Cultural Ecosystem Services in Agroforests

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Abbreviations

CES	Cultural ecosystem services
ES	Ecosystem services
NOAA	United States National Oceanic and Atmospheric Administration
spp.	Species
TEK	Traditional ecological knowledge
VAC	*Vườn Ao Chuồng* (garden-pond-livestock in Vietnamese)

Introduction

Cultural Ecosystem Service Definition and History

The Millennium Ecosystem Assessment defined cultural ecosystem services (CES) as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Millennium Ecosystem Assessment 2005). Many other ecosystem service typologies include CES or some variant on the concept (Costanza et al. 1997; De Groot et al. 2002; Boyd and Banzhaf 2007; Costanza 2008; Kumar 2012). For example, Fish et al. (2016) wrote that CES are "the contributions ecosystems make to human well-being in terms of the identities they help frame, the experiences they help

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Table 1 Examples of CES adapted from the Millennium Ecosystem Assessment (2005)

Cultural ecosystem service	Description
Cultural diversity	Cultural diversity, or the diversity of cultural expressions, is affected by and affects biological diversity (Pilgrim et al. 2009). It can contribute to resiliency of human societies (Turner et al. 2003)
Spiritual and religious value	Natural elements, ecosystems, and/or landscapes may hold religious or spiritual value(s) for many cultures (Albanese 1991)
Knowledge systems and education	Many cultures have developed complex knowledge, practice, and belief systems from observing local ecosystems (Berkes 2008). Ecosystems can also serve as a "living classroom" for study and scientific research (Falkowski et al. 2015)
Inspiration	Ecosystems can provide inspiration for art, architecture, technology, etc. (Carlson 2000; Shu et al. 2011)
Aesthetic value	Individuals and cultures perceive aesthetic beauty in natural elements, ecosystems, and/or landscapes (Cooper et al. 2016)
Social relationships, identity, and cohesion	Ecosystems define relationships between individuals both within and between communities. The identities individuals use to define themselves and their communities can be associated with resource management, religious belief, and cultural heritage, which are also provided by ecosystems (Clayton and Opotow 2003)
Recreation and tourism	Ecosystems provide opportunities for recreation and for nature tourism. Examples include bird-watching, photography, stargazing, camping, climbing, hiking, hunting, and fishing (Ceballos-Lascuráin 1996)
Therapeutic benefits; mental and emotional health	Ecosystems provide emotional and mental health benefits, including stress reduction (Buzzell and Chalquist 2009)
Cultural heritage and sense of place	Many cultures are closely tied to the places where they developed. These natural landscapes become imbued with cultural and historical meanings that are passed between generations and maintained through customary practices and social institutions, thereby contributing to their cultural identity (Berkes 2008)

enable, and the capabilities they help equip." Alternately, Chan et al. (2012) phrase their definition as "ecosystems' contributions to the nonmaterial benefits … that humans derive from human-ecological interactions."

Despite differences in classification schemes and definitions, CES are generally considered to provide humans with intangible, constructed benefits resulting from the interactions between sociocultural and environmental systems, such as social cohesion, cultural identity, mental and physical health, and intellectual and spiritual stimulation (Daniel et al. 2012; Milcu et al. 2013) (Table 1). The interconnectedness of these two spaces makes a socioecological framework useful for understanding CES. The environment enables development, expression, and maintenance of cultural practices, which in turn shapes the structure and function of the environment (Fish et al. 2016). For example, ecosystems support wildlife which local people can hunt. Hunting can be a valuable cultural practice that creates community, shapes identity, and provides recreational opportunities, or hunting can be the focus of other cultural practices, such as dances and legends. These practices can shape the

environment by affecting wildlife populations. Environmental changes, such as population shifts, can affect practice, as is in the case of taboos that limit hunting during particular seasons to maintain resources.

The Millennium Ecosystem Assessment reported that 70% of CES are being degraded or used unsustainably worldwide, largely as a result of land cover change. Many of these CES are not substitutable or replaceable. This decline reduces the benefits humans obtain from CES and negatively influences other ES, such as regulating and supporting ES (Millennium Ecosystem Assessment 2005). For example, sacred groves in India are being deforested as perceived economic value of land exceeds its religious value (Chandrakanth et al. 2004; Osuri et al. 2014). This conversion not only impacts spiritual benefits from the groves, which may be preserved as spaces for deities, but also reduces water retention (regulating) and wildlife habitat (supporting) services (Chandran and Hughes 1997; Bhagwat et al. 2005a, b). This conversion further reduces CES such as religious identity and social cohesion in communities (Kandari et al. 2014; Tilliger et al. 2015; Wehi and Lord 2017).

Long-term traditions associated with CES, such as cultural identity and aesthetic appreciation, can slow environmental degradation and land conversion (Sneed et al. 2013). CES tend to hold deep value for stakeholders and thereby serve as an important way of relating to nature, facilitating support for environmental protection and stewardship (Chan et al. 2012; Daniel et al. 2012; Fish et al. 2016). For example, indigenous land management practices and traditional governance structures have consistently and effectively limited deforestation in the Brazilian Amazon. Even though they are often located in frontier zones with high deforestation rates, indigenous reserves have inhibited deforestation within their traditional lands as effectively as strict, non-extractive reserves and parks, underscoring the importance of maintaining traditional cultural practices and sovereignty (Schwartzman et al. 2000; Nepstad et al. 2006).

Assessing CES

CES are rarely measured directly because they are typically intangible. Instead, proxy indicators provide indirect CES assessments. Hirons et al. (2016) provide a comprehensive overview of CES assessments, including shadow and hedonic pricing, anthropological methods and participatory GIS, and narrative and artistic methods. These methods can be quantitative or qualitative, be monetary or nonmonetary, ignore or involve stakeholders, and be spatially explicit or implicit. Care must be taken to choose the appropriate CES method for a particular socioecological context and research objective. For instance, using photos to consider the value of peoples' visual perceptions of landscapes as ecosystem services is useful for gauging aesthetic cultural ecosystem services. This qualitative method can be spatially explicit if photos are georeferenced. However, this approach may be biased toward sites that are easily accessible, and while it can be made quantitative by counting the number of photographs taken of a particular site, it cannot assess the quality or importance

of the aesthetic ecosystem service to different stakeholders. It is also difficult to quantify this metric monetarily, which may be desirable in some decision-making frameworks (Kelemen et al. 2015; Hirons et al. 2016).

Several barriers have limited the integration of CES into decision-making. First, the concept of "culture" itself is fluid and open to interpretation (Satz et al. 2013). While this does not preclude the incorporation of CES into comprehensive frameworks, decision makers must be clear as to how they are defining CES and their benefits. The abstract and intangible nature of CES makes them difficult to classify and measure for decision-making. Furthermore, while CES have value, most are not easily monetized. It is also debated whether they should be quantified in economic terms even if it were possible to do so with precision. Economically valuing CES may result in the commodification and undervaluation of services that are often described as indescribable and priceless (Milcu et al. 2013; Satz et al. 2013; Fish et al. 2016). This risk leads to concerns of incommensurability between CES and other ES. Although this problem can be addressed using deliberative approaches, it precludes tidy decision-making procedures (Chan et al. 2012).

The complex feedback between environmental spaces and cultural practices makes implementing CES assessments difficult (Fish et al. 2016). The distinction between benefits, services, and values can be tenuous (Milcu et al. 2013). The values associated with CES may change over time and vary among stakeholder groups. Furthermore, CES may differ across spatiotemporal scales (Satz et al. 2013). As a result, they may hold different values within and between scales of social organization (e.g., individual, community, and society) (Chan et al. 2012). For example, while a backcountry hiker and farmer may have different perceptions of the aesthetics of a particular landscape, both may share a similar appreciation for the aesthetic CES provide to the society of which they are a part. Additionally, many CES overlap, which may lead to double counting. For example, traditional ecological knowledge (TEK) can be considered an education service or a cultural heritage service (Chan et al. 2012; Daniel et al. 2012).

The diversity of CES frameworks makes comparing CES results difficult (Costanza 2008). While some have argued that this lack of consistent and concrete frameworks has precluded their integration into holistic assessments of ES, many CES frameworks exist that could be used for this purpose (Chan et al. 2012; Gould et al. 2015; Felipe-Lucia et al. 2015; Fish et al. 2016). Limited CES assessment implementation may be due to perceived imprecision and intangibility or limited understanding of CES assessment methods. Several authors raised the second point, noting that research in CES tends to be based on social science methods such as ethnographic interviews and participatory mapping, underscoring the importance of collaborations between biophysical and social scientists (Milcu et al. 2013; Fish et al. 2016).

As a result, CES are considered less frequently than other ecosystem service categories in research (Hernández-Morcillo et al. 2013). Furthermore, CES tend to not be the primary focus of projects; more commonly, they are a secondary component of broader analyses. The difficulties associated with quantifying CES make valuing them in an economic context particularly challenging (Milcu et al. 2013).

More than half of the assessments that have considered CES focused on recreation and tourism, which is unsurprising given that it may be the most easily quantifiable and economically valued metric. Other CES, such as inspiration and religious and spiritual services, were only considered in a combined 10% of cases (Milcu et al. 2013; Hernández-Morcillo et al. 2013).

Cultural Ecosystem Services in Agroforests

Proponents of agroforestry often argue that agroforests are sustainable in part because they are managed to provide multiple ecosystem services (Zhang et al. 2007; Jose 2009; Power 2010; Letcher et al. 2015). For example, Altieri and Toledo (2011) point out that peasant agroecosystems in Latin America place a high degree of importance on traditional knowledge, empower smallholder communities, serve as an opportunity for expression of often marginalized cultures, and integrate biophysical and social processes into management. Moreno et al. (2017) show that agroforests throughout Europe provide recreation, tourism, education, aesthetic beauty, and cultural heritage.

Indigenous peoples often note the importance of CES in their land management systems. TEK is a knowledge-practice-belief complex. Therefore the natural history of the region, their environmental management systems (e.g., agroforests), social institutions, and cultural practices are all nested and inextricably linked. In fact, the concept of natural gifts in many indigenous cultures as discussed by Kimmerer (2014) closely reflects the ecosystem service concept. Although indigenous worldviews may reject an anthropogenic perspective of nature solely as service provider, they do recognize themselves as part of a web of reciprocity between themselves and nature (Kimmerer 2011; Chan et al. 2012). Perhaps coincidentally, Díaz et al. (2015) use the term "natural gifts" to describe ecosystem services in establishing the framework for the Intergovernmental Platform on Biodiversity and Ecosystem Services.

That said, it is important to note that CES are not exclusive to traditional or indigenous agroforestry systems. Because traditional and nontraditional agroforestry systems apply the same principles of socioecological organization and management, they both may offer the benefits of social cohesion, heritage, recreation, aesthetic beauty, education, and inspiration to communities around the world. A distinction between CES provided by traditional and nontraditional agroforests is the spiritual component, which may not be prioritized in the latter.

Despite their importance, CES are rarely considered in ecosystem service assessments in agroforestry systems, mirroring the trends described in section "Cultural Ecosystem Services in Agroforests" (Tengberg et al. 2012; Tilliger et al. 2015). For example, in a special issue dedicated to ecosystem services in the journal *Agroforestry Systems*, only 1 of 19 articles considered CES (Jose 2009). The ecosystem service assessment tool (Tsonkova et al. 2014) for agroforests lacks any mention of CES. We

were able to identify only three manuscripts that explicitly assessed CES in agroforests (Langenberger et al. 2009; Calvet-Mir et al. 2012; Moreno et al. 2017).

This limited consideration of CES is particularly distressing given the positive feedback between environmental degradation in agroecosystems and loss of the CES they provide (Tilliger et al. 2015). CES are often one of the primary management objectives in agroforests due to their high value for individual land managers and communities (Barrena et al. 2014). Calvet-Mir et al. (2012) found that CES, such as relaxation, aesthetic beauty, and cultural heritage, are the most valued ecosystem services for both scientists and practitioners in their study of homegardens in Spain. Cultural, regulating, and supporting ecosystem services provided by agroforests are also highly correlated, so the loss of CES will likely deleteriously affect other ES (Calvet-Mir et al. 2012; Tilliger et al. 2015).

Case Studies

We have selected agroforests from around the world that have been developed in a wide range of sociocultural and environmental contexts in order to illustrate CES of agroforestry systems. After describing each agroforestry system and how its function influences the CES it provides, we describe how socioecological changes have affected how it is managed, its CES, and the feedback between the two. We do not advocate for or evaluate any particular framework for assessing CES as it would be inappropriate to do so without primary data and a deeper understanding of each of these systems. After presenting these case studies, we will highlight some common themes elucidated from this overview, which can inform recommendations about future work regarding CES in agroforestry research.

Lacandon Maya Milpa: Chiapas, Mexico

Description and History

The Lacandon Maya likely settled in the humid lowlands of southwestern Mexico more than 2–3 centuries ago after fleeing the Yucatan Peninsula of Mexico after the Spanish conquest (Palka 2005). They adapted to local environmental conditions by developing a swidden, successional agroforestry system, which has been called the *milpa* cycle (Ford and Nigh 2016).

At the end of the dry season around March and April, the Lacandon agroforestry cycle (Fig. 1) is initiated by the farmer slashing patches of vegetation typically measuring less than two hectares. Farmers will preferentially clear secondary forest vegetation as opposed to mature forest, which is maintained as a source of many ecosystem services, including seed rain and wildlife habitat and provisioning game, timber, firewood, and wild edible plants (Nations and Nigh 1980). Farmers then

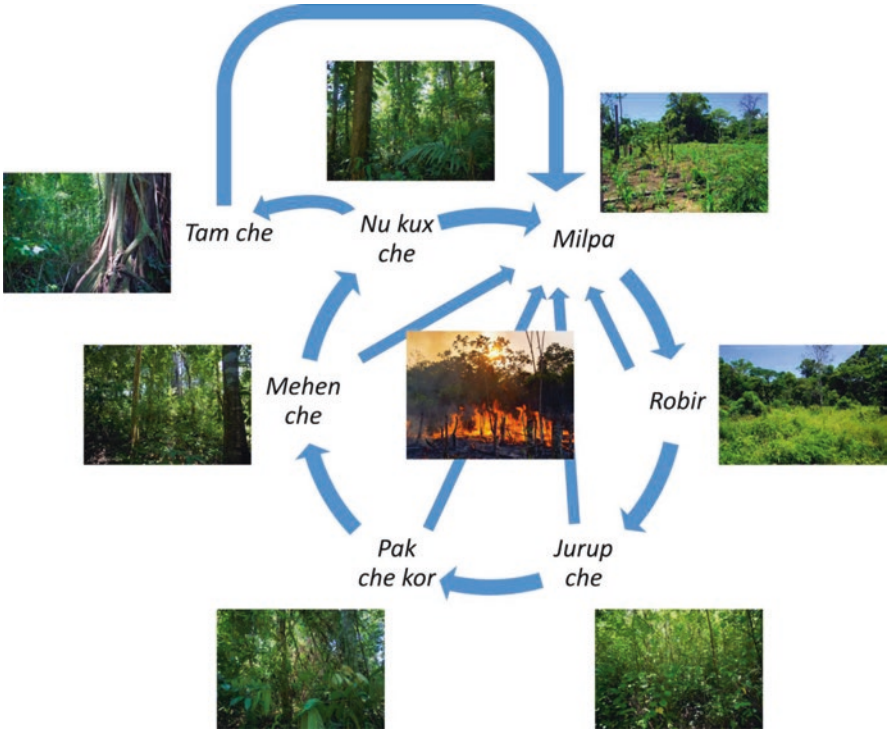

Fig. 1 Diagram of the Lacandon Maya milpa cycle

burn the slash just before the onset of the rainy season in May. This burn creates biochar, which serves as a soil amendment (Nigh and Diemont 2013).

Lacandon farmers cultivate a diverse polyculture of crops in the first stage of the *milpa* cycle. This stage, called *milpa* in Spanish or *kor* in Lacandon Mayan, is dominated by *Zea mays* but can contain between 50 and 100 different crop species and cultivars, including both annual herbaceous and perennial tree crops (Falkowski et al. 2019b). After 3–5 years, *milpa* production begins to decline due to declining soil fertility and increased weed populations. At this point, farmers allow the plot to go fallow (Diemont and Martin 2009). While fallowing connotes a lack of management, Lacandon farmers actively manage these stages, although not to the same degree as *milpas*. For example, Lacandon farmers plant or clear ruderal herbaceous vegetation around naturally occurring tree seedlings of slow-growing species just before fallowing a *milpa* plot. They encourage the growth of these species because they are valuable for either provisioning (e.g., timber) or regulating (e.g., soil fertility enhancement) services they provide in latter successional stages. Lacandon farmers recognize several distinct stages in the fallow period based upon a suite of physical characteristics, such as canopy cover, biomass, dominant plant species, and light transmission. These include, in order, *robir, jurup che, pak che kor, mehen che,* and *nu kux che.* Fallow periods can last from 2 to 60 years before the plot is slashed

and burned again (Falkowski et al. 2019a). In general, Lacandon farmers prefer to wait until at least the *pak che kor* stage (i.e., at least 5 years) to make *milpa* again in order to restore soil fertility after cultivation (Falkowski et al. 2016). In addition to actively managing fallow succession, Lacandon farmers hunt, fish, and gather medicinal and edible plants from these secondary forest stages (Nations and Nigh 1980).

Cultural Ecosystem Services

The management of traditional agroforestry systems, such as that of the Lacandon Maya, is often imbued with cultural meaning. Agroforests have historically served as infrastructure for TEK education in Lacandon communities. TEK is passed down from generation to generation as parents and grandparents guide their children and grandchildren in managing agroforests. In the process, Lacandon youth learn about the natural history of the region, as well as traditional agroecological management (Falkowski et al. 2015). In addition to the education CES provide to Lacandon communities, Lacandon farmers have actively collaborated with researchers to study ecology in their agroforests (Diemont and Martin 2009; Falkowski et al. 2016).

Lacandon agroforests also provide therapeutic and aesthetic CES. Lacandon farmers sometimes plant particular flowering species in their *milpas* in part because they are beautiful. Farmers remark that they enjoy spending time in the forest because it is enjoyable and "tranquil" (Adolfo Chankin, personal communication, July 2017). Tourists are attracted to the region due to its natural beauty and the unique cultural history of the Lacandon. They learn about forest ecosystems and Lacandon Maya history while visiting. Many Lacandon families are increasingly reliant upon the income associated with ecocultural tourism (van den Berghe 1995).

According to Alcorn and Toldeo (1998), *milpa* is not exclusively—or even primarily—a spatial concept defined as an agricultural production system. It is a social institution and a process that is encoded in a cultural script, or an internalized plan used to make decisions given cultural and social constraints. These cultural scripts are transmitted between generations through legends, beliefs, and social events. Thus, traditional Maya culture influences land management systems and vice versa. Rodas et al. (1940) said that the Maya "do not raise maize to live, they live to raise maize." Nigh (1976) noted that "… the making of *milpa* is the central, most sacred act, one which binds together the family, the community, the universe … *milpa* forms the core institution of Indian society in Mesoamerica and its religious and social importance often appear to exceed its nutritional and economic importance." Maintaining *milpa* agroforests integrates Lacandon smallholders into a network of reciprocity that ensures assistance in times of social, economic, or ecological stress. It is also associated with social status and a fundamental component of Lacandon cultural identity and heritage (Alcorn and Toldeo 1998).

Particular agroforestry management events are marked by religious ceremonies (Alcorn and Toldeo 1998). Many of the materials used for these events are obtained from the agroforestry system itself. For example, *balche* is a ceremonial beverage

made by fermenting honey and the sap from *Lonchocarpus* spp. trees. Copal—an aromatic resin from the *Protium copal* tree—was traditionally burned as an offering to the gods. Many gods in the traditional Lacandon pantheon were associated with nature and with agroforests (e.g., the god of corn). Given that legends and stories are often metaphors encoding these scripts, elements of *milpa* agroforestry management permeate Maya mythology and cosmology. For example, according to the Popol Vuh—the Maya creation story—humans are made from maize. *Ceiba pentandra* is the axis mundi that connects the underworld (*Xibalba*), terrestrial world, and celestial world, as well as being tree species that grew at the site where humans were created. To this end, *C. pentandra* trees are often maintained by Lacandon in advanced forest (*tam che*) stands (McGee 2002). In a legend indicative of the connection of gods to Maya agroforestry, the wind god, Chäk Ik Al, rendered a strong wind that destroyed the forest. The creator god, Hachäkyum, who was displeased with his creation, then burned the felled trees. Chäk Ik Al brought a strong storm that inundated the world. The only survivors were the people and plants Akinchob, the god of the *milpa*, placed in a canoe. This people, the ancestors of the Lacandon, then repopulated the earth and planted their *milpas* (McGee 1990). This legend mirrors the process for making a *milpa*, wherein farmers fell vegetation, burned the slash, and planted their crops at the onset of the rainy season. Thus, cultivating *milpa* is a sacred act commemorating creation itself (McGee 2002).

Socioecological Changes

Socioecological changes in the last decades have fundamentally altered the way Lacandon Maya value CES, and led to similar changes in their agroforestry management and livelihood strategies. Immigration to the Lacandon region spurred by land reforms increased population density and development of the Lacandon rainforest throughout much of the twentieth century. Lacandon territory decreased because of deforestation, expanding from logging roads and newly established agricultural settlements, as well as population declines caused by outbreaks of diseases to which the Lacandon had not been exposed. Due to these reasons and government resettlement, they were clustered together in more centralized communities (Perera and Bruce 1986; Boremanse 1998; McGee 2002).

The Lacandon largely abandoned their traditional religion by the early 1990s as missionaries converted young people and the older generation died, taking their traditions and rituals with them (McGee 2002; Palka 2005). McGee (2002) points to three main causes for the decline of the traditional Lacandon Maya religion: a decline in the necessity of healing rituals with increasing access to modern medicine, a shift from traditional subsistence agriculture to a tourism-based economy, and the introduction of Western institutions and technologies, namely television and primary schools, which facilitated a growing divide between younger and older generations.

The weakness of the peso made Mexico an attractive destination for international tourists. Some Lacandon capitalized on this tourist boom by selling souvenirs at the

nearby ruins of Palenque and Bonampak. Tourists also began to travel to the Lacandon communities along newly constructed roads. Some residents built lodges and restaurants to meet the growing demand for tourist infrastructure (McGee 2002). This shift away from subsistence agriculture to a tourism-based market economy has had profound changes on Lacandon Maya culture and TEK.

Lacandon communities transitioned from a subsistence-oriented economy to one based on income from tourists. The income from providing souvenirs, room, and board for tourists is far greater than can be earned by maintaining traditional agroforests, so many people have abandoned agroforestry. The shift away from traditional healing and agricultural practices obviated the need for healing rituals and asking for bountiful harvests, so younger Lacandon saw little need to practice them (McGee 2002).

The income from tourism allowed Lacandon to purchase nonlocal goods and changed the socioecological structure. After attending school (where they are taught in Spanish, but not Lacandon Mayan), children often play on the computer or watch television instead of working alongside their parents in agroforests. The proliferation of purchased goods in Lacandon communities has resulted in shifting perspectives on social standing. Increasingly, material wealth is the indicator of social status as opposed to effective *milpa* cultivation and wisdom acquired with age. As opposed to older Lacandon who tried to maintain their traditional lifeways, younger generations tend to seek material wealth, providing them with more social capital. This change has led to tensions between the younger and older generations (Valle-García 2014). Men typically earn more money through tourism. The ability to purchase products such as store-bought clothes and commercial food products depreciated products made by women, such as clothing and food, increasing the gap in power between the genders (McGee 2002). Finally, certain families have profited more from tourism than others, leading to tension between families and socioeconomic disparity (Valle-García 2014).

The increasing role of tourism in the local economy has changed Lacandon traditional agroforestry management. Few farmers still manage traditional *milpas*. Even if they did not abandon agriculture altogether, they have less time to manage their *milpas*. To compensate for lost labor, farmers may reduce the diversity of their *milpas* to ease management; hire additional workers; or add chemical fertilizers, herbicides, and pesticides (McGee 2002).

This case study exemplifies how changing socioeconomic conditions drive changes in agroforestry management and CES valuation, accelerating and/or magnifying socioecological change. That said, the integrity of traditional Lacandon culture, and *milpa* agroforestry in particular, has helped maintain practices which may have eroded faster. Tourism serves as a double-edged sword in this situation. On the one hand, tourism in Lacandon communities has encouraged traditional practices to be maintained, such as wearing traditional dress. On the other, it has also contributed to a commodification and abandonment of some cultural practices at the expense of others (van den Berghe 1995).

VAC Homegardens: Vietnam

Description and History

Many Vietnamese smallholders cultivate diverse homegarden agroforests. Households manage homegardens to mimic the structure of the surrounding natural ecosystems. While their primary function is to provide provisioning ecosystem services such as foods and medicines, they also often hold cultural and social significance. Homegardens are an example of a socioecological system that includes a household, the community to which it belongs, surrounding ecosystems, and the plants and animals incorporated into the homegarden itself (Kumar and Nair 2010).

One of the most common homegardens in Vietnam is the *Vườn Ao Chuồng* (VAC), which translates to garden-pond-livestock. This system likely originated in the rich soils of the Red River Delta in northern Vietnam and subsequently spread throughout Vietnam in the later half of the twentieth century. Homegardens served a critical role in ensuring subsistence for rural smallholders during the wars with France and Vietnam during this period. The spread of VAC systems can be largely attributed to the communist government's support for small-scale integrated agroecosystems in an attempt to improve food security for rural smallholders (Luu 1992). The campaign resulted in a dramatic increase in homegarden cultivation. Today, up to 90% of rural families maintain some form of homegarden, and approximately 44% of all households maintain the complete VAC system, which consists of gardens, livestock, and aquaculture. On average, these systems provide 30–60% of rural families' income and most of their subsistence (Mohri et al. 2013) (Fig. 2).

In general, homes are situated near the pond for easy disposal of domestic and kitchen waste, which is drained into the water to support stocked fish populations and aquatic vegetation which in turn supports ducks. Households plant a diverse polyculture of crops in the garden, including annual crops (e.g., sweet potato and sugarcane) and fruit trees (e.g., orange, banana, and apricot trees). Many of these plants are cultivated either for food or for traditional medicine. Families fertilize their crops with livestock manure and pond silt. They use kitchen scraps and weeds to feed poultry and pigs (Luu 1992; Mohri et al. 2013).

VAC system design and management are adapted to local conditions, including topographical, economic, ecological, and cultural factors. Trinh et al. (2003)

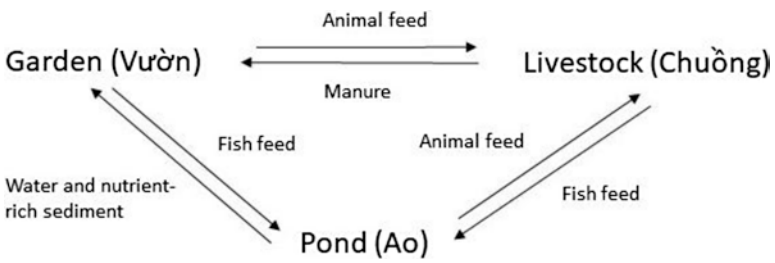

Fig. 2 Diagram of VAC system components and exchanges. Adapted from Thanh (2010)

identified four different kinds of VAC systems depending on their location and how resources are managed. These include fruit trees in southern Vietnam, aquaculture ponds and livestock in the Red River Delta and central Vietnam, vegetables in the Red River Delta and central Vietnam, and forest trees throughout the country.

Cultural Ecosystem Services

In addition to their importance for rural smallholders as sources of income and subsistence, VAC systems provide many CES. While still nascent, there is a growing body of research regarding the ecological function and impacts of VAC agroecosystems (Trinh et al. 2003; Sekhar 2007; Vlkova et al. 2011; Nguyen et al. 2013b; Mohri et al. 2013). Furthermore, these VAC systems are the result of and embody centuries of accumulated traditional ecological and cultural knowledge through maintenance of the agroecosystem itself.

Prior to the *Đổi Mới* Renovation in 1986, which led to a drastic and rapid loosening of government regulations, farmers were not given a choice in crop selection and farmland was collectivized. However, farmers were permitted to maintain small, private homegardens for subsistence (Mohri et al. 2013). As such, crop selection in VAC homegardens is mediated strongly by cultural practices. Trinh et al. (2003) describe how *Areca catechu* fruit, *Piper betle* leaf, and lime (*Citrus* spp.) are often grown and consumed together, particularly at weddings when the combination represents the union between husband and wife. This combination of crops has been metaphorically encoded into folklore and legends, both underscoring their importance and describing how they are to be managed and used. They are also important for religious and spiritual experiences due to their role as gifts and offerings during festivals and weddings. During the Vietnamese New Year (*Tết*) celebrations, household shrines must include five fruits that symbolize elements of Vietnamese Buddhism: *Musa* spp. *Citrofortunella microcarpa* or *Citrus* spp., *Capsicum* sp. or *Vitis vinifera*, *Citrus grandis*, and *Pyrus pyrifolia* (He 1991). Other crops utilized for cultural purposes during *Tết* festivities include *Momordica cochinchinensis* (used to dye rice red), *Phrynium parviflorum* (used to wrap rice cakes), and *Saccharum officinarum* (placed by doorways to prevent evil spirits from entering the home). These crops are widespread and commonly cultivated in traditional VAC homegardens (Hodel et al. 1999).

VAC agroecosystems provide therapeutic and aesthetic CES. Farmers plant certain trees because they are beautiful (e.g., orange tree and acacia) and note that they like to spend time socializing and relaxing in their homegardens (Vlkova et al. 2011; Nguyen et al. 2013b). The growing importance of tourism to the Vietnamese economy may spur further development of ethnotourism in regions where homegarden cultivation is central to the cultural expression ethnic minority groups (Sekhar 2007; Vlkova et al. 2011; Shih and Do 2016). This change may be underway given the prevalence of homestays throughout rural tourist areas in Vietnam. Ecotourism development itself can lead to changes in agroecological management and cultural expression (Cochrane 2008; Kontogeorgopoulos et al. 2015).

VAC homegarden cultivation and management are a source of cultural identity for rural smallholders in Vietnam, including many ethnic minority groups such as the Nung and H'mong (Sekhar 2007). Farmers express pride in their management acumen. Ethnic minority homegardens are also typically managed differently from those of the Kinh majority, illustrating the cultural differences between the two groups. Homegardens of ethnic minorities typically contain more medicinal plants, but the vegetable crops are less diverse than Kinh homegardens. This difference is in part due to the residence patterns of ethnic minority groups, most of which live near forests in the midland and mountainous areas of northern and central Vietnam, allowing them to collect food from these unmanaged ecosystems. The homegardens of ethnic minorities generally contain fewer commercial crop varieties and more crops that are used in regional traditional cuisine, in part because their communities are commonly located further from market hubs and dense population centers (Trinh et al. 2003).

Socioecological Changes

VAC management continues to evolve as new crops and forms of resource management are integrated into the system. Rice cultivation, forestry, and biogas production are increasingly incorporated into the VAC. Changes in management, composition, structure, and function come from local government support to foreign investment in agriculture in Vietnam. VAC systems have consequently shifted from subsistence and culturally important crops to market-oriented resource management (Mohri et al. 2013). This shift has been attributed to the *Đổi Mới* renovation and decollectivization policies of the late 1980s and early 1990s, which opened Vietnamese markets to increased foreign investment. Before these policies, homegardens were more necessary for subsistence; farmers diversified their VAC to increase their resilience to environmental stochasticity. With open markets homegarden cultivation is increasingly becoming an opportunity to produce economically valuable crops, such as *Arachis hypogaea, Acacia* spp., and *Hevea brasiliensis* (Sekhar 2007).

Despite these market changes, the biodiversity within VACs today still remains high. It is unclear, however, whether traditions will be maintained along with culturally important crops, or reductions in these crops will erode cultural practice. Sekhar (2007) found that commercialized homegarden agroforests contained less than half the plant species of traditional systems. He also observed that they were managed more intensively with shorter fallow periods and increased fertilizer inputs. Alternatively, Fey (1989) found that commercialized homegardens were more diverse than subsistence homegardens, suggesting that homegardens may still be a refugia for culturally important species that are not economically valuable. However, this finding only takes into account species richness, not plant community composition. Increased commercialization of VAC systems is associated with exacerbated economic inequality, reduced use of traditional medicinal plants, and increased land privatization and fragmentation (Trinh et al. 2003; Mohri et al. 2013).

Increasing population density and growing economic inequality between rural and urban populations have also resulted in urban migration as rural families abandon their farms and homegardens to pursue more economically profitable activities in cities. While many former rural residents maintain customs and cultural practices, their cultural expressions are shifting with changes in livelihoods, physical environment, and social community. Traditional medicine is still practiced in cities (Albala 2014). Religious beliefs are generally transferable, so culturally important crops are still used in traditional rites and ceremonies in urban environments (Mazumdar and Mazumdar 2012). However, urbanization has reconfigured family structures in Vietnam, commonly leading to the breakdown of support networks (Barbiéri and Bélanger 2009). Urbanization, cultural shifts, and increasing income have increased meat consumption in Vietnam, thereby increasing the value and management intensity of the livestock component of VAC systems outside cities (Albala 2014; Hansen and Jakobsen 2020). Fast food is also becoming an increasingly staple component of urban Vietnamese diets, replacing traditional home-cooked food (Baumann 2006). In turn, this has resulted in marked increases in cardiovascular disease, obesity, and other diet-related health problems which compound health issues associated with poor air and water quality in urban environments (Cuong et al. 2007; Lâm et al. 2011; Nguyen et al. 2013a; Kien et al. 2017).

Rubber Homegardens: Brazil

Description and History

Rubber tappers who reside in the Brazilian Amazon share a cultural identity originally centered on their common history as peasant laborers for rubber estate owners during the nineteenth century (Weinstein 1983). Many rubber tappers were and are *caboclos*: Amazonian mestizos of mixed indigenous and European ancestry. While many rubber barons abandoned their land following the collapse of the Brazilian rubber industry after World War II, rubber tappers, or *seringueiros*, remained and continued small-scale rubber tapping operations.

Rubber cultivation in the Brazilian Amazon ranges in management intensity from forests with a high percentage of naturally occurring *Hevea brasiliensis* trees to intentionally planted rubber agroforests (Murrieta and Rueda 1995). Leaf blight (*Microcyclus ulei*), which is endemic to South America and decimates *H. brasiliensis* plantations, precludes the development of extensive rubber plantations in Amazonia (Gouyon et al. 1993). Despite this, smallholders have long planted relatively small rubber tree agroforest groves or supplemented natural *H. brasiliensis* stands with additional trees for their latex and edible seeds (Schurz et al. 1925) (Fig. 3).

H. brasiliensis is also often a dominant component of smallholder homegardens. Rubber agroforests are generally swidden agroecosystems in which *H. brasiliensis* seeds are planted between annual crops. The annual crops are typically cultivated

Fig. 3 Brazilian homegarden with cultivated rubber trees (*H. brasiliensis*), cupuaçu (*Theobroma grandiflorum*), and açai (*Euterpe oleracea*). *H. brasiliensis* is the large stem at the center of the photograph. Image courtesy of Goetz Schroth and originally published in Schroth et al. (2003)

for approximately 2 years, after which point the plot is left fallow. Many farmers also extract timber and non-timber forest products besides rubber from these agroforests (Schroth et al. 2003). Other forms of agroforestry management are also common in the region, such as intercropped black pepper/orange agroforests (Smith et al. 1996).

Cultural Ecosystem Services

Rubber tapping has historically been at the core of the local economy and has indelibly influenced the culture (e.g., music and legends) and social structures (Vadjunec et al. 2011; Gomes et al. 2012). In the 1960s and 1970s, the Brazilian Government enacted policies to encourage colonization and development of the Amazon frontier, including selling lands informally owned by *seringueiros* to wealthy ranchers from southern Brazil. In response, the rubber tappers' identity shifted to emphasizing the sustainability of their resource management systems, especially relative to cattle ranching. They formed trade unions which allowed them to collectively fight for their rights to the land and continued resource management. These social institutions were both a product and source of common rubber tapper identity. In this way,

identity as *seringueiros*—once a source of socioeconomic stigma—became a globally recognized symbol of environmental stewardship and badge of honor (Gomes et al., 2012).

Agroforest homegarden plant communities are seen as being parts of kin networks, and different plants have unique histories which are in turn tied to particular uses and characteristics. While primarily cultivated for provisioning ecosystem services, *caboclo* homegardens are also maintained for their aesthetic beauty. Ornamental plants such as *Rosa* spp. are often included in homegardens. Homegarden management is also an expression of the syncretism that typifies *caboclo* religious worldviews (WinklerPrins and De Souza 2005). Other plants, such as *Jatropha gossypiifolia*, are cultivated for use in traditional plant-based medicines. Others still are selected for their uses in syncretic religious practices that incorporate elements of traditional native religions and Catholicism (Miller et al. 2006).

Seringueiro culture and social institutions, which are both predicated upon historic rubber tapping, represent a deep and long-term understanding of *H. brasiliensis* physiology, ecology, and management which has been passed down from generation to generation for centuries (Schroth et al. 2004). More recently, there has been some renewed research interest in traditional *seringueiro* management because their cultivation and extraction techniques seem to sustain rubber production to a greater degree than industrial methods in Southeast Asia. While most research regarding rubber agroforestry has centered on agroecosystems in southeast Asia, which dominates global rubber production, there has been a great deal of research on rubber cultivation and management in Brazil historically given that *H. brasiliensis* is native to the region.

Finally, the region is well known for its biodiversity and protected areas. This conservation ethic, combined with the global support for rubber tappers during clashes with cattle ranchers in the 1980s, can help draw tourists to the region's extractive reserves and rubber agroforests (Schroth et al. 2004).

Socioecological Changes

Rubber tapper heritage and identity continue to adapt to social, political, and economic changes. The Brazilian federal government has recently cut rubber subsidies, global rubber prices have been declining steadily for at least the past two decades, and the Amazon frontier is becoming increasingly integrated with national and international markets (Hoelle 2011; Gomes et al. 2012). As the economic viability of rubber tapping declines, *seringueiros* have increasingly adopted agriculture and cattle ranching. This shift contravenes their own identity as forest stewards of their extractive reserves, as it is associated with environmental degradation and deforestation, as well as being at the root of their conflict with cattle ranchers in the 1970s and 1980s (Hoelle 2011; Gomes et al. 2012). Because the activities of rubber tapping and forest management are fundamental to *seringueiro* identity, many *seringueiros* were emotionally impacted by this change. One rubber tapper commented, "We all became sad and didn't know what to do." However, this reaction

was mixed. “Life is better now … I would do exactly what I am doing now if the price of rubber improved,” said another former rubber tapper (Salisbury and Schmink 2007).

Traditional definitions of *seringueiro* identity no longer apply as a result of these lifestyle shifts. While many local residents still identify as rubber tappers, this self-identification is not inherently associated with resource management, but rather historical occupancy and participation in social organizations (Salisbury and Schmink 2007; Vadjunec et al. 2011; Hoelle 2011). Only 33% of households Vadjunec et al. (2011) interviewed stated that rubber tapper identity is contingent upon practicing rubber tapping management. These views are not necessarily homogeneous, and a great diversity exists in individuals’ reasoning for self-identifying as rubber tappers (Gomes et al. 2012). The increase in cattle ranching among *seringueiros* has caused tensions in communities historically unified by a common resource management identity. While some of those who still tap rubber understand the motives of community members who have transitioned to cattle ranching, others see it as a betrayal. Cattle ownership is generally seen as a status symbol, exacerbating tensions between community members as rubber tapping is associated with poverty and lack of education (Salisbury and Schmink 2007; Vadjunec et al. 2011; Hoelle 2011).

In addition to changing parameters of identity, the changes in land management have impacted the expression of *seringueiro* culture. For example, country music, rodeos, and Western cowboy attire are increasingly common and popular in historically rubber tapping regions. Meat is increasingly central to the diet (Hoelle 2011; Gomes et al. 2012). Thus, CES of identity and heritage provided by rubber agroforests are being replaced by those provided by cattle ranches and cowboy culture.

In addition to the changes in rural livelihoods, urbanization is shifting demographics in the Brazilian Amazon. Many *caboclo* rural migrants continue to manage homegardens in cities as a tie to their cultural heritage and to supplement their diets and incomes. They exchange garden products in a “network of giving” that is more than just an informal market that ensures food security. It also strengthens social ties and promotes a feeling of well-being and affection. For example, individuals who remain in rural areas but visit family in urban environments bring goods that cannot be produced in urban homegardens. This exchange ensures dietary diversity for urban residents and a sense of familial connection for isolated rural residents (WinklerPrins and De Souza 2005). Thus, urban residents have adopted agroforest homegarden management to provide them with CES in a new environment.

Cultural traditions and social institutions allow for the enforcement of rules governing resource management. Therefore, it is questionable whether *seringueiro* communities will continue sustainable forest extractivism. Although permitting economic development and resource use through rubber tapping management has been shown to limit deforestation, continued socioeconomic pressures may combine with cultural trends to facilitate further expansion of cattle ranching among *seringueiro* communities. While CES associated with rubber tapping and rubber agroforestry management, such as cultural identity, may be replaceable with cattle culture, this shift could be associated with reductions in regulating and supporting ecosystem services. The flexible cultural boundary of this group makes them more

open to changes that can either increase or decrease their ecological and cultural resilience (Berkes and Folke 1998).

Tree-Vine Vineyards: Portugal

Description and History

Ancient Greek viticulturalists grew grapevines along trees and trellises as high as 15 m using a technique known as "high vine," which was thought to be the source of the best wine (Thompson 1937). The Greeks introduced high vine viticulture to the Etruscans (Surico 2000), and the Romans subsequently transplanted their traditional vineyard management as they conquered other cultures throughout what is now Europe, including Portugal (Anderson 2000).

Modern-day Portuguese traditional vineyards are a mix of high vine management types that have trees and those that do not have trees to support the vines. High vines that are supported by concrete poles and metal wire rather than trees can be found throughout much of northwestern Portugal (Altieri and Nicholls 2002), while vineyard agroforestry management is patchily distributed and generally restricted to an area within 20 miles of the city of Braga in the Minho region (Altieri and Koohafkan 2004; Koohafkan and Altieri 2017). Even within this region, vineyards are dominated by high vines that do not include trees and conventional forms of viticulture that are not high vine at all (Fig. 4).

Fig. 4 A vineyard agroforest in the Minho region of northwest Portugal

Vineyard agroforests are typically found in multifaceted family farms, most of whose land is dedicated to cultivating a polyculture of crops surrounded by a perimeter of trees. Farmers space these trees approximately 10 m apart, string several wires between them, and cultivate three or four grapevines at the base of each tree. As the vines grow, farmers interweave them within the tree branches and festoon them along the wire between the two trees, creating mixed foliage of grape and tree leaves. Historically, farmers have used numerous tree species, many of which also provide fruits or nuts, such as cherry, chestnut, and oak (Stanislawski 1970; Altieri and Nicholls 2002). Farmers pollard trees once a year between February and March, encouraging young branches to support new grapevine growth as the growing season progresses. Tree foliage fills in and becomes a dense cover for the grapevines before the hot and sunny summer months of July and August. Despite high temperatures of 23 °C and monthly precipitation in these months averaging only 40 mm over 2 days (NOAA n.d.), farmers do not irrigate these grapes, even as modern row single-species viticulture in the region requires regular irrigation.

Farmers employ tall ladders to reach the grapes for harvest in September. Traditionally, farmers and their families would stomp the grapes by foot to make wine. These traditional vineyard agroforests can produce more than 1000 L of low-proof effervescent wine, from what is essentially a living fence surrounding a 2 ha farm. Families consume the resulting table wine throughout the entire year.

Cultural Ecosystem Services

Viticulture agroforestry has been traditionally a central part of family activity in the Minho region, and is integral to the family economy. The home, while not located within the agroforest, is typically within an easy walking distance. Daily management activities, such as weeding field crops within the vineyard agroforest, often involve the entire family, while annual activities, such as planting, pollarding, harvesting, and winemaking, involve extended families. Even as land is divided, extended families will share equipment and human resources for larger annual activities, such as pollarding, tilling the field, grape harvest, and winemaking. These agroforestry management practices serve to unify family around a shared activity, providing an opportunity for bolstering relationships within the nuclear family and with distant relations.

Vineyard agroforest landscapes are fairly open. Parcels have no divisions beyond the living fence trees and intertwined grapes that surround field crops. This openness contrasts with other private conventional vineyards in the area, many of which are surrounded by perimeter fencing and guarded by dogs. As a result, traditional vineyard agroforests provide space for relaxation and recreation for the general public. Visitors can stroll through between vineyard agroforest parcels, despite not being community members or members of the farming family.

The landscape of vineyard agroforests provides an important and unique agroecological aesthetic (Stanislawski 1970). During winter, the pollarded trees offset by the bare fields accentuate the quiet and cold of the season. After this bareness

comes the activity of spring, as families begin to prepare the fields, and then the summer months, during which families and wildlife are active daily.

Socioecological Changes

Agroforestry viticulture around Braga has changed markedly over the past few decades. Although traditional family farms remain, they are increasingly sold to landowners from outside the community because most of the agroforests are maintained by older farmers, and members of younger generations are less interested in farming than their parents. Although new owners do not typically remove the trees after purchasing these farms, they rarely focus on traditional vineyard agroforest maintenance. Many fields are abandoned, and trees are rarely pollarded. Older grapevines are neither pruned nor replaced and no longer provide abundant grapes for winemaking as a result. Traditional winemaking techniques have been largely replaced by machinery, if not discontinued entirely. These changes are not entirely the result of local social changes, but also result from economic incentives.

Vineyard agroforests have been converted to row cropping vineyards with drip irrigation. According to interviewed farmers, various European Union agricultural incentive programs provide benefits to landowners who wish to modernize their traditional vineyards, which are considered to be less productive than those employing commercial grape-growing techniques. Trees are absent from these conventional monoculture viticulture systems. While traditional agroforestry vineyards require considerable labor, grapevines under row cropping require irrigation, infrastructure, and fuel resources (far above traditional viticulture). As a result, these row systems may sacrifice other ecosystem services (e.g., recreation, aesthetic), and may reduce the system's resilience to environmental change (including climate change) (Costa et al. 2016; Hannah et al. 2013; Viers et al. 2013).

Conclusions and Recommendations

Common Themes

Agroforests consistently provide a wide range of CES. These services are perceived as among the most valuable ES provided by agroforest ecosystems (Martín-López et al. 2012). While production-oriented rationales for agroforestry are no doubt important to agriculture, it is imperative to consider culture and other social factors as well.

The desire to maintain CES can promote sustainable agroecosystem management and limit environmental degradation. Just as biodiversity loss and environmental degradation are pressing global concerns, so too is the loss of cultural diversity. Indeed, many have argued that the two are inextricably linked (Díaz et al.

2006; Clark et al. 2014). Any attempts to address the former must engage the latter to be successful, which poses challenges associated with interdisciplinary and intercultural work involving multiple stakeholders. It also implies that addressing one issue offers an opportunity to address the other.

While CES are central to many cultures, the socioecological systems that create value for CES are open and must adapt to changes, which are not necessarily normative (Berkes and Folke 1998). Cultural heritage is a product of not only the past, but also how it is maintained, expressed, valued, and transmitted in modern society (Tengberg et al. 2012). While it can be argued that CES are not replaceable, the case studies presented here indicate that cultures find cultural value in changing ecosystems as well (Hirons et al. 2016). That said, while different ecosystems may both provide similar CES, more research is necessary to assess the nature of these ES and whether changes have also impacted the quantity or quality of services.

Framework for Assessing Cultural Ecosystem Services in Agroforests

Brown et al. (2014) provide a general framework for developing ecosystem service indicator frameworks. The first step is identifying and consulting with stakeholders to determine management objectives. It is then useful to develop a conceptual model and determine key questions regarding potential indicators. Data acquisition can also be done collaboratively to provide local stakeholders with a vested interest in the work. This step is critical in cases of CES which are the product of stakeholder interactions with the environment. After indicators are calculated, findings should be broadly communicated so that the indicators can be evaluated and refined with stakeholders to ensure accuracy and comprehensiveness. Because all of these steps involve local stakeholders, building positive relationships is critical.

Calvet-Mir et al. (2012), Barrena et al. (2014), Nahuelhual et al. (2014), Tilliger et al. (2015), and Tengberg et al. (2012) describe additional methods that aim to explicitly assess CES in agroecosystems. The interdisciplinary concept of cultural landscapes, which is well established in land-use science, social sciences, humanities, and paleoecology, may offer a useful framework for integrating cultural services into broader assessments of ecosystem services. Cultural landscape research includes methods for assessing and valuing CES at multiple spatiotemporal scales using participatory research, historical land-use analysis, ethnographic surveys, and spatial analysis. However, the cultural landscape research community seems primarily focused on historical assessments of cultural services, which risks overlooking how persisting systems are adapting to modern changes (Schaich et al. 2010).

Researchers must undertake CES assessments with cultural sensitivity and attention to nuance. The CES framework has the potential to integrate multiple disciplines and epistemologies in identifying important factors that sustain socioecological systems However, if implemented carelessly and callously, it can also be used to

further marginalize the stakeholders, ecosystems, and services they aim to assess and protect (Hirons et al. 2016).

Although CES are currently relegated to the periphery of most ecosystem service assessments, the number of studies incorporating CES is growing. This new body of literature offers many new frameworks for assessing CES and incorporating them into decision-making processes. While this change is admirable, an overemphasis on quantification and placing multiple ecosystem services into a single scale for ease of comparison may obfuscate that ecosystem services are a conceptual tool that facilitate holistic exploration of socioecological systems and the way humans relate to nature. While CES present certain challenges to incorporation into comprehensive ES assessments, their fundamental role in socioecological systems makes them critical to consider in some way, even if it is imprecise or indefinite.

The Future of Cultural Ecosystem Services in Agroforests

A future scenario in which CES are increased according to the Millennium Ecosystem Assessment (2005) is the "adapting mosaic," in which watershed-scale landscapes are the basic socioeconomic unit. Local institutions are strengthened so as to improve the collective understanding of local ecosystem function and sustainable management. Emphasis of economic growth is replaced with steady-state economics focused on decreasing economic inequality, stabilizing population, and restricting economic expansion (Daly 1991). Sociocultural and biological diversity is emphasized, maintained, and celebrated in order to ensure resilience of socioecological systems in the face of change. Local institutions are connected through socioeconomic networks to share knowledge and resources in addressing socioecological problems (Millennium Ecosystem Assessment 2005).

This narrative underscores the importance of maintaining ecocultural diversity. Agroforestry management offers a way in which all three pillars of sustainability—social, economic, and environmental—can be achieved. While CES are under threat due to cultural, economic, and environmental homogenization associated with globalization, they also offer a potential way to minimize the negative impacts associated with these trends.

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