ENVIRONMENTAL AND SOCIO-ECONOMIC EFFECTS OF INTENSIVE AGRICULTURE: THE VIETNAM CASE

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Abstract

Coffee market has been dominated for centuries by South America producing countries, basically Brazil and Colombia, whereas in other countries, the coffee tree was introduced later, as in Vietnam by the French during the 1850s, where production was relatively insignificant until re-unification in 1975. With the policy of constructing new economic zones and above all the start of "Doi Moi" plan in 1986, the production of coffee raised exponentially so nowadays Vietnam is the second producer of coffee in the world. The increase in crop production took place by incorporating new lands into agriculture and by introducing intensive agriculture to increase yield, that affected terrestrial ecosystems.

The present study examines the effects on the Vietnam coffee production driven by this policy. From the analysis of data it can be concluded that stagnation in production could be due both to ecological and socio-economic factors related to intensive agriculture.

Riassunto

Il mercato del caffè è stato dominato per secoli dai paesi produttori del Sud America, fondamentalmente Brasile e Colombia, mentre in altri paesi, la pianta del caffè è stata introdotta più tardi, come in Vietnam dai francesi nel 1850, dove la produzione è stata relativamente insignificante fino al momento della nuova unificazione nel 1975. Con la politica della realizzazione di nuove zone eco-

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nomiche e, soprattutto, l'avvio del progetto "Doi Moi" nel 1986, la produzione del caffè è aumentata in modo esponenziale cosicché oggigiorno il Vietnam è il secondo produttore di caffè nel mondo. L'aumento della produzione agricola è avvenuto con lo sfruttamento di nuove terre e l'introduzione dell'agricoltura intensiva per aumentare la resa, il che ha influenzato gli ecosistemi terrestri. Il presente studio esamina gli effetti della produzione del caffè in Vietnam generati da questa politica. Dall'analisi dei dati si può concludere che la stagnazione nella produzione potrebbe essere dovuta sia a fattori ecologici che socio-economici connessi all'agricoltura intensiva.

Keywords: Vietnam, coffee, intensive agriculture, landscape, ecology.

Introduction

Coffee was first planted in Vietnam in 1857. The land area dedicated to coffee remained minimal at just a few thousand hectares until the 1970s. From the mid-1970s until the 1990s Vietnam's coffee was traded exclusively with other Communist countries, basically on a barter basis with the former Soviet block for industrial products. Modest growth in the planted area - totalling about 30,000 hectares - occurred as a result of this trade and the technological support of the former Soviet Union and Eastern block countries. It is only since the early 1990s, however, that production increased dramatically to now make Vietnam, since 2000, the second largest producer worldwide of coffee surpassing Colombia and the single largest exporter of the Robusta variety (1-3).

Vietnam's dramatic coffee expansion in recent years occurred as a result of the intersection of three series of events: an overwhelming, and at least partly unexpected, response to the government's initial direct stimuli, which was combined with agricultural liberalization and spurred by a uniquely favourable set of developments in the world market for coffee. In fact to reach average current (2001-2004) Colombian production (nearly 700 kt), Vietnam tooks only 20 years starting from 4.38 kt in 1980 (Figure 1) (4-8).

Vietnam coffee production has achieved an impressive development with an annual output of approximate 800,000 metric tons of green beans because in the decade between 1990 and 2000 Vietnamese farmers, approximately 80% of them smallholders, planted about half a million hectares of Robusta coffee trees.

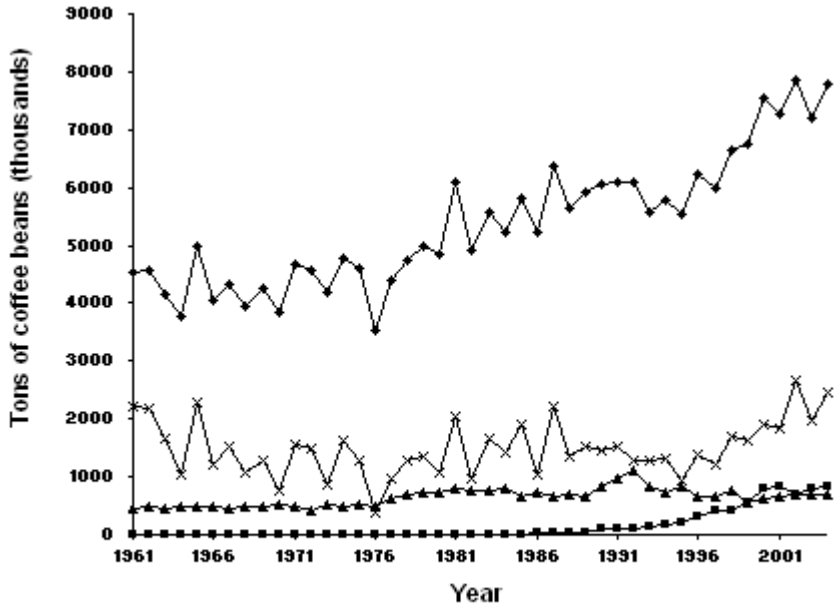

Fig. 1 - Selected coffee production statistics for the years 1961- 2004. (♦) World, (▲) Colombia, (▪) Vietnam, (x) Brazil.

This meteoric rise has been matched also by an equally fast changes in policies and market structure. In the past decade Vietnam has moved from a planned economy to a much more open market orientation, as a result, it is one of Asia's fastest-growing countries. While many benefits can be attributed to the coffee sector's growth, there are also questions about how equitable the socio-economic impact has been and about the overally sustainability of the sector (9-12).

Incorporating of land into coffee production during the period of the Doi Moi

The Socialist Republic of Vietnam is divided into 64 administrative units that consist of three large municipalities and 61 provinces that are further subdivided into districts. It has a total land area of 32,956,000 ha.

The initial impetus to significantly increase coffee production was partly the result of a policy decision - Doi Moi - that allowed the establishment of the private sector in agriculture. This shift from communal to private ownership began a significant land reform process.

In 1988, Vietnam established its own form of the Chinese Household Responsibility System that gave farmers the rights to keep some of their production. At the same time, farm prices were steadily increased, before being liberalized, and input prices dropped as Vietnam liberalized its import regime. In the first five years of reform, the average output-input price ratio rose by about 35% (2, 13, 14).

The subsequent 50% drop in the nominal prices of fertilizer led to a large swing away from organic fertilizer and toward imported chemical fertilizers. This resulted in a large overall gain in agricultural productivity and some indications of excess use of agrochemicals that contributed to environmental degradation.

The average annual growth rate of coffee production area was approximately 15% in the 1990s, officially reaching a peak of 506,500 ha in 2004 with private estimates being even higher. Also coffee production yields grew faster due to intensive agriculture that resulted in a peak of 2.4 t/ha in 1997 (Figure 2) (2-15).

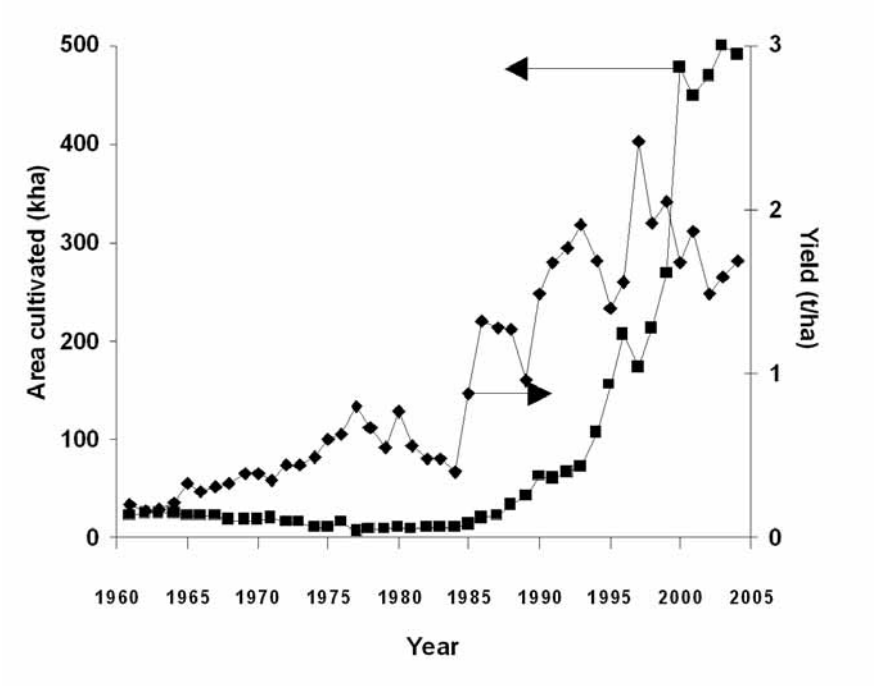

Fig. 2 - Yield and area cultivated in Vietnam: selected coffee statistics for the years 1961-2004.

This extraordinary productivity puts Vietnam at the forefront of the producing countries. It is apparent, therefore, that Vietnam's coffee expansion occurred as a result of the intersection of two independent series of events: an overwhelming, and at least partly unexpected response by a motivated and industrious group of producers to the government's initial stimulus combined with uniquely favourable developments in the world market for coffee (2-16).

Robusta coffees thrived in many of the upland areas and were quickly recognized as lucrative crops. The initial expansions of the coffee growing areas occurred in and around Dak Lak province with government encouragement of the internal migration of ethnic Vietnamese (Kinh) into the western parts of the Central Highlands, the so-called New Economic Zones of these provinces. Some other ethnic minorities also settled agricultural areas in response to government urging. Up until the late 1980s, the state owned and operated most farms, but by the early 1990s, about half of the coffee farms were in private hands, mostly, as long-term leases to farmers. In 2003, only approximately 5% of the coffee acreage is still state owned and operated (2-17).

The expansion of the coffee industry in Vietnam

In recent years, the rapid development of the coffee industry in Vietnam has been of interest to many international traders. From a country with low levels of coffee production, which was not known by many consumers, within 20 years Vietnam became the second largest coffee exporter in the world, after Brazil, with approximately half a million hectares of coffee, of which 90% is traded, yielding about 800,000 tons of green coffee. The turnover of coffee exports is between US$700-800 million.

Coffee is therefore classified as one of the main agricultural products, second in importance after rice. The coffee industry also has a large workforce and has created many jobs in the countryside and rural areas (18-20).

The coffee planted in Vietnam is mainly Robusta (Coffea canephora). The main coffee growing areas are the basalt red soil areas in the Central Highlands and other provinces in the south east, such as Dong Nai, Ba Ria Vung Tau, Binh Phuoc, etc.

Coffee has also spread to the North, from Khe Sanh, Quang Tri, Phu Quy, Nghe An, Son La and Tay Bac (10-16).

Vietnam can be roughly divided into two different coffee regions divided by the Hai Van mountain pass. This natural border, in general terms, splits Vietnam into two different climatic areas: the south, where Robusta is well adapted, particularly to the basalt soils of the Western highlands, and Dong Nai province and the north, whose higher altitudes are better suited to Arabica production. Arabica experiments in the more arid Lang Son province and frost-prone areas, like Son La province, have been disappointing. The most recent published figures are that 506,500 hectares in 2004 are planted to coffee, nearly all of it Robusta with the exception of 26,000 hectares in Arabica (Table 1) (15, 21- 22).

TABLE 1

PRIMARY COFFEE PRODUCING AREAS IN VIETNAM (2004)

Province	Planted Area in Hectares
Dac Lak	234,000
Lam Dong	100,000
Gia Lai	75,000
Kon Tum	11,000
Dong Nai	60,000
Robusta Total	480,000
Son La	3,500
Lai Chau	500
Lan Bai	700
Thanh Hoa	4,100
Ngho an	3,000
Quang Tri	3,500
Yhe Thien Hoa	500
Dak Lak	2,200
Gia Lai	500
Lam Dong	8,000
Arabica Total	26,500
Grand Total	506,500

The government has suggested that it would like to reduce the total planted area by about 100,000 hectares over the next seven years in an attempt to rationalize production with market demand.

This includes a greater reduction in Robusta acreage and an increase in Arabica. However, most agree that it would be difficult to mandate such a reduction and, that ultimately, such decisions would be taken on an individual basis by farmers. There has been more success with the on-farm diversification to other crops than with the actual uprooting of coffee, although it has happened to a limited extent, mostly in less productive areas or with older trees. The data on planted areas have shown a fairly close correlation to major price changes in the international markets. Table 2 shows recent figures on exports and annual average prices of Robusta (2-15).

TABLE 2

COFFEE EXPORTS, VALUES, AVERAGE EXPORT PRICES FROM 1990 TO 2005 IN VIETNAM

Year	Export (kt)	Value (1000 US $)	Average Export Price (US$/t)
1990	45.34	55,539.5	1,224.96
1991	42.03	51,188.61	1,217.91
1992	73.32	71,497.33	975.14
1993	83.97	86,842.66	1,034.21
1994	212.44	407,880.57	1,919.98
1995	248.72	656,560.65	2,639.76
1996	241.06	421,113.56	1,746.92
1997	330.98	615,630.90	1,860.02
1998	387.74	688,921.07	1,776.76
1999	439.68	625,806.63	1,423.32
2000	572.86	598,891.72	1,045.44
2001	713.31	455,191.68	638.14
2002	687.65	392,431.41	570.68
2003	697.73	503,113.91	721.07
2004	848.95	665,456.46	783.86
2005	801.63	834,445.72	1,040.94

Coffee production in Vietnam is characterized by the attempt to pursue an intensive high-input of fertilizers strategy. The de facto production policy has exclusively promoted this one method that has been the predominant model for all producers, both large and small. Only those farmers who lack resources or access to credit, fail to apply considerable quantities of fertilizer. This heavy reliance on inputs has successfully raised output yields to extraordinarily high levels. However, this has come at a considerable cost. These costs can be measured both in monetary terms and in a potentially risky dependence on continued high input use to achieve these yields.

The vast majority of fertilizers and other inputs are imported and increasingly expensive for most farmers. Recent global hikes of energy costs have further increased fertilizer prices while coffee prices remained relatively low.

Use of synthetic fertilizers in Vietnam more than doubled during the 1990s to about 5 Mt in the year 2000. There was a 93% increase in imported fertilizers during the 1990s and a 277% increase in local production. Domestic fertilizer production - primarily urea and simple phosphates - totals approximately 1.5 Mt and is dominated by large companies, although nearly 200 enterprises comprise the sector. Vietnam also produces relatively low cost NPK (nitrogen, phosphorus, potassium) blends but these are most often imported, allegedly due to quality concerns (2).

Environmental impact

Economic reforms in 1986 and the opening of new markets for cash crops since 1993, provided incentives for investments in coffee plantations. Monoculture coffee planting has been the most widespread. Spontaneous migrations of farmers from the northern and central coast provinces in the 1990s have increased the pressures on forest lands.

The rapid expansion of areas planted to coffee due to high coffee prices in the last few years has undoubtedly created ecological and socio-economic impacts (24-26).

In Lam Dong province, a large forest area has been converted for mulberries, tea and coffee. The shift from mulberries and tea to coffee has also been observed. Concerns have been raised as to the economic as well as environmental risks associated with this behaviour. In many areas, growth is accompanied by excessive deforestation, soil quality depletion and degraded watershed function.

The rapid and uncontrolled expansion of coffee over a large area in Dak Lak province, for example makes water resources scarce (27). There is a real concern regarding the sustainability of natural resources in the Central Highlands of Vietnam because of an history of agricultural decisions based on short-term market feasibility that dominated the economic landscape, the failure to consider long-term consequences on the natural resource base and flirtatious market conditions (28). These have been foreseen to generate negative impacts on the livelihood of the small farmers.

The rapid changes in the landscape and the associated degradation of the natural resources and the environment in the upland areas created a concern for people and policy makers regarding sustainable development. Natural resource management has become a central theme in planning for agricultural sustainability in the recent years (29-30).

Most of the coffee expansion in Vietnam has happened in an uncontrolled manner, much of which without government knowledge. The consequences in ecological terms, deforestation, land degradation and a significant drop of the groundwater level are becoming visible (27).

Robusta coffee is mainly grown on deep weathered Rhodic Ferralsols on basalt that cover an acreage of 234,000 ha or approximately 36% of Dac Lak province (31). Since the shrub needs irrigation during the dry season, to break flower bud dormancy and to initiate fruit setting, every hectare of coffee requires 1,500–3,000 m^3 of water under locally advised management. Irrigation water is extracted from surface water stored in artificial ponds and water reservoirs (20.8%), from natural rivers, streams and lakes (28.5%) and from groundwater (56.6%) extracted from about 2,500 wells in Dak Lak province (i.e. 1 well per 59 ha). According to local estimates, the groundwater resources in Dak Lak province are presently exploited for 71% of their total capacity. More than 95.5% of the extracted water is used for irrigating perennial industrial crops, coffee in particular, while only 4% is for urban use and 0.2% for the industrial sector (32-34).

Logistic study of coffee production

In the initial approach to an equation of population growth, due to Pierre-Francois Verhulst, the growth rate of individuals dP/dt depends on the number of individuals P, the Malthusian parameter r and on the maximum number K of the individuals the system can sustain with water, food and energy resources it has (the so called “carrying capacity”), as stated in the equation (I) (35).

$$dP/dt = r\,P\,(1- P/K) \quad \text{(I)}$$

The solution (II) of this differential equation is the so called "logistic curve":

$$P = K / 1 + e\,–r\,(t-t_0) \quad \text{(II)}$$

This behaviour is applicable to the production of some commodities, such as coffee, provided we consider P as the annual production.

This behaviour can be argued, for example, in the case of coffee, when landscape for cultivation, water and fertilizers, are initially abundant and the production starts exponentially, later the rate of exploitation of new land decreases, the quality and quantity of water declines, the supply of fertilizers is not sufficient so the production rate decreases reaching the inflection point. Finally production will approach K, the carrying capacity of the landscape system.

Several works were made to apply this approach to world oil production and to commodity production (36-39), by utilizing various mathematical tools. In this paper we propose an alternative approach to the fitting of the curve to data, by using a least square like method (40).

Both time and correspondent production known data, have been arranged in matrices P and T:

$$P = (p_1, p_2, \ldots, pn)$$
$$T = (t_1, t_2, \ldots., tn)$$

We introduce the error as the sum of squared errors, computed between data calculated from the equation we are looking for (P(ti)) and known data (Pi):

$$e = \sum_{i=1}^{n} (P(t_i) - P_i)^2 \quad \text{(III)}$$

by assuming:

$$P(t) = K\,h(t) \quad \text{(IV)}$$

where:

$$h(t) = 1/\ 1+e\text{-}r(t-t_0) \quad \text{(V)}$$

function (3) becomes:

$$e = K_2 \langle H,H\rangle - 2K\langle H,P\rangle + \langle P,P\rangle \quad \text{(VI)}$$

where <,> indicates the dot product where:

$$H = (h(t_1), \ldots, h(tn))$$

Minimizing the error, by assuming de/dK = 0 we have:

$$K = \langle H,P\rangle / \langle H,H\rangle \quad \text{(VII)}$$

By substituting equation (VII) in (VI) we have:

$$e = \langle P,P\rangle - (\langle H,P\rangle^2 / \langle H,H\rangle) \quad \text{(VIII)}$$

Function (VIII) depends only on r and t_0 and can be studied retrieving the minimum and with known r and t0 we can calculate K from (VII) in order to represent equation (II), the logistic plot, together with historical data production. By this approach we can estimate, with good approximation, future development of the production of coffee, by utilizing only historical production data.

The program individuates, in this case, r=0.3928, t_0=1997 with a calculated K=916,140 t. This means that since 1997 the growth rate of coffee production starting to decline and the possible highest production of the economic sistem may be situated around 900,000 tons of green coffee beans.

The curve in Figure 3 represents the best fitting for a logistic expansion of coffee production in Vietnam; from statistical calculations, assuming the total sum of squares, St as:

$$S_t = \sum_{i=1}^{n} (P_i - \overline{P})^2 \quad \text{(IX)}$$

The coefficient of determination has been calculated with the formula:

$$R^2 = 1 - \frac{e}{St} \quad \text{(X)}$$

obtaining R^2=0.977, that indicates a good correlation between calculated and historical data.

From these calculation we can evaluate that Vietnam is approaching the highest possible annual production rate of green coffee, namely the carrying capacity of this productive system; this is in good agreement with the observation that the area harvested is approaching the maximum area that satellite exploration indicates as suitable for coffee production, about 600,000 hectares.

The inflection point fall within 1997 so in this year expansion rate in coffee production begins to decline; this event can be correlated to the falling in the average export prices as reported in table 2 and with falling in yields of coffee harvesting, reported in figure 2.

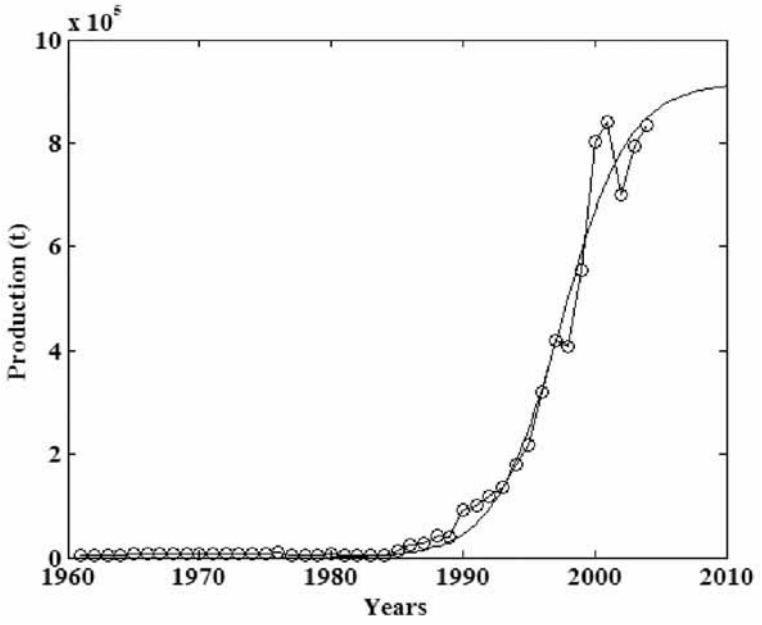

Fig. 3 - Logistic plot of the function (II) of coffee historical production data (circles) 1961-2004 in Vietnam.

As can be seen, since 1995, the export price of coffee steadily decreased and this economic factor could have affected the rate of expansion and determined the appearing of the inflection point in the logistic curve as done by the ecological factors, related to the presence of a peak in harvesting yields in 1997.

Conclusions

Coffee industry in Vietnam is a very special case of an economic expansion driven by an unexpected response to the government's direct stimuli, combined with both agricultural liberalization and a uniquely favourable set of developments in the world market, basically a sharp rise in coffee export prices that reached a maximum in 1995. This unique set of variables resulted in an impressive and exponential expansion of coffee production that now makes Vietnam, since 2000, the second largest producer worldwide of coffee surpassing Colombia and the single largest

exporter of the Robusta variety. However agricultural land suffered severe environmental impact while intensive coffee production exploited more and more landscape for coffee harvesting.

This expansion suffered ecological limits related to the carrying capacity of the regional landscape suitable for coffee production and to water degradation, fertilizer scarcity, social effects due to migration of farmers (41, 42) that probably have generated a peak in the coffee harvesting yields in 1997. This environmental and social limits probably overlapped with economic factors affecting the production growth, in particular coffee export prices that began to fall since 1995.

This combination of factors may have been responsible for the reduction of production growth rate, visible in the inflection point of the logistic curve of coffee production in Vietnam, located in 1997.

In this particular case, intensive agriculture practices in coffee production generated environmental and socio-economic effects limiting further expansion of this commodity and resulting in a logistic behaviour of annual coffee production in Vietnam. The analysis of the logistic expansion of coffee in Vietnam, as depicted by the model, indicates the next decade, as the last period of growing in coffee production and that the country could reach the annual production peak (about 900,000 t) because of environmental and socio-economic factors due to intensive agriculture.

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