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Toward sustainable coffee production in Vietnam: More coffee with less water

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ABSTRACT

Inefficient use of irrigation water threatens coffee production in Vietnam, the second largest producer worldwide after Brazil. This paper examines the irrigation issues that constrain sustainable coffee production in Vietnam. The period from January to April is a crucial time in the growth of the coffee crop. It requires irrigation, because rainfall only provides 25% of the potential crop evapotranspiration demand. According to crop phenology, this period also requires induced water stress, because it coincides with breaking the dormancy of flower buds and initiation of cherry development, which is crucial for achieving high yield. This paper proposes an irrigation supply of 120 or 150 mm between January and April in a year preceded by good or average rainfall respectively, in November and December. This is equivalent to 364 or 456 liters/plant/round in 3 rounds/year, which is only 70% of the locally recommended level by the Ministry of Agriculture and Rural Development. Synchronizing this irrigation supply with the management of other inputs could increase average yield up to 4000 kg/ha, from the present level of 2400 kg/ha making coffee production both sustainable and economically viable. In order to achieve this, building capacity of farmers to follow the irrigation and input application schedules is crucial.

1. Introduction

Sustainable coffee production in Vietnam has both global and national importance. Globally, Vietnam is the second largest coffee producer after Brazil, and accounts for 14.5% of total production (ICO (International Coffee Organization), 2011). It is also the largest producer of Robusta coffee with a share of about 40% of global Robusta production. Nationally, coffee is the second largest export crop after rice (Giovannucci et al., 2004) and its production supports the livelihoods of a large proportion of the rural agricultural population, of which more than 75% are those with small landholdings (Giovannucci et al., 2004).

Irrigation is crucial for growth of the coffee crop during the dry season between January and April (Carr, 2001). Crop phenology requires a period of water stress, after which irrigation helps in breaking flower bud dormancy, triggers homogeneous blossoming and initiates cherry development, which is crucial for achieving high yield. Groundwater is the major source for irrigation of the coffee crop (Cheesman and Bennett, 2005), and excessive groundwater pumping (one well per hectare) causes declining water table levels in the upper unconfined and lower confined aquifers (D'haeze et al., 2003). This threatens sustainable coffee production in Vietnam and coffee supply globally.

The irrigation application as advised by the Vietnamese Ministry of Agriculture and Rural Development through state extension services is 650 liters/plant/round in three rounds (Cheesman et al., 2007). Field experiments under controlled conditions indicate that even induced water stress with lower irrigation would not reduce coffee yields (Crisosto et al., 1992; D'haeze, 2004). However, in reality, smallholders with limited access to information irrigate more than twice the recommended level (D'haeze, 2008), with the belief that yield increases linearly with irrigation amount. Although this is still financially viable, the cost of irrigation is about 15–20% of the total production costs, in terms of labor, energy and equipment costs (D'haeze, 2008). Hence, improving irrigation water management will not only address the groundwater issues but also will reduce the costs of production, increase profits and economic water productivity.

This paper assesses improved water management options for sustainable coffee production in Vietnam. The Central Highlands now accounts for 90% of the total coffee area in the country (GSO (Government Statistics Office), 2011). The Dak Lak Province in the Central Highlands, which is the focus area for this study, has a coffee area of about 260,000 ha (in 2009–2011), almost half the total coffee area of the country. This study hypothesizes that it is possible to reduce the volume of irrigation without having a significant effect on, or even increasing, coffee yield. This is possible by better scheduling of irrigation in the dry months to meet water requirements

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during critical periods of crop growth, especially for breaking the dormancy of flower buds and developing cherries. The overall objective of this paper is to identify improved water management options for sustainable coffee production by:

- estimating the consumptive water use (CWU) and irrigation water withdrawals in coffee production in Dak Lak Province, and
- exploring the relationships between productivity, gross and net income of coffee with CWU and irrigation application, to identify induced water stress and its impacts on yield and income, and possible entry points for water management interventions.

The analysis in this paper focuses on the CWU, in particular, by groundwater irrigation. The analysis first assesses the rainfall and irrigation CWU, and the induced water stress on the coffee trees. Next, it identifies the pathways for sustainable coffee production by identifying the relationships between farm management practices, especially irrigation management with coffee yields, gross income and production costs. Finally, the paper suggests methods for reducing irrigation to induce water stress that result in increase in both physical and economic water productivity.

The paper has 5 sections. Section 2 provides the details of the methodology and data used for the analysis. Section 3 provides the results. Section 4 discusses the implications of results on water management. The final section concludes the paper with suggestions for sustainable coffee production in Dak Lak Province.

2. Methodology and data

2.1. Consumptive water use of coffee production

The CWU of coffee production is the actual evapotranspiration (ETa) in the production process of green coffee beans. It has two components: (a) rainfall CWU – the water consumption of rainfall stored in soil moisture (rainwater insofar as it does not become runoff), and (b) irrigation CWU – the water consumption from surface water and groundwater irrigation.

In a given production cycle – usually January to December for coffee trees in Dak Lak Province – the total CWU is the sum of ETa in four growth periods: (a) initial (flower-bud initiation from December to January), (b) development (flowering from February to April), (c) middle (fruit growth from May to September), and (d) late stage (ripening and harvesting from October to November).

The actual ETa is a part of ETc, the potential evapotranspiration under standard conditions, which is the product of reference evapotranspiration (ETo) and crop coefficients (Kc) (Allen et al., 1998). Equation (1) shows ETc for the jth month in the ith growth period.

$$ETc_{ij} = \begin{cases} \min(ETo_{ij} \times Kc_i, EffRf_{ij}) & \textit{for rainfed crops} \\ EffRf_{ij} + \min(IrrSu_{ij}, ETo_{ij} \times Kc_i - Effrf_{ij}) & \textit{for irrigated crops} \end{cases} \tag{1}$$

where EffRf is the effective rainfall (Equation 2), which is the part of rainfall (RF) that is effective at the root zone of the crop and *IrrSu* is the irrigation supply.

$$EffRf_{ij} = \begin{cases} RF_{ij} \times (125 - 0.2\,RF_{ij})/125 & \textit{if } RF_{ij} \le 250\,mm \\ 125 + 0.1 \times RF_{ij} & \textit{if } RF_{ij} > 250\,mm \end{cases} \tag{2}$$

Since ETa = Ks × ETc, the total CWU is shown in Equation (3):

$$CWU = \sum_{i=1}^{4} \sum_{month\ j \in growth\ period\ i} Ks_i \times ETc_{ij} \tag{3}$$

Ks_i is water stress coefficient or soil water availability function (Allen et al., 1998; FAO, 2012), which mainly depends on crop phenology and induced water stress. Field experiments show that rainfall or irrigation water help break the dormancy of the flower buds and initiate cherry development after some induced water stress (Crisosto et al., 1992).

This study estimates the CWU of coffee, assuming K*s* is equal to one under no soil–water stress condition, for comparison with the actual CWU that farmers are achieving with their irrigation application. The study assumes, based on expert opinions, that the seepage fraction of irrigation is about 20–30%. The CROPWAT program, version 8.0 (FAO, 2012), estimates the monthly ETo and effective rainfall (*EffRf*).

2.2. Analysis of farm management data

Water is only one input in the production process. Crop yields, production costs and gross income depend on many other factors such as plant density, plant age, pruning, weeding, fertilizer application, etc. This study uses a multiple regression analysis with second order terms to identify the relationships between different factors of production (Equation 4).

$$Y_{it} = \alpha_0 + \sum_{j=1}^{J} \alpha_j X_{ijt} + \sum_{j=1}^{J} \sum_{l=1}^{J} \beta_{jl} X_{ijt} \times X_{ilt} + \sum_{j=1}^{5} \gamma_{ijt} I_{ijt} \tag{4}$$

where:

Y	Green coffee bean yield (kg/ha) or gross income or production cost (USD/ha). Product and input prices are the basis for gross income or production cost estimates, and expressed in 2005 constant prices using the consumer price index of Vietnam (FAO (Food and Agriculture Organization), 2010) as price deflator. The production cost is the sum of the cost of pruning (hired and family labor costs only), weeding (labor and rented equipment cost), irrigation (labor, fuel and rented equipment cost), fertilizer application (value of fertilizer, labor and equipment cost) and harvesting (labor cost only).
X_{i1}	Age since the year of planting, where Robusta coffee trees generally start bearing cherries after 3 years of planting, and the yield reaches a maximum after 13–14 years of planting.
X_{i2}	Plant density (number of plants/hectare). The recommended plant density is about 1100 plants/ha.
X_{i3}	Rainfall CWU + irrigation supply (mm). The total as well as monthly values indicate how well irrigation, in addition to rainfall inputs, provides the water requirements during critical stages of crop growth.
X_{i4}	Quantity of the nutrient nitrogen (N) in fertilizer (kg/ha).
X_{i5}	Quantity of the nutrient phosphorus (P) in fertilizer (kg/ha).
X_{i6}	Quantity of the nutrient potassium (K) in fertilizer (kg/ha).
X_{i7}	Number of days of labor used for pruning (days/ha). Pruning is an important activity in coffee production. This study takes the number of days per hectare of labor as a proxy for the extent of pruning.
X_{i8}	Number of days of labor used for weeding (days/ha). Weeds compete with crops for nutrients and water, and hence form an important constraint for high productivity. The number of days per hectare of labor is a proxy to indicate the extent of weeds.
I_{i1}-I_{i4}	Dummy variables for the years from 2006 to 2009 (1 for year t and 0 otherwise). They capture the variation of yield across years due to other explanatory factors such as climate, which this analysis does not consider.

The subscripts i and t represent the ith farmer in the tth year; α is the regression coefficient of J linear terms of variable X; β is the regression coefficients of second order terms of X_j and X_l; and γ is the regression coefficients of dummy variables representing years (2006, 2007, 2008 and 2009) and small landholding sizes (<0.5 ha).

The marginal productivity and production costs are important for understanding the potential water and cost savings. The marginal productivity is shown in Equation (5):

$$\frac{dY}{dX_j} = \alpha_j + 2 \times \beta_{jj} \times X_j + \sum_{l=1}^{J} \beta_{jl} X_{jl} \tag{5}$$

2.3. Climate and farm management data

Monthly rainfall and other climatic data (minimum and maximum temperature, relative humidity, wind speed and sunshine