

# **Agroterrorism and the Corn Monoculture in the United States**

**by**

**Richard Greco**

B.Sc., Concordia University, 2010

Research Project Submitted in Partial Fulfillment  
of the Requirements for the Degree of  
Master of Arts

In the

Department of Political Science  
Faculty of Arts and Social Sciences

**© Richard Greco 2012**

**SIMON FRASER UNIVERSITY**

**Summer 2012**

All rights reserved.

However, in accordance with the *Copyright Act of Canada*, this work may be reproduced, without authorization, under the conditions for "Fair Dealing." Therefore, limited reproduction of this work for the purposes of private study, research, criticism, review and news reporting is likely to be in accordance with the law, particularly if cited appropriately.

# Approval

**Name:** Richard Greco  
**Degree:** Master of Arts (Political Science)  
**Title of Thesis:** *Agroterrorism and the Corn Monoculture in the United States*

**Examining Committee:**

**Chair:** David Laycock, Graduate Chair

---

**Alexander Moens**  
Senior Supervisor  
Professor

---

**Anil Hira**  
Supervisor  
Professor

---

---

---

---

**Tsuyoshi Kawasaki**  
External Examiner  
Associate Professor, Political Science, Simon Fraser  
University

**Date Defended/Approved:** June 29, 2012

---

## Partial Copyright Licence



The author, whose copyright is declared on the title page of this work, has granted to Simon Fraser University the right to lend this thesis, project or extended essay to users of the Simon Fraser University Library, and to make partial or single copies only for such users or in response to a request from the library of any other university, or other educational institution, on its own behalf or for one of its users.

The author has further granted permission to Simon Fraser University to keep or make a digital copy for use in its circulating collection (currently available to the public at the "Institutional Repository" link of the SFU Library website ([www.lib.sfu.ca](http://www.lib.sfu.ca)) at <http://summit/sfu.ca> and, without changing the content, to translate the thesis/project or extended essays, if technically possible, to any medium or format for the purpose of preservation of the digital work.

The author has further agreed that permission for multiple copying of this work for scholarly purposes may be granted by either the author or the Dean of Graduate Studies.

It is understood that copying or publication of this work for financial gain shall not be allowed without the author's written permission.

Permission for public performance, or limited permission for private scholarly use, of any multimedia materials forming part of this work, may have been granted by the author. This information may be found on the separately catalogued multimedia material and in the signed Partial Copyright Licence.

While licensing SFU to permit the above uses, the author retains copyright in the thesis, project or extended essays, including the right to change the work for subsequent purposes, including editing and publishing the work in whole or in part, and licensing other parties, as the author may desire.

The original Partial Copyright Licence attesting to these terms, and signed by this author, may be found in the original bound copy of this work, retained in the Simon Fraser University Archive.

Simon Fraser University Library  
Burnaby, British Columbia, Canada

revised Fall 2011

## **Abstract**

Corn is the largest and most valuable crop in the United States and a key component for ethanol fuels, processed foods, and feed for livestock. This crop may be threatened by those seeking to harm the U.S. economy by destroying or rendering corn unusable. Agroterrorism is a subtype of bioterrorism, which would use pathogens or pests to accomplish its goals.

The current measures to protect the United States corn crop from being a target of agroterrorism are inadequate and underestimate the level of damage that could be done. Estimates place damage to corn at levels as high as 70% crop loss and total a worth of billions of dollars. Because of this potentially large impact several solutions are suggested.

The most secure means of protecting the U.S. from agroterrorism is through reduction of monoculture and increasing biodiversity. While some reduction is possible, it is less feasible in the current economic climate, thus the next best alternative is to take more preventative actions.

The best preventative measures the U.S. can take is to create a public/private partnership between farmers, government officials, and biotechnology companies. These groups working together would attempt to detect and predict human manipulation or natural evolution of diseases that would be used by agroterrorists. Ideally these steps would be undertaken on the small scale, using funds from reduced corn subsidies to aid in its growth and development. So long as monoculture remains so widespread in U.S. agriculture, steps should be taken to address the insecurities it creates.

**Keywords:** Agroterrorism; Monoculture; Food Security; United States Agriculture; Corn

# Table of Contents

Approval.....	ii
Partial Copyright Licence .....	iii
Abstract.....	iv
Table of Contents.....	v
List of Tables.....	vii
List of Figures.....	viii
<b>1. Introduction .....</b>	<b>1</b>
<b>2. Nature of the Target.....</b>	<b>4</b>
2.1. The Crop and the Market.....	4
2.2. Vulnerability.....	11
2.3. Consequences .....	16
<b>3. Nature of the threat .....</b>	<b>21</b>
3.1. Relevant Examples.....	21
3.1.1. The Starlink Example .....	22
3.2. Natural Threats.....	24
3.2.1. Invasive Species .....	24
3.2.2. Pesticides and Resistance .....	27
3.2.3. Genetic Engineering.....	28
3.3. Agroterrorism.....	29
<b>4. Nature of the Solution .....</b>	<b>33</b>
4.1. Current Strategies .....	33
4.2. Weaknesses.....	37
4.2.1. Information Sharing.....	37
4.2.2. Preparedness.....	37
4.2.3. Inspections.....	38
4.2.4. Reactivity .....	38
4.3. New Proposals .....	39
4.3.1. Policy Goal 1: Damage Mitigation through Target Reduction .....	42
4.3.1.1. Method 1: Subsidy Reduction or Removal - Biomass .....	42
4.3.1.2. Method 2: Incentivize Corn Substitutes - Biodiversity.....	43
4.3.1.3. Method 3: Incentivize Geographic Spread – Connectivity .....	44
4.3.1.4. Implementation: Timing .....	45
4.3.2. Policy Goal 2: Pre-emption and Dissuasion .....	46
4.3.2.1. Method 1: Pathogenic Prediction .....	46
4.3.2.2. Method 2: Public/Private Partnerships .....	47
4.3.2.3. Implementation: Starting Small .....	48
4.3.2.4. Policy Cost and Feasibility .....	49

<b>5. Conclusion.....</b>	<b>51</b>
<b>References.....</b>	<b>54</b>

## List of Tables

Table 3.1: Characteristics of Natural Threats to Corn .....	25
Table 4.1 Government Agency and Duties .....	34

## List of Figures

Figure 2.1: 2011-2012 U.S. Corn Projected Uses.....	5
Figure 2.2: Corn Price and Yield since 1961 .....	7
Figure 2.3: Corn Price Accounting for Inflation Since 1961 .....	8
Figure 2.4: Corn Subsidies since 1995.....	10
Figure 2.5: Crops Resistance to Transmission: Corn, Soy, Wheat, and Cotton .....	13
Figure 2.6: Corn and Soybean Yield: Bushels per Acre since 1924.....	14
Figure 2.7: Ethanol Corn Supply Flow .....	15
Figure 2.8: Uses for U.S. Corn .....	18
Figure 3.1: Starlink Corn Supply Flow .....	23
Figure 4.1: Department of Homeland Security Spending for Agriculture by Use .....	35
Figure 4.2: Summary of Suggested Policies.....	41



# 1. Introduction

Agroterrorism is the name given to a man-made threat, where terrorists harnessing pathogens or pests target and attempt to destroy the food supply while still in the field. It is a sub field of bioterrorism, which uses living infectious agents to cause death, fear, and social disruption. Unlike bioterrorism, agroterrorism does not seek to cause immediate death or injury, seeking instead to cause economic disruption and cause fear. Corn is the largest field crop in the United States, outstripping the next few crops combined (Agricultural Commodity by Country 2012) which makes it a large target for attack. Due to the concentration of the corn crop geographically and genetically, large stretches of monoculture exist and destabilize the natural world around it by reducing biodiversity and increasing biomass and connectivity of a single crop. In nature whenever there is a large supply of energy, as in large stretches of food crops, animals, insects, or diseases eventually capitalize on this overabundance and grow prolifically. This in turn destroys the food crop as the pathogen or pest spreads from field to field using it for nourishment. Should corn remain such a heavily used crop in such a concentrated geographic area, eventually nature or man may develop a pest or disease that will severely harm the corn supply, at the very least in the short run. Corn is a key product in many industries and is in part responsible for the low-cost foods the U.S. experiences. Due to corn's huge value the situation cannot be left as it is without risking a great shock to the agricultural economy, the food industry, and the welfare of U.S. citizens.

The goal of this project is to provide feasible policy suggestions that tackle the shortcomings within the current methods of reducing the threat of agroterrorism. This work is meant to address those in a position to influence or create policy concerning agroterrorism and as such is primarily educational and prescriptive. To understand the potential dangers and gaps in policy that exist toward agroterrorism, this research has been organized in the following manner.

The second section, 'Nature of the Target', examines why corn is an ideal target for agroterrorists. Corn is an integral commodity worth over \$28 Billion between several industries including livestock, ethanol fuels, and processed foods (Agricultural Commodity by Country 2012). In addition to being a valuable target, corn, being an extremely large monoculture in the U.S., has several characteristics that create vulnerability. Biomass, biodiversity, and connectivity are criteria by which to see if a crop is vulnerable, and corn has high risk in each of these sectors. Corn is tightly packed together geographically and is lacking genetic diversity, creating a dangerous combination of weaknesses that could be exploited.

The third section, 'Nature of the Threat', shows what form and damage diseases or pests could have on crops, and which are worth more consideration and why. There have never been any documented cases of agroterrorism thus far. However, drawing on historical natural biological disasters, such as the Great Potato Famine of Ireland, important comparisons and equivalencies may be drawn. Understanding the natural threats to crops means understanding the tools agroterrorists could use to inflict harm. Certain diseases and pests to corn represent significantly more danger than others and will be examined. It can be assumed that the natural threats to corn would be enhanced and exacerbated by strategic planning and contamination. As such the natural threats could be seen as a baseline, from which point human acts could bring about even more dramatic effects.

The fourth section, 'Nature of the Solution', evaluates current policies and offers methods to compensate for what the status quo lacks. These solutions are not to be taken as monolithic. Rather, these solutions are often synergistic with each other and can be used in varying degrees to reach specific levels of solutions. Each method within each policy goal can stand on its own and will play a part in reducing the vulnerability of the United States corn crop.

The primary policy goal, called Damage Mitigation through Target Reduction, opts for reducing the size of the corn crop before any damage could be done. The first method to achieve damage mitigation would be to rework the subsidy structure in place for agriculture to reduce the amount of corn produced as well as its concentration. The second method would be to promote corn substitutes, thereby reducing demand for and

reliance on corn. The third method would be to promote the geographic spread of croplands so that there are areas of different crops between fields of corn. The second set of policy goals, called Pre-emption and Dissuasion, desire more preventative measures to be taken to counter agroterrorism before taking place rather than relying on reactive policies. These options leave corn as a large crop but attempt to prepare for and prevent any such attack. The first method to achieve pre-emption is to create a continually operated set of laboratories to track and predict progression of diseases and other threats to crops. The second policy goal would be to promote or create public/private partnerships that enhance information sharing between agencies and reduce costs by splitting them between actors. Ultimately a set of incentives to create a more biodiverse set of crops in general should be implemented to curtail any risks agroterrorism could pose.

It will be concluded that a mixed solution using the funds from lowered subsidies to finance laboratories and support a public/private partnership would be both feasible and effective.

## 2. Nature of the Target

The goal of the following sub-sections is to elaborate on why corn is currently at risk, and what some consequences of such risk could be. It will be concluded that corn is vulnerable, and a substantial loss of yield in the short or long term would significantly damage the U.S. economy and harm several major industries. Furthermore, the subsidy system within the U.S. aids in promoting three key indicators of vulnerability: biomass, low biodiversity, and connectivity. Agriculture in the United States has grown to encompass three major food crops above all the others: corn, wheat and soy. Corn is by far the largest in volume, totalling over 316 billion metric tons (MT) in 2010 dwarfing both soybeans and wheat combined, with soy totalling 90 billion MT and wheat 60 billion MT (Agricultural Commodity by Country 2012). As such, there is a huge energy and food cost that can be attributed to the destruction of this crop, with corn containing far more biomass than many of the other largest crops combined.

### 2.1. The Crop and the Market

Corn is not just a crop; it is the crop that has overtaken all others in in the United States in just a few decades. It is versatile and can make the best use of the nitrogen rich fertilizers that are cheap and accessible to farmers (Pollan 2006). Not only is the corn crop worth almost \$30 billion (Agricultural Commodity by Country 2012), but the majority of it is consumed within the United States, as seen in **Figure 2.1**. The two primary uses of corn are either as animal feed, or a fuel, with the Dried Distillers Grains (DDG) first being used as a fuel, then as a feed. One variety of corn, Yellow Number 2, stands above the other genetic strains being by far the most popular (Pollan 2006). Its popularity, however, limits the biodiversity of the crop and creates something dangerously close to a perfect monoculture. Even though the U.S. out-produces every other country in corn grown, it still has a much lower level of genetic diversity in its crops (Vigouroux et al. 2008). Understanding more about this crop and its place within the

economy will be valuable to creating a policy that will tackle the problems this monoculture creates.

**Figure 2.1: 2011-2012 U.S. Corn Projected Uses**

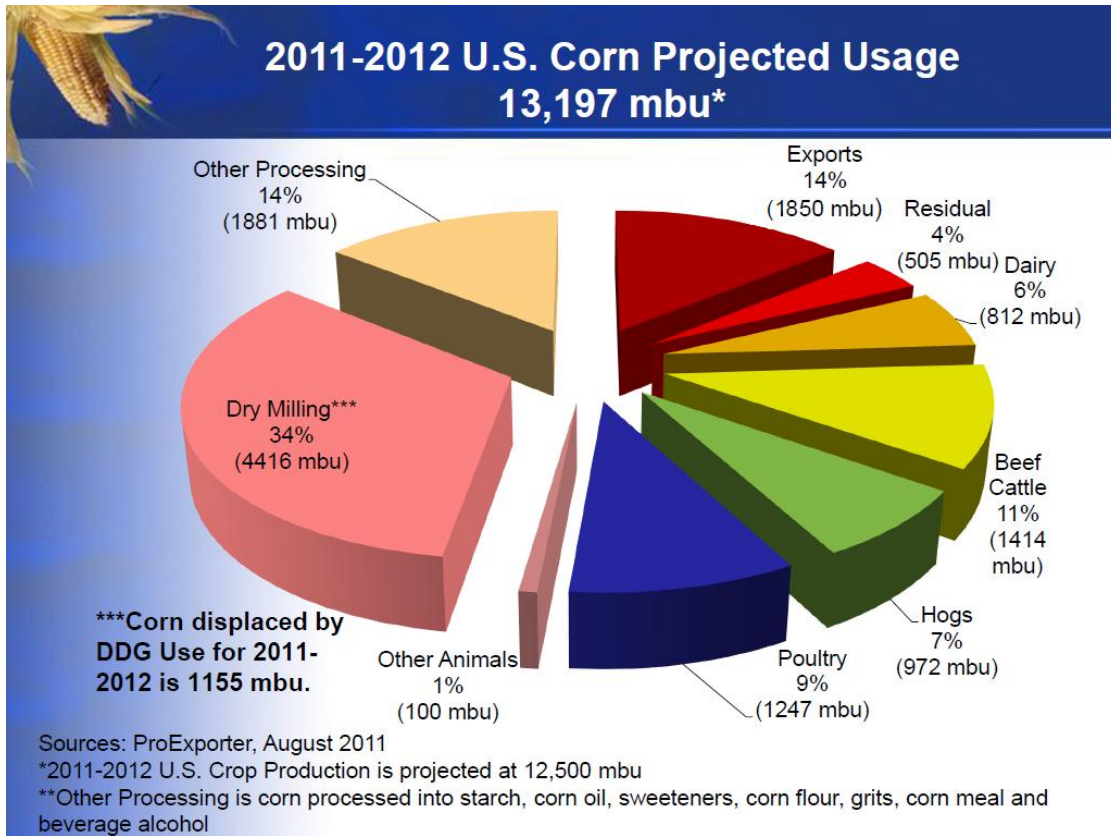


Image Taken From: 2011-2012 U.S. Corn Projected Usage 2012

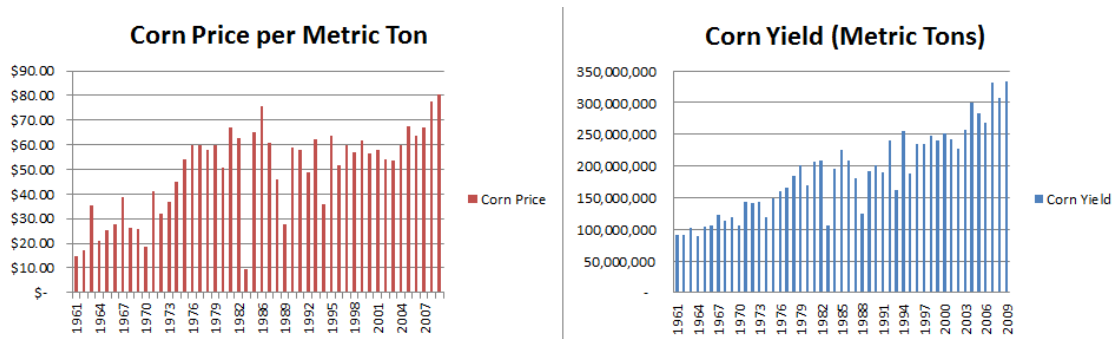
Monoculture is an unfortunate result of the industrialized agricultural system in place today in the United States. To stay competitive and create the most efficient yield per acre ratio for a given crop, certain measures are taken. Genetic strains that provide higher yield, more resilient crops, or are otherwise more economically valuable are chosen over the other varieties of the same crop (Vigouroux et al. 2008). This method values money over diversity of genes, which in the natural world is a dangerous path to go down (Pollan 2006). Genetic diversity is one of the foundations of success in the plant and animal world, allowing the most capable varieties to survive and carry on their genetic strain. Economies of scale also force farms to be economically viable by having larger plots of land with more corn per acre and using larger scale equipment to harvest

corn most efficiently. This creates tightly packed fields, all with very similar genetic strains of corn. The economic maximization process has other effects on the agricultural and food industries of the United States.

With most people encountering food only at supermarkets in North America, it is easy to forget that food needs to be grown, cleaned, processed, bagged, tagged, boxed and freighted many kilometers before reaching someone's plate. It would probably be safe to say that most people in the United States take for granted that there will be food available despite weather, economic crises, or political events. Fewer citizens are working directly in the fields and in the growing phase of the agricultural process, yet more food is being produced than ever before (Agricultural Commodity by Country 2012). As time goes on the proportion of the population involved directly with the beginning of the food chain is diminishing (Diakosavvas 2011). Less than 2% of U.S. population concern themselves with farming, leaving the other 98% far less connected to the food they consume every day (Corn Farmers Coalition 2012). This increasing industrialization helps drive food prices lower and isolates and divorces food consumers from food growers.

The value of corn per bushel and the amount of corn produced yearly has been more or less on the rise since the 1960's. Additionally, the push towards heightened returns from subsidies, by benefiting farmers that produced more corn per acre, began in the 1970's. The rising prices during this time are an indicator that demand for corn was rising as well. Increases in demand have come from movements to expand exports through export subsidies and liberalizing foreign markets, as well as the growing livestock industry in the United States in the 1980's and 1990's (Winders 2009) and the ethanol fuel boom in the first decade of the 21<sup>st</sup> century (USDA Feed Grain Baseline 2010-19, 2012). Data of the price and yield volume of corn every year between 1961 and 2009 in the U.S. shows a continual rise for both factors, as seen in **figure 2.2** (Agricultural Commodity by Country 2012). It is likely that the increasing demand for corn, as well as the government subsidies issued, have played a major role in this trend. Demand for cheap and abundant corn not only helped fuel the growth of this crop, but also the heavy reliance on it.

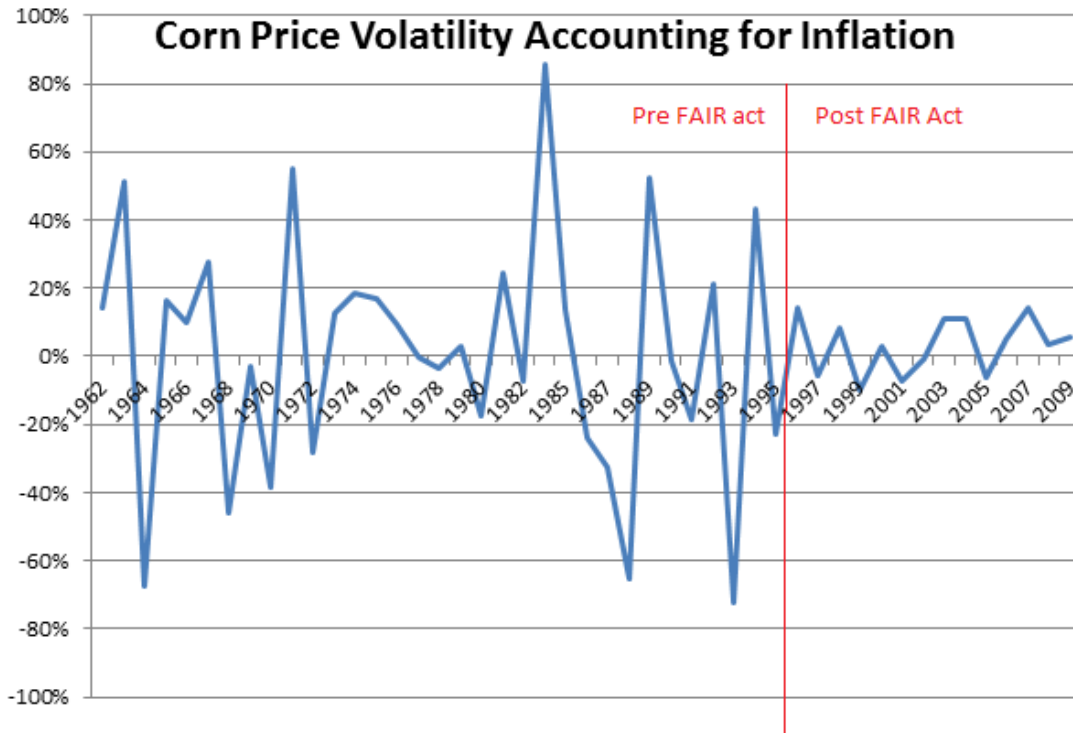
**Figure 2.2: Corn Price and Yield since 1961**



Source: Agricultural Commodity by Country 2012

If this growth trend is compared to the Consumer Price Index (CPI) during the same time, it can be noted that since the 1996 Federal Agriculture Improvement and Reform (FAIR) Act also known as the 1996 Farm Bill, there has been a significant reduction in price volatility (Consumer Price Index 2012). The rises and falls in price have decreased substantially, levelling to much more moderate swings in price which can be seen in **Figure 2.3** (Agricultural Commodity by Country 2012). These trends imply that subsidy systems can to some degree insulate a market against shocks. Since 1996, the major forces attempting to aid stability in the market have been counter-cyclical payments, crop insurance, and market loss assistance payments. It is important to note, however, that the shocks discussed within this paper fall within a range which may not be able to cater to massive losses without significant government intervention (Monke 2007). Such concerns will be covered further in Section 2.2 - Vulnerability. Subsidies have been an important aspect in the history of development in American agriculture, and require some explanation.

**Figure 2.3: Corn Price Accounting for Inflation Since 1961**



Source: Agricultural Commodity by Country 2012

The subsidy system of the U.S. has undergone several major shifts, but has not diminished in scope for the most part. After the 1996 FAIR act many of the old payment systems were replaced by what was seen at the time as cost-saving solutions. One major change was the move away from supply and acreage limiting programs, allowing farms to become ever larger (Diakosavvas 2011). Another aspect, which was an attempt to stabilize crop prices, was the removal of deficiency payments. These payments guaranteed a certain price for a crop determined by the difference between market prices and a target price that was to be reached. Should the market value fall below the target price (floor), payments were made to farmers; otherwise they received the market price. This was replaced with a target price based on historical prices, not current prices or production and farmer planting decisions, like the deficiency payments were (Diakosavvas 2011) and these are now called counter-cyclical payments. As well, the addition of more choices for farmers through the Average Crop Revenue Election (ACRE) program gives more choice to farmers through different payment and insurance methods in an attempt to promote stability.



The consequence of the move from deficiency to counter-cyclical was to promote more production and efficiency. Since the target price to be reached was determined by historical averages of individual farms, the farmers benefited from increasing production to push that target number as high as possible. This guaranteed that if there was a sudden fall in price or production the farmer would have a support system whose effect was determined by their own actions. Passing a law with such changes warrants some discussion.

The 1996 reform bill required the convergence of many aspects and actors, national and international, for it to be passed, which came about when the many different crop interests agreed that there was a crisis afoot (Lehrer 2010). Contributing factors included low and volatile prices the years before and high payouts by the government. Thus there would need to be a broad consensus from the agricultural community that the current subsidy system needs change for any sort of reform policy to be put in place to regulate monoculture and reduce the threat of agroterrorism.

**Figure 2.4** (State, Congressional District & County Data 2011) shows the trend and breakdown of subsidies given specifically to the corn industry since 1995. As can be seen, subsidies to the industry provide large levels of support to farmers. Total worth of maize grown in the United States in 2009 was worth \$28.3 Billion (Agricultural Commodity by Country 2012), with \$3.7 Billion coming to corn farmers in subsidies (State, Congressional District & County Data 2011). Thus, subsidies account for over 13% of that year's crop final sale value. Direct Payments have made up a stable income for corn farmers since 1996, and are given to each farmer determined by their historical yield. This comes to \$0.28 per bushel produced and is given unless opted out of for a different program (Farm and Commodity Policy: Program Provisions: Direct Payments 2009).

**Figure 2.4: Corn Subsidies since 1995**

Corn Subsidies\*\* in the United States totaled \$81.7 billion from 1995-2011.

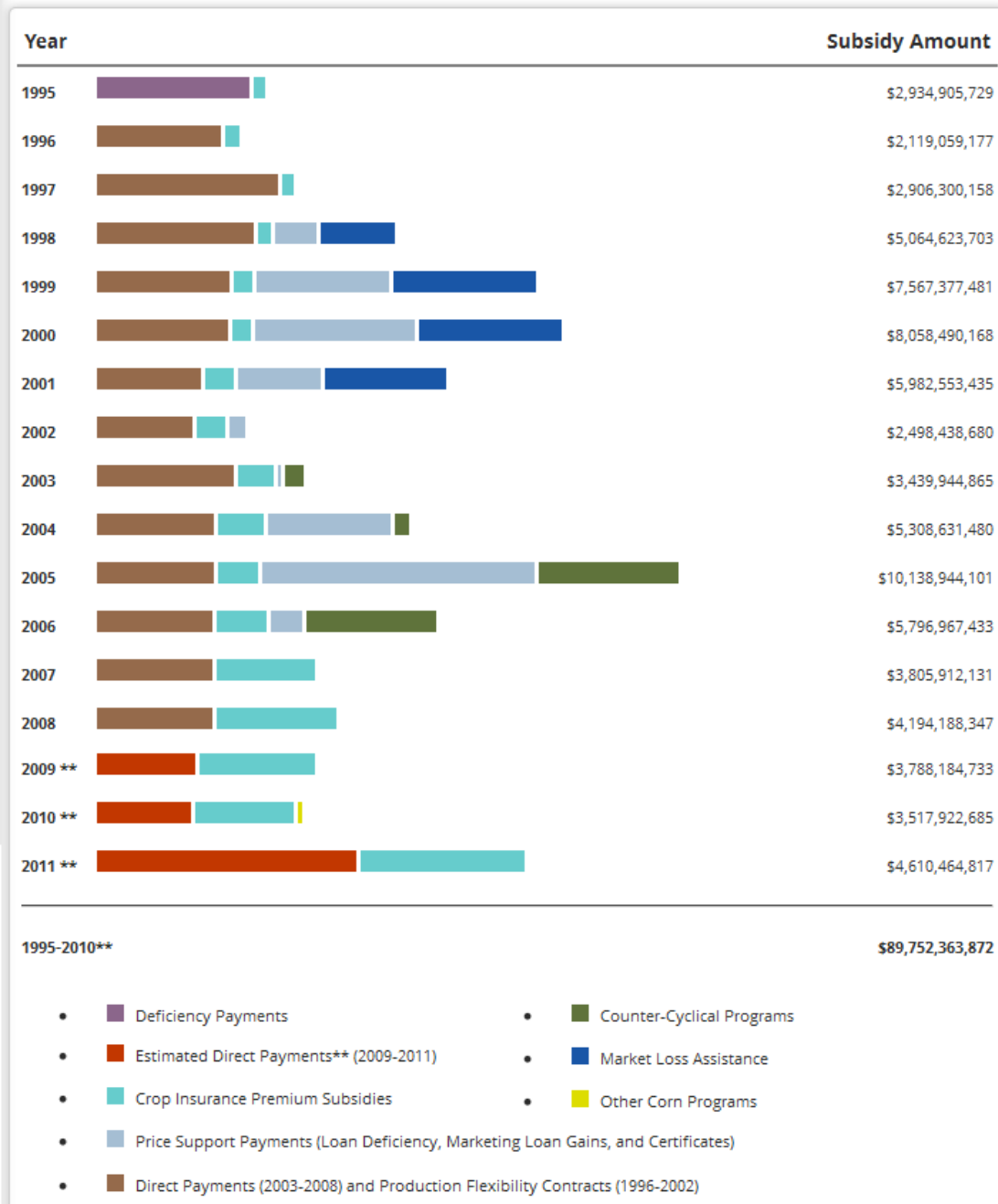


Image Taken From: State, Congressional District & County Data 2011

\*\* Marked figures are estimates only.

Included within the subsidies given during recent years has been insurance based support. Crop Insurance subsidies are given only to those farmers seeking such

insurance on their crops. Catastrophic levels of insurance, where over 50% of the crop is lost, is covered in whole by the government, and as crop loss insurance covers less drastic contingencies, it is covered less and less by government subsidies (Diakosavvas 2011). Insurance increasingly covers the loss of revenues, as opposed to yield. This guarantees a certain level of revenue for those purchasing this insurance determined by the disparity between real and expected revenues.

Another aspect that **Figure 2.4** can shed light on is how corn ranks compared to other crops. Accounting for all other commodity subsidies given out, corn received nearly 50% of the funds, with \$80 of \$167 billion since 1995 going to corn farmers (State, Congressional District & County Data 2011). This speaks to the incredibly important place of corn within the agricultural industry, and to how much value is placed on it.

Furthermore, since efficiency in crop growth is rewarded with larger subsidies, three effects occur. Firstly, as mentioned before, crop concentration per acre increases, which has the effect of placing more of a target in a smaller area. Secondly, it promotes larger farming companies since the economies of scale benefit large plots of land and bigger equipment. Finally, corn is inadvertently supported more than other crops due to the fact that it is the most efficient crop for increasing the production to acreage ratio (Pollan 2006). Each of these three factors makes corn more vulnerable to natural crop loss and agroterrorism which will be seen in more detail in the following section.

## **2.2. Vulnerability**

The three key factors in determining the “...accident waiting to happen” as posed by monoculture, which greatly determine agroterrorist risk as well, (Holling 2001) are connectivity, biomass, and biodiversity (Fraser 2006). Connectivity levels are determined by the proximity between crop fields; the closer together the more connected they are and the more at risk as well. Biomass is determined by the amount of organic material present in a given space, with more being riskier. Biodiversity is determined by the number of different organisms inhabiting a given area, with fewer species increasing the fragility of the area. Corn is at high risk in each of these three areas due to industrial level farming and how it has risen to such prominence.

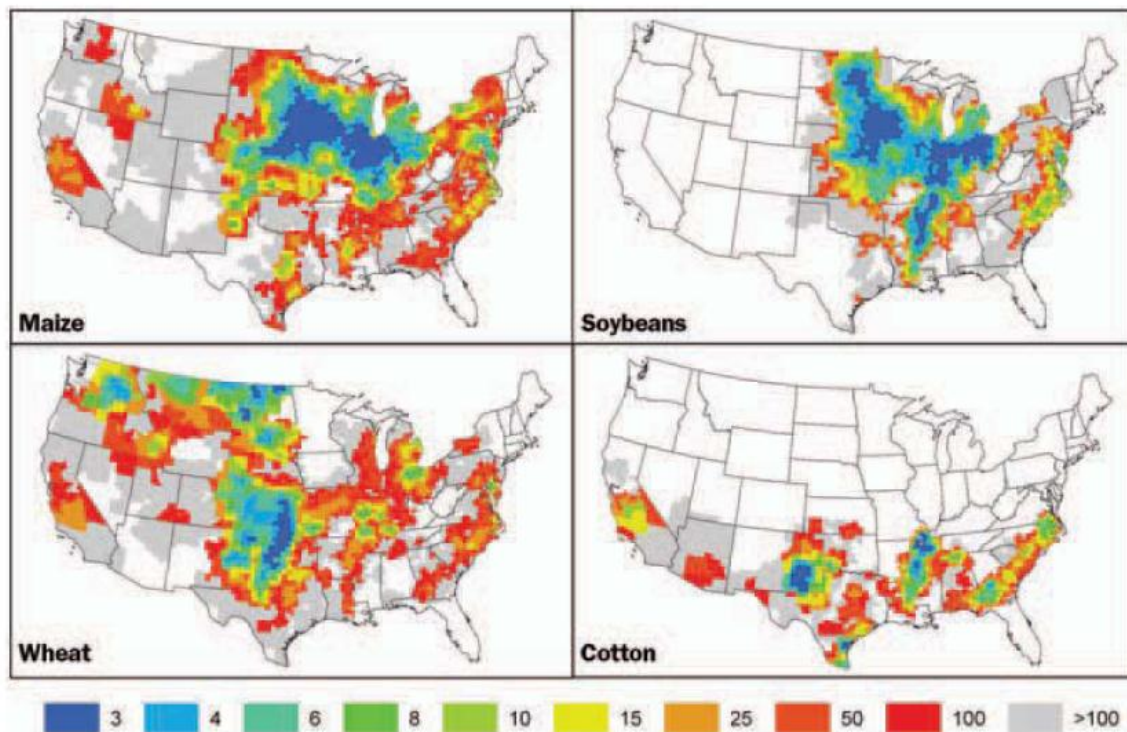
As mentioned earlier, the subsidy system in place intensifies these three traits. Firstly, biodiversity falls since certain types of corn are more efficient with the fertilizers and pesticides available and produce increased yield. *Bacillus thuringiensis* (BT) corn, for example, has been genetically modified to contain an enzyme helpful in protecting it from pests (Wu 2008). Thus genetic diversity falls as one or few species of corn rise above the others in usefulness. Secondly, connectivity has increased since certain locations like Iowa are best suited for the growth of corn. As well, centralized locations are best for equipment use between fields, tightening spread even further to maximize technological capital. One final factor contributing to this connectivity is that since direct payments benefit those who produce the most bushels of corn it incentivizes more bushels per acre, with farmers trying to place more plants in any given field. Finally, biomass rises as more corn is grown over all, with subsidies benefiting efficient and bountiful growers.

This is, of course, not to say that subsidies are the sole cause of the overabundance of corn. However, from a policy perspective the other characteristics that allow corn to be so well established cannot easily be changed. Characteristics like the costs and access to fertilizers, the optimal climate, the crop characteristics, market demand, the economies of scale, and other factors all benefit the growth of the corn crop and the increasing vulnerability as seen through the three indicators of connectivity, biodiversity, and biomass. These other factors, however, cannot readily be changed, and thus have been passed up to a certain extent throughout this project as areas of interest. Taking these vulnerabilities as granted, there are implications which need to be considered further.

Research has been done to determine how these three factors affect disease and pest spread. **Figure 2.5** (Margosian 2009) shows the concentration of the four largest crops in the United States, with maize showing large areas of low Resistance to Transmission (RT). Similar to the terms of connectivity, biomass, and biodiversity above, RT is a rating of how capable these locations are at resisting the spread of crop-based diseases. The blue areas contain crops in such proximity and with such a lack of biodiversity that the RT rating is low. This means diseases or pests would easily travel across fields if introduced, contaminating and destroying more crops with even greater speed. Additionally, since crop proximity is part of the resistance to transmission

grading, the areas where pests and diseases can transfer easiest would also be the areas that would be producing the most corn per acre. Thus the most vulnerable areas would also have the most crops to lose and be the most valuable.

**Figure 2.5: Crops Resistance to Transmission: Corn, Soy, Wheat, and Cotton**



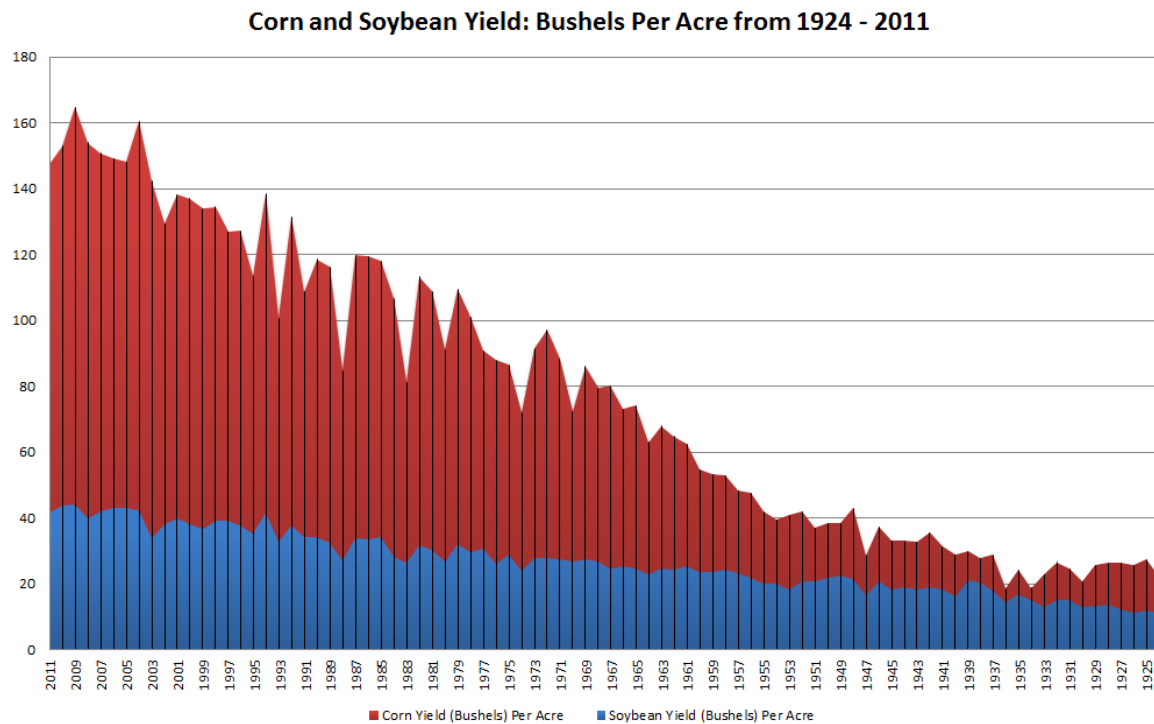
*Connectivity of four US crop species measured by the landscape resistance to transmission, across a range of thresholds for host availability requirements by a pathogen or pest.*

Image Taken From: Margosian 2009

This problem of connectivity has been worsening as the concentration of bushels of corn per acre has been steadily on the rise. **Figure 2.6** (NASS - Charts and Maps - Field Crops 2012) shows how corn has compared to the other crop with the lowest RT score, soybeans, in yield per acre since 1924. Based on the criteria outlined earlier, concentration of corn per acre is an excellent indicator of how these have changed over time. Yield per acre affects biomass, connectivity, and to a lesser extent biodiversity. As can be clearly seen corn has seen a manifold increase in efficiency over the years and

this trend does not seem to be slowing down. Such a trend poses a problem considering that now if any one field is contaminated and the corn is lost, there will be a larger drop in absolute yield as each field produces more corn. The extreme concentration of corn is highlighted by the fact that the U.S. has a 20% higher corn yield per acre than any other country (Corn Farmers Coalition 2012). This is potentially one reason why U.S. corn dominates world markets with almost 50% of all exports worldwide (Agricultural Commodity by Country 2012). Soybeans, on the other hand, have seen a much more moderate growth in efficiency and yield, which is telling of how well suited corn is to industrialized agriculture.

**Figure 2.6: Corn and Soybean Yield: Bushels per Acre since 1924**

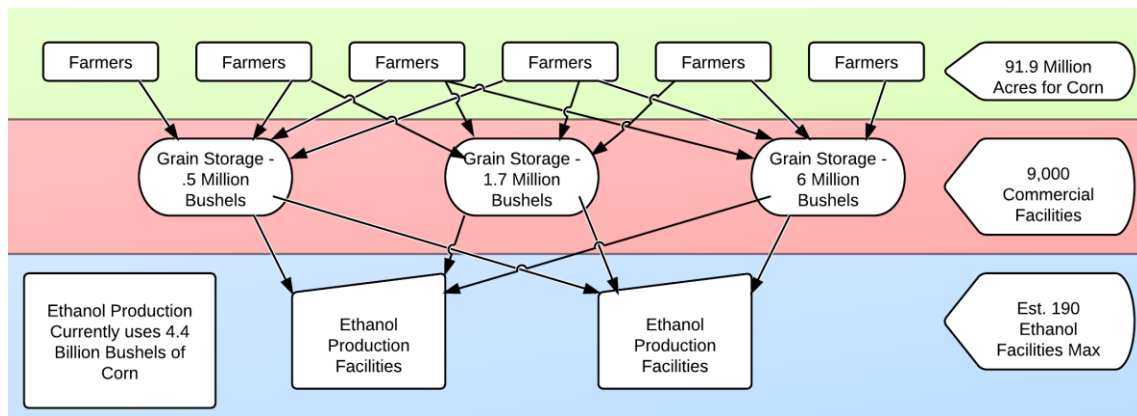


Source: Agricultural Commodity by Country 2012

As an example of vulnerability even beyond that of what can be seen in the field, in **Figure 2.7** the corn supply flows from field to the processing plants for ethanol are outlined. There is an increased concentration of ownership at each step, allowing an attack on the more concentrated facilities to contaminate or destroy that much more corn. It begins with farmers bringing their corn of a specific grade and variety to the

respective storage facilities, which are usually grain elevators, ranging in size from approximately .5 to 6 million bushel capacity. Of approximately 9,000 locations, based on proximity and transport availability, will truck and freight approximately 4.4 billion bushels towards ethanol production in dry milling (2011-2012 U.S. Corn Projected Usage 2012). Supposing the samples of ethanol facility capabilities done by Wu are accurate, each ethanol facility produces approximately 82 million gallons of ethanol (Wu 2008). As well, corn ethanol production has been capped by the Energy Independence and Security Act of 2007 at 15 billion gallons (Ethanol Myths and Facts 2011). Thus, supposing the same ratio of facilities to ethanol production (82 million gallons per facility), there should be no more than 190 ethanol facilities, so long as corn ethanol production is limited by law to 15 billion gallons. While this concentration does create a weakness for targeted attacks, there is one benefit. Concentration of ownership may allow ethanol industry leaders to support legislation protecting corn from agroterrorism since they will be almost universally vulnerable to shocks of such a specific commodity.

**Figure 2.7: Ethanol Corn Supply Flow**



Source: Kind 2010, Stebbins 2010 and 2011, and Wu 2008

While not covered here in detail, vulnerabilities concerning post-harvest contamination or destruction of food crops can be examined through this and similar flow charts for the major corn-based industries. Namely, locating ‘choke points’ in supply chains, such as the ethanol production facilities in the diagram above, can identify vulnerabilities in a system. For example, one ethanol production facility has more corn pass through it than any other step along the chain, making its loss more costly than one

of the many grain storage silos. Identifying these points would allow proper precautions to be taken to secure the most valuable facilities.

The flowchart in **Figure 2.7** is specific to ethanol fuels, but feedlot operations for livestock have some similarities. While not as concentrated as ethanol in terms of location, there are 4 major companies that purchase, slaughter, and market some eighty percent of all of the cattle raised and imported in the United States. Tyson, Cargill subsidiary Excel, Swift & Company, and National do not raise cattle, but instead purchase them from farmers to be brought to feedlots. They 'finish' the cattle, bringing them to market weight quickly on feed that is overwhelmingly derived from corn. This logistical method is similar to how corn is grown by farmers and sold to the agribusiness or ethanol industry based on the variety of corn being grown (Pollan 2006). These feedlots can be very large in size, holding thousands of cattle in what are known as feedlots or Concentrated Animal Feeding Operations (CAFOs) (General Information on Concentrated Animal Feeding Operations 2012). As seen earlier, if corn supply is hurt, so are the livestock industries that are heavily reliant upon it. The next section will elaborate on what to expect from damage to the corn and agricultural industries in the United States.

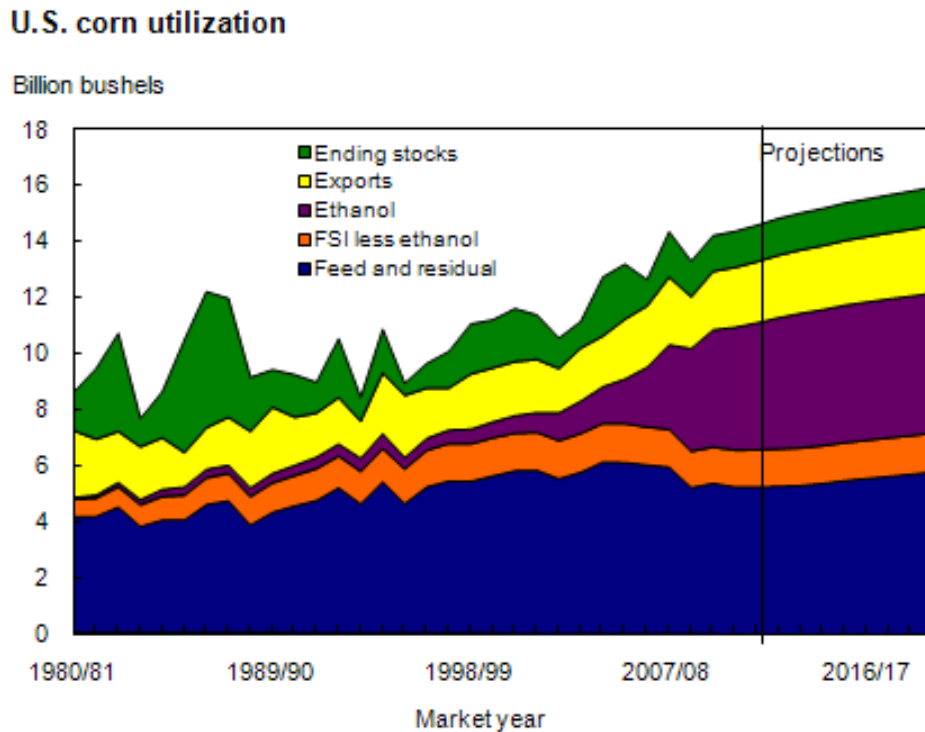
### **2.3. Consequences**

In 2007 the U.S. provided around 10% of the world's total exports for agriculture (Diakosavvas 2011). Such figures make American food security a world-wide issue. For corn, this number is much larger, with the U.S. accounting for around 50% of world corn exports (USDA ERS – Corn: Trade 2012). Developing countries import roughly between one third and one half of all corn exported worldwide. Taiwan, Japan, and South Korea make up virtually the entire developed Asian market with around a quarter of the world's corn exports, with the Middle East and North Africa consuming around one sixth (USDA ERS – Corn: Trade 2012). These countries stand to suffer from a sudden loss of cheap food energy should the U.S. corn supply be damaged, quarantined or otherwise be taken out of the market.



Exports, as seen back in **Figure 2.1** on page 5, are close to 2,000 million bushels, showing that the international demand for corn is substantial, with over 100 million metric tons being exported worldwide, and almost half of that coming from the United States. As well, **Figure 2.8** shows that this demand has been consistent over recent years, decreasing in size relative to the other uses of corn. This is important to note because of two reasons. Firstly, the export stability may be threatened in the wake of an agroterrorist attack. International bans through the World Trade Organization (WTO) for fear of contamination or infection could arrest exports in the short term and damage potential trade relations in the long term. Secondly, while exports have been reliable over the years, the lack of growth in exports means that, proportionately, more corn has been consumed within the U.S. as production increased. As production increases and a growing percentage of corn stays within the United States, the more the consequences of an attack on the corn supply would stay within American markets and thus affect U.S. industries and civilians more than the international markets and peoples.

**Figure 2.8: Uses for U.S. Corn**



Source: *USDA Agricultural Projections to 2019*, February 2010.

Image Taken From: *Corn: Trade: USDA Feed Grain Baseline 2010 – 2019*, 2012

Domestic markets are even more reliant on a consistent food supply than the international realm. By damaging the food supply and limiting output for one or more years, there will be long-lasting consequences which different industries will have to face. These industries include feed for animals like poultry, beef and pork, processed foods, and the growing ethanol fuel segment. A clearer breakdown can be seen in **Figure 2.8** (*USDA Feed Grain Baseline 2010 – 2019*, 2012), where the substantial growth of the ethanol industry is apparent. Dry milling, the process used to derive ethanol fuels, is just over one third of all corn used looking back to **Figure 2.1**. In the same figure, over 1800 million bushels (mbu) goes towards refinement into processed foods. Thus, the total usage of corn breaks down almost evenly into three sections: one third to ethanol, one third to feed, and one third to other uses, the majority of which is for exports and some for human consumption.

This reliance on corn may seem manageable, with financial damage able to be contained to just farmers if there are substitutes available for corn. However, no single agricultural product is capable of filling in for a large vacuum of corn. Corn substitutes are available and are comparable in cost to corn, with the reduction of subsidies making costs more conducive for alternatives from domestic and foreign origins. This does not mean, however, that these substitutes are viable options. The large gap stems from the fact that the production of these crops is so limited in yield that a loss of the corn supply in the short run would be impossible to fill through any number of the available substitutes.

Since corn is so heavily sought after due to years of marketing, the diverse uses developed for it, and the subsidy system supporting it. Because of this there are few readily available sources to replace it. Corn alternatives to replace feed, for example, would vary from animal to animal. In 2009 corn was priced at \$84 per metric ton, and made up the majority of feed for CAFO cattle, the largest consumer of feed-grade corn. Alternatives for feed include oats (\$75 per Metric Ton (MT)), barley (\$82 per MT), and sorghum (\$97 per MT) (Agricultural Commodity by Country 2012). While comparable to maize in price, the total supply of each of these is less than 3% of the total corn grown in the U.S., making substitution unlikely without driving up prices dramatically given a large enough corn supply loss. Feeding cattle without ready substitutes for corn-based feed carries with it a major set of problems.

Very few cattle raised are fed no grain whatsoever. Similarly, virtually no cattle are fed only grains since birth, with most being fed grains only during certain stages of development. The popular practice for cattle is to 'finish' them with grain in the last few months of their lives to add the desired taste corn and grains bring to the meat and fat of the animal (Pollan 2006). Depending on the severity of corn crop loss, consequences for livestock could vary greatly. At best it would simply drive feed prices much higher, and thus the cost of meats would rise. At worst it is possible that there will be such a lack of feed that livestock farmers may be forced into euthanizing their animals rather than have their cattle starved. This stems from Concentrated Animal Feeding Operations (CAFOs) and their methods. To make cattle and meat more affordable and competitive in cost, the criteria of land usage for grazing was minimized by replacing grasses with grains.

CAFO-raised cattle currently use on average 32 pounds of feed, 24 pounds of which are corn, to feed one of their cattle every day (Pollan 2006). This method allows cattle to gain 1 pound of weight for every 8 pounds it is fed (Pollan 2006). Thus for every 6 pounds of corn lost from the 8 pounds of feed, the livestock industry, assuming there is no substitution whatsoever, would suffer a 1 pound loss of beef. Thus these numbers can be used to estimate the total amount of beef lost given a loss in corn supply, although in a rather simplistic way.

This process of concentrated feeding means many cattle use much less room yet take less time to grow to slaughter weight. CAFO cattle require much fewer acres since feed replaces the need for grazing and there is little room given for movement. Traditionally, grass-fed cattle require approximately a little over 1 acre per month to survive (Cussins 2008). Should a CAFO owner, housing over 1000 cattle, suddenly lose access to feed it would be very demanding to find an alternative source of food for all of these animals. To prevent cattle from suffering it would require as little time as days if not hours to locate alternative food sources. According to the EPA, the U.S. currently has over 15,000 CAFOs, many of which house pigs and chickens in addition to cattle, all of which usually use corn as a base for their feed (United States. Environmental Protection Agency. Producers Compliance Guide for CAFOs 2003). This results in thousands or hundreds of thousands of acres of grassland needed for every month that there is no corn for feed for these livestock. A large contamination would make it difficult to continue to grow these animals to weight, driving up costs drastically and further affecting the market.

The next section will discuss the areas of interest concerning agroterrorism. This includes relevant historical examples of crop loss, naturally occurring threats, and how these relate to agroterrorism against the United States.

## **3. Nature of the threat**

### **3.1. Relevant Examples**

The estimates of how much damage intentional pathogenic or pest-related crop attacks could cause is unknown. As an historic example, the Great Potato Famine in Ireland, which destroyed around 66% of the potato crop and led to widespread famine, was caused in large part by the same characteristics corn has today in the United States (Fraser 2006). Similar levels of biomass, biodiversity, and connectivity in any crop leave it vulnerable to pests and diseases. The one major difference to note is that corn, unlike potatoes, is not a necessary crop for survival of the populace. While corn supply loss has the potential to dramatically increase food prices and thus the food insecurity of the population (LeBlanc 2005), it would likely not cause many to go hungry. Even if the government were not to step in, corn loss would not risk famine or food shortages domestically, although the consequences abroad could be different.

Another example which had less of a dramatic impact but is more relevant to this study is that of the 1970 leaf blight in the United States (Fletcher et al. 2006). The leaf blight contaminated and destroyed roughly 20% of the corn crop in the United States that year, resulting in around \$1 billion in losses (Tatum 1971). While there were likely less institutions and resources available to address the situation than currently exist, it is still an example of how one disease could have far-reaching consequences. During the time that the blight happened, corn production was roughly one third of what it is today. Not only does this speak to the larger potential of loss, but also to the increased criteria of risk seen earlier through connectivity, biomass, and low biodiversity (Margosian 2009). A similar threat released today could potentially do more than 20% damage to the corn crop since corn is now more vulnerable along the three main criteria, potentially leading to a manifold increase in losses. In the case of this 1970 leaf blight, corn reserves, the unused corn from the previous season, were almost not enough to account

for the losses experienced. Corn reserves were barely less than 1 billion bushels in 1970, with the loss estimated at close to 800 million bushels (Tatum 1971).

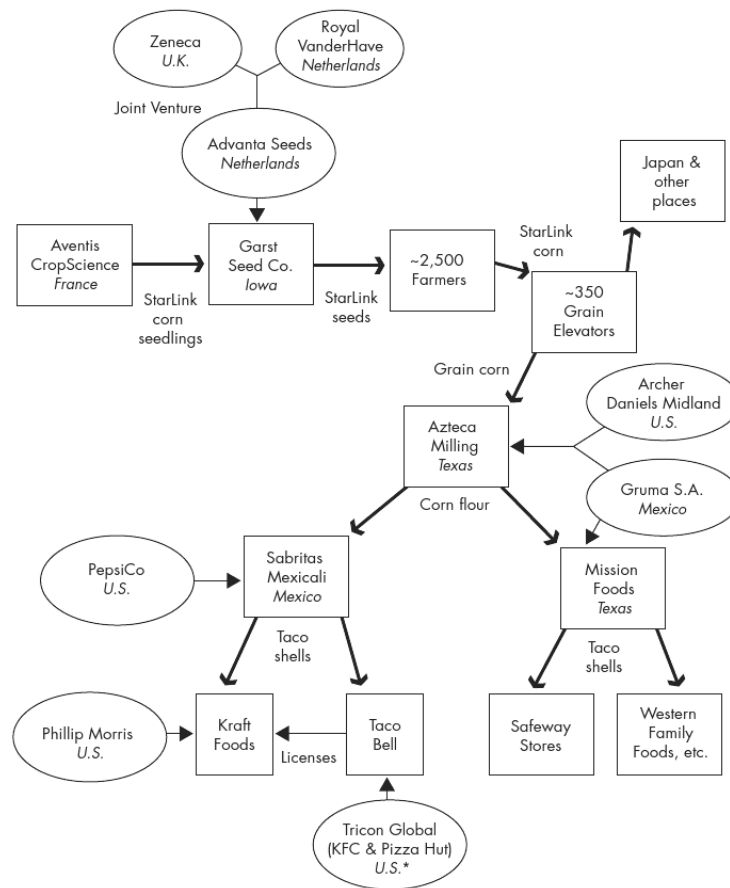
Comparing these numbers to the current agricultural system is not promising for security. News reports place corn reserves somewhere between the 16-year low of 851 million bushels, and a three-year high of 1.8 billion bushels (Wilson 2012). This is roughly equivalent to somewhere between 6% and 13% of current corn yield (Agricultural Commodity by Country 2012). While corn production roughly tripled from 1970 to 2009, the corn reserves have, at best, less than doubled (Agricultural Commodity by Country 2012). It may be true that there are more resilient strains of corn in the United States today than in the 1970's, and there are more agencies ready to respond to crop diseases, but a low level of reserves would give little recourse to a dramatic loss of corn supply. While not a solution, storage may be able to keep businesses going in the short term through smaller shocks while not being too costly.

### **3.1.1. *The Starlink Example***

The 1999 - 2000 Starlink corn incident shows a different sort of example of potential problems from agroterrorism. Starlink corn, a potentially allergenic strain of corn not meant for human consumption, was found in taco shells, forcing large-scale recalls. This all began when Starlink corn was approved for use in the field so long as it was kept out of food meant for humans. The failure was eventually traced back to the natural world, which policy makers failed to predict. The gene promoting a protein that was potentially allergenic was spread from the Starlink-only fields to the neighboring ones through natural pollination and reproduction of the corn plant (Nestle 2010).

This shows not only how policy makers could be lax in their diligence towards placing appropriate limitations on potentially dangerous crops. This example could also be interpreted as a case where the policy makers lacked the knowledge required to appropriately regulate a genetically modified organism (GMO). After the Starlink corn was genetically mixed with neighboring fields, it followed a path as seen in **Figure 3.1** (Nestle 2010).

**Figure 3.1: Starlink Corn Supply Flow**



The chain of production, distribution, and marketing of StarLink corn through the food system in 2000. Square boxes contain the principal elements in this chain. Ovals indicate corporate ownership. The diagram reveals the difficulties of keeping StarLink corn separated from conventional corn during growth, harvest, storage, and processing.

\*Tricon Global changed its name to Yum! Brands, Inc. in 2002.

Image Taken From: Nestle 2010

The result of this genetic spread was telling in how the United States Department of Agriculture (USDA) would act towards corn contamination. Approximately 2,500 farmers shipped their grain to around 350 different grain elevators. Once there the contaminated corn went to only 2 places: exported to Japan, and to one milling plant in Texas to create corn flour for tacos. In this scenario the corn was simply a potential allergenic threat that could have posed health risks to those ingesting it. The spread occurred due to inability to separate two varieties of corn but it is easy to see how other

forms of contamination could create similar problems. The Starlink example eventually led to the USDA spending around \$20 million to purchase the contaminated corn products from store shelves to protect the population (Nestle 2010). Other forms of contamination could be expected to be handled in a similar manner, ending with government agencies purchasing contaminated food to preserve the stability of the farming industry.

The next section will examine what some of the potential contaminants could be and their characteristics.

## **3.2. Natural Threats**

Corn will likely keep growing as a crop in the U.S., creating a large dependency on it for feed, food, and fuel, aided in part by subsidies and tax breaks. Should corn continue to grow it will be a biological energy source that exceeds all others in the natural world. Furthermore, since not all animals or pests can access this energy, having large supplies of one crop benefits only those animals that can use the only abundant resource around. If trends continue as they are, subsidies will keep being spent to promote a crop that limits what pests and diseases can use for nourishment, thus begging nature to develop some way of harnessing the energy of corn. A large scale collapse of the corn supply would severely damage or ruin many companies and industries that depend on corn's abundance. Along with the costs of increased crop damage that comes with monoculture, it is very likely that the government would need to intervene should there be a large shock or collapse of the corn industry. Any more growth of this \$28 billion crop, especially at the cost of other crops, would prove more and more costly in the case of any natural or agroterrorist borne pathogen. The nature of these dangers needs to be examined if the risk of agroterrorism is to be understood more fully.

### **3.2.1. *Invasive Species***

Invasive species have always been a concern, able to create massive shifts in biospheres by being able to consume what previously was inaccessible to the local population. Evolution between cohabiting species is like an arms race, in that each



species is competing with the others and over time develop traits which give them an edge in survival and procreation. A huge aspect of this comes from the ability to harness and access food or energy. Mutations between generations of any species allow new traits to be produced which may give an insect, for example, the ability to eat a different section of a plant or become resistant to naturally occurring or artificial pesticides. This usually occurs in tandem with other animals, giving a sort of balance to the arms race and not having many plants or animals gain the upper hand for too long. However, introducing a foreign animal, plant, or even microbe, could cause untold damage to other species not adapted to the new addition to the environment. Mutations external to the biosphere that native plants and animals inhabit can bring threats that have not been seen nor prepared for. The power nature holds for adaptability is unequalled. It will be seen in the next section that adaptability, through selective breeding and survival of the fittest, may be a key factor for agroterrorists in their creation of biological weapons.

To assess the potential threats, without delving into the scientific realm of plant biology and pathogens, some simplifications need to be made. The table below details some of the more common natural threats to corn and some of their characteristics. Each of the examples below are molds, diseases or pests that cause damage to corn crops every year, and make up the yearly losses seen in corn production. The threats on this table are far down on the list of potential dangers, and serve only as examples of the characteristics commonly found in nature.

**Table 3.1: Characteristics of Natural Threats to Corn**

Natural Threats to Corn	Mold	Disease	Pest
Longevity	High Multi-season potential	Short	Short
Visibility	Low	Low	High
Efficiency	Low	High Within-season contamination rate	Mid-Range
Example	soil-borne fungus: <i>Fusarium oxysporum</i>	Rust Diseases, Potato Blight	Corn Borer, Root Worm

Sources: Madden 2002, Jackson 2008, O'Day et al. 1998

Seen above are several examples of diseases or pests and the different attributes they have. The main three types of natural threats that could be harnessed by agroterrorists are molds, pests, and diseases. Generally speaking each category of threat has strengths and weaknesses that are different than the other. The key attributes are longevity, visibility, and efficiency. Longevity is how long a threat would stay in the field, and this can usually be ended naturally between seasons for threats that have low longevity. Certain threats, like certain fungi, stay in the soil and need added effort to spot and remove. Visibility is how easy a threat is to spot. Pests are by far the most obvious, especially in larger amounts. However, molds and diseases are generally lower in visibility, and the degree to which any one is visible depends on the specific disease or mold. Efficiency is how well any given threat is capable of destroying the crop in the time it is present. This can be seen in how much damage is to be expected within a single season. Threats to corn with high longevity and efficiency as well as low visibility would be a very good candidate for destruction. There are currently several naturally occurring threats that have been noted by policy makers as a very real potential danger as invasive species, primarily due to the high efficiency they are expected to have.

Two natural and invasive threats are highlighted by the Code of Federal Regulations (CFR) 331.3 (b) that could be a major threat to corn (Plant Protection Quarantine 2005). The variety of the Philippine downy mildew (PDM) and the Brown Stripe downy mildew (BSDM) that can affect corn are viewed as possibly the most dangerous natural threat to corn found so far. As will be seen in more detail later, it is these sorts of dangerous fungi that require the Department of Homeland Security (DHS) to place significant amounts of funding into agricultural (border) security and customs (Monke 2007). It is interesting to note that both these threats and those of the other crops listed in CFR 331.3 are nonindigenous species to the United States (Fletcher et al. 2006). This means that all it could take for a serious contamination of U.S. crops is the transport of a small quantity of living bacteria from another continent.

The particular pathogens of PDM and BSDM are particularly versatile and virulent, with several factors being of major concern. Firstly, BSDM can survive in the winter, residing in necrotic plant tissue or the soil. Secondly, leaves containing these mildews, if air dried, can be viable for up to four years. Thirdly, both types of mildew spread through both wind and water, allowing a variety of means for transmission.

Finally, under ideal conditions the newly introduced mildew can mature within ten days and spread rapidly (Putnam 2007 and Byrne 2007).

It has been estimated that up to 70% crop loss is to be expected in areas where one of these two downy mildew molds is present (Putnam 2007 and Byrne 2007). They are native to areas near India, Indonesia, and the Philippines and have not yet become a concern for farmers in the United States. In 2006 a recovery plan for PDM and BSDM was instituted, showing that certain agro-threats are currently part of the policy process and being prepared for (Monke 2007). For a mildew to become a threat beyond what is seen naturally there needs to be an advanced form of introduction to crops. The process of creating a method to introduce a disease or mold to crops with the goal of destroying said crops is called weaponizing an agent. One form of weaponization that is considered a possibility is for the mildew or other contaminant to be liquefied and placed in the containers of crop duster planes (Morris 2007). This allows fast and far spread of the agent, supposing it remains active and viably contagious. However, because of the efficacy of these pathogens, weaponizing them may not even be necessary since their natural proclivity to destruction needs no additional help to cause large amounts of damage.

The next section looks at how human action and innovation can unintentionally create weaknesses in the crop that was intended to be protected.

### **3.2.2. *Pesticides and Resistance***

Thus far each of the natural pests, weeds, and diseases within the United States cause manageable damage. Estimates suggest that there is between \$31 and \$38 billion in natural crop loss every year due to pests, animals, diseases, and weeds (Oerke 2005). It is important to note that this is after efforts to limit these damages have been implemented. Pests, for example, are primarily eradicated through pesticides and similar methods can be used on weeds. One worry concerning such methods is that it forces natural selection of the hardiest and most resistant pests. Heavy chemical use could potentially breed pesticide-resistant pests, which could in the short term cause higher levels of damage, at least until new pesticides are developed. Damage would be limited by how fast new efficient pesticides could be developed or introduced into an area. This

is similar to the natural arms race, as mentioned earlier, except it requires human ingenuity and resourcefulness to defend against pests as they evolve to compensate for our attacks against them. Such a solution, however, should be limited if possible since it may cause more problems than humans can foresee.

One example of how pesticidal arms races can be detrimental can be seen through the recent speculation concerning bee populations decline. Bees are a very important pollinator, allowing fertilization to occur between plants and acting as an intermediary in the lifecycle of vegetation. However after recent bee populations have been in sharp decline some are speculating it may be caused by certain pesticides (Philpott 2012). Should pollinators suffer a large loss in population, whole areas may see plants unable to reproduce and thus not be able to produce seeds, fruits, or in the case of corn: grains. Should pesticide use require continual evolution alongside the pests that grow resistant to it, care must be taken to ensure that the chemicals do not cause larger problems than the symptom they are attempting to alleviate. The next section on genetic engineering contains similar challenges to those seen above.

### **3.2.3. Genetic Engineering**

Corn, one of the many genetically modified organisms (GMOs) involved in agriculture, has been engineered by different companies to have specific traits that would maximize the yield of the crop. One of the more popular forms of this is what is called BT corn. This is a gene that promotes a certain protein growth, protecting the corn plant from a variety of pests and fungi. Since being commercialized in 1996, a total of 27% of corn grown in the U.S. was of the BT variety as of 2004, and has likely increased since then (Wu 2008). There are several risks concerning BT corn that have not yet been addressed

Primarily, the lower biological diversity that is inherent with monoculture increases the chance and degree of damage done by new varieties of pests or diseases. As genes are introduced into an agricultural system by man, those same genes spread naturally to other fields, just as in the Starlink example, sometimes with farmers unknowingly growing a different type of corn than originally thought (Nestle 2010, Wu 2008). There are two effects derived from this. Firstly, since the BT gene is becoming so

widespread and is mixing with or varieties of corn, it is contributing to the loss of biodiversity amongst the corn crop. Secondly, BT corn would allow insects more opportunities to be in contact with the pesticidal protein it produces. This in turn allows more opportunities for nature to become resistant to its effects (Wu 2008). The same protein has been used in traditional sprayed pesticides before, but now with the corn producing the protein continually, there is more exposure than before the modified crop was so wide-spread. Thus the proliferation of this BT gene may not just increase the total number of pests exposed to it, thereby creating its own nemesis, but also create a larger supply of corn susceptible to BT resistant pests.

Genetically modified crops are very widespread in the United States. In 2000 the corn crop was composed of only 25% genetically engineered plants, while in 2010 that number has risen above 85% (Adoption of Genetically Engineered Crops in the U.S.: Extent of Adoption 2011). The Starlink example shows how better monitoring and prediction is needed when permission to plant is granted for GMOs. Likewise, it may be impossible to predict effects of a new organism before it is actually introduced, so after-the-fact monitoring is also important in the safety of the ecology and agriculture of a country.

### **3.3. Agroterrorism**

The United States has seen its share of threats and has made enemies while engaging on the world stage. While security has been one of the larger concerns of U.S. policy makers, especially during the last decade since 9/11, the number and diversity of potential threats requires some to be taken more seriously than others. Physical attacks against people's lives directly, like bombings or shootings, have rightly been seen as the most important eventuality to prevent. This focus, however, creates an isolated bubble of intense interest on the final targets of an attack, neglecting some other areas that are less commonly considered, such as agroterrorism.

Agroterrorism, mentioned briefly earlier on, is a subfield of bioterrorism, which is a subfield of terrorism. Most would know bioterrorism as the use of biological agents to kill or infect a population. Agroterrorism differs in that the final goal is not to kill, but to

destabilize through fear and economic harm. Some may be tempted to ask “why agroterrorism?”. There are two main facets to this choice. The first is safety, and the second is intention. Safety comes from the fact that unlike other forms of terrorism, the lives of those working with these agents and introducing them to crops are safe. That is to say that the bacteria, molds, or pests involved with crop damage are not a threat to human lives, and thus if a terrorist wishes to remain safe while striking a blow against a society, agroterrorism would fulfill certain criteria. The other aspect is that agroterrorism would be difficult to track back to any individual or group, protecting those involved from prosecution or worse.

The second aspect is the intention of the attack. According to Iversen (2004), agroterrorism lacks the showy aspect of explosions and the satisfaction of immediate results, but may be no less effective on a psychological level. Not having to worry about where the next meal will come from is a recent phenomenon in human history and only applies to certain privileged people, most North Americans included. The sudden loss of this privilege would add to the fear and emotional fallout of an attack. The emotions of dread and outrage (Nestle 2010) can be used to gauge how much effect agroterrorism may have on the human psyche. The less people are in control, the more vulnerable they feel, and thus the more dread. With a food production system that is largely divorced from the lives of those who rely on it, little control can be exerted by the population and thus the consequences of an attack could be grave. Additionally, concerning the choice of agroterrorism, there is the issue of accountability. Terrorist groups may want to gain media attention from their efforts, and as such agroterrorism may not be the best way towards notoriety. While not as immediately menacing as traditional terrorist attacks, there is something disconcerting about malignant access to vital food supplies. The resulting notoriety, which certain terrorists would seek rather than simply causing harm for harms sake, would be very dependent on the media’s reaction.

A second factor that explains the rationale for agroterrorists is the fact that agroterrorism need not pose a direct threat to human lives, but rather targets the stability of the economy. Damaging the industries reliant on corn not only could cost billions in crop loss, but even more in lost jobs and subsequent losses of production as industries are unable to produce ethanol, livestock, or refined foods. It is still necessary that the

confidence of the public is to be protected and preserved. Even if very little physical damage is done, the psychological fallout and fear may damage the economy just as harshly through lost confidence and increased uncertainty (Fletcher et al. 2006). This method also allows those groups that do not wish to be murderous to still undermine an economy or society to do so without a direct death toll.

The speed with which any natural or agroterrorist threat can be discovered and reacted to is of great importance. In 1999 for example, it took over 5 years for the Plum pox virus to be noticed and reported (Madden 2003, 158). Similarly in Florida it took an estimated 2 years before the citrus canker outbreak was diagnosed in 1995 (Fletcher et al. 2006). The only beneficial aspect of an especially destructive crop disease is that it would be noticed sooner due to the increased level of damage being done. This inability to detect threats in the field is a result of the vast areas of land covered by crops in the United States, the costs involved with manpower, the inability to automate testing, and the expertise required to identify a disease, mold, or pest and determine its threat level.

Despite a large fallout of monocultured crops being considered inevitable by ecologists (Holling 2001), the estimates of when and how badly the market would suffer from a large crop loss are uncertain. The estimate concerning PDM and BSDM ranges between 20% and 70% crop loss, which totals somewhere between \$4 and \$16 billion dollars (Putnam 2007). Relating this back to the \$20 million Starlink buy-back, a contamination of similar magnitude to a BSDM or PDM contamination would produce an enormous shock in the agricultural markets and force billions to be spent compensating farmers. With such a large part of the American economy at stake more urgency can be seen in the prevention of agroterrorism, as opposed to after-the-fact compensation.

Because of the large land area agriculture uses in the United States, there are difficulties concerning monitoring and security. These problems are exacerbated by the ethereal nature of pathogens, being largely invisible until contamination signs manifest themselves on the crop. Even once noticed, there remain barriers to tracing when or how these diseases, molds, or pests were introduced into the cropland if through man-made means. Unlike explosives or other forms of physical damage, pathogens take up relatively little space and may be able to disperse unnoticed and over large distances. For example, naturally occurring mold spores from as far away as Cuba frequently cross

over into the mainland United States every year on air currents (Madden, 2003). The mold affects tobacco plants and is a contributor to the natural losses seen every year of this crop. While it is outside the scope of this research, it is feasible to imagine a scenario where mold spores can be spread to United States crops from other countries.

By intentionally targeting the food supply, terrorists, dissidents, or radicals of any sort may be able to cause a large impact on a psychological and an economic level. Agroterrorism also has the ability to cause more damage than is actually done due to the interpretation of the event by purchasers of corn. The marketability of the corn crop may be damaged in the short to long term if it is not trusted to be safe (Morris 2007). Even if the contamination is not zoonotic, meaning able to infect or harm people, there will be a certain level of fear and outrage associated with the product. Depending on the severity of the media attention an agroterrorist event gets it is possible that the crop loss caused will only be a fraction of the market loss seen afterwards as demand for corn falls and consumer confidence is hurt.

In the next section the methods, current and proposed, to limiting the dangers of agroterrorism will be discussed.



## 4. Nature of the Solution

The potential threat of agroterrorism has not gone unnoticed in the policy making board rooms. It has, however, seen little concrete and definitive steps taken which would limit the threat effectively. Below is a discussion on what is currently being done, how it falls short and what efforts would address some of the major deficiencies.

### 4.1. Current Strategies

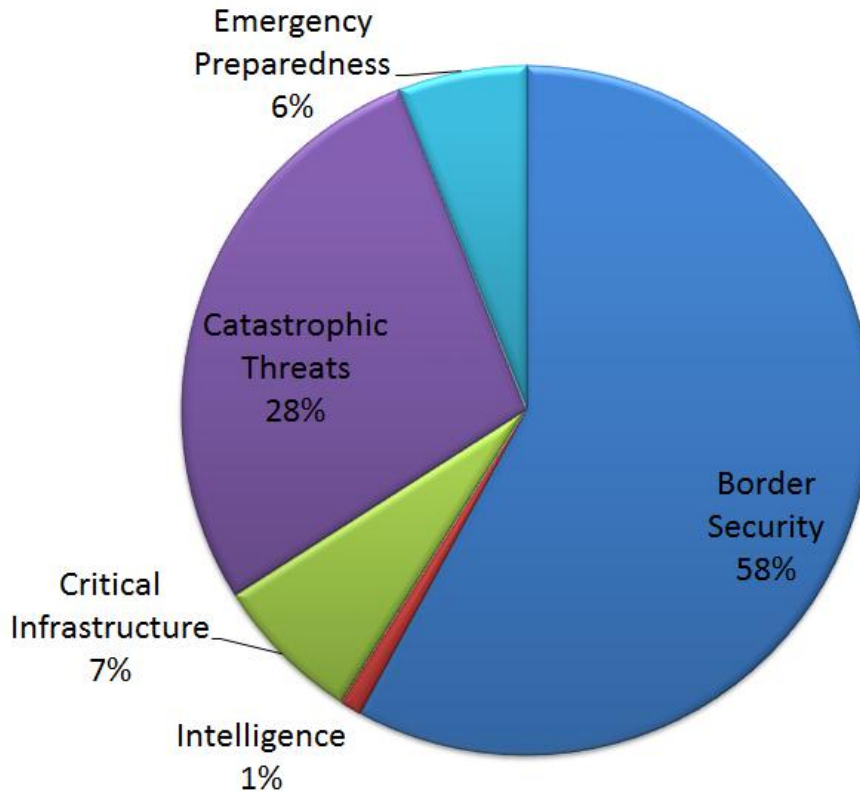
To understand the strategies of combating agroterrorism, some information concerning the agencies involved in food, agriculture, and security need to be discussed. There are a variety of state actors in place for regulating and safeguarding the American food chain. **Table 4.1** shows these actors, their responsibilities and their funding in various years. Of these, the Food and Drug Administration (**FDA**), The Food Safety Inspection Service (**FSIS**), the Agriculture Research Service (**ARS**) within USDA, the Grain Inspection Packers and Stockyards Administration (**GIPSA**), and the Environmental Protection Agency (**EPA**) are the ones most directly involved with plant food safety in the United States. While there are many organizations to deal with food safety and health, these departments have been very limited in their capabilities to address safety concerns over the years (Nestle 2010). The USDA, as seen during the Starlink Example, has a very limited budget when it comes to purchasing back contaminated corn. This example cost the USDA around \$20 million to purchase back products that contained the potentially allergenic corn not meant for human consumption (Nestle 2010). Inspections are also costly and receive resistance from the private sector.

**Table 4.1 Government Agency and Duties** Budget in \$ Millions (Year)

<i>Department of Health and Human Services</i>	
The Food and Drug Administration (FDA) – Regulates all foods except meat, poultry, and eggs. Regulates Animal Drugs and feeds	\$3,268 (2010)
Center for Disease Control and Prevention (CDC) – Surveys and investigates foodborne disease outbreaks	\$10,884 (2010)
<i>United States Department of Agriculture</i>	
Food Safety and Inspection Service (FSIS) – responsible for safe and correctly labeled meat, poultry, and eggs.	\$1,176 (2010)
Agricultural Research Service (ARS) – Determines problems and solutions for agriculture between the farm and consumption	\$1,100 est. (2012)
Grain Inspection, Packers and Stockyard Administration (GIPSA) – Inspects corn, sorghum, and rice	\$40 (2011)
<i>Environmental Protection Agency (EPA) – Protect human health through the environment</i>	\$20,000 est. (2011)
<i>Department of Homeland Security (DHS) – Security and Emergency preparedness</i>	\$57,000 est. (2012)
Animal and Plant Health Inspection Service (APHIS) – Protecting and promoting agricultural health, and regulating GMOs	\$421 (2006)
<i>Sources in order: Food and Drug Administration 2012, Center for Disease Control and Prevention 2012, United States Department of Agriculture 2012, Food Safety and Inspection Service 2012, About ARS 2012, Appropriated Funding for Fiscal Years 1996-2011 2012, Environmental Protection Agency 2011, Department of Homeland Security 2012, Monke 2007, Nestle 2010</i>	

The Animal and Plant Health Inspection Service had \$421 million in 2006 (Monke 2007) in their budget authority, up from a level too low to mention in 2001 (Nestle 2010). As well, the Food Safety and Inspection Service spent less than \$20 million (Monke 2007) of its 2006 budget of over \$700 million towards agricultural security and inspections. One major new player in the defense of U.S. crops is the Department of Homeland Security (DHS) which has been allocated over \$800 million for agriculture (Monke 2007). **Figure 4.1** (Monke 2007) shows the uses of this spending.

**Figure 4.1: Department of Homeland Security Spending for Agriculture by Use**



Source: Monke 2007

Border security is by far the largest expense for the DHS when it comes to agricultural safety. This is due to the dangers of invasive species, which have been acknowledged in the Code of Federal Regulations section 331.3 (b). These border inspections for agriculture have been carried out in large part by another class of border agents that the DHS calls Agricultural Specialists (Monke 2007).

Despite the recent nature of agroterrorism there have been active responses by the United States government and its agencies. The U.S. government has aimed to create policies and initiatives to curb the threats and risks of agroterrorism that go beyond simple border controls. Many of the efforts that have been made, however, comes from smaller and less significant sections of a larger concern towards bioterrorism. More direct attacks at human life, such as with contaminating meat with *e.coli* or other such bacteria, have been a more central concern (Morris 2007). This

concern has increased over time as well since as of 2007 over 75% of all beef consumed in the U.S. pass through only 2% of the nation's feedlots (Morris 2007).

Much of the effort to curb agroterrorism is in the form of reactionary policies such as laboratory and emergency information sharing networks to respond to agroterrorist attacks. The Information Sharing and Analysis Center (ISAC) and the National Bio and Agro-Defense Facility (NBAF) are two initiatives in place to deal with, among other things, agricultural threats like pathogens or bacteria (Monke 2007). Food ISAC began in 2002 and is the central point for federal law enforcement and intelligence officers to get and to send information regarding agroterrorism, and other food related threats. As of 2005 AgGard was created to encourage agricultural community members, like farmers, to share information with one another and the relevant security departments through a secure internet connection concerning any suspicious activity or events (Monke 2007).

The NBAF, created in 2006, deals primarily with animal borne diseases like Foot and Mouth Disease (Morris 2007). The NBAF currently has several facilities ranging from biosafety level 1 (BSL 1) (low hazard material) to 4 (highly hazardous material). It is worth noting that even though these facilities are where dangerous pathogens are housed and studied for the United States, they are not always located there. Currently, the U.S. has no BSL 4 agricultural facility, with the facilities that are used for such lab work residing in Canada or Australia (Monke 2007). These locations in the United States and elsewhere are where testing is being conducted and where samples for tests during an emergency would likely go. Their security has been increased after the terrorist attacks of 9/11, making them more secure from those who would seek to access their pathogens or destroy their ability to function (Monke 2007).

The USDA also has laboratory networks of its own. The goal of these networks is to "improve the diagnosis and detection of a deliberate or accidental disease outbreak" (Monke 2007, 29). These networks harness institutions such as universities and other organizations, like the Center for Disease Control (CDC), to involve hundreds of labs to respond to emergency situations. This includes testing samples of diseases and pests and attempting to create countermeasures in the event of an outbreak amongst crops.

Even with all of these efforts, however, there are some points of concern that would need to be addressed for the risk of agroterrorism to be properly mitigated. The next section examines some of the areas where current policy towards agroterrorism is lacking and why these issues should be addressed.

## **4.2. Weaknesses**

No system of defense can be perfect, and in the end determining at what point a target is secure enough depends on many factors. Determining this requires further research on the costs and a more in-depth risk analysis than is possible within the scope of this study. That being said, the areas of interest below are likely candidates for a weak link in the chain of agroterrorist defense. These weak segments, regardless of funding available or the worth of given risk assessments, warrant consideration, at the very least so as to predict what sorts of systemic failures can be addressed

### **4.2.1. *Information Sharing***

One major weakness that has arisen after the DHS became involved with agroterrorism relates to organizational effectiveness. There have been complaints from the USDA and other agencies that the effort of the DHS to integrate security information networks has been less than successful (Monke 2007). A low level of information sharing, while attempting to be reduced by certain policies seen earlier, still seems to be falling short of the desired efficiency. Similarly, there is no systematic method of information sharing between the DHS and other departments concerning the agroterrorist preparation exercises performed by the DHS (Morris 2007). This leads to useful information being hoarded by one agency when all those involved in food security, like the USDA and FDA, could benefit from it.

### **4.2.2. *Preparedness***

The USDA is not without problems of its own. Firstly, the USDA has little ability to restrict contaminated food, and even when it does it must pay the producer for that which was taken off the markets. In the Starlink example such efforts were to protect the farmers who would have lost the entire value of their corn had it simply been pulled from

the market. While the contamination was contained, there was no blame that could be easily placed. Each blamed the others, from farmers to transporters to processors. It is possible that a similar contamination could occur that would force larger amounts of corn to be bought by USDA agencies, saving the industry but costing instead the departments that would hold the burden of correcting for the contamination. This ends up costing the taxpayers, and may eliminate much, if not all, of the funds of the USDA given a large enough contamination. Such a practice could be wholly unfeasible should there be a large scale loss in the corn supply due to an agroterrorist attack or invasive species.

#### **4.2.3. *Inspections***

There is strong resistance from industry towards the various inspectors, with threats to inspectors being common. In 2001, 252 reported cases of violence against inspectors were noted, highlighting the friction between industry and safety regulators (Nestle 2010). These incidents add to the costs of inspections, requiring frequent rotation of staff and lead to low levels of compliance. This is costly not only due to the lower level of performance and the redundancies needed to ensure adequate quality; it is also a symptom of governmental and private actors' inability to cooperate. Without cooperation between farmers and government officials it is next to impossible to create a functioning system against agroterrorism.

#### **4.2.4. *Reactivity***

The largest concern given the policies towards agroterrorist security already in place is the seeming reliance on post-attack solutions, with border security being the only real exception (Monke 2007). This ignores the possibility of a domestic agroterrorist which has been highlighted by these agencies themselves as a real possibility (Morris 2007). Likewise, without any efforts to curb the massive production of and reliance on corn and not proposing any real preventative measures, the corn crop would still be at risk. While reducing the longevity of any such threat is a huge priority, it seems too risky to leave the corn crop as large as it is without further preventative actions.

### 4.3. New Proposals

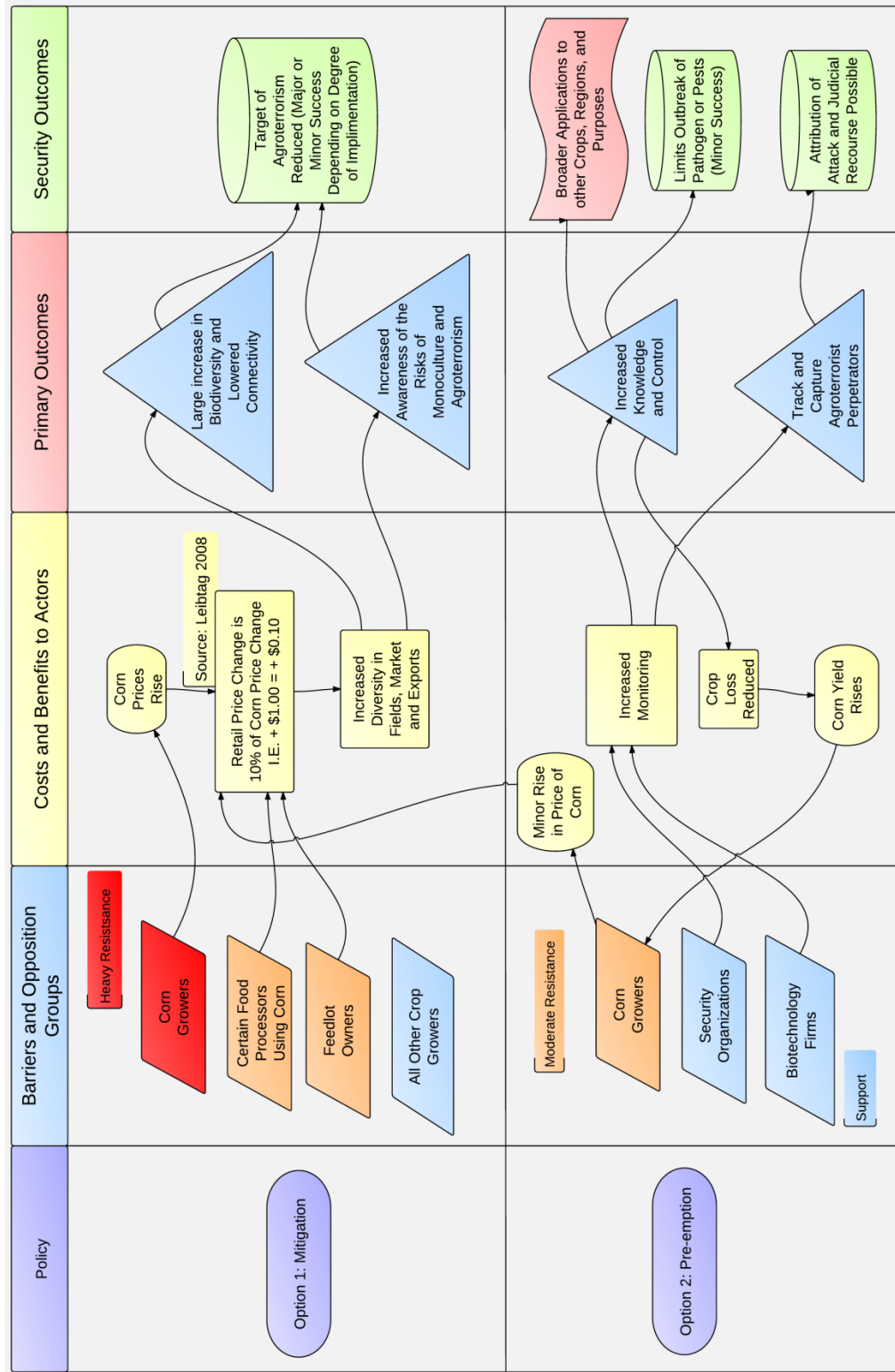
The difficulty in addressing agroterrorism stems from several factors. Firstly, since corn has become a prominent crop in the U.S., corn growers have developed into a strong lobby as well as gained the support of other industries that benefit from corn production. Secondly, government legislators thus far have no significant mandate if they wanted to change this system and attempt to reduce monoculture, with the only group supporting the reduction in monoculture being environmentalists who have little economic sway. Finally, subsidies are by far easier to give than to take away, which limits the viability of policy options affecting subsidies. One factor facilitating the removal of subsidies, however, is the international pressure for fairer trade, one example being the WTO. There are many international groups that would benefit from lowered support to American agriculture, with trade deals often hinging on such a reduction in market distorting payments. While historically domestic pressures carry more clout than international ones (Winders 2009), the international realm is another weight added onto the scale in favor of reduced subsidies.

While examining the policies below, it is important to keep in mind the status quo of corn and U.S. agriculture which has been outlined above. The abundance of corn and lack of biodiversity are likely to continue if no action is taken, extending how long these weaknesses are present and potentially exacerbating them in the future. It is difficult, however, to place a probability on the likelihood of an agroterrorist attempt on U.S. soil. While there have been biological attacks against U.S. food and citizens (Olson 2012) there have been no known attempts to damage agriculture in the field with biological weapons. However, advances in biological and information technologies make this more likely, allowing easier access for anyone seeking the tools needed to learn about and carry out agroterrorism. There have even been cases of poor security checks being performed for entrance into secure areas in FDA facilities, potentially giving access to dangerous material to those seeking to use them maliciously (Monke 2007). There is opportunity to access information and resources that are critical to agricultural security through academic research and espionage. So long as the U.S. has enemies that wish to disrupt and cause chaos, there is a potential for agroterrorism to be the means chosen.

The potential solutions available to address the agroterrorist threat fall into two broad categories: Damage Mitigation and Threat Pre-emption. Damage Mitigation is based on elimination of the reliance on monoculture, by depending more heavily on more diverse crops, and/or by dispersing the locations these crops are grown in to reduce the likelihood of extensive contamination. Threat Pre-emption, on the other hand, assumes corn will remain a target and keep its current layout. However, frequent monitoring and physical security measures can be used to impede and stop any attempts made to contaminate crops and create countermeasures for those pathogens that are deployed successfully. These policies and their predicted consequences have been summed up and simplified in **Figure 4.2** below. Each policy, if followed fully, has a different set of supporters and opponents, costs, benefits, and outcomes. Looking over this figure will give a more complete picture of what each policy is expected to accomplish.



Figure 4.2: Summary of Suggested Policies



Source: Leibtag 2008

### **4.3.1. Policy Goal 1: Damage Mitigation through Target Reduction**

These three methods discussed below are attempts to reduce and remove the weaknesses to agroterrorism inherent in the corn crop mentioned earlier on. These methods aim to eliminate the three criteria for agroterrorist and monoculture risk: biomass, biodiversity, and connectivity. If these methods were to be implemented to a wide enough degree and achieve the desired results, it would weaken and hinder agroterrorist efforts against U.S. corn crops. These methods would require agroterrorists to attack more locations, different crops, and with different pathogens, to be able to achieve the same level of economic damage. This goal of having a more biodiverse agricultural landscape is the only real long-term method of keeping U.S. agriculture secure. Any other method falls short of the protection offered here, and is only limited due to feasibility.

#### **4.3.1.1. Method 1: Subsidy Reduction or Removal - Biomass**

It is important to note that any successful policy for the short and long term would need to reduce or remove incentives on any geographically concentrated and economically important crop like corn. Without elimination, or at least reduction, of subsidies to major crops like corn, crop acreage will be artificially high. Without subsidies corn fields would be diminished in size and breadth, acting to reduce corn biomass, minimizing the risks of that characteristic of vulnerability. This would at the very least save the government and taxpayers money, but would also have the additional effects of balancing out the other crops in relative size to corn, allowing a more equal distribution of risk between them. As the largest target diminishes so too does the total damage possible on that one crop. To circumvent this and to do damage comparable to a successful attack on corn, agroterrorists would require the successful contamination of many different crops, requiring at least one new weaponized pathogen per crop as opposed to just one for corn. Impeding their logistics would not only make an agroterrorist attempt less likely, as complexity is a deterrent, it would give more opportunity for failure and pre-emptive capture.

Subsidy reduction would be synergistic with Method 2, which aims to increase substitutes for corn. By reducing support for the largest crops, like corn, other crops

would rise in relative size and value and increase the difficulty an agroterrorist would face in carrying out a successful attack.

#### **4.3.1.2. Method 2: Incentivize Corn Substitutes - Biodiversity**

Attempting to create a better market environment for corn substitutes requires the most private actor involvement and heaviest regulation. Unlikely to be opted for voluntarily by businesses, this plan is based around the idea that corn substitution will reduce the demand for corn and thus increase the biodiversity of U.S. agriculture. Substitutes can be promoted through incentives placed on secondary industries like livestock, processed foods, and ethanol, either by penalizing high corn usage or by promoting alternatives. Without incentives there would be a cost borne by producers if they were to switch from one input to another, and would ultimately increase the price consumers would need to pay. For this method it would require the general populace to bear the burden through either another program requiring tax-based funds, or higher food costs. These prices may be offset by the savings seen through subsidy reduction in Method 1 above. Using simple economics, incentives would need to bridge the cost gap between corn and its alternatives, potentially requiring more money up front as infrastructure may need to change.

Such incentives would benefit those within industries who use substitutes for the crops which are considered to be at risk or a target for agroterrorism. These incentives would be limited by both the substitution costs of goods, which the subsidy would have to exceed, and by the specific industries seeking diversification in crop use. While being very cumbersome as far as legislation goes, requiring specific rules for each product, these incentive policies could apply to all crops and all products, thereby mitigating part of the claim of one group being discriminated against financially. Such a reduction would not only reduce the likelihood of attacks on corn, but all large crops affected by these financial incentives. The only way this could be feasible would be through a slow transition, from either the private only or the public aided method.

Estimates suggest that by intelligently expanding the use of other crops, resilience of corn may be increased to such an extent that yield would increase by 23% (Anderson 2011). Through crop rotations and increased biodiversity corn can be both more resiliently and more efficiently produced. This increased productivity would help

offset some of the costs associated with corn reduction and substitution. The growth in supply of substitution crops would lower their prices, all else kept equal. What was done for corn, which could work for other crops, is the implementation of marketing subsidies to help create demand for these growing sectors (Diakosavvas 2011). This would help prevent the price of these substitutes from falling too low due to increased supply.

#### **4.3.1.3. Method 3: Incentivize Geographic Spread – Connectivity**

Similar to the previous method, incentivizing geographic spread would seek to undermine the vulnerability characteristic of connectivity. Currently, certain states like Iowa contain many more acres of corn than others, all of which are relatively close to one another. With the above two methods, corn would be smaller but it would likely still be large enough to warrant targeting. By spreading the remaining fields of corn out more evenly between states and counties, it would be more difficult for any one pathogen to contaminate multiple fields when introduced to one area. This would require agroterrorists to apply their pathogen to many fields to harm a large portion of corn, and the natural spread of the disease would have large barriers of other crops which it could not be able to pass.

Incentives or penalties would likely work as follows. The first would penalize farmers planting fields in too close a proximity to other fields carrying the same crop. The second would benefit those farmers who keep a certain distance away or are separated by a certain number of fields with other crops. The larger the financial penalty or reward, the more farmers would consider it worthwhile to switch locations. This however ignores the reality that location matters heavily to farmers and their crops. Thus these negative or positive incentives for geographic spread may need to be even larger than those of the substitution incentives. Since there are climate, economic, and many other reasons for the current geographic corn layout, there may be resistance from farmers on several fronts. However, having open discussion between farmers and policy makers would allow location strategies and needs to be discussed and courses of action agreed upon. There would also be opportunity for questions to be fielded and an understanding of the dangers of agroterrorism to be understood. What should not be overlooked is that while farmers work for themselves for profit, the security of their goods is important to the society as a whole. As well, gradual implementation would allow farmers to come to

terms with the necessary difficulties of protective measures, and to plan for the eventual changes.

#### **4.3.1.4. Implementation: Timing**

These three methods attempt to limit the damage of the three characteristics of biomass, connectivity, and lack of biodiversity. Feasibility concerns for the above suggestions are justified. There are many factors limiting these methods in their initial formulation let alone implementation. What has been needed in the past for reform in the agricultural sector is a broad consensus amongst different crop growers as well as livestock, food processors, and potentially even ethanol producers, that there is a crisis or need for reform. What precipitates a crisis are usually drops in prices and profits and has been seen in the past to be a critical factor (Diakosavvas 2011). Since all other growers would likely benefit from corn being displaced, there would be a good deal of unity from other growers towards this solution. That being said, the ideal time for such a push towards diversification would be during such a 'crisis', giving the proposed changes the best chance of succeeding. It may be possible to use the threat of agroterrorism as a reason as well, since all these efforts are to preserve the security of the farmers and their crops. However, it is likely that such long-term solutions like the suggestions above will require patience and careful timing to be implemented. This, unfortunately, may not be until after the first agroterrorist attack occurs.

With the correct planning, the costs of these methods may not be too prohibitive. Eliminating direct payment subsidies altogether would make available roughly \$1.5 to \$3 billion every year (State, Congressional District & County Data 2011). There are currently plans in motion to eliminate all direct payments on all crops, replacing them with larger insurance programs. Such a change in the farm programs would save close to \$2 billion every year (Abrams 2012). The \$2 billion could then, at least in part, be reinvested into promoting biodiversity and geographic spread of crops, allowing the U.S. to reduce their monoculture and their food vulnerability. The extent to which this funding will be successful has yet to be determined, with more market research being needed to analyze the elasticity of crop and location to financial incentives. The next policy goal focuses less on the target than on those who would be committing these attacks.

### **4.3.2. Policy Goal 2: Pre-emption and Dissuasion**

In this approach the following methods, assuming corn is still a target, seek to provide heightened monitoring and study of diseases, molds, and pests. By frequently testing crops for contamination the ability to detect potential risks while in the field is increased allowing the appropriate groups and agencies to go through the processes of preparing solutions towards any of these damaging organisms in advance. Sharing the information gathered with farmers, biotechnology firms, and government agencies would provide each with additional knowledge to prepare in their own ways for an agroterrorist attack. This policy is economically feasible for two reasons. First, costs are spread between private actors in farming and biotechnologies, and the public security organizations, all of whom benefit from a safe crop. Secondly, if naturally occurring crop loss, estimated at over \$30 billion (Oerke 2005), may be mitigated through such research, it may prove to save more money than it costs, even without agroterrorism being factored in.

#### **4.3.2.1. Method 1: Pathogenic Prediction**

Prediction provides a mixed effort against agroterrorism amongst public and private groups. Homeland security or military-level study of diseases and molds could give insight into how would-be agroterrorists may develop pathogens or modify pests to inflict the most damage. Much like the yearly flu shot, scientists may be able to extrapolate from current pathogens and see how one would evolve into a larger threat. Similarly, scientists could determine which of these diseases and molds would be the most dangerous to crops given the evolutionary possibilities and how to stop them before the need arises. Seeing how a pathogen evolves or how one could use natural selection in labs to develop a more dangerous threat would give scientists a means to predict potential changes to current natural threats. Furthermore, these scientists would be able to prepare whatever is necessary to eliminate these threats before they occur. Finally, these labs would be able to infer what tools and equipment is needed for certain types of pathogens or pests, sharing this information with the appropriate information and security agencies.

This method would include a specialized subsection that acts as a deterrent and dissuade agroterrorists. Pathogenic Forensics, as outlined by Fletcher et al. (2006), is

designed to act as the protocols and methods by which scientists could trace back and root out the source of outbreaks. This also includes determining whether or not a disease is of the natural occurrence from year to year or if it had been introduced and comes from a differing genetic stock. Since microbes reproduce so frequently it is possible to determine if certain microbes have been grown or bred in isolation from the rest of the natural population (Fletcher et al. 2006).

To properly execute such an initiative requires frequent testing and building a fairly up to date compendium of the major pathogens that could threaten corn crops. For each crop it is common for there to be between 10 and 15 major and noteworthy diseases (Fletcher et al. 2006). This is a substantial undertaking when considering the number of crops that are produced within the United States. However, the three most valuable food crops, corn, soybeans, and wheat, exceed the value of the fourth most valuable crop, tomatoes by roughly 6 times, 5 times, and 2 times, respectively (Agricultural Commodity by Country 2012). While still requiring much sampling of many acres, this strategy places such testing and database creation within the realm of the possible.

Creating an infrastructure of labs that would be continually running tests and gathering data on pathogens and pests would provide two very important benefits to the security of American agriculture. Firstly, it would provide a baseline level of pathogenic contamination from which expectations could be extrapolated. This includes determining how natural diseases spread, potentially limiting their damage, identifying the most damaging diseases, as well as determining what levels of contamination are normal in nature. Secondly, it would allow for a full-time staff of lab workers and scientists to be ready for any natural or man-made pathogenic outbreak and to research these diseases and how they are spread. Preparing a workforce for daily efforts and emergency response capabilities would create a specialized team to counteract an agroterrorist threat. With billions of dollars at stake, some preventative costs are warranted.

#### **4.3.2.2. Method 2: Public/Private Partnerships**

Not only would a partnership policy be of interest to farmers, but also food processors, biotechnology companies, and various security agencies of the U.S. federal government, including the military. This would also benefit the general population,

securing the availability and prices of their food supply. Farmers and processors would benefit from reduced loss of and increased stability for corn, the crop they both rely on. The military would have increased knowledge of the threats biological agents may pose and how they may be brought about. Knowing the resources used to create such threats would also aid in the detection of potential perpetrators. The biotechnology companies would benefit by participating in the research and applying what is learned to their own business. In short, these companies would be tasked with determining the best methods to prevent any of the threatening agents from being destructive in the first place. Alternatively, such companies could be contracted by a publicly funded laboratory for additional assistance.

The layout of powers given to public and private actors requires further study, and will determine the overall functions that are assigned to whom. Similar to the creation of the BT gene seen earlier, these biotechnology firms, contracted or otherwise, could devise not just preventative gene modifications to corn, but also molds or pests that fight other molds and pests. By sharing costs and findings amongst partners, it may be possible to develop new breeds of plants or predict and eliminate potential threats before they emerge.

By increasing the interconnectivity between relevant groups, all of whom benefit from safer corn, there can be more opportunities to share information between parties. It also increases the lines of communication between relevant parties and has the potential to help reduce the tensions between inspectors and officials on the one hand and farmers and producers on the other. It is also possible to decentralize part of the process by giving farmers the tools they need to take samples and mail them regularly for testing. This would give farmers control, reduce costs and create an efficient division of labor, assuming of course that such tests could be possible.

#### **4.3.2.3. Implementation: Starting Small**

These two comprehensive preventative proposals, however, are severely limited in two respects. Firstly, the land used for crops in the U.S. is extremely large, accounting for over 1.65 million square kilometers (CIA World Factbook 2012). Monitoring this would be an enormous task even with decentralization, and require expertise in many different forms of plants, pests, diseases and molds for those in the lab. The first problem bleeds



into the second, which is cost. Paying the manpower required to study many fields of crops could rise beyond feasibility. While there are currently many laboratories in emergency networks as seen earlier, these are not continually paid staff. As such, finding the funding and manpower for lab technicians and the equipment required for the lab will likely be considerable.

The problem of cost may be mitigated in several ways, however. By uniting different actors (farmers, processors, biotechnology, military, information and security agencies, and the USDA) costs would be shared amongst them all, while providing a benefit to them all. If this is still not enough to reduce costs, a focus could be placed on a single region seen as most susceptible, likely in the state that produces roughly 20% of all U.S. corn: Iowa (Crop Production 2011 Summary 2012). Potentially, this could serve as an early warning area for the rest of the corn supply, and at the very least act as a training grounds for how to deploy scientists or farmers and testing equipment most efficiently for disease tracking. Likewise, it would be possible to test how efficient different distributions of responsibility work amongst the groups. An example would be to see if it is actually feasible to simply give farmers the tools to perform rudimentary tests and mail their findings to a lab at set intervals to track disease prevalence and spread.

One final benefit from starting small is to create a framework for authority and hierarchy across organizations to deal with agroterrorist threats. By creating clear lines of authority and jurisdiction appropriate action can be taken when certain circumstances arise. The ARS is an appropriate candidate to wield much authority in agroterrorist matters, with over 90 research locations, over 2,000 scientists and researchers employed for them, and with the mandate to find solutions to agricultural problems (About ARS 2012). Augmenting the mandate of an already existing and functioning government body would likely cost less and be easier to do than creating a new network from scratch.

#### **4.3.2.4. Policy Cost and Feasibility**

The major limiting factor for both policy goals seen above is cost; opportunity costs and incentives for the first goal (Prediction), and hiring and infrastructure costs for the second (Partnerships). Beyond this, the first goal, which would drastically change the subsidy structure for agriculture in the U.S., includes the costs of lack of market support

and even resistance. In addition, the first goal requires incentivizing many farmers, food processors, and livestock owners, likely costing substantially more than the second goal. For both goals, however, funds could be gained from reduction or removal of the direct payment subsidy that affects all farmers. This could be augmented to affect only the farmers of the largest and most vulnerable crops, thereby increasing the support from the smaller farmers.

## 5. Conclusion

The Pre-emption and Dissuasion policy goals are the most feasible set of options discussed, allowing partnerships which are mutually beneficial and aids in the funding difficulties of any new task being undertaken. The other set of options, Damage Mitigation through Target Reduction, is more preferable, leaving little to chance concerning crop security and is a more long-term solution from both man-made and natural risks. While warning and expertise concerning threats to corn may indeed help prevent major outbreaks, so long as corn remains such a monolithic crop in American agriculture it will remain an Achilles heel should it be targeted. Human threats aside, whenever there is a single large food source; nature tends to find a way to harness it eventually. With the aid of human intervention, the natural world may develop a means of harnessing corn energy and bypassing pesticides sooner. Biodiversity is the only real long-term means towards a safe food supply, without any one crop dominating agricultural production. While in the short run there is little to fear and corn continues to grow in presence and influence in the market and industries, the unlikely natural or man-made disease could cause an incredibly costly shock. Following the first set of policy suggestions for Damage Mitigation would dramatically reduce the costs of any one crop being annihilated by spreading risk across many targets instead of just one. As biotechnology becomes more accessible to those around the globe it is more and more likely someone will use it for some malicious end.

So long as subsidies benefit efficient farmers, crop concentrations will only increase, promoting monoculture as well as dangerously high levels of geographic concentration. The difficulty lies in the fact that efficiency is necessary for competitiveness, even if in this case it is promoted through government intervention. Removing Insurance subsidies may reduce the stability of the corn crop in markets, which is undesirable. Direct Payments could be changed from being applied to all farmers relatively equally to a system that does not benefit the largest crops. This would

promote other smaller crops over the largest and most at risk crops. Monoculture, the key source of the vulnerability of the U.S. crop, would also be stymied.

Another factor which would make removal of the direct subsidies economically beneficial is the international market. Namely, ethanol produced in other countries, like sugar cane ethanol in Brazil, is “considerably more efficient” than feedstock-based ones in the United States (Hira and Guilherme de Oliveira 2009). Rather than using direct subsidies to indirectly promote an inefficient industry to make it competitive, that money could be spent creating the infrastructure needed to secure United States crops. Politically, feasibility is improved by the fact that subsidies have been a sore spot for international trade agreements on agriculture (Winders 2009), and their removal would allow new deals to be struck, promoting other, more efficient industries.

A key goal of agricultural policy should be to promote a bio diverse set of crops which can be interchanged between one another in their end use as best as possible in case one were to disappear. That being said, there are clear benefits towards policy options geared towards information gathering and prevention. An information network created between major actors with a common goal of protection of an industry would have benefits outside of those of agroterrorism by reducing natural damages to crops and reducing tensions between groups. If a strong partnership is formed, then it could be a launching point to help lead to true biodiversity generation through policy reform.

Efforts should be made to introduce partnerships between the different groups that rely on corn or the other major U.S. crops. Their initial goal, once a partnership has been established, should be to test out the most efficient means to gather and share data on diseases and pests. From there, a greater assessment can be made of which pathogens or pests could be used as a weapon and which naturally occurring threat causes the most damage currently. Further, with the aid of intelligence organizations, discussion of how these diseases may be introduced to fields could determine the limits of what is feasible for agroterrorists. Further risk assessment and mitigation strategies can stem from such a partnership and more concrete actions can be taken if seen necessary.

This project strongly suggests that, among important players in agriculture, industry, government, and security, there should be more cooperation to try and understand and take preventative actions against agroterrorism. Without this first step of open discussions and concerted effort, concrete policies like research labs and reduced crop size may never occur.

## References

- "2011-2012 U.S. Corn Projected Usage." *U.S. Grain Flows*. Pro Exporter Network. Web. 22 Feb. 2012. <<http://www.proexporter.com/>>.
- "About ARS." *Ars.usda.gov*. Agricultural Research Service, 6 May 2012. Web. 07 June 2012. <<http://www.ars.usda.gov/aboutus/aboutus.htm>>.
- Abrams, Jim. "New Farm Bill Would End Direct Payments to Farmers." *US News*. U.S. News & World Report, 03 June 2012. Web. 06 June 2012. <<http://www.usnews.com/news/us/articles/2012/06/03/new-farm-bill-would-end-direct-payments-to-farmers>>.
- "Adoption of Genetically Engineered Crops in the U.S.: Extent of Adoption." *ERS.USDA.gov*. United States Department of Agriculture - Economic Research Service, 01 July 2011. Web. 19 June 2012. <<http://www.ers.usda.gov/data/biotechcrops/adoption.htm>>.
- "Agricultural Commodity by Country." *FAOSTAT*. Food and Agriculture Organization of the United Nations, n.d. Web. 01 Aug. 2012. <<http://faostat.fao.org/DesktopDefault.aspx?PageID=339>>.
- Anderson, Randy L. "Corn Tolerance to Weed Interference Varies with Preceding Crop." *Weed Technology* 25.3 (2011): 486-91. Print.
- "Appropriated Funding for Fiscal Years 1996-2011." *Gipsa.usda.gov*. Grain Inspection Packers and Stockyard Administration, 2012. Web. 07 June 2012. <<http://www.gipsa.usda.gov/about/budget.html>>.
- Byrne, Jan, and Ray Hammerschmidt. Diagnosis of Philippine Downy Mildew Caused by *Peronosclerospora philippinensis*. *PlantManagementNetwork.org*. Michigan State University, 2007. Web. 8 May 2012. <<http://www.plantmanagementnetwork.org/proceedings/npdn/2007/posters/05DownyMildew.pdf>>.
- "Consumer Price Index." *Bls.gov*. Bureau of Labor Statistics, 17 Feb. 2012. Web. 28 Feb. 2012. <<ftp://ftp.bls.gov/pub/special.requests/cpi/cpiat.txt>>.
- "Corn Farmers Coalition." *Corn Farmers Coalition*. Web. 22 Feb. 2012. <<http://www.cornfarmerscoalition.org>>.

- "Crop Production 2011 Summary" *Usda.gov*. United States Department of Agriculture - National Agriculture Statistics Service, Jan. 2012. Web. 31 July 2012.  
<<http://www.usda.gov/nass/PUBS/TODAYRPT/cropan12.txt>>.
- Cussins, Steven W. "How Much Does a Cow Eat?" *NRCS.USDA.gov*. Natural Resources Conservation Service, 2008. Web. 06 May 2012.  
<<http://www.ks.nrcs.usda.gov/news/coneds09/CowEats.html>>.
- Diakosavvas, Dimitris. *Evaluation of Agricultural Policy Reforms in the United States*. Paris: OECD, 2011. Print.
- "Ethanol Myths and Facts." *EERE.Energy.gov*. U.S. Department of Energy - Energy Efficiency and Renewable Energy, 23 Aug. 2011. Web. 28 Feb. 2012.  
<[http://www1.eere.energy.gov/biomass/ethanol\\_myths\\_facts.html](http://www1.eere.energy.gov/biomass/ethanol_myths_facts.html)>.
- "Farm and Commodity Policy: Program Provisions: Direct Payments." *Ers.usda.gov* ERS/USDA Briefing Room. United States Department of Agriculture - Economic Research Service, 15 June 2009. Web. 21 May 2012.  
<<http://www.ers.usda.gov/briefing/farmpolicy/directpayments.htm>>.
- Fletcher, J., C. Bender, B. Budowle, W. T. Cobb, S. E. Gold, C. A. Ishimaru, D. Luster, U. Melcher, R. Murch, H. Scherm, R. C. Seem, J. L. Sherwood, B. W. Sobral, and S. A. Tolin. "Plant Pathogen Forensics: Capabilities, Needs, and Recommendations." *Microbiology and Molecular Biology Reviews* 70.2 (2006): 450-71. Print.
- Fraser, Evan D.G. "Food System Vulnerability: Using past Famines to Help Understand How Food Systems May Adapt to Climate Change." *Ecological Complexity* 3.4 (2006): 328-35. Print.
- "General Information on Concentrated Animal Feeding Operations." *EPA.gov*. United States Environmental Protection Agency, 27 Mar. 2012. Web. 22 May 2012.  
<<http://cfpub.epa.gov/npdes/afo/info.cfm>>.
- Hira, Anil, and Luiz Guilherme De Oliveira. "No Substitute for Oil? How Brazil Developed Its Ethanol Industry." *Energy Policy* 37 (2009): 2450-456. Print.
- Holling, C. S. "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4.5 (2001): 390-405. Print.
- Iversen, Amy, and Neil Greenberg. "Food for Thought." *Psychiatric Annals* 34.9 (2004): 720-27.
- Jackson, Tamra A. "Rust Diseases of Corn in Nebraska." [Http://www.ianrpubs.unl.edu](http://www.ianrpubs.unl.edu). University of Nebraska, Nov. 2008. Web. 04 Apr. 2012.  
<<http://www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=720>>.

- Kind, Mark. "Kansas City Ag Giant DeBruce Agrees to Sell to GaviLion." *Kansas City Business Journal*. 10 Oct. 2010. Web. 27 Feb. 2012.  
<<http://www.bizjournals.com/kansascity/news/2010/10/19/GaviLion-will-buy-DeBruce.html>>.
- LeBlanc, Michael, Betsey Kuhn, and James Blaylock. "Poverty amidst Plenty: Food Insecurity in the United States." *Agricultural Economics* 32.S1 (2005): 159-73. Print.
- Lehrer, Nadine. *U.S. Farm Bills and Policy Reforms: Ideological Conflicts over World Trade, Renewable Energy, and Sustainable Agriculture*. Amherst, NY: Cambria, 2010. Print.
- Leibtag, Ephraim. "Corn Prices Near Record High, But What About Food Costs? But What About Food Costs?" *Ers.usda.gov*. Economic Resource Service - United States Department of Agriculture, Feb. 2008. Web. 19 Mar. 2012.  
<<http://www.ers.usda.gov/AmberWaves/February08/Features/CornPrices.htm>>.
- Madden, Laurence V., and Mark Wheelis. "THE THREAT OF PLANT PATHOGENS AS WEAPONS AGAINST U.S. CROPS." *Annual Review of Phytopathology* 41 (2003): 155-76. Print.
- Margosian, Margaret L., Karen A. Garrett, J. M. Shawn Hutchinson, and Kimberly A. With. "Connectivity of the American Agricultural Landscape: Assessing the National Risk of Crop Pest and Disease Spread." *BioScience* 59.2 (2009): 141-51. Print.
- Monke, Jim. *Agroterrorism: Threats and Preparedness*. N.p.: BiblioGov, 2007. Print.
- Morris, Grant L. *A New Kind of War: Are We Prepared For Agroterrorism?* CreateSpace, 2007. Print.
- "NASS - Charts and Maps - Field Crops." *NASS - Charts and Maps - Field Crops*. National Agriculture Statistics Service, n.d. Web. 01 Aug. 2012.  
<[http://www.nass.usda.gov/Charts\\_and\\_Maps/Field\\_Crops/cornac.asp](http://www.nass.usda.gov/Charts_and_Maps/Field_Crops/cornac.asp)>.
- Nestle, Marion. *Safe Food: the Politics of Food Safety*. Berkeley: University of California, 2010. Print.
- O'Day, Maureen, Anastasia Becker, Armon Keaster, and Laura Kabrick. *Corn Insect Pests: A Diagnostic Guide*. Columbia, MO: MU Extension, University of Missouri-Columbia, 1998. Print.
- Oerke, E.-C. "Crop Losses to Pests." *The Journal of Agricultural Science* 144.01 (2005): 31-43. Print.
- Olson, Dean. "Agroterrorism." *FBI*. Federal Bureau of Investigation. Web. 28 Mar. 2012.  
<<http://www.fbi.gov/stats-services/publications/law-enforcement-bulletin/february-2012/agroterrorism>>.



- Philpott, Tom. "90 Percent of Corn Seeds Are Coated With Bayer's Bee-Decimating Pesticide." *Motherjones.com*. Mother Jones, 16 May 2012. Web. 24 May 2012. <<http://m.motherjones.com/tom-philpott/2012/05/catching-my-reading-ahead-pesticide-industry-confab>>.
- Plant Protection Quarantine Select Agents and Toxins, 70 FR 13278 C.F.R. § 331.3 B (2005). <[http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title07/7cfr331\\_main\\_02.tpl](http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title07/7cfr331_main_02.tpl)>
- Pollan, Michael. *The Omnivore's Dilemma*. New York: Penguin Group, 2006. Print.
- Putnam, Melodie. Brown Stripe Downy Mildew of Corn. *PlantManagementNetwork.org*. Oregon State University Plant Clinic, 2007. Web. 8 May 2012. <<http://www.plantmanagementnetwork.org/proceedings/npdn/2007/posters/02BrownStripeDowneyMildew.pdf>>.
- "State, Congressional District & County Data." *2011 Farm Subsidy Database*. Environmental Working Group. Web. 22 Feb. 2012. <<http://farm.ewg.org/progdetail.php?fips=00000>>.
- Stebbins, Christine. "Stuffed US Grain Elevators Brace for Huge Harvest." Ed. Lisa Shumaker. *Reuters*. 25 Aug. 2010. Web. 27 Feb. 2012. <<http://www.reuters.com/article/2010/08/25/usa-grains-harvest-idUSN2512608720100825>>.
- Stebbins, Christine. "Gavilon to Buy Union Elevator PNW Grain Elevators." Ed. Lisa Shumaker. *Reuters*. 24 Mar. 2011. Web. 27 Feb. 2012. <<http://www.reuters.com/article/2011/03/24/usa-gavilon-pnw-idUSN2417892020110324>>.
- Tatum, L. A. "The Southern Corn Leaf Blight Epidemic." *Science* 173.3991 (1971): 1113-116. Print.
- "United States." *CIA World Factbook*. CIA. Web. 19 Feb. 2012. <<https://www.cia.gov/library/publications/the-world-factbook/geos/us.html>>.
- United States. Department of Health and Human Services. Center for Disease Control and Prevention. *FY 2012 - Justification of Estimates for Appropriations Committees*. Center for Disease Control and Prevention, 2012. Web. 7 June 2012. <[http://www.cdc.gov/fmo/topic/Budget%20Information/appropriations\\_budget\\_for\\_m\\_pdf/FY2012\\_CDC\\_CJ\\_Final.pdf](http://www.cdc.gov/fmo/topic/Budget%20Information/appropriations_budget_for_m_pdf/FY2012_CDC_CJ_Final.pdf)>.
- United States. Department of Health and Human Services. Food and Drug Administration. *FY 2012 - Justification of Estimates for Appropriations Committees*. Food and Drug Administration, 2012. Web. 7 June 2012. <<http://www.fda.gov/downloads/AboutFDA/ReportsManualsForms/Reports/BudgetReports/UCM243370.pdf>>.

- United States. Department of Homeland Security. *FY 2013 Budget in Brief*. Environmental Protection Agency, 2012. Web. 2 August 2012. <<http://www.dhs.gov/xlibrary/assets/mgmt/dhs-budget-in-brief-fy2013.pdf>>.
- United States. Environmental Protection Agency. National Service Center for Environmental Publications. *Fiscal Year 2011 Financial and Program Performance*. Environmental Protection Agency, 2012. Web. 7 June 2012. <<http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=P100DPXU.PDF>>.
- United States. Environmental Protection Agency. *Producers Compliance Guide for CAFOs*. EPA.gov, 2003. Web. 6 May 2012. <[http://www.epa.gov/npdes/pubs/cafo\\_prod\\_guide\\_ch2.pdf](http://www.epa.gov/npdes/pubs/cafo_prod_guide_ch2.pdf)>.
- United States. United States Department of Agriculture. Food Safety and Inspection Service. *2012 Explanatory Notes Food Safety and Inspection Service*. Food Safety and Inspection Service, 2012. Web. 7 June 2012. <[http://www.fsis.usda.gov/PDF/FY2012\\_Budget\\_Explanatory\\_Notes.pdf](http://www.fsis.usda.gov/PDF/FY2012_Budget_Explanatory_Notes.pdf)>.
- United States. United States Department of Agriculture. *FY 2013 BUDGET SUMMARY AND ANNUAL PERFORMANCE PLAN*. United States Department of Agriculture, 2012. Web. 7 June 2012. <<http://www.obpa.usda.gov/budsum/FY13budsum.pdf>>.
- "USDA ERS – Corn: Trade" *ERS.USDA.gov*. United States Department of Agriculture - Economic Research Service, 28 May 2012. Web. 31 July 2012. <<http://www.ers.usda.gov/topics/crops/corn/trade.aspx>>.
- "USDA Feed Grain Baseline 2010-19." *Www.ers.usda.gov*. United States Department of Agriculture - Economic Research Service, 28 May 2012. Web. 31 July 2012. <<http://www.ers.usda.gov/topics/crops/corn/market-outlook/usda-feed-grain-baseline,-2010-19.aspx>>.
- Vigouroux, Yves, Jeffrey C. Glaubitz, Yoshihiro Matsuoka, Major M. Goodman, Jesús Sanchez G., and John Doebley. "Population Structure and Genetic Diversity of New World Maize Races Assessed by DNA Microsatellites." *American Journal of Botany* 95.10 (2008): 1240-253. Print.
- Wilson, Jeff. "U.S. Corn Reserves May Double." *Bloomberg News*. Daily-journal.com, 12 May 2012. Web. 23 May 2012. <<http://daily-journal.com/archives/dj/display.php?id=491122>>.
- Winders, William. *The Politics of Food Supply: U.S. Agricultural Policy in the World Economy*. New Haven: Yale UP, 2009. Print.
- Wu, May. *Analysis of the Efficiency of the U.S. Ethanol Industry 2007*. Rep. U.S. Department of Energy, 27 Mar. 2008. Web. 28 Feb. 2012. <[http://www1.eere.energy.gov/biomass/pdfs/anl\\_ethanol\\_analysis\\_2007.pdf](http://www1.eere.energy.gov/biomass/pdfs/anl_ethanol_analysis_2007.pdf)>.