Deforestation and Agroforestry Adoption in Tropical Forests: Can We Generalize?

Some Results from Campeche, Mexico and Rondônia, Brazil

James F. Casey[1]
and
Jill L. Caviglia[2]

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[1] Department of Economics, Washington and Lee University, Lexington, VA 24450, Phone: (540) 463-8102, Fax: (540) 463 8638, caseyj@wlu.edu

[2] Department of Economics and Finance, Salisbury State University, Salisbury, Maryland 21801-6860, Phone: (410) 546-5591, Fax: (410) 546-6208, jlcaviglia@ssu.edu

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ABSTRACT

The adoption of sustainable agriculture and other sustainable forestry methods that can help to reduce tropical deforestation have received a great deal of attention in the literature (Adesina and Zinnah 1993, Akinola and Young 1985, Feder and Slade 1984, Holden 1993, Kebede et al. 1990). Although results from different studies can be compared in an absolute sense, there are very few individual studies that compare results and determine, through empirical analysis, whether policy can be universally applied. This paper uses farm-level data to determine whether some universal conclusions can be drawn about the adoption of agroforestry by peasant farmers in developing countries by comparing the land use choices of farmers in Rondônia, Brazil and Campeche, Mexico.

The empirical results indicate that education level and the degree of exposure to information about agroforestry significantly influence the adoption of agroforestry and that deforestation levels for farmers in both nations are influenced by the size of the farm lots. The two communities used in the analysis differ in terms of tradition, history, geography, and economics but both experience a link between deforestation and imperfect information. Policies that address imperfect information in developing countries are likely to decrease deforestation as well as improve the well being of residents.

JEL Classification: Q12 , Q0, O13
Key Words: Brazil, Mexico, Agroforestry, Tropical Deforestation, Sustainable Agriculture, Adoption, Amazon, Campeche, Rondônia

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1. Introduction

Tropical forests cover a mere 7 percent of the Earth's land surface, yet almost half of the world's biota are found exclusively in these forest ecosystems (Wilson 1988). The repercussions of tropical deforestation are, therefore, extensive in terms of losses in biodiversity. Over fifty five percent of global deforestation occurring between 1980 and 1990 took place in only seven countries; Brazil, Mexico, Venezuela, Malaysia, The Democratic Republic of Congo, Bolivia, and Indonesia (Abramovitz 1998). Our research focuses on tropical deforestation in Brazil and Mexico. Current estimates of rates of deforestation in Mexico range from 400,000 to 1,500,000 hectares per year, or about 2 percent of total forest cover in the country (Barbier & Burgess 1996). The largest losses are occurring in tropical evergreen forests, located almost entirely in the southeastern part of the country (Cairns et. al 1995). Between 1991 and 1996 annual tropical deforestation averaged over 1.8 million hectares per year in Brazil, representing 0.4 percent of the Amazonian region (Alves 1999). A majority of Brazil's deforestation is occurring in the south, southeast, and northeast borders of Legal Amazonia. As the tropical forests of Brazil and Mexico continue to be degraded and depleted, the promotion and adoption of sustainable activities become increasingly important.

The adoption of sustainable activities, such as agroforestry, sustainable logging and agro-pastoral production systems can help to greatly reduce deforestation (Scherr 1993). Even so, many individuals and firms do not practice sustainable activities, and many governments do not support these efforts by offering land stewardship incentives or implementing environmentally sound policies. There have been numerous studies on the adoption of sustainable practices in

tropical regions such as agroforestry (Holden 1993, Adesina and Zinnah 1993, Lin 1991, Kebede et al. 1990, Akinola and Young1985, Feder and Slade 1984), sustainable logging (McCormick 1998, Kahn et al. 1997, Lovejoy 1986a, 1986b, Allen 1985), and agropastoral development (Dercon 1997, Gryseels 1988). Although the results of these studies can be compared in an absolute sense, there do not exist many comprehensive studies that compare results and determine, through empirical analysis, whether policy can be applied universally.
Most of the comparative empirical work on deforestation has focused on cross-country levels of analysis with aggregate data (Barbier and Burgess 1996, Kahn and McDonald 1995, Cropper and Griffiths 1994, Rudel 1989, Allen and Barnes 1985, Lugo et al. 1981).

This article uses farm-level data to determine whether universal conclusions can be drawn about the adoption of agroforestry by peasant farmers in developing countries by comparing the land use choices of farmers in Rondônia, Brazil and Campeche, Mexico. A combined set of 347 observations is used to estimate deforestation levels, the adoption of agroforestry (a sustainable agricultural system), and the extent of agroforestry adoption by small-scale farmers. The results of these estimations are used to investigate the similarities and differences between Brazilian and Mexican farmers and to generate universally applicable regional policies to reduce deforestation. A major contribution of our work is the use of farm-level data, collected by each of the co-authors. This factor alone allows for an added depth to the analysis due to familiarity with the regions used in the analysis.

2. Background and History of Study Areas

One state that is experiencing high rates of deforestation in Brazil, is the state of Rondônia. A majority of the deforestation in Rondônia is the result of slash-and-burn agriculture initiated in this region of the Amazon during the 1960s and 1970s under government settlement programs (Caviglia 1999, 1998). These settlement programs include the creation of the Cuiabá-Pôrto Velho interstate highway (BR-364) that runs through the heart of the state. Relatively fertile soils, in combination with highway access, attracted many settlers to the region, resulting in a ten-fold migration increase during the 1970s (Mahar 1989). The new highway and system of feeder roads opened a formerly remote area, facilitating the deforestation process. Migration to Rondônia continued to increase in the 1980s when BR-364 was paved, and, as a result, further pressure was placed on the forest regions. The deforested area of Rondônia increased from 4,000 km^2 in 1978, to 58,000 km^2 by 1988, 65,534 km^2 by 1990 and to 79,702 km^2 (or 27% of the state) by 1996 (Anderson 1993, Goldenberg 1992, Diógenes 1999). Population growth, road construction, and government subsidization of deforestation (i.e. subsidization of cattle ranching and coffee) have all contributed to the high rate of deforestation in Rondônia (Southgate 1992, Mahar 1989).

Campeche, located on the Yucatan Peninsula in southeastern Mexico, is the home of the Calakmul Biosphere Reserve (CBR). The CBR extends over 723,185 hectares (1.7 million acres). Its forests are contiguous with those of the Peten in Guatemala and the northwest forest of Belize, making this area one of the largest expanses of tropical forest in the world. The United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and the Biosphere program accepted Calakmul into its international network of international biosphere reserves in 1993. The CBR is considered to be one of the most important sites for biodiversity conservation in all of Mexico (Ericson 1996). Population in Campeche’s tropical forests has been increasing since the late 1960s, due to migration mostly from the neighboring states of Tabasco, Chiapas, and Veracruz. In 1960 Campeche was one of the least populated states in Mexico with a population density of 2.9 persons per square kilometer. By 1990 this number reached 9.41 persons per square kilometer (Ericson 1996). The increases in population density and the creation of the biosphere reserve, which removes forested areas from other uses, place added pressure on an already substantially degraded resource (the tropical forests surrounding the CBR).

The settlement of Ouro Preto do Oeste, and seventeen individual communities located in south-central Campeche (see Figure 1) were chosen for this study for three main reasons: 1) both areas were settled in the 1970s and 1980s through government sponsored programs designed to alleviate population and other social problems in different regions of their countries, 2) both the regions were settled by small-scale farmers who are more familiar with farming in temperate climates, and 3) both regions have been exposed to agroforestry through extension programs initiated by local governmental and non-governmental organizations. The history and land-stewardship are similar in the regions, however, there are differences in land ownership, the size of the farm lots, types of cultivated crops, and local traditions. Determining whether policy, that can help to reduce deforestation in Brazil is also applicable in Mexico, and vise versa, is important to environmental policy in general.

2.1. Similarities Between Rondonia and Campeche

Rondônia and Campeche are similar in that both states were recently settled to alleviate

FIGURE 1 HERE

political and population pressures in different areas of their respective nations. As a result, farmers from temperate climates were relocated to tropical regions. Thus farmers, familiar with temperate farming techniques, transferred these same practices to tropical areas. The harvesting of temperate products in tropical regions is inefficient and impossible to sustain for long periods of time (Fujisaka et al. 1998, Pedlowski et al. 1997, Browder 1994, Uhl et al. 1989). Tropical soils contain most of their nutrients in the leaf litter and topsoil. Trees with buttressed roots are therefore an essential part of successful tropical agricultural systems. Temperate crops, when planted mono-culturally, do not maintain the tree system and quickly deplete the nutrient base. Tropical vegetation, on the other hand, quickly removes nutrients from rapidly decaying leaf litter in the upper most layer of the soil, before the heavy rainfall of the region washes the nutrients away. Crop systems that are adaptive to the needs of tropical soils will be successful in tropical regions. Agroforestry, which incorporates trees and perennial crops with the production of annual crops,[1] is a sustainable form of agriculture in the tropics.

2.2. Differences Between Rondônia and Campeche

A major difference between the two regions is the amount of undisturbed forest that remains. Brazil contains the largest continuous expanse of tropical forest in the world (Myers 1994). The majority of deforestation in Brazil has occurred along the exterior border of Amazonia. Interior Amazonia, with the exception of the city of Manaus, is still largely undisturbed. Although Rondônia, on the exterior of the Legal Amazonia, contains only a small portion of undisturbed forest in Brazil, deforestation in this state significantly impacts national

[1] Agroforestry, or inter-cropping, is a farming technique that requires that only small rows of forest are cut down in order to plant crops. The row crops are planted with standing trees. The inter-cropping of annual and perennial crops between standing trees is necessary to sustainably produce crops in the tropics because of the unique soil that is found in these regions. Tropical soils hold most of their nutrients in the top one inch of the soil and in the litter that lies above the soil. Trees provide nutrients through the cycle of litter fall and by absorbing the nutrients quickly into their root systems. When trees and perennial crops are not present, the litter cycle is broken and the nutrients are quickly washed away by the heavy rain of the area, making the production of many agricultural crops difficult and unsustainable.

rates. It is expected that if the rate of deforestation can be reduced in Rondônia, then the need to settle further into the interior of Brazil can be reduced, since most of the Amazonian population lives along its outside borders and migration to the Amazon has severally slowed since the 1980s.

Currently, the Brazilian Amazon is not under tremendous pressure from the migration of new residents. After government supported settlement programs ended in the 1980s, and land was no longer provided free of charge by the government, migration to the region tapered off. The current pressures on the rainforest stem from Amazonian residents who plant non-native crops and devote land to cattle ranching. Tropical soils cannot support these activities for long periods of time. When the land is rendered useless by these activities, the farmers and ranchers must move to new undisturbed lands, closer to the interior of the Amazon to survive. One main objective of policy is to protect the undisturbed forest and biodiversity that will be lost as conversion of the forest to agricultural land continues.

Conversely, the forests of Campeche are primarily secondary growth forests ranging in age from twenty to over one hundred years old. The biological diversity of these forests is of tremendous global significance as evidenced by its inclusion in the UNESCO program. Environmental policy in this region is aimed at curtailing the intrusion of farmers into currently forested areas in order to conserve forest diversity, both plant and animal. This entails implementing agricultural systems that are more sedentary in nature, such as agroforestry. As long as populations continue to grow and place more pressure on the land-base in Campeche through unsustainable activities, forests will continue to be degraded and destroyed in this biologically rich region.

2.3. Farming Techniques and Tropical Soils in Rondônia and Campeche

A majority of the farmers from Ouro Preto and Campeche use slash-and-burn agriculture. This agricultural method requires that large areas of forest are cut and burned to plant monocultured annual crops (such as rice, beans, corn, and peppers). The burned vegetative matter introduces nutrients to the soil that can be used by future vegetation. However, the new plants and constant leaching by heavy tropical rains rapidly exhaust these nutrients. Thus, tropical soils, by nature of their climate, contain few nutrients in the root zone. Instead, the nutrients are captured by large leaves and absorbed by buttressed root systems and fungi. Trees, and the litter that they provide, play a prominent role in the nutrient cycle of tropical forests. As leaves, branches, and seeds fall to the forest floor, the matter is rapidly decomposed due to the high temperature and abundant moisture.

Slash-and-burn agriculture destroys the most intricate part of the tropical nutrient cycle: the trees. Agroforestry, or sustainable agriculture, incorporates trees in the farming system either in rows (by replanting trees or by clearing only small rows of forest) or scattered throughout the plot. This agricultural method is sustainable in tropical soils because nutrients are kept from washing away with the rainfall. In a variety of studies in Mexico and Brazil, agroforesty has been found to provide continuous cropping and greater yields than slash-and-burn agriculture (Browder 1989). Since the benefits of agroforesty in the tropics are numerous, the slow adoption of this farming technique must be addressed. The determinants of the adoption of agroforestry (in addition to the determinants of deforestation) are estimated in the empirical analysis.

3. Theoretical Model of Adoption Choice

The farmer has the choice of whether to adopt the newer farming technique, agroforestry, or not. A simple representation of these choices follows.[2] For more detailed models of land use decisions by farmers in tropical regions see Ehui and Hertel (1989), Ehui and Preckel (1990) and Barbier and Burgess (1997). A portion of each lot is devoted to agricultural production. A farmer may choose slash-and-burn agriculture or agroforesty (alone or in combination with slash-and-burn agriculture) in order to maximize profit. The farmer will maximize agricultural income according to the following equation:

$$\max Y_{ij} = P_{ij}{}^{U} Q_{ij}{}^{U} - I_{ij}{}^{U} R_{ij}{}^{U} + (P_V{}^{S} Q_V{}^{S} - I_{ij}{}^{S} R_{ij}{}^{S}) \qquad (1.)$$

where i represents the individual farmer, j represents the country (either Brazil or Mexico), Y is income, P^U represents a matrix of prices for products produced unsustainably under slash-and-burn, Q^U represent a matrix of quantities of products that are produced unsustainably, I^U represents a matrix of prices of inputs that are required for unsustainable products and R^U represents a matrix of quantities of inputs necessary to produce unsustainable crops. P^S, U^S, I^S, and R^S represent the matrices mentioned above, for the production of sustainable products produced with agroforestry.

The farmer maximizes utility by maximizing the profit derived from agricultural production. Following Adesina and Zinnah (1993) and Rahm and Huffman (1984), utility maximization is based on the non-observable underlying utility function that ranks the preference of the i*th* farmer according to the farming method that is chosen. The non-observable underlying

[2] It was found that a majority of farmers who adopted agroforestry also maintained monocultured annual crops on a portion of their lots. The choices which face the farmer are therefore represented as choosing to use slash-and-burn agriculture or using agroforestry either exclusively or in combination with slash-and-burn agriculture. The choice to maintain annual crops in addition to adopting agroforestry reduces the risk associated with the new technology. It is assumed in the analysis that once the benefits of agroforestry are realized, that farmers will not need or desire to maintain monocultured annual crops. This view is shared by the non-governmental organization, IPHAE (Instituto de Pré-História, Agricultura e Ecologia), that administers training in agroforestry in Rondônia.

utility function is represented by: V_{ij}. Utility is derived from observable lot and farmer characteristics (such as lot size, percent of the lot which is primary forest, the number of hectares of secondary growth, and age and education of the household head), and from the observable farming method characteristics (such as yield, income, and the labor-leisure ratio).

$$\begin{aligned} &\max V_{ij} \\ &\textit{where} \qquad \max V_{ij} = \max \Pi_{ij} \end{aligned} \tag{2.}$$

The farmer therefore chooses slash-and-burn agriculture iff:

$$V_{ij}^{U} > V_{ij}^{S} \tag{3.}$$

and chooses to use agroforestry iff:

$$V_{ij}^{U} < V_{ij}^{S} \tag{4.}$$

This theoretical model is a simple representation of farmer choice and based on a more sophisticated model of adoption. See Caviglia and Kahn (forthcoming), Kebede *et al*. (1990), Lin (1991), Shakya and Flinn (1985) and Rahm and Huffman (1984) for more detailed models of the adoption of agricultural technologies in developing nations. A common theme throughout these papers is that the adoption of agricultural methods, that increase welfare and/or income, often occur at low diffusion rates in developing countries. Many farmers are either not willing to adopt the new technology or are constrained by capital resources and/or market failures and cannot adopt the potentially superior technology. The adoption of agroforestry in Campeche and Ouro Preto do Oeste has also occurred at a slow rate. Our empirical model estimates the determinants of adoption.

The choice of agricultural method is represented in the empirical analysis with a two-stage Tobit model that estimates the probability that a farmer will adopt agroforesty and the extent of

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In addition, this view is supported in the literature (Almeida and Campari 1995, Dale et al. 1994).

adoption once the adoption decision is made. This theoretical model may also be adjusted to incorporate the decision to deforest or not. This alternative will not be explored in this paper. See Pfaff (1999) for a derivation of this theoretical model. The determinants of deforestation are explored in the empirical analysis.

4. Data Description

The data used in the empirical analysis were gathered on site in both Rondônia and Campeche. The data from Rondônia consist of 171 observations collected between September 1996 and January 1997. The data from Campeche consist of 176 observations collected from January 1998 through March of the same year. A brief summary of the data follows. See Table 1 for the variable definitions.

TABLE 1 HERE

Tables 2 through 5 present an overview of the farm lots and farmers in Rondônia and Campeche. The average farmer in Rondônia 48 years old, has eight people living on the lot, has lived on the lot for 11 years, and has a farm of 71 hectares. The average lot in Rondônia is divided between agricultural production (14 percent), cleared land (61 percent), and undisturbed forest (24 percent). Only 10 percent of the farmers in Rondônia have been exposed to sustainable agricultural techniques through extension programs, neighboring farmers, or friends and only 6 percent actually use some form of agroforestry.

The average farmer in Campeche 38 years old, has six people living on the lot, has lived on the lot for 11 years, and has a farm of 49 hectares. The average lot in Campeche is divided between agricultural production (9 percent), cleared land (45 percent), and forest cover (51 percent). In contrast to Rondônia, 46 percent of farmers in Campeche have had some formal exposure to sustainable agriculture and 68 percent have experimented with tree planting on their farms.

TABLES 2 - 5 HERE

5. The Empirical Model and Results

Two models are estimated using the 347 observations collected in Rondônia, Brazil and Campeche, Mexico. These models include the estimation of: 1) the probability of adopting agroforesty and the extent of adoption once the adoption decision is made, and 2) the major determinants of deforestation. Both of these estimates are run as restricted and unrestricted models to determine if there are significant structural differences in the estimation of Brazilian and Mexican land-use choices. Chow tests and other comparative statistics are used to determine whether the restricted or unrestricted models are empirically supported.

The probability of adopting agroforesty and the extent to which it is adopted (once the adoption decision is made) is estimated using a two-stage Tobit model. This procedure was chosen over both the probit and logit models, which only estimate the probability of adoption, because the extent of adoption is pertinent to policy implications. The Tobit model estimates adoption and the extent of adoption based on the concept of a threshold value of the dependent variable. The extent of adoption is influenced by the adoption decision. Therefore, failure to model the adoption decision can lead to a selection bias. The extent of adoption is measured as the number of hectares devoted to agroforesty.

5.1 Estimation of the Probability and Extent of Adoption

The probability and extent of adoption is estimated first using variables indicating farmer characteristics (such as education level, exposure to agroforesty, and family size), lot characteristics (such as years living on the lot, lot size, and the percent of the forest that is undisturbed forest) and interactive variables that correspond to country (the dummy variable is one for observations from Brazil and zero for observations from Mexico) with the explanatory variables (Table 1).

The probability and extent of adopting sustainable agriculture are estimated as restricted and unrestricted models. The unrestricted model includes interactive variables indicating country (i.e. Brazil or Mexico) while the restricted model does not. The unrestricted model predicts the probability of adoption more accurately (83 percent of the results are predicted correctly) and is significant at the one percent level. In addition, a likelihood-ratio test reveals there is a significant difference between the restricted and unrestricted estimations and therefore the unrestricted model is the appropriate model (Tables 6 and 7). Both models are presented, but the analysis and conclusions are based only on the unrestricted model.

According to the unrestricted model, education level (*School*), exposure to agroforestry (*Expose*), the dummy indicating the relation between country and time on the lot *(Cyears*), the dummy indicating the relation between country and exposure *(Cexpose*), the dummy indicating the relationship between country and percentage of forest remaining (*Cperfor*), and the amount of cropland under cultivation (*Cropland*) are all significant and positively related to the adoption of agroforestry. These results suggest that educated farmers and those farmers who have been exposed to agroforesty (through extension agents and/or the neighboring farmers) are more likely to adopt agroforesty. These specific results are important since these two variables may be influenced through policy. The

TABLE 6 HERE

TABLE 7 HERE

results of the model therefore suggest that support of educational infrastructure and the dissemination of information could increase the adoption rate of agroforesty and assist in reducing deforestation. The significance of *(Cyears)* indicates that as Brazilian farmers increase their time on the lot, they are even more likely to adopt agroforestry than Mexican farmers. Additionally, the variable indicating the relation between country and exposure *(Cexpose*) is also significant indicating that exposure has more impact on Brazilian farmers. This impact is likely greater in Brazil because the farmers that participate in agroforestry programs are assisted by trained agronomists, that plan and follow up with the agroforestry plots.

C*brazil*, the dummy variable indicating country, is significant and negatively related indicating that Brazilian farmers are less likely to adopt agroforesty. It is likely that the probability of adopting agroforestry is smaller for the Brazilian farmers because in comparison to the Mexican farmers, they have been exposed to agroforestry to a smaller degree. (The number of programs initiated in Rondônia is smaller than the number in Campeche). In addition, the programs were initiated about five years earlier in Campeche.

Also significant and negatively related to the decision to adopt agroforestry is the dummy indicating the relation between country and amount of cropland *(Ccrop).* In Mexico, much of the current agroforestry usage is focused on reforestation of degraded lands. Therefore, it makes sense that farmers who have cleared more land for agriculture will have access to more open or degraded land that is used in the reforestation program.

Also estimated, in the second stage of the model, is the extent of adoption measured by the number of hectares under agroforestry cultivation. Based on the f-statistics and adjusted r2 values, it is clear these models do not provide much information. This is not a surprising result, however, when we consider the lack of variability in the extent of adoption. For example, only thirty-eight percent of the farmers interviewed are currently using agroforestry and of these, seventy-five percent have less than two hectares planted. Perhaps as farmers begin to use agroforestry more extensively in the future, we will have more to say about the potential explanatory variables for the extent of adoption decision.

5.2 Estimation of the Determinants of Deforestation

The second model that is estimated is an ordinary least squares regression used to determine the major factors contributing to deforestation. Again, we test for structural differences between the unrestricted and restricted models. According to the Chow test results, the unrestricted model best represents the data, as was the case in the estimation of the probability of adopting agroforestry. Both models are presented, but the analysis and conclusions will be based on the unrestricted model. The overall (unrestricted) model is significant at the 0.01 level. The adjusted R-squared is 0.77 (Table 8).

Variables positively correlated with levels of deforestation are the size of the lot *(lotsize)*, the dummy indicating the relation between lotsize and country (*Clot*), the number of years at the present location (*years*), and total farm income (*income97*). These results indicate that farmers with larger lots, in particular those farmers with larger lots in Brazil deforest greater amounts of land. Also, farmers who have remained on the lot for a longer period of time, and have greater incomes deforest greater amounts of land. Deforestation levels are therefore related to resources. Farmers that have more land and more income deforest more. It is likely that the relationships between land, income, and deforestation are circular. That is, farmers with more land deforest more creating income, which leads to increased capital (i.e., the ability to deforest), which leads to higher incomes and so on. Therefore, it is essential that policies be employed to break this cycle. Policies that promote sustainable activities and make these activities such as agroforestry or sustainable logging, profitable are likely to be successful in decreasing deforestation levels.

The only significant variable negatively correlated with level of deforestation is the dummy indicating the relation between years at the present location and country (*Cyear*). This result shows that farmers in Brazil who have lived on their farms longer have cleared less, relative to farmers in Mexico. This result indicates that established farmers deforest less, and that this effect is stronger in Brazil. It is likely that the effect is different between the two countries due to differences in settlement years and the difference in the number of years that agroforestry programs have been supported in the local areas.

TABLE 8 HERE

6. Conclusions and Policy Implications

So, can we generalize? This paper set out to see if universal conclusions could be drawn about the use of agroforestry by peasant farmers in developing countries. We tested this hypothesis using farm level data from Rondônia, Brazil and Campeche, Mexico. The empirical findings suggest that we can make some universally conclusive statements. Specifically, exposure to information about agroforestry and the level of educational achievement play significant roles in the decision to adopt agroforestry. In other words, the combination of our data allows for the generalization that information and the ability to assimilate information are important regardless of other cultural and/or socioeconomic distinctions.

With a first glance, we find similarities and differences between farmers in Rondônia and Campeche. Through further econometric investigation we discover some significant differences between the two groups. The use of both restricted and unrestricted models reveal structural differences between the two data sets. Farmers in Mexico have had more exposure to agroforestry, are more likely to have implemented agroforestry and use it more extensively than farmers in Brazil. Interestingly, the variable indicating the relation between country and exposure is positive and significant revealing that farmers in Brazil are more likely to adopt agroforestry if they are exposed to the relevant information. One key problem is that these farmers have had minimal exposure. However, there may be tremendous gains to be made from the dissemination of information pertaining to agroforestry in Brazil. This is perhaps the most important finding of our empirical work for it clearly supports a recommendation to increase efforts to disseminate information about agroforestry in Brazil and Mexico. Additionally, the land-income-deforestation-income cycle is an important issue. Incentives must be in place to enable farmers to break this cycle of slashing and burning the forest while not suffering negative economic consequences.

We were also concerned with whether or not previous work focusing on macro-level data was sufficient. In light of our findings, we see there is much to be learned from on-site farm-level data. We are certainly not concluding that macro-level data is not necessary, only that it needs to be enhanced with farm level information in order to more fully understand decisions pertaining to deforestation and the use of agroforestry.

Although there are differences between the situations in Brazil and Mexico, it is clear from our empirical findings that education and previous exposure to agroforestry are the two most important variables in the decision to adopt agroforestry. Agroforestry has been presented as a sustainable alternative to current methods of production in the tropics. If the method is to succeed, accompanying investments in education and extension programs must be a part of the overall implementation strategy for agroforestry practitioners.

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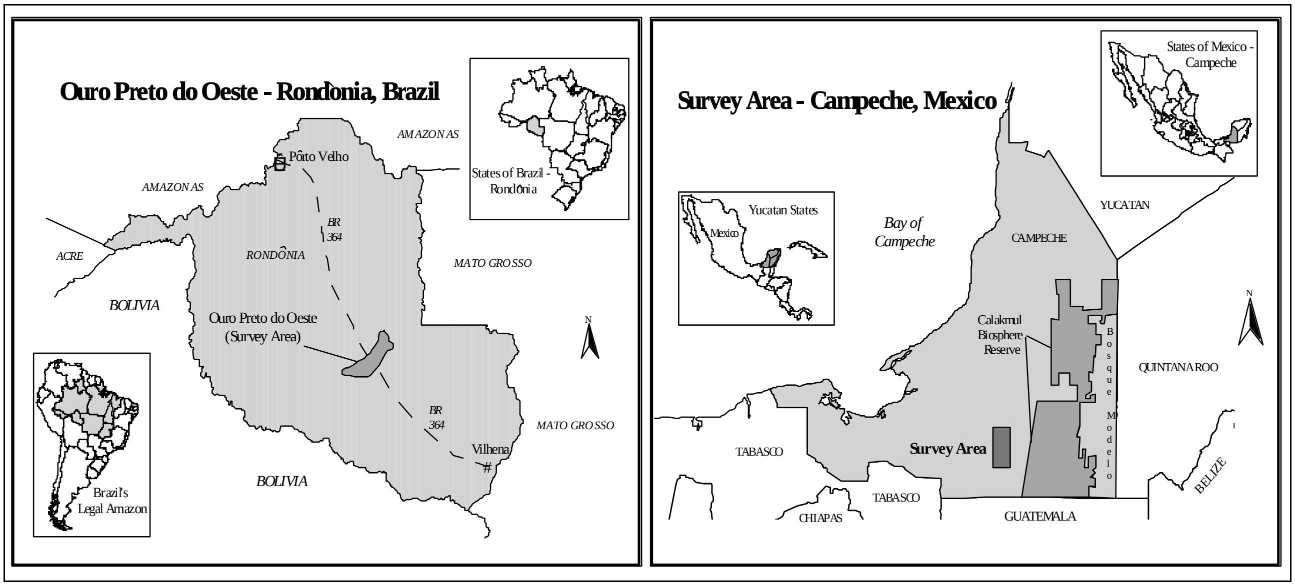

Figure 1 - Survey Areas in Brazil and Mexico

Table 1 – Descriptive Statistics and the Variables Used in the Empirical Analyses

Variable	Definition
Lotsize	size of the lot, in hectares
Forest	number of hectares on the lot devoted to undisturbed forest
Cropland	number of hectares on the lot devoted to agriculture
Clear	number of hectares on the lot that have been cleared
Agrofor	number of hectares on the lot devoted to agroforestry
%Forest	percent of the lot that is undisturbed forest
%Crop	percent of the lot that is devoted to agriculture
%Clear	percent of the lot that has been cleared
Family	number of family members living on the lot
Males	number of males over ten years old living on the lot
School	education of the male household head, value ranges from 0-3; when edu=0 no education, edu=1 primary school completed, edu=2 secondary school completed, edu=3 college or equivalent completed
Years	number of years on the farm lot
Age	age of the household head
Expose	exposure to agroforesty through extension agents, friends, and/or other farmers; expose=1 if the family has been exposed to agroforestry, expose=0 if the family has not been exposed to agroforestry
Inc97	total farm income, 1997 dollars
Country	dummy variable indicating country; country=1 for observations from Brazil, country=0 for observations from Mexico
Cschool	Country * School
Cexpose	Country * Expose
Cfamily	Country * Family
Cyears	Country * Years
Clotsize	Country * Lotsize
Cperfor	Country * Perfor
Ccrop	Country * Cropland
Cinc97	Country * Inc97

Table 2 Land Use in Brazil (in hectares)

	mean	min	max
lotsize	70.6	10	325
forest	16.6	0	135
crops	7.4	0	36
clear	46.4	2	260
agrofor	.11	0	4
% forest	23.8	0	72.7
% crop	14.5	0	80
% clear	61.5	16	100
N=171			

Table 3 Land Use in Mexico (in hectares)

	mean	min	max
lotsize	49	1	120
forest	28	0	95
crops	3	0	18
clear	19.5	0	100
agrofor	1.6	0	16
% forest	50	0	96
% crop	9	0	100
% clear	44	0	100
N=176			

Table 4 Brazilian Farmer Characteristics

	mean	min	max
family	8.4	1	37
males	4.3	1	20
school	.69	0	3
years	11	1	26
age	48.19	19	82
expose	.09		
N=171			

Table 5 Mexican Farmer Characteristics

	mean	min	max
family	6	2	14
males	3	1	9
school	.51	0	3
years	10.9	1	36
age	38.3	16	74
expose	.46		
N=176			

Table 6 - Probability and Extent of Adoption - Unrestricted Model

	Probability of Adopting Agroforestry			***Extent of Adoption (Hectares)***		
Variable	**Coefficient** (n=347)	**z=b/s.e.**	**Marginal Impacts**[a]	**Coefficient** (n=131)	**z=b/s.e.**	**Marginal Impacts**[a]
Constant	1.11E-02	0.023	3.04E-03	0.53667	0.45	0.30598
School	0.30714**	1.886	8.42E-02	0.45646	1.297	0.26025
Cschool	0.23668	0.728	6.49E-02	0.8596	1.059	0.4901
Expose	0.72128***	3.397	0.19775	1.5593***	3.169	0.88901
Cexpose	1.06*	1.841	0.29062	2.3917*	1.685	1.3636
Family	-2.94E-02	-0.767	-8.07E-03	-0.15362*	-1.707	-8.76E-02
Cfamily	7.52E-02	1.391	2.06E-02	0.25807*	1.8	0.14714
Years	-8.24E-03	-0.459	-2.26E-03	-4.18E-02	-0.967	-2.38E-02
Cyears	9.20E-02**	2.21	2.52E-02	0.24222**	2.242	0.1381
Lotsize	-5.16E-03	-1.129	-1.42E-03	-2.73E-02***	-2.406	-1.56E-02
Clotsize	2.79E-03	0.424	7.64E-04	2.05E-02	1.139	1.17E-02
Perfor	0.25997	0.569	7.13E-02	1.5922	1.436	0.90778
Cperfor	2.1179*	1.666*	0.58065	4.6837	1.451	2.6704
Cropland	0.15474***	2.333	4.24E-02	0.42875***	3.37	0.24445
Ccrop	-0.2831***	-3.113	-7.76E-02	-0.76304***	-3.536	-0.43505
Inc97	-3.05E-05	-0.409	-8.37E-06	-1.58E-05	-0.091	-9.02E-06
Cinc97	6.93E-05	0.824	1.90E-05	1.09E-04	0.526	6.20E-05
Cbrazil	-3.8287***	-3.939	-1.0497	-10.388***	-4.259	-5.9226
Lambda				3.0363***	15.365	

Probability Model:		**Extent of Adoption (Hectares):**	
Chi2 (17)	213.87***	F (18,112)	0.88
Pseudo R-squared	.4649	Adj. R squared	.02
Number of Correct predictions	287 (83%)		

***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively

[a]Marginal impacts are the partial derivatives of E[y] = [*] with respect to the vector of characteristics. They are computed at the means of the independent variables.

Table 7 - Probability and Extent of Adoption - Restricted Model

	Probability of Adopting Agroforestry			***Extent of Adoption (Hectares)***		
Variable	**Coefficient** (n=347)	**z=b/s.e.**	**Marginal Impacts**	**Coefficient** (n=131)	**z=b/s.e.**	**Marginal Impacts**[a]
Constant	-0.4674	-1.407	-0.15907	-1.145	-1.219	-0.41242
School	0.34883***	2.67	0.11872	0.6857**	2.138	0.24699
Expose	0.87559***	4.69	0.29798	2.0101***	4.211	0.72404
Family	2.12E-02	0.896	7.22E-03	2.58E-04	0.004	9.31E-05
Years	1.60E-02	1.097	5.44E-03	2.81E-02	0.721	1.01E-02
Lotsize	-1.96E-03	-0.69	-6.68E-04	-1.29E-02	-1.491	-4.65E-03
Perfor	0.44559	1.173	0.15165	1.6779	1.641	0.60436
Cropland	-1.45E-02	-0.554	-4.94E-03	3.33E-02	0.469	1.20E-02
Inc97	1.74E-05	0.703	5.93E-06	5.25E-05	0.736	1.89E-05
Cbrazil	-1.8518***	-7.065	-0.63021	-4.9969***	-6.485	-1.7999
Lambda				3.1989***	15.252	

Probability Model:		**Extent of Adoption (Hectares):**	
Likelihood ratio test	191.1350***	F (10,120)	1.23
Pseudo R^2 squared	.4155	Adj. R squared	0.02
Number of Correct predictions	277(80%)		

***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively

[a]Marginal impacts are the partial derivatives of E[y] = [*] with respect to the vector of characteristics. They are computed at the means of the independent variables.

Table 8 - Estimation of Total Deforestation on Lot

	Unrestricted Model			*Restricted Model*		
Variable	**Coefficient** (n=347)	**Standard Error**	**t-ratio**	**Coefficient** (n=347)	**Standard Error**	**t-ratio**
Constant	5.7486	4.7501	1.21	-11.66***	3.0171	-3.865
Male	-0.21151	0.63596	-0.333	-0.52428	0.38217	-1.372
Cmale	-0.73319	0.74639	-0.982			
Lotsize	0.17793***	4.70E-02	3.788	0.57738***	2.58E-02	22.4
Clot	0.56302***	5.41E-02	10.412			
Sustain	0.1407	2.4262	0.058	-0.58719	2.4999	-0.235
Csus	-7.0994	5.363	-1.324			
School	0.15151	1.6104	0.094	-0.62664	1.3386	-0.468
Csch	-3.3762	2.3266	-1.451			
Years	0.31512**	0.18504	1.703	0.406***	0.14962	2.714
Cyear	-0.54932***	0.27039	-2.032			
Inc97	0.14321E-02***	0.74038E-03	1.934	0.48680E-03***	0.21210E-03	2.295
Cinc97	-0.10569E-02	0.76448E-03	-1.383			
Cbrazil	-4.0344	5.6811	-0.71	13.226***	2.6233	5.042
F statistic (13,333)	92.21***			F statistic (7,339)	113.32***	
R¯squared	0.78			R¯squared	0.70	
adjusted R-squared	0.77			adjusted R-squared	0.69	