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Report

Measuring and Managing the Environmental Cost of Coffee Production in Latin America

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Abstract

Coffee is a major international commodity, and because of this, coffee production has the potential for considerable global impacts on the environment. These impacts can include the consumption of energy, water, land and the loss of native forest. Here we quantify these costs using Costa Rica as a case study, and describe an initiative undertaken at the Montes de Oro Cooperative in which these impacts are reduced substantially through the development and application of alternative technologies. We show how these processes reduce the consumption of resources, and also reduce economic costs to the farmer, thus providing a market-based incentive for conservation. The initiatives undertaken at Montes de Oro can provide a model for the future, for reducing the environmental costs of coffee production, while simultaneously improving the economic conditions of the people in coffee producing regions.

Keywords: biodiversity, bird, coffee, conservation, energy, integrated open canopy, processing, production

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INTRODUCTION

Reaching a vast international market, coffee is one of the most significant agricultural systems in Latin America, where 700,000 coffee farmers manipulate forty percent of the agricultural lands to generate $10 billion annually (Rice & Ward 1996, Conservation International 2002). There has been substantial discussion of the environmental costs of coffee production, although this discussion has focused primarily on coffee cultivation and its contribution to the displacement of natural habitats and communities (Rappole *et al*. 2003, Komar 2006). Less attention has been given to the potentially important costs of coffee processing. Coffee processing as traditionally practised consumes substantial amounts of energy, water and space, and this consumption can have potentially significant impacts on native tropical biodiversity.

In this article we quantify these costs of conventional coffee processing in Costa Rica, and then present alternative coffee processing technologies that have been developed at the Montes de Oro Cooperative to mitigate these impacts. We show how these alternative technologies consume a fraction of the energy used by conventional coffee processing, and whatever energy is consumed is produced using renewable sources such as solar power or co-generation. Furthermore, we describe how these technologies reduce the consumption of water and space, and finally describe a novel method of coffee cultivation that substantially reduces the impacts of growing coffee on the loss of forest-associated species. Because these novel processing technologies and methods for cultivation provide economic benefits to farmers, as well as reduce the ecological impacts, they represent a potentially effective market-based mechanism for conservation in the coffee-growing regions.

ENERGY CONSUMPTION AND COFFEE PROCESSING

Conventional coffee processing is energy intensive. After coffee is picked, the pulp and mucilage must be removed, which requires two separate processes. Then the coffee must be dried and the parchment removed, and finally the coffee must be sorted. All these steps require energy, although the electricity required for drying represents nearly eighty percent of the electricity required for processing coffee (Instituto del Café de Costa Rica [ICAFE] 2006). The remaining demand is used for the other processes (depulping, washing, sorting, etc.). The energy consumption and energy costs associated with coffee drying are uniform throughout Latin America, as the same equipment design is used throughout the region, and electricity costs are linked to the world oil prices. The cost of firewood to provide thermal energy is also fairly uniform and to a large part influenced by the diesel prices for transportation (MDI field surveys 2004-2009).

The majority of coffee in Costa Rica is dried using electricity and firewood (ICAFE 2006). Conventional coffee drying consumes on an average 12.5 kWh of electricity and 0.07 cu. m of firewood, per 100 lbs of green coffee (ICAFE 2006). Assuming a net export of 203,244,004 lbs of green coffee annually (ICAFE 2007) and the rates of electrical energy consumption from Table 1, coffee drying in Costa Rica consumes on the order of 25,405,000 kWh of electricity (enough to power a community in Costa Rica of some 13,534 people [UNDP 2007]). These energy costs impose a financial burden on small farmers, and savings on electricity costs provided by solar driers increases the viability of small coffee operations, which otherwise could be converted to other types of land use with lower ecological value, such as cattle production, commercial development or housing.

In addition to electrical energy, coffee drying in Costa Rica consumes approximately 142,268 cu. m of wood per year. Based on an extrapolation of the amount of fuel wood consumed for the drying process (ICAFE 2006), we estimate that throughout Mesoamerica, approximately 6,509 hectares of forest are cut to supply the firewood used to dry the coffee harvest each year. This is roughly equivalent to 3 sq. cm of wood per cup of coffee. Thus, reducing the amount of wood used for drying coffee could make a significant contribution to tropical forest conservation.

The Montes de Oro Cooperative has reduced their energy consumption dramatically through the development and implementation of new technologies. The most important of these innovations is a new solar/biomass coffee drying technology. This is a hybrid system that uses a combination of solar thermal and biomass gasification to dry coffee beans in a vertical, tower-like, natural convection drying chamber (Figure 1). The coffee flow inside the chamber is controlled by moving trays that cycle through the tower during the approximately 24-hour drying period. The thermal energy required for drying is supplied by solar thermal collectors during the day, and the gasification of coffee husks (see a little later in the article) is carried out at night or during rainy periods. The alternative technology requires a 30 to 40% larger initial capital investment over conventional drying equipment, depending on the configuration, although the solar/biomass equipment will pay for itself in energy savings within six to seven years.

Energy conservation will be further realized at Montes de Oro through the practise of co-generation, using waste products from coffee production to produce electricity through a thermo-chemical gasification process that is currently operational at Montes de Oro. This co-generation will be able to produce 15 kWh of electric power, more than sufficient to supply the 2 kWh required for the solar/biomass dryer. For gasification, coffee parchment is collected and gasified by a thermo-chemical reaction called pyrolysis, in which the carbohydrates of the parchment are broken down to their fundamental molecular components. A gaseous mixture of hydrogen, carbon monoxide and oxygen are the main components of the so-called producer gas, which is a fuel that burns similar to natural gas or propane, although with a lower energy content. With this

Figure 1: Industrial solar coffee dryers installed at the Montes de Oro Cooperative, Mirimar, Costa Rica. Each tower contains rotating trays on which coffee is placed for drying. Heat for drying is derived from exterior-mounted solar hot-water collectors as also for the gasification of coffee parchment

Table 1

Energy and water consumption of conventional coffee processing (ICAFE 2006) compared with the amount used to process an equivalent amount of coffee at Montes de Oro (Montes d'Oro Production Statistics)

	Electricity $ 0.20/kWh		Fuel $ 12/cu. m firewood		Water ($ 0.0005/l)	
	Conventional	Montes de Oro	Conventional	Montes de Oro	Conventional	Montes de Oro
Consumption/100 lbs green coffee	12.0 kWh	2 kWh	0.07 cu. m	0.0 cu. m	1,000 l	36 l
Cost/100 lbs green coffee	$ 2.40	$ 0.40	$ .84	$ 0.00	$ 0.50	$ 0.018
Consumption for a typical cooperative (1,000,000 lbs/year)	120,000 kWh	20,000 kWh	700 cu. m	0.0 cu. m	10,000,000 l	360,000 l
Net cost for a typical cooperative	$ 24,000	$ 4,000	$ 8,400400	$ 0.00	$ 5,000	$ 180

gas, a boiler is operated to heat water when solar resources are not available during the night or rainy or cloudy periods, and/or a generator is operated to produce electricity.

WATER CONSUMPTION AND COFFEE PROCESSING

Conventional coffee processing uses large quantities of water to remove the outer pulp and mucilage and transport the waste products. On an average, these processes use between 1,000-2,000 liters of water per 100 lbs of green coffee (ICAFE 2006). At Montes de Oro the consumption of water has been reduced by the adoption of a fully mechanized process in which the fruit or pulp of the cherry and the mucilage surrounding the bean is mechanically separated from the bean by friction. This differs from the conventional "washed coffee" in which the pulp is removed mechanically and the coffee is fermented in concrete tanks to remove the mucilage. Using the semi-washed process the cooperative at Montes de Oro has reduced its water consumption to about 36 liters of water per 100 lbs of green coffee, an over 90% reduction of water consumption.

In addition to the obvious advantages of conserving water, this process has two other important advantages in terms of less land area and reduction in construction costs. With the "semi-washed" mechanical method, the water that is used has a higher concentration of sugars and other organic matter, and thus is suitable for use in the production of biogas. This contrasts with the more diluted product resulting from conventional "washed" processing, which cannot be used to generate biogas. Secondly, because less water is used, the settling ponds do not have to be as large as conventional settling ponds. This reduces construction costs, which can be considerable, as well as the need for land, which is also expensive.

COFFEE CULTIVATION AND FOREST-ASSOCIATED SPECIES

A final cost caused by coffee cultivation that has received a lot of attention is the displacement of native forest by coffee cultivation. The loss of forest and the potential loss of native biodiversity resulting from coffee cultivation and processing is substantial. On account of the great extent of land under coffee cultivation, as well as studies reporting high species diversity of multiple taxa in shade versus sun coffee (Perfecto *et al*. 2003), coffee has gained the attention of the conservation community. Although preferable to sun coffee in terms of the preservation of tropical rain forest biodiversity (Greenberg *et al*. 1997), recent studies have revealed the important limitations of shade coffee, particularly "commercial polyculture" (Moguel & Toledo 1999), which is the only type of shade coffee cultivation widely practised in Costa Rica (Somarriba *et al*. 2004). These include the loss of resident tropical species that depend on primary forests because many of the important habitat features typical of mature forests, such as lianas, bromeliads and large trees, are under-represented or absent in all but the most rustic coffee plantations (Rappole *et al*. 2003).

At the Montes de Oro Cooperative, a new system has been developed for coffee cultivation that maintains native forest without sacrificing yields. This system is termed "Integrated Open Canopy" or "IOC" Coffee (Arce 2003), in which coffee is planted in 1-3 ha patches with varying amounts of shade, depending on local conditions, but typically too little to qualify for shade coffee certification. Coffee patches are surrounded by an equivalent amount of forest. A typical parcel within the cooperative would be 4-6 ha in size, which would result in units of production consisting of 2-3 ha coffee and 2-3 ha of forest. The important feature of this system, from a standpoint of biodiversity, is that it maintains forest habitat for species that do not use shade coffee plantations.

To test the potential for IOC to support forest-associated species not found in shade coffee plantations we sampled birds in seven sites each in IOC plantations, shade coffee plantations and primary forests, from December to February 2005-2006 and 2006-2007, using standardised mist netting (Karr 1981). Shade coffee plantations were best characterised as "commercial polyculture" as described by Moguel & Toledo (1999), which describes nearly all the shade coffee in Costa Rica (Somarriba *et al*. 2004). Each site was sampled once for three consecutive days with 10, 12-m long nets placed in a grid 25 m apart. We captured 2,131 individuals representing 154 species during 6,618 net hours. We calculated species richness separately for all species and for species that were captured most often in forests, using sample-based rarefaction (Gottelli & Colwell 2001). We did not analyse species richness of the generalist species separately because they were not of conservation concern (Rappole *et al*. 2003). Species richness of all species combined was similar in shade coffee and IOC coffee plantations; however, IOC coffee farms supported higher numbers of forest-associated species than shade farms (Figure 2). Furthermore, the similarity in species composition between forest and IOC was 40% greater than the similarity

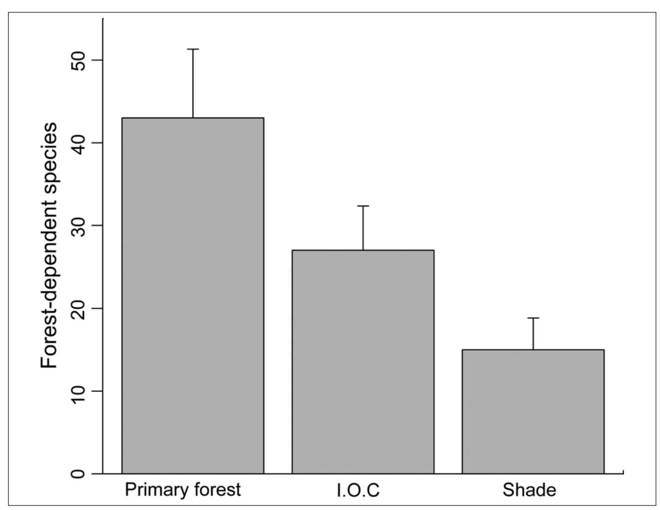

Figure 2: Species richness of forest-associated birds at the Cooperative Montes de Oro, Costa Rica, 2005-2007, calculated using sample-based rarefaction. Non-overlappping 95% confidence intervals indicate that species richness of forest-associated birds was significantly greater in IOC coffee plantations than in shade coffee

between forest and shade coffee (Chao-Jaccard similarity index 0.81 and 0.58, respectively). Nonetheless, the number of forest-associated species in IOC farms was significantly lower than in primary forest sites, probably because IOC samples included younger forest, as well as nets in coffee.

IOC coffee production also offers important economic benefits to farmers. First of all, the more open conditions result in greater yields. Shade coffee in the Montes de Oro region typically yields 300-500 lbs/ha, whereas, IOC coffee yields 1,500-2,000 lbs/ha of coffee (Montes de Oro Production Statistics), but since half of the land is forest, this comes to 750-1000 lbs/ha, still considerably higher than shade. Higher yields in IOC are attributable to a number of factors. IOC coffee is generally subject to lower levels of disease because producers have the option to create conditions of high illumination, which is known to discourage coffee leaf spot disease (*Mycena citricola*; Avelino *et al*. 2006). The protecting adjacent forest can also increase yields because many coffee pollinating insects depend upon forests for nesting habitat (Ricketts *et al*. 2004). Forest buffers in IOC coffee also serve to protect coffee plants from wind damage (Harvey *et al*. 2004), and help control erosion by disrupting and absorbing the flow of surface water (Pimentel *et al*. 1987). Finally, in cases where forest areas are being allowed to regenerate, they can qualify for carbon credits under the Kyoto Protocol. As IOC coffee provides economic benefits to farmers while contributing to the conservation of native forest, it represents another example of a market-based conservation incentive developed at Montes de Oro.

CONCLUSION

The initiatives undertaken at the Montes de Oro Cooperative can substantially reduce the consumption of resources associated with the processing and production of coffee. These activities provide a model for the future, for reducing the environmental costs of coffee production, while simultaneously improving the economic conditions for the people in coffee-producing regions, and providing incentives for individuals to engage in agricultural practices that conserve natural resources and biodiversity.

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