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# **Impact of United States Corn-based Ethanol Production on Land Use**

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## **Abstract**

The purpose of this research was to determine whether indirect land use occurs and if so to what extent. Indirect land use is a change from non-cropland to cropland (e.g. deforestation) that may occur in response to increasing scarcity of cropland. As farmers worldwide respond to higher crop prices in order to maintain the global food supply and demand balance, pristine lands are cleared and converted to new cropland to replace the crops for feed and food that were diverted elsewhere to biofuels production. We examine the impact of corn-based ethanol production in the United States on land use in other countries.

***Keywords:*** ethanol, energy, biofuel, pristine lands.

## **INTRODUCTION**

Previous investigations have shown that the United States cannot meet its daily energy consumption without depending on foreign countries for supply of energy. The rising cost of production due to dwindling global reserves, transportation, tariffs, and fluctuations in oil prices, as well as concerns about climate change makes it virtually impossible for the US to continue its reliance on petroleum as the prevalent source of energy.

To dampen the effects of oil price shocks on the US economy and reduce the greenhouse gas emissions, policymakers have legislated economic incentives for converting grains to biofuels. The economic incentives have stimulated the production of roughly 12 billion gallons of ethanol, requiring the use of approximately 4 billion bushels or one fourth of the total U.S. corn production. The new demand for corn from ethanol has created price impacts on corn, corn based products and other U.S. crops that compete for the same land resources as corn.

Environmental groups have voiced concerns that the increased crop prices resulting from ethanol production will stimulate the expansion of agricultural production into pristine lands and thus negate any environmental benefits associated with a shift from oil based fuels to bio-based fuel. The degradation of pristine areas due to increased agricultural production has been delineated as “indirect” land use.

According to the International Energy Agency, an estimated 14 million hectares of land were used for the production of biofuels and by-products in 2006, which accounts for approximately 1 percent of globally available arable land. At the global level, projected growth of biofuel production by 2030 could require 35 million to 54 million hectares of land depending on the policy scenario. It has also been predicted that even with modest greenhouse gas

regulations, 1.5 billion hectares, equivalent to current total global farmland, could be under biofuel crops by 2050.

Farmers worldwide respond to higher crop prices in order to maintain the global food supply and demand balance. Some have argued that pristine lands are cleared and converted to new cropland to replace the crops for feed and food that were diverted to biofuels production. However, others have argued that less developed countries in Africa and South America have been aggressively expanding agricultural lands at the expense of pristine areas as a development objective and any relationship between changes in U.S. crop markets and foreign land use is coincidental. The estimated total cultivable area in Africa (807 million ha) and South America (552 million ha) constitute 80 percent of the world's reserve agricultural land. According to Fisher et al 2002, 80 percent of this land is already under crop production. Indirect land use has become an assumed concept and there has been little research to confirm or deny its existence. However, national policies such as the new 2007 Energy Act and the currently debated cap and trade legislation provide two examples where the assumed presence of indirect land use has a major impact on the structure of policy.

The purpose of this research is to determine the existence of indirect land use. The research will provide policymakers with an estimate of the relationship between U.S. land use changes, market prices and the associated amount of pristine land area destruction in Brazil and South Africa.

## **RESEARCH OBJECTIVE**

The objective of this research was to determine the relationship between U.S. land use changes, market prices and the land use changes (indirect land use) in other countries.

The specific objectives are to:

- Determine the impact of increased U.S. biofuel production on corn prices
- Determine the impact of corn prices on land use changes in other countries
- Determine the impact of corn prices on changes in world cropland.

## **REVIEW OF LITERATURE**

The indirect effect of ethanol on land area has been a major focus of recent US biofuel literature and policy. The rise and fluctuations in oil prices, dwindling oil supply and increase in global demand for energy consumption has led policymakers to look into mandates for ethanol production in the years to come (Farrell et al., 2006). As a result of the global challenge for energy, the Renewable Fuel Standard (RFS) mandates in the Energy Independence and Security Act (EISA) of 2007 require that 36 billion gallons of ethanol be produced in 2022. Starting from 2015, this same act requires a minimum of 3 billion gallons per year of ethanol to be produced from cellulosic sources and a maximum of 15 billion gallons to be produced from conventional corn starch. These mandates would bring about an increase in the demand for agricultural commodities, especially the “biofuel crops.”

In the United States, biofuels are mainly produced from corn which is grown on existing agricultural land. Indirect land-use effects may exist if corn is diverted to energy markets from traditional markets such as food, animal feed and high fructose corn syrup. As energy policies encourage more biofuel use the demand for corn will increase, corn prices will rise and

subsequently more acres may shift to corn production. Land use changes, in response to commodity price changes, including shifts within and between major categories (i.e., rangeland, cropland) have been documented in the United States (Mills et al., 1992). Indirect land use changes (the conversion of non cropland to cropland acres due to increased agricultural production) are also expected. Many studies have analyzed the impacts of increased biofuel production on land use change.

Du et al. (2008) analyzed the impact of biofuel on the cash rents for Iowa farmland under hay and pasture. The study investigated the relationships between cash rental rates for cropped land and non-cropland (hay and pastureland). The authors found that the linkage between crop prices and the amount of cropped land was justified by analyzing the effect of product market prices on shares of cropped land in total farmland. The authors analyzed the determinants of cash rental rates for four types of non-cropped farmland using a panel data regression model with explanatory variables such as expected corn price, soybean price, and feeder cattle prices were considered. Other variables used included population density, non-cropland soil quality, and the proportion of non-cropland in each data reporting area. Their analysis demonstrated that an increase in corn price will lead to conversion of non crop land to corn production, thereby leading to an increase in cash rental rates for non crop land. The use of low quality land on an expanded scale to produce feedstock for cellulosic ethanol production would result in demand for nonprime farmland, thereby reducing the pressure on prime farmland rates. Based on their findings, the authors concluded that the long run equilibrium impact of ethanol production on lower grade land is uncertain.

While the Du et.al. study focuses on changes in U.S. land use patterns, the larger concern with indirect land use is the conversion of biodiverse lands to cropland such as the tropical rainforests of Brazil.

Searchinger et al. (2008) estimated the impact of increased use of corn for biofuel production on land use change in the U.S. and other countries. They based their results on a modified version of the FAPRI (Food and Agricultural Policy Research Institute) model for the United States agricultural commodity and biofuel markets. This model was used to estimate changes in cropland in individual countries around the world due to a significant increase in corn-based ethanol using 13 different crops. Historical data on land was used to estimate where new crops will be planted, what land will be converted, and what emissions will result. They found that the rise in ethanol production in the United States by 14.8 billion gallons would divert corn from 12.8 million ha of US cropland and bring 10.8 million ha of additional land into use. Additional use of land would include 2.8 million ha in Brazil, 2.3 million ha in both China and India, and 2.2 million ha in the United States. The basic model results were criticized to be unlikely due to the land effects (Wang and Haq, 2008). First, they considered the amount of corn area diverted to ethanol to be too low and the sizable section of land that was converted to crop use in the basic model results were from pasture and unused crop area. Second, the baseline for global food supply and demand and cropland availability without the U.S. biofuel program is not clearly defined in their model.

Fabiosa et al. (2009) examined the impact of the emerging biofuel market on U.S. and world agriculture using the multi-market, multi-commodity international FAPRI (Food and Agricultural Policy Research Institute) model. The study focused on ethanol expansion in the United States, Brazil, China, European Union (EU), and India. These five countries were



considered in this study because they constitute the bulk of the world ethanol market with Brazil and the United States rated as the largest ethanol producers in the world. The international FAPRI model was used to quantify a sequence of two ethanol shocks: first, an exogenous increase in U.S. ethanol demand, and second, an exogenous increase in world ethanol demand (in Brazil, China, the EU, and India). A “shock” multiplier was computed for land allocation decisions for crops by country. In comparing the shocks, a proportional impact multiplier was computed on key variables and report of their 10-year average values was summarized. The key variables include land, prices, trade, production and consumption. The shock multipliers show the sensitivity of land allocation to the growing demand for ethanol, not only in countries with sizeable ethanol markets but also in other countries growing feedstock crops and crops competing for land with these feed stocks. The study highlighted the movement of land away from major crops competing for land with feedstock crops. The authors stated that, “Due to the high tariff on ethanol in the U.S, increased U.S. demand for ethanol translates into a U.S. ethanol production expansion which was seen to have global effects on land allocation as higher coarse grain prices transmit worldwide”. Changes in U.S. coarse grain prices also affect U.S. wheat and oilseed prices, which also reflect on world markets. They concluded that, expansion in Brazil ethanol use primarily affects land used for sugarcane production in Brazil and to a lesser extent in other sugar-producing countries, but with small impacts on other land uses in most countries. It was revealed that a 1-percent increase in U.S. ethanol use would result in a 0.009 percent increase in world crop area. Most of the increase in world crop area is through an increase in world corn area. Brazil and South Africa respond the most, with multipliers of 0.031 and 0.042, respectively. Their results suggest an impact multiplier of 1.64 million acres per 1 billion gallons

of additional ethanol use, which is lower than the acreage effect estimated in the Searchinger et al (2008) study.

Wyatt et al (2008) conducted an experiment that highlights the sensitivity of land use changes to the assumption regarding the ability of land to be converted from one use to another. They used the FAPRI-MU model of key US agricultural commodity and biofuel markets and representation of world agricultural and biofuel markets. This model is a modified version of the biofuel and agricultural market representation used by Searchinger et al (2008). Based on their findings, an inverse relationship exists between the responsiveness of land allocation (which is a key element of overall supply response in the medium term), and the magnitude of price effects. Wyatt et al. (2008) pointed out that “Brazilian ethanol markets may be as sensitive to prices as US markets and with uncertainties about area and ethanol market effects taken into account, a particular path of US imports may be associated with any number of land use effects”.

Elobeid et al. (2006) used a multi-commodity, multi-country system of integrated commodity models to estimate the impact of increased corn-based ethanol production on US and world agricultural commodities. They found that the total production of corn based ethanol would reach over 36 billion gallons based on an equilibrium corn price of \$4.05 assuming the price of oil to be \$60 per barrel. At this level of production, 95.6 million corn acres would be required to produce 15.6 billion bushels reducing the exports of corn.

Tokgoz et al. (2009) analyzed the impact of crop prices on yields in the long run, especially crops used in biofuel production. The analysis concluded that in terms of first generation biofuels, yield growth is required for the long-term potential of biofuel expansion if land extensification is to be reduced. They found that biofuel expansion may imply increased

land use for feedstock production in the medium term, but growth in the feedstock yields will tend to mitigate the impact on crop prices and land use over the long term.

Ferris and Joshi (2009) examined the effects of increased biofuel production on key agricultural variables and consumer prices using a multi-sector econometric model of US agriculture, AGMOD. This model was developed at Michigan State University, and covers a wide range of major commodities such as livestock, dairy, poultry, and field crop sectors, including by-product feeds. The endogenous variables in AGMOD are those variables that are generated within the model and measure behavioral relationships such as how farmers respond to profits and how consumers respond to prices and availability of products. The exogenous variables are those which are external to the model and enter the solution as assumptions, such as is being introduced by the renewable fuel scenarios. Other exogenous variables include population, per capita incomes, energy prices, interest rates, and exchange rates (Ferris, 2005). They came up with a conclusion that the mandate could be met with a proportionate increase in crop area and a reduction in land under the Conservation Reserve Program.

De La Torre Ugarte et al. (2003) used the POLYSYS model, which comprises various bio-energy crops to study the impacts of biofuel and climatic policy on land use. The four major factors that are included in the POLYSYS simulation are national demand, regional supply, livestock, and aggregate income modules (De La Torre Ugarte, 2000). POLYSYS is structured as an interdependent module system simulating livestock supply and demand, crop supply, crop demand, and agricultural income. POLYSYS is derived from earlier models such as the Policy Simulation Model (POLYSIM) (Ray 1976) and the Regional Allocation Summary System (RASS) (Huang et al. 1988). Crops that are endogenously considered in POLYSYS include corn, grain sorghum, oats, barley, wheat, soybeans, cotton, and rice. The crop supply module is

composed of 305 independent regional linear programming (LP) models, and each represents the land allocation decision in a specific geographic region.

The crop supply module first determines the hectares in each Agricultural Statistical District (ASD) that are available to enter crop production, shift production to a different crop, or move out of crop production. The supply module uses 305 LP models to allocate available acres among competing crops based on maximizing returns above costs.

De La Torre Ugarte et al. (2003) reported that to produce bio-energy on the level needed to make an economic profit, approximately 17 million hectares of agricultural cropland would be needed to be converted to crop acres and bio-energy producing crops. Large scale production of bio-energy crops will have impacts on the agriculture sector in terms of quantities of grain crops available for livestock feed, prices of food for both human and animal consumption, and production location.

Fargione et al. (2008) found that a carbon debt is created when natural lands are cleared and converted to biofuel production and to crop production when agricultural land is diverted to biofuel production, this carbon debt applies to both direct and indirect land use changes. This study focused on different scenarios of wilderness being converted, Brazilian Amazon to soybean biodiesel, Brazilian Cerrado to soybean biodiesel, Brazilian Cerrado to sugarcane ethanol, Indonesian lowland tropical rainforest to palm biodiesel, and U.S. Central grassland to corn ethanol. The carbon debt was defined as the amount of CO<sub>2</sub> released during the first 50 years of this process of land conversion. For the two most common ethanol feedstocks used today, the study found that sugarcane ethanol if produced on natural cerrado lands would take 17 years to repay its biofuel carbon debt, while corn ethanol if produced on newly converted U.S. central grasslands would result in a carbon debt repayment time of 93 years.

Many studies have been carried out by researchers working on the GTAP global general equilibrium model using biofuel markets and detailed land data. Hertel et al. (2008) used the Global Trade Analysis Project (GTAP) model to examine the global land use effect of the corn ethanol mandate in the U.S. and a biofuel blend mandate in the European Union in 2015. This study examined how the presence of each of these mandates influences the other, and also how their combined impact influences global markets and global land use patterns. The study concluded that these mandates are likely to have significant impacts on global land use.

Reilly et al. (2009) used the general equilibrium EPPA model to examine the implications of greenhouse gas reduction targets over the 2015-2100 periods for second generation biomass production and changes in land use. Their simulations suggest that it is possible for significant biofuel production to be integrated with agricultural production in the long run without having dramatic effects on food and crop prices.

Keeney and Hertel (2009) worked on general equilibrium analysis of land use impacts of biofuels with the focus on the role of crop yield growth as a means of avoiding cropland conversion in the face of biofuels growth. They examined the agricultural land use impacts of mandate driven ethanol demand increases in the United States in a formal economic equilibrium framework which allows them to examine the importance of yield price relationships. The study concluded that both the acreage response and bilateral trade specifications are critical considerations for predicting global land use change from the biofuels boom.

Kanlaya et al. (2010) stated that “The Environmental Protection Agency (EPA) used several models to determine the amount of indirect land use associated with biofuels regulations; two of these models used aggregate crop supply elasticity.” California Air Resources Board (CARB) used the Global Trade Analysis Project (GTAP) model to estimate indirect land use,

which uses a U.S. cropland supply elasticity to determine its elasticity of land transformation (Ahmed, Hertel, and Lubowski 2008). GTAP is a computable general equilibrium model that allocates land within a region to maximize total returns to land. It was found that less land is required to produce ethanol when compared to the Searchinger et al. (2008) study. In the CARB study, each additional billion gallons of corn-starch based ethanol requires only 726,000 acres; about 60 percent less compared to the estimates by Searchinger et al. (2008). Primarily as a result of this reduced acreage, CARB estimated that the GHG emissions associated with land use change were 70 percent less than those estimated by Searchinger et al. The GHG emissions due to land use change were reduced from 104 grams of CO<sub>2</sub> equivalent per MJ of ethanol to 30 grams of CO<sub>2</sub> equivalent per MJ of ethanol.

The U.S. and Brazilian components of the FAPRI modeling system, used by EPA, made use of the aggregate crop supply elasticity. The California Air Resources Board (CARB) and EPA concluded that increased crop prices from biofuels expansion will increase deforestation in the Amazon rainforest in Brazil. The logic of this conclusion was based on that fact that increased demand for cropland in Brazil is largely met by converting pasture to cropland. The Global Trade Analysis Project model was questioned by the Renewable Fuel Association (RFA) to reliably predict land-use change impacts. First, the model underestimates the productivity of marginal lands in the U.S. that could be converted to crops. Second, it fails to account for increased gains in crop productivity over time, and does not account for incremental expansion of ethanol production.

Various studies have examined farmers' acreage response, but few of these studies have reported the acreage elasticity at each country's level focusing on specific crops and regions. The acreage elasticity with respect to price in the United States is of importance in understanding

how a change in crop returns, in terms of prices, will affect deforestation rates (Tweeten and Quance 1969). Houck and Ryan (1972) studied the acreage response of corn from 1948 to 1970. They looked into different groups of variables affecting planted corn acreage: government policy, market influence, as well as other supply determinants. Additional variables have also been used to explain changes in agricultural land use. The additional variables include output price (Lee and Helmberger 1985; Tweeten and Quance 1969), expected price (Gardner 1976), acreage value (Bridges and Tenkorang 2009), and expected net returns (Chavas and Holt 1990; Davison and Crowder 1991). Davison and Crowder argued that using expected net returns in explaining acreage is better than using price alone, as net returns account for changes in input prices.

This work differs from previous research in that it focuses on estimating the change in land use resulting from increased ethanol production. It does this by way of using supply and demand equations to reflect how ethanol production affects land use system.

### **IMPORTANCE OF RESEARCH**

This research will help policy makers understand the causes of indirect land use. Certainly, cropland is increasing in some nations at the expense of other land uses. The question is, is this change in reaction to global events such as the US increased demand for biofuels or internal events such as the increased profit associated with crop production versus other land uses.

## CONCEPTUAL FRAMEWORK

The overall objective of this research is to determine the relationship between U.S. corn production and price and the land use changes (indirect land use) in Brazil and other countries.

The supply and demand economic model will be used to determine how producers and consumers respond to changes in the price of corn. The supply-demand model is a partial equilibrium model representing the determination of the price of a particular good and the quantity of that good sold to the market. Economists hold the view that price determines both quantity demanded and quantity supplied.

According to the producer theory, supply and price are proportional, the higher the price of a commodity, the higher the quantity supplied by the producer. In a scenario like this, there is need to look into both supply and demand response to price. Biofuel demand will bring about an outward shift (increase) in the demand curve resulting in higher output leading to an increase in price.

Price can be expressed as a function of quantity supplied, as shown below.

$$P = f(Q_s)$$

Quantity supplied as a function of price.

$$Q_s = f(P)$$

$$Q = \text{Yield} * \text{Acreage planted}$$

Economic theory can be used to explain the response of supply to price or vice versa in relation to US corn ethanol production. The expansion of U.S. corn ethanol production will bring about an increase in demand for corn, resulting in a rise in the market price of corn due to the pressure on supply. The supply curve responds to the prices, it is therefore not static, but a marked shift always occurs after a series of increases in price.



Reese et al. (1992) studied the implications of increased biofuel production and they concluded that “higher crop prices in the biomass scenarios induce a conversion of nonagricultural land to crop production”. Farmers in the U.S. and abroad can respond to the change in the price of corn by increasing their yield, only if the price of corn increases more than the relative price of corn substitutes, this can be justified by the law of supply. Therefore it is important to determine how corn producers and consumers respond to a change in the market price and to know if their response will bring additional land into production. Considering this fact, we need to explore the following key research questions:

- What crop production will be decreased by farmers in response to a higher corn price?
- How will countries overseas respond to a change in the US corn price and will the exports be affected?
- How will demand for corn be met?

Using the model below;

Change in Acreage =  $f(C_p, P_s, W_{pc}, Pop, T, GDP, UEP, \dots, X_K)$

$C_p$ : Price of corn in Brazil / input prices such as fertilizers

$P_s$ : Price of Soybean in US

$W_{pc}$ : World price of corn

$Pop$ : Population

$T$ : Time

$GDP$ : Gross Domestic Product

$UEP$ : U.S Ethanol production

$X_K$ : Other variables

## **RESEARCH FRAMEWORK**

The chart below explains how the ethanol policy will bring a change in both demand and supply of corn. As the U.S. ethanol industry increases its demand of corn, there will be increase in U.S. corn price. Therefore, how will demand for corn be met in United States? There is need for additional supply to meet both the ethanol producers and consumers demand for corn. In order to meet this need, will more land be brought into production of corn overseas?

## **METHOD AND PROCEDURES**

The Environmental Protection Agency (EPA) and California Air Resources Board (CARB) have undertaken research to determine the amount of indirect land use associated with biofuel regulation (Ahmed, Hertel, and Lubowski 2008). In their study, the aggregate crop supply elasticity was used to estimate the land transformation associated with biofuel regulation. In the present research, supply and demand models will be used to determine how producers in Brazil will respond to changes in corn price in the United States. The reason for using this model is to determine how producers response to an increase in demand for corn, as the Energy Independence and Security Act (EISA) of 2007 requires that 36 billion gallons of ethanol be produced in 2022.

Producer theory explains that changes in relative prices lead to changes in input demand. Input demands reflect both the extensive changes (when there is expansion of land for crop production) and the intensive changes (when more inputs are used to increase yield). This model seems adequate and reliable to determine whether the increase in corn price as a result of increased demand will result in the conversion of land in Brazil.

## COLLECTION OF DATA

This analysis focused on the corn production sector in the United States where the impact of the ethanol mandate arises. Data collected from 1960-2008 on corn production, price of corn in US, price of soybeans, world price of corn, corn exports in US from USDA Data and Statistics (Feed Grain Yearbook) were used for the estimation. Data on Brazil land in corn were obtained from the Economic Research Service (ERS/USDA). The reason for considering the world price of corn in this data and not price of corn in the US is that US ethanol policy will bring about increase in demand for corn which will lead to an increase in corn prices in the United States. The US is the world's largest corn exporter and higher prices resulting from increased US corn demand will spill over to world corn market. The price of soybeans will also be used as soybean is a substitute for corn in the ethanol production. The GDP of the main importing countries was calculated as the weighted average of these importing countries per capita GDP. The weight will be determined by the proportion of corn exported to these countries from 1960-2008.

### Econometric model:

Regression analysis was used to determine Brazil land in corn as a function of the independent variables, explained below:

$$Y_t = \beta_1 + \beta_2 Ps_t + \beta_3 WPct + \beta_4 GDP + \beta_5 Pop + \dots + \beta_K et \quad et \sim N(0, \sigma)$$

The coefficients of  $\beta_2, \beta_3, \beta_4, \dots, \beta_K$  are unknown parameters. The parameter  $\beta_{K-1}$  will measure the effect of a change in the variable  $x_{tk}$  upon the expected value of  $y_t$ , while holding other variables constant.

$Y_t$  = Change in Acreage

$\beta_1$  = intercept

$Ps$  = Price of Soybean in U.S.

WPC= World price of corn

Pop: Population

GDP: Gross Domestic Product

UEP: U.S Ethanol production

X<sub>K</sub>: Other variables

### Correlation estimate

#### Brazil Total cropland /Brazil corn Acreage

	<i>Brazil Agricultural area</i>	<i>Brazil Area Corn Harvested (1000 HA)</i>
Brazil Total cropland(1000 HA)	1	0.886724894
Brazil Area Corn Harvested (1000 HA)	0.886724894	1

#### Price of Corn vs Ethanol Production

	Price of Corn	US Ethanol Production
Price of Corn	1	0.58643872
US Ethanol Production	0.58643872	1

#### Price of Corn vs GDP

	Price of Corn	GDP per capita
Price of Corn	1	0.605172089
GDP per capita (constant 2000 US\$)	0.605172089	1

#### Price of Corn vs Population

	Price of Corn	Population, total
Price of Corn	1	0.626324768
Population, total	0.626324768	1

Brazil total cropland was seen to be highly correlated to corn acreage, therefore corn acreage was used for the estimation. Price of corn was also correlated to ethanol production, GDP and population.

In this estimation, corn acreage was used as a function of time and price of corn.

The estimated equation below explains land (acreage) as a function of time and price of corn in Brazil, U.S, Canada and China. The results of this estimate are shown in Table 1 below.

$$Land = f(Time)$$

$$Land = f(Time, Price\ of\ Corn)$$

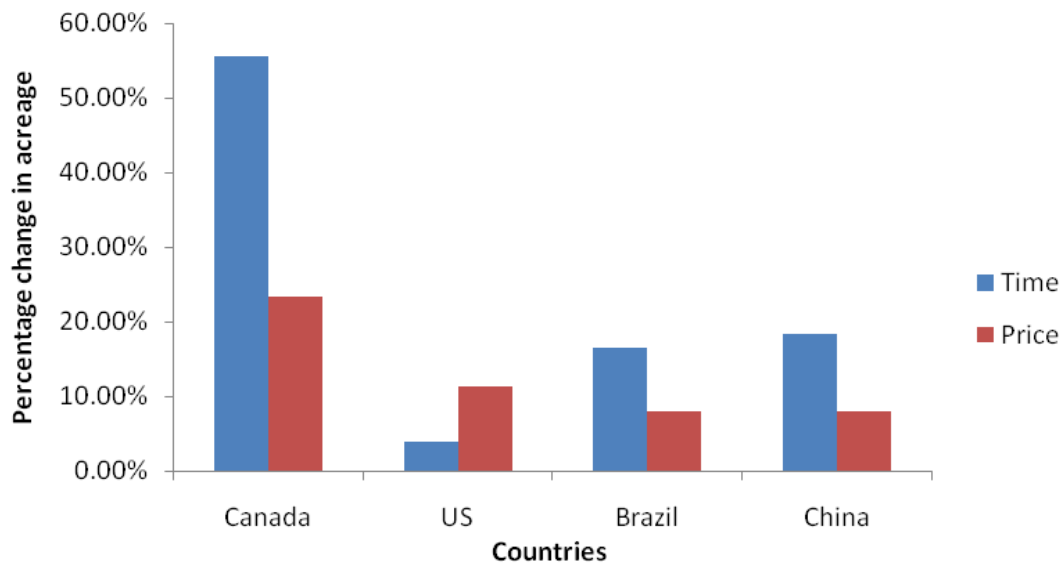


Figure 1 Relationship between acreage, time and price

Table 1. Result of regression for acreage as a function of time and price of corn

Country	Intercept	Time	Price of Corn	Dummy	R <sup>2</sup>	N
Brazil	8.808* (0.034)	0.165* (0.325)	0.079** (0.037)		0.878	50
US	10.007* (0.048)	0.039** (0.023)	0.114** (0.053)	-	0.396	50
Canada	4.789* (0.081)	0.555* (0.038)	0.234** (0.088)	-	0.932	50
China	9.295* (0.052)	0.184* (0.024)	0.079 (0.057)	-	0.788	50
Pooled	8.112* (0.381)	0.236 (0.179)	0.127 (0.412)	0.450** (0.235)	0.046	200

Note: Numbers in parentheses are standard errors, \*\*, \* represent 5% and 1% statistical significant levels respectively.

Result from Table 1 indicates that price of corn and time have positive and significant relationship on land use in Brazil, U.S, Canada and China. By holding other factors constant, 1% increase in price of corn and time would result in 7.9% and 16.5% increase in acreage in Brazil respectively.

Similarly, holding other factors constant, 1% increase in price of corn and time would result in 11.4% and 3.9% increase in acreage in the U.S respectively.

For Canada, 1% increase in price of corn and time would result in 23.4% and 55% increase in acreage in Canada respectively when other factors are held constant.

In China, 1% increase in price of corn and time would result in 7.9% and 18.4% increase in acreage in China respectively when other factors are held constant.

### **Expected Results & Conclusion:**

The outcome of this research will help to determine if indirect land use truly exists and serve as a key indicator to forecast the future supply and demand of grains, as well as address challenges of land mass and its conversion. Based on our current estimates, it is hypothesized that indirect land use from ethanol production is minimal.

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