POVERTY, COMMODITY PRICES AND AGRICULTURAL
DEFORESTATION: LESSONS FROM THE ECUADORIAN
COAST

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ABSTRACT

Deforestation literature commonly associates rising commodity prices with forest loss. Informal interviews in Manabí, Ecuador suggested that corn crops from forest conversion are often abandoned before harvest. Medium-resolution satellite imagery was used to formally measure the conversion of forest to cornfields. Between 2000 and 2005, despite a 185% increase in real domestic corn prices, coastal Ecuador experienced a 2.2% increase in total forested area. This observed forest gain contradicts the widely cited FAO Global Forest Resources Assessment deforestation rates. A multi-disciplinary approach brings into question the utility of national level patterns in sub-regional decision-making. When conducting future research, scholars must consider the original scale of measurement before applying past deforestation estimates.

Keywords: tropical deforestation; agricultural expansion; commodity prices; land use; remote sensing; Ecuador

Subject Terms: Deforestation – Ecuador; Deforestation -- Economic aspects -- Ecuador; Deforestation – Tropics; Agriculture – Tropics; Agricultural prices -- Developing countries; Agriculture -- Economic aspects -- Ecuador
DEDICATION

Manabitas: sin ustedes este trabajo no habría sido posible. Desde el fondo de mi corazón, gracias por sus dirección y colaboración. Espero que podamos continuar con este espíritu y trabajar unidos para nuestro futuro común.

Residents of Manabí: without you, this work would not have been possible. Deepest thanks for your immeasurable guidance and collaboration. I hope this document will help us to continue “working for our common future”.
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LIST OF ACRONYMS

AVHRR  Advanced Very High Resolution Radiometer

CAN    Comunidad Andina de Naciones
       (Andean Community)

CIF    Cost, Insurance and Freight price

FAO    Food and Agriculture Organization of the United Nations

FOB    Free on Board price

GDP    Gross Domestic Product (per capita)

GIS    Geographic Information Systems

INEC   Instituto Nacional de Estadística y Censos
       (Office of National Statistics and the Census, Ecuador)

LANDSAT-TM USGS Landsat Thematic Mapper Satellite and Images

MAG    Ministerio de Agricultura, Ganadería, Acuacultura y Pesca
       (Ministry of Agriculture, Livestock, Aquaculture and Fisheries, Ecuador)

NOAA   National Oceanic and Atmospheric Administration, USA

SAFP   Sistema Andino de Franjas de Precios
       (Andean Price-Band System)

SICA   Servicio de Información y Censo Agropecuario de Ecuador
       (Ecuador Agricultural Census & Information System Technical Assistance Project)

USDA   United States Department of Agriculture

USGS   United States Geological Survey
1: INTRODUCTION

1.1 Background

Agriculture and forests have long been the main sources of land use conflict. The deforestation literature has considered this conflict with agriculture from a variety of perspectives. Studies of agricultural deforestation have primarily considered shifting agricultural terms of trade, opportunity land costs and shortened investment horizons for agricultural returns. As the majority of the literature conceptually focused exclusively in either a forestry or agricultural perspective, very few definitive conclusions have been offered.

With the exception of general equilibrium models (Stenberg & Siriwardana, 2005) there have been few multi-disciplinary approaches in describing links between agriculture and forestry. Most studies remain sectoral in nature. Although academic focus has recently shifted to include the impact of institutional and individual decision-making models, there remains limited utilization of emerging remote-sensing technologies. Despite recent improvements in satellite resolution and reductions in imagery costs, the literature continues using deforestation rates determined by analyst opinion, forestry export data and broad-resolution satellite imagery.

This author’s previous project experience was scoping afforestation projects on abandoned agricultural lands in Ecuador. By developing agricultural
development plans for individual properties, the goal was to enable land-use planning for the larger watershed. The planning process was a combination of field observations in coastal Ecuador and informal interviews with both landowners and tenant farmers. These activities were originally conceived to determine socioeconomic and institutional influences on local forest conditions. Casual interviews quickly uncovered a perception that corn commodity prices were driving the conversion of forest to agricultural uses. The aim of this study is to quantify this land-use dynamic.

1.2 Attempt to Explain the Overlooked

Although the observation that forest is cleared when agriculture is more profitable may seem rudimentary, it raises important questions. What are the deeper links between poverty, commodity prices and deforestation?

Deforestation of an individual’s private land represents a liquidation of assets (Angelsen & Wunder, 2003; Chambers & Leach, 1989; Food and Agriculture Organization of the United Nations [FAO], 2003; Sunderlin et al., 2005). Conversion of forest to agricultural lands is a potential survival or livelihood decision.

Focused rurally, Ecuadorean corn production represents 4% of total GDP, provides direct employment for 140,000 workers and is the sole source of income for 98,951 households (SICA, 2003). While these numbers tend to portray corn as the product of the poor, the sector represents hope for the poor. The total
area planted nationally has sustained 15-46% annual growth for the past two decades (Borja & Williams, 2004; SICA, 2003).

The casual observation that mid-slope forests were cleared for crop development became more intriguing when field visits identified that these areas were also often out of production. With an average per capita holding of 2.6 hectares, plots in coastal Ecuador are for the majority, forested land on the upper hillsides. Comprising a further third of the holding, valley bottomland is typically devoted to a small residence with outbuildings. Remaining valley bottomland is used for water intensive crops (e.g. tomatoes, melons, and squash) with uncultivated land creeping up the slope. Farmers and landowners have offered that these buffering lands between the forest and farmstead were deforested when corn prices were high.

At present, only informal interviews and casual observations confirm the observed dynamic. Based on corn commodity prices, the increased clearing of land for production quickly saturates the local futures market. Corn prices subsequently plummet with the oversupply from recently cleared land for production. For resource economists, this cycle is reminiscent of A.A. Harlow’s 1960 publication, “The Hog Cycle and Cobweb Theorem”. An increased total area of corn in production, and hence increased supply, results from the deforestation decision. With increased supply, a reduction in corn prices occurs. Low wholesale purchase prices lead producers to leave corn crops to spoil. This price instability results in mid-slope, deforested land above residences and water sources. Sedimentation, lowered water tables and slope erosion are
commonplace in the tropical clay soils (Harden, 1996). These abandoned crops and fields threaten homes, lives and livelihoods. Whereas the hydrological and forestry impacts of this dynamic are well studied, the economics are not.

The question I intend to research for this project follows. To what extent does the variation in corn commodity prices explain the rate of deforestation in Ecuador? Section 2 of this paper provides a review of the both the relevant deforestation and agricultural economics literature. Following an outline of the methodology used to evaluate the link between agricultural prices and deforestation in Section 3, results are offered in Section 4. A discussion of the quality of the outcome and the methodology/data can be found in Section 5. The paper concludes with parting lessons from the Ecuadorean case and the applicability of these results throughout the broader region.
2: LITERATURE REVIEW

2.1 Deforestation Processes

2.1.1 Primary Causes

As with many landscape-level problems, the proximate causes of deforestation in Ecuador, or any country, are highly contested in the literature. Perhaps the only point of agreement amongst practitioners is that the harvesting of forest products rarely drives deforestation (Geist & Lambin, 2002; Lambin et al., 2001).

A central theme and common conclusion of most publications on deforestation is that causality is complex and rooted in a combination of factors. Although the forestry industry has the most logical impact on forests, there is a multitude of forest users with large impacts. Beyond the consensus, the drivers of deforestation have been considered from the perspective of: population growth (Bilsborrow, 1987; Inman, 1993; Rudel, 1989; Southgate, 1994); international market prices (Capistrano & Kiker, 1995; Perrings, 1989); firewood use (Jokisch, 2002); land tenure policies (Deacon, 1995; Fearnside, 2001; Southgate, Sierra & Brown, 1991); oil booms (Sunderlin & Wunder, 2000; Wunder, 2001b; Wunder, 2003); macroeconomic policies (Capistrano & Kiker, 1995; Cruz & Repetto, 1992; Rich, 1994); and even economic development itself (Inman, 1993; Rudel, 1989). (summarized in Figure 1).
Ehrhardt-Martinez (1998) attempted to categorize the deforestation literature by differences in the theoretical approaches by geographers, economists and demographers – (i) Neo-Malthusian, (ii) modernization or (iii) dependency theory based. Despite the typical, exclusionary portrayal of these three independent paradigms, Ehrhardt-Martinez found that neo-Malthusian and modernization theories were both compatible and explained parallel processes significantly. In this light, the abovementioned agricultural causes of deforestation could alternatively be categorized as (i) population growth, (ii) modernization or (iii) dependent development.
Growing evidence exists for a slowing of Latin American deforestation rates as economies shift to petroleum-based fuels (Bhattarai & Hammig, 2001; Cropper & Griffiths, 1994; Koop & Tole, 1999; Shafik, 1994). Ehrhardt-Martinez (1998) put forward the theory that any relationship between the level economic development and deforestation (modernization theory) would have to be a curvilinear relationship. This curvilinear relationship has since been expanded upon, wherein low to intermediate levels of development have high rates of deforestation, and more highly developed countries use of wood alternatives offers a lower rate of deforestation. Despite the emerging articles in support of this dynamic, Barbier & Burgess’ 2001 statistical synthesis of the deforestation literature found inconsistent results for the presence of this “Environmental Kuznet’s Curve”.

Ecuador has been the subject of a series of national and region-specific studies of deforestation dynamics. As with most Ecuadorean works, Sven Wunder’s 1996, 2000 and 2001 studies all examine causes of deforestation with a focus on the Andean and Oriente regions of the country. These works conclude that income from wood is a temporary resource that provides income for reinvestment in agriculture. (Wunder, 1996) In a 2002 sub-regional study of North-Western Ecuador, Rodrigo Sierra found that during the 1980’s there was a close link between forest degradation and commercial logging. It was noted that this dynamic was limited to that single region.
Nationally, a policy focus on road-building, frontier expansion, transnational transportation strategies and oil development in the Oriente\(^1\) have also been seen as major, possible drivers of deforestation in Ecuador (Wunder, 2001b). Through statistical analysis, Southgate et al. 1991 found increased population, proximity to urban centres/roads and tenure insecurity lead to increased rates of deforestation in eastern Oriente of Ecuador.

The work most relevant to the dynamic offered in my hypothesis is the paper by Capistrano & Kiker (1995) that concluded there was a significant, positive relationship between agricultural prices and deforestation. Capistrano & Kiker cautioned that this relationship was only present in certain periods, and disappeared in others. Both Barbier & Burgess (1996) and Panayotou & Sungswuwan (1994) found a positive correlation between agricultural commodity prices and deforestation rates. Wunder (2001b) postulated that agricultural protection policies had a role in masking the decline in competitiveness of Ecuadorean agriculture. As agriculture is the end use for most of the nation’s forests, any distortions in the competitiveness of agriculture would create an incentive to deforest where other market opportunities or uses existed. This study aims to evaluate to applicability of these findings to the Ecuadorean case.

2.1.2 Deforestation Rates

The deforestation literature for Latin America has commonly focused on the competition of agriculture for land-use or attempted to measure the rate at

\(^{1}\) The Amazonian portion of eastern Ecuador
which deforestation processes were occurring. Methodologies for the literature have varied from micro-level surveys of individuals' land-use patterns to multiple country regression analyses at the global level. Given the various approaches taken to forest degradation, it comes as no surprise that estimates of the deforestation rate are highly varied (Table 1).

<table>
<thead>
<tr>
<th>Author</th>
<th>Estimated Annual Deforestation (ha/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAO 1981 (1980 FRA)</td>
<td>315,020</td>
</tr>
<tr>
<td>FAO 1995 (1990 FRA)</td>
<td>215,316</td>
</tr>
<tr>
<td>FAO 1997 (1997 FRA)</td>
<td>178,192</td>
</tr>
<tr>
<td>FAO 2001 (2000 FRA)</td>
<td>126,684</td>
</tr>
<tr>
<td>FAO 2006 (2005 FRA)</td>
<td>184,501</td>
</tr>
<tr>
<td>Cabarle et al. 1989</td>
<td>341,000</td>
</tr>
<tr>
<td>SUFOREN 1991</td>
<td>120,000</td>
</tr>
<tr>
<td>WRI 1992</td>
<td>340,000</td>
</tr>
<tr>
<td>Amelung &amp; Diehl 1992</td>
<td>306,000</td>
</tr>
<tr>
<td>FAO 1993 (FRA 1990)</td>
<td>238,000</td>
</tr>
<tr>
<td>WRI 1994</td>
<td>238,000(^2)</td>
</tr>
<tr>
<td>INEFAN 1995</td>
<td>106,000</td>
</tr>
<tr>
<td>Sierra 1996</td>
<td>15,223</td>
</tr>
</tbody>
</table>

The 1960’s and 70’s saw extensive anthropological and sociological studies of human impacts on the forest. These disciplines continued through the literature of the 1980’s and 90’s but were ancillary to more frequent publications on global patterns of forest change. Many reasons have been postulated for the spatial-consciousness of the 1980’s, mostly drawing from a globalization, neoliberal or Marxist perspective. In the land-use and development

\(^2\) Actual quoted figure is a range: 136,000-340,000 ha/yr depending on methodology/definition
communities, the global study of forest dynamics is best attributed to the inaugural Global Forest Resources Assessment (FRA) in 1981 by the Food and Agriculture Organization of the United Nations (FAO).

Past iterations of the FAO’s Forest Resources Assessments, beginning in 1948, had primarily focused on topics for professional foresters and policy makers. Of the conservation indicators introduced in the 1980 FRA a multi-temporal assessment of country-specific deforestation rates had the greatest impact. Prior works had focused on regional rates of deforestation as estimated by ‘professional opinion’ of experts. This approach was however both a snapshot of a dynamic relationship and methodologically impossible to replicate. Based on national forest inventories in two time-periods, the 1980 rate of deforestation began measurement in both absolute and proportional terms. The FAO published further iterations of Forest Resources Assessments in 1990, 2000 and 2005, with improvements in methodologies as appropriate.

As retroactive measurements of past FAO assessments have not been conducted, it remains unclear if the methodological changes over time are fruitful. The total amount of forest in Ecuador for 1990 as measured in the FRAs for 1990 and 2005 was 11,962,000 and 13,817,000 hectares respectively (Figure 2). On methodological differences alone, there is nearly a 2 million hectare discrepancy based. Both Grainger (1996; 2008) and Ehrhardt-Martinez (1998) have strong summaries on the reliability and measurement of this FAO data. Simply put, a continuous spectrum of deforestation data from 1990 to present is simply not available.
The integration of satellite imagery and land-use studies has without a doubt allowed for more detailed and methodologically consistent analyses of deforestation. Increasingly more nuanced detection of changes in land use and forest cover is now possible on an annual or even monthly basis. Despite the increased availability of alternatives and the methodological inconsistencies with the FAO, deforestation assessments continue to rely upon the FAO datasets. While simultaneously citing the FAO as the best available data source, discussion sections of these works commonly question the quality of data, contain endless caveats for conclusions and deliver scathing smears of the FAO's assessment methodologies (Allen & Barnes, 1985). Many are conducting incorrect time-series interpolations of the static FAO data.
The goal of this study is to move beyond the FAO datasets. This will not however be the first attempt. Earlier studies by Barbieri, Bilsborrow & Pan (2005), Marquette (1998); Mena, Bilsborrow & Mcclain (2006); Perz (2001; 2005), Pichón (1997; 2002), Rudel & Horowitz (2001); Sierra (2002) and Sierra & Stallings (1998) were conducted at the household-level, observing the influence of annuals as a minor component of a larger forest-use matrix. This study will be the first to revisit the role of annual crops in Ecuadorean deforestation using remote sensing.

Outside of Ecuador, there have been Latin American studies linking the role of annual crops to the rate of deforestation in Brazil (Chomitz & Thomas, 2003; Moran, Siqueira & Brondizio, 2006), Mexico (Abizaid & Coomes, 2004; Deininger & Minten, 1999; Turner, Geoghegan & Foster, 2004) and Bolivia (Pendleton & Howe, 2002). Prior studies have used finer resolution remote sensing products to measure deforestation processes in Ecuador, but without consideration of the proximate or underlying causes. Deforestation rates and patterns were evaluated using remote sensing by Keating (1997) and Vina & Rundquist (2004), however those study areas did not include Manabi province. For Ecuador, this will be the first attempt to measure explicitly the role of agricultural prices in deforestation processes.

### 2.2 Agricultural Deforestation

In the same manner that foresters consider the impact of agriculture on their resource, agronomists examine the influence of forestry on agriculture.
Discussions of deforestation are inextricable from those of agricultural expansion and frontiers. Deforestation-commodity models can be classified by their sectoral focus: timber models and agricultural commodity models. Barbier et al. (1995) provides a prime example of a timber model, while commonly used agricultural models are found in Cannock & Cuadra (1990), Elnagheeb & Bromley (1994) and Gockowski (1997).

Given their roots in traditional agricultural and timber supply & trade models, all three find higher agricultural and timber prices lead to greater deforestation. Most deforestation models only differ from other timber and agricultural supply and trade models in that the authors explicitly note the link between greater production and deforestation. Under the above conditions, practically any supply or trade model for a commodity implicated in deforestation could be considered a deforestation model (Kaimowitz & Angelsen, 1998).

2.2.1 Agricultural Expansion / Frontier Development

There are two dynamics commonly associated with agricultural expansion and deforestation. The first dynamic occurs under conditions of government policies actively promoting colonization of forested areas (Browder, 1988; Hecht, 1985; Mahar, 1989). Colonization programs that prioritize land use for small farmers and new settlement creation best exemplify this (Walker, 1993). Road infrastructure created to linking these new settlements creates opportunities for deforestation and land-use conversion (Nepstad et al., 2002). Infiltration and development of previously forested areas cause the rate of deforestation to grow
exponentially in surrounding regions. Intentional agricultural and farm development are goal of this first dynamic.

In the second dynamic, agricultural clearing through frontier development is a secondary outcome of commercial logging interests. Commercial logging takes place in remote rural areas, and requires road infrastructure between forest and market. Logging creates incentive for small farmers to clear new settlements adjacent to the remaining logging road or through creation of secondary branch roads (Rudel & Roper, 1997). Newly cleared areas are ultimately preferred to second or third cycle fields, as the intensive rotations of cash and export crops rapidly deplete nutrients. These new agricultural frontier settlements provide settlers both market access infrastructure and primary forest to convert to first generation fields.

It is important to distinguish between frontier environments commonly portrayed in the literature, and the dynamics at work in coastal Ecuador. Frontier expansion is indeed underway in the Oriente. In contrast, the majority of areas with above average and moderately productive soils have already been cleared in coastal Ecuador. Little forest remains to be infiltrated and few contiguous corridor tracts exist. Remaining parcels are typically patches at the back of private land holdings, as previously described.

2.2.2 Agricultural Commodity Prices

According to economic theory, price is established by equation of demand and supply. However, where a considerable time lag exists between the price
change for a commodity and the resulting supply response, Ezekiel's 1938 cobweb relationship may arise (Dean & Heady, 1958). When considered specific to agricultural markets, where a time lag exists between planting and harvesting, the amount planted must be determined before future prices are known. The decision to plant is informed by either past prices (adaptive expectations) or an estimate of the future price based on all available information (rational expectations – John Muth, 1961).

Figure 3: Illustration of cobweb cycle dynamics

Under either form of expectations, there is an error between the expected and realized price. As demonstrated in Figure 3, the equilibrium price is found at the intersection of the supply and demand curves. Just as was discovered in the informal interviews, at some point a poor harvest occurs (period one: t=1). As the corn supplies fail (Q1), a price increase occurs (P1). Given the time lag
between planting and harvesting, the producer assumes today’s price (P1) when making his planting decisions. As the price of corn is high, many producers sow corn in an attempt to gain from the potential windfall. The rapid rise in the area planted (Q2) causes an unexpected reduction in price at harvest time (P2). Equilibrium price is eventually reached after many iterations and cycles towards either the equilibrium price or another poor harvest.

There have been many past studies analyzing cobweb applicability. The cobweb theorem is quite popular in the agricultural economics literature and has been applied to lemons (French & Bressler, 1962), hogs (Dean & Heady, 1958), beef (Ehrich, 1969), apples (Carman & Kenyon, 1969), cherries (Carlton, 1956) and pears (Ricks & Edwards, 1966). Broader analyses of farmer supply dynamics have also been performed to varying degrees of success (Heady et al., 1961; Nerlove, 1958, 1956; Nerlove & Buchman, 1960).

Both Nicholas Kaldor’s 1934 and Ezekiel’s 1938 cobweb theorems require three conditions to explain the functioning of a commodity market. Firstly, producers plan in period t for output in period t + 1 on the basis of prices in period t; (b) production plans, once made, cannot be changed until the following time period; and (c) price must be determined by the quantity sold. All three of these conditions are met in the case of coastal Ecuadorean corn markets.

This study of land use interactions between corn commodity prices and deforestation makes no attempt to model or analyze over the long-term. Despite a focus on the modern period, some historical context and placement of the modern period is of use. The long-term dynamics of hard corn prices are
demonstrated in Figure 4. Real price indices were created through deflation by the United Nations Manufacturing Unit Value (MUV) index (Ocampo & Parra, 2003).

Figure 4: Index of real hard corn market prices (1970=100) and historical change in prices as indicated by natural logarithm. (Data Source: Oxford Latin America Economic Database, 2008)
3: METHODS

3.1 Conceptual Framework

Following the work of Angelsen & Kaimowitz (1999), the interaction between deforestation and agricultural commodity prices can best analyzed through a conceptual framework with five components: (i) magnitude and location of deforestation; (ii) agents of deforestation; (iii) choice variables; (iv) agents’ decision parameters; and (v) macroeconomic and policy instruments.

As a basic analysis of the proximate causes of deforestation in coastal Ecuador, the study hypothesizes that agricultural price is the key choice variable. The probable influence of other agent choice variables is recognized, and is addressed in the discussion section. For this analysis, the magnitude and location of deforestation is the variable of interest. Agricultural supply chains, or individual farmers as hypothesized here, are considered the agents of deforestation (Figure 5).

Finally, although the influence of policy instruments is indirect in this analytical framework, policy has an integral role in any discussion of agriculture. After an initial evaluation of the interaction between Ecuadorean corn prices and deforestation rates, the influence of macroeconomic and policy instruments on both prices and deforestation activities is considered.
Figure 5: Map of corn production chain in Ecuador, representing possible agents of deforestation. (Data Source: SICA, 2003)

3.2 Study Area

The Estuary of Río Chane, Manabí, was been chosen for the study area. Nearly 40% of Ecuador’s corn acreage is located in Manabí province (INEC-MAG-SICA, 2002). The study zone of Bahía de Caráquez and the estuary of the Chone River are located on the western coast of the Republic of Ecuador, approximately to 1°35” of south latitude and 80°25” of longitude west.

As part of the province of Manabí, the study area encompasses three cantons: Sucre, Rocafuerte and Chone (Figure 6). The Río Chone extends from the town of Salinas west-northwest 17 km to the river’s discharge in the ocean at

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3 In terms of production it is much less – yields are quite low compared to national average
Bahía de Caráquez. Surrounded by coastal hills, the drainage and 25km long estuary is formed by the confluence of the rivers Chone and Carrizal (Figure 6).

Bounded by estuary and beaches, the region consists of deciduous dry tropical forest, mangrove and La Segua swamp. Primary forest is prone to strong pressures from agriculture and the wood exploitation. Cultivated area is mainly comprised of forage grass (Paja sp, Panicum sp.) and short cycle crops. Cultivation of peanut and soybean has grown in the last years, propelled by edible oil producing companies that guarantee product purchase. (Almeida-Guerra, 2002). Permanent cultivations occupy a large portion of the land surface and consist of coffee, citric fruits and banana.
3.3 Approach

Traditional trade and commodity models are limited in their examination the near-term impact of output and input prices. Modelling forest clearing in a partial equilibrium framework is possible, to the extent that timber production or cropped areas prove to be good proxies for deforestation. These variables are typically measured through government reported production area or extrapolations of harvest/yields.

Past measurements of self-reported agricultural production acreage are not good proxies for deforestation. Forests can be cleared for different land-uses. As previously discussed, logging frequently does not lead to complete removal of tree cover. Agriculture can expand either at the expense of forest or of fallow and other existing agricultural uses. Given these oversights, I present an alternate and more direct measure of the area of corn in production. Measurement of corn acreage in Manabí through annual satellite imagery will facilitate a more accurate examination of the interaction between corn prices and deforestation.

3.3.1 Deforestation

Studies related to changes in landscape and land-use have been taking place due to Manabi’s growing economic importance. Recent studies were based on GIS techniques to identify different land-use activities in the region. The distribution of these activities was then compared over time by repeated analysis of satellite images (Almeida-Guerra, 2002).
Despite advances in remote-sensing technology, past studies and the often cited FAO deforestation rate for Ecuador all possess a major, critical flaw. Imagery costs often prohibit national level studies from making use of the most contemporary products. Most national level analyses are conducted with sub-optimal data of a broader and cheaper resolution. Generally, there is little need for farm-level data in a national deforestation survey. The differences provided over time between photos at a national scale are sufficient to make estimates of the national rate of change in forest cover.

In national level surveys, NOAA-AVHRR satellite imagery with a resolution of 1 kilometre by 1 kilometre (100 hectares) is typically used. Resolution refers to the ‘graininess’ of remote sensing and satellite imagery. Each pixel on the photo represents a small city. Newer LANDSAT-TM and MODIS technology imagery both have an extensive back-catalogue and resolutions of 30m and 500m respectively. These increased resolutions represent 0.09 hectare pixels for LANDSAT images and 25 ha pixels for MODIS. The common use of reduced resolution NOAA-AVHRR imagery can be primarily attributed to the further reduction in the per photo cost from $2500 to $750 US.

For global and national level surveys, coarse resolution imagery use is scale appropriate. A conceptual problem arises within the literature, however, when sub-national and regional studies begin applying FAO and NOAA-AVHRR derived deforestation rates for household and micro-level studies. The purpose of this study is to link individual farmers’ actions to deforestation. A simple correlation of the FAO’s annual deforestation rate with average corn prices is not
sufficient. National scale data provides neither the information nor resolution required for this task. Farm-level information on the temporal trend of deforestation is required.

To move beyond the FAO deforestation data, changes in agricultural acreage were used as a proxy for deforestation. The change in acreage was calculated using 500-metre resolution Moderate Resolution Imaging Spectroradiometer (MODIS) 32-day mosaics were used to measure annual deforestation from 2000-2005 at a meso-scale. This spectrum of images is offered as an alternative methodology for the FAO that is more financially feasible than global analysis using 30m-resolution LANDSAT images.

The increased resolution of MODIS imagery makes it possible to track farm-level changes in forest cover. Using Multispec™ Image Classification software, the area of forest, grassland, rowed crops, urban and bare soil on each photo were calculated. By comparing data across photos and between years, it was then possible to track the change in forest area to either cropland or bare soil.

For the period 2000-2005, MODIS monthly mosaics of surface reflectance were combined into annual imagery. The annual MOD44B imagery was then processed into a Vegetation Continuous Fields (VCF) product. Each pixel for each annual image was assigned a percent vegetative cover value. Using the temporal spectrum of images, the change in vegetative cover (pixel value) could then be tracked over time. Increases in pixel values represent forest improvement, while decreases in pixel values represent forest degradation. As
outlined earlier, maintaining consistency with the FAO’s terminology, deforestation was defined as a degradation of forest cover below 10%. This process simultaneously establishes a deforestation rate that is specific to the region of corn production and accounts for individual farm decisions.

3.3.2 Commodity Prices

At the farm level, we must also consider the price of corn – the commodity price portion of the discussion. Domestic data is available through the joint World Bank and Ecuadorean Agricultural Census (Servico de Informacion y Censo Agropecuario - SICA) project. For the period January 1996 to December 2006, the World Bank funded the collection and dissemination of domestic prices\(^4\). The agricultural census facilitated the collection of sub-regional market price data for both domestic producer and wholesale prices. International prices are available from the FAO Commodities and Trade Division.

Using the Ecuadorean Census data (SICA), the trend of corn producer and wholesale prices was established for the region. While domestic consumption accounts for 98% of corn production in Ecuador (SICA, 2003), replicability to other regions is essential. As such, an essential step was to determine whether Ecuadorean domestic prices and price increases are similar to that of international price fluctuations. With both commodity price and deforestation trends established, interactions between the two were examined.

\(^4\) World Bank Project ID# P007135
Figure 7: Nominal hard corn prices from January 1996 to March 2006 (Data Source: MAG, 2008)

Figure 8: Real hard corn prices from January 1996 to March 2006, expressed in year 2000 dollars. (Data Source: MAG, 2008)
3.3.3 Interaction between Commodity Prices and Deforestation

With only three FAO data points directly measured in the 1996-2006 period for which domestic corn prices are available, there were clear data limitations. In the best-case scenario, nearly 926 weeks of price data (18 years X 52 weeks) of data would be available. If earlier price data had been published, then all ten (10) FAO Forest Resources Assessment datasets could be processed. The five-year lapses in FAO deforestation measurement necessitated the development of a methodology, which adopts past suggestions of improvements and address ongoing data availability issues.

Medium-resolution MODIS imagery for the inclusive years of 2000-2005 were used to calculate uninterrupted measurements of annual deforested area. It is important to note that the absolute level of annual deforestation, not the rate of change, was measured. With these data, there was sufficient data to evaluate both visual and basic correlations with the more frequent price-series data.

The volume and frequency of data extracted from remote sensing products often proves insufficient for some statistical tests. An alternative to the single observation, annual imagery approach adopted here is the development of a stratified sampling approach for each photo. In spite of this alternative methodology, FAO estimates of the rate of deforestation show that even a massive reduction in the area of one million hectares of forest still shows only a +/- 0.2% variation in the annual rate of deforestation (FAO, 2007).

For an analysis of the influence of commodity prices on deforestation processes, both the limited annual variation and data points realistically require
image stratification to obtain a greater volume of data. As the aim of this study was not to generate regression coefficients, but to examine the broader interaction between commodity prices and deforestation, a stratified sampling approach was not adopted. The core analysis presented is a graphical analysis. Utilization of the varied measurements of deforestation from the literature (Table 1) is assessed in the discussion section.
4: RESULTS

4.1 Agriculture Commodity Prices

As demonstrated in Figure 9, domestic wholesale prices were a strong predictor of domestic producer prices ($R^2 = 0.972$). Optimally, domestic producer prices would be assessed. Producer prices are the most likely information to influence an individual's expectation decision to clear forest for corn production. Given that domestic data was available for only a period of six years, and given the strong association between domestic wholesale and producer prices, wholesale prices were deemed to act as a reasonable measure of commodity prices in Ecuador (Figure 10).

![Figure 9: Scatterplot demonstrating association between Ecuador's real domestic wholesale and producer corn prices](image-url)

Figure 9: Scatterplot demonstrating association between Ecuador’s real domestic wholesale and producer corn prices
4.2 Deforestation Rates

For the period 2000-2005, annual MODIS imagery, as seen in Figure 11 could have been evaluated with the naked eye, without any further processing. Temporal patterns and differences are however, difficult to ascertain in raw MODIS form. By calculating the vegetation percent information for each pixel over time, it was then possible to construct an annual deforestation rate based on actual observations. Annual change in forested area was measured by the net difference in percent vegetation from MODIS imagery (Figure 12). When examining the panel figure, degraded and/or newly deforested areas are
identified in purple/pink. Regenerating areas or those with increasing forest cover are seen in green hues. Areas with unchanged forest composition over time appear clearly in grey.

Spectral histograms were created for each image that summarize individual images by the number of pixels per hue. On a basic level, the difference between the number of green and pink pixels for two photos would be the net deforested rate (Table 2). Year over year change statistics as calculated per pixel are found in Table 3. There appears to be almost no change in the proportion of forested and agricultural land between 2000 and 2005. Forested area increased by 2.2% over the period (green), while agricultural lands decreased by 1.2% (purple).
Figure 11: Manabí, Ecuador depicted as percent forest cover classification of MODIS imagery for 2000-2005 (Data Sources: Hansen et al. 2006; Global Land Cover Facility (GLCF, 2009))
Figure 12: Annual and net change in forest cover for Manabi Province, Ecuador from 2000 to 2005, as interpreted from MODIS mosaic imagery (purple/pink – newly degraded, green – improving/newly regenerating, grey – no change) (Data Sources: Hansen et al. 2006; Global Land Cover Facility (GLCF, 2008))
4.3 Influence of Agricultural Prices on Deforestation Rate

Interaction between real international corn prices and deforestation is demonstrated in Figure 13. Despite a continual rise in corn prices over the ten-year period, the total deforested area in Manabí, Ecuador actually decreased annually. This initial result appears to discredit the informal information from farmers that as real international prices have increased over time, the
deforestation rate has increased (more forested area). When deforestation rates are high there appears to be no direct influence on the amount of forested area.

Figure 13: Interaction between domestic corn prices and Ecuador's deforestation rate
5: DISCUSSION

The use of medium-resolution satellite imagery has revealed that despite higher agricultural prices, deforestation has actually decreased in coastal Ecuador. This directly contradicts the often cited FAO Forest Resources Assessments which have observed more broadly that the national deforestation rate in Ecuador has been rapidly increasing over the same period. Could the findings of this study be applied to the broader region or internationally?

5.1 Agricultural Prices

5.1.1 Temporal and Seasonal Variation

Applicability of this study to the broader region can be explored by an examination of the correlation between real domestic wholesale prices and the international price (Figure 14). A revisit to Figure 8 leads to the conclusion that international and Ecuadorean wholesale prices are not linked (Pearson Correlation Coefficient = -0.015). In real terms, the international hard corn price was nearly stagnant over the ten year study period, while the domestic price continuously climbs. A weak coefficient of determination ($r^2 = -0.103$) and Durbin-Watson measure of nearly zero (0.135) may indicate strong positive autocorrelation in international and domestic price residuals.\(^5\)

\(^5\) Durbin-Watson measures range from 0 to 4, where 2 represents no autoregressive behaviour, and the extremes of 0 and 4 present positive and negative autocorrelation.
Given the Durbin-Watson result and a very weak association between domestic wholesale and international corn prices (Figure 14), an AR1 transformation was performed. Figure 15 reveals the strong seasonal and monthly fluctuations in the domestic price data. This is consistent with the double harvest seasons in Ecuador, wherein the winter plant represents 80% of the total annual harvest. Rainfall during the November to January season is an essential determinate of both winter yields and annual crop success. Beyond the seasonal and annual fluctuations, domestic corn prices began to rise above international prices in September 1998. Given an average domestic corn premium of nearly $98 per metric ton over the ten year period (Figure 16), a discussion of local distortions and environmental factors is warranted.
Price Premium to Domestic Wholesalers over International Prices (USS/Metric Ton)

% Annual Change in Real Hard Corn Price

Figure 15: Percent annual change in international and domestic wholesale corn prices (Data Source: MAG 2008)

Price Premium to Domestic Wholesalers over International Prices

Figure 16: Domestic wholesale price premium over international prices (Data Source: MAG 2008)
### 5.1.2 Domestic Distortions

Higher farm prices, trade liberalization, producer subsidies, and currency devaluations have all been attributed to increased deforestation (Barbier, 2001). Specific to agricultural price and deforestation assessments, Ehrhardt-Martinez (1998) used sectoral inequality as a measure of policy and preference for agriculture against other sectors. Heath & Binswanger (1996) found that the value of farmland far exceeds the capitalized value of farm profits. It is also the case that throughout Latin America, land represents a hedge against inflationary pressures endemic in the region. Soaring inflation and the fixed exchange rate regime up until dollarization in January 2000 reduced Ecuadorean agriculture competitiveness (Wunder, 2001b). It is possible that urbanization drew labor away from land-clearing agriculture during this period.

In studies of Colombian deforestation, John Heath & Hans Binswanger note that “distortions in the land market in Colombia create a price structure that limit farmers’ access to land ownership” (1996, p.65). For the Ecuadorean case, not all deforestation decisions can be attributed to agricultural investment, as land tenure laws require modification of forest cover as proof of productive use. Ecuador remains one of the few remaining countries in the world to recognize squatters’ rights. Forested land that is not in production is frequently the target of squatters and as a result is often deforested in stages to provide proof of residency.
5.1.3 Direct Government Price Interventions

As a member country of the Comunidad Andina (CAN) trading bloc, Ecuador coordinates a basket of commodity prices with fellow member countries Colombia, Bolivia and Peru. The Andean Price Band System (SAFP)\(^6\) has been in place in Ecuador since January 1995\(^7\), as an annually calculated tariff quota, with price floors and ceilings for 13 agricultural staples – including corn. SAFP was initiated with the explicit intention of both stabilizing the volatile cost of agricultural imports and buffer domestic producer/consumer prices from international price distortions.

The base tariff rate for hard corn imports in Ecuador is 15%, which is then subject to a SAFP tariff quota if no bilateral trade agreement exists. Current international corn prices are then evaluated against a calculated floor and ceiling price. Based on the average daily close of FOB international prices over the previous 60 months, price ceilings and floors are calculated each fiscal year by adding and subtracting the standard deviation from the historical average. If the current international price falls within the “band” created by the ceiling and floor, then no additional trade tariff is applied. When international prices are lower than the floor, tariffs are applied to bring the price of foreign corn within the domestic band. Similarly, should the international price be higher than the band’s ceiling, the initial 15% tariff would be reduced.

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\(^6\) Sistema Andino de Franjas de Precios - December 7th 1994, Decision 371 of the Cartagena Agreement Commission

\(^7\) Ecuadorean Executive Decree 2485A - January 30th 1995
It is hypothesized that these price distortions in Ecuador have potentially shifted the preference for investment to agriculture. This would be consistent with the CAN’s stated aim of domestic protection against international price volatility. In the process of protecting domestic agricultural/consumer interests, it is conceivable that this shift in policy preference has externalized the costs to the forest. Forest resources are subsequently undervalued by this domestic distortion, increasing investment in agriculture. Increased domestic area cultivated would require an increased conversion of forest to field.

Although the intention of the Andean Price Band is to protect domestic interests, this conflicts with the observed prices in this study. Despite moderation of international prices for consumers and producers, domestic prices still tended to fluctuate more dramatically than internationally (Figure 8). It is still plausible that that speculation, oversupply and saturation result from investment decisions under high domestic prices.

Further investigation into the abandonment of crops prior to harvest due to a cobweb related price drop, would require this study to focus solely on a single MODIS pixel color. Processing capabilities would have to be focused on only those pixels that were forested in period t-1 (green), became deforested in period t (purple), and within a silviculturally appropriate period had regenerated to forest (green). Any corn-related increase in deforestation represents a short-term investment strategy whereas forest resources in rural Ecuador may actually offer a long-term, emergency form of capital for the poor.
5.2 Trees as Savings – Forestry and the Poor

Earlier in the introduction of this study, it was stated that, “conversion of forest to agricultural lands is therefore potentially survival and livelihood decision”. The relationship between poverty and deforestation is fairly well established (Harrison, 1992). This dynamic is best summarized in that, “the poor are not ignorant of the processes of deforestation or blind to its effect – they cut because they must.” (Eckholm, Foley, Barnard & Timberlake, 1984, p.6) To say that this statement finds ubiquitous acceptance in the literature is untrue.

Literature on asset-based poverty approaches characterize deforestation as either ‘pull’ motives which are opportunity based, or ‘push’ scenarios of survival-driven action. Sven Wunder’s 2001 study of six Sierra villages confirmed the observed phenomenon of local deforestation and inheritance related deforestation. As families grew and resource decisions created intra-family strife, lands were divided and any forested land was cleared on each new parcel to provide for the inhabitant family unit.

Alternatively, Sierra 2001 contests forest-based poverty alleviation as a push motive, but more as a pull. Agricultural deforestation is often viewed as an investment in future land-use and is most often undertaken by capital-abundant, middle-class entrepreneurs. For the poor, the upfront costs of labour and inputs are prohibitive for the landless and/or credit-lacking poor.
5.3 Deforestation Rates

5.3.1 Measurement Difficulties

According to the USGS, inter-annual comparison of the MODIS percent tree cover product (VCF) should be conducted with extreme caution, as there is a plethora of reasons for temporal fluctuations in forested percentage from year to year. It is expected that an official multi-year change product derived from VCF will soon be completed. At present, the only professional product available for change data is the MODIS Vegetative Cover Conversion product. This product however has no coverage for dry-tropical forest regions, which dominate the study area. It was this data limitation that precipitated the author's chosen methodology.

Although the author accepts the note for caution when comparing images temporally, attempts were made to control for the variability found in MODIS-VCF data. The temporal nature of even a single MODIS mosaic accounts for frequent cloud cover endemic to the Andean foothills. Admittedly, clouds cover influence could have been further reduced by utilization of the moisture layer from MODIS. Again, neither time nor funding allowed for the acquisition and process sing of this dataset.

To assess the quality of pixel classification, for sample pixels ground-truthing against LANDSAT images and the 1:1,000,000 scale landscape map of Ecuador was performed. Optimally, classification of imagery requires a stratified ground-sampling exercise where a selection of classified pixels is visited in person to verify a valid land use interpretation. Unfortunately, time and funding
did not permit for a formal evaluation in this manner. The fieldwork previously completed by the author in Ecuador, for a previous project, also allowed for a personal recognition of many land use changes in the imagery.

5.3.2 Agriculture as a Deforestation Proxy

Modelling forest clearing in a partial equilibrium framework is possible, to the extent that timber production or cropped areas prove to be good proxies for deforestation. Using changes in agricultural acreage as a proxy for deforestation also carries certain pitfalls. Although commercial logging is considered a separate deforestation process from agriculture, it can be difficult to differentiate between the two using satellite imagery. A second strong factor against the use of agricultural area as a proxy for deforestation is that acreage expansion may be into non-forested areas such as savannahs and grasslands (Jokisch & Lair, 2002). Once deforestation data has been collected, it is methodologically complicated to differentiate between new and pre-existing deforestation.

Measurements of deforestation by the FAO and in the broader literature fail to draw a clear distinction whether deforested area in year t, also includes newly deforested area tallied in year t-1 that has not yet regenerated.

Beyond the difficulties of measuring agricultural deforestation, it is plausible that commodity prices are not the sole variable driving deforestation rates. As mentioned earlier there are traditional supply models and partial equilibrium trade models for specific agricultural and forest commodities. Although the use of these models is perhaps beyond the project scope, model
makers claim production of these commodities is a direct source of forest clearing. Hence, any factor that stimulates production indirectly induces deforestation. As with other supply and trade models, the principal explanatory variables in these models, as previously described are prices, income and population.

Cannock & Cuadra (1990) model the production area of corn, rice, beans and cassava in the Peruvian Amazon. Total production area was modelled as a function of previous area, output prices, an index of production costs, credit availability and public investment in agriculture. Output prices are functions of international prices, exchange rates, the price of substitutes and government subsidies to grain markets. The anticipated result was a positive effect on total production area.

Elnagheeb & Bromley (1994) present what they call an "acreage response model" for sorghum production in Sudan. Despite a different crop and region of study, their main assumption was that sorghum production is a proxy for deforestation. Expected sorghum prices, rainfall, yield, charcoal prices, production costs and risk determine sorghum area. The first four variables are correlated with higher acreage\(^8\) (and therefore deforestation) and the second two with lower acreage. An additional element to be considered at the household decision level is charcoal prices. High charcoal prices, or other non-timber forest products (NTFP’s) encourage greater land clearing because farmers can partially recoup their land clearing costs by selling the charcoal produced.

\(^8\) Area under cultivation (planted)
Gockowski (1997) emphasizes how changes in cocoa prices affect forest clearing by changing the relative profitability of the various crops planted by farmers. He proposes that a decline in cocoa prices will lead farmers to shift their attention towards plantains and cocoa yams, both of which require more forest clearing. Although the terms of trade for agriculture tend to encourage deforestation, this does not necessarily hold for relative price changes between agricultural products. In fact, lower cocoa prices can actually stimulate higher deforestation, as they induce farmers to shift from perennial crops into more land-intensive annual crops.

In this study these dynamics were not examined, as land use for annuals and perennial crops appear similarly without extensive ground-truthing. The focus of this assessment was to examine the conversion of forest to annual corn production. Future studies may wish to allocate additional resources to ground-truthing, specifically to differentiate between annual and perennial crops.

5.3.3 Challenges of Differing Scales

Basing agricultural and forest-based policy decisions on national level measurements is misguided. Although a direct correlation between corn commodity prices and deforestation rates was not found for coastal Ecuador, the FAO’s increasing rate of deforestation for Ecuador was found to be inaccurate. As the largest producing region of corn in Ecuador, Manabí has actually witnessed a decline in the rate of deforestation despite both increasing corn
prices and decreasing corn yields. Efforts to further interpret this dynamic will rely upon household-level studies to link individual decision-makers with “pixels”.

Agricultural policy decisions, such as Ecuador’s pending land reform and agricultural input pricing policies, should take note of the varying spatial rates of deforestation and clearing. Manabí and neighbouring Esmeraldas province are both commonly cited as the regions with the most rapidly declining forest landbase in the country. While the absolute rate of deforestation remains high and nearly unchanged, this study certainly draws into question the FAO’s claims regarding the rate and direction of second-order change.

5.3.4 Research Value of Deforestation Trends?

To date only one Shafik (1994) has worked extensively with a true rate of deforestation, with most authors preparing absolute deforestation levels. Ehrhardt-Martinez’s scathing 1998 review of the literature noted that most studies to date have found relationships and constructed regression analyses that were “largely atheoretical and methodologically lax”. These studies consisted of correlations between deforestation and variables which were either readily available or already a researcher’s field of expertise. Limited original research has been conducted to capture new data or trends.

Although some may view this study as methodologically lax in its multi-disciplinary approach, an attempt was made to process new data and trends. Beyond the limitations of the research environment, the methodology used here has built upon the past literature. By actually testing the suggested approaches
from prior discussions and conclusions, this meso-level study from coastal Ecuador has attempted to transcend the environment of conflicting relationships for policy makers.
6: CONCLUSIONS

Agriculture and forestry are traditionally portrayed as conflicting land-uses. This study examined the influence, at the farm-level, that corn commodity prices had on deforestation rates in coastal Ecuador. The deforestation literature has previously assumed a positive relationship between corn commodity prices and deforestation rates in Ecuador. These assumptions have to date been based on national-level forest inventories by the FAO, involved limited remote-sensing data and have not been widely examined for Ecuador. It was initially hypothesized that a one-year time lag should exist between the deforestation rates and corn commodity prices.

The results of this study found that no relationship existed between deforestation rates and corn prices in coastal Ecuador. In fact, while the often cited FAO Global Forest Resources Assessments have reported increasing deforestation rates in Ecuador, this study found that deforestation rates have been steadily decreasing in coastal Ecuador (2000-2005). Contrary to the initial hypothesis, the observed decrease in deforestation occurred during a persistent rise in the real domestic price for corn.

A comparison to previous publications shows that these new findings are best attributed to the finer-resolution MODIS satellite imagery and increased (annual) frequency of measurement employed in this study. The intriguing results and innovative, multi-disciplinary approach highlight three important
considerations for future deforestation assessments. First, while the late twentieth century saw the reintroduction of individual decision-makers into the land-use literature, we continue to measure deforestation issues with national-level tools. The increasing availability and decreasing cost of satellite imagery warrants the use of finer-resolution satellite data.

Secondly, the academic community must overcome the widespread reliance on FAO deforestation rates. Each author must consider whether use of these pre-packaged, readily accessible, national-level data is both temporally and scale-appropriate. When FAO data is not appropriate, authors must be willing to adopt alternative methodologies, perhaps borrowing from other disciplines.

The final lesson from this paper is that further study must be conducted to discover the true reason for abandonment of recently cleared, mid-slope fields in coastal Ecuador. Although local farmers have conveyed that domestic corn prices are precipitating cycles of deforestation and crop abandonment, the results of this study are inconsistent with that position. Regardless of the findings of this study, the dynamic of crop abandonment and erosion in rural Ecuador continues. Given the hydrological, economic and climatic vulnerabilities of coastal Ecuador, uncovering the cause(s) of this dynamic is essential to continued growth and prosperity.
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