# **Ecosystem Services from Trees in Coffee Agroecosystems**

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Coffee (*Coffea*) production in Hawaii and globally is primarily carried out on small farms of 10 acres or less. Although a few large plantations can contribute disproportionately to the total volume of coffee produced, the majority of coffee on the world market comes from small farms scattered throughout various coffeegrowing regions in the tropics. While coffee is a shade-adapted plant, maximum yields can be achieved in a full-sun environment with sufficient water, nutrients, and pest and weed management. In Hawaii, most small farmers have the capacity to provide supplemental irrigation and fertilization to make trees unnecessary for



Coffee cherries

healthy and sustainable production. However, it is still common for small farms in Hawaii and elsewhere to include trees either as part of a diversified production system (e.g. macadamia, avocado, citrus, bananas, or timber) or for the benefits they provide to the coffee crop or the producers and farm laborers. Below is a summary of some of the ecosystem services trees can and do provide for coffee and other diversified agricultural systems, adapted from a recent book chapter reviewing ecosystem services from smallholder forestry and agroforestry systems (Idol, et al. 2011). While the scope is global, the examples included are relevant for Hawaii's coffee farmers.

Trees provide direct products and services to coffee producers. Fruits, nuts, fuel, animal feed, and timber are just a few categories of products that trees provide. In Hawaii, examples of fruit and nut species commonly found with coffee include bananas (*Musa* spp.), macadamia nuts (*Macadamia integrifolia*), avocado (*Persea americana*), mango (*Mangifera indica*), and bread-fruit (*Artocarpus altilis*), among others (NRCS 2010). The typical wide tree spacing and intensive management provided for the coffee often improves the growth and yield of the tree crops, especially for timber trees that are otherwise rarely given supplemental irrigation or fertilization. Not surprisingly then, timber trees generally do better as part of an intercropping system than when grown alone.

Tree crops on coffee farms normally contribute less than 20% of the total income, but they provide flexibility in response to changing commodity prices. This practice diversifies risk and protects producers who cannot otherwise survive several years of low coffee prices. In Hawaii, our reputation for high-quality coffee buffers producers somewhat from fluctuations in world markets. However, diversification with tree crops can be used as a strategy to quickly take advantage of emerging markets for new products or increased prices for secondary crops.



Monkeypod over coffee. Shade managed by pruning lower branches as trees grow taller.

Trees can also provide important services for the coffee plants. Windbreaks are common in coffee farms due to the high sensitivity of coffee leaves to wind. Tree shade reduces air temperature, increases relative humidity, and thus reduces evaporative demand from coffee plants. Even under well-watered conditions, coffee leaves under full sun will close their stomates under high evaporative demand in the late morning, effectively shutting down photosynthesis for the day (Steiman and Idol, person. observ.). While shade may reduce maximum fruit set and yield, it can reduce overbearing dieback and biannual yield fluctuation in high-sun environments.

The benefits of trees for soil and water conservation are well-recognized. Tree root systems hold soil in place and create large pore space for increased infiltration. Tree leaves and other organic debris provide soil cover to reduce rainfall impact, minimizing runoff and erosion. On slopes, trees can be especially important as part of terrace formation, anchoring soil in place. However, trees alone cannot prevent downslope erosion, so rock walls or other structures are necessary to maintain terraces.

Trees are also important for nutrient cycling in coffee farms. While trees do compete for available soil nutrients, they return much of the nutrients taken up as leaf litter and fine root turnover each year. Trees in agroforestry systems have been found to capture fertilizer nutrients that leach below the crop rooting zone (Allen, et al. 2004), reducing groundwater contamination and again, recycling these nutrients back to the soil. In the tropics, nitrogen-fixing trees are commonly used as a source of green manure to actively fertilize crop plants growing underneath them or in adjacent fields. N return in leaf litter from these trees can exceed the annual N requirement of the coffee plants (Beer 1988). In Hawaii, monkeypod is a N-fixing tree that is commonly used to for shade in coffee farms below 1500 ft elevation (Elevitch, et al. 2009). Koa is a native nitrogen fixer that can be grown with coffee at higher elevations (above 2000 feet). There are many traditional tropical nitrogen fixers that are found in Hawaii but less widely used, such as *Gliricidia sepium*, *Inga edulis*, improved and even seedless *Leucaena* varieties. Management of these trees, including spacing, pruning of the canopy, and thinning or removal of large trees, is necessary to ensure the proper balance of benefits to the coffee while minimizing resource competition (e.g. Youkhana and Idol 2011).

Biodiversity conservation is a global issue for coffee farms, since many farms are adjacent to forested areas or in former forested landscapes. In the survey of Hawaii coffee farms, we found several examples of higher-elevation farms that have retained native tree cover and were engaged in active restoration of the forest by clearing invasive species and making space

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for native plants (Elevitch et al. 2009). It was the ability of these farms to plant and harvest coffee that provided the income and opportunity to undertake restoration in the first place, slowly transforming a degraded parcel into a working agroforestry farm with native overstory trees and understory plants. While many coffee farms in Hawaii do not have the luxury of being situated in a native forest, there is interest in using koa as a plantation species, with coffee grown as an understory crop.

The ecosystem services from small farms and agroforestry systems often benefit the larger society. In turn, there are efforts to officially recognize and



*Coffee planted in an ohia lehua forest. The native shrub mamaki in the foreground.* 

compensate producers for providing these benefits. In coffee production, sustainability certification has been around for decades, with a plethora of eco-labels currently in the marketplace. However, most of these certification schemes target developing country producers, and so Hawaii farmers have not by and large sought sustainability certification. The major exception to this is organic certification, which is structured in the US not so much as a recognition of ecosystem services, but as a reward for compliance with a set of recommended and prohibited practices. Regardless, trees are often seen as facilitating organic production through their contribution to organic nutrient cycling, reduction in stress to the coffee plant, reduced pest and/or weed pressures, and improved overall efficiency of water, light, and nutrient capture. Payments for ecosystem services, most of which focus on retention or planting of trees for watershed protection, are becoming increasingly common in the developing world and are being considered and implemented in the mainland US. In Hawaii, watershed protection has been achieved primarily through land use zoning, e.g. the state forest reserve system and conservation use zoning.

One option that is well established in Hawaii's coffee farms is agro- or eco-tourism. This enterprise-based approach to promoting ecosystem services is sometimes preferred over direct payments. Such tourism seeks to conserve the natural environment and rural character of an area while maintaining the well-being of people engaged in natural resource management, including agriculture. Tourists seeking these opportunities generally spend more per person than the average. And clearly there can be economic benefits to producers with this additional revenue stream, from simple guided tours of the farm to on-site lodging and associated services. Trees are a vital component for not only promoting the ecosystem services visitors expect but also enhancing the overall visitor experience. Additionally, products and handicrafts made from trees on the farm are an easy sell to visitors and provide tangible connections to the farm as well as memories of the experience.

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In summary, trees have been and continue to be an important part of small-scale coffee farms, even in Hawaii. They have the potential to provide multiple products and services, facilitate organic production, and support the development of agro- or eco-tourism enterprises. Maintaining and integrating trees on coffee farms, even in ideal growing areas, is recommended to maintain and enhance the sustainability of coffee production and the flow of benefits to the surrounding environment and society at large.

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Measuring the stem diameter of ohia lehua trees to estimate biomass and carbon sequestration.