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Corn-Based Ethanol Production in the United States and the Propensity for Pesticide Use

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Corn-Based Ethanol Production in the United States and the Propensity for Pesticide Use

A Master Thesis

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of

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by

David G. Jones

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Abstract of Thesis

Corn-Based Ethanol Production in the United States and the Propensity for Pesticide Use

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Charles Town, West Virginia

Dr. Elizabeth D'Andrea, Thesis Professor

The purpose of this research is to identify the link between corn-based ethanol production demand in the United States and the increased propensity for pesticide use within large industrial corn cropping systems. Methodology used in this study incorporates increases in herbicide tolerant corn plantings, increases in overall corn planted acres, and trends in corn ending stocks seen in the United States in response to ethanol demand. A correlation between each variable and ethanol production trends will provide insight into their relationship. Findings in this study show positive correlations between specific variables and ethanol production trends. Increasing reliance upon corn crop to facilitate the production of ethanol will likely cause increasing levels of pesticide applications in the future to cope with market volatility as a result of reduced carryover amounts and increases in monocrop corn acreage. New management strategies will be required to reduce the need for greater pesticide inputs to meet ethanol demands.

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Introduction

Farming is vital to the well-being of the world's population. The production of grain, fruits, vegetables, dairy, and meat are completely necessary for the survival, through proper nutrition, of consumers throughout the world. The United States agricultural system is unparalleled with 143 billion dollars in annual sales of crops and 153 billion dollars in annual sales of the livestock category (U.S. Environmental Protection Agency, 2012). Producing these numbers are approximately 2.2 million farms in operation in the United States as of 2012 (Vilsack and Clark, 2014). About 51 percent of the entire land area in the U.S. is used for agricultural purposes (Osteen et al., 2012). According to the USDA 2012 Census of Agriculture, the current total amount of harvested cropland in the United States is 314,964,600 acres. To further reflect the importance of agriculture is the amount of output in the farm sector that has been seen over the years. Agricultural output in the United States has nearly tripled since 1948. Farm production output increased 1.9 percent annually between 1984 and 1999 (Dimitri et al., 2005). Furthermore, the level of farm output in 2009 was 170 percent above the level of output in 1948 (Osteen et al, 2012). Farmers all across the country are discovering new ways to squeeze more production out of the same amount of space.

A review of historical data reveals the extent to which the U.S. farming industry has changed. In 1900 41 percent of the entire U.S. workforce was employed in agriculture. As years progressed, this number began to fall and by 2002 only 1.9 percent of the U.S. labor force was employed in the agricultural sector. Fewer than one million tractors were used in farms in 1930 and by 1960 there were 4.7 million tractors in use on farms (Dimitri et al., 2005). There are obvious reasons for drops in the labor force while agricultural harvests increased. Those being the advent of farm machinery such as combines allowed the farmer/land owner to reach new heights in the planting and harvesting of crops with less manual labor. However, farming "inputs" such as new machinery alone did not bring us to the booming level of agriculture seen today; other chemical inputs were integral during the transition. As the 1900's became a distant memory in U.S. agriculture, so did the variety of crops grown on the farm. Today, the vast majority of large industrial farms are focused on producing one specialty crop (i.e. monocrops) within huge tracts of land, instead of the historical practice of growing several different crop varieties on smaller pieces of agricultural land. Monocrops present their own set of challenges when it comes to controlling pests. One example of this is an increased reliance on pesticides which may be the result of reduced, naturally occurring pest biocontrol systems that have vanished as a result of replacing natural ecosystems with additional crop acreage (Landis et al., 2008).

Compared to years past, the number of farms has fallen from a peak of approximately 7 million in the early part of the nineteenth century to approximately 2.2 million today. Today we have fewer farms that control much larger pieces of crop land. In 2009, small farm operations constituted 88 percent of the total farms in existence, however large scale farms were responsible for more than 80 percent of the total value of production including large scale farms with annual sales of 500,000 or more (Osteen et al., 2012). An airplane ride over the "Cornbelt" of the Midwestern U.S. would reveal vast expanses of agricultural land usually covered by one crop – corn or soybeans. Chemical inputs such as pesticides have made it possible for the increased production of specialty crops within vast expanses of land with less worker involvement.

Pesticides have been a part of Unites States agriculture for quite some time. Using herbicides such as glyphosate (aka Roundup) has become a necessary input for most industrial corn farms. Glyphosate and many other pesticides are used to ensure a quality crop and maintain crop yields by greatly reducing and sometimes eliminating the pressure of a very broad range of pests, including insects and weeds, that would otherwise feed upon or compete with the succulent produce and make it unfit for market sale. What farmers define as pests of agriculture may consist of any number of things including, fungus, viruses, weeds, and even fish. To be expected, there is a particular pesticide chemical that has been engineered toward combating each individual type of pest, there are even pesticides for fish. Add to this, the varying geographic regions of the U.S. that present their own challenges of growing crops as each region is home to its own unique form of pest and climate that farmers must account for. This makes the need for pesticides that much more important, particularly when growing crops in a geographic region that does not mimic the natural type of climate which would be advantageous to the variety of crop being grown. In the United States, farming practices can be split into two main categories: those farms that use pesticides, fertilizers, and other chemical inputs and those farms that do not, i.e. organic farms. Farms that find it necessary to follow a pesticide and nutrient regiment are known conventional or industrial farms.

The United States has been experimenting with pesticides since the 1900's and over the years, researchers have refined the potency of pesticides and created thousands of different chemicals to be used in farm fields all across the U.S. After World War II, the United States saw a dramatic shift toward more reliance on pesticides in agriculture. Pesticides such as DDT were used heavily because of their cheap costs and broad level of effectiveness in controlling pests. However, it was later discovered that this chemical and others like it were detrimental to the environment, and were later banned by government Agencies such as the EPA. Unfortunately, the effect of DDT on bird populations was already in full swing with a number of species such as the Bald Eagle being moved to a federally endangered listing due to plummeting populations as a result of residual contact with the pesticides. In spite of the documented environmental risks, chemical manufacturers continued to develop a host of chemical pesticides. A summary report of 21 selected crops by the U.S. Dept. of Agriculture shows the dramatic increase of pesticide use in the United States from 196 million pounds used in 1960 to 632 million pounds used in 1981. Not only did the amount of pesticides used increase, but the varieties of crops receiving the pesticides increased. The same summary report specifies that only 5 to 10 percent of crops such as corn, wheat and cotton were treated with herbicides (the most common form of pesticide in the United States) in 1952. However, by 1980 herbicide use had become prevalent in 90 to 99 percent of corn, cotton, and soybean farms (Fernandez-Cornejo et al., 2014). In the United States alone, insecticide use has increased 10-fold between the years 1945 and 1989 (Horrigan et al., 2002). According to Pimentel et al. (1993), overall pesticide use within the U.S. had increased 33-fold since 1945. Pesticides have become so prevalent in conventional farming today as a result of the benefits they provide. Most notable is the tangible benefit of direct crop returns (Pimentel, 2005). These benefits are perhaps most clearly accounted for by the fact that some crops like apples and cotton may be treated with pesticides up to twenty times in one season (Pimentel et al., 1993). Unfortunately, the sustained annual application of copious amounts of pesticides is a cause for great concern due the negative environmental and health impacts associated with their use. The U.S. Environmental Protection Agency has identified the impacts of farming practices including the runoff of chemicals to be responsible for 70 percent of the pollution in the nation’s rivers and streams (Horrigan et al., 2002).

In 2005 there were more than 600 different pesticides used in conventional farms all across the United States at an annual cost of 10 billion dollars (Pimentel, 2005). According to the latest United State Department of Agriculture market estimates, 877 million pounds of pesticides were applied to conventional croplands in the U.S. in 2007 at a cost of 7.9 billion dollars (Pesticide Use and Markets, 2012). Of the total applied, the lion's share of 72 percent was comprised of herbicides (Grube et al., 2011). Interestingly, the total amount of cropland utilized today has not significantly increased since 1960. This scenario shows that there is approximately 640 million pounds more pesticides being applied to roughly the same amount of cropland area. Such a pronounced and sustained increase in pesticide use within the U.S. is merely a reflection of the necessity for amplified production of certain crops in response to market demand. Simply stated, pesticides help ensure a healthy crop return in big commercial agricultural operations. This entry seeks to identify the major market influences resulting in pesticide use as they pertain to industrial corn production within the United States. As market demand for corn grain increases, it is important to realize the increases in pesticide application that may accompany it. Increased industrial agricultural acreage of monocrops like corn is likely to cause increased levels of pesticide application. This prediction is especially relevant when presented with the current and future trends of ethanol production and demand within the United States. Exacerbating the effects of market demands on corn production are the tangible effects that global warming may pose to crops.

Pesticide pollution from agricultural applications poses a significant threat to human and environmental health. Pesticide pollution can be the result of pesticides leeching into groundwater supplies, runoff into the natural environment, direct contact, and residual pesticides in food. Humans have been practicing agriculture for more than 10,000 years, but it has only been in the past 50 years that farmers have become so heavily reliant upon pesticides (Horrigan et al., 2002). Over the past 50 years, industrial agriculture and systematic pesticide applications have become synonymous. The major reason for this trend can be seen in the historical data. As a result of pesticide and other chemical inputs, farmers have seen increases in production from 30 bushels of corn per acre in 1920 to 134 bushels per acre in 1999, which equates to a 350 percent increase in crop production (Horrigan et al., 2002). Unfortunately, pesticides have a ripple effect within our natural environment as ecosystem damages occur. Out of the drastic amount of pesticides applied in U.S. agriculture annually, it has been estimated that only 0.1 percent of the chemicals actually reach target pests, leaving 99.9 percent to impact the environment (Horrigan et al., 2002). Environmental impacts of pesticides are far reaching and accounting for every level of damage within animal species and mankind is simply unattainable. Some of the documented negative effects of pesticides to non-target victims include damages to bird populations and predator prey relationships. Prey insects are able to recover faster from pesticide damage than their associated predators (Horrigan et al., 2007). This may cause an explosion of pest numbers as predator species populations are slow to recover, in turn causing more pesticide applications to control pest outbreaks. One of the most documented concerns of pesticide use in recent years has been the impact to honeybee populations across the country. Honeybees and wild bees are so important to the U.S. economy because they are solely responsible for pollinating many types of fruits, vegetables, and other crops. They are also integral to the production of about one third of U.S. and world crops (Pimentel, 2005). There were 4.4 million honeybee colonies in 1985, but a reduction in honeybee colony numbers to less than 1.9 million in 1997 has been attributed to pesticide exposure. Pesticides are known to weaken a bee's immune system leaving it more susceptible to natural enemies such as mites. Pesticides can also disrupt the reproduction and development of honeybees. The majority of the 5,000 species of wild bees in the U.S. have disappeared from agricultural lands as a result of pesticide exposure (Horrigan et al., 2002). It has been estimated that up to 20 percent of all honey bee colonies within the U.S. are negatively affected by pesticides and the economic impact of partial honeybee loss is expected to be approximately 25 million dollars per year (Pimentel, 2005). Beyond the scope of beneficial insects, pesticides entering the natural environment have also been known to compromise the immune function of dolphins, seals, and whales (Horrigan et al., 2002).

To be of greatest concern are the impacts posed to the human population from pesticide exposure. Pesticides and their residues can enter the human body by inhalation, ingestion (residual pesticide in food), and direct skin contact. Certain cancers as well as reproductive and endocrine system disorders may accompany exposures to pesticides (Horrigan et al., 2002). Corn production in the United States requires copious amounts of pesticide applications during critical times of plant development. Two of the most commonly used herbicides in corn production are atrazine and alachlor. These two herbicides are also noted as endocrine disruptors. In 1991, over one half all pesticides used in the U.S. were applied to corn, soybeans, or cotton (Horrigan et al., 2002). Residual consumption of pesticides by the human population provides weighty evidence of the far reaching consequences of pesticide use. The bioaccumulation of residual pesticides within fish and other animals results in apex predators, such as tuna, containing extremely concentrated levels of pesticide residues in comparison with the surrounding seawater. A study conducted in 1967 showed fish eating cormorants to contain internal DDT type pesticide levels 520,000 times higher than the surrounding seawater (Horrigan et al., 2002). These figures show the depth of residual pesticide persistence in the environment and the tendency of human exposure when consuming animal products.

Literature Review

Corn Prominence in U.S. Agriculture

Certain crops are so important to the U.S. economy that in many farms they are grown year after year, i.e. continuously, for up to 3 years within the same fields to keep up with demand. This type of crop production directly conflicts with traditional and more sustainable farming practices that utilize crop rotations and no harvest years to allow the earth a period of rest from particular crop production. The prime example of this increased production phenomenon is corn, which has become the most important staple grain product in our U.S. economy. Corn is an extremely versatile crop that has a number of uses both within the United States and throughout the world. Feed grain for livestock and grain for ethanol production constitute the two largest uses of corn grown in the U.S., with ethanol being a fairly recent addition. Corn accounts for over 95 percent of the total feed grain production in the United States (USDA, 2015). At its peak, corn production in the United States comprised over 95 million acres in 2012-13 (Charts and Maps, 2015). From 2006 to 2007 the amount of corn acreage increased 19 percent nationally, further reducing crop diversity (Landis et al., 2008).

U.S. Corn-based Ethanol Production

As reflected by the abundance of industrial corn acreage within the U.S., the demand for ethanol fuel has also increased dramatically in recent years. The need for alternative energy substitutes is becoming more apparent than ever before in the United States in light of dwindling oil reserves, insecure sources of oil, and the tangible evidence of global climate change in response to burning fossil fuels. Other market and policy incentives that contribute to the push toward ethanol production include historically rising crude oil prices and the enactment of the Energy Policy Act of 2005 and the Energy and Independence Security Act of 2007. Corn-based ethanol production is growing rapidly as an alternative source of combustion energy and the United States is a proven leader in ethanol production. In 2006, an excess of 99 billion pounds of corn grain was used to produce 4.8 billion gallons of ethanol (Vadas, et al., 2008). The United States is churning out large numbers of new ethanol processing plants to receive more corn product at a faster pace. As specified in an Iowa Ag Review published report, there were 105 ethanol refineries producing a combined 5 billion gallons of ethanol in 2006 with another 46 new plants under construction during the same year which would add another 3 billion gallons of ethanol to the equation. Add to this another 300 proposals for new ethanol plants that would incorporate with existing plants to sustain 20 billion gallons of ethanol output annually (Hart, 2006). Since Iowa Ag Review was published, the EPA website for dry mill ethanol states that 145 facilities existed in 2008 with an additional 61 plants undergoing construction (U.S. Environmental Protection Agency, 2015).

The demand for ethanol alone has caused more farmers to plant corn in response to higher profits obtained by its sale. Approximately 20 million acres of crop land has been switched over to corn since the 1980's (USDA, 2015) In 2007, land planted in corn was at its highest level in 44 years with 92.6 million acres of land set aside for this one crop (Osteen et al., 2012). The acreage devoted to corn constitutes approximately one third of the entire agricultural output of the United States and carries the U.S. as the largest producer of corn in the world generating 32 percent of its supply (U.S. Environmental Protection Agency, 2013). 20 percent of corn produced in the U.S. is exported to other countries. In fact, corn is the largest component of global course-grain trade by the U.S. with corn exports reaching 61 million metric tons of product in the years 2006 and 2007 (USDA, 2015). In spite of these already massive figures, projections by the USDA indicate that several million more acres of corn acreage will be needed in the next several years in order to meet industrial demands, which consist largely of ethanol production (Daberkow, et al., 2008). Vadas et al. (2008) further specifies the U.S. goal of replacing up to 30 percent of gasoline use with ethanol by the year 2030.

Since the movement toward ethanol production in the early 2000's, there has been a dramatic increase in the amount of ethanol produced by U.S. refineries. The most recent estimates show over 14 billion gallons of ethanol produced in the U.S. in 2014. This is a giant leap past the 5 billion gallons produced in 2006. Government mandates and policy incentives have combined to create a drastic movement toward the production of ethanol. Surprisingly, the share of ethanol in the gasoline market is relatively small; representing only 3.5 percent of gasoline use by motor vehicles in the U.S. in 2006. In contrast, ethanol represented 14 percent of corn use in the U.S. in 2006. USDA projections show ethanol's share in the corn industry to have increased markedly to 30 percent in the years 2008/10 and hovering there in years to come (Westcott, 2007). Increases in ethanol's share of corn muscle out the shares of other staple uses of corn such as feedstock.

Government mandates along with other policy incentives have created an environment which makes ethanol production more profitable than ever before for refineries and farmers alike. USDA projections show ethanol production to steadily increase past 14 billion gallons annually in years to come (Westcott, 2007). As industrial farming continues to focus on corn production to provide grain fuel as the main component of ethanol production as well as keeping up with food market demands, it is important to realize the role that pesticides will play in facilitating that production. Specifically, the reliance on pesticides in the future as market demand for corn continues to grow.

As ethanol demand prompts further reductions in standard corn crop rotations in favor of 2-3year monocrop systems, the need for stronger levels of pesticide applications will likely occur. This assumption is based on historical data for corn production dating as far back as 1945, when farmers only applied a fraction of the amount of pesticides used today. Corn production in the 1940's used minute and sometimes zero levels of pesticide inputs. During that time, only 3.5 percent of the total corn crop was lost to insect pests. Since that time, and in spite of a 1000-fold increase in insecticide use in corn today, crop losses to insects have increased to 12 percent (Pimmentel et al., 1993). Deferring to information provided by Pimmentel et al. (1993), 40 percent of corn was grown continually without a varying crop rotation as of 1993. In 1993, 60 percent of continuous corn acreage was treated with insecticides as opposed to less than 20 percent of acreage treated with insecticides that included a crop rotation (Padgitt, n.d.). Monoculture corn production is frequently associated with adverse environmental, yield, and cost effects when compared to a more diversified cropping system (Daberkow et al., 2008). The current and growing level of continuous, monocrop corn production appears to contribute to such exponential increases in pesticide use.

Inefficiency of Corn-to-Ethanol

Corn is perhaps the most versatile and profitable crop ever produced, however it is also one which requires the greatest amount of pesticides to be successfully grown in such a demanding setting. Corn requires more pesticides than any other crop grown in the U.S.

(Pimentel and Patzek, 2005). In 2007, the share of pesticides applied to corn crop lands was 40 percent of the total applied in U.S. conventional agriculture acreage (Pesticide Use and Markets, 2012). Of five crops surveyed in 1982, corn was responsible for 52 percent of the entire pesticide use within all five crops (Osteen et al., 2012). The pesticide requirements of corn grown in the United States is shown by the fact that 98 percent of all U.S. corn acreage received pesticides in 2010 with two thirds of those being comprised of herbicides (Agricultural Chemical Use, 2011). In typical conventional corn production scenarios, pesticides may be applied in three phases: before planting, before plant emergence, and after plant emergence. Some of the more common herbicides applied to corn are Acetochlor, Atrazine, 2, 4-D and glyphosate isopropylamine salt. Research by the National Agriculture Statistics Service evaluated 25 States that accounted for 93 percent of corn acreage in the United States. Within this acreage the most common pesticides applied were herbicides consisting of glyphosate isopropylamine salt, Atrazine and Acetochlor. The combined application of these three pesticides alone in 2010 was 136,856,000 pounds. Glyphosate isoproplyamine salt was the most prevalent chemical applied at a rate of 1.065 pounds per acre, or 57,536,000 pounds of herbicide, equivalent to 66 percent of the crop acreage surveyed (Agricultural Chemical Use, 2011).

Pimentel and Patzek (2005) and Vadas et al. (2008) provide solid evidence which suggests that corn is the least efficient method of turning grain into ethanol. A study by Vadas et al. (2008) shows that corn is the least efficient producer of ethanol when grown in a continuous setting as opposed to a rotation schedule with another crop such as alfalfa. Vadas et al. (2008) indicate that offsetting a continuous crop production with planting another crop such as alfalfa reduces erosion and the necessity of fertilizer inputs such as nitrogen. The amount of chemical and mechanical inputs required to sustain a continuous crop such as corn negatively offset the ethanol energy produced from the corn grain. For instance, the increased mechanical tillage requirements with continuous corn promote erosion. Additional inputs of nitrogen are required to sustain a continuous corn crop, whereas rotating plantings with a perennial crop such as alfalfa the need for nitrogen inputs is greatly reduced (Vadas et al., 2008). An added 30 to 50 pounds of nitrogen may be required to sustain continuous corn plantings (Nielsen et al., 2007). Because of these additional mechanical and chemical inputs, Vadas et al. (2008) show that continuous corn only produced two times the energy that it consumes during the growing season. In spite of its drawbacks, the shift toward enhanced corn-based ethanol production has already begun. Recent research shows that continuous corn planting methods currently constitute approximately one fourth of all corn acreage (Daberkow, et al., 2008). Against this backdrop it is important to fully realize the impact that increased corn harvests may have on the environment by looking at the amount of pesticides that may be applied in future harvest years. It should be noted that Vadas et al. (2008) and Daberkow et al. (2008) show that increased pesticide use with continuous corn production is not significantly increased in particular study scenarios. These studies are not without merit, however this entry intends to show that in a broader scope of national corn production, which includes increased plantings of herbicide tolerant crops, there will be a propensity for increased pesticide use as corn-based ethanol demand and global climate change continues.

Future Corn Industry Market Volatility

Perhaps the most alarming result of such a high market demand for corn is the reduction in carryover stocks seen in recent years. 17.5 percent of carryover stock in 2005/06 was reduced to 7.5 percent in the 2006/07 harvest year. Reduced levels of carryover stocks will create a volatile market for corn that is susceptible to market shocks which are triggered by any reductions in production which causes include instances of drought (Westcott, 2007). Other triggers for market shocks will readily include crop losses to pests. Reduced carryover stocks of corn make more apparent the level of market demand and value placed on corn production within the U.S. The inelastic quality of ethanol demand shows a market that does not respond to changes corn price from year to year (Westcott, 2007). Therefore, ethanol demand for corn will remain relatively constant regardless of price points. In response to this level of market demand there will likely be a continuous, high level of pressure placed on industrial agriculture in the future to consistently produce large quantities of usable crop without wavering.

Increased attention to producing only corn will have indirect effects on other crops such as soybeans. For example, corn producers may choose to grow corn continuously for 2-3 years without incorporating a traditional rotational crop such as soybeans. Reduced soybean crop availability due to reduced plantings will cause soybean prices to rise and additionally reduce carryover amounts. This will create a similar volatile market which is also susceptible to market shocks, which may be triggered by crop losses from pests. Increased corn production results in greater market demand for soybeans, which in turn, results in higher market pressure to continually produce a good, clean crop. If industrial corn production continues to consume enormous tracts of land and carryover stocks remain low there may be domino effect of market volatility as other staple crops, such as wheat, are sidestepped by farmers as they pursue the more profitable option of corn production. As a result of ethanol demand for corn, overall market volatility in the agricultural sector as a whole is likely to increase (Westcott, 2007). Instances of crop loss from variations in weather and crop loss from pests will likely become more intolerable than ever before in light of the spread of market volatility in U.S. agriculture. As industrial farming responds to ethanol demand and the ripple effect of market volatility begins to spread there will likely be a shift away from any current or future steps toward Integrated Pest Management practices as farmers express more reliance upon pesticide input to ensure a sellable crop in order to keep up with demand.

Pesticides and Climate Change

Another key element that must be accounted for which has the potential to spur tremendous increases in toxic pesticide use in the future setting of industrial agriculture is climate change. Carbon dioxide in the earth's atmosphere has the nature of trapping heat within that atmosphere causing an overall rise in temperature. Evidence of this trend is seen in rising sea levels, global temperature rise, warming oceans, shrinking ice sheets and overall glacial retreat. Global climate change, and in particular global warming, is most likely human induced (NASA, 2015). Current projections by global climate models have shown global warming to increase by 2.7 to 10.4 F degrees by the end of the century. With that is an increase in global precipitation by 5 to 15 percent (Rosenzweig et al., 2001).

Many would agree that the effects of global climate change have been seen and felt in recent years. Extreme weather events have been occurring all across the globe and one would be hard pressed to examine or even live through one of these events without the notion that something is out of the ordinary. Farmers and consumers alike are expected to be affected by global and regional climate change (Rosenzweig et al., 2001). Increasing levels of climate extremes may promote pest and disease outbreaks within crops (Tubiello, et al., 2007). There is a general expectation that global warming from climate change will cause insect pests to increase in numbers at mid and high latitude regions (Diffenbaugh, et al., 2008). In the setting of an agricultural market that is driven by an inelastic demand of ethanol that will continue and likely become even more pronounced in years to come, there is a real concern as to the catastrophic level of market collapse that can occur when faced with increased pest pressures as a result of climate change. In the U.S., a single severe weather event can pose agricultural economic damages greater than 1 billion dollars (Rosenzweig, et al., 2001). With a future agricultural market of corn that is already strained to keep up with demand, a more concentrated pesticide regimen will likely be the upmost priority of any industrial corn operation in order to help ensure a full crop harvest. It has become apparent that the continued buildup of greenhouse gases contributing to a warming trend will be expected to affect regional infestations of weeds and insects (Rosenzweig, et al., 2001). In light of these predictions, it is more important than ever to set the tone regarding the likely role that pesticides will have in industrial agriculture based on current predictions of increased pest infiltration as climate change continues to progress.

Climate is the main driving force behind successful agricultural production of any sort. Solar radiation, temperature, and precipitation are the main components of crop growth. These three facets of climate can also influence plant diseases and pest infestations. Changes in weather patterns can increase crop vulnerability to diseases and pests. Furthermore, diseases and pests are expected to expand northward in light of changing temperatures (Rosenzweig, et al., 2001). This is particularly concerning when viewing the majority of corn production that occurs in the Midwestern U.S., with northern states such as Indiana, Iowa, and Illinois accounting for the bulk of production. Through climate change projections, one of the most prevalent pests, the corn earworm, is expected to expand its range northward into the upper Midwestern States, a prime area of corn production (Diffenbaugh, et al., 2008). It is difficult to predict the level of increased pest pressures in the future due to varying levels of climate from year to year and the numerous species of pests and their associated characteristics. However it has been determined that there is some level of influence that climate has on pest populations. The spatial and temporal distribution of agricultural pests is determined largely by temperature, light, and water (Rosenzweig, et al., 2001). Earlier insect activity in the spring and the proliferation of some species of insects has occurred in the U.S. and Canada in response to higher temperatures (Tubiello, et al., 2007). With increasing temperatures already occurring and further increases predicted, there is also likely to be a continuing expansion of pest populations and distributions. Precipitation is the most important variable that affects crop-pest relationships with moisture stress having direct and indirect effects that make crops more vulnerable to pests (Rosenzweig, et al., 2001). With an expected rise in global precipitation amounts, this may be the single most important factor to account for when anticipating rises in pest populations in U.S. industrial agriculture. The analyses of most studies show that a warmer climate may cause pests (consisting of weeds, insects and plant pathogens) to become more active and possibly expand their geographical range resulting in an increased use of agricultural chemicals such as pesticides (Rosenzweig, et al., 2001).

Pest Resistance and Herbicide Tolerant Corn

Industrial monocrop systems, including corn production, perpetuate a reliance on pesticides due in large part to pests developing a resistance to those chemicals applied to them. As vast expanses of land have increasingly been gobbled up for monocrop production since the 1940's, the unilateral approach to chemically treating pests within these farms has increased as well. Removing crop rotations and natural predators from the equation and relying solely on chemical inputs year after year has provided the ideal setting for pests to develop chemical resistance. The widespread and consistent use of pesticides has caused target pests which are usually comprised of insects and weeds to develop a frightening level of resistance. A report by the United Nationals Environmental Program has labeled pest resistance as one of the top four environmental problems of the world and crop loss due to pesticide resistance are estimated at 1.5 billion dollars annually (Pimmentel, 2005). Insect species exhibiting pesticide resistance has increased from less than 20 species in 1950 to over 500 species documented in 1990 (Horrigan et al. 2002). Again, this coincides with increases in industrial monocrop production within the U.S. Pesticide resistance alone frequently generates a need to apply several additional applications of pesticides to maintain the same crop yields (Pimmentel, 2005). In light of current estimates regarding global warming, the incidence of pest resistance is likely to compound the need for toxic pesticide use as pest numbers and their geographic ranges continue to expand. Contributing to pest resistance within industrial agriculture is the practice of using herbicide tolerant (HT) crops such as HT corn.

HT crop varieties are a somewhat recent scientific development and have also become a widely popular option for farmers within the past 10-15 years. They are included in the general category of genetically modified organisms (GMO). HT crops are genetically engineered to withstand the direct application of herbicides without dying and the most common HT crops being grown are corn, cotton, and soybeans (Benbrook, 2009). HT crops are particularly attractive to big industrial farm operations that seek to produce a large number of monocrop varieties, such as corn because they allow the farmer to apply certain types of pesticides without regard to crop damage. This simpler approach to weed management affords farmers an easy and flexible management strategy when addressing weeds (Madsen & Streibig, n.d.) HT crops are also particularly attractive to large industrial corn farms which house a minimal labor force to physically address the need for pest management. Farmers have begun to use HT varieties more often because weeds have proven to be the more formidable nuisance when growing crops such as corn (Fernandez-Cornejo, J. and Weschler, S., 2014). One prime example of an HT crop grown today is "Roundup Ready" corn, which is genetically engineered to withstand the direct application of glyphosate (aka Roundup) that would otherwise kill or stunt the crop during the growing season (Benbrook, 2009).

Unfortunately, HT crops have caused an increase in herbicide use of 382.6 million pounds over the last 13 years (Benbrook, 2009). Weed resistance is largely responsible for this increase. It appears that HT crops have not simplified pest management issues, but rather exacerbated the problem by making the management of weeds more difficult and more costly for the farmer. This is due to weeds developing resistance which requires the farmer to apply additional herbicide active ingredients, increase application rates, and spraying singular application herbicides multiple times (Benbrook, 2009). The use of herbicides on HT crops rose 31.4 percent from 2007-2008 and glyphosate use within HT corn fields has reached an average annual increase of 18.2 percent (Benbrook, 2009).

Federal Enactments Push Corn Production

However, in spite of corn's inefficiency in producing ethanol and high pesticide requirements, it remains the primary mechanism for ethanol production in the United States. A land owner's interest in corn is greatly influenced by government subsidy payments which have historically been available to big industrial farms as well as incentive payments provided to oil refineries to purchase ethanol for blending with gasoline. Federal farm subsidy programs, in general, support only a handful of crops, one of which includes corn. In 2012 corn producers received approximately 2,700,000,000 dollars in subsidy payments. Reganol et al. (1990) further specifies that corn, other feed grains, soybeans, wheat, and cotton received three fourths of all U.S. subsidies and those crops accounted for two thirds of all crop land use. Past records indicate that federal and state subsidies for ethanol production totaled more than three billion dollars annually and were mainly received by large corporations, making ethanol production very lucrative (Pimmentel and Patzek, 2005). It appears that corn has undoubtedly become the pinnacle crop in the U.S. for ethanol production and perhaps this transition occurred before the plethora of scientific studies which identify it as the least efficient way to produce biofuel. Regardless, the current level of corn production in the U.S. remains strong at over 80 million acres and growing.

The prevalence of pesticides within our environment in future years due to increasing corn production can largely be determined by the extent to which federal subsidies continue to sponsor ethanol production. The provisions set forth in the Renewable Fuel Standards Program identify the goals of the United States for renewable fuel production in years to come; of which ethanol is a large component. This Program has been in operation since the Energy Policy Act of 2005 and has been further revised based on the requirements of the Energy Independence and Security Act of 2007. According to the program, renewable fuels should become a 26 billion gallon per year industry by 2022 and replace 7 percent of gasoline and diesel consumption (Renewable Fuels Association, 2005-2015). Evidence of the trend toward higher ethanol blends in gasoline can be seen by a recent allowance of refineries to incorporate 15 percent ethanol per gallon of gasoline – previously the blend limit was set a t 10 percent. Also, very recently companies such as DuPont are establishing methods of producing cellulosic ethanol from corn husks. Traditionally corn based ethanol is produced from the corn grain only. Today large companies such as DuPont are investing millions of dollars in research and development in order to extract more ethanol from previously unusable parts of the corn plant such as the husk. These examples are provided to show that intensive pesticide applications will likely grow to ensure crop returns within an expanding industrial corn-to-ethanol farming and market sector that will probably be slow to incorporate other types of ethanol relevant crops on such a large scale based on the fact that so much emphasis is already being place on ethanol produced from corn.

Methodology

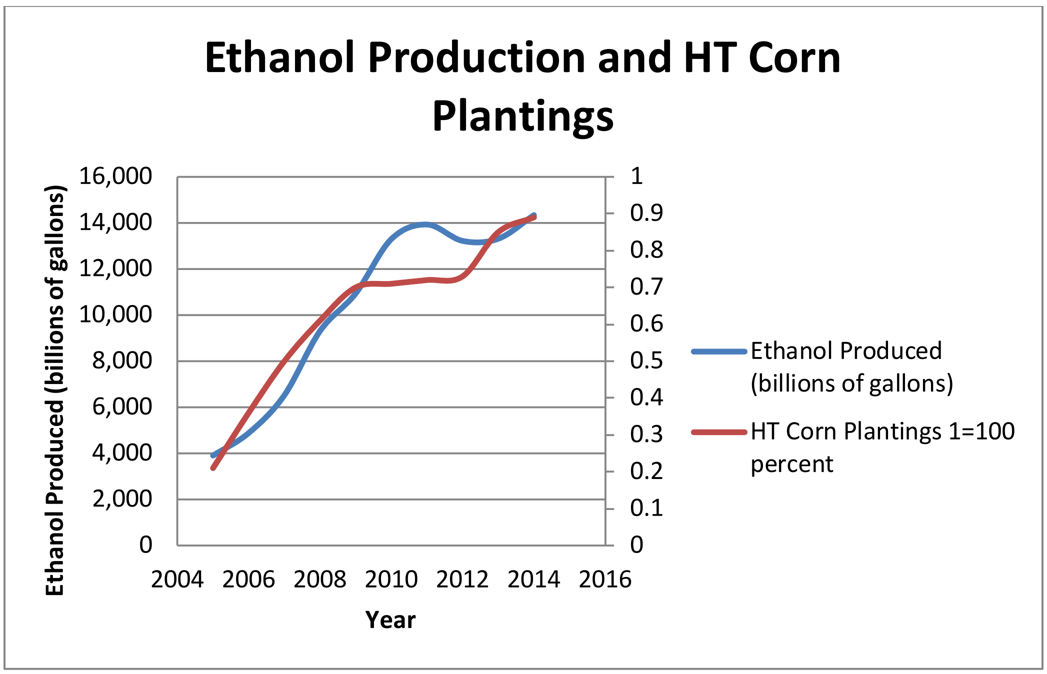
Data Collection Technique

The United States Department of Agriculture (USDA) provides trends regarding the percentage rates of adoption of herbicide tolerant (HT) corn plantings as they replace standard, non-HT plantings in total U.S. corn acreage. This federal statistic will be used in this study to determine the correlation between ethanol production and the trend of HT corn plantings that have occurred in years past.

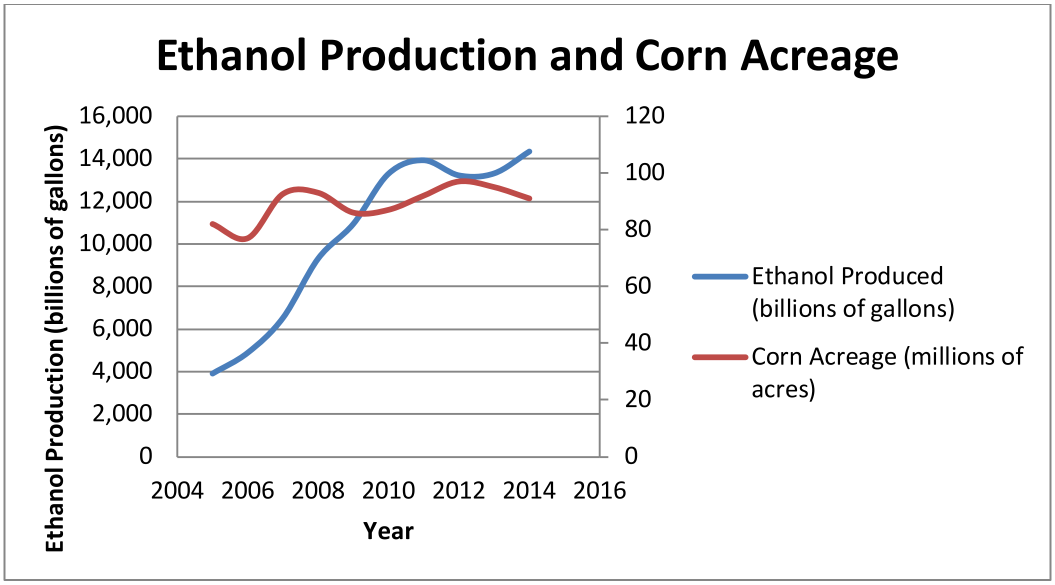
Additionally, a correlation analysis between ethanol production and total annual corn acreage planted will also be conducted. Trends for corn acreage planted are also provided by the USDA. Both correlations will begin with a baseline of 2005 due to the fact that it was the time of enactment of the Energy Policy Act of 2005 in which the Renewable Fuel Standard began operation. Through the initiation of the Renewable Fuel Standard, federal and state government subsidies and associated market incentives for ethanol production began to enter the industrial corn and ethanol industry spurring an increase in production levels. To utilize an analysis that relies on a direct relationship between corn production and ethanol demand as opposed to a correlation between various other ethanol capable crops is justified in this study due to the fact that nearly all ethanol produced in the U.S. is made from corn (Biofuels Issues and Trends, 2012).

Ending corn grain stocks in relation to ethanol production numbers will be correlated as well. The corn ending stock trends in billions of bushels are obtained from The Hightower Report dated April 13, 2015. Start and end years for this analysis will be 2009-2015 due to the extent of previous end grain data provided by The Hightower Report. Furthermore, the production of ethanol for the year 2015 has been calculated at 15,790 (in billions). This figure is the average predicted increase in 2015 when considering the federal ethanol production goal of 26 billion gallons by the year 2022.

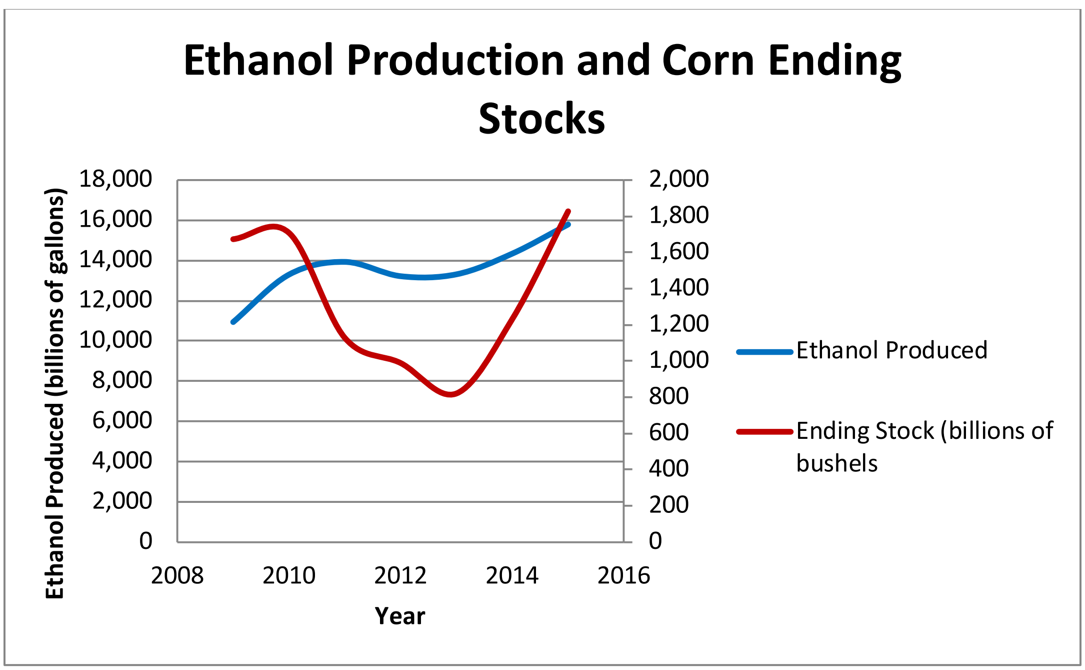
Correlation Analysis



Correlation = 0.951653



Correlation = 0.650844



Correlation = 0.058587

Study Limitations

The reliance upon corn-based ethanol production appears to be ingrained and continuing. However, there remains a small level of uncertainty regarding the incorporation of other ethanol capable crops such as switchgrass or sugarcane. Since corn requires more pesticide quantities than any other crop grown in the U.S., any switch to other forms of ethanol capable crops will likely present some level of reduction in pesticide use. Technological advances in ethanol production may or may not seek other varieties of plants to meet ethanol demand in years to come.

Variances in weather patterns will also play a critical role in the amount of pesticides used. Warmer and more humid growing seasons will likely require greater quantities of pesticide applications to control weeds and insects as this type of environment is more conducive to pest prevalence (Rosenzweig et al., 2001). The USDA has predicted that several million more acres of corn crop land above historical levels will be needed to meet market demand for corn by-products, particularly ethanol (Daberkow et al, 2008). Corn production may expand to warmer and more humid climates or remain in upper regions of the U.S. as existing crop acreage is converted to corn. The intensity of ethanol demand will dictate the extent of spread in geographic range utilized for corn production.

Results

The results of the correlation analysis in table 1 show a very strong relationship between ethanol production and increases in herbicide tolerant corn plantings. Such a strong positive correlation between these two variables is a good indicator of the importance that corn maintains in the ethanol production industry. The importance of corn is illustrated by the increase of herbicide tolerant corn plantings that are thought to promote greater yields, likely in response to greater ethanol demand. It also provides weighty evidence regarding the propensity for increased pesticide use in the future as weed resistance amongst corn plantings continues to grow resulting in increased pesticide application frequencies and inputs.

The relationship of corn acreage and ethanol demand over a yearly spectrum in table 2 shows two variables that coincide nicely. Increases in overall corn acreage will likely include increases in overall pesticide applications, especially in light of increased herbicide tolerant plantings which contribute to weed resistance.

The correlation analysis conducted in table 3 does not show a strong positive relationship between corn endings stocks and ethanol demand on an annual basis. This is to be expected based on the varying output of corn production in the United States due to causal factors such as weather. However, there remains a positive correlation between the two and this will likely become more pronounced in years to come as ethanol assumes its more prominent role in energy production.

Discussion

Market Demands Drown Integrated Pest Management

Integrated Pest Management (IPM) has been looked upon as a viable alternative to indiscriminate pesticide applications since the 1960's. It is perhaps the only substantial governmentally sponsored, subsidized, and studied method of reducing pesticide pollution by offering farmers an alternative and more ecosystem friendly approach to dealing with pests. IPM incorporates the simultaneous control of multiple types of pests, but requires the attentiveness and awareness of the farmer. Regular monitoring of pests and their natural enemies as well as adhering to pesticide thresholds are the most important aspects of IPM and its benefits to the natural environment. The best way to look at IPM is by a farming practice in which farmers seek all tactics (both natural and mechanical) to suppress pests and only looking to broadcast pesticide application as a last resort. The IPM system utilizes crop rotations, intercropping, and other methods of disrupting pest life cycles; one example being the reliance upon natural insect pest predators to control pests instead of chemical inputs (Horrigan et al., 2002).

Unfortunately, to date there has been a significant failure of IPM in its adoption within the industrial agriculture sector. Ehler (2006) identifies three main reasons contributing to difficulty of implementing IPM. Firstly, IPM is demanding and time consuming. This reason alone is enough to steer farmers away in light of the new ethanol demands and overall market volatility due to reduced carryover stocks seen in agriculture today. Second, many pest control consultants hired by farmers are actually employed by the pesticide companies, making any meaningful suggestions in natural pest management a conflict of interest for them. Finally, agricultural pest scientists have resisted the study of IPM as a whole and seem to focus on individual strands of the discipline, resulting in very few pest management strategies capable of accounting for numerous, multi-faceted scenarios (Ehler, 2006). If one were to adopt IPM within the farm setting there must be an accepted percentage of crops that will be lost to disease or pests as the result of more eco-friendly techniques employed to control pests. That type of allowance will not suffice in a changing agriculture industry which leaves little room for error. Industrial agriculture is also drifting away from intercropping and standard crop rotations in light of market demand for corn, further reducing the capacity for natural methods of disrupting pest cycles. For these reasons, there will likely be even less interest in IPM in the future. Sadly, there are few if any, other governmentally adopted approaches for pest management which put ecosystem integrity at the forefront and are known to be successful. In light of these facts, reliance upon pesticides will likely continue and expand in future years. The opportunity for utilizing a quick fix by applying reduced-risk pesticides or planting genetically modified crops will easily outweigh the demands of IPM implementation within the commercial farm setting (Ehler, 2006).

Government Support for Pesticide Research

It is quite possible that there are numerous other ways to grow corn that require less pesticide input. Research into maintaining crop species variations to even a mild degree may be one way which corn production can continue, but with reduced pesticide use. Reducing the level of monocrop corn acreage by incorporating other species of valuable food crop within the same fields may provide a barrier to the spread of species specific pests. This type of research, however, is not the norm. Horrigan et al. (2002) states that of the 30,000 agricultural research projects funded by the USDA listed on their Current Research Information System in 1995, there were only 34 that had a strong organic element. The trend toward pesticide reliance is reflected here by the amount of research contributing to its perpetuation.

Summary

Oil is a finite resource that has been the primary means of fuel for auto transportation and many other energy demands for many years. With an exponentially increasing population base within the United States there will likely be a growing thirst for fuel energy to be used in automobiles and other combustion engines. The U.S. government has poured in billions of dollars in subsidy payments to promote the production and use of ethanol as an early stage blend with gasoline to begin to offset our reliance on oil. However, the concept of corn-based ethanol production appears to have negative effects that are equal to or greater than the energy opportunities obtained from its production. In this entry we have seen the input requirements of monoculture, industrial corn within the U.S. and the potential environmental consequences of its continued use to meet ethanol demands in the future is concerning. The question remains: Do the benefits of lessening oil dependence from corn-based ethanol production outweigh the expanding environmental impacts of pesticides used to facilitate that production? To become increasingly energy independent, the United States may be sacrificing the environmental integrity of our country in the pursuit of increased yields from industrial, monocrop corn production to meet ethanol demand.

Recommendation

This recommendation is based on a realistic and implementable pest management strategy specifically geared toward industrial monocrop systems with a goal of reducing pesticide application amounts. A readily implementable pest management strategy is important in this situation based on the current level of exhibited propensity for pesticide use within industrial corn crop production in the United States. To begin with, an amendment to the Energy Policy Act of 2005 would be the first stage of my recommendation. The amendment would include a provision for appropriating federal and state government funds to pay the cost of employing pest management specialists. The pest management specialists would be employed by the federal government on the basis of an independent, third party contractor. It has been noted by Ehler, (2006) that the current pest managers employed by farms may, in many instances, work for the pesticide companies in which the farm they are consulting acquires its pest management chemicals. Naturally, there is a tendency for the employee to make recommendations that include the prescription of pesticides manufactured by the company they represent. Seeking the employment of a non-associated, independent contractor would thus eliminate any employer/employee conflicts of interest when making valid pest management recommendations they may not include an extensive pesticide regimen. The pest management specialists are to be stationed as temporary or sustained residence on site at industrial monocrop farms throughout the United States with the main goal of providing pest management strategies that put Integrated Pest Management in the forefront.

Further research into this opportunity is needed as a means to reduce the pesticide use in the U.S. At a rate of 837 million pounds of pesticides applied in 2007, there is no reason to believe that his rate will not exceed 1 billion pounds in years to come as the deferred reliance upon ethanol increases.

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