A MATHEMATICAL MODEL FOR SMALL FARMERS IN RONDONIA, BRAZIL

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This paper contributes towards the economic evaluation of small farms in the tropics and demonstrates why this analysis can be both complex and unique. A Cobb-Douglas type Production Function has been developed, for a number of micro regions within the state of Rondonia, Brazil, as the basis for constructing predictive models. The models have been based on an empirical study and illustrate the relationship between the production output of a number perennial crops and certain physical and socio-economic variables. The results indicate that a significant relationship exists between output and certain constraints. In many cases, expected relationships do not exist and this is explained in the study by the unique dynamics of the small farmer situation.

1. THE EMPIRICAL CONTEXT

The state of Rondonia, in the Northwest of Brazil, remained largely undeveloped until the 1960's, when the discovery of mineral reserves and the development of the first state highway coincided with a series of national projects to develop and integrate Rondonia into the national economy (Bunker, 1982 and Alvares-Afonso, 1992).

Against this background of national objectives Rondonia became the focus of a "spontaneous" migratory boom. This was complimented by socio-economic factors that included the modernisation of Brazil's agriculture and the displacement of a large sector of the rural population. In this process of transformation, the government focused on land use practices that moved away from smaller farms and traditional crops to large scale capital intensive farming that focused on export crops (Milliken, 1988).

The arrival of a million migrants in the state of Rondonia in Brazil has been associated with extensive small-scale farms that are not sustainable (Fearnside & Salati, 1985; Milliken, 1988; Fearnside, 1990). These farms are characterised by the clearing of tropical rainforest (Barbier *et al.*, 1991). The state of Rondonia as a whole, is cited as an example of one of the most accelerated examples of land clearing and destruction ever witnessed in the humid tropics (Fearnside, 1990).

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The small farmer in Rondonia is primarily engaged in shifting agriculture which has been extensively documented (Jacobs, 1988 and Eden *et al.*, 1990). This practice involves a number of stages of land use that are typically labour intensive due to the technologies involved (Veneziano, 1996 and Oliveira, 1997) and is non sustainable at higher demand levels and results in the need to clear new land (Van Leeuwen, 1992). It is, however, the economically most effective form of land use open to the small farmer (Milliken, 1988).

The central land use problem of low productivity and non-sustainability is the result of physical and socio-economic constraints allied to a lack of suitable technology. Small farms in the tropics often involve complex intercropping and agri-silvicultural relationships that form part of a continuous cycle of changing land use. Because of these constraints, increased production can, generally, only result from the clearing of additional land (Van Leeuwen, 1992). Recent new technologies for perennials, however, indicate that production can be substantially increased and farming systems can be sustainable (de Miranda & Mattos, 1995 and Oliveira, 1997).

Agricultural output in Rondonia consists of annual crops, perennial crops and livestock. The land use cycle begins with the planting of annual crops which should only be seen as a means of converting rainforest to its ultimate use, namely perennial crops or pasture. The principal annual crops are maize, rice, beans and manioc (IBGE, 1996). Annual crops are important sources of consumption and cash in the start up phase of the farm (Milliken, 1988; Pedlowski, 1992 and De Miranda & Mattos, 1993). Coffee forms the most important source of income followed by the sale of beef and milk (Pedlowski, 1992 and IBGE, 1996). The principal perennial crops are coffee, cacao and bananas with Rondonia producing 20% of the total coffee production for Brazil (Veneziano, 1996).

The majority of small farms have limited access to markets and support services due to long distances, lack of own transport and a poor road infrastructure. Local prices have acted as a constraint to production with the return to these crops often being lower than the return to off-farm labour (Milliken, 1988). These problems are compounded by problems with government marketing systems. Farmers often sell to local merchants or organisations at reduced prices (Milliken, 1988; Pedlowski, 1992; De Miranda & Mattos, 1993; Veneziano, 1996 and Oliveira, 1997).

Other constraints include a lack of credit, capital and access to hired labour and suitable technologies compounded by poor health and education facilities (FAO-CP, 1987; Milliken, 1988; Pedlowski, 1992 and De Miranda & Mattos, 1993). In addition, small farmers have a history of problems concerning their ability to interact with official institutions (Bunker, 1982). The development of cattle pasture has been significantly encouraged (Milliken, 1988) whilst low domestic and international commodity prices, together with a lack of access to credit, have affected the production of annuals and perennials (Barbier *et al.*, 1991; Bunker, 1982 and Veneziano, 1997).

Land use in Rondonia has been significantly affected by Brazil's agricultural, monetary and fiscal policies together with national and international prices. Government policy has favoured large-scale capital intensive farming systems producing non-traditional export crops whilst at the same time keeping food crop prices low (Barbier *et al.*, 1991). At the same time small farmers have been faced with declining prices of traditional crops, marginal land and inappropriate technologies (Milliken, 1988 and Pedlowski, 1992).

This paper proposes to develop a predictor model, for small farmers in Rondonia, Brazil, to explain the impact of certain variables on production as well as explain why other variables have not influenced agricultural outputs. This paper, moreover, attempts to explain some of the factors that may influence small farmers land use decisions as well as the difficulties of data collection and interpreting the results of the mathematical modelling. More specifically, this study will investigate the relationship between the agricultural output of coffee, cocoa and bananas and certain physical and socio-economic constraints to production. The physical constraints include area, soil, temperature and rainfall and the socio-economic constraints consist of labour inputs, producer prices, farm size, capital inputs, irrigation facilities, number of family members and the level of education. This paper first examines the actual situation in Rondonia, followed by a brief review of small farmer characteristics, before presenting the theoretical assumptions, the data, the empirical study, the results and the conclusion.

2. REVIEW OF THE RELATED LITERATURE

The colonisation of the lowland tropics of Latin America has been largely spontaneous. This push towards the frontier is a product of rural poverty in areas of traditional peasant concentration combined with other factors like population growth, poor soil, lack of access to land, stagnant or labour reducing technologies and lack of opportunity in the urban-industrial area (De Janvry & Sadoulet, 1989).

Small-scale agriculture is widespread throughout the tropics and is cited as a prime cause of forest destruction (Jacobs, 1988). It is also clear that the scientific and technical knowledge that will enable farmers in most tropical countries to meet demand, is not yet available (Ruttan, 1988).

The general view of the causes of non-sustainable small farming systems in the tropics has been described as a combination of human population growth, cultural maladaption, inappropriate technology and poor soils (Jacobs, 1988). This problem has been compounded by government policies that have promoted inappropriate technologies (Barbier *et al.,* 1991). It is important to realise that the factors constraining agricultural development in any country are unique (Hayami & Ruttan, 1971; Ruttan, 1980; Timmer, 1981 and Eicher & Staatz, 1990) and there is no such thing as a typical underdeveloped country (Staatz & Eicher, 1990). However, it is estimated that small farmers account for 40 % of the gross value of crop and livestock production in Latin America in 1980 and 41 % and 33 % respectively of the gross value of coffee and cacao (De Janvry and Sadoulet, 1989).

The discipline of land evaluation has been extensively documented in agronomic science (FAO, 1976 and Dumanski & Onofrei, 1989). Dumanski & Onofrei (1989) cite the evaluation of agricultural output as the single most important indicator for agricultural land evaluation. Moreover, there are wide ranges of mathematical modelling techniques for farming systems and in this regard Delforce (1993) suggests the highly constrained nature of the typical small farmer make constrained optimisation appropriate where a profit maximising linear model is used. The Cobb-Douglas Production Function is the most widely used model where output is a function of a range of constraints (Debertin, 1986). There is also a need for more effective methods of collecting economic data for small farms in the tropics in order to develop reliable appraisal models (Scherr, 1992 and Barbier, 1993).

Chinene (1991) lists 21 land qualities and 74 subqualities that act as key physical constraints to agricultural output. Climate and soil have been described as the main environmental factors determining crop yield (Ogunkunle, 1993). Agricultural yield has been positively related to total rainfall (Dennett *et al.,* 1981) and the productivity of soils is affected when slope exceeds 6 % (Pierce *et al.,* 1993).

The socio economic constraints that small farmers face are often similar in many developing countries (Kloos, 1991). The small farmer is a calculating economic agent (Eicher & Staatz, 1990) motivated primarily by profitability (Hyman, 1984) and his choice of land use is based upon the situational rationality of the conditions and the constraints (Schultz, 1979; Milliken, 1988 and Timmer, 1988). Much of the small farmer's economic return is non-market

(Barbier, 1993) and growing subsistence needs often absorb an increasing amount of output (Morgan & Solarz, 1994). The poor spend a higher percentage of their income on food and are therefore more sensitive to changes in food prices (Mellor, 1978; Mellor, 1988). Household food security is an important factor in farmers' decision making (Lin, Yao & Wen, 1988).

Most rural farms have less than 10 workers (Chuta & Liedholm, 1990). The availability and cost of labour is a vital constraint that earns decreasing returns (Dvorek, 1992) and the farmers' choices of cropping patterns impact heavily on labour requirements (Mellor, 1978). Credit and capital constraints are cited as the greatest perceived needs, but in many cases farmers' problems are compounded by ineffective management (Chuta & Liedholm, 1990) or problems relating to land tenure (Lin, Yao & Wen, 1988).

Factors that act as constraints to agricultural output include poverty, lack of education, population growth and government policy (Morgan & Solarz, 1994). Other problems include an absence of markets, poor infrastructure, and a lack of transport, communications and health facilities. Funding and an inability to interact with institutions are also cited as constraints (Bunker, 1982; Mellor, 1988; Morgan & Solarz, 1994). Further problems include the corruption and incompetence of officials and high costs accrued by the small farmer in their dealings with institutions (Bunker, 1982).

Agricultural policies have a significant effect on the choice of the crop and the volume of agricultural output (Mellor, 1978; Zhao, Hitzhusen & Chern, 1990; Moberg, 1992 and Morgan & Solarz, 1994). However, there is considerable evidence that international trade and monetary and fiscal policies have more effect on agriculture than agricultural policy does (Pasour, 1990 and Eicher & Staatz, 1990). National and international trends in prices, costs and interest rates also influence the output of the small farmer (Moberg, 1992) and because most countries engage in international trade, domestic and international prices are inseparable (Schuh, 1987).

Well meaning but perverse tenancy and labour reforms in Brazil have driven people off smallholdings and encouraged large-scale farmers to mechanise or convert to ranching. Brazil also employs a progressive land tax rate which farmers can manipulate by converting idle land under forest to pasture or to limited agricultural production (Binswanger & Elgin, 1988).

Larger farming systems are invariably closer to the corporate enterprise and government systems and are thus better positioned to adopt new technology and subsidies (Hayami, 1981; Bunker, 1982; Hayden, 1984; Chuta & Liedholm, 1990 and Pasour, 1990). Lenders tend to concentrate funds in the hands of the rich because this reduces their administration, risk and transactions costs (Adams & Vogel, 1986). Contrastingly, smaller farmers face higher transport and transactions costs, reduced credit facilities and a lack of access to other institutions and infrastructures (Myint, 1979 and Bunker, 1982).

Non-farm activities constitute an important primary source of rural employment in developing countries (Chuta & Liedholm, 1990) and it is estimated that 66 % of all farm households in Latin America derive more than 50 % of their income from off-farm sources (De Janvry & Sadoulet, 1989). Absolute rural poverty in Brazil is listed at 73 % of the rural population with the bulk of this poverty located on small farms (De Janvry & Sadoulet, 1989).

Eicher and Staatz (1990) argue that there are multiple technological paths to agricultural growth and that these paths are based on country or regional based specifics affecting the factors of production. They also conclude that the grain-fertiliser technologies of the Green Revolution have been more successful in Asia than Latin America where a higher percentage of small farmers live in poor natural resource zones (Eicher & Staatz, 1990). This problem has been compounded by the fact that technology development is favoured for areas of greater potential world-wide (Scobie & Posada, 1978 and Byerlee, 1989) and by the time needed to generate and install new technology (Eicher & Staatz, 1990).

Developing countries have traditionally supported a low level of research and investment in technology for non-colonial crops and have been unable to adapt imported technologies (Krishna, 1982). In addition, given the static technology where labour is the major cost input (Dvorek, 1992), agriculture typically operates near the top of the total production curve (Mellor, 1978).

Ruttan (1988) maintains that it is clear that scientific and technical knowledge is not yet available that will enable farmers in most tropical countries to meet current demand (Ruttan, 1988). It is also argued that much of the available technology is for developed countries with large scale farming systems and is not suitable for adaptation by the small farmer in developing countries (Ruttan & Hayami, 1972).

In Latin America increased production in frontier areas generally still requires additional land because of a lack of developed technology allied to poor conditions (Bates, 1990). In addition, agricultural modernisation has resulted in a rapid change in the large farm sector and a low to insignificant change in the small farm sector (Janssen & de Londono, 1994).

Small farmers in a number of developing countries have demonstrated that increased efficiency can significantly affect agricultural output given the state of technology (Hayami & Ruttan, 1972 and Bravo-Uretha & Evenson, 1994). The allocation and timing of resources have a significant affect on production (Janssen & De Londono, 1994) with labour being especially important (Skoufas, 1993 and Dvorek, 1992). There is thus a significant link between increased agricultural output and technical change combined with improved management. Furthermore, technology transfer is only optimised where small farmers participate (Arbab & Stifel, 1992 and Jannsen & De Londono, 1994).

3. THE THEORETICAL FRAMEWORK

The theoretical framework is based on agricultural production theory (Debertin, 1986). This theory deals with the choices and constraints faced by the farmer, as a producer, in order to maximise profitability. A key element of this theory is the technical relationship that transforms inputs into outputs where output is a function of variable inputs (Carlson, 1974).

It is proposed, for the purposes of this study, that a modified Cobb-Douglas type production function (Debertin, 1986), best describes the technical relationship between output Y and the input bundle X. The amended Cobb-Douglas, a multiplicative function, can be represented for example as follows:

$$Y = Ax_1^a x_2^b x_3^c \ldots x_n^z$$

where Y = production output, A is a constant , x_1 to x_n are the independent variables and a to z are the exponents of the independent variables. In this context production output of coffee, cocoa and bananas will be a function of certain physical and socio-economic characteristics. The physical characteristics will be area, soil, rainfall, altitude and temperature and the socio-economic variables are labour inputs, producer crop prices, farm size, capital inputs, the level of irrigation, number of family members and the level of education.

In conclusion the shortfalls of the proposed model, a modified Cobb-Douglas, are outweighed by the simplicity of its construction and use. It is important to bear in mind the general shortfalls of neo classical production functions. These factors assume that full information exists and is incorporated in the construction of the model. This study has been significantly affected by a complete lack of or insufficient data with respect to certain variables. In addition, insufficient full information is illustrated by differing cultural and technological factors that exist in Rondonia and world-wide. These factors, including, as an example, the work ethic and personal technological knowledge, have not been captured in the construction of production functions.

4. THE DATA

This study incorporates time series data that has been compiled from 1978 to 1995 in forty municipalities in Rondonia. This data has then been consolidated into eight micro regions. The data used includes the agricultural output of small farmers in Rondonia and some of the physical and socio-economic characteristics that occur in this region. The data used is both of a primary and a secondary nature. Details of agricultural output are largely secondary whilst the data of the characteristics is primary and secondary.

The reliability of the data could be subject to the varying levels of commitment and expertise available in the forty municipalities of Rondonia during the period 1978 to 1995. In this regard the data on rainfall was often compromised by the temporary closure of weather stations. In addition, certain data with respect to the variables was only available every time a census was taken. This resulted in a limited number of observations with respect to capital inputs, irrigation facilities, number of family members, the level of education and use of credit facilities. Insufficient data also existed with respect to land tenure and management measures.

5. THE EMPIRICAL MODEL AND RESULTS

The data has been arranged in tabular format to represent the dependent variable, agricultural output, and a number of physical and socio-economic constraints, the independent variables, that affect output. The data has been arranged in both time series format. The dependent variable is listed by crop type. The three perennial crop types used in the model are bananas, cocoa and coffee. The data for each crop type have been compiled for a specific year for the municipal areas of Rondonia. The output is given in tons per hectare sold for cocoa and coffee and in bunches (x 1000) per hectare for bananas.

The independent variables which have been selected as typical constraints to agricultural output include both physical and socio economic factors that exist in the state of Rondonia.

The physical factors are area, time, soil conditions, rainfall and altitude. Certain variables have been combined due to their highly collinear relationship. In this regard the variable, area, has been used as a proxy measure for labour input whilst the variable altitude has been used as a proxy measure for temperature. The socio economic variables are labour inputs, producer prices, capital input, farm size in hectares, use of irrigation, family size and the level of education.

The area is given in hectares and output per hectare calculated. The soil has been evaluated on two bases in terms of productivity by using one scale graded from 0 to 100 and another graded from 0 to 120. In the first instance productivity is based on agricultural potential as assessed by the Radambrasil Program and in the second case agricultural potential is based on the soil type that occurs in each municipality.

The rainfall is also listed in two categories, namely number of days of rain per annum and the total annual rainfall in millimetres. The altitude is included in meters. Producer prices are listed in dollars (US) because of the numerous currency changes and inflation.

The other socio economic variables have only been included in years where a census has been undertaken. This includes 1980, 1985 and 1995. These variables include details of capital input in terms of equipment, the average farm size in hectares, an indicator of the level of technical assistance available in the municipal area, the degree of irrigation used in the municipality, total credit received per municipality and the average family size.

The data have been arranged in tables for each crop type. The annual output in weight per crop type has been listed for every municipal area for the years 1978 to 1995. In the same table, for each observation, the relevant physical and socio-economic data have also been included.

The Results: State of Rondonia

The following multiplicative equations, transferred into logarithms, were obtained for the micro regions for the period 1978 to 1995 using regression analysis for the perennial crop bananas All variables are significant at the 10 % level.

Comment: Banana

The output of bananas is primarily influenced by the area planted and labour inputs as demonstrated by the elasticity of production which ranges from 0.9 to 1.3 for the eight micro regions. The area planted has been used as a proxy measure for labour input which has a highly positive relationship with the area planted. Producer Price has a significant relationship with output

Table 1: Banana

Equation Ln Y	Micro region							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Constant	0.0396 (0.310)	-10.2994 (-3.607)	6.2980 (2.588)	0.3464 (1.121)		3.8282 (1.717)	-26.627 (-2.698)	0.3074 (-2.235)
LnX_1			0.0941 (1.917) 1.1700*					
LnX_2	0.9588 (43.886) 1.000*	1.3135 (15.151) 1.9125*	1.0285 (26.57) 1.1500*	0.9332 (23.875) 1.0000*		0.9889 (22.159) 1.0016*	1.080 (33.478) 1.6015*	1.0145 (44.543) 1.0000*
LnX_3		1.8822 (3.324) 1.0125*					7.0000 (2.838) 2.0753*	
LnX_6			-1.3196 (-2.752) 1.016*			-0.5116 (-1.776) 1.0016*		
LnX_7							-0.8259 (-3.521) 2.8657*	
R^2	0.9877	0.9397	0.9742	0.9390		0.9670	0.9903	0.9876
Cp	0.507	1.2036	3.3498	0.0071		2.6537	4.2133	-0.9774

Table 2: Cocoa

Equation Ln Y	Micro region							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Constant	-0.8321 (-3.520)		-1.7944 (-3.327)	-1.3518 (-3.614)			4.736 (3.401)	-0.8572 (-1.916)
LnX_1	0.1329 (1.807) 1.6885*			0.1588 (2.045) 1.0065*				
LnX_2	0.9238 (13.513) 1.6885*		1.1243 (17.512) 1.0000*	1.0820 (23.509) 1.0065*			1.1952 (19.448) 3.8228*	1.0097 (14.886) 1.0000*
LnX_7							-1.0418 (-3.607) 3.8228*	
R^2	0.9582		0.9359	0.9420			0.9866	0.9568
Cp	0.7759		1.6671	1.0899			2.7813	1.2916

Table 3: Coffee

Equation Ln Y	Micro regions							
	1	2	3	4	5	6	7	8
Constant	-0.0609 (-0.283)	-0.3388 (-3.205)	-4.3466 (-2.546)	0.7499 (1.637)	-	0.4227 (0.929)	-8.576 (-3.358)	-0.2583 (-0.775)
LnX_1	0.1417 (3.000) 1.0177*				-	0.2921 (2.620) 1.0418*	0.3944 (2.832) 1.0839*	
LnX_2	1.0075 (22.520) 1.0177*	1.0552 (53.167) 1.0000*	1.0464 (51.236) 1.0497*	0.9276 (17.120) 1.0000*	-	0.9615 (17.206) 1.0418*	1.1838 (21.749) 1.1438*	1.0518 (26.028) 1.0000*
LnX_5			0.2164 (2.889) 1.0894*		-			
LnX_6					-		0.9491 (2.984) 1.1250*	
LnX_7			0.5919 (1.937) 1.075*		-			
R^2	0.9639	0.9926	0.9926	0.8879	-	0.9543	0.9685	0.9644
Cp	1.8716	-0.2096	2.7484	0.3849	-	1.3958	2.2861	1.0796

In the above equations the variables are as follows:

Y = Agricultural Output, X_1 = Producer Price, X_2 = Area in Hectares, X_3 = Soil Rating 1, X_4 = Soil Rating 2, X_5 = Rainfall in days per annum, X_6 = Rainfall in mm per annum and X_7 = Altitude in Meters.

The Multiple Coefficient of Determination (R^2), the Mallows Cp which is used as an indication of Serial Correlation, the t-statistic in parenthesis and the Variance Inflation Factor *, used as an indicator of Multicollinearity, are listed for each micro region.

in micro region 3 only but appears to have a marginal influence on output as evidenced by the small coefficient of production 0.09. The soil suitability of micro regions 2 and 7 has a significant relationship with output and appear to strongly influence output on examination of their coefficients of production which are 1.9 and 7.0 respectively. Rainfall appears to have no significant relationship with output except for micro region 6 where there is a negative relationship between output and increased rainfall and this has a moderate effect on output as evident from the elasticity of production of 0.5. In both micro regions 3 and 7 altitude has a significant relationship with output. In both cases an increase in altitude appears to adversely affect the output of bananas. There is a negative relationship between altitude and temperature and the elasticity of this variable appears to have a strong influence on output with elasticity of production ranging between 0.8 and 1.3.

Comment: Cocoa

The output of cocoa is primarily influenced by the area planted and the labour inputs as demonstrated by the significant relationships in all the developed equations of the micro regions. There is a positive relationship between the area planted and the labour inputs. The elasticity of production in the equations ranges between 0.9 and 1.2 and would indicate a strong effect on output. Producer prices appear to have a significant relationship with price in micro regions 1 and 4 which collectively accounts for 47.6 % of the state's production. On examination of the coefficients of production, price only marginally impacts on the output of cocoa in the developed production functions showing a coefficient of production of between 0.13 and 0.16. In micro region 7 altitude appears to have a significant relationship with output which is inversely affected by an increase in altitude and a reduction in temperature. The coefficient of production of this variable suggests a reasonably strong influence on output as evidenced by the negative coefficient of production of -1.0.

Comment: Coffee

The output of coffee is primarily influenced by the area planted and the labour inputs as demonstrated by the significant relationships in all the equations for the micro regions. There is a positive relationship between the area planted and the labour inputs and area has been used as a proxy measures for labour inputs. The influence of area and labour on output is considerable and is reflected in a coefficient of production (E^p) of between 0.93 and 1.18. Producer prices appear to have a significant relationship with output in micro regions 1, 6 and 7. These micro regions however only account for 4 % of the state's production of coffee. The influence of price on output in these regions is marginal in micro region 1 and moderate in micro regions 6 and 7 as evidenced by the coefficients of production of these variables which are 0.14, 0.29 and 0.39 respectively. There appears to be no significant relationship between soil suitability for perennials and output with respect to coffee. Rainfall appears to have a significant relationship with output in micro regions 3 and 7 which account for 29 % of the state's production. In micro region 3 rainfall only impacts moderately on production (E^p = 0.21) output whilst in micro region 7 this influence appears to be much stronger (E^p = 0.95). In micro region 3 altitude appears to have a significant relationship with production output that is influenced moderately by this variable (E^p = 0.59) as in the examples of bananas and cocoa. In the case of coffee in micro region 3 however, an increase in altitude suggests an increase in output thus a drop in temperature would influence increased production in this micro region.

6. INTERPRETATION OF RESULTS

This study demonstrates that there is a significant relationship between agricultural output and some of the independent variables in some of the micro regions. The models can be used as a basis to predict the production output for coffee, cocoa and bananas in some of the principal municipal areas. The models could also be used by institutions such as banks as a basis for estimating the revenue producing potential of the farmer or area concerned. At present a prediction of output in Rondonia is performed annually on the basis of area planted and the models could be used to improve this function.

In certain cases, the lack of significance between the dependent variable and some of the independent variables can be explained by the unique and complex interactive factors that affect small farm output in the region.

The high level of significance between the production of perennials and area-labour inputs is supported by the lack of any significant technological developments in the period 1978 to 1995. Small farm inputs consist primarily of family and contracted labour. Production increases, using the existing technology, are only achieved by an increase in the area planted and there is a positive relationship between area planted and labour inputs.

In the case of coffee, which is the single largest source of income for small farms, labour inputs make up 74 % of total input cost using traditional technologies. Recently, new technologies have reduced labour inputs to 67 % and it can be expected that in the future there could be wider spread adoption of these methods by small farms. The extent of labour inputs for coffee ranges between 26 and 66 man-days per hectare per annum depending on the age of the plantation.

Producer prices

Historically small farmer production has been influenced in certain periods by regional prices that in turn have been affected by national and international trends in perennial crop markets. Small farmers have also been encouraged to plant perennials at certain times by the state. This can be illustrated by the planting of cocoa in the 1970's when world prices were high and there was large scale state support for the planting of this crop in micro region 3. Conversely many coffee plantations were abandoned in 1988 due to the depressed international price of coffee.

The lack of responsiveness between output and price as well as the elasticity of production could be affected by a number of factors. These factors are:

- The initial investment cost in time and capital is relatively high and the majority of small farms are unable to obtain bank credit. An additional problem is often the lack of contracted labour in certain municipalities.

- Perennial crop plantations have a life cycle of between eight and forty years in the case of coffee and cocoa respectively and only start producing between the second and fourth year after planting. There is thus a significant lag between the decision to plant and the initial production. Thereafter the farmer is in an inelastic production situation for many years during which markets could display a high degree of price volatility. Farmers are thus influenced to sell output rather than abandon plantations provided that the local prices exceed the cost of inputs for that specific year. This forced sale is also influenced by a general lack of storage facilities.

- The producer prices reflected in this study are the average prices received for the different types of the respective crop. In the case of coffee the average price would reflect the average combined market value of C. robusta, C. arabica and C. cenophora. It is thus likely that in many areas the production of a lower or higher priced type could reduce the significance of the relationship between output and price.

- Small farmers are paid different prices because of the quality of the perennial. There can thus be different prices paid in the same municipality for the same crop type due to quality which is largely influenced by post harvesting processing.

- In certain municipalities farmers have been paid on the basis of the weight of the output of a perennial irrespective of the type or quality.

- Evidently, up to 1991, a large majority of farmers sold production to middlemen at a wide variety of prices. These middlemen mostly offered vital services to the farmer like the collection and transport of output. The result was that farmers received a net price depending on the extent of services received and these prices were not necessarily consistent from one municipal area to the next.

- A range of different prices were paid to farmers in the various municipalities that were often based on the strength of producer associations, storage facilities and distance from the consumer centres. Historically the state of Rondonia has also received lower producer prices than other producer states. An example of this is that the same blend of cocoa has historically received higher prices in the state of Bahia than Rondonia. This range of different prices has thus affected the significance of the relationship between output and producer prices.

- Production has been affected by the price of inputs like fertilisers, fungicides and pesticides. Rondonia has traditionally paid a much higher price for these inputs which have also been subjected to sharp price increases at certain times. As an example of this the price of fertiliser rose by 300 % in 1983. The result of these high input costs has been that farmers neglect to use them and output is adversely affected regardless of the prevailing prices.

- The lack of family or contract labour has acted as a major constraint to small farmers responding to prices.

- The social preferences of small farmers have significantly affected the planting of perennials in Rondonia regardless of the prevailing producer prices in the state. A majority of small farmers originate from the Centre-South of Brazil and thus have a personal experience of coffee. This has influenced them to plant coffee regardless of prices whilst at the same time has been a constraint to the planting of cocoa. In addition cattle pasture and the production of beef is by far the most predominant form of land use in the state despite the fact that small farmers could potentially earn more income from perennials. There are a number of reasons for this and they include a higher measure of security, social status, tax incentives, reduced transport problems and enhanced land values in an increasingly speculative market. This preference for cattle has occurred regardless of state and World Bank initiatives to increase the output of perennials.

Soil type

In general the micro regions with the more fertile soil types have produced a high percentage of the state's production of perennial crop types. For example, the more fertile micro regions 3,4 and 8 produce between 80 % and 90 % of the total state's production of coffee and cocoa. The regression equations, apart from micro regions 2 and 7 (bananas) , have not included soil type as a significant variable. In Micro Regions 2 and 7, bananas could

possibly be grown in a range of highly fertile and infertile areas. Because of this, the coefficients of production are highly responsive.
A number of factors could contribute towards the lack of a significant relationship in the regression equations as well as influence the coefficients of production. They are:

- The agricultural output of a crop type in any particular year could result from a wide range of soils within any one municipality. This study has employed an average fertility index and there could be significant standard deviation in any specific year.

- The topographical conditions of an area can affect production. In the case of coffee an elevation of above 12 ^{0} reduces crop output due to erosion.

- Plant spacing has a major impact on output per hectare in the same soils. For example between 800 and 1100 cocoa plants can be installed per hectare and coffee which has traditionally been spaced at 4 meter x 3 meter can now be spaced at 4 meter x 1 meter.

- Inputs like fertilisers, pesticides and fungicides can affect output per hectare. Loss of output in certain municipalities has ranged from between 20 % and 40 % in times when outbreaks of pests and diseases have occurred.

- Improved management and new technology, in limited areas, have clearly demonstrated a significant change in production per hectare. Improved plant spacing, intercropping, weeding and cleaning, pruning and post harvesting techniques have demonstrated increases in output. In addition the governments insistence on the planting of monocultures has reduced output per hectare as a result of the increase in pests and disease.

- Different genetic strains of the same crop type have produced significant different levels of output in the same soil types.

- The effect of altitude can influence production in the same soil types. The temperature and humidity changes would suggest the reason for this but this could also include an increased probability of topographical changes.

- The output per hectare can be reduced as a result of the consumption habits of the farm family. This is particularly the case with respect to the production of bananas.

- The practice of intercropping makes the measurement of output per area more prone to error.
- The age of the plantation, regardless of the soil type, affects production.

- The production of perennials, especially bananas, are adversely affected by the dry period between May and October. Furthermore the majority of farmers lack irrigation systems.

Altitude

The general regression equations suggest that altitude and therefore temperature has a significant affect on production in a number of micro regions. This is supported by evidence that the production of certain coffee types is best suited to specific altitudes whilst the production of bananas and cocoa generally requires hotter conditions. Cocoa and bananas are best suited to annual temperatures of over 26 degrees centigrade. In general, the more elevated regions of Rondonia will be less suitable for production for these two crop types. By contrast, the production of certain coffee types is better suited to higher elevations. Café Arabica, for example, is best suited to altitudes of 500 meters whilst Café Robusta is best suited to altitudes of between 250 and 500 meters. These examples are adequately represented by the regression equations.

The significance of altitude on production output could be reduced due to the following factors. These factors are:

- Different soil types can occur at the same altitude.

- Different topographical conditions can exist at the same altitude.

Rainfall

In general, the regression equations indicate a low level of significance between the output of perennials and rainfall. In the case of bananas in micro region 6, the negative relationship between output and rainfall could be as a result of flooding that could cause erosion in the more elevated municipalities.

The lack of significance could be the result of the following factors:

- Inaccurate or insufficient recording of data by the weather stations which was closed for lengthy periods in the late 1980's and early 1990's.

- The average rainfall for Rondonia over a thirty year period measures over 2000 mm per annum with a relatively limited standard deviation. Droughts are a rarity and, because of the relative steadiness of these rainfall patterns, the significance of their effect on output is reduced. Moreover, the various micro regions of Rondonia have very similar rainfall patterns. This significance is further reduced where the minimum requirement of perennials in Rondonia is considerably less than the average rainfall of the state.

Other socio economic variables

The socio-economic variables of farm size, family size, capital inputs, irrigation and level of education have been rejected by the models due to the insufficient number of observations. These observations only occurred in years when a census was taken and this includes 1980, 1985, 1990 and 1995.

7. CONCLUSION

The estimated relationships can be usefully employed as broad based predictive models for the micro regions and could be used as a starting point for the construction of models for individual municipalities. The development of predictive models for individual municipalities will require further empirical studies. This study believes that further detailed and more location specific empirical studies are required.

This study demonstrates that broad-based predictive models can be timeously developed in a cost-effective manner by using existing sources of data. In this regard, the available databases can be more effectively used to develop broad-based models that can then be used as a guideline for more location specific models. In addition, the construction of these models could be effected in other areas and countries where similar conditions occur provided that these models recognise the general shortfalls of neo-classical production functions and are specifically adapted to the uniqueness of each situation.

This study would suggest that the reason for the general lack of predictive models for small farms in the tropics is because of a combination of highly complex interactive physical and socio-economic factors combined with the difficulty of data collection and available data bases. The complexity of these constraints would tend to support the null hypothesis of this study and contribute towards the reasons as to why the modelling of small farm systems in the tropics has been so limited. In this regard, the developed regression equations should be seen as a contribution towards quantifying the dynamics of small farm systems in the tropics. It is also proposed that this would contribute towards problems like land use evaluation , land valuation and the prediction of output.

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