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# BIOFUEL IMPACT ON FOOD PRICES INDEX AND LAND USE CHANGE

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**ABSTRACT.** Biofuel (ethanol and biodiesel) has played a major role in developing cleaner alternative fuel. However, some papers, mostly based on economic model, have been published that question the use of biofuels, claiming that biofuels cause more land to be diverted to crop production and cause food prices to increase. With over a decade's worth of data since the biofuel boom in the early 2000s, the model predictions were compared with the data and statistical analysis was performed to compare between before and after biofuel era to study the impact of biofuel on food prices and land use change.

Agricultural Census data shows that agriculture land in the United States has decreased each year since the 1950s. Total cropland decreased by 88 million acres from 1950 to 2012. The Energy Independence and Security Act strictly limits the amount of land that can be used for biofuel crop production. Furthermore, papers arguing that biofuels have caused dramatic land use change, based the argument from satellite data, which has been shown inaccurate. In terms of food prices, U.S. food price index in increasing at 2.6% per year linearly with $R^2$ of 0.91 from 1991 to 2015, fully encompassing the biofuel boom. Comparatively, the inflation rate from 1981 to 1991 was 3.8% per year, and the rate from 1973 to 1981 was 8.3% per year. From this research, we have found that biofuels have not had a significant impact on land use change or food prices.

***Keywords. Biofuels, crop production, food prices, fuel crops, land-use change, satellite imagery.***

## Introduction

Biofuel production is a large part of the U.S. initiative for cleaner energy. Reports have shown soybean biodiesel to produce 5.34 to 5.54 units of energy per unit of fossil fuel used in its production and reduce Green House Gas (GHG) emissions by 81.2 percent (Pradhan et al., 2011; Pradhan et al., 2012). Likewise, reports on corn ethanol found an energy ratio of 1.5 when not including byproduct credits, or 2.1 to 2.3 when including byproducts (Gallagher et al., 2016), and a 24 percent reduction in GHG emissions (Flugge et al., 2017). Despite these established life cycle analysis (LCA) results, and similar results from studies by the Environmental Protection Agency (EPA), U.S. Department of Energy (USDOE), and the U.S. Department of Agriculture (USDA), some researchers have reached the conclusion that biofuels are more harmful to the environment than petroleum. A 2008 article in the journal *Science* by Searchinger et al. (Searchinger et al., 2008) was the first widely publicized report discrediting the Renewable Fuel Standard (RFS). The report claimed that past LCA studies failed to count the carbon emissions that occur when farmers respond to higher prices and convert forest and grassland to new cropland. In addition, the authors contended that higher crop prices led to higher food prices, lower food consumption, and poorer diets in developing countries. A 2015 paper by Lark et al. (Lark et al., 2015) also argued the U.S. biofuel boom resulted in significant cropland expansion. As well, a 2015 research paper by DeCicco and Krishnan (Decicco and Krishnan,

2015) claimed that a flawed accounting system engrained in LCA has caused studies to underestimate the $CO_2$ emissions of corn ethanol (*Renewable Fuel Standard*, 2015). Since these reports, the "land use change (LUC)" and "food versus fuel" debates have intensified.

It has been over ten years since the beginning of the biofuel boom. Enough empirical data is available to verify the predictions relating the biofuel production and LUC. Data is also available to determine if food prices rose with increased biofuel production. The purpose of this paper was to determine the accuracy of reports using biofuel models, satellite imagery, and other non-observable methods that have shown unintended consequences of biofuel policies. Statistical analyses were used to determine if there are significant correlations between biofuel production, land use change, and food prices.

## Agricultural Land Use in the United States

Agricultural census data from 1950 to 2012 showed that land dedicated to agriculture has declined. Total acreage decreased by approximately 246 million acres between 1950 and 2012. Some farmland was converted to residential, commercial, and industrial uses, and there was an increasing trend in land used for rural parks, wilderness areas, and wildlife refuges (Nickerson et al., 2011). Total wood land has been in steady decline, falling from about 220.5 million acres in 1950 to 77 million acres in 2012. Permanent Pasture and Rangeland has fluctuated greatly, beginning with 416.8 million acres in 1950 and ending up at 415.3 million acres in 2012. Total crop land has decreased significantly, starting at 478 million acres in 1950 and dropping to 390 million acres in 2012. Total cropland included cropland harvested, cropland used for pasture or grazing, failed/abandoned cropland, summer fallow, and idle cropland (*Census of Agriculture*, 2017).

Harvested Cropland started at a high point of 344.5 million in 1950 and fluctuated greatly, reaching a ten year high of 314.9 million acres in 2012. Harvested Cropland is any cropland that has been harvested for any crop, including tree crops, vineyards, berries, nurseries, and greenhouses. Other Pasture and Grazing Land experienced the most change over the study period. This category included land used only for pasture or grazing that could have been used for crops without additional improvement. Starting at 64 million acres in 1950, Other Pasture and Grazing Land had dropped to its lowest point in the study of 12.8 million acres in 2012. However, there have been definitional changes for this land use type over the years which correlate to significant drops in acreage in this category. This methodological inconsistency doesn't always allow for direct comparisons between the years (Nickerson et al., 2011). Looking at changes in other land use categories, it is likely that land in Other Pasture and Grazing went to other purposes. Summing up increases in Other Cropland, Permanent Pasture and Rangeland, Woodland, and Harvested Cropland, only 7.4 million acres remain that likely went to non-agricultural use.

Along with the USDA Census of Agriculture and FSA crop acreage data, the National Agricultural Statistics Service (NASS) collects data on annual crop plantings. Corn acreage increased from 79.5 million acres in 2000 to 88 million acres in 2015, with a high of 97.3 million acres in 2012. Soybeans rose from 74.2 million acres in 2000 to 82.6 million acres in 2015. Exports of soybeans, vegetable oil, and protein meal have been increasing as wealthier populations shift from staples to more diversified products (Lee et al., 2016). Increasing biodiesel growth also contributed to soybean oil demand, as U.S. biodiesel production increased from 8.75 million gallons in 2001 to 1,260 million gallons in 2015 (*USDOE*, 2017a). While corn and soybean acreage have increased, acreage in other crops has declined. Wheat acreage declined from 62.5 million acres in 2000 to 55 million acres in 2015. There was a modest decrease in sorghum acreage over the study period, with average acreage falling from 8.32 million acres over the 2000 to 2007 period to 7 million acres from 2008 to 2015. Likewise, barley acreage averaged 4.6 million acres from 2000 to 2007 and dropped to 3.37 million acres from 2008 to 2015. Reductions in wheat, barley, and sorghum accounted for much of the increase in corn and soybean acreage (Riley, 2015).

In addition to crop substitution, corn and soybean production benefited from higher crop yields. Corn yields rose from 33 bushels per acre in 1950 to a high point of 178 bushels per acre in 2007 with a slight decrease to 151.94 bushels per acre in 2012 correlating with the drought of 2012. Soybeans also moved from 17 bushels per acre in 1950 to a high of 40.4 bushels per acre in 2007, slightly decreasing to 38.46 in 2012. These increases in yield have not only been for biofuel crops, however. Wheat, for example, steadily increased from 14 bushels per acre in 1950 to 44 bushels per acre in 2012 (*Census of Agriculture*, 2017).

### The EPA's Aggregate Compliance Approach

The Energy Independence and Security Act of 2007 (EISA) limits the types of feedstocks that can be used to make renewable fuel, as well as the land used to produce them. Renewable biomass that qualifies for the program includes planted crops and crop residues harvested from "existing agricultural land" cleared or cultivated and actively managed fallow and nonforested land as of December 19, 2007 (Schnepf and Yacobucci, 2013). The EPA developed an aggregate land use approach to verify the eligibility of renewable biomass. Using the USDA's Farm Service Agency (FSA) crop acreage data, the EPA assesses land use change from year to year. The first step of this approach involved determining the total amount of "existing agricultural land" in the United States at the enactment date of the EISA, which was 402 million acres. Secondly, at the end of each calendar year the EPA conducts a posterior assessment of total agricultural land to determine if the national agricultural land acreage increased above the 2007 baseline. If the EPA finds that the total amount of qualified land used for feedstock production is equal to or greater than 397 million acres – i.e. within 5 million acres of the EPA's established 402 million acre baseline – an investigation is triggered. Using this approach the EPA has determined that the national aggregate baseline of 402 million acres has not been exceeded since the RFS2 was first implemented in 2010 (*Regulation of Fuels and Fuel Additives*, 2010).

### The Conservation Reserve Program

Land exiting the CRP also increased the availability of land for growing crops. The CRP was created by the Food Security Act of 1985, which authorized the USDA to establish contract payments to agricultural producers and landowners to remove highly erodible land from cropland and pasture production for a period of 10 to 15 years. When contracts expire, landowners have the choice of leaving the program or re-enrolling (Sullivan et al., 2004). Cropland offered for the CRP must have been planted to an agricultural commodity in recent years. The maximum amount of land that can be enrolled in the program is set by Congress, typically through Farm Bill Legislation. As of September 2016, about 411,000 acres were approved for General sign up enrollment and over 1.3 million acres in Continuous enrollment. Total acreage under contract was 23.9 million, just slightly below the legislated maximum of 24 million acres set by the 2014 Farm Act (*Conservation Reserve Program Statistics*, 2017). The 2014 Farm Act reduced the CRP acreage cap by 25 percent from the previous 32 million acre enrollment cap set by the 2008 Farm Act. The 2008 maximum of 32 million acres was also a cut in enrollment from 39.2 million acres set in 2002. However, the lower acreage limits largely reflected a declining interest in the program beginning in the late 2000s, as increasing commodity prices enticed farmers to leave the program and return acreage to crop production (Classen, 2016).

## Biofuel Coproducts as Animal Feed

The primary coproduct of U.S. ethanol production is distillers' dried grains (DDG). About a third of every bushel used to make ethanol ends up as DDG, or about 17.5 pounds per bushel (Riley, 2015). DDG output began to increase significantly along with increased ethanol production. By 2005, DDG production had met feed demands at 7 million metric tons. This continued to increase until leveling off at 35 million metric tons of DDG produced and 25 million metric tons of DDG in demand. In recent years, mills started to produce another coproduct by extracting corn oil before the DDG is processed. Data for U.S. biodiesel production showed the use of corn oil increasing from 64 million pounds in 2009 to 1,068 million pounds in 2013 (USDOE, 2017a). In 2015, 1,057 million pounds of corn oil were used to make an estimated 132 million gallons of biodiesel. Adding these coproducts to the ethanol production process has increased the supply of biodiesel and feed without adding more resources, including land, to corn production.

Similar to distillers' grains relationship to ethanol, the production of soybean meal increases as more soybean oil is used to make biodiesel. For every bushel of soybeans crushed, about 11 pounds of oil are produced, along with 44 pounds of the meal which supplies about 19 pounds of protein animal feed (Pradhan et al., 2009). Processed soybeans are the world's largest source of animal protein feed and the United States is the world's leading soybean producer (Ash, 2017a). The amount of soybean oil used to produce biodiesel increased from 1,680 million pounds in 2009/10 to 5,037 million pounds in 2014/15 to help meet the RFS2. The soybeans crushed to produce the soybean oil for biodiesel also resulted in the production of soybean meal, ranging from 7.3 billion pounds in 2009/10 to almost 22 billion pounds in 2014/15 (USDOE, 2017b; M311K – Fats and Oils, 2012).

## Food Price Inflation Rate

Several opponents of biofuel production have argued that biofuel production has increased the prices of biofuel crops and, in turn, the prices of food. However, USDA data shows that while crop prices may be increasing, US food price inflation remained stable through the biofuel boom (Figure 1). Using trend lines, we find that from the period of 1973 to 1981, food prices were increasing at a steady rate of 8.3 percent per year with a coefficient of determination ($R^2$) of 0.99, and standard error of 2.7%. From 1981 to 1991 this had dropped to a rate of 3.8 percent increase per year with an $R^2$ of 0.98 and standard error of 1.7%. Finally, trend lines show that from the period of 1991 to 2015 there was a rate of 2.6 percent increase per year with an $R^2$ of 1.00 and standard error of 1.1%. This period encompasses the biofuel boom, yet does not demonstrate an associated increase in food price inflation during that time period.

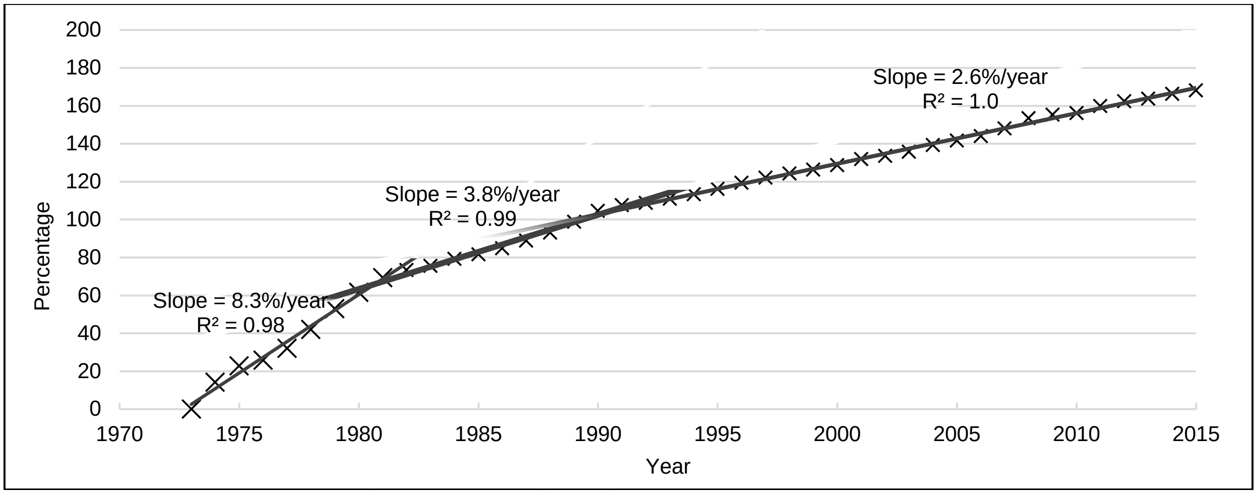


**Figure 1: The United States food price index inflation from 1973 baseline, 1973 to 2015. Source: Kuhns and Levin, 2017.**

While food price inflation rates in the United States have been decreasing, the U.S. has been ramping up biofuel production. Using trend lines, we find that ethanol production from 1980 to 2000 grew at a rate of 67.9 million gallons per year. From 2000 to 2010, the height of the biofuel boom, ethanol production grew exponentially, increasing from 1.6 billion gallons produced in 2000 to 13.3 billion gallons produced in 2010. Growth slowed down from there, with production increasing to 14.8 billion gallons in 2015 (Annual U.S. Fuel Ethanol Production, 2016). Similarly, biodiesel production from 2001 through 2008 also followed an exponential growth trend. This embodied the growth from the production of 9 million gallons of biodiesel in 2001 to 678 million gallons in 2008. From here production fluctuated, reaching 1,263 million gallons in 2015 (USDOE, 2017a).

Crop prices have increased over the course of the study. Corn prices have increased from $1.02 per bushel in 1960 to $3.71 per bushel in 2015. Generally, corn prices remained around $1.00 a bushel until 1973 when prices began drastically increasing. By 1974, prices were at $2.92 per bushel, almost triple the previous price. In 2007, prices began to climb again. Starting at $3.39 per bushel, corn continued to rise to a historic high of $6.67 per bushel in 2012. Prices fell in the final years of the study, reaching $3.71 per bushel in 2015. Soybeans and wheat followed similar trends. Soybeans started off around $2.50 per bushel from 1960 to 1970. From here prices grew, showing a sharp increase in 1973 to $6.50 per bushel. Prices started to rise again in 2007 reaching $7.75 per bushel and maxed out at $14.07 per bushel in 2013. From here prices began to fall, finally reaching $9.49 per bushel in 2015. Likewise, wheat fluctuated between $1.00 and $2.00 per bushel from 1960 to 1972 before jumping up to $4.48 in per bushel in 1974. Prices jumped up again in 2007 to $5.76 per bushel and reached a historic high of $8.01 per bushel in 2008. In 2015 prices had fallen back down to $5.27 per bushel (Good and Li, 2017). While biofuel demand likely had some part in increasing crop prices, there are many other attributing factors, including market speculation, stockpiling policies, trade restrictions, macroeconomic shocks to money supplies, exchange rate, and economic growth. Climate change and spikes in oil and energy prices have also had a large impact on crop production and prices. Oil prices, in particular, can have dramatic effects on food price volatility, with a 1% increase in oil price volatility correlating to a 0.42-0.45% in food price volatility (Tedesse et al., 2014). Economic factors can have a severe effect as well; for example, the export boom of the 1970s caused food prices to sky rocket, with corn prices almost tripling (Ray, 2015). When comparing crude oil prices and crop prices during the biofuel boom, there was a similar pattern in price changes (Figure 2). A significant correlation (0.87) was found between crude oil and corn prices. Likewise, a correlations of 0.87 and 0.89 were found for crude oil vs. soy and crude oil vs. wheat respectively. Similar patterns also arose when comparing crude oil prices to the International Food Price Index (FAO Food Price Index, 2017), demonstrating a calculated correlation of 0.96. A function to predict the International Food Price Index using crude oil price was developed:

$$FPI = 41.78*N+1.24*COP-201.39.$$

Where COP is the crude oil price in $/barrel and N is the global human population in billions. The predicted FPI had a correlation of 0.98 when compared to actual FPI from 2000 to 2015.

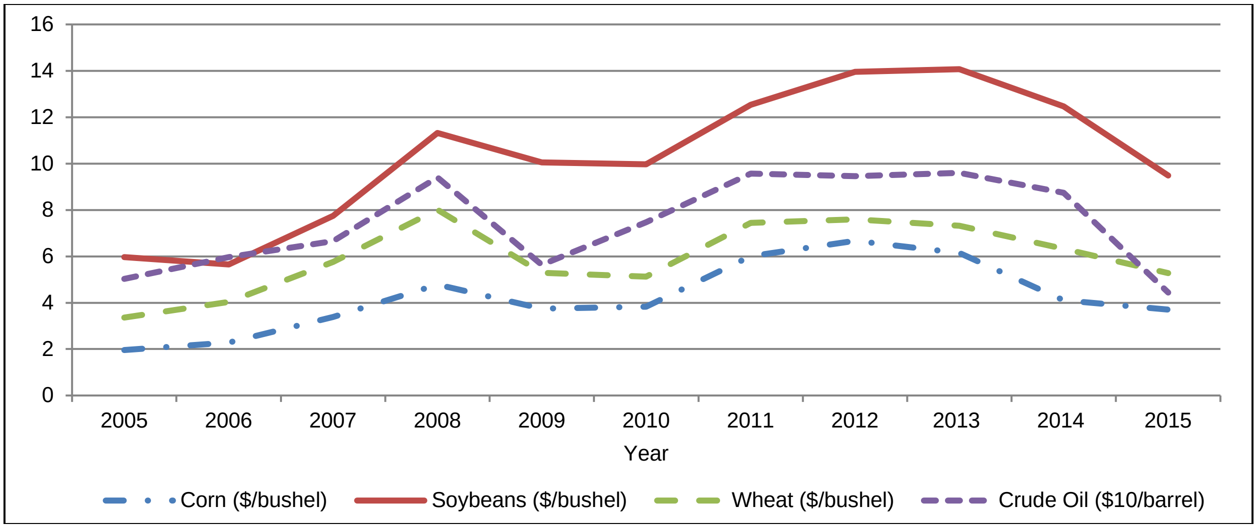


**Figure 2: U.S. crude oil prices compared to crop prices, 2005 to 2015. Sources: Good and Li, 2017; USDOE, 2017c.**

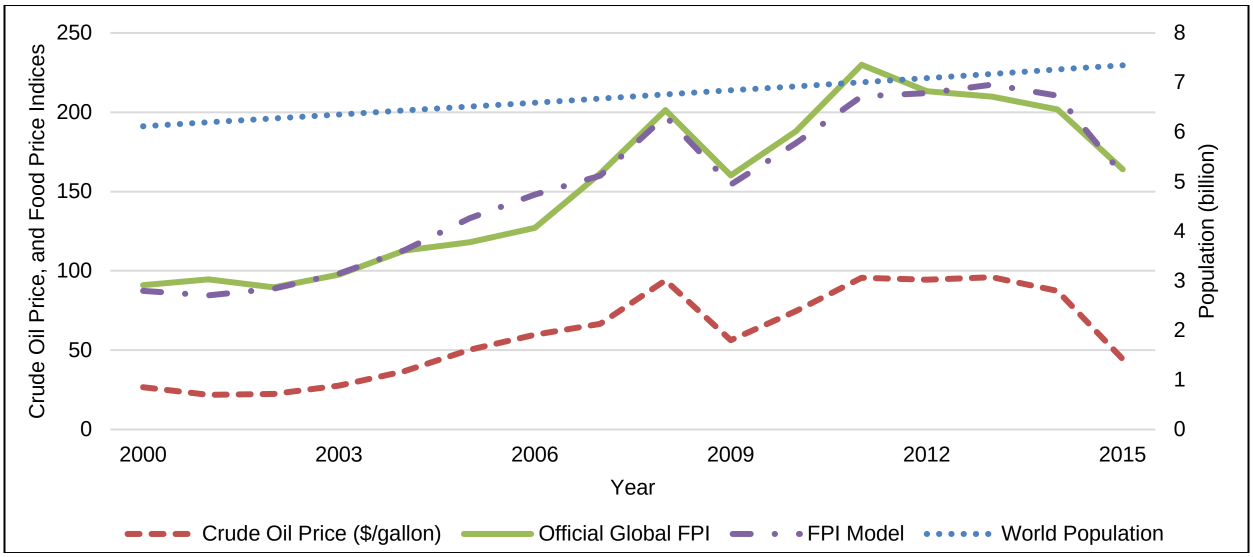


**Figure 3: Crude oil price vs the International Food Price Index, 2000 to 2015. Sources: USDOE, 2017c; FAO Food Price Index, 2017; Population, 2017.**

# Addressing Prior Research

Empirical data does not support claims that increases in biofuel production caused U.S. cropland expansion. For example, Searchinger et al. (2008) results are based on an economic scenario that resulted in annual U.S. corn ethanol production increasing to upwards of 30 billion gallons in 2016. This result is unrealistic as the EISA limits the annual corn ethanol requirement to 15 billion gallons starting in 2015. In order to satisfy the large quantity of corn needed for ethanol use, the model reduces U.S. corn exports by over 62 percent from the 2008 level. With the exception of the 2012 drought year, the largest reduction in corn exports occurred in 2009, when exports fell from the 2008 record high of 2,437 million bushels to 1,849 million bushels. Over the last three crop years, exports have been relatively steady, averaging about 1,895 million bushels or about a 22 percent drop compared to 2008. Also adding to the authors' inflated global acreage requirements were model predictions of sharply declining soybean and wheat exports. However, soybean exports have been increasing since the early 1990s, reaching a peak of 1,843 million bushels in 2014 (Ash, 2017b). Wheat exports have fluctuated sharply over time with no apparent trend since 2000 (Bond and Liefert, 2017; Custom Query, 2017). However, assuming that increases in biofuel production are solely responsible for higher commodity prices is shortsighted. Other factors have played a major role, including increasing world per capita consumption of animal products, rising energy prices, depreciation of the U.S. dollar, slower growth in agricultural productivity, and changes in trade practices in some countries (Trostle et al., 2011).

Another major weakness in the Searchinger et al. paper is assumptions about land conversion. They assume that increases in global corn acreage could not come from existing cropland and would have to come exclusively from deforestation and cultivating grasslands for crop production. However, according to the data found in this report agricultural land has been decreasing in spite of increased biofuel production. Searchinger et al. assumed that China would convert about 5.7 million acres of grassland into cropland, but China adopted policies in the late 1990s to do just the opposite, i.e., convert marginal cropland into grassland and forest land (Wang and Haq, 2008; Bennett et al., 2014).

Using satellite-based data to measure annual U.S. agricultural land use change, Lark et al. concluded that there was a significant amount of previously untouched grassland converted to cropland from 2008 to 2012. As reported above, the Census of Agriculture did show an increase in harvested cropland and a marked decline in cropland used for pasture or grazing. Cropland used for pasture and grazing and CRP cropland are included in the total cropland acreage reported by the Census and qualify for feedstock production under the Renewable Fuel Standard. The use of satellite data cannot provide information on certain land uses as opposed to land covers and land misclassification. This is a common problem with satellite imaging (Mueller and Copenhaver, 2009). For example, satellite imaging can't distinguish between cropland used to grow hay, and pasture land used for grazing (Nickerson et al., 2011). Therefore, much of the converted grassland identified by Lark et al. is likely cropland as defined by the Census. Moreover, a 2013 report by Wickham et al. (2013) found that the National Land Cover Dataset used by Lark et al. to cross-check their work was less than 40% accurate in determining agricultural gain and loss (Dunn et al., 2015). Acknowledging these inaccuracies, the NASS notes "Pixel and acreage counts are not official estimates" when looking at change analysis with the NASS Cropland Data Layer program Lark et al. utilized (NASS, 2016). . Another indication that they likely overestimated the amount of grassland converted to cropland in some states comes from data reported in NASS's Crop Production Annual Summary (*Crop Production Annual Summary*, 2017). Looking at estimates of area planted of principal crops in North Dakota, the survey reported about 23.7 million planted acres in 2008 compared to about 23 million acres in 2012, or about a 735,000 acre decline. In contrast, using satellite imaging data, Lark et al. concluded that cropland acreage expanded by 206,418 acres from 2008 to 2012 in North Dakota.

The well-publicized papers by DeCicco and coauthors have also made claims that ethanol and policies encouraging biofuel production are likely increasing greenhouse gas emissions and causing cropland expansion worldwide (DeCicco and Krishnan, 2015; DeCicco et al., 2016). The authors assert that biofuel production has been causing LUC that in turn increases GHG emissions (*Renewable Fuel Standard*, 2015). However, none of the research papers by DeCicco and coauthors provide any data or other evidence that biofuel production has caused GHG emissions to rise due to LUC. They simply cite other research, namely the papers by Searchinger et al. and Lark et al.

The three papers reviewed above assume that the RFS biofuel mandates could only be satisfied with global cropland expansion. In addition, it is assumed that new cropland would be needed to satisfy the RFS and this could only come from deforestation and converting grasslands. DeCicco et al. and Lark et al. started their analysis with the premise that any LUC occurring since the implementation of the RFS had to be entirely related to biofuel mandates. However, these papers lacked the methodology to measure the correlation between biofuels and commodity prices, feedstock production and LUC, and the effect of commodity prices on food prices.

## Conclusion

Based on model output, and erroneous assumptions, some research paper claimed that biofuel has a negative impact on land use change and food price. This paper compares the land use change trend and food price index before and after biofuel era. The USDA Census data shows total agricultural land declining since the 1950s. Total acreage decreased by approximately 246 million acres between 1950 and 2012. Over the years, farmland shifted to urban uses and there is more land dedicated to rural parks, wilderness areas, and wildlife refuges. There have been definitional changes for this land use type over the years which correlate to significant drops in acreage in this category falsely pointing a shift in land use change.

Focusing on cropland, the Census data recorded about 88.6 million acres less in 2012 compared to 1950, but it has fluctuated over the study period. Annual decisions to use cropland for crop production are generally based on commodity prices, changes in government programs, and expectations of net returns. More evidence that cropland has not been increasing are results from the EPA's Aggregate Compliance Approach, which uses various sources of annual data to track changes in the agricultural land base. Using this method, the EPA determined that total existing cropland, as measured in 2007, has not increased since the RFS2 was first implemented in 2010.

An analysis of food price index from a period of 1973 to 2015, showed a three distinct linear inflation rates. The inflation rate was 8.3% from 19973 to 1981; The rate was reduced to 3.8% from 1981 to 1993 and the inflation rate further reduced to 2.6% per year from 1993 to 2015 with $R^2 = 0.99$ and the standard error of 1.7%. Biofuel mostly started after year 2000. It was argued that the production of biofuel also produces more animal feed such as DDG and soybean meal, which makes 80% of the soybean. It was concluded that biofuel production has had no significant impact on the and had no significant impact on food price inflation rate.

This study points out in the opposite direction to some model predictions claiming that biofuel will increase crop land and that biofuel will aid to food inflation rate. In was concluded that biofuel represent a cleaner alternative to offset petroleum fuel usage with no measurable difference in land use change or food price inflation rate.

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