers throughout Ethiopia (Petit, 2007) to promote biodiversity and ecosystem services.

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