MEASURING AND MANAGING THE ENVIRONMENTAL COST OF COFFEE PRODUCTION

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Summary

Coffee is a major international commodity, and because of this, conventional coffee processing has the potential for considerable global impacts on the environment. These impacts include the consumption of energy, water and land. We describe an initiative undertaken at the Montes de Oro cooperative in which these impacts are reduced substantially through the development and use of alternative technologies. We show how these processes reduce the consumption of resources, and also reduce economic costs to the farmer. 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 economic conditions for the people in coffee producing regions.

Introduction

Reaching a vast international market, and dominating the agricultural landscape in Latin America, coffee may serve as the most significant system of agriculture in preserving biodiversity. In Latin America alone 700,000 coffee farmers manipulate of 40% of agricultural lands to generate $10 billion annually, making it the leading legal agricultural export (Rice and Ward 1996, Conservation International 2002). There as been substantial discussion of biological costs of coffee cultivation as well as potential strategies to ameliorate these impacts through the use of shade coffee cultivation (Pimental et al. 1992), however coffee production has many other important costs which are less widely recognized, which include the consumption of energy, water and space for production and processing. For example, wood consumption to fire driers is a principal source of tropical deforestation. Based on an extrapolation of the amount of fuelwood consumed for the drying process

(Instituto del Café de Costa Rica [ICAFE] 2006), we estimate that throughout Mesoamerica, approximately 6,509 hectares of forest are cut to supply the firewood used to dry the coffee production each harvest. This is roughly equivalent to 3 cm^2 of forest per cup of coffee.

At the Montes de Oro Cooperative these costs have been reduced through the development of alternative coffee processing technologies that consume a fraction of the energy as conventional coffee processing, and what energy is consumed is produced using renewable sources such as solar power or cogeneration. The process they use also consumes much less water. Here we describe these processes and contrast them with the costs of conventional coffee production.

Energy Conservation

As noted above, conventional coffee processing is energy intensive. After the 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 of these steps require energy. Assuming a net export of 203,244,004 lbs of green coffee (ICAFE 2007) and the rates of 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)) and 142,268 m^3 of wood per year. The Cooperative at Montes de Oro has reduced their energy consumption dramatically through the development and implantation of new technologies.

The electricity required for drying represents nearly 80% of the electricity required for processing coffee, the remaining demand is used for other processes (depulping, washing, sorting etc). Therefore, the most important of these innovations is their new solar/biomass coffee drying technology. The majority of coffee in Costa Rica is dried using electricity and firewood (ICAFE 2006). Conventional coffee drying consumes on average 12.5 kWh of electricity and 0.07m^3 of firewood, per 100lbs of green coffee (ICAFE 2006). The alternative solar/biomass technology uses a highly-efficient drying chamber, which requires 20% of the electricity as compared to conventional dryers, and the use of firewood is eliminated entirely. The thermal energy required for drying is supplied by solar thermal collectors during the day and the gasification of coffee husks at night or during rainy periods.

Energy conservation will be further realized at Montes de Oro through the practice of cogeneration, using waste products from coffee production to produce electricity, using either a biodigestion process or a gasification process. The biodigestion is a microbal-driven process, while the gasification process is a thermal process. This cogeneration will be able to produce 15kWh of electric power, more than sufficient to supply the 2kWh required for the solar/biomass dryer. The waste products used in biodigestion are mucilage and waste water. Mucilage is collected in holding tanks, calcium carbonate is added to lower the acidity, and then allowed to ferment in a biodigestor , from which methane gas is produced. The methane gas is then used to generate electricity to operate the dryer. For gasification, coffee parchment is collected and gasified by a thermal reaction called pirolosis, in which the carbohydrates of the parchment are broken down into to is 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, though with a lower energy content. With this gas, a boiler is operated to heat water when the solar resources are not available during the night or rainy or cloudy periods, and/or a generator is operated to produce electricity. Cogeneration provides additional benefits through the elimination of waste, which accounts for 82% of coffee cherry, the fresh picked coffee, by weight. Finally, the savings will increase the viability of small coffee operations, which otherwise could be converted to other types of land use with lower ecological value, such as commercial development or housing.

Water conservation

Conventional coffee processing uses large quantities of water to remove the outer pulp and mucilage and transport the waste products. On 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 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.

Destruction of habitat

A final cost of 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. Because of the great extent of land under coffee cultivation, as well as studies reporting high numbers of resident and migrant birds in comparison to sun coffee (Greenberg et al. 1997), coffee, in particular “shade coffee,” has gained the attention of the conservation community. Although preferable to sun-coffee in terms of the preservation of tropical rain forest biodiversity, recent studies have revealed important limitations of shade coffee, particularly “commercial polyculture” (Moguel and Toledo 1999), which is the least intensive method of shade coffee cultivation widely practiced in Costa Rica (Somarriba 2004). These include the loss of resident tropical species that specialize on primary forests (Rappole et al. 2003). Shade coffee also has limitations from an economic standpoint, which may include low yields relative to other forms of coffee cultivation (Perfecto et al. 2005).

At the Montes de Oro Cooperative, a new system has been developed that maintains intact 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 little or no shade depending on local conditions, but typically too little to qualify as shade coffee. Coffee patches are surrounded by an equivalent amount of forest, typically secondary forest.

Parcels within the Cooperative are typically 4 hectares in size, resulting in units of production consisting of 2 ha coffee and 2 ha of forest.

IOC coffee offers numerous advantages over conventional shade systems. 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 1,500-2000 lbs/ha of coffee, but since half of the land is forest, this comes to 750-1000 lbs/ha, still considerably higher than shade. Another important advantage is that IOC preserves a greater proportion of forest dependent fauna than shade coffee (Chandler et al. unpublished data, Fig. 1). These absence of these forest dependent species has been identified as an important limitation of shade coffee (Rappole et al. 2003), but IOC coffee provides an important advantage over shade coffee in this regard.

In addition to higher yields and greater biodiversity benefits, 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*) (Mitchell 1985). Forest buffers may also discourage the spread of disease from adjacent coffee parcels (Patricio et al. 2008 [Annals of Applied Biology Blackwell 2008]). Forest buffers in IOC coffee also serve to protect coffee plants from wind damage (Harvey et al. 20004), and help control erosion by disrupting and absorbing the flow of surface water (Pimentel 1987). A final benefit of IOC coffee is that the adjacent forest buffers can consist of regenerating forest and still accommodate more forest specialists than shade coffee (Chandler et al. unpublished data). Because these forest areas are being allowed to regenerate, they can qualify for carbon credits under the Kyoto Protocol.

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 economic conditions for the people in coffee producing regions.

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Table. 1. Energy and water consumption of conventional coffee processing (ICAFE 2006) compared with the amount used to process and an equivalent amount of coffee at Montes de Oro (Montes d'Oro Production Statistics).

	Electricity $0.20/kWh		Fuel (half wood, half parchment) $12/m^3 firewood		Water	
	Conventional	Montes de Oro	Conventional	Montes de Oro	Conventional	Montes de Oro
Consumption/100lbs green coffee	12.0 kWh	2 kWh	0.12 m^3	0.0 m^3	1,000 l	36 l
Cost/100lbs green coffee	$2.40	$0.40	$0.72	$0.00	$0.50	$0.018
Consumption for a typical benficio (1,000,000 lbs/yr)	120,000 kWh	20,000 kWh	1,200 m^3	0.0 m^3	20,000 m^3	720 m^3
Net cost for a typical benficio	$24,000	$4,000	$7,200	$0.00	$10,000	$360

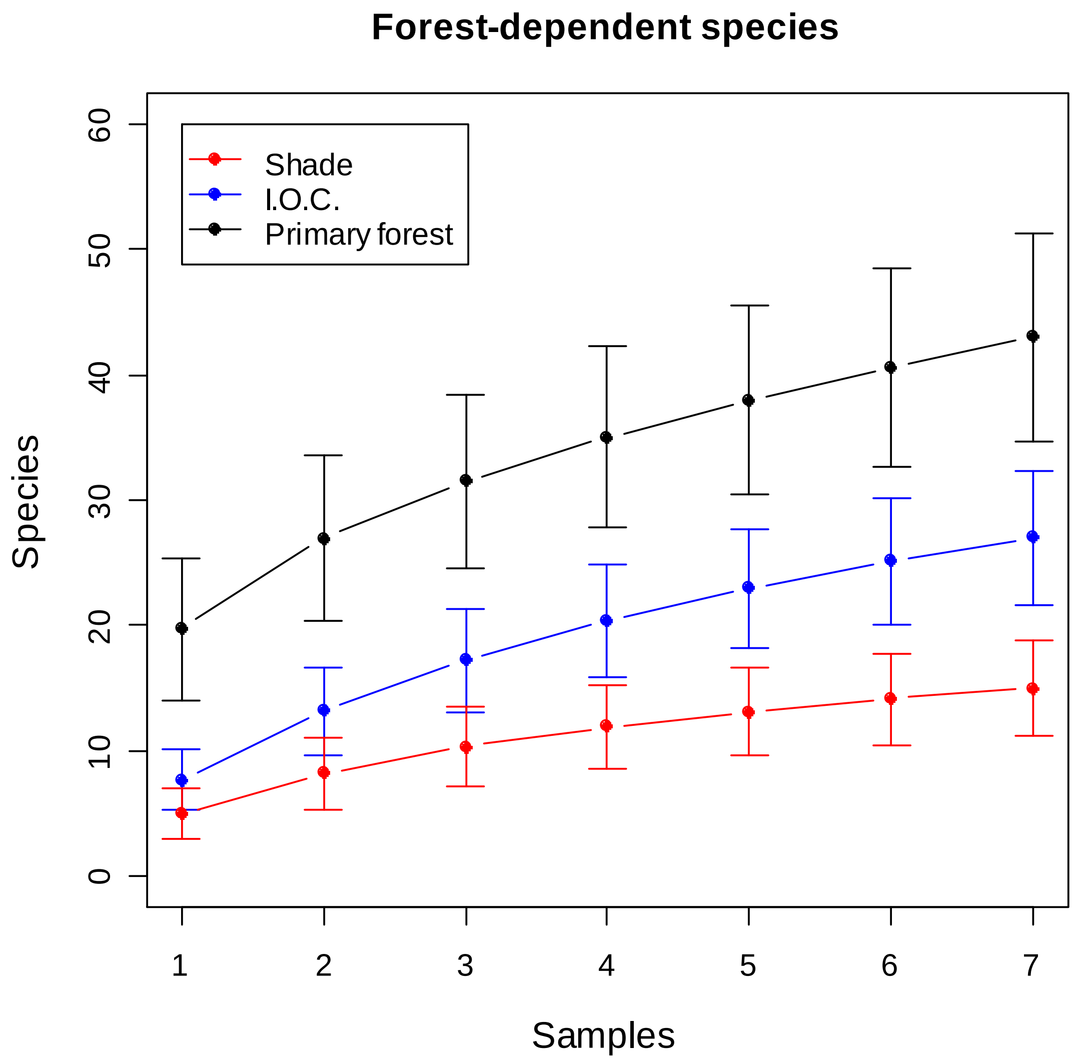

Fig. 1. Forest bird diversity compared among forest, shade coffee and IOC coffee at the Cooperative Montes de Oro, Costa Rica, 2005-2007.

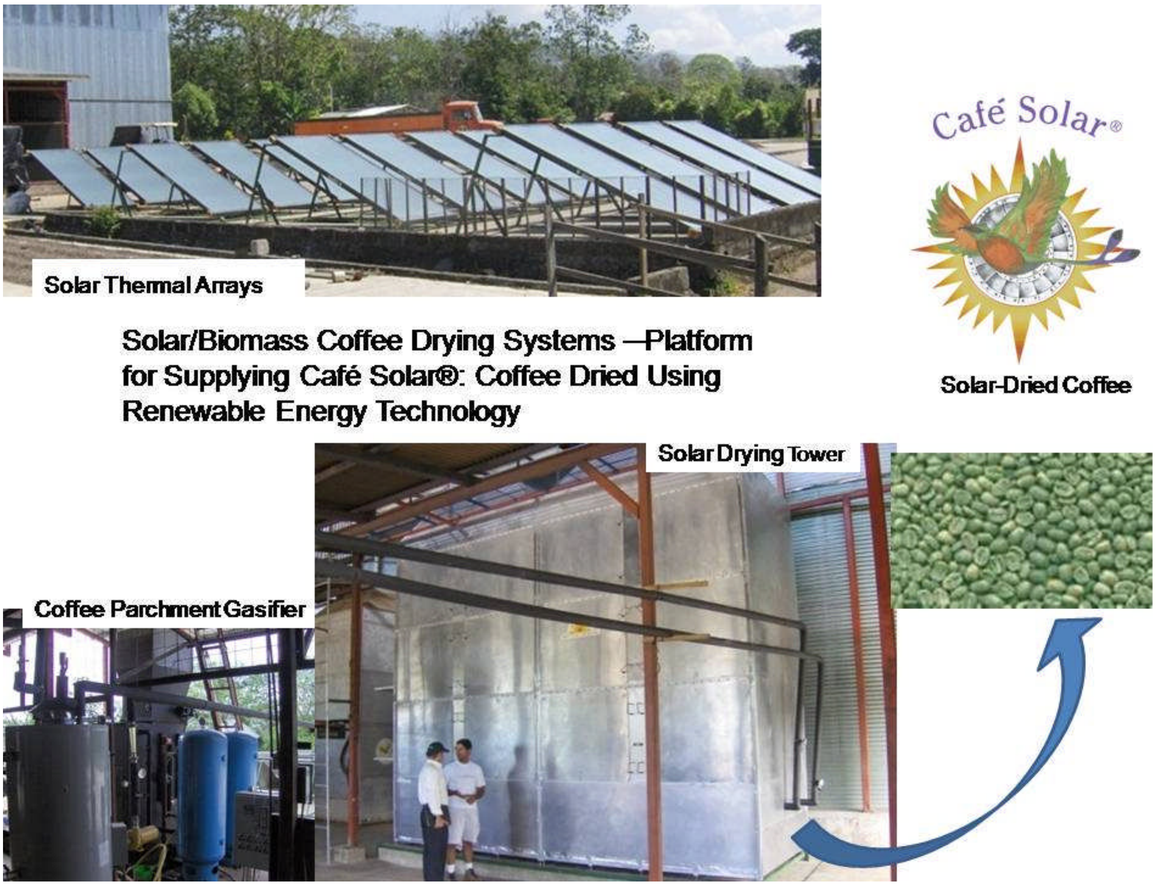

Fig. 2. Solar/Biomass drying systems at Cooperative Montes de Oro, Costa Rica.

Fig. 3. Wood used to dry coffee using conventional dryers, Costa Rica.