A Review of Ecosystem Services, Farmer Livelihoods, and Value Chains in Shade Coffee Agroecosystems

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Abstract Cultivation, processing, and consumption of coffee are dynamic processes that connect coffee farmers and agro-ecosystems with coffee drinkers spanning the globe. As a cash crop, coffee cultivation gained popularity in the Old and then the New world, and flourished under colonial regimes of the nineteenth and twentieth century. Coffee production patterns and management styles have changed drastically

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in the past two centuries and continue to shift, with the greatest recent expansions in East Asia. Traditionally, coffee is cultivated under a canopy of shade trees, a practice that ensures the longevity of the farm, supports biodiversity, and provides communities with a broad array of ecosystem services. However, many modern management schemes abandon shade practices. On the other hand, specialty coffee markets, like certified organic, certified shade (Bird Friendly), Fair Trade, and other certified coffees have gained recent popularity, though they still represent a small fraction of the global coffee economy. The global coffee economy is comprised of a wide array of coffee value chains that connect farmers with consumers, and thus impact farmer livelihoods at multiple spatial scales. Key players in the coffee value chain include local cooperatives, national government agencies, and global certification agencies. Similarly, ecosystem services provided by shade coffee occur at local, regional, and global scales, including pollination, erosion-control, and carbon sequestration, respectively. While the ecological and socio-economic costs and benefits associated with shade coffee are clear, this review reveals that there are many challenges to bridging sustainable coffee management with livelihood security. Furthermore, in this review we identify existing gaps in the literature and a number of promising research directions concerning the ecological and socio-economic impacts of coffee production.

1 Introduction

In this review, we synthesize the history and current standing of coffee production and the state of science on ecosystem services and farmer livelihoods associated with coffee production. We use a multi-scalar approach to organize ecological and social interactions taking place at local, regional, and global scales. Specifically, we address the following questions: (1) What is the history of coffee? (2) How is coffee produced, and by whom? (3) What are the ecological costs and benefits associated with coffee? (4) What are the socio-economic costs and benefits associated with coffee? Ultimately, as a synthesis of these topics, we ask (5) What future directions can research take in order to address current gaps in our understanding of the ecological and socio-economic aspects of coffee production?

Across the globe, over 400 billion cups of coffee are served per year (Illy 2002). While coffee is consumed around the world, few people recognize the extensive journey taken by the beverage. From seed to cup, this journey employs more than 25 million people, from farmers and laborers to roasters and distributors (Donald 2004). The first step in the coffee life cycle begins on coffee farms (Fig. 1), which in 2008, covered over 9.7 million ha of land worldwide (FAO 2008). Within these farms, coffee is cultivated under a wide range of vegetation management types that provide varying levels of shade (e.g. Philpott et al. 2008a; Moguel and Toledo 1999). For example, coffee management can span from 'rustic' coffee, where coffee shrubs are grown under a dense canopy of tropical trees (approximately 90% cover), to 'sun' coffee, where coffee shrubs are grown in the absence of shade trees and in direct sunlight (0% cover) (Fig. 2). Coffee bushes need 4–6 years before they begin producing the ripe cherries that farmers and workers harvest. After harvesting, the

Fig. 1 Forest fragments and coffee plantations in Chiapas, Mexico

Fig. 2 Sun coffee in Costa Rica (*left*), and shade coffee in Nicaragua (*right*)

cherries are processed to separate the fruit and hull from the beans or seeds. The beans are then dried, sorted multiple times, roasted, shipped for sale and distribution, brewed and consumed (Prendergast 1999). If stored properly, coffee beans can last for more than 8 months and maintain much of their flavor. This makes the coffee value chain more flexible than most other tropical agricultural products, such as bananas and oranges (Talbot 2004).

The simplicity of the coffee production process, however, masks the complexity and diversity of networks that are involved in organizing coffee landscapes, coffee farm owners, and coffee farm workers across local, regional, and global scales. At a local scale, human effort combines with ecological processes through different farming practices to produce coffee beans. Thus, if managed appropriately, coffee farms can dually produce coffee and support biodiversity (reviewed in Perfecto and Vandermeer 2008a; Perfecto et al. 1996). At a local and landscape scale, biological diversity maintained within coffee farms offers a range of provisioning and regulating ecosystem services, such as water storage, coffee flower pollination, and pest control (e.g. Lin 2007; Perfecto et al. 2004; Klein et al. 2003c). At a global scale, coffee vegetation management affects a grower's ability to qualify for premium-providing 'organic' or 'bird-friendly' certification (e.g. Philpott et al. 2007) or potentially earn carbon credits (e.g. Dossa et al. 2008). Thus, coffee management impacts ecological systems and socio-economic livelihoods, rendering these two aspects of coffee cultivation inextricably linked at local, regional, and global scales.

Despite this interconnectedness, few reviews have moved beyond the case study approach to attempt a global synthesis of ecological and socioeconomic costs and benefits of shade coffee production. In this review, we will examine the ecosystem service and farmer livelihood issues associated with coffee production. Specifically, we will review (1) the history, ecology and geography of shade coffee, (2) coffee production patterns, (3) the ecological costs and benefits associated with coffee, (4) the socio-economic costs and benefits associated with coffee, and (5) the current gaps in the literature concerning the ecosystem science and livelihood security involved in coffee production.

2 Ecology, History, and Geography of Shade Coffee

2.1 *Crop Characteristics*

Coffee belongs to the genus *Coffea*, which includes more than 103 species (Davis et al. 2006). Only two species are commercially viable: Arabica coffee (*Coffea arabica* L.) and Robusta coffee (*Coffea canephora* Pierre ex Froehner). Arabica grows in mid-elevation (600–1,500 m) regions and yields a smooth, slightly acidic beverage after roasting, whereas the lower-elevation (0–800 m) Robusta is more tolerant to growth in full sun (Wilson 1999) and produces a relatively harsher cup of coffee with higher caffeine content (Charrier et al. 2009). Because the Arabica species produces higher quality coffee, it generates more economic value; in contrast, Robusta generates higher yields per plant than Arabica, but produces beans that specialty markets generally consider of lower quality and economic value (Bacon 2005a). A third species, *C. liberica* Bull ex Hiern., is regionally important within Africa and Asia but is not sold globally (Charrier et al. 2009). Of the 48 coffee exporting countries listed by the International Coffee Organization (ICO), 27% export Robusta exclusively, 29% export both Arabica and Robusta, and 44% export only Arabica (ICO 2010).

Coffee growth, photosynthesis, and production require specific ecological and physical environmental characteristics, limiting the specific regions in which coffee is grown. For example, coffee is dependent on seasonal rainfall in the tropics both for production of flower buds (following a drought) and flowering (following a dry-season rain) (Carr 2001; Cannell 1983; Magalhaes and Angelocci 1976). Water availability, as well as small changes in temperatures, can affect coffee photosynthesis (Cannell 1976; Nunes et al. 1968). Because coffee is not frost resistant (DaMatta 2004), the upper elevations and latitudes at which coffee can be cultivated are limited. Likely due to its evolution in the understory of tropical forests, the maximum photosynthetic rate of Arabica plants are at moderate temperatures and under moderate levels of shade (Lin et al. 2008; Nutman 1937) and thus it has traditionally been cultivated as an understory crop. Understory crops are trees, shrubs, vines, or other plants that thrive in the environment under the canopy of taller trees, are often grown within orchards, and may also be cultivated in natural forests or conservation areas (Elevitch and Wilkinson 2000).

While coffee's genetic center of origin and its early beginnings as a product lie in Ethiopia, concerted plantation production has its roots in the Near East, amid the terraced slopes of what is now Yemen. The beans moved around the world with Arab traders, religious leaders, many undocumented social networks, and later with European colonial powers seeking to disengage from dependency upon the Near East traders for the bean. Spanish traders introduced the beverage to Western Europe in 1528, and upon reaching Italy, coffee caused such a stir as to be targeted by a number of priests as "Satan's Drink". Its aroma and taste, however, moved Pope Clement III to bestow baptismal status on it shortly thereafter, securing coffee a place in Christendom as an acceptable beverage (Ukers 1922).

Once coffee gained a foothold in Western Europe, its spread throughout the colonial world was all but certain. While the French, British, and Dutch took coffee to the tropical regions of the Old World, it was the French who first brought it to the New World tropics where, as an introduced crop, it was free of most of its natural enemies (insect pests and fungal diseases) and thrived. Like many tropical agricultural commodities pursued by the Colonial governments, coffee's early history also was intertwined with that of slavery (Clarence-Smith 2003). Something of a novelty at first, coffee formed the backbone of newly found economic freedom in Latin America after the Spanish started to relinquish their colonial hold in the 1820s. Coffee became closely allied with the Liberal movement in Central America, for instance, as the crop that would replace faltering dyestuffs like indigo and cochineal, which had fallen in economic value (Biderman 1982).

The latter half of the 1800s saw coffee emerge as one of Latin America's principal cash crops, rising to prominence as an important generator of foreign exchange. Labor was cheap as slavery and forced labor were common on larger coffee plantations, and land, often following displacements of indigenous peoples, was plentiful. With aid from governments using repressive policies to secure both labor and land, coffee flourished throughout the American tropics (McCreery 1995; Williams 1994). By 1900, coffee's physical and social landscapes were well on their ways to changing the region. As mentioned, coffee's spread in the Old World pre-dated its expansion in the Americas, due largely to the efforts of the Arabs, the first to discover and cultivate coffee for large scale production, and the Dutch (Ukers 1922). As coffee spread to more and more countries in order to satisfy European and later North American demand, the management of shade within the coffee farms became a hotly debated subject.

The United States Department of Agriculture, as a consequence of the "...recent acquirement of tropical territory by the United States...", as well as "...the much controverted question of the shading of the coffee tree", tasked Special Agent for Tropical Agriculture Mr. Orator Fuller Cook to examine the shade issue for the USDA. Through personal observation and a literature review, he produced the authoritative report in 1901 on the subject which is still cited today by coffee researchers. Cook (1901) stated in his report on global shade coffee trends, that Brazil and parts of the East Indies favored a reduced shade or open-to-the-sun management style, a condition possibly due more to the natural land cover and climate at least in Brazil, than other factors. His assessment of the degree to which shade is needed in coffee plantations hinged on production, but always with an eye toward the health of the plant and some of shade's indirect effects. He especially identified the role of the canopy in protecting against drought and erosion, as well as the beneficial effects of nitrogen fixing by leguminous shade trees.

2.2 *Modernization or 'Technification' of the Coffee Sector: From Shade to Sun*

Unlike most of the basic grains and certain other food crops, coffee escaped the early pressures of the Green Revolution and the intensification of production that was the hallmark of that transformative process. Yet, different situations and forces converged to alter the production practices of coffee in a number of countries. In Central America and parts of South America, for instance, the arrival of the coffee leaf rust, *Hemileia vastatrix* Berk., created a virtual panic among producers and national level institutes responsible for production. With the assistance of the United States Agency for International Development (USAID) of $81 million and eight multi-year (and some multi-country) projects, a modernization or renovation wave swept the countries of Nicaragua, Guatemala and Honduras, among others, in efforts to head off the effects of the rust (Rice and McLean 1999). The efforts, spearheaded by a USAID-funded regional office called Promecafe, promoted the introduction of new high-yielding varieties, the removal of shade and an increase in the planting density of coffee bushes. The rationale behind the widespread modification was both commercial and agronomic. An 'open-to-the-sun' environment would diminish any dampness, which is conducive to the rust's development, and the planting changes would increase yields, provided the appropriate kinds and levels of inputs were used. The regional transformation represented an intensification of coffee that had been proven in Costa Rica, where yields of 1,500–2,000 kg/ha had been reported for a number of years. However, countries like Nicaragua and El Salvador did not experience such dramatic technological change in their coffee farming, due – at least in part – to decreased investments on coffee plantations and social marginalization as associated with armed conflict in the 1970s and 1980s (Bacon et al. 2008b).

Conversion from shade to sun coffee in Colombia was more abrupt, with nearly a century of shade coffee production before intensification efforts began. In 1895, shade management in Colombia was displayed as an example to emulate for Jamaica, the British colony's prize coffee producer at the time. A Mr. Thompson of the British Foreign Office applauded and attributed the success of Colombia's yields (1,022 kg/ha) to its use of shade trees, even to the point of identifying the elevation ranges in which genera like *Cassia*, *Erythrina*, and *Inga* were used. So impressed was Thompson by Colombia's yields that he stated "...were the Jamaica plantations yielding to the same extent as those of Colombia, the value of the output would be increased ...to double...yearly" (Cook 1901). He concluded, moreover, that the quality of Colombian coffee was far superior to that of Jamaica.

The variability in shade management styles across the global coffee landscape today in many ways relates back to the time of Cook's assessment. Environmental factors, such as altitude, climate, and local disease problems combined with social processes and structures, to produce a range or gradient of shade management across the globe. The Western Ghats region of India also has a history of shade mainly for reasons of protection from the coffee leaf rust. In these systems, the native forest was retained but trees were thinned because of the perceived detriment to coffee plants due to heightened local competition (Cook 1901). In parts of Indonesia such as Java, shade trees were maintained as a windbreak and foil against the spread of fungal diseases (Cook 1901). Cook's conclusion about shade is one of geographic conditionality: farmers should develop site and subject-dependent plans based upon local conditions and growers' attitudes about how best to deal with the vagaries of nature while cultivating this perennial cash crop.

Transformation of the coffee landscape from shade to sun coffee is extensive but uneven across the globe. Approximately 40% of Latin American shade coffee farms have been converted to low shade systems (Rice and Ward 1996). Today, we find Latin American farming systems largely unchanged since the 1996 survey. Colombia is still dominated by a relatively intensively managed coffee sector that was modified beginning in the 1970s to control disease and increase yields (Guhl 2004). Sun coffee still characterizes Brazil's sector, with a very few producers in places like northern Saô Paulo or Pernambuco maintaining diverse canopies over their coffee (R. Rice, personal communication with Marco Croce).

Differences in shade management are evident within countries as well (Table 1). Guatemala's Huehuetenango region tends to have a diverse shade cover dominated by native *Inga* spp., whereas the region around the city of Antigua (which suffers periodic near-frost temperatures from cold air masses from the north) has a monoculture canopy of *Grevillea robusta* A. Cunningham ex R. Br., an exotic Australian native that can withstand low temperatures. In the Guatemalan cloud forest regions of San Marcos or Coban, by contrast, farmers manage little to no shade because of daily cloud cover. When shade trees are planted, such as *Erythrina* spp. and *Gliricidia* spp., they are pollarded into low-stature cover. Guatemala's national

Table 1 Percent coffee area managed beneath different technological/shade levels

Country	% Area in diverse shade/traditional management	% Area in monoculture shade/medium technology	% Area in sun coffee/ intensified management
Peru	90	8	2
Haiti	100	–	–
Vietnam	5	20	75
Kenya	15	←------85*------→	
Honduras	35	45	20
Indonesia	25	35	40
Brazil	←------5*------→		95
Guatemala	40	58	2
El Salvador	24	75	1
Colombia	30	←------70*------→	

Asterisk denotes no differentiation between categories. (Sources: Interviews and mail correspondence with the following individuals and/or institutions: Peru: Jessica Rojas, Junta Nacional del Café, 2010, and agronomist Gerardo Medina of Rainforest Alliance; Vietnam, Truong Hong, Vice Director of Vietnam's Coffee Research Centre, 2010; Colombia, SICA/AFIC, 2009; Haiti, Centre National de l'Information Geo-Spatiale, 1998; Mexico, SIAP and Rene Avila Nieto, staff statistician at AMCAFE 2010; Honduras, Edgar Ibarra and Filiberto Olloa, at the Instituto Hondureño del Café, 2010; Indonesia, Dr. Misnawi, researcher at the Indonesian Cocoa and Coffee Research Institute, 2010; Kenya, Isabella Nkonge at the Coffee Board of Kenya and Juliana Jaramillo at the International Centre of Insect Physiology and Ecology (Nairobi), 2010; Guatemala, Anacafe Director of Research Dr. Francisco Anzueto, 2010; Colombia, intensified management can include scant, monoculture shade cover, Guhl 2004).

coffee association, Anacafe, reports that some 98% of the country's coffee grows beneath a shade cover, dominated by *Inga* spp. trees, with some 15 species accounting for 47% of the shade trees found in coffee (Anacafe 2008). Coffee defined as 'shade-grown' in these cases has a fairly low-diversity tree cover composed mainly or completely of the native genus *Inga* or the exotic *Grevillea robusta*. The percent area of coffee grown beneath a diverse shade cover in Guatemala is estimated to be only 40% (R. Rice, personal communication with F. Anzueto).

In Colombia, much of the coffee area underwent intensification (i.e., shade tree removal) since the 1970s, due principally to the fear of coffee rust's imminent arrival. Yet, the Santander region in the southeastern part of the country maintained a diverse shade cover of towering trees, many of which were once part of the original forest. The cultural identities and values of coffee farmers deeply influence the types of shade coffee maintained (Moguel and Toledo 1999). Observers in both Mexico and Colombia have described patterns of more diverse shade and trends towards organic coffee production in communities with stronger indigenous identities (Moguel and Toledo 1999).

In Vietnam, recent decades have seen the coffee area expand in the northern highland region. The species *C. canephora* is tended in irrigated systems in the open sun. A quick look at the United Nations Food and Agriculture Organization's data for coffee production in Vietnam since 1965 show this phenomenal rise, mainly in

Table 2 Vietnam's coffee transformation, 1965–2008 (FAO 2010)

Year	Area harvested (ha)	Yield (kg/ha)	Production (tons)
1965	22,800	329	7,500
1970	18,600	392	7,300
1975	11,400	596	6,800
1980	10,820	776	8,400
1985	14,060	875	12,300
1990	61,857	1,487	92,000
1995	155,000	1,406	218,000
2000	476,900	1,683	802,500
2005	497,400	1,512	752,100
2008	530,900	1,989	1,055,800

the 1990s, that positioned that country as one of the top two or three in production (Table 2). Between 1965 and 2008, area increased by 2,200%, yields by 83% and production by 13,900%. Nearly all increases were for Robusta coffee, produced beneath little or no shade cover and aided by irrigation and chemical inputs, the results of which have led to large scale environmental and socioeconomic decline in the highlands region of that country (D'Haeze et al. 2005; Kotecha et al. 2003).

Although few debate the social and ecological importance of shade coffee, there is a lack of independent empirical research documenting the extent of shade grown coffee and landscape changes in ecologically important coffee growing territories. The most comprehensive review of these issues focused on Latin America and was conducted nearly 15 years ago (Rice and Ward 1996). In many countries, such as Nicaragua and El Salvador, 95% of the coffee is managed under a diversified shade canopy (Rice and Ward 1996). Studies conducted since 2000 have documented high levels of shade tree diversity in smallholder farmers, with more than 100 species found on 34 farms in Nicaragua and over 120 species on 54 plots in El Salvador (Méndez et al. 2010b). In contrast, shade tree diversity has declined in some larger coffee farms. Furthermore, as a result of government incentives and desires to increase yields, farmers have gradually removed or reduced shade cover assuming that higher light and more dense cropping patterns lead to higher yields (Staver et al. 2001). Although more research is needed to fully understand the multiple drivers of change in coffee landscapes, it is clear that the changing structure of global coffee value chains will continue to exert a substantial influence upon these processes (Topik et al. 2010; Jaffee 2007; Perfecto et al. 1996).

3 Conventional and Alternative Coffee Value Chains

Here, we summarize global coffee production, trade statistics and trends, which are relevant to describing the coffee value chain. Our review of coffee value chains considers the dominant trends in global markets, the emergence of specialty and sustainably certified value chains and the key stakeholders that participate at local, regional, and global scales.

3.1 Global Production and Trade Statistics

Coffee is one of the most valuable legally traded commodities from the developing world (FAO 2010), bearing relevance to many national economies (O'Brien and Kinnaird 2003). Between 14 and 25 million families are actively involved in coffee production, and millions more depend on coffee for their livelihoods (Lewin et al. 2004; Oxfam 2001). The vast majority of producers, estimated at more than 70%, are smallholders farming less than 10 hectares (ha) (Lewin et al. 2004; Oxfam 2001). These producers make a significant, though currently uncalculated, contribution to the 8.2 million metric tons produced in 2008 (FAO 2010).

Although global production statistics tend toward smallholders, there are large differences in the relative fraction of smallholder vs. estate farms among the top 20 producing countries (Table 3). During 2008, coffee was produced in more than 70 countries, located throughout the tropics. The top producers are Brazil, Vietnam, Colombia, and Indonesia, with each country generating more than 68,000 metric tons of green coffee in 2008 (FAO 2010, Table 3), and Brazil providing more than twice that of second-place Vietnam (2.7 vs. 1.1 million tons, respectively). Yields among global producers vary substantially, with the highest yields recorded coming from Martinique (25,000 kg/ha) and the lowest from Suriname (190 kg/ha) (FAO 2009). Specialty coffee (e.g. organic, fair trade, and shade-grown coffee) accounts for approximately 9–12% of all coffee production (Raynolds et al. 2007; Van der Vossen 2005) of which Mexico, Central America, Columbia, and Peru are the market leaders (Lewin et al. 2004). Likewise, coffee area varies greatly between countries (e.g. from >2 million ha in Brazil to 10 ha in Tonga), with around 10 million ha a constant feature in tropical landscapes globally since at least 1965. Worldwide, land in coffee production in developing countries is significant, with several of the top producers controlling more than 5% of agricultural land area in coffee production (FAO 2010). Data for Table 3 were gathered directly from the Embassies and agricultural ministries among the world's top 20 coffee producing countries. However, we complemented this data with a review of the published and grey literature and consultations with FAO databases.

A simple farm-sized based typology of coffee producers provides important background for our subsequent analysis seeking to understand coffee commodity chains and the drivers of conservation practices in shade and sun coffee landscapes. Coffee smallholders represent most coffee farmers, yet they may not represent the majority of all coffee produced. Furthermore, only a limited number have formed smallholder cooperatives that enable them to have a direct stake in coffee exports and further downstream in the coffee commodity chain (Rice 2000). Although often more evenly distributed than other agricultural and ranching landscapes, land ownership patterns in many coffee growing communities and countries remains highly concentrated. Large coffee estates, including those with more than 50 ha of coffee production, often control exports and purchase coffee from small and micro producers.

The majority of producers worldwide are coffee smallholders managing less than 10 ha of coffee (Table 3). This is an important global figure, but it should be

Table 3 Coffee production statistics for 2008[a]

Country	Coffee yield (hg/ha)	Coffee production (tons)	Area in production (ha)	No. of producers (<10 ha)	No. of producers (10–100 ha)	No. of producers (>100 ha)
Brazil	12,594	2,790,858	2,216,014	220,554	30,900	1,656
Vietnam	19,886	1,055,800	530,900	500,000	200[b]	
Colombia	9,399	688,680	732,656	520,069	7,540	0
Indonesia[c]	6,987	682,938	1,313,309	1,259,656	53,653[b]	
Ethiopia	6,715	273,400	407,147			
Mexico	3,516	265,817	755,843	507,377	3,166	–
India	7,660	262,000	342,000			
Guatemala[d]	10,400	254,800	245,000	50,000	9,092	3,557
Peru	6,973	225,992	324,062	136,000	23,900	100
Honduras	9,476	217,951	230,000	81,680	5,026	51
Uganda	7,989	211,726	265,000			
Costa Rica[e]	11,102	107,341	96,681	46,705	3,120	802
Haiti	3,863	35,000	90,600	800	–	–
El Salvador	6,345	97,727	154,000	17,869	2,881	282
Philippines	7,903	97,428	123,269	263,836	11,845	–
Côte d'Ivoire	3,478	80,000	230,000			
Kenya	2,709	42,000	155,000	700,000	4,000[b]	
Papua New Guinea	10,771	75,400	70,000			

(continued)

Table 3 (continued)

Country	Coffee yield (hg/ha)	Coffee production (tons)	Area in production (ha)	No. of producers (<10 ha)	No. of producers (10–100 ha)	No. of producers (>100 ha)
Nicaragua	6,275	72,727	115,883	29,000		167 (more than 50 ha)
Venezuela	3,810	70,311	184,536			
Madagascar	5,360	67,000	125,000			
Thailand	8,111	50,442	62,186			

[a] Source: FAO statistics (http://faostat.fao.org) for most yield, production and area data

[b] No. of producers >10 ha

[c] Indonesia data given in ha by Dr. Misnawi and the Cocoa and Coffee Research Institute of Indonesia (2008), with no differentiation above the 10 ha category; Kenya, Coffee Board of Kenya and Dr. Juliana Jaramillo, 2010; El Salvador, Ana Elena Escalante of the Consejo del Café de El Salvador, 2010

[d] Guatemala (size categories are <10 ha, 10–45 ha, and >45 ha) data from Anacafe's Dr. Francisco Anzueto, Director of Research, 2010, and CEPAL, nd; Vietnam, Mr. Truong Hong of Vietnam's Coffee Research Centre, 2010; Colombia, SICA/AFIC, 2009; Haiti, Centre National de l'Information Geo-Spatiale, 1998; Mexico, SIAP and Rene Avila Nieto, staff statistician at AMCAFE, 2010; Honduras, Edgar Ibarra and Filiberto Olloa, at the Instituto Hondureño del Café, 2010; Brazil, Instituto Brasileiro de Geografia e Estatistica, Censo Agriopecuario, 2006; Philippines, Census of Agriculture, 2002. Peru, farm size classes are <5 ha, 5–100 ha, and >100 ha, and obtained from Peru's Junta Nacional del Café staff member Jessica Rojas and agronomist Gerardo Medina of Rainforest Alliance

[e] Costa Rica size categories based on production data provided by Sr. Deryhan Muñoz Barquero at the Instituto del Café de Costa Rica, 2010

used with caution. A closer look demonstrates that size ranges mask several important trends observable within specific countries and regions when the data are further segmented. In Mesoamerica (including Mexico and Central America), most coffee producers are substantially smaller than the 10 ha standard used for delineating a producer as a smallholder. A 2002 report published by a regional office of the United Nations (CEPAL 2002) found that more than 68% or 394,716 of the 573,000 plus farmers in this region are micro-producers managing less than 2 ha of coffee. In other coffee producing countries, such as Rwanda, the majority of farms are so small that they are measured in the number of coffee trees (about 300, as compared to many Mesoamerican smallholder farms that generally have from 1,500 to 2,500 coffee bushes per ha). In Central America, smallholders represent 85% of coffee producers and control 18% of coffee production lands, while the largest producers and industrial operations managing farms larger than 50 ha represent fewer than 3.5% of all coffee farmers and control about 49% the area in coffee production (CEPAL 2002). However, it should be noted that the trends in Latin America, especially after the 1999 coffee crisis, show a decrease in the number of large estates and an increase in the number of smallholder and micro-producers (Topik et al. 2010). These trends in the size of coffee producer operations are strongly influenced by the changing structures and incentives within the coffee value chain.

3.2 *Coffee Value Chains and Global Markets: An Introduction*

In its journey from tree to cup, coffee passes through the hands – directly or indirectly – of several players in the commodity chain. This value chain runs thread-like through a number of sequential steps, supported tangentially by production networks like machine manufacturers and transport services (see Sturgeon 2000), all of which are essential to getting the finished product to its destination. Growers, processors, exporters, importers, roasters, distributors and retailers form the normal categories of those involved, with repetitive handler groups (except for producers and roasters) being inserted in the chain in some cases (Fig. 3).

While the division of surplus (profits) has bounced back and forth over time, with growers usually getting a smaller share, recent years have seen those in producing countries – growers and national governments alike – receiving a smaller fraction of the profits (Fridell 2006; Oxfam 2002). Low international prices are one of the problems that are accentuated when the crisis of oversupply recurs (which is cyclical for most commodities). The early 2000s, for instance, saw coffee prices fall to levels that resulted in the value of coffee itself representing only 18% of the retail price – compared to 64% in the mid-1980s (Oxfam 2002). This reflected not only the general deterioration of terms of trade for producing countries over the last several decades, but the sharp collapse in coffee prices due to the breakup of the ICA and neoliberal policies spawned by multi-lateral institutions like the IMF and the World Bank. Neoliberalism is a political-economic theory,

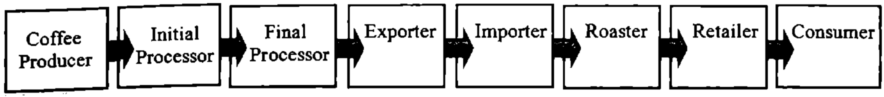

Fig. 3 The coffee commodity chain

class-based project, and regulatory practice (Harvey 2005). The central proposition is that by forcefully liberating individual entrepreneurial freedoms, through robust private property rights, free trade, and the power of free markets, well-being of all in society will be maximized (Watts 2007). According to this proposition, neither the state nor civil society should influence market factors, such as prices or costs of production.

Profits in coffee value chains are uneven and often dependent on the costs of production. They are not particularly high compared to other industries, but in certain cases, especially in times of crisis for growers, profits elsewhere in the value chain can be enormous (Oxfam 2002). In 2000–2001, Ugandan farmers received $0.14 for a kilo of unprocessed coffee that at retail would fetch more than $26.00 as instant coffee in the United Kingdom (Oxfam 2002). Accounting for weight loss during the processing and roasting of the coffee, that represents a 7,000% price increase in the journey from farm to shopping cart. For a roasted and ground package of the same coffee in the US, the increase would be around 4,000% (Oxfam 2002). Seen another way, if we assume that 5 pounds of the Ugandan farmer's fresh cherries are needed to make a pound of roasted beans which makes 40 servings of coffee that retail for $2.00 a cup, the $0.70 received by the grower fetches $80.00 at retail, which is an 11,000% increase. A recent and systematic comparison conducted during a period of low green coffee prices (in 1999 and 2000) and selling coffee from Tanzania to Italy by the pound (not the cup), found that 8.7% of final retail value of low quality Robusta coffees stayed on the farm, in comparison to only 3.9% of the high end 100% Arabica coffees (Daviron and Ponte 2005). However, green coffee prices have increased substantially from their depths in the coffee crisis of 2001 (Bacon et al. 2008a). From 2006 through the end of 2008, prices for green Arabica coffee increased by 24% and they were 60% above 2006 levels through September 2010 (FAO 2010). This has resulted in slightly higher percentages of retail price for bulk roasted conventional coffee accruing to exporters and growers. Recent data from the FAO show that global average coffee prices paid to growers increased 25% from January of 2006 through the end of 2008 (FAO 2010). Global data is not readily available to estimate changes in retail prices. However, during the same time period the average price of bulk conventional roasted coffee in the US cities increased by only 13% (US Department of Labor 2010). These numbers suggest that in the case of conventional coffees sold to supermarkets, and not specialty coffee sold by the cup, exporters and growers have recently captured 15–20% of the total retail value, a situation that was similar to those in the 1970s and early 1980s when the international coffee agreement sought to control supply to maintain more stable prices to producers (Talbot 2004).

3.3 Specialty and Certified Coffees

The specialty coffee market seeks to differentiate its coffees from the bulk commercial coffees in the mainstream markets (i.e., those purchased from supermarket shelves in large cans of Folgers® and Maxwell House®) based on sensorial attributes expressed in the cup (Läderach et al. 2006) and, to a lesser extent, sustainability. The closer attention to the qualities of coffee and the relationships with coffee producing communities and exporters initially led to the creation of many distinct global coffee value chains organized around coffee qualities and in some cases (especially those associated with early fair trade and organic coffees) notions of fairness, livelihoods, and ecology (Goodman 2008). Several countries are taking advantage of their promising production conditions for specialty coffee to develop Denominations of Origin (DO) such as Antigua in Guatemala, Marcela in Honduras, Veracruz in Mexico and several denominations in Colombia, among others (Daviron and Ponte 2005). DO are based on unique quality growing conditions expressed in a unique sensorial quality (Läderach et al. 2009).

Although the specialty coffee market segment was pioneered by small-scale artisanal roasting companies active since the early 1970s (Bacon 2005a; Dicum and Luttinger 1999), during the past decade several large coffee companies have diversified their rent capturing strategies into this market. In the past, most profits were sought via an 'economies of scale' approach. However, the recent emphasis on the qualities of coffee and the coffee drinking experience could be broadly categorized as an emergence of a more 'flexible' value chain, where an array of coffee products (i.e., espressos, lattes, and now frappuccinos) targeting specific consumer categories and niche marketing opportunities have emerged. Many small-scale roasters and cafes have also used the qualities and more direct relationships with coffee producing communities as an effective business strategy to expand their market share. Most of these businesses are organized within the specialty coffee market segment.

During the past two decades the specialty segment has gained a considerable following, sustaining annual retail market value growth rates that generally topped 10% since the mid 1980s (Giovannucci et al. 2008). The decline of the International Coffee Agreement (ICA) and withdrawal of national coffee marketing boards and rural assistance programs also contributed to the rise of the specialty coffee market sector (Bacon et al. 2008a). The Specialty Coffee Association of America (SCAA), one of the few industry associations with a relatively progressive track record, also provided fertile ground for launching several grower and civil society-based sustainability certification programs. The shade coffee category, along with organic and fair-trade coffees, may well represent a challenge for the established markets, conceptually if not economically.

Sustainable coffee certification is an umbrella term encompassing several types of certifications, and combinations of certifications. While Fair Trade focuses on the trade relationships, organic certification standards regulate the production process and require a separate chain of custody throughout different processing stages in the value chain. The overall organic market, which extends well beyond coffee, is significantly larger than Fair Trade markets. This is in part because the organic certification system has existed for a longer period of time and also developed a very diverse and often contested decentralized regulatory system. Most organic standards include the need for 'ecological' management of farms, including soil conservation practices which permit very little or no use of synthetic fertilizers and pesticides, prohibit genetically modified crops, and require intensive on-farm record keeping, among many other criteria (Van der Vossen 2005). Farms are certified organic by third party inspectors who follow an international code for each crop. Mexico exported the first certified organic coffee in 1967 (S. Philpott, personal interview with Walter Peters), and as of 2007, North American coffee drinkers had spent over one billion dollars on organic coffee (Giovannucci et al. 2008). Today, the leading certified organic coffee exporting countries include Ethiopia, Peru, and Mexico. Nicaragua is also among the top exporters with close to 10% of its coffee farmers certified as organic.

Table 4 offers a comparative analysis that considers the largest third-party sustainability certifications in the coffee industry. While the five certification programs listed in the table below have initially targeted the rapidly expanding specialty coffee market segment, both the Rainforest Alliance and Utz Certified have started to sell large volumes of certified products to the conventional coffee industry. Smithsonian's Bird Friendly certification program has the highest agro-environmental standards, requiring more than ten different species of diverse shade trees and certified organic production as well as general guidelines to conserve soil and water (Bacon et al. 2008a). Rainforest Alliance, Utz Certified, and Fair Trade all have several agro-environmental standards restricting the use of many of the most toxic pesticides and herbicides (generally based on an expanded version of the 'dirty dozen' list initially popularized by the Pesticide Action Network) and the expectation that all national laws will be implemented, but synthetic fertilizers and most pesticides, fungicides, and herbicides are permitted. A discussion of the enforcement of these standards is beyond the scope of this review. However, it is important to note that some of these standards are basic requirements that must be attained prior to certification, while others are goals towards which farms, farmers, and local organizations are expected to move over several years of annual inspections. The social standards, often based on non-discriminatory conventions from the International Labor Organization, are also summarized in the table below. The final column in Table 4 shows that Fair Trade, organic, and the Smithsonian's Bird Friendly certification programs have first sought to partner with small-scale farmers and their collective organizations, while Rainforest Alliance and Utz Certified started by certifying large-scale coffee plantations (Ponte 2008).

Given the number of stakeholders involved in the coffee value chain, it is not surprising that they operate at multiple, and often overlapping scales. These scales are at once spatial and temporal, and the boundaries characterizing them are not easily defined. This social science approach to scale defines the term as emerging

Table 4 A comparison of sustainable coffee certification standards

Certification	Coffee market segment	Agro-environmental standards	Social criteria	Size and geography of producers
Fair Trade (FT)	Specialty and some conventional markets	Highly toxic agrochemicals use restricted (standards go beyond national laws), water conservation buffer zones around water bodies No genetically modified organisms (GMOs)[a]	Prioritizes smallholder producer cooperatives (co-ops receive minimum coffee prices plus premium for social development), standards restrict child labor, guarantee freedom of association and right (rt) to collective bargaining, buyers encouraged to sign long term contracts directly with smallholder co-ops and provisions access to credit	Started w/ indigenous smallholder cooperative in Latin America 800,000 plus individual smallholders affiliated with 250 producer cooperatives in Latin America, expanded coverage to Asia and Africa post 2000
Organic	Specialty	Prohibit the use of synthetic fertilizers and agrochemicals, encourage integral soil management, no GMOs	Freedom of association and right to collective bargaining, working conditions, equal treatment, etc.	Started w/ larger farms and indigenous smallholder cooperative in Latin America (Mexico), now prevalent in Latin America, Ethiopia and elsewhere

(continued)

Table 4 (continued)

Certification	Coffee market segment	Agro-environmental standards	Social criteria	Size and geography of producers
Utz certified	Specialty and conventional market segments	Focus on enforcing adherence to national laws and avoiding use of illegal agrochemicals, several standards to reduce contaminations	Originally were a direct adaption of the Global Good Agricultural Practices (GAP) criteria to coffee, standards for record keeping, better and documented use of agrochemicals, labour rights and access to health care and education for employees and their families	Started w/ larger farms in Guatemala partnering with large retail outlet
Rainforest alliance	Specialty and increasingly conventional	Restricted agrochemical use, encourages social and water conservation, shade trees standards: canopy cover of mixed native trees	Freedom of association, safe and clean working environment, the national legal minimum wage, dignified housing, medical care, free education, health, training	Started w/ larger farms in Central America, post 2004–2006 has adjusted standards for smallholder organizations, many operations in Brazil, Vietnam
Smithsonian migratory center's Bird-Friendly (BF)	Specialty coffee markets	Requires organic certification plus at least 10 shade tree woody species on farm and presence of larger trees, stream buffer zones, and secondary plant diversity	Social criteria are same as organic, much of BF coffee is also FT certified	Started with smallholder cooperatives in southern Mexico and also piloted on some larger farms

Sources: Modified and adopted Bacon et al.(2008a): 348–149; based on data from Ponte (2008), Raynolds et al. (2007)
Sources: [a]according to TransFair USA's website
http://www.transfairusa.org/content/about/overview.php, but we have yet to see this clearly elaborated within the international regulations
http://nationalzoo.si.edu/ConservationAndScience/MigratoryBirds/Coffee/quick_reference_guide.cfm
http://www.rainforest-alliance.org/agriculture.cfm?id=standards_farms

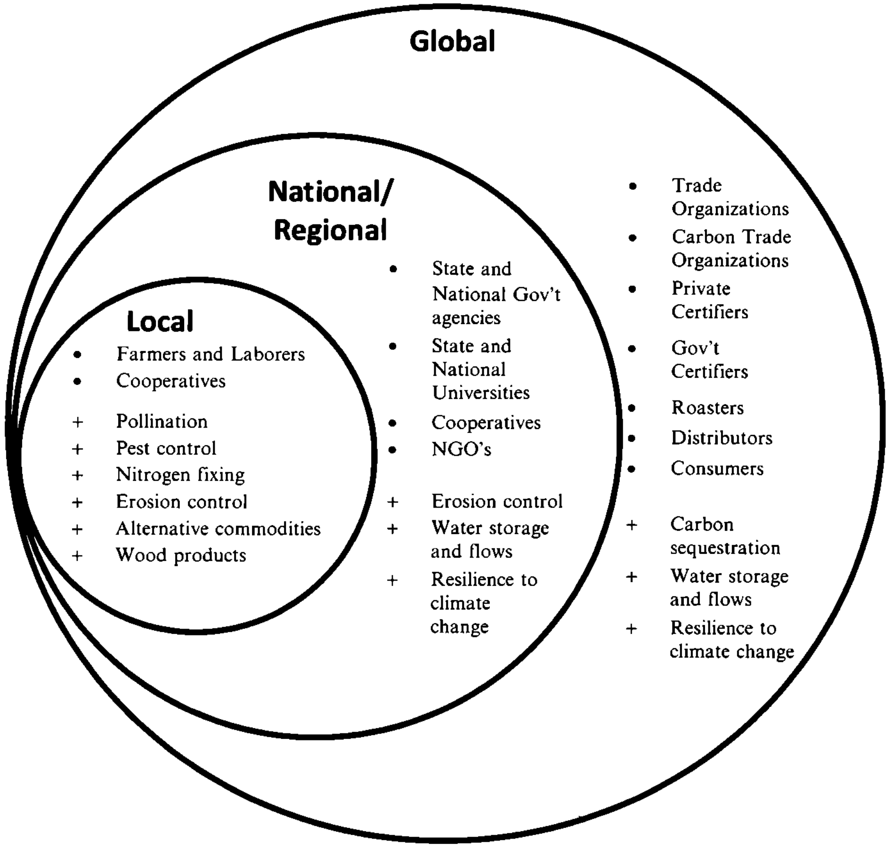

Fig. 4 Representation of local, national/regional, and global stakeholders (•) and ecosystem services provided within shade coffee farms (+)

out of economic, cultural, and social interactions and thus representing a social construction difficult to divorce from human interactions or activities (Sayre 2005; Brenner 2001; Marston 2000). However, those interested in interdisciplinary research and the connections between social and ecological approaches to scale must seek the commonality in definitions. As Sayre (2005) states: "It is obvious that social and ecological phenomena are intimately linked across scales; it follows that the problems of one cannot be resolved in isolation from those of the other". From the standpoint of the producer involved with shade coffee and its associated benefits, controversies and nuances, we find three scales at which stakeholders operate and/or interact: (1) local/community, (2) national/regional, and (3) global (Fig. 4). Despite the economic connections between scales, the stakeholders themselves rarely understand the depth or scope of issues facing the others within the commodity chain.

3.4 Local and Community Scale Coffee Value Chains

The local or community scale of the coffee value chain includes farmers, farm workers and others falling within a farm's sphere of influence at the level of production. At the most fine-grained scale, the farm itself is the unit, with decisions by the operator affecting ecological processes as well as his or her own socioeconomic rewards. While concerned with the management of the farm, a very local, site-based operation, small landholders often are members of cooperative organizations, placing them into a distinct scale of activities, commitments and benefits. Faced with phenomena at the global scale, a small producer subjected to international price fluctuations might respond by deciding to seek organic, fair trade, or shade certification. The challenge in this case could be of temporal scales, defined on the one hand by niche market fashions that shift rapidly, and on the other by the perennial nature of coffee and shade trees, and the time it can take to be certified (the transition period imposed by certification standards). A single grower practicing environmentally beneficial land stewardship (i.e., maintaining a biologically diverse shade, low-input coffee system, and protection of water sources) because of necessity (little income for inputs, managing a diverse system for the array of products it provides, etc.) can be catapulted into community, national, and global scale arenas once he or she decides to connect with a local agency that certifies coffees according to international standards. Unlike growers laboring within the anonymous collective of producers supplying beans to meet the global demand for industrially produced coffees, farmers involved in certified coffee production aim at meeting codified standards and satisfying specific interests of consumers. The documentation associated with certifications creates an audit trail as the certified coffee passes from player to player along the chain. Paperwork leads back to the individual farm, and documents not only all stakeholders handling the coffee, but obliterates the anonymity in which non-certified producers exist. The documentation, identification, and recognition of certified producers create relationships and scalar interactions arguably unrealized prior to certification.

3.5 National and Regional Scale Value Chains

The national or state scale is one of cooperative unions, social movements, non-governmental organizations and government ministries, that along with other organizations and within legal institutional frameworks, create the web of social connections that enable and influence the journey of the coffee seed from plant to the point of export (Bair 2009). An individual farmer and cooperative member operating at this scale is often and usually brokered by the cooperative leadership or professional staff. In other cases, like Indonesia, this is done by private exporters who prepare and fund activities related to certification – and reap some of the associated rents. Growers contend with national tax laws often attached to coffee exports as a way of funding marketing and/or research institutes as in Colombia or Costa Rica, or marketing boards that control nearly all exports as has been the case for Kenya and Ethiopia (Akiyama et al. 2003). These same national scale entities often provide technical advice through extension workers, and sometimes support a degree of social development (e.g. the Colombian Coffee Federation) the aim of which is to increase quantity and quality exports and thus subsequently capture more revenues.

The regional scale may well encompass more than a single country, as with the mountain ranges of Central or South America where much of the world's coffee is produced. Growers at this scale, while distinct in terms of nationality, live and manage farms in indistinguishable locales ecologically and culturally, as with growers living on either side of the border between Chiapas, Mexico, and Guatemala. As ecosystems are often defined by their watersheds and topographic structure, growing practices are often similar within regional watersheds, even though political boundaries may divide them. Price differentials and coffee origins are shaped by international perceptions and the quality, consistency, communications, and marketing of coffee exporters and thus growers on one side of a national boundary may suffer price punishment due to origin, even though the ecological, climatic and processing conditions of the two origins are the same (Daviron and Ponte 2005). Climatic phenomena like frost, drought or hurricanes can also affect entire regions. The result of such extreme events can devastate production across national borders, affecting local farmers adversely while growers in untouched regions can benefit from the higher prices caused by scarcity in supply.

3.6 Global Coffee Value Chains

Globally, there are trade organizations, certifiers, and governmental bodies accrediting certifiers, roasters, and consumers. From a basic, traditional commodity chain relationship, growers enter into global relationships, directly or via mediators, in questions of quality and quantity. Increasingly, however, the "latte revolution" (Ponte 2002) has pushed many growers toward specialty coffees defined by high-quality processing, fortunate origin location, certification, or some blend of these features. The growth of specialty coffee has created a consumer who is more aware of where, how, and by whom the coffee is produced, and what its impact on the environment, the grower, biodiversity and even climate change might be. To the extent that demand for specialty coffees with some characteristics addressing consumers' concerns increases, the local farmer (in this case a member of the Global South) will be influenced to produce in specific ways governed by the interests of northern roasters, retailers and consumers.

A definite re-orientation of scale related to organic certification came into play within the last decade when the global organic community shifted from a relatively self-monitored organizational structure channeled through the International Federation of Organic Agricultural Movements (IFOAM) to the more formalized regulations of the USDA's National Organic Program, as well as the Japanese analogue (JAS) and the European Union's supra-national control over organic products. Even though the activities under the IFOAM period were global in nature, the state and supra-state power brought to bear on farmers and certification agencies when these markets of the global North moved to oversee certification introduced new geographies of political regulation into the system. The audits and quality control hurdles that agencies currently face are not simply bureaucratically tangled; they are costly in terms of personnel workloads and the payment of fees for accreditation (Mutersbaugh 2005).

3.7 *Neoliberal Reforms and the Post 1999 Coffee Crisis*

The changing management of coffee systems is also influenced by the evolving structures of the coffee value chain and the prices paid for this global commodity. In 1999, prices paid to producers for the green beans they sold through the international coffee commodities market plunged causing a humanitarian and in some cases an ecological crisis in many coffee growing regions (Oxfam 2002). However, the 1999 coffee crisis, also known as the 'global coffee crisis' provided researchers with insight into the mechanism of change in coffee landscapes (Bacon et al. 2008b; Rice 2003; Varangis et al. 2003). Consensus has it that the withdrawal of the United States from the International Coffee Agreement (ICA), the established pact between producing and consuming countries that controlled global inventory and prices, resulted in the dumping of warehoused stocks into the market and causing prices to plummet in the early 1990s (Eakin et al. 2006; Varangis et al. 2003). This, combined with increased consolidation in the roasting and trading phases of the value chain, rapid roll-back of direct state involvement in coffee production and marketing, and with existing farmer vulnerabilities created the most recent coffee crisis (Goodman 2008). Corrected for inflation, the "30-year" low price levels were actually 100-year lows, well below the price of production (Varangis et al. 2003). A buyer's market undoubtedly helped to keep prices at basement levels, resulting in a scramble to sell coffee with little leverage for growers. But growers were not the only ones to suffer.

The low coffee prices resulted in a crisis due to the persistent vulnerabilities among many coffee producers, conditions exacerbated by a broader, deeper crisis related to the systematic exclusion of farmers and agricultural workers, global economic woes, low commodity prices generally, and extreme weather events like hurricanes (Bacon et al. 2008b). The generalized low prices translated into stress within the banks and government coffers, which in turn meant that capital usually flowing from coffee revenues was not to be found, adding to national anxieties and frustration. Low prices, weakened financial linkages, and diminished government revenues also resulted in disruption of commerce, transportation and other socio-economically linked activities. Producers resorted to strategies like planting alternative crops, migrating to the US to find work, neglecting and/or outright abandoning their farms in order to cope with imperiled livelihoods. The act of curtailing all cultural practices in order to save on production costs was a strategy that obviously cut into rural wages from day labor, a common source of income for rural families in coffee regions. Some strategies were more severe; reports from Anacafe staff in Guatemala included farmer suicides.

While the low prices were devastating for producers and others with economic links to the coffee production sector, it did not necessarily translate into lower prices for consumers. Roasters seemed to have maintained or only slightly lowered prices at the retail level, turning what was a crisis for growers into a golden opportunity for their own bottom lines – at least for the large coffee companies. One report from an industry trader stated that the 15% return seen by roasters in normal times climbed to 110% during this crisis period (Rice 2003). An extended case study reveals how several of these processes interplayed.

The trajectory and institutional linkages related to Mexico's coffee sector over the past several decades showcase the efforts, aims, and consequences of commodity production in a dynamic global environment buffeted by economic and socio-political winds. As a country, Mexico is representative of many coffee producers in that its 95,000 producers tending 400,000 ha of coffee in 1985 were dominated by smallholders with an average of 3 ha of coffee, accounting for 84% of the coffee area (Nolasco 1985). An expanding global economy and the concomitant increasing demand for coffee since WWII helped, coupled with state led development (and electoral patronage) models prevalent at the time combined to establish the National Mexican Coffee Institute (INMECAFE) in 1958, the charge of which was to oversee production, processing and marketing of coffee (Jaffee 2007). State-based coffee marketing and support agencies, like INMECAFE, were fundamentally important in retaining and storing coffee exports as part of the international coffee agreements established in an effort to maintain prices that could sustain a degree of positive development outcomes. Coffee exporters and important countries negotiated important economic clauses (including quotas for production and imports) through the International Coffee Agreements (ICA). The ICA was put into force in the 1960s not only for price stability, but also as a geopolitical strategy to help stem social unrest and the threat of communism so feared at the time, and providing dependable (if perhaps not totally adequate) prices to growers (Dicum and Luttinger 1999).

During this expansion period for coffee, INMECAFE promoted the intensification of coffee production via experimental stations and a network of offices providing technical assistance. A monoculture, shade-less coffee system was advocated, even though the yields resulting from INMECAFE's technical assistance did not match those associated with other sources of technical assistance (Nolasco 1985). However, many of the state-led efforts to convince smallholders to eliminate shade trees failed. Furthermore, INMECAFE had greater influence in certain areas of Mexico, such as Veracruz, but much less among the more marginalized states of Oaxaca and Chiapas. The indigenous populations represent a larger proportion of the inhabitants in both states, and these states would also emerge as global pioneers in organic, shade and Fair Trade coffee production (Nigh 1997). The strong networks of smallholder coffee cooperatives, indigenous community level management or ejidos and community associations provided the social capital for partnering with northern certifiers, scientist and coffee roasters that led to the early pilot testing and eventual development of the major certification programs for organic, shade, and fair trade coffee (Bacon et al. 2008a). By the early 1990s, coffee cultivation area had nearly doubled and the number of growers nearly tripled (Calo and Wise 2005). INMECAFE targeted small and medium sized farmers with the goal of introducing and spreading a technological package involving the coffee monoculture mentioned above. The widespread adoption of neoliberal political and economic reforms as evidenced by the passage of international trade agreements, such as the North American Free Trade Agreement, and the privatization of state based industry and activities accelerated in the 1990s profoundly influenced the coffee sector (Topik et al. 2010; McCarthy 2004). Under the Neoliberal model, free markets are expected to optimize benefits to society. Damages to the environment and or social wellbeing are often characterized as an 'externalities' (e.g. pollution). In these cases, most, though not all promoters of this approach suggest that the state play an important role creating new property rights and establishing a new market that proponents claim will enable private profit seeking to spur innovative solutions (Kay et al. 1997). Critics of Neoliberalism highlight the often violent means that governments and corporations employ to maintain this system (Harvey 2005) and show the negative empirical consequences as measured by uneven development patterns (Watts 2007), persistent economic poverty, and usurped rights of many local and indigenous communities. Researchers have also questioned the efficacy of Neoliberal approaches to solving pressing environmental problems (Marsden et al. 1996; McCarthy 2004), suggesting they are not up to addressing the root social causes and long term drivers of climate change, pollution, and biodiversity loss at global scales (Peet and Watts 2004).

The deregulation of the international coffee markets following the collapse of the international coffee agreement in 1989, the rollback of state investments in coffee marketing, technical assistance and exports, and the fraying rural social safety net are all evidence of Neoliberal trends in the coffee sector (Topik et al. 2010; Bacon et al. 2008b). In Mexico, the national government began to pull support from social programs (although it maintained more than many other governments) and state supported coffee marketing and technical assistance institutions like INMECAFE. With the collapse of the ICA in 1989 and the subsequent dismantling of INMECAFE in 1993, growers were left virtually on their own to face the shocking reality of trade liberalization. Price supports that had given them \$1.00–\$1.40 per pound for their coffee gave way to below-production cost prices of only \$0.50 per pound (Calo and Wise 2005). It is worth noting that the social unrest seen as a threat in the 1960s when the ICA was formed actually blossomed 1 year after INMECAFE's breakup and 5 years after the collapse of the ICA (ICAFE 1989). In 1994, during the Zapatista uprising in Chiapas, 36% and 30% of the coffee area and producers, respectively, protested the signing of the North American Free Trade Agreement (NAFTA) and made headlines throughout the world (AMECAFE 2010).

4 Ecological Processes and Ecosystem Services

4.1 Ecological Processes in Coffee Landscapes

Ecosystem services are ecological functions that sustain and improve human life (Daily 1997). Globally, ecosystem services such as pollination, pest control, erosion control, watershed management, and carbon sequestration, provide an estimated economic value of $18 trillion annually (Costanza et al. 1997). According to the Millenium Ecosystem Assessment (MEA 2005), an international and comprehensive study of global resources, an ecosystem service is defined as any benefit that humans obtain from an ecosystem. The MEA divided ecosystem services into four categories, (1) 'provisioning services', such as water, food, and forest products, (2) 'regulating services', such as the regulation of climate, waste, and floods, (3) 'cultural services', such as aesthetic, spiritual, or recreational benefits, and (4) 'supporting services', such as nutrient cycling and photosynthesis. Thus, the key 'provisioning services' within shade coffee farms are the coffee yields themselves, along with the fruits and forest products often gathered within these systems. A 'regulating service' value of pollination would be the increase in production of coffee within a farm, while the 'supporting service' value of pollination would be the reproduction of native non-crop plants that benefit other ecosystem services, such as the provision of erosion control by a native tree that also grew as a result of pollination (i.e., Kremen et al. 2007).

Shaded coffee plantations are increasingly valued for their contributions to biodiversity conservation and the provisioning of ecosystem services. Within shade coffee farms, as in other landscapes, ecosystem services function at different spatial scales (local, regional, and global), thus the ecological and economic benefits garnered from these services depend on the stakeholder composition at multiple spatial scales. Additionally, ecosystem services interact with one another in complex ways (Bennett et al. 2009), making it important to examine how these interactions play out within coffee plantations. In the sections below, we review the ecosystem services provided by shaded coffee plantations at local, regional, and global scales (Fig. 4). While there is overlap between services provided across spatial scales, we believe that it is beneficial to highlight the scales at which specific ecosystem services have the greatest impact on stakeholders.

4.2 Coffee Management Paradigms

Coffee plantations were traditionally cultivated under the canopy of a native forest, but coffee management systems practiced today follow a strong gradient from rustic to sun plantations. These different management systems have drastically different names depending on the farmers, researchers, or conservationists asked, but have many common features. Typically, more traditional practices include growing coffee under the canopy of a native forest ('rustic', or 'home garden' in Ethiopia where Arabica coffee evolved). As shade management is 'intensified', the resulting plantations have lower canopy cover, fewer shade trees, fewer shade tree species, fewer epiphytes, and more weeds (Philpott et al. 2008b; Moguel and Toledo 1999). Generally, although not always, shade management intensification is accompanied by increases in the use of synthetic agrochemicals (e.g. pesticides, fungicides, herbicides, and fertilizers). Many previous authors have outlined the details of coffee management gradients specific to Mexico (Moguel and Toledo 1999), Latin America (Philpott et al. 2008b), and parts of Asia (Craswell et al. 1997). Here, we summarize common characteristics of different management systems and the ecosystem services they provide (Table 5).

4.3 Local Scale Ecological Processes and Ecosystem Services

Biodiverse shade coffee plantations can support substantial native biodiversity, much of which contributes to provisioning, regulating, and supporting ecosystem services, including the supply of firewood, pollination and pest control services, erosion control, and nitrogen fixation. Dozens of studies have documented and summarized that shade coffee intensification, defined as the reduction in shade tree canopy richness and complexity (Moguel and Toledo 1999), generally leads to significant losses of diversity for trees, epiphytes, birds, bats, arthropods, small mammals, and amphibians (Perfecto et al. 1996, 2007; Greenberg et al. 1997a; Gallina et al. 1996). Reductions in tree diversity, removal of epiphytes, or other changes in the vertical structure of the vegetation can lead to further losses of animal diversity within agroforestry systems (Jha and Vandermeer 2010; Cruz-Angon et al. 2008; Philpott et al. 2008b; Gillison et al. 2004).

Specifically, biodiversity losses due to this type of intensification lead to significant losses of diversity of natural enemies (e.g. ants, birds, parasitoid wasps) with important implications for pest control services, a key regulating service provided by the shade coffee landscape (Philpott et al. 2008a; Perfecto et al. 1996, 2007). For example, ants and spiders reduce damage to coffee plants caused by the coffee berry borer, *Hypothenemus hampei* Ferrari (Larsen and Philpott 2010; Armbrecht and Gallego 2007; Perfecto and Vandermeer 2006; Vélez et al. 2001) and the coffee leaf miner, *Leucoptera coffeella* Guer. (De la Mora et al. 2008; Lomeli-Flores 2007). These studies report up to a 74–99% removal of the borers from occupied coffee berries (Armbrecht and Gallego 2007), suggesting that at a field scale, farmers could substantially benefit from reduced coffee berry losses if their farms provide sufficient ant habitat. Both birds (Kellermann et al. 2008) and bats (S. Philpott, personal communication with K. Williams-Guillen) also prey on the borers, and these services can save farmers from costly coffee losses due to borer damage (Kellermann et al. 2008). More generally, birds are important predators of arthropods in shaded coffee plantations (Borkhataria et al. 2006; Greenberg et al. 2000;

Table 5 Characteristics of coffee management systems[a]

Management style	Tree composition	Tree richness (No.)	Canopy cover (%) and height (m)	Shade strata	Coffee density	Canopy management techniques	Additional management / certification	Potential ecosystem services provided	Reviewed in
Rustic	Native forest canopy	25	>90% >15 m	3	Low – medium	Minimal canopy intervention	Bird-friendly, Rainforest Alliance or organic typically possible	Pollination, pest control, biodiversity, natural disaster protection, climate regulation, nutrient maintenance	Jha and Vandermeer (2010) and Philpott et al. (2008a)
Traditional polyculture	Some forest trees and some planted timber and fruit trees	10–20	60–90% 15 m	3	Low – medium	No or little pruning of the shade canopy	Bird-friendly, Rainforest Alliance or organic typically possible, usually with compost	Alternative food/ timber sources, pollination, pest control, biodiversity, natural disaster protection, climate regulation	Jha and Vandermeer (2010), Philpott et al. (2008a), and Méndez et al. (2007)

(continued)

Table 5 (continued)

Management style	Tree composition	Tree richness (No.)	Canopy cover (%) and height (m)	Shade strata	Coffee density	Canopy management techniques	Additional management / certification	Potential ecosystem services provided	Reviewed in
Commercial polyculture	Mostly planted canopy trees (timber and fruit trees) and N-fixing legumes. Few very abundant genera	5–10	30–60% 12–15 m	2	Medium – high	Regular pruning of canopy, removal of epiphytes	Rainforest alliance or organic typically possible, mixture of compost and agrochemical control	Alternative food/ timber sources, pollination, pest control, biodiversity	Jha and Vandermeer (2010) and Philpott et al. (2008a)
Shade monoculture	Canopy dominated by one species or genus of tree (i.e. *Inga* spp.)	1–5	<30% 10 m	1	High	Regular pruning of canopy, removal of epiphytes	Usually with agrochemical inputs	Minimal soil erosion control	Lin (2007)
Sun coffee	With rare isolated trees or without tree canopy	0	0% NA	0	High	Na	Usually with agrochemical inputs	Minimal soil erosion control and organic matter incorporation from coffee leaf litter	Philpott et al. (2008a)

[a]Based on Philpott et al. (2008a)

Johnson 2000) and may be able to quickly respond to pest outbreaks (Perfecto et al. 2004). Ants are more important predators in shaded coffee farms than in sun farms (Armbrecht and Gallego 2007) and functional or behavioral diversity of predatory species within coffee agroecosystems may enhance ecosystem services in general (Philpott et al. 2009; Van Bael et al. 2008). Thus, not only is the loss of predators significant for conservation purposes, but it will likely limit the regulating service of pest predation.

Furthermore, biodiversity within shaded coffee plantations may also perform important pollination services for crops (Klein et al. 2008), another key regulating and supporting ecosystem service. Both commercial species of coffee (*C. arabica* and *C. canephora*) benefit from pollinator visits (Klein et al. 2003a) and studies have shown that coffee pollinator species may be lost with agroforestry management intensification (Jha and Vandermeer 2010; Klein et al. 2003c). Large numbers of visits by honeybees (*Apis mellifera* L.), for example, correlate with higher coffee fruit set and fruit weight (Manrique and Thimann 2002; Roubik 2002; Raw and Free 1977). Native bees (including both social and solitary bees) augment pollination services to coffee, especially where diverse assemblages visit coffee plants (Klein et al. 2003b). Increased fruit set due to enhanced insect pollination at a per-bush level, can contribute to increased yields and farmer income at a farm scale, often worth tens of thousands of dollars (Ricketts et al. 2004).

In addition to pest control and pollination services, shaded coffee plantations provide a variety of other regulating services at the local level. Moderate levels of shade can hinder fungal diseases, such as the coffee leaf rust, which can have major impacts on coffee foliage and yields (Beer et al. 1998). Namely, trees create windbreaks, slowing the horizontal spread of spores of the coffee leaf rust (Soto-Pinto et al. 2002; Schroth et al. 2000), though incidence of other fungal diseases (e.g. coffee leaf spot, *Mycena citricolor* Cke.) may increase with vegetation complexity at local and regional scales (Johnson et al. 2009). Vegetation complexity at the canopy level can also provide weed reduction. In plantations with at least 40% canopy cover, many weeds, including grasses, can be completely eliminated (Beer et al. 1998; Muschler 1997). Furthermore, many common shade trees used in coffee agroforests (i.e., *Inga* spp.) provide the regulating service of fixing nitrogen and augmenting the nutrient content of soils (Beer et al. 1998), saving farmers the cost of expensive nitrogen inputs. Thus shaded plantations offer a number of potential ecosystem services at the local scale.

The shade component also generates important provisioning services in the form of direct products that provide socioeconomic benefits to coffee farming communities. Understandably, the array of tree species providing shade can also yield useful products in the form of fuelwood, building materials, fruits and ornamental or ceremonial plants (Rice 2008; Escalante 1995; Escalante et al. 1987; Lagemann and Heuveldop 1983), showing how non-coffee products can supply income to the farm household – especially during months when coffee income is depleted. In El Salvador, the shade tree canopy provides firewood for smallholder households for an equivalent value of 1 month of income generated by all the members of the household (Bacon et al. 2008a). The trees and plants within some shade systems

Table 6 Shade levels and impact on quality reviewed in studies from Latin America

Reference	Country	Positive impact	Negative impact	Observation
Läderach et al. (2009)	Colombia	>50% shade	<50% shade	Optimal growing zone
Vaast et al. (2006)	Costa Rica	45% shade	0% shade	Optimal growing zone
Muschler (2001)	Costa Rica	High shade level	Low shade level	Sub-optimal growing zone
Lara-Estrada (2005)	Nicaragua	46–63%	≤45%	Optimal growing zone
Decazy et al. (2003)	Honduras	Not evaluated	<44%	Optimal growing zone
Guyot et al. (1996)	Guatemala	High shade level	Low shade level	Optimal growing zone

also provide cultural services for coffee growers, as in the Peruvian cases of ritual plants from the farm being taken and given as offerings to the earth/mountain – "Pacha Mama" – in some of the indigenous communities on the Apurimac/Ene River region (R. Rice, personal communication with growers 2000, Peru).

Another local scale provisioning service provided by shade is the potential to improve the quality and flavor, since quality is a characteristic of production, and adds economic value to the product. While it has long been agreed that shade is the main factor enhancing coffee plantation sustainability in sub-optimal coffee zones (Beer et al. 1998), recent studies have also revealed that shade cover is beneficial as a means to improve coffee quality (e.g. taste, texture, pH), though the amount of shade needed for optimal quality varies for each bioregion. For example, a study in Colombia found that higher shade levels yield better quality than lower shade levels (Läderach et al. 2009). In Costa Rica, zero shade has a negative impact and 45% shade has a positive impact on coffee quality (Vaast et al. 2006), while in Nicaragua 45% or less had a negative effect and 46–63% had a positive effect (Lara-Estrada 2005). In Honduras, coffee with less than 45% shade was of inferior quality (Decazy et al. 2003), and in Guatemala high shade levels benefited coffee quality. The optimal shade level for the 0–20°N latitude is therefore probably somewhere between 45% and 70%, though the actual numbers are site specific and related to the overall production system and environment (Läderach et al. 2009) (Table 6).

4.4 *Regional Scale Ecological Processes and Ecosystem Services*

At a regional level, shade coffee plantations contribute to the regulation of services such as water conservation, watershed management, soil conservation, and landslide prevention. Coffee is grown throughout the tropics, but is susceptible to changes in local weather patterns (Carr 2001), with yield declines in years with lower precipitation (DaMatta et al. 2003; Salinas-Zavala et al. 2002). Furthermore, there is also a narrow temperature range under which coffee growth rates and yields are highest (Cannell 1976; Alegre 1959). Maintenance of these temperature and humidity conditions can benefit coffee producers with greater yields, but climate extremes (including regional dry and wet periods) may put coffee producers at risk (Lin 2010, 2007). A study conducted in the coffee growing Soconusco region of Chiapas, Mexico, examined daily and seasonal temperature and humidity conditions in the soil under three coffee management systems ranging in shade intensification (traditional polyculture, commercial polyculture, and shade monoculture) (Lin 2007). Lin (2007) found much greater daily fluctuations in temperature and relative humidity in the low shade sites compared with the higher shade sites – fluctuations that put coffee outside of the ideal temperature range for the region. There was also greater water loss from the soils in the low shade sites. Thus, shaded and diversified shade coffee farms provided greater climate regulating services, with potential impacts on coffee berry development and overall per bush yield.

Because coffee is grown in wet tropical climates, often on sloping mountainous regions, coffee landscapes are highly at risk of natural disasters including landslides associated with hurricanes, and will likely experience more frequent disturbances as climates continue to change. In 2005, a hurricane passed through the Soconusco region of Chiapas, Mexico, and caused extensive damage to the coffee harvest and to the landscape (Philpott et al. 2008c). Philpott and colleagues (2008c) examined economic damage to coffee farms (e.g. fruits lost to heavy rainfall) and the number of roadside landslides in a full range of coffee shade management systems. They found no differences in terms of economic damage depending on shade management system; however, they found that farms with more complex vegetation (i.e., less intensive farms) experienced significantly fewer landslides as a result of the hurricane. Additionally, this factor was more important than the amount of forest nearby and a number of topographic features (distance to rivers, elevation, and slope). The climate-regulating protection provided by increased vegetation complexity also has been recognized by coffee cooperative leaders in Guatemala and Mexico.

Furthermore, impacts from Hurricane Stan and land use changes following the hurricane in the Siltepec municipality of Chiapas have been examined; an area previously dominated by coffee production (G. Cruz-Bello, personal communication and unpublished data). Riparian areas suffered more total soil loss from the hurricane than non-riparian areas, and farmers were more keenly aware of the risks of growing coffee near rivers. Given concern about erosion and potential crop loss, many farmers were changing their land use practices. While some chose to grow maize in order to improve food security, many continued growing coffee. In these coffee growing areas, the majority of farmers with coffee left standing after the storm were changing their practices in order to increase the number of shade trees within their fields, with the knowledge that this may help buffer future climate-related disasters. Thus, across a number of regions, coffee growers have come to know that shade coffee can at least partially mitigate some climate-related natural disasters, saving potential crop loss and providing a key regulating ecosystem service.

Shade coffee farms also have gained recent attention for their role in serving as a corridor for organisms, such as pollinators and pest predators, moving between forest fragments within the region. Specifically, migratory birds, which are often pest predators, often utilize shade coffee farms while making their long-distance journey between temperate and tropical regions (e.g. Bakermans et al. 2009; Greenberg et al. 1997b). Molecular-based and mark-recapture studies have shown that key pollinators are able to migrate through shade coffee farms, between forest fragments. These include organisms such as butterflies (Muriel and Kattan 2009), and native bees (Jha and Dick 2010). Because shade coffee farms facilitate pollen and seed dispersing animals, native trees dependent on these dispersers are able to maintain reproduction and key gene flow processes across shade coffee systems (Jha and Dick 2008, 2010). These trees provide regulating services in the form of erosion control (Jha and Dick 2008) and also support native pollinators that are essential during the coffee bloom (Jha and Dick 2010). Thus, unlike sun coffee systems, which are often less permeable to dispersing organisms (e.g. Muriel and Kattan 2009), shade coffee farms can serve as habitat corridors for ecosystem service providing organisms moving regionally between forest fragments. Shaded coffee may also provide regional scale ecosystem services related to biodiversity conservation by enhancing the ecological quality of buffer zones near protected areas.

In order to take a closer look at the global spatial relationship between coffee cultivation and protected areas (PAs), we used the World Data Base on Protected Areas (WDPA consortium, 2005) and the Spatial Production Allocation Model (SPAM) database on crop production (You 2005). The WDPA was initiated by a United Nations (UN) General Assembly resolution in 1962 to record the status of the world's PAs, known as the UN List. There have been 13 editions of the UN List between 1962 and 2003, produced collaboratively by IUCN and the United Nations Environment Program -World Conservation Monitoring Centre (UNEP-WCMC). We used the latest digital version of 2005. SPAM relies on a collection of relevant spatially explicit input data, including crop production statistics, land cover and land use data, biophysical crop "suitability" assessments as well as any prior knowledge about the spatial distribution of specific crops or crop systems. Additionally SPAM uses crop production data at the national level reported by Food and Agriculture Organization of United Nations (FAO) and similar data within subnational boundaries compiled through a network of organizations.

The coffee institutions included in the analysis quantify their coffee areas using Geographical Information Science (GIS), either through delimitation of the areas by GIS, by remote sensing or by expert knowledge. Depending on the method, the information is more or less precise. As well, in the course of farmers shifting to other crops or renovation programs, the estimated coffee areas change constantly. On a global scale, we combined the SPAM and WDPA data to quantify the protected areas and areas under coffee production (Fig. 5). The output of the SPAM database on crop production generates maps with a 10 by 10 km resolution; the different shading of the pixels indicates the amount of harvested area per 100 km^2. According to the SPAM data, the global extension of coffee is approximately 1,008,600 km^2 and the extension of protected area registered under the WDPA database is 2,515,600 km^2. To assess the national coffee and protected areas in Mesoamerica we used information from coffee areas obtained from national coffee institutions and the WDPA data used for the global assessment (Fig. 6).

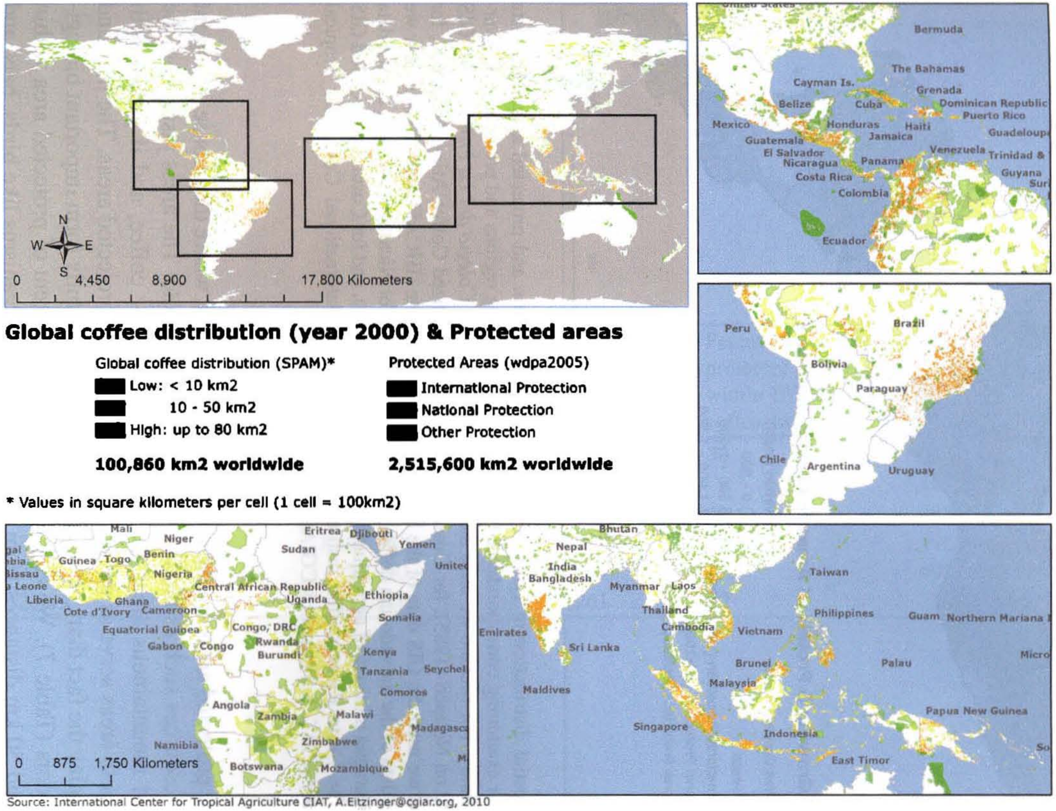

Fig. 5 Spatial distribution of global coffee cultivation and protected areas (Source: International Center for Tropical Agriculture, CIAT, A.Eitzinger@CGIAR.ORG, 2010)

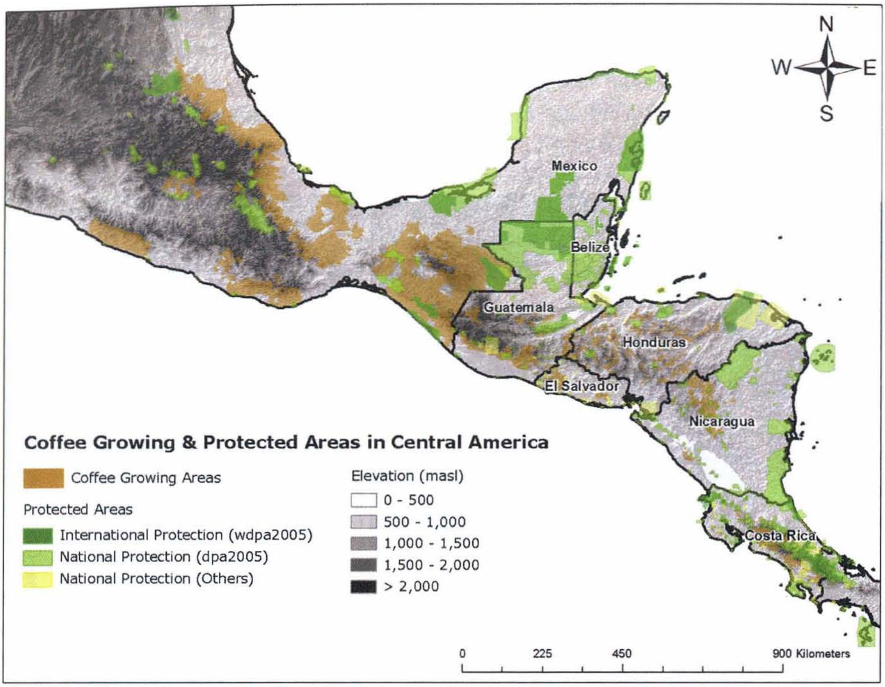

Fig. 6 Spatial distribution of Latin American coffee cultivation and protected areas. The data sources for examining correspondence between coffee producing regions and protected areas varied by country. For Mexico we used the reedited data of the *El Colegio del La Frontera Sur* GIS lab, based on Nolasco (1985), for Guatemala we used the digitized Coffee Atlas 2006/2007, for Honduras we used the GIS data of the Honduran Coffee Institute (IHCAFE), for El Salvador we used GIS data of the Salvadorian coffee institute (PROCAFE), for Nicaragua we used census data of the Nicaragua ministry of agriculture and forestry (MAGFOR), and for Costa Rica we used GIS data of the Costa Rican coffee institute (ICAFE) (Source: International Center for Tropical Agriculture, CIAT, A.Eitzinger@CGIAR.ORG, 2010)

Many protected areas are located in mountain chains, where they house important natural resources such as biodiversity, water, carbon, etc. The areas just below the protected mountainous areas are often designated for coffee, and if grown with shade, these areas serve as natural buffers around the protected areas. The map and table display the fact that coffee and protected areas jointly form important biological corridors (Table 7). We chose to examine the percent of protected area within 10 km and 50 km distances from coffee area, since organisms like birds, bats, and bees in tropical habitats disperse across short and long distances (Dick et al. 2008). In El Salvador, 72% of the protected areas are within a 10 km radius of all coffee growing areas, whereas in Costa Rica it is 32%, and in other Mesoamerican countries less than 15%. In El Salvador, 100% of the protected areas are within a 50 km radius of all coffee growing areas, in Costa Rica 84%, and in remaining countries less than 40%.

Table 7 Calculated protected and coffee areas by country

Country	Coffee areas (ha)	Protected areas (ha)	Coffee and protected area overlapping (ha)	Protected areas within 10 km distance (ha)	Percent of protected areas within 10 km of coffee area (%)	Protected areas within 50 km distance (ha)	Percent of protected areas within 50 km of coffee area (%)
Costa Rica	674,960	1,495,944	58,037	477,326	32	1,253,415	84
Guatemala	1,015,706	3,236,582	95,976	289,280	9	1,162,055	36
Honduras	1,304,765	1,272,725	32,678	146,450	12	485,793	38
Mexico	14,638,625	15,538,540	1,199,191	1,790,808	12	2,816,498	18
Nicaragua	777,004	2,202,118	70,930	145,384	7	495,950	23
El Salvador	312,689	58,650	12,188	42,261	72	58,650	100

4.5 Global Scale Ecological Processes and Ecosystem Services

At the global level, shaded agroforestry systems may be large contributors to the regulating services of carbon sequestration and climate change mitigation. Tropical deforestation and the use of fire in agricultural areas are leading contributors to increases in atmospheric CO_2 concentrations (Canadell and Raupach 2008; IPCC 2007). However, agroforestry systems, such as shaded coffee, have received attention for their potential to store and sequester relatively high levels of carbon (Canadell and Raupach 2008; Roncal-Garcia et al. 2008; Brown 1996). Soto-Pinto et al. (2010) examined the capacity of several shaded coffee systems, maize systems, and pastures to store carbon in Chiapas, Mexico. They found that *Inga*-shaded organic coffee maintains carbon in the soil organic matter to an equal extent as nearby forests, and that less intensive shaded plantations (organic and non-organic traditional polycultures) maintained more carbon than other land-use types examined. They suggest that these multi-strata coffee agroforests thus make important contributions for reducing emissions by deforestation and degradation (REDD) (Soto-Pinto et al. 2010).

In Brazil, Palm et al. (2005) found that simple shaded coffee systems (1–3 tree species) sequestered an additional 55 t of carbon per hectare in above ground biomass than in unshaded coffee monocultures. In Togo, shaded coffee plantations sequestered 53 additional tons of carbon in above ground biomass compared with an unshaded plantation (Dossa et al. 2008). However, it is important to take into account that intensively managed plantations, which use heavy applications of synthetic fertilizer, release N_2O, another greenhouse gas. This release would decrease the total contribution to climate mitigation from these systems. A recent study comparing N_2O emissions from heavily fertilized unshaded and shaded monocultures in Costa Rica found that shaded plantations released higher levels from having overall higher N from litter and N-fixation by *Inga* shade trees (Hergoualc'h et al. 2008). Thus, the management of fertilization and selection of species in shade coffee plantations will influence the level of climate mitigation provided by these systems.

At a global scale, the climate regulating services provided by shade coffee may become increasingly important as the planet faces more extreme weather events in the face of global climate change. Currently, climatological models predict general drying in parts of the Caribbean and Central America, coupled with stronger and later-season hurricanes (Neelin et al. 2006; Webster et al. 2005). Heavy rain and driving winds can wreak havoc during flowering and fruit bearing periods, the timing of which is coincident with hurricane season. Furthermore, much of the world's coffee-growing regions set fruit in April or May and fruit ripens anywhere from late August through November. If late season extreme-climate events, such as hurricanes, increase in frequency with global climate change, the existence of shade cover will be of even greater importance to buffer these events and thus sustain livelihoods and preserve ecosystem services in the face of global change.

The most representative Global Circulation Models (GCM) of the Fourth Assessment Report (AR4) for the Special Reports on Emission Scenarios (SRES)

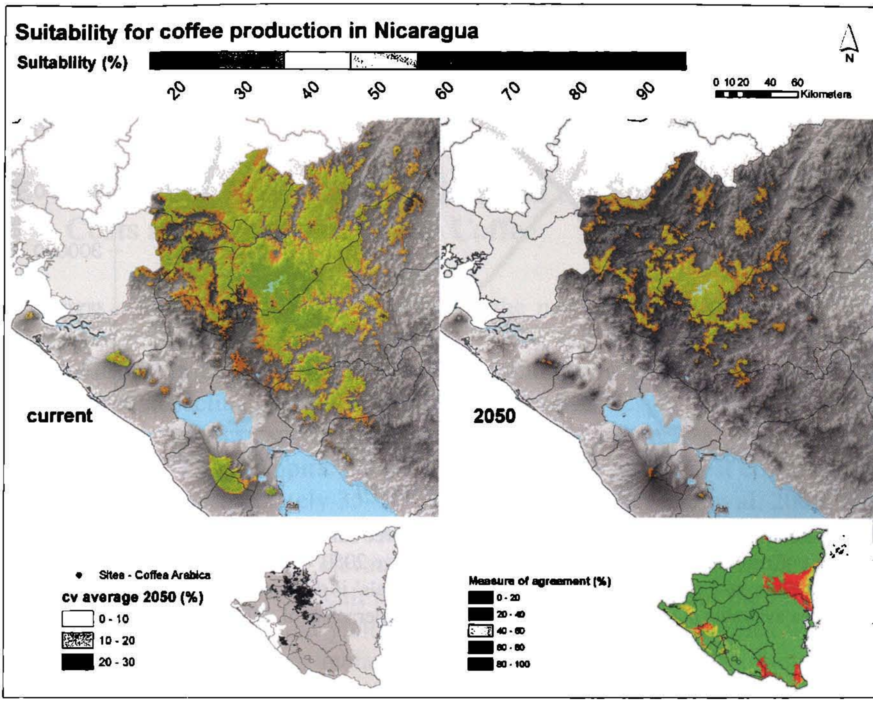

Fig. 7 Predicted (according to MAXENT) suitability for coffee production in the Nicaragua coffee-producing areas today and in 2050 (*large maps*) and the coefficient of variation (*CV*) and Measurement of Agreement for the study area with the points representing the sampled *Coffea arabica* farms (*small map*) (Modified from Läderach et al. (2010))

A2a (business as usual) emission scenario draws a trend of decreasing precipitation and increasing temperature for coffee-producing regions in Nicaragua (Läderach et al. 2010). The results of MAXENT (Phillips et al. 2006), a crop prediction model, indicates an important decrease in the suitability of coffee-producing areas in Nicaragua by 2050 (Fig. 7). There is a general pattern of decrease in the area suitable for coffee and a decrease in suitability within these areas. Suitability for coffee will move upwards on the altitudinal gradient with climate change, with lower-altitude areas having low to no suitability for coffee growing. The areas in 2050 that will still be moderately (40–60%) suitable for coffee production are mainly areas that currently show particularly high (>70%) suitability.

The optimum coffee-producing zone in Nicaragua is currently at an altitude between 800 and 1,400 m above sea level (masl); by 2050 the optimum elevation will increase to between 1,200 and 1,600 masl. Between today and 2050, areas at altitudes between 500 and 1,500 masl will suffer the greatest decrease in suitability and the areas above 1,500 masl the greatest increase in suitability. As the suitable altitude increases, less and less land area will be available at mid-elevation for coffee growing regions, like those in Nicaragua (Fig. 8, green line labeled Area).

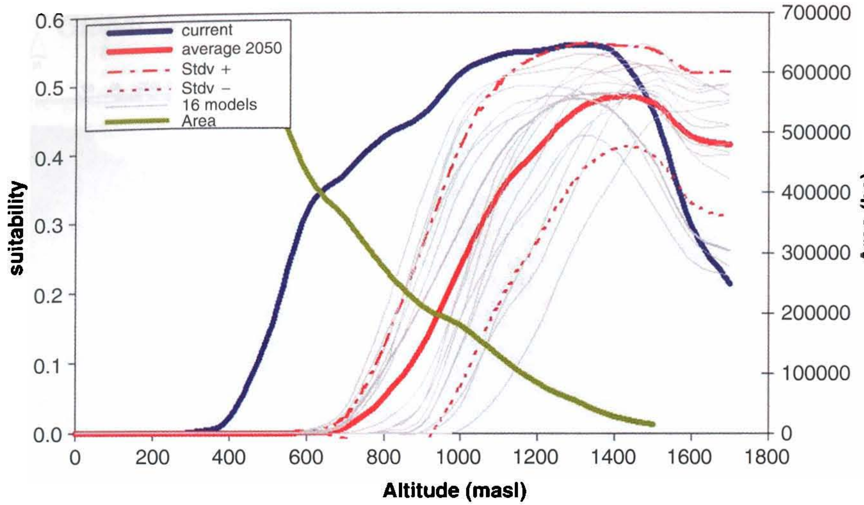

Fig. 8 Relation between current and future (2050) coffee suitability and altitude of coffee (*Coffea arabica*). 'Current' refers to current suitability, 'Average 2050' is the average suitability predicted in 2050, 'Stdv +/–' is the Standard Deviation, '16 models' is the average for 16 GCM, and 'Area' is the area available at each altitude (Modified from Läderach et al. 2010)

The first step in adaptation is to reduce the vulnerability of coffee farmers to climate change. In this regard, use of technical "no regret" measures that strengthen the resilience of the system (e.g. sound agronomy, sustainable management of natural resources) will be beneficial to growers and their livelihoods and may as well minimize the effects of climate change. In areas that will become unsuitable for growing coffee, farmers will need to identify alternative crops. In areas that will remain suitable for coffee, but with some reductions in suitability, agronomic management might be adapted to buffer the impacts of climate change. Drought resistant varieties, irrigation, and shade cover are all useful practices that can be implemented; shade cover can decrease average temperatures by up to 4°C (Vaast et al. 2006).

Areas where coffee is not grown today, but which in the future will become suitable for coffee, need strategic investments to develop coffee production. Account needs to be taken of environmental viability, since higher altitudes are often forest reserves that provide environmental services to the lowland population and to agriculture. The shift in altitude will definitely increase the pressure on land at higher altitudes. In regions that may be forced to abandon coffee, existing supply-chain actors need to think carefully about what their role in this transition may be. There are substantial investments in coffee processing and drying facilities, but it might be possible to use some of these facilities for other, non-coffee crops that are better adapted to projected future climates. In addition to physical infrastructure, many coffee-growing regions boast a highly qualified and specialized group of business services focused on coffee. If they continue to specialize on coffee, they will need to adapt and move to other regions, or if they choose not to move, they will need to begin to work on other crops. This combination of physical and human capacity is a current strength of coffee-growing areas and may well be leveraged to help identify and promote a planned transition to other income sources.

5 Interacting Ecosystem Services and the Socio-Economic Costs and Benefits of Shade Coffee

Farmers cite increases in coffee yields as the main reason for removing shade trees and native vegetation (Staver et al. 2001), but the ecological evidence on the relationship between shade and yield is far from clear. Some studies have demonstrated declines in yield with higher shade cover (Lagemann and Heuveldop 1983; Nolasco 1985), while some have documented increases (Ramírez 1993; ICAFE 1989). Other empirical studies have reported the highest coffee yield at intermediate (approximately 35–50%) canopy cover (Perfecto et al. 2005; Soto-Pinto et al. 2000; Muschler 1997). Because so many factors affect coffee yields, including soil conditions, elevation, precipitation, inputs, coffee variety, and shade, it has been very difficult to make clear statements about the relationship between shade, per se, and yield or even to compare across studies with more quantitative methods (e.g. meta-analysis) (Perfecto et al. 2005). Nonetheless, reviews have demonstrated that increases in shade tree diversity do not directly affect coffee yields (Peeters et al. 2003; Romero-Alvarado et al. 2002), and thus biodiversity and its associated provisioning ecosystem services may be easily promoted by increasing shade tree diversity, if not density, within coffee agroecosystems (Jha and Vandermeer 2010).

As discussed, a number of empirical studies show that plant and animal diversity within shade coffee systems provide pest control, pollination, and erosion control services; however, the potential economic benefit of these services often remains obscure to farmers because producers are infrequently directly rewarded for these services (Giovannucci 2003). In response to this lack of information, a few recent studies have quantified the economic value of ecosystem services in coffee agroecosystems. For example, a study on coffee pollination by native bees in Costa Rica calculated that coffee plants located within 1 km of a Costa Rican forest fragment had increased yields (>20% higher), an amount that totaled $62,000 of added income for the farm studied (Ricketts et al. 2004). This represents substantial benefits to farmers and highlights the importance of maintaining forest fragments in agricultural landscapes, even if small. An additional study conducted in the Blue Mountains of Jamaica documented that pest control services provided by birds to combat the coffee berry borer improved yields between 1% and 14% (Kellermann et al. 2008). In economic terms, this amounted to>$4,000 for farmers of the four small farms investigated, or between 2% and 69% of the per capita gross national income for Jamaica for each farm (Kellermann et al. 2008).

But coffee yields are not the only provisioning service provided by shade coffee systems. One often overlooked factor in assessing relationships between coffee yields and farm revenue is that shaded coffee farms with a diverse assemblage of trees often provide other sources of income to farmers. Shaded coffee farms include additional revenue from timber and non-timber products from the shade trees (Somarriba et al. 2004). In Peru, shade tree products may account for ~30% of revenues for each farm, especially fruits and firewood rather than timber (R. Rice, unpublished data 2002). Escalante et al. (1987) found that fruits from the shade canopy accounted for 55–60% of income, and timber for 3%. In Costa Rica, fruit sales accounted for 5–11% of income from coffee growing areas (Lagemann and Heuveldop 1983). Available products from the shade tree canopy reduce vulnerability to market fluctuations and household dependence on outside products while increasing local commerce. Thus, product diversification can reduce the need to exploit nearby forests. Perhaps most importantly, shade tree canopy products can buffer farmers in tough financial periods, especially when coffee prices are very low (Escalante et al. 1987).

Despite a basic understanding of the independent ecosystem services acquired with shade coffee farms, very little research has examined how ecosystem services may interact. One review, conducted across a number of modern agricultural systems, revealed that most often, the only ecosystem service considered is the production of the marketed commodity, with little thought to regulating services such as water and air filtration, disease suppression, and wildlife habitat (Robertson and Swinton 2005). Recent work has also pointed to the need to consider the multiple ecosystem services present in a particular area in order to promote synergistic services and avoid tradeoffs that may enhance one service at the expense of another (Bennett et al. 2009; Robertson and Swinton 2005). For example, within the shade coffee system, practices used to enhance one regulating service, such as planting fast growing tree species for carbon sequestration, may impact other services, such as the provisioning services provided by the coffee crop, or the regulating service of pollination derived from supporting bees dependent on diverse shade tree canopy. What is needed is an orientation towards understanding the full agro-ecological system and the many ecosystem services provided within it, which will provide a better understanding of how these services are coupled and what potential trade-offs may exist (Robertson and Swinton 2005; Robertson et al. 2004).

Recent research (Raudsepp-Hearne et al. 2010) proposes visualizing ecosystem service 'bundles' that allow for an examination of the different types of ecosystem services, and how each service within the bundle is enhanced or reduced as a result of management interventions. These interactions can be expected to differ depending on the type of shade coffee systems, geographical location and socio-economic context. Méndez et al. (2009) found that a higher density and diversity of shade trees resulted in small-scale, individual farms having a higher potential for provisioning services (e.g. timber, fruit and firewood) than larger, collectively managed cooperatives. However, additional shade tree products came at the expense of lower coffee yields, showing a negative interaction between two different types of provisioning services (Mendez et al. 2009). In addition, these differences in provisioning services did not significantly affect regulating services in the form of above ground C stocks from the shade tree canopy. Henry et al. (2009) conducted an in-depth examination of the interactions between plant biodiversity and regulating (C sequestration) and provisioning (food production) ecosystem services in smallholder farms of Kenya. Although the study only included a few coffee plots, the results showed that plant biodiversity had no effects on C stocks, but that increasing C sequestration by adding more trees would have a negative effect on food production. Similar interactions might be seen in smallholder coffee households that manage different types of agricultural crops in addition to coffee. Future research needs to focus on the trade-offs involved with interacting ecosystem services and the optimal strategies for long-term ecosystem service provision and conservation across multiple shade coffee landscapes.

6 Farmer Livelihoods, Vulnerability and Change

6.1 Sustainable Livelihoods

A livelihoods-based approach seeks an integrated assessment of the way that individuals and households access and use a diversity of assets to "make a living and make it meaningful" (Bebbington 2000). We selected this focus because it links the economic elements of "making a living" – including food security, monetary incomes, and barter – with the cultural dimensions of making it meaningful. Scoones (1998) elaborated a working definition, stating that "A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living." Planners conducting livelihoods assessments consider the social assets (i.e., participation in a cooperative or other local association, networks of friends and family etc.), natural assets (i.e., the land, water and microclimates that a household could potentially use), financial assets (i.e., loans and savings), physical assets (i.e., houses and equipment) and potentially many other assets including those related to cultural memory, shared experiences, and local knowledge, as well as human capabilities that are embedded in the relationships that households use to articulate their livelihood projects (Scoones 2009, 1998; Bebbington 1999) (Fig. 9).

Although several scholars initially limited the discussion of livelihoods to a categorization of these different assets, sometimes referred to as the five capitals (social, natural, physical, human and built capital), many community-based researchers and those interested in deeper theoretical work related to development and sustainability were keen to also address contextual variables (Bebbington 1999, 2000). This includes the multi-scale political, economic, and ecological structures and processes that influence the construction or depletion of assets and that intercede in a household or individual's ability to access (Ribot and Peluso 2003) the benefit flows at a particular moment in time (Scoones 2009). The vulnerability context also influences several broader trends, including seasonality (i.e., dry vs. rainy season, and/or particularly cold, hot or wet year), the presence of sudden shocks to a livelihood

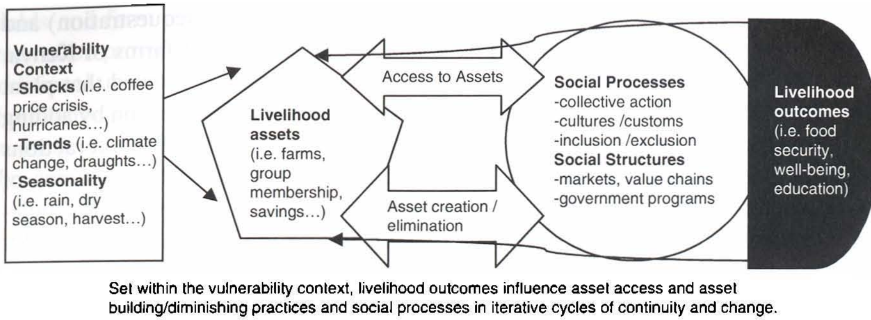

Fig. 9 Livelihoods change framework for coffee smallholders (Modified from Amekawaa et al. 2010)

system (e.g. a flood, hurricane, drought, market or political collapse) and other, ongoing stressors of daily life.

To discuss vulnerability in the context of this review, we draw from a political ecology approach that uncovers the social processes (e.g. economic poverty, exclusion, poor land use planning) and environmental degradation that can transform an external shock or low level stressor (seasonal drought, decreasing real income, or climate change) into a disaster with measurable social and ecological impact (Wisner et al. 2004). An important focus also concerns the different strategies that households use to cope with shocks. Some strategies, such as certain types of farm and livelihood diversification can increase intermediate-term sustainability, while others, such as pulling children out of school to work, can contribute to persistent poverty (Devaux et al. 2009). Households with more sustainable livelihoods are able to cope with and recover from shocks, maintain or enhance their capabilities and assets, and provide more sustainable livelihood opportunities for the next generation (Chambers 1992, 1991). Less vulnerable livelihoods have lower exposure to shocks and stressors and are more capable of mitigating the consequences of the hazards that do affect them.

6.2 *Types of Livelihoods*

The diversity of coffee-dependent livelihoods ranges from the part time barista making espressos in northern cities to the seasonally employed coffee pickers balancing upon the steep slopes of southern mountain landscapes. Coffee livelihoods also include traders, export managers and farmers, among others. On both ends of the value chain these part-time coffee workers often face structural difficulties. In the United States, most baristas do not have access to basic health care and can often make salaries that are close to the minimum wage. In the coffee growing regions, coffee pickers are often migratory laborers that exist as marginalized members of society (frequently with indigenous origins) living in some of the world's most economically poor countries (Oxfam 2002). Paid by the pound of coffee cherries harvested, these pickers may earn as little as $2–$10/day (Oxfam 2002).

Coffee pickers and rural coffee laborers (who may also do the pruning, fertilizing, and weeding) were among the most vulnerable to the post 1999 coffee crisis (Bacon et al. 2008b; CEPAL 2002). Many did not have access to key livelihoods assets, most of which come from owning land, and were also cut off from access to collectively managed forests or range land. The direct economic impact as larger farms in Central America (over 50 ha) stopped maintaining and often harvesting their farms included the loss of more than 40 million days of work (CEPAL 2002). Although personal observation suggests the importance of coffee shade fruit trees in provisioning workers with food and a cooler environment during the coffee harvest, we are not aware of any systematic studies evaluating the effects of shade vs. sun coffee upon coffee farm worker livelihoods.

A rapidly growing literature concerns the multiple dimensions of coffee farmer livelihoods. Three studies involving farmers in Mexico, Nicaragua, El Salvador and Guatemala found that coffee remains the most important income source and a core component of their livelihood strategies (Méndez et al. 2010a; Bacon et al. 2008a; Jaffee 2007). Previous and ongoing livelihood-oriented studies that assessed the relationships between indigenous identities and organic coffee production have yielded contradictory results. This research shows a positive initial fit (Nigh 1997) and tensions between community life and the increasingly high expectations and reporting requirements associated with the annual organic inspections (Mutersbaugh 2004). Others have documented the gender relations and issues of inequality, exclusion and empowerment among coffee farmers and within smallholder cooperatives (Lyon et al. 2010; Hanson and Terstappen 2009). The research findings to date reveal persistent inequalities as women are continually marginalized and certifications, such as Fair Trade, have not yet delivered on their gender-related goals. Finally, several studies include a comparative analysis addressing several livelihood outcomes, such as food insecurity, education, incomes, and vulnerability among farmers connected to certified networks vs. those selling only to conventional coffee value chains (Méndez et al. 2010a; Arnould et al. 2009).

An overwhelming result of these studies reveals persistent livelihood difficulties among most small-scale coffee farmers in Mesoamerica (Méndez et al. 2010b; Bacon et al. 2008b; Jaffee 2007). Jaffee's insightful book discussed the seasonal, 'hungry' or 'thin months', communicating what many Mexican rural development planners and researchers have long known (Jaffee 2007). Another study involving 469 households in Mesoamerica found that 63% of those interviewed reported that they struggled to meet their basic food needs (Méndez et al. 2010a). A comparative study involving 177 households in northern Nicaragua also documented similar trends and revealed that the average households, including those connected to Fair Trade and organic markets, generated less than a dollar a day per person from their coffee production (Bacon et al. 2008b).

6.3 *Do Sustainable Coffee Certifications Improve Farmer Livelihoods?*

The post-1999 coffee crisis provided a dramatic natural experiment or common treatment to study the effects on farmers of participation in cooperatives and different certified coffee networks. Two large quantitative studies in Latin America showed that Fair Trade and organic certifications are able to provide some benefits to smallholder farmers, but that these remain small in terms of a broader livelihood perspective (Méndez et al. 2010a; Arnould et al. 2009). Certifications were able to provide higher prices, but since the volumes sold were relatively low, this did not amount to significant increases in income. No effects were observed in terms of improving access to food through purchasing or production, which is one of the persistent challenges of smallholder and cooperative coffee farmers. However, some of the benefits reported included improvements in access to health, credit, and savings. In addition, farmers reported links to international development networks as an important benefit that has the potential to support farmers when combined with other development or environmental support (Méndez et al. 2010a). Although there are nuances, local exceptions and occasionally differences in methodology and interpretation, a summary of the available evidence related to the studies and observations included in this review suggest the following findings concerning the relationships of coffee smallholder livelihoods, certifications, and global markets:

1. The livelihood conditions among smallholders are generally difficult and suffered severely during the post 1999 coffee crisis (Méndez et al. 2010b; Arnould et al. 2009; Jaffee 2007; Bacon et al. 2005). Few studies have been published with data emerging after 2006 when green coffee commodity prices started to increase. The available studies, personal observations from travel to coffee growing regions, interviews, and conferences, as well as preliminary findings from works in progress involving this review's authors suggest that while the more pinching dimensions of the post 1999 coffee price crash such as the humanitarian crisis, broad-based job losses and abandoned coffee farmers have decreased, seasonal hunger, marginalization and vulnerabilities persist (Peyser 2010; Renard 2010).
2. Participation in cooperatives connected to Fair Trade, often partially mitigates exposure and thus livelihood vulnerability to falling coffee commodity prices and – for those that can access the market – it could potentially offer support through international development networks to diminish the negative consequences of other changes to the vulnerability context, such as food shortages, hurricanes, and earthquakes (Jaffee 2007; Raynolds et al. 2007; Bacon 2005a).
3. Farmers affiliated with these cooperatives often have more access to credit and in selected cases are more likely to practice sustainable land management practices (i.e., soil and water conservation practices on the farm, avoidance of pesticides) than their conventional counterparts (Méndez et al. 2010a).
4. Empirical realities, including the persistence of hunger and ongoing gender inequalities and uneven development within coffee growing regions, contradict

the enthusiastic publicity associated with many certifications, including Fair Trade, Rainforest Alliance and Utz Certified (Lyon et al. 2010; Bacon et al. 2008a; Lyon 2008; Jaffee 2007; Fridell 2006; Mutersbaugh 2004).

5. Coffee cooperatives can be effective local organizations for coordinating collective action and have enabled hundreds of thousands of smallholders to retain the title and use of their lands. Those that have developed administrative capacity and accountability to their membership, as well as external partners can also provide valuable technical assistance, leverage international development funding to improve coffee yields and quality, and support a wide array of social development and diversification projects (Raynolds et al. 2007). Examples can be found among several of the pioneer cooperatives in Nicaragua, such as SOPPEXCCA and PRODECOOP, as well as the stronger cooperatives in Mexico and Peru (i.e., CIPECAFE in Peru and CESMACH in Chiapas, Mexico).

6.4 Diversification Within Coffee Production Systems

Coffee production systems and the landscapes into which they are embedded often include other cropping systems. The majority of smallholder coffee farmers are peasant producers farming for subsistence. With few resources other than their own labor and a small plot of land, their "coffee farms" are much more than that. For example, farmers in Mexico and Central America often also cultivate corn-bean-squash systems and manage pastures (Méndez et al. 2010a; Philpott et al. 2007); coffee smallholders in Brazil farm sweet potato, sugar cane, black pepper and various fruit crops (Steward 2007); and farmers in Indonesia normally also cultivate rice and perform aquaculture (Waltert et al. 2005). Within the coffee plots themselves, farmers worldwide often incorporate a high number of different plants, including fruits (e.g. orange, banana, mango, avocado, durian), nuts (e.g. candlenut), wood products for timber or firewood, and additional export crops (black pepper, cinnamon, cloves) (Philpott et al. 2007, 2008b; Rice 2008; Méndez et al. 2007; Michon et al. 1986). In Peru, growers in the Apurimac/Ene river valley make use of up to 13 different species of bananas (*Musa* spp.) alone.

A comparative study conducted in El Salvador and Nicaragua found that households growing shade coffee managed at least four distinct types of plant functional types, including shade trees, agricultural crops, medicinal plants and epiphytes (Table 8) (Méndez et al. 2010b). Plant agrobiodiversity was found in four locations, including shade coffee plantations, homegardens, agricultural plots, and living fences. Shade trees, medicinal plants, and epiphytes were found in several locations, while crops were only found in agricultural plots. Trees were the most species-rich group, with a total of 123 and 106 species in El Salvador and Nicaragua, respectively. Diversity of agricultural crops was similar in both countries, but differences were observed in the types of crops grown and the number of varieties. Nicaraguan households managed thirteen varieties of corn and nine varieties of beans, a higher figure than what was found in El Salvador.

Table 8 Additional crops grown by households cultivating shade coffee in Nicaragua and El Salvador (Modified from Méndez et al. (2010b))

Agrobiodiversity type	Growth habit	No. of species	Uses reported	Value reported by farmers
El Salvador				
Trees	Woody perennial	123	S, FW, Fr, M, T	Firewood obtained from shade trees saved households an average of $71.50 per year in 2002.
Agricultural crops	Herbaceous	7	F, M	62% of the sample (n = 18) reported producing at least 40% of the food used by the family in 1 year
Medicinal plants	Woody perennial, shrubs, herbaceous	119	F, M, FW	Medicinal plants are valued because farmers cannot afford modern medicines or health care.
Nicaragua				
Trees	Woody perennial	106	S, FW, Fr, M, T	Farmers reported an average of $167 per year from firewood sales, in addition to covering their own firewood needs.
Agricultural crops	Herbaceous	7	F, M	Average of 50% of food is produced in these fields
Orchids	Primarily epiphytes	96	O	Aesthetic and ornamental

Uses reported: F = Food; Fr = Fruit; FW = Firewood; M = Medicinal; S = Shade; T = Timber; O = Ornamental

The Nicaraguan coffee farmers also had a higher number of coffee varieties (eight), compared to their El Salvador counterparts (two). Medicinal plants, which were only found in El Salvador, contained a high diversity of species and growth habits (119 species of trees, shrubs, and herbs).

6.5 *Farm Size Cooperatives, Livelihoods and Shade*

The different livelihood activities of coffee farmers can have implications for the design and management practices of their shade coffee. These practices can in turn influence the associated biodiversity and ecosystem services of a particular farm or landscape. Guadarrama-Zugasti (2008) compared management practices related to agrichemical use between small-scale and large farms. He found that small-scale producers were using lower levels of synthetic pesticides and fertilizers per farm, which resulted in fewer soil and water contamination problems than those observed in larger farms. He then used several indicators to develop a farmer typology, identifying at least eight different production strategies, including 'coffee/corn farmer', 'agricultural worker/coffee farmer', and 'hobby coffee farmer'. These different types of farmers were then associated with varying intensities of agrochemical use, soil erosion, and incomes. The results showed that small-scale farmers that were using practices with low environmental impact were slowly transforming to more intensified management, such as used by larger growers. Methodologies such as this one could prove useful to re-think common shade coffee system classifications and to provide an interdisciplinary synthesis that identifies the most effective interventions. The typologies developed by Moguel and Toledo (1999), which describe shade tree canopies and management regimes, are useful to characterize the biophysical structure of agroecosystems, but may not adequately describe livelihood strategies. The heterogeneity of farmer livelihood strategies is often overlooked (Shulman and Garret 1990) and few studies have connected farmer types with issues of sustainability and technological change (Guadarrama-Zugasti 2008).

Farmer cooperatives have been instrumental for smallholders to negotiate coffee farming and commercialization at different scales. In Nicaragua, strong cooperative unions have been able to become national leaders in coffee production and commercialization, while also embracing environmentally friendly production (Bacon 2005b, 2010). Research in El Salvador and Nicaragua also has found that origin, type, and governance of coffee farmer cooperatives can have a direct effect on management practices and the resulting levels of biodiversity and ecosystem services provided by plantations (Méndez et al. 2009, 2010b). These studies showed that individually managed farms that belonged to farmer associations contained higher levels of shade tree species diversity and uses (i.e., fruit, firewood, timber) than plantations where cooperatives used centralized collective management arrangements.

7 Discussion: Synthesis and Policy Directions

7.1 *Need for an Integrated Multi-scaled Interdisciplinary Framework*

While local and regional coffee landscapes have broad impacts on both ecosystem services and farmer/worker livelihoods, it can be challenging to simultaneously analyze both impacts within a single coffee value chain. This is partially due to the fact that investigation of each of these areas requires a distinct methodological approach, and that the high number of transactions between farmer/worker and consumer make it difficult to relate coffee revenue to worker livelihoods (for details see Sect. 5). Additionally, although many ecosystem services within agricultural landscapes are appreciated by people, they currently have limited market opportunities, and remain largely unrewarded (Swinton et al. 2007; Robertson and Swinton 2005). Because provisioning services, such as farm products, have market values, these services take precedence over recreational, supporting, and regulating services. Many studies suggest that in order for policy to consider ecosystem services without market value, an alternative valuation technique must be employed (Swinton et al. 2007; Robertson and Swinton 2005).

Within the shade coffee system, there are only a few examples where ecosystem service value has been estimated. One can be seen in the work of Philpott et al. (2008c) who examined both erosion control services and economic yields from a single coffee growing region in Chiapas, Mexico. As described in Sect. 3.4, by examining both economic and ecological data, the study revealed that road conditions, not coffee yields, were most negatively affected by hurricane damage. Thus, the erosion control provided by dense and diverse shade trees had a direct positive economic impact on coffee transport infrastructure, rather than on coffee yield. A number of other studies have also taken the initial step of quantifying the socio-economic gains procured by ecosystem services within coffee farms (described in Sect. 3.6). For example, researchers have revealed that local forest patches increase the pollinating activity in coffee farms, a service calculated to be worth $128.6 USD/ha per year in a Costa Rican farm and $1,860 USD/ha in a Brazilian farm (De Marco and Coehlo 2004). Kellerman et al. (2008) similarly quantified the value of bird-mediated pest control to be worth $44–$105/ha USD.

In many of these examples, however, the research does not specifically discuss the actual economic impacts of ecosystem services on farmer/worker livelihoods. As the science currently stands, we know little about the direct and changing impacts that ecosystem services have on worker/farmer livelihoods (i.e., how people make a living and how they make it meaningful). We suggest that future research utilize a multi-scalar approach to examine both livelihoods and interacting ecosystem services within shade coffee landscapes. For example, the value of biodiverse shade coffee farms is visible not only in coffee yields but also in the contribution to regional and global water conservation and carbon sequestration; however, the costs/benefits of the entire ecological and socio-economic system are not often simultaneously understood. In order to improve farmer livelihoods and promote long-term sustainability in shade coffee landscapes, we need to define goals for these regions (McAffee and Shapiro 2010) and work towards a long-term vision where both livelihoods and ecological sustainability are taken into consideration.

7.2 Biologically Rich Lands, Economically Impoverished People

The evidence from many coffee landscapes confirms the persistent paradox of 'rich lands and poor people' (Peluso 1994). In other words, coffee growing regions often have very nutrient-rich soils, high biodiversity, and ideal climates for crop cultivation, yet the incomes generated from these landscapes are minute. Farm families that sustain some of the most vital ecosystem services in fragile mountain landscapes, such as regional water storage and carbon sequestration, also are among the most socially marginalized and economically impoverished (Bacon et al. 2008b). This paradox reveals the way that the dominant state-backed development models and current configuration of coffee value chains have undervalued and poorly compensated farmers, farm workers and shade coffee landscapes (Trujillo 2008). The empirical evidence shows that millions of coffee farmers continue to struggle for survival despite the major contributions made to producing high quality coffees and generating ecosystem services (Bacon et al. 2008b; Jaffee 2007).

Although resistance and alternative approaches prevail in many places, including many smallholder coffee landscapes, such as the Zapatistas in Chiapas (Watts 2007; Fox 1994), a raft of Neoliberal policies remains the dominant trend in many coffee growing communities (Topik et al. 2010). As defined in Sect. 3.7 of this chapter, the Neoliberal influence is visible through the passage of free trade agreements, the collapse of the International Coffee Agreement (that governed the markets from 1962 to 1989), the rollback of state invested agriculture and rural development, and the fraying of social safety nets (Talbot 2004). Although the dissolution of bureaucratic, frequently ineffective and occasionally corrupted state-backed marketing boards and coffee extension agencies opened the spaces for rapid growth of market-based sustainability certifications, both organic and fair trade systems originated in social movements outside and prior to this Neoliberal shift in coffee market governance, and – at least initially – represented alternative approaches to agricultural production, trade, and consumption (Bacon 2010).

The empirical evidence shows direct and indirect benefits associated with the rise of sustainable coffee certifications (Méndez et al. 2010a; Jaffee 2007; Philpott et al. 2007; Bacon 2005a), but persistent hunger and livelihood insecurities remain the dominant trend. Thus far, much of the biodiversity and many of the valuable ecosystem services have persisted at both farm and regional scales (e.g. Perfecto et al. 2007). However, without a change in the predominant coffee value chain there is reason to believe that the vulnerability of the livelihoods of shade coffee farmers will continue to increase. Accelerating climate change, volatile markets, and inequalities in the coffee value chain (among others) could potentially overwhelm the local resiliency that these systems have demonstrated the past half century. The challenge before us is to fundamentally re-think the current approach. This includes a re-orientation of the strategic and technological approaches with the participation of a wide diversity of stakeholders prior to the selection of the most promising policy directions. This process could generate investments and actions that are commensurate with effective action at multiple scales.

7.3 *Political Possibilities and Policy Options*

Business as usual will likely lead to the continued decline of many diverse shade coffee production systems in the Americas, resulting in social and physical landscape transformations that the regions cannot afford. While non-governmental and private concerns have made inroads and some headway in promoting the shade coffee concept, it could be argued that governments need to act upon the opportunity before them. It is worth noting, for instance, that the United Nations' Millennium Development includes one assessment addressing poverty and another focusing on environmental sustainability (Goals 1 and 7, respectively). Meeting these goals with the support of governments and the international community in coffee producing countries could potentially turn the tide to favor the conservation and enhancement of shade coffee livelihoods and landscapes. For many producing countries facing rural poverty and biodiversity threats, the increasing support of shade coffee consumption is an opportunity to boost rural income and support native biodiversity, especially when compared to the unsustainable alternatives of deforestation and pasture establishment. Our review of politics and policies that influence the future of shade coffee is guided by three normative goals: (1) improved rural livelihoods, (2) cultural survival, and (3) the conservation and recovery of vital ecosystem services. A critical starting point are the current practices, knowledge systems and organizations (often cooperatives and ejidos, but sometimes NGOs, coffee roasters, state agencies and others) that have helped sustain important ecosystem services and culturally diverse coffee farmers. While the current configurations of coffee value chains and government regulation also are a necessary starting point, this need not constrain the horizons of political possibility. In fact, the coffee industry is full of innovative examples and partnerships geared towards the improvement of livelihoods, the strengthening of local organizations and the conservation of ecosystem services (Linton 2005). Two recent examples include farmer exchanges that were undertaken with the support of coffee industries. First, farmers from Nicaragua visited Peru to learn best practices for organic compost making, and in the second case, farmers and cooperative leaders from Rwanda were able to visit Nicaragua to learn about the strategies used to build strong smallholder cooperatives and improve coffee quality (Bacon et al. 2008b). However, these specific examples could be part of a broader proposal to involve a wider range of farms and farm workers. The following sections touch upon several of the strategic themes to consider for all stakeholders interested in maintaining or promoting sustainable coffee production.

7.3.1 Ensure That 'Sustainability' Covers Basic Human Needs

Among international industry associations, many of which lobby for decreased regulation and dodge critical issues of social and environmental sustainability, the specialty coffee industry stands out for its efforts to promote sustainability through certifications, pledges to global development, and direct farm and community level investments (Dicum and Luttinger 1999). It has served as an effective platform for launching many mainstream initiatives from certified organic and Fair Trade products to social responsibility partnerships for education and environmental conservation in coffee growing communities.

Despite these industry, non-profit and governmental commitments to sustainability in the specialty coffee sector, the research shows that many smallholder farmers continue to negotiate hunger on an annual basis (Méndez et al. 2010b). Although the paradox of hungry farmers and farm workers is hardly monopolized by small-scale coffee producers, witness for example, the high levels of hunger and rural poverty that plague California's Central Valley, one of the world's most agriculturally productive landscapes (Harrison et al. 2002). Thus, evidence from both 'developed' and 'developing' countries suggests the need to re-focus efforts upon the basic needs and environmental justice / social equity dimensions of sustainability (Shiva 2008; Agyeman et al. 2003).

The Brundtland Report, which established one of the few commonly accepted definitions of sustainability, recognized the fundamental importance of food, water, housing, education and health especially among the most economically poor and marginalized (WCED 1987). "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In other words, truly sustainable systems require an evaluation of farmer livelihoods, ecosystem services, and well-being. Existing sophisticated marketing schemes for socially just and ecologically beneficial coffee will soon begin to ring hollow if the basic needs of farmers and workers are not addressed.

Longer-term solutions to these challenges will address global scale processes such as the structure and governance of coffee value chains (Bacon 2010; Topik et al. 2010; Daviron and Ponte 2005), state investments (Talbot 2004), and climate changes (Lin et al. 2008) that are re-shaping the vulnerability context in which small-scale coffee growing communities must operate. The same global challenges continue to undermine the sustainability of global food systems across a wide diversity of foods and commodities (Perfecto et al. 2009; Watson and Herren 2009). The responses to these challenges will shape the future of food and agriculture with their profound corollary affect upon ecosystem services, rural livelihoods, and food security. With these global trends in mind, the following sections consider several strategies that could improve livelihoods and sustain ecosystems in coffee growing communities. Two effective strategies to address both hunger and rural livelihood vulnerability are through diversification and sustainable intensification.

7.3.2 Farm and Livelihood Diversification

For both economic and ecological security, the diversification of crops and livelihoods is essential for coffee producers (Rice 2008). As discussed in Sect. 5, maintaining a diverse array of crops provides farmers with (1) alternative income sources in case of crop losses, (2) income across the growing season, (3) reductions in pest pressure, and (4) food for home consumption. Diversification of shade trees can also help farmers garner ecosystem services (Méndez et al. 2009). As reviewed in Sect. 4, the planting and diversification of natural vegetation and shade trees provides fertilization, erosion control, and habitat for pollinators and pest-predators. Livelihood diversification could include on-farm and off-farm income sources, such as honeybee management, timber harvesting, construction, and the sale of crafts. This could be further enhanced with training, small-scale capital investment, and mentoring to innovate rural enterprises focused on processing agricultural products for storage and sale, accelerating communication, and in some cases, community-based rural tourism. Examples of incipient agro-ecotourism projects in shade coffee communities can be found in Central America. Starting in 2003, cooperative unions in Matagalpa, Nicaragua, launched an agro-ecotourism project with the support of researchers and the NGO Lutheran World Relief (Bacon 2005b). The project has received more than 1,200 visits from Fair Trade networks, foreign universities, and solidarity organizations. However, despite these accomplishments, the farmers face persistent challenges, including an insufficient number of visitors to cover the costs of the program, a factor that could be addressed with increased advertising (Méndez et al. 2010b).

Intensification efforts have focused on strategies to increase yields and decrease food loss from storage and crop loss from drought. One of the most effective, albeit costly strategies for increasing yields is through irrigation, especially in areas dependent on rain-fed agriculture. Second and third strategies are soil fertility improvement and selection and sharing of heirloom and local seed varieties (especially corn, beans, rice and other subsistence crops) that are locally desired and resistant to extreme weather and changing precipitation patterns (Méndez et al. 2010b). Multi-cropping with local seeds can be encouraged by funding of local seed banks and extension services aimed at subsistence crop cultivation. Many communities have long histories of local subsistence crop cultivation, but little has been recorded about the implementation of these practices. Civil society and local group involvement is necessary to resurrect these practices for a diversified farming system as evidenced through activities such as the non-profit support for the Mesoamerican farmer to farmer movement (Holt-Giménez 2006). Although civil society investment remains important, especially to develop innovative and pilot community-level initiatives that support diversification, intensification, afforestation and food security (Pretty 2002), the structural drivers affecting persistent hunger, the fraying rural safety net for health and educational opportunities, and broader scale investments may require a new type of state-led regulation and investment (Watson and Herren 2009; Bacon et al. 2008b).

7.3.3 Revive Strategic State Action

National, state and local governments together with the citizens and residents of coffee growing communities are fundamental stakeholders in sustainable community development in coffee growing regions. The state also remains a central participant in creating, coordinating and enforcing the political, economic and agri-environmental standards that structure important components of the coffee value chain (Bacon 2010; Talbot 2004). Since 1989, the role of national governments in directly influencing global coffee markets and prices paid to the producers (through the International Coffee Agreement) and organizing international marketing and production practices has decreased as most governments adopted Neoliberal approaches (Topik et al. 2010; Talbot 2004). In many cases, rural poverty rates have increased together with accelerating rates of environmental destruction (Heynen 2007). This is not to say that top down state control and a closed communist government offers an effective solution to sustainability challenges in these regions. Recent evidence reveals high levels of environmental contamination and social marginalization accumulated in many of the post-socialist states, such as Vietnam and Hungry, now in "transition" (O'Rourke 2004). However, the transition to a form of capitalism nearly devoid of state regulation and dominated by transnational firms and national elites taking advantage of the cheap privatization of state agencies and power vacuums to dramatically accelerate the rerates of natural resource exploitation maybe the worst of both worlds (O'Rourke 2004). When coupled with the evidence of persistent livelihood vulnerabilities in coffee growing regions, the conclusion is that states must regain their active roles in providing basic services to their populace and protecting ecosystem services if the negative results of a hands-off policy are to be curtailed and reversed.

Investment in the rural sector in ways that support sustainable coffee production is one way states could begin addressing multiple problems within their borders. Incentives directed toward farmers who maintain diverse shade within coffee plots would better assure the longevity of such management practices and allow producers to make a living while being good stewards of the land. Creation of regulations aimed at preserving biodiversity via agroforestry promotion could be a strong pillar in these efforts. Likewise, establishing and streamlining an infrastructure that supports farmers' efforts and brings in foreign exchange at the same time, would work to the benefit for both the state and its people.

Most national governments claim that jurisdiction and elaborate plans play a key role in contributing to longer term food security, rural education, and health care in coffee growing communities and elsewhere. For example, according to the FAO Special Rapporteur, "the right to food" is now alive in 24 constitutions as well as in different national policies, food security institutions, and courts (http://www.srfood.org/index.php/en/component/content/article/684-revising-the-cfa-five-proposals-for-the-dublin-consultation). This right has been embedded into the constitutions of many of the world's top 20 coffee exporting countries. More targeted investments include current programs such as Mexico's rural subsidy programs to assure school attendance and reduce vulnerability in rural areas, which now generate up to 20% of the income among coffee growing households (C. Bacon, personal communication with T. Barham). The current challenge may be one of financing these programs but also a deeper coordination connecting rural civil society, international development agencies and firms within the coffee value chain to create a more innovative and fairer partnership with coffee growing communities (Bacon et al. 2008b).

7.3.4 Improve Certification Systems

Given the existing coffee infrastructure, the most commonly employed method to 'integrate' ecosystem service acquisition and farmer/worker livelihoods is via farm-scale coffee certification. The ecological and socioeconomic benefits of certification (e.g. fair trade, organic, bird friendly, Sect. 4, Table 4) vary substantially between certification types, primarily because certification systems set different ecological standards, offer different economic incentives to different agents (directly to growers vs. to certification agencies), and differ in the price premium provided (Bacon et al. 2008a; Raynolds et al. 2007; Calo and Wise 2005). While organic and fair trade certification may raise coffee export prices (Bacon et al. 2008a), certification alone cannot provide incentives for optimal biodiversity conservation within coffee farms (Bacon et al. 2008a; Jaffee 2007; Philpott et al. 2007). Furthermore, organic certification alone often fails to cover the additional costs associated with certification and maintenance (Calo and Wise 2005). Fair trade premiums have yielded mixed effects, with some studies citing high returns (Calo and Wise 2005), while others demonstrate that fair trade premiums do not provide workers with higher wages or greater security than those working in uncertified coffee farms (Valkila and Nygren 2010). Finally, recent research has documented that when discounted for inflation, the real price premiums and minimum prices delivered to farmers by the leading sustainability certifications have declined during the past decades and with it the prospects for providing a strong incentive for more sustainable management (Bacon 2010).

Among the most important benefits of Fair Trade is the establishment of smallholder cooperatives that have gained a competitive foothold in export markets. In most cases, the colonial history of coffee has excluded these organizations from direct access. If these cooperatives are accountable to their members, business partners, and development agencies, they can emerge as a vital defense assuring smallholder access to land and advancing local development. Thus far, many smallholder cooperatives have been successful at establishing slightly better pay for their members and more secure markets for their coffee (Bacon et al. 2008a; Jaffee 2007). However, creating and maintaining these cooperatives so that they are accountable to their membership is a collective action challenge. Meeting this challenge involves a combination of community organization, support from state agencies (Fox 1996), and, in the case of certifications, non-profit investment in order to meet standards and improve the capacity of the certification industry (Bacon et al. 2008a). Thus, state, universities, certification agencies and socially responsible coffee firms could be involved with farmers to contribute to building alternative cooperative models and participatory certification initiatives that more effectively deliver benefits to both coffee drinkers and coffee-growing regions (Jaffe and Bacon 2008).

Another challenge to the existing certification system is that only a few certifications are currently available, thus farms that provide substantial ecosystem services, but do not qualify for the specifics of existing certifications, are left out. Without drastically changing the certification system, a number of changes could be made to make the process more effective. First, costs to farmers of inspection and certification are too high, especially within the Fair Trade system (e.g. Philpott et al. 2007). This is partially due to the monopoly held by FLO-CERT, which is the only Fair Trade certification agency in the world. Unfortunately, this semi-independent agency is plagued by poor management. Fair Trade retail sales have now topped 3 billion dollars, easily covering its operating costs; yet it continues to increase fees charged to producers.

If other Fair Trade certifying agencies were allowed into the market, all certifiers would have to compete in order to provide certification for producers, forcing them to charge producers more reasonable fees. Additionally, coffee producers could seek a combined certification approach (i.e., both fair trade and organic) which might help balance out the costs and returns of both certification systems (Philpott et al. 2007; Calo and Wise 2005). However, given the current cost of certification, this may be prohibitive, especially for small land-owners that do not produce large quantities of coffee (Calo and Wise 2005). Third, the initial costs of certification and transition could be subsidized by government agencies, or could be paid by the farmers only after the first years of profit are secured. University extension could also play a critical role in aiding in this initial transition stage, be providing government subsidized support and services.

Finally, the certification system could also be revised so that it does not discount the involvement of small land-holders. For example, the price of certification could be proportionate to the amount of land in cultivation. This may be tricky as certification costs need to minimally cover the expense of employing experts who must visit the farms periodically. However, it is possible that multiple individual farms could coordinate certification visits and thus reduce costs. In order to evaluate the feasibility of these alternatives, it is important that we fully understand the time, manpower, and cost involved with each step in the process of certification. Future work could explicitly explore the financial, institutional, and community support needed to transition a single farm from non-certified to Fair Trade, organic, or biodiversity friendly coffees.

7.3.5 Compensation for Ecosystem Services

Another, more direct method to secure both ecosystem services and farmer livelihoods is via Payments or Compensation for Ecosystem Services (PES) which provides payments from the beneficiaries directly to the land holders (reviewed in Engel et al. 2008). These payments could reward landowners who preserve water filtration, erosion control, pest-control, and pollination services within shade coffee landscapes, without forcing them to pay certification fees. While PES are not designed to single-handedly regulate land management, they may be used for providing incentives, especially in conjunction with extension services that provide land-holders with management information (Engel et al. 2008), such as Mexico's national certification initiative, Certimex (Calo and Wise 2005). Two examples of existing 'hybrid' PES programs are Mexico's 'Payment for Ecological Services-Hydrological (PSA-H), and the 'Program for the Development of Markets for the Ecosystem Services of Carbon Sequestration, the Derivatives of Biodiversity, and to Promote the Introduction and Improvement of Agroforestry Systems' (PSA-CABSA) (McAfee and Shapiro 2010), both of which are administered by the National Forestry Commission (CONAFOR). The PES for PSA-H, is paid by communities living downstream of the forest fragments and is based on the local opportunity costs of cutting forest. According to recent estimates, the annual payment of

$18.2 USD per ha is enough for more than 40% of forest owners to prefer conserving forests to cutting them (Jaramillo 2002).

However, the PES system has been shown to face many challenges, especially for smallholders and poor rural communities (Rosa et al. 2004). Studies reviewing the efficacy of PES practices have provided a number of critiques, most stemming from the fact that PES relies on a neoliberal framework, where nature is converted into a tradable commodity (McCauley 2006). This is because the practices of marketing and measuring commodity values do not often fit with the unpredictability and unquantifiable quality of nature, the social and cultural practices of potential stakeholders, or the policies of local or state governments (McAfee and Shapiro 2010). Many worry that PES policies will only further exploit the poor (Lovera 2004) or will disrupt their relationships with the landscape (Barreda 2004). The PSA-H and the PSA-CABSA of Mexico received substantial opposition from the farming communities, who viewed the ecosystem services as valuable contributions not only to regional and global markets, but also to local peasant livelihoods. They insisted that these ecosystem services are produced not only by nature, but also by the *campesino* communities who manage the landscapes. While the PSA-H was highly federally controlled, it only benefitted a small portion of land owners, and involved little input from community members. The more successful PSA-CABSA additionally involved a coalition of farmers and cooperative leaders, provided incentive for a wider range of land-managers, and supported environmental restoration that specifically also provided farmers with livelihood security (McAfee and Shapiro 2010). Thus, in the development of a sustainable PES system, it is essential that local stakeholders are involved and that restoration practices are also linked to farmer livelihoods (Rosa et al. 2004).

Deciding the value of a particular ecosystem service, such as erosion control, within agricultural landscapes may be challenging. Current employed practices for ecosystem valuation in agriculture are relatively rudimentary (Robertson and Swinton 2005; Gutman 2003; Daily 1997). According to a recent review, for ecosystem services that are currently unvalued, but have a measurable consumer-driven demand, there are three basic models that can be used to determine value: (1) the 'travel cost' method, where value is determined from the amount consumers would spend to gain access, (2) the 'hedonic price analysis' method, where the value is determined by the estimated contribution to the overall real-estate value of the land, and (3) the 'averting expenditures' method, where value is estimated based on the price consumers are willing to pay to avoid exposure to harmful outputs from the ecosystem (Robertson and Swinton 2005).

Assessing value for services that completely lack any connection to existing markets is even more challenging. One potential method is that of 'stated preference', which relies on surveys asking consumers how much they would be willing to pay for a service (e.g. Freeman 1993). While this method is increasingly utilized, one drawback is that it requires consumers to be educated about the environmental service being evaluated (Robertson and Swinton 2005). A second method takes the opposite approach, which relies on surveys asking producers what they would be willing to accept to provide the service. One example of this method is the erosion control value that the World Agroforestry Centre (ICRAF) began implementing in the early 2000s (Jack et al. 2009). In this program, a number of workshops on erosion control techniques were conducted in a coffee farming village in Sumatra. Farmers were then polled by a private auctioning system in order to find out the payment needed for them to conduct the erosion control techniques on their land (Jack et al. 2009). By keeping the actual bids private, farmers were not 'out-bidding' one another. Instead, the bids were then used to come up with an appropriate uniform price for the management practices across villages.

Based on these examples, it is clear that PES may involve long periods of negotiation and research, and most importantly, it is necessary to incorporate many stakeholders in the discussion. This means that federal and international policies for PES systems need to be locally-developed for each coffee-growing region. Adequate information needs to be provided to all stakeholders, and substantial discussion of the action plan must take place before policy decisions are made. Though this may sound daunting, this process conducted on a small-scale could save large amounts of time, money, and strife in the long run.

8 Conclusions

Studies in agroforestry systems have been highly useful in making conceptual and theoretical strides in the field of ecology (Greenberg et al. 2008). Agroforestry studies have provided ideal locations in which to determine and distinguish the impacts of local vegetation and landscape factors on biodiversity (e.g. Jha and Vandermeer 2010; Tscharntke et al. 2008), to examine relationships between biodiversity and ecosystem services (e.g. Klein et al. 2008), and to study tropical spatial ecology, difficult in more heterogeneous tropical forests (Perfecto and Vandermeer 2008b). Studies in agroforests are some of the first to examine relationships between biodiversity of vertebrates and ecosystem function, specifically demonstrating the importance of a diversity of vertebrate predators for providing ecosystem services (Philpott et al. 2009; Van Bael et al. 2008). Thus, the insights from coffee studies have also enriched the ecological literature.

Insights from research with coffee producers and their organizations have enriched the social sciences. First, the willingness of many smallholder cooperatives to permit researchers to enter deep into their histories and thus facilitate detailed research with their members. Coffee has emerged as an important test case for assessing the effects of different certification programs and more broadly assessing several potentially alternative forms of globalization. This research on the coffee value chain links global tendencies – including countertendencies – with local outcomes and continues to pioneer many approaches that are later used to assess other value chains (such as cacao and cotton) (Ponte 2008; Talbot 2004). Finally, the shade coffee systems of Mesoamerica offer an empirical research arena for participatory and interdisciplinary research collaborations (Méndez et al. 2010b; Bacon et al. 2008b; Rice and Ward 1996). However, there is much work ahead to integrate innovative ecological research in shade coffee (Lin 2010; Perfecto and Vandermeer 2008b; Philpott et al. 2004) with analysis on livelihoods, community and value chains (Bacon et al. 2008b; Mutersbaugh 2004). This points to the need to develop more interdependent, interdisciplinary, and generative research approaches to better understand these dynamic systems.

In order to support ecological and livelihood supporting coffee systems, it is essential that we consider all stakeholders in the coffee production chain (Fig. 4). The first set of players, involved at the local spatial scale, include coffee farms, farmers, laborers, and the communities they comprise. Some of these individual communities form cooperatives to secure the community's role in the local coffee market and to streamline the transition between growers and buyers. The management of the coffee farm depends primarily on the practices of the farmers and laborers, and these practices can have major impacts on the ecosystem services garnered (e.g. pollination, pest-control, fertilization). At a larger, regional scale, government agencies, NGO's, and universities play a critical role in regulating and modifying coffee management practices, distribution processes, and coffee prices. However, the influence of these players (should) also reach back to the practices and people involved at the local scale of coffee cultivation. Regional landscapes are comprised of a mosaic of communities, many of which support different crops, cattle, or urban centers. Regions benefit greatly from the enhanced water storage, erosion control, and resilience offered by biodiverse shaded coffee landscapes. A wide range of organisms with extended migration patterns (e.g. migratory birds) benefit from large clusters of biodiverse shade coffee communities. Thus, sound stewardship of land at a regional scale is of critical importance.

Finally, at the largest spatial scale, a number of key players have colossal impact on coffee land management and livelihoods. These include world government and private trade organizations, government and private certifiers, roasters, distributors, and consumers. Organizations and consumers, in their willingness to consider the broader impacts of their consumption, determine the profit margins for global distributors. One of the most challenging realizations of this review is that individuals and landscapes that generate important ecosystem services at the local farm scale do not necessarily harvest the benefits in terms of income, incentives, and opportunities. Only a small portion of the benefits reaped by retailers in specialty (e.g. organic) markets actually reaches individuals who participate in coffee production in the early stages. Further, key regulating ecosystem services provided by shade coffee, such as water storage, water filtration, erosion control, and carbon sequestration are not rewarded in current markets. The lack of direct compensation to farmers threatens current and future coffee ecosystems and farmer livelihoods. In summary, in order to build sustainable and livelihood-serving shade coffee landscapes, it is essential that we (1) incorporate worker livelihoods and well-being into global concepts of sustainability, (2) encourage farmers to diversify their coffee systems for greater resilience to risk and global change, and (3) improve certification and potential payment systems in order to compensate shade coffee farmers for the innumerable services that their shade coffee landscapes provide.

Creating stronger linkages between farmers, community members, certifiers, global agencies, researchers and consumers will allow for greater transparency and response to the ecological processes and well-being of all stakeholders in the global coffee production system.

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References

Agyeman J, Bullard RD, Evans B (2003) Just sustainabilities: development in an unequal world. MIT Press, Cambridge

Akiyama T, Baffes J, Larson D, Varangis P (2003) Commodity market reform in Africa: some recent experience. Econ Syst 27:83–115

Alegre C (1959) Climates et cafeiers d'Arabie. Agron Trop 14:25–48

AMECAFE (2010) Data prepared and provided by Jose Luis Benvidez of the Asociacion Mexicana de la Cadena Productiva del Café, A.C, 7 July 2010

Amekawaa Y, Sseguyaa H, Onzerea S, Carranzaa I (2010) Delineating the multifunctional role of agroecological practices: toward sustainable livelihoods for smallholder farmers in developing countries. J Sustain Agr 34:202–228

Anacafe (2008) Green book: Guatemalan coffees. Guatemalan National Coffee Association, Guatemala City

Armbrecht I, Gallego MC (2007) Testing ant predation on the coffee berry borer in shaded and sun coffee plantations in Colombia. Entomol Exp Appl 124:261–267

Arnould EJ, Plastina A, Ball D (2009) Does fair trade deliver on its core value proposition? Effects on income, educational attainment, and health in three countries. J Public Pol Market 28:186–201

Bacon C (2005a) Confronting the coffee crisis: can fair trade, organic and specialty coffees reduce small-scale farmer vulnerability in northern Nicaragua. World Dev 33:497–511

Bacon CM (2005b) Confronting the coffee crisis: Nicaraguan farmers use of cooperative, fair trade and agroecological networks to negotiate livelihoods and sustainability. PhD dissertation, University of California-Santa Cruz, Santa Cruz

Bacon CM (2010) Who decides what is fair in fair trade? The agri-environmental governance of standards, access, and price. J Peasant Stud 37:111–147

Bacon C, Méndez VE, Brown M (2005) Participatory action-research and support for community development and conservation: examples from shade coffee landscapes of El Salvador and Nicaragua. Center for Agroecology and Sustainable Food Systems (CASFS), University of California-Santa Cruz, Santa Cruz

Bacon CM, Méndez VE, Flores Gomez MA, Stuart D, Díaz Flores SR (2008a) Are sustainable coffee certifications enough to secure farmer livelihoods? The millenium development goals and Nicaragua's fair trade cooperatives. Globalizations 5:259–274

Bacon CM, Mendez VE, Gliessman S, Goodman D, Fox J (2008b) Confronting the coffee crisis: fair trade, sustainable livelihoods and ecosystems in Mexico and Central America. MIT Press, Cambridge

Bair J (2009) Frontiers of commodity chain research. Stanford University Press, Stanford

Bakermans MH, Vitz AC, Rodewald AD, Rengifo CG (2009) Migratory songbird use of shade coffee in the Venezuelan Andes with implications for conservation of Cerulean warbler. Biol Conserv 142:2476–2483

Barreda A (2004) Invasiones invisibles, subsidios perversos, guerra continua. Hojarasca, La Jornada 20–23

Bebbington AJ (1999) Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. World Dev 27:2021–2044

Bebbington A (2000) Reencountering development: livelihood transitions and place transformations in the Andes. Ann Assoc Am Geogr 90:495–520

Beer J, Muschler R, Kass D, Somarriba E (1998) Shade management in coffee and cacao plantations. Agroforest Syst 38:139–164

Bennett E, Peterson G, Gordon L (2009) Understanding relationships among multiple ecosystem services. Ecol Lett 12:1–11

Biderman J (1982) Class structure, the state and capitalist development in Nicaraguan agriculture. PhD dissertation, University of California-Berkeley, Berkeley

Borkhataria R, Collazo J, Groom M (2006) Additive effects of vertebrate predators on insects in a Puerto Rican coffee plantation. Ecol Appl 16:696–703

Brenner N (2001) The limits to scale? Methodological reflections on scalar structuration. Prog Hum Geog 25:591–614

Brown S (1996) Present and potential roles of forest in the global climate change debate. Unasylva 47:3–10

Calo M, Wise TA (2005) Revaluing peasant coffee production: organic and fair trade markets in Mexico. Global Development and Environment Institute, Medford

Canadell JG, Raupach MR (2008) Managing forests for climate change mitigation. Science 320:1456–1457

Cannell M (1976) Crop physiological aspects of coffee bean yield: a review. Kenya Coffee 41:245–253

Cannell M (1983) Coffee. Biologist 30:257–263

Carr M (2001) The water relations and irrigation requirements of coffee. Exp Agric 37:1–36

CEPAL (2002) Globalizaci6n y desarrollo. CEPAL, Santiago

Chambers R (1991) In search of professionalism, bureaucracy and sustainable livelihoods for the 21st century. Ids Bull-I Dev Stud 22:5–11

Chambers R (1992) The self-deceiving state. Ids Bull-I Dev Stud 23:31–42

Charrier A, Lashermes P, Eskes A (2009) Botany, genetics and genomics of coffee. In: Wintgens JN (ed.) Coffee: growing, processing, sustainable production. Wiley-VCH, Weinheim, pp 25–60

Clarence-Smith W (2003) The coffee crisis in Asia, Africa, and the Pacific, 1870–1914. In: Clarence-Smith W, Topik S (eds.) The global coffee economy in Africa, Asia and Latin America, 1500–1989. Cambridge University Press, Cambridge, MA, pp 100–119

Cook O (1901) Shade in coffee culture. United States Department of Agriculture, Division of Botany, Washington, DC

Costanza R, D'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260

Craswell ET, Sajjapongse A, Howlett DJB, Dowling AJ (1997) Agroforestry in the management of sloping lands in Asia and the Pacific. Agroforest Syst 38:121–137

Cruz-Angon A, Sillett TS, Greenberg R (2008) An experimental study of habitat selection by birds in a coffee plantation. Ecology 89:921–927

D'Haeze D, Deckers J, Raes D, Phong T, Loi H (2005) Environmental and socioeconomic impacts of institutional reforms on the agricultural sector of Vietnam land suitability assessment for Robusta coffee in the Dak Gan region. Agric Ecosyst Environ 105:59–76

Daily GC (1997) Nature's services: societal dependence on natural ecosystems. Island Press, Washington, DC

DaMatta F (2004) Ecophysiological constraints on the production of shaded and unshaded coffee: a review. Field Crop Res 84:99–114

DaMatta FM, Chaves ARM, Pinheiro HA, Ducatti C, Loureiro ME (2003) Drought tolerance of two field-grown clones of *Coffea canephora*. Plant Sci 164:111–117
Daviron B, Ponte S (2005) The coffee paradox: global markets, commodity trade, and the elusive promise of development. Zed Books, London
Davis AP, Govaerts R, Bridson DM, Stoffelen P (2006) An annotated checklist of the genus *Coffea* L. (Rubiaceae). Bot J Linn Soc 152:465–512
De la Mora A, Livingston G, Philpott SM (2008) Arboreal ant abundance and leaf miner damage in coffee agroecosystems in Mexico. Biotropica 40:742–746
De Marco P, Coelho FM (2004) Services performed by the ecosystem: forest remnants influence agricultural cultures' pollination and production. Biodivers Conserv 13:1245–1255
Decazy F, Avelino J, Guyot B, Perriot JJ, Pineda C, Cilas C (2003) Quality of different Honduran coffees in relation to several environments. J Food Sci 68:23–56
Devaux A, Horton D, Velasco C, Thiele G, López G, Bernet T, Reinoso I, Ordinola M (2009) Collective action for market chain innovation in the Andes. Food Policy 34:31–38
Dick CW, Jones FA, Hardy OJ, Petit RJ (2008) Spatial scales of seed and pollen-mediated gene flow in tropical forest trees. Trop Plant Biol 1:20–33
Dicum G, Luttinger N (1999) The coffee book: anatomy of an industry from crop to the last drop. The New Press, New York
Donald PF (2004) Biodiversity impacts of some agricultural commodity production systems. Conserv Biol 18:17–37
Dossa EL, Fernandes ECM, Reid WS, Ezui K (2008) Above- and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. Agroforest Syst 72:103–117
Eakin H, Tucker C, Castellanos E (2006) Responding to the coffee crisis: a pilot study of farmers' adaptations in Mexico, Guatemala and Honduras. Geogr J 172:156–171
Elevitch CR, Wilkinson KM (2000) Agroforestry guide for the Pacific islands. Permanent Agriculture Resources, Holualoa, 240 pp
Engel S, Pagiola S, Wunder S (2008) Designing payments for environmental services in theory and practice: an overview of the issues. Ecol Econ 65:663–674
Escalante F (1995) Coffee and agroforestry in Venezuela. Agroforest Today 7:5–7
Escalante F, Aguilar R, Lugo P (1987) Identifacion, evaluacion y distribucion espacial de especies utilizadas como sombra en sistemas tradicionales de cafe (*Coffea arabica*) en zonas del estado Trujillo, Venezuela. Venezuala Forestal 3:50–62
FAO (2008) Food and Agriculture Organization. Resource document. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor. Accessed Oct 2010
FAO (2009) FAOSTAT: crops. Resource document. http://faostat.fao.org/site/567/default.aspx#ancor. Accessed Oct 2010
FAO (2010) FAOSTAT: crops. Resource document. http://faostat.fao.org/site/570/default.aspx#ancor. Accessed Oct 2010
Fox J (1994) The roots of Chiapas. Econ Polit Weekly 29:119–1122
Fox J (1996) How does civil society thicken? the political construction of social capital in rural Mexico. World Dev 24:1089–1103
Freeman A III (1993) The measurement of environmental and resource values: theory and methods. Resources for the Future, Washington, DC
Fridell G (2006) Fair trade and neoliberalism – assessing emerging perspectives. Lat Am Perspect 33:8–28
Gallina S, Mandujano S, Gonzalez-Romero A (1996) Conservation of mammalian biodiversity in coffee plantations of Central Veracruz. Agroforest Syst 33:13–27
Gillison AN, Liswanti N, Budidarsono S, van Noordwijk M, Tomich TP (2004) Impact of cropping methods on biodiversity in coffee agroecosystems in Sumatra, Indonesia. Ecol Soc 9:16–23
Giovannucci D (2003) Emerging issues in the marketing and trade of organic products. In: Monograph in the proceedings of the OECD workshop on organic agriculture, OECD, Paris, Sept 2002
Giovannucci D, Liu P, Byers A (2008) Adding value: certified coffee trade in North America. In: Liu P (ed.) Value-adding standards in the North American food market – trade opportunities in certified products for developing countries. FAO, Rome, pp 33–49

Goodman D (2008) The international coffee crisis: a review of the issues. In: Bacon CM, Mendez VE, Gliessman S, Goodman D, Fox J (eds.) Confronting the coffee crisis: fair trade, sustainable livelihoods and ecosystems in Mexico and Central America. MIT Press, Cambridge

Greenberg R, Bichier P, Angon AC, Reitsma R (1997a) Bird populations in shade and sun coffee plantations in Central Guatemala. Conserv Biol 11:448–459

Greenberg R, Bichier P, Sterling J (1997b) Bird populations in rustic and planted shade coffee plantations of Eastern Chiapas, Mexico. Biotropica 29:501–514

Greenberg R, Bichier P, Angon AC, MacVean C, Perez R, Cano E (2000) The impact of avian insectivory on arthropods and leaf damage in some Guatemalan coffee plantations. Ecology 81:1750–1755

Greenberg R, Perfecto I, Philpott SM (2008) Agroforests as model systems for tropical ecology. Ecology 89:913–914

Guadarrama-Zugasti C (2008) A grower typology approach to assessing the environmental impact of coffee farming in Veracruz, Mexico. In: Bacon CM, Méndez VE, Gliessman SR, Goodman D, Fox JA (eds.) Confronting the coffee crisis: fair trade, sustainable livelihoods and ecosystems in Mexico and Central America. MIT Press, Cambridge, pp 127–154

Guhl A (2004) Coffee and landcover changes in the Colombian coffee region landscape 1970–1997. Ensayos, Bogota

Gutman P (2003) Macroeconomics for sustainable development. Program Office, World Wildlife Fund, Washington, DC

Guyot BD, Gueule JC, Maniez JJ, Perriot J, VL Giron (1996) Influence de l'altitude et de l'ombrage sur la qualité des cafés Arabica. Plantations, Recherche, Développement 3:272–283

Hanson L, Terstappen V (2009) Collaboration on contentious issues: research partnerships for gender equity in Nicaragua's fair trade coffee cooperatives. J Agromedicine 14:105–111

Harrison G, DiSogra C, Manalo-LeClair G, Aguayo J, Yen W (2002) Over 2.2 million low-income California adults are food insecure; 658,000 suffer hunger. UCLA Healthy Policy Research Brief

Harvey D (2005) A brief history of neoliberalism. Oxford University Press, Oxford

Henry M, Tittonell P, Manlay RJ, Bernoux B, Albrecht A, Vanlauwe B (2009) Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. Agric Ecosyst Environ 129:238–252

Hergoualc'h K, Skiba U, Harmand JM, Henault C (2008) Fluxes of greenhouse gases from Andosols under coffee in monoculture or shaded by *Inga densiflora* in Costa Rica. Biogeochemistry 89:329–345

Heynen N (2007) Neoliberal environments: false promises and unnatural consequences. Routledge, London

Holt-Giménez E (2006) Campesino a campesino: voices from Latin America's farmer to farmer movement for sustainable agriculture. Food First Books, Oakland

ICAFE (1989) Instituto del Café de Costa Rica. Manual de recomendaciones para el cultivo del café. Ministerio de Agricultura y Ganadería, San Jose

Illy E (2002) The complexity of coffee. Sci Am 6:86–91

International Coffee Organization (ICO) (2000) Monthly statistics. http://www.ico.org/prices/m1.htm. Accessed July 2010

IPCC (2007) Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Intergovernmental Panel on Climate Change, Wembley

Jack BK, Leimona B, Ferraro PJ (2009) A revealed preference approach to estimating supply curves for ecosystem services: use of auctions to set payments for soil erosion control in Indonesia. Conserv Biol 23:359–367

Jaffe R, Bacon C (2008) From differentiated coffee markets toward alternative trade and knowledge networks. In: Bacon CM, Mendez VE, Gliessman S, Goodman D, Fox J (eds.) Confronting the coffee crisis: fair trade, sustainable livelihoods and ecosystems in Mexico and Central America. MIT Press, Cambridge, pp 311–336

Jaffee D (2007) Brewing justice: fair trade coffee, sustainability, and survival. University of California Press, Berkeley

Jaramillo L (2002) Estimación del costo de oportunidad del uso de suelo forestal en ejidos a nivel nacional. DGIPEA working paper. Instituto Nacional de Ecología, México

Jha S, Dick CW (2008) Shade coffee farms promote genetic diversity of native trees. Curr Biol 18:1126–1128

Jha S, Dick CW (2010) Native bees facilitate gene flow across shade coffee landscapes. Proc Natl Acad Sci 107:13760–13764

Jha S, Vandermeer J (2010) Impacts of coffee agroforestry management on tropical bee communities. Biol Conserv 143:1423–1431

Johnson MD (2000) Effects of shade-tree species and crop structure on the winter arthropod and bird communities in a Jamaican shade coffee plantation. Biotropica 32:133–145

Johnson MD, Levy NJ, Kellermann JL, Robinson DE (2009) Effects of shade and bird exclusion on arthropods and leaf damage on coffee farms in Jamaica's Blue Mountains. Agroforest Syst 76:139–148

Kay M, Franks TR, Smith L (1997) Water: economics, management and demand. E & FN Spon, London

Kellermann J, Johnson M, Stercho A, Hackett S (2008) Ecological and economic services provided by birds on Jamaican Blue Mountain coffee farms. Conserv Biol 22:1177–1185

Klein AM, Steffan-Dewenter I, Tscharntke T (2003a) Bee pollination and fruit set of *Coffea arabica* and *C. canephora* (Rubiaceae). Am J Bot 90:153–157

Klein AM, Steffan-Dewenter I, Tscharntke T (2003b) Fruit set of highland coffee increases with the diversity of pollinating bees. Proc R Soc Lond B Biol Sci 270:955–961

Klein AM, Steffan-Dewenter I, Tscharntke T (2003c) Pollination of *Coffea canephora* in relation to local and regional agroforestry management. J Appl Ecol 40:837–845

Klein AM, Cunningham SA, Bos M, Steffan-Dewenter I (2008) Advances in pollination ecology from tropical plantation crops. Ecology 89:935–943

Kotecha S, Hieu P, Kuit M, Von Enden J, Swinkels R (2003) Vietnamese coffee competitiveness and policy options to improve it. Conference summary found at. www.xttmnew.agroviet.gov.vn/en/stories/Coffee_Policy_brief.pdf

Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R, Packer L, Potts SG, Roulston T, Steffan-Dewenter I, Vazquez DP, Winfree R, Adams L, Crone EE, Greenleaf SS, Keitt TH, Klein AM, Regetz J, Ricketts TH (2007) Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecol Lett 10:299–314

Läderach P, Oberthür T, Niederhauser N, Usma H, Collet L, Pohlan J (2006) Café especial: factores, dimensiones e interacciones. In: Pohlan J, Barrera J (eds.) El cafetal del futuro: realidades y visiones. Shaker, Aachen, pp 141–160

Läderach P, Oberthür T, Pohlan J (2009) Management of intrinsic quality characteristics for specialty coffee – a framework developed and tested in coffee growing regions across Latin America. Dr. Müller Verlag, Saarbrück, Germany, 157 pp

Läderach P, Lundy M, Jarvis A, Ramírez J, Pérez P, Schepp E, Eitzinger KA (2010) Predicted impact of climate change on coffee supply chains. In: Leal Filho W (ed.) The economic, social and political elements of climate change. Springer, Berlin, pp 703–724

Lagemann J, Heuveldop J (1983) Characterization and evaluation of agroforestry systems. CATIE, Turnalba

Lara-Estrada LD (2005) Efectos de la altitud, sombra, producción y fertilización sobre la calidad del café (*Coffea arabica* L. var. *caturra*) producido en sistemas agroforestales de la zona cafetalera nor-central de Nicaragua. Agroforestry. Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba

Larsen A, Philpott SM (2010) Twig-nesting ants: the hidden predators of the coffee berry borer in Chiapas, Mexico. Biotropica 42:342–347

Lewin B, Giovannucci D, Varangis P (2004) Coffee markets: new paradigms in global supply and demand. World Bank, Washington, DC

Lin BB (2007) Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agric For Meteorol 144:85–94

Lin BB (2010) The role of agroforestry in reducing water loss through soil evaporation and crop transpiration in coffee agroecosystems. Agric For Meteorol 150:510–518

Lin BB, Perfecto I, Vandermeer J (2008) Synergies between agricultural intensification and climate change could create surprising vulnerabilities for crops. Bioscience 58:847–854

Linton A (2005) Partnering for sustainability: business–NGO alliances in the coffee industry. Develop Prac 15:600–614

Lomeli-Flores J (2007) Natural enemies and mortality factors of the coffee leaf miner *Leucoptera coffeella* (Guerin-Meneville) (Lepidoptera: Lyonetiidae) in Chiapas, Mexico. PhD dissertation, Texas A&M University, College Station

Lovera S (2004) Environmental markets impoverish the poor. Resource document. Ecosystem Marketplace. http://ecosystemmarketplace.com/pages/article.opinion.php?componentid=2268 &componentversionid. Accessed Oct 2010

Lyon S (2008) We want to be equal to them: Fair-trade coffee certification and gender equity within organizations. Hum Organ 67:258–268

Lyon S, Bezaury JA, Mutersbaugh T (2010) Gender equity in fair trade-organic coffee producer organizations: cases from Mesoamerica. Geoforum 41:93–103

Magalhaes A, Angelocci L (1976) Sudden alterations in water balance associated with flower bud opening in coffee plants. J Hortic Sci 51:419–421

Manrique AJ, Thimann RE (2002) Coffee (*Coffea arabica*) pollination with africanized honeybees in Venezuela. Interciencia 27:414–416

Marsden T, Munton R, Ward N, Wahtmore S (1996) Agricultural geography and the political economy approach: a review. Econ Geogr 72:361–375

Marston S (2000) The social construction of scale. Prog Hum Geogr 24:219–242

McAfee K, Shapiro EN (2010) Payments for ecosystem services in Mexico: nature, neoliberalism, social movements, and the State. Ann Assoc Am Geogr 100:579–599

McCarthy J (2004) Privatizing conditions of production: trade agreements as neoliberal environmental governance. Geoforum 35:327–341

McCauley DJ (2006) Selling out on nature. Nature 443:27–28

McCreery D (1995) Wage labor, free labor and vagrancy laws: the transition to capitalism in Guatemala. In: Roseberry W, Gudmundson L, Kutschbach MS (eds.) Coffee, society, and power in Latin America. Johns Hopkins University, Maryland, pp 1920–1945

Méndez VE, Gliessman SR, Gilbert GS (2007) Tree biodiversity in farmer cooperatives of a shade coffee landscape in western El Salvador. Agric Ecosyst Environ 119:145–159

Méndez VE, Shapiro EN, Gilbert GS (2009) Cooperative management and its effects on shade tree diversity, soil properties and ecosystem services of coffee plantations in western El Salvador. Agroforest Syst 76:111–126

Méndez VE, Bacon CM, Olson M, Morris KS, Shattuck AK (2010a) Agrobiodiversity and shade coffee smallholder livelihoods: a review and synthesis of ten years of research in Central America. Prof Geogr 62:357–376

Méndez VE, Bacon C, Olson M, Petchers S, Herrador D, Carranza C, Trujillo L, Guadarrama-Zugasti C, Cord6n A, Mendoza A (2010b) Effects of fair trade and organic certifications on small-scale coffee farmer households in Central America and Mexico. Renewable Agric Food Syst 25:236–251

Michon G, Mary F, Bompard JM (1986) Multistoried agroforestry garden system in West Sumatra, Indonesia. Agroforest Syst 4:315–338

Millenium Ecosystem Assessment (MEA) (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC

Moguel P, Toledo VM (1999) Biodiversity conservation in traditional coffee systems of Mexico. Conserv Biol 13:11–21

Muriel SB, Kattan GH (2009) Effects of patch size and type of coffee matrix on ithomiine butterfly diversity and dispersal in cloud-forest fragments. Conserv Biol 23:948–956

Muschler RG (1997) Shade or sun for ecologically sustainable coffee production: a summary of environmental key factors. In: Proceedings of the 3rd scientific week, CATIE, Turrialba, 3–7 Feb 1997, pp 109–112

Muschler RG (2001) Shade improves coffee quality in a sub-optimal coffee zone of Costa Rica. Agroforest Syst 51:131–139

Mutersbaugh T (2004) Serve and certify: paradoxes of service work in organic-coffee certification. Environ Plann D 22:533–552

Mutersbaugh T (2005) Fighting standards with standards: harmonization, rents, and social accountability in certified agrofood networks. Environ Plann A 37:2033–2051

Neelin JD, Munnich M, Su H, Meyerson JE, Holloway CE (2006) Tropical drying trends in global warming models and observations. Proc Natl Acad Sci USA 103:6110–6115

Nigh R (1997) Organic agriculture and globalization: a Maya associative corporation in Chiapas, Mexico. Hum Organ 56(4):427–435

Nolasco M (1985) Cafe y sociedad en Mexico. Centro de Ecodesarrollo, Mexico City, 454 pp

Nunes M, Bierhuizen J, Ploegman C (1968) Studies on the productivity of coffee, I: effect of light, temperature, and CO_2 concentration on photosynthesis of *Coffea arabica*. Acta Bot Neerl 17:93–102

Nutman F (1937) Studies on the physiology of *Coffea arabica*, I: photosynthesis of coffee leaves under natural conditions. Ann Bot 1:353–367

O'Brien TG, Kinnaird MF (2003) Caffeine and conservation. Science 5619:587

O'Rourke D (2004) Transition environments: ecological and social challenges to post-socialist industrial development. In: Peet R, Watts M (eds.) Liberation ecologies: environment, development, social movements. Routledge, London

Oxfam (2001) Bitter coffee: how the poor are paying for the slump in coffee prices. www.globalexchange.org/campaigns/fairtrade/coffee/OxfamPriceReport.pdf

Oxfam (2002) Mugged: poverty in your coffee cup. www.oxfam.org.uk/resources/papers/mugged.html

Palm C, Van Noordwijk V, Woomer P, Alegre J, Arevalo L, Castilla C, Cordeiro D, Hariah K, Kotto-Same J, Moukam A, Parton W, Ricse A, Rodriques V, Sitompul S (2005) Carbon losses and sequestration alter land use change in the humid tropics. In: Palm CA, Vosti SA, Sanchez PA, Ericksen PJ (eds.) Slash-and-burn agriculture: the search for alternatives. Columbia University Press, New York, pp 41–63

Peet R, Watts M (2004) Liberation ecologies: environment, development, social movements. Routledge, London

Peeters LYK, Soto-Pinto L, Perales H, Montoya G, Ishiki M (2003) Coffee production, timber, and firewood in traditional and *Inga*-shaded plantations in Southern Mexico. Agric Ecosyst Environ 95:481–493

Peluso NL (1994) Rich forests, poor people: resource control and resistance in Java. University of California Press, Berkeley, 336 pp

Perfecto I, Vandermeer J (2006) The effect of an ant-hemipteran mutualism on the coffee berry borer (*Hypothenemus hampei*) in southern Mexico. Agric Ecosyst Environ 117:218–221

Perfecto I, Vandermeer J (2008a) Biodiversity conservation in tropical agroecosystems – a new conservation paradigm. Ann NY Acad Sci 1134:173–200

Perfecto I, Vandermeer J (2008b) Spatial pattern and ecological process in the coffee agroforestry system. Ecology 89:915–920

Perfecto I, Rice RA, Greenberg R, VanderVoort ME (1996) Shade coffee: a disappearing refuge for biodiversity. Bioscience 46:598–608

Perfecto I, Vandermeer JH, Bautista GL, Nunez GI, Greenberg R, Bichier P, Langridge S (2004) Greater predation in shaded coffee farms: the role of resident neotropical birds. Ecology 85:2677–2681

Perfecto I, Vandermeer J, Mas A, Pinto LS (2005) Biodiversity, yield, and shade coffee certification. Ecol Econ 54:435–446

Perfecto I, Armbrecht I, Philpott SM, Soto-Pinto L, Dietsch TV (2007) Shaded coffee and the stability of rainforest margins in Latin America. In: Tscharntke T, Leuschner C, Zeller M, Guhadja E, Bidin A (eds.) The stability of tropical rainforest margins, linking ecological, economic and social constraints of land use and conservation. Springer Environmental Science Series, Heidelberg

Perfecto I, Vandermeer J, Wright A (2009) Nature's matrix linking agriculture, conservation and food sovereignty. Earthscan, London

Peyser R (2010) Hunger in the coffee lands. Specialty Coffee Association of America, Anaheim

Phillips S, Anderson R, Sapohire R (2006) Maximum entropy modeling of species geographic distributions. Ecol Model 190:231–259

Philpott SM, Maldonado J, Vandermeer J, Perfecto I (2004) Taking trophic cascades up a level: behaviorally-modified effects of phorid flies on ants and ant prey in coffee agroecosystems. Oikos 105:141–147

Philpott SM, Bichier P, Rice R, Greenberg R (2007) Field-testing ecological and economic benefits of coffee certification programs. Conserv Biol 21:975–985

Philpott SM, Bichier P, Rice RA, Greenberg R (2008a) Biodiversity conservation, yield, and alternative products in coffee agroecosystems in Sumatra, Indonesia. Biodivers Conserv 17:1805–1820

Philpott SM, Lin BB, Jha S, Brines SJ (2008b) A multi-scale assessment of hurricane impacts on agricultural landscapes based on land use and topographic features. Agric Ecosyst Environ 128:12–20

Philpott SM, Arendt WJ, Armbrecht I, Bichier P, Diestch TV, Gordon C, Greenberg R, Perfecto I, Reynoso-Santos R, Soto-Pinto L, Tejeda-Cruz C, Williams-Linera G, Valenzuela J, Zolotoff JM (2008c) Biodiversity loss in Latin American coffee landscapes: review of the evidence on ants, birds, and trees. Conserv Biol 22:1093–1105

Philpott S, Soong O, Lowenstein J, Pulido A, Tobar-Lopez D, DeClerck F (2009) Functional traits and ecosystem services: bird predation on arthropods in tropical agroecosystems. Ecol Appl 19:1858–1867

Ponte S (2002) The 'Latte Revolution'? Regulation, markets and consumption in the global coffee chain. World Dev 30:1099–1122

Ponte S (2008) Greener than thou: the political economy of fish ecolabeling and its local manifestations in South Africa. World Dev 36:159–175

Prendergast M (1999) Uncommon grounds: the history of coffee and how it transformed our world. Basic Books, New York

Pretty JN (2002) Agri-Culture: reconnecting people, land, and nature. Earthscan Publications, London

Ramírez L (1993) Producci6n de café (*Coffea arabica*) bajo diferentes niveles de fertilizaci6n con y sin sombra de *Erythrina poeppigiana* (Walpers). In: Cook OF (ed.) *Erythrina* in the new and old worlds. Nitrogen Fixing Tree Association, Paia, pp 121–124

Raudsepp-Hearne C, Peterson GD, Bennett EM (2010) Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proc Natl Acad Sci USA 107:5242–5247

Raw A, Free JB (1977) Pollination of coffee (*Coffea arabica*) by honeybees. Trop Agric 54:365–370

Raynolds LT, Murray D, Heller A (2007) Regulating sustainability in the coffee sector: a comparative analysis of third-party environmental and social certification initiatives. Agric Hum Values 24:147–163

Renard M (2010) The Mexican coffee crisis. Lat Am Perspect 37:21–33

Ribot JC, Peluso NL (2003) A theory of access. Rural Sociol 68:153–181

Rice R (2000) Noble goals and challenging terrain: organic and fair trade coffee movements in the global marketplace. J Agric Environ Ethics 14:39–66

Rice R (2003) Coffee production in a time of crisis: social and environmental connections. SAIS Rev 23:221–245

Rice RA (2008) Agricultural intensification within agroforestry: the case of coffee and wood products. Agric Ecosyst Environ 128:212–218

Rice PD, McLean J (1999) Sustainable coffee at the crossroads. Consumer's Choice Council, Washington, DC

Rice R, Ward J (1996) Coffee, conservation, and commerce in the Western Hemisphere. The Smithsonian Migratory Bird Center and the Natural Resources Defense Council, Washington, DC

Ricketts TH, Daily GC, Ehrlich PR, Michener CD (2004) Economic value of tropical forest to coffee production. Proc Natl Acad Sci USA 101:12579–12582

Robertson GP, Swinton SM (2005) Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Front Ecol Environ 3:38–46

Robertson GP, Broome JC, Chornesky EA, Frankenberger JR, Johnson P, Lipson M, Miranowski JA, Owens ED, Pimentel D, Thrupp LA (2004) Rethinking the vision for environmental research in US agriculture. Bioscience 54:61–65

Romero-Alvarado Y, Soto-Pinto L, Garcia-Barrios L, Barrera-Gaytan JF (2002) Coffee yields and soil nutrients under the shades of *Inga* sp. vs. multiple species in Chiapas, Mexico. Agroforest Syst 54:215–224

Roncal-Garcia S, Soto-Pinto L, Castellanos-Albores J, Ramirez-Marcial N, de Jong B (2008) Agroforestry systems and carbon stocks in indigenous communities from Chiapas, Mexico. Interciencia 33:200–206

Rosa H, Kandel S, Dimas L (2004) Compensation for environmental services and rural communities: lessons from the Americas. Int Forest Rev 6:187–194

Roubik DW (2002) Tropical agriculture – the value of bees to the coffee harvest. Nature 417:708–708

Salinas-Zavala CA, Douglas AV, Diaz HF (2002) Interannual variability of NDVI in northwest Mexico. Associated climatic mechanisms and ecological implications. Remote Sens Environ 82:417–430

Sayre N (2005) Ecological and geographical scale: parallels and potential for integration. Prog Hum Geogr 29:276–290

Schroth G, Krauss U, Gasparotto L, Aguilar JAD, Vohland K (2000) Pests and diseases in agroforestry systems of the humid tropics. Agroforest Syst 50:199–241

Scoones I (1998) Sustainable rural livelihoods: a framework for analysis. Institute for Development Studies (IDS), Brighton

Scoones I (2009) Livelihoods perspectives and rural development. J Peasant Stud 36:171–196

Shiva V (2008) Soil not oil: environmental justice in a time of climate crisis. South End Press, Cambridge

Shulman M, Garret P (1990) Cluster analysis and typology construction: the case of small-scale tobacco farmers. Sociol Spectrum 10:413–428

Somarriba E, Harvey C, Samper M, Anthony F, Gonzalez J, Staver C, Rice R (2004) Biodiversity in coffee plantations. In: Schroth G, Fonseca G, Harvey C, Gascon C, Vasconcelos H, Izac AMN (eds.) Biodiversity in coffee plantations. Island Press, Washington, DC, pp 198–226

Soto-Pinto L, Perfecto I, Castillo-Hernandez J, Caballero-Nieto J (2000) Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico. Agric Ecosyst Environ 80:61–69

Soto-Pinto L, Perfecto I, Caballero-Nieto J (2002) Shade over coffee: its effects on berry borer, leaf rust and spontaneous herbs in Chiapas, Mexico. Agroforest Syst 55:37–45

Soto-Pinto L, Anzueto M, Mendoza J, Ferrer GJ, de Jong B (2010) Carbon sequestration through agroforestry in indigenous communities of Chiapas, Mexico. Agroforest Syst 78:39–51

Staver C, Guharay F, Monterroso D, Muschler RG (2001) Designing pest-suppressive multistrata perennial crop systems: shade-grown coffee in Central America. Agroforest Syst 53:151–170

Steward C (2007) From colonization to "environmental soy": a case study of environmental and socio-economic valuation in the Amazon soy frontier. Agric Hum Values 24:107–122

Sturgeon T (2000) Turnkey production networks: a new American model of industrial organization? Industrial Performance Center, Working paper, MIT, Cambridge

Swinton SM, Lupi F, Robertson GP, Hamilton SK (2007) Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. Ecol Econ 64:245–252

Talbot JM (2004) Grounds for agreement: the political economy of the coffee commodity chain. Rowman and Littlefield Publishers, Lanham

Topik S, Talbot J, Samper M (2010) Introduction globalization, neoliberalism, and the Latin American coffee societies. Lat Am Perspect 171:5–20

Trujillo L (2008) Coffee production strategies in a changing rural landscape: a case study in Central Veracruz, Mexico. In: Bacon CM, Mendez VE, Gliessman SR, Goodman D, Fox JA (eds.) Confronting the coffee crisis: fair trade, sustainable livelihoods and ecosystems in Mexico and Central America. MIT Press, Cambridge, pp 69–98

Tscharntke T, Sekercioglu C, Dietsch T, Sodhi N, Hoehn P, Tylianakis J (2008) Landscape constraints on functional diversity of birds and insects in tropical agroecosystems. Ecology 89:944–951

Ukers W (1922) All about coffee. The Tea and Coffee Trade Journal Company, New York

USDL (2010) US Department of Labor, Bureau of Labor Statistics. Resource document. http://data.bls.gov/cgi-bin/dsrv. Accessed Oct 2010

Vaast P, Bertrand B, Perriot J-J, Guyot B, Genard M (2006) Fruit thinning and shade improve bean characteristics and beverage quality of coffee (*Coffea arabica* L.) under optimal conditions. J Sci Food Agric 86:197

Valkila J, Nygren A (2010) Impacts of fair trade certification on coffee farmers, cooperatives, and laborers in Nicaragua. Agric Hum Values 27:321–333

Van Bael SA, Philpott SM, Greenberg R, Bichier P, Barber NA, Mooney KA, Gruner DS (2008) Birds as predators in tropical agroforestry systems. Ecology 89:928–934

Van der Vossen HAM (2005) A critical analysis of the agronomic and economic sustainability of organic coffee production. Exp Agric 41:449–473

Varangis P, Siegel P, Giovannucci D, Lewin B (2003) Dealing with the coffee crisis in Central America: impacts and strategies. In: World Bank Policy Research #2993. World Bank, Washington, DC

Vélez M, Bustillo A, Posada F (2001) Hormigas de la zona central cafetera y perspectivas de su uso en el control de *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae). Resúmenes XXVIII Congreso (ed. by Sociedad Colombiana de Entomología), Pereira

Waltert M, Mardiastuti A, Muhlenberg M (2005) Effects of land use on bird species richness in Sulawesi, Indonesia. Conserv Biol 18:1339–1346

Watson R, Herren R (eds) (2009) International assessment of agricultural knowledge, science and technology for development (IAASTD): synthesis report. Island Press, Washington

Watts MJ (2007) What might resistance to neoliberalism consist of? In: Heynen N, McCarthy J, Prudham S (eds.) Neoliberal environments: false promises and unnatural consequences. Routledge, London, pp 273–279

WDPA Consortium (2004) National IUCN protected areas, global. Downloadable Data. UNEP, IUCN, Oct 2004

Webster PJ, Holland GJ, Curry JA, Chang HR (2005) Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309:1844–1846

Williams R (1994) States and social evolution: coffee and the rise of national governments in Central America. University of North Carolina, Chapel Hill

Wilson K (1999) Coffee, cocoa and tea. CABI, Wallingford

Wisner B, Blaikie P, Cannon T, Davis I (2004) At risk – natural hazards, people's vulnerability and disasters. Routledge, London

World Commission on Environment and Development (WCED) (1987) Our common future. Oxford University Press, Oxford

You LWS (2005) Assessing the spatial distribution of crop production using a cross-entropy. Int J Appl Earth Obs 7:310–323