Evaluating the Use of Genetically Modified Crops in the North Country

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Summary:

The issue of whether or not it is acceptable to alter the genetic material of an organism is largely dependent on one's values. Nonetheless, with values aside, during the process of bioengineering genetic alteration is precisely what happens. Even the name "bioengineering" combines two words that are almost contradictory. "*Bio* refers to *life*, what is not mechanistically predictable or controllable - and engineering refers to making the blueprints for machines that are predictable - but not alive" (Batalion 2000). The decisions that we are going to have to make in the near future concerning genetic modification could have huge effects on the way we live and on genetic diversity around the globe. Decisions concerning monitoring practices, government involvement in genetically modified (GM) crop regulation, issues with patenting nature and farmer's livelihoods could have effects on human health, what is socially acceptable and how we value natural systems.

Genetic engineering has made a rapid entrance onto the agricultural scene in recent years. The first GM crop that was available commercially was released in 1996. The first GM crop released was round-up ready soybeans and now there are over 40 different varieties. Genetically modified crops are now grown by over 8.5 million farmers in 21 different countries and over 90 million hectares are devoted to GM crops, with this amount growing consistently every year (Sanvido 2006). In the United States, as much as 25% of the arable land is used for GM crops and GM ingredients appear in at least 2/3 of all U.S. processed food (Batalion 2000).

Locally, GM crops are already widely used. For example, genetically modified corn, soybeans, and alfalfa are all being grown in the North Country. These crops are

engineered to be Round-up ready so that the chemical herbicide Round-up can be used in fields without negatively affecting their growth. This is extremely useful to farmers because it reduces the huge problem of weeds. Round-up resistant canola is available and could become increasingly important if the North Country becomes involved in biodiesel production. Much of the corn planted in the North Country now comes "triple-stacked," which means that it is genetically engineered to be Round-up ready and also have a resistance to two major pests; root worm and corn borer (Barney Personal Communication).

The environmental, social and human health effects of change of this magnitude are still largely unknown. In Europe, environmental organizations and public interest groups have been protesting GM crops because of recent studies showing the negative effects of GM corn on Monarch butterfly caterpillars (Whitman 2000) Scientists, economists, government officials and sociologists among others are currently looking into the possible effects of such a large scale rapid change. Some of the issues being analyzed include the escape of transgenes, the development of "super weeds", effects on small scale and organic farms and the health effects on humans. As data begins to pour in, we can already begin to see that GM crops are complex issue with many different stakeholders.

Agriculture is an extremely important issue in Saint Lawrence County. Saint Lawrence County has over 1,600 farms using over 403,000 agricultural acres. St. Lawrence Country has is more acreage being used for agriculture than any other county in New York State. The total cash value of the agriculture in Saint Lawrence County during the 2000 growing season was estimated at over 96 million dollars (Jenny 2003).

Farmers in Saint Lawrence County generally use rotation as a farming practice (Barney Personal Communication). The most commonly used rotation method is to plant corn for three years and then switch to a sod crop such as wheat for five years. Some farmers in Saint Lawrence County are forced to grow all sod crops because the soil is not right for growing corn (Barney Personal Communication).

Farming in the Saint Lawrence County is not an easy task. Some of the main difficulties in farming in St. Lawrence County, as well as in any other agricultural areas, include weeds and pests. The main pests in the area are Rootworm and Corn Borer and in an attempt to deal with these problems, local farmers are more frequently turning to the use of GM crops. A transition from conventional corn, soybeans, and alfalfa to GM versions is rapidly increasing in the North Country (Bordeau Bros. 2007). Many local farmers are also hoping that a Round-up ready Sweet Corn will be developed (Barney Personal Communication). One reason for the delay in GM Sweet Corn is that Sweet Corn can be very sensitive to chemicals and therefore it is difficult to manage weeds in Sweet Corn fields.

The use of genetically modified organisms (GMOs) has, in recent years, become an issue of increasing concern. There are many benefits, as well as concerns, with using GM crops. Some of the main benefits using GM crops are that they could provide to the North Country are pest resistance, herbicide tolerance, and cold tolerance. Pest resistance involves introducing crops with a gene which allows them to produce their own natural pesticides. These pest resistant crops allow farmers to produce higher yields by preventing loss of crops to pests. Pest resistant crops can also be beneficial to the environment because they produce their own natural pesticides, which reduce the need

for farmers to spray chemical pesticides. In this way, pest resistant crops could drastically reduce chemical pesticide use and the subsequent run off and accumulation of pesticides in the environment (Whitman 2000). As mentioned earlier, these pest resistant crops are already used widely by local farmers (Barney Personal Communication).

The next benefit to using GM crops is herbicide tolerance. Weeds are a big issue in Saint Lawrence County, as with most places and it requires a lot of time and energy to remove them. By using crops engineered to be herbicide resistant farmers can apply a blanket spray of chemical herbicides which will remove the weeds quickly and easily. These crops are already used extensively in Saint Lawrence County (Barney Personal Communication). It is also sometimes claimed that herbicide resistant crops could be beneficial to the environment. Since, these crops allow farmers to apply one large application, which kills all the weeds instead of many small applications, it is possible that less total herbicide will be applied (Whitman 2000). This claim will be examined further as a possible concern to using GM crops.

A final benefit to using GM crops that could be especially important in Saint Lawrence County is cold tolerance. Cold tolerant GM crops are created by the introduction of a gene from cold fish. These cold tolerant crops can survive frosts which there traditional counterparts could not (Whitman 2000). The North Country is a cold area especially by farming standards and these cold tolerant crops could potentially be very useful to North Country farmers. Currently, cold tolerant crops are not being used in the North Country, at least not to any major extent (Barney, 2007). Although there are many benefits to using genetically modified crops, many people, including North

Country farmers, have concerns as to the possible impacts of using GM crops (Barney Personal Communication).

Problem Definition:

The rapid increase in the use of GMOs has become an issue of increasing concern. Some of the possible side effects include, the escape of transgenes in the environment (Batalion 2000; Gould 1998; Ives 1996; Powles et al. 1998; Sandermann 2006; Stewart et al. 2003; Whitman 2000), the evolution of "super weeds" and "super pests" (Cambell et al. 2006; Reichman et al. 2006; Zhao et al. 2000), increased soil toxicity (Cattaneo et al. 2006; Heard et. Al 2006), risk to non-target species (Hogervost et al. 2006; Richards et al. 2005; Schuleret al. 1999; Strandberg et al. 2005) and loss in diversity of available seeds (Batalion 2000; Cummings et al. 2002; Cureton et al. 2006). Many of these issues have to potential to reduce the biodiversity in an area where GM crops are being used. The potential side effects listed and their importance to citizens in the North Country are influenced by many economic, social and human health issues.

One of the many issues with using genetically modified crops is that altered genes may escape into the surrounding environment. Organisms may inherit genetic material from modified organisms through cross-pollination or other mechanisms and this new genetic material may become incorporated into the genome of other species (Sandermann 2006; Stewart et al. 2003). The release of genetic material is a concern because many of the characteristics of GMOs are designed to withstand severe conditions including drought and heavy doses of biocides such as pesticides and herbicides. If it is possible for this genetic material to be exchanged with the wild relatives of these GMOs, then it is

also possible that the wild versions may also inherit some of the tolerant characteristics of the GM Crops. The escape of genetic material has many implications with respect to effects on local biodiversity and conservational efforts.

The three most commonly proposed mechanisms for the evolution of herbicide resistant weed biotypes are 1) pre-existing tolerances, 2) gene flow between GM crops and wild relatives, and 3) random genetic mutation (Sandermann 2006). The first mechanism deals with the rule of heterogeneousness in weed populations. In any given weed population there will be herbicide sensitivity in some individuals, as well as naturally occurring herbicide resistance in a few individuals (Sandermann 2006). These pre-existing resistances are essentially selected for by humans through the use of herbicides. Increased herbicidal use because of herbicide resistant GM crops has increased the selective pressure on wild populations and increased the frequency of tolerant genes. The individuals in a weed population who can withstand herbicides are allowed to continue to grow and reproduce, passing there genetic material and tolerances on to the next generation. The main point that Sandermann is trying to convey is that there is a difference between pre-existing tolerances and newly acquired traits due to random genetic mutation leading to evolved resistance (Sandermann 2006). The first mechanism for the evolution of herbicide resistant is more or less a side effect of new trends in genetic engineering and the creation of genetically modified crops.

In 1996, the Monsanto Company released a strain of round-up ready soybeans followed by round-up ready maize, cotton, canola and alfalfa in following years. Round-up resistant corn and soybeans are extensively grown in the North Country (Barney Personal Communication). These crops have been genetically modified to be tolerant to

glyphosate, which is the active ingredient in Round-Up®, a herbicide. Since the majority of weeds are not resistance to glyphosate, farmers can spray their fields without having to worry about killing their crops. By not having to worry about damaging their crops, farmers can save time, energy and money, while increasing yields (Bordeau Bros 2007)

In 1997, a year after round-up ready crops were first available commercially, the first case of herbicide resistant rigid ryegrass (*Lolium rigidium*) was reported in Australia (Powles et al. 1998). Since 1996, there have been six other reported cases of glyphosate resistant weedy species including morning glory (*Ipomoea* spp.), common lambsquarter (*Chenopodium album*) and velvetleaf (*Abutilon theophrasti*) (Sandermann 2006). The combined effect of increased herbicide use and evolution of herbicide resistance has the potential to affect biodiversity in local ecosystems. Increased herbicide use will potentially kill or weaken individuals within a species that are not resistant and the resistant individuals will have a competitive advantage. This competitive advantage, can change communities through competition which has the potential to decrease the biodiversity in the area.

The second and third proposed mechanisms for evolution of herbicide resistance in weed populations described by Sandermann (2006) are 2) gene transfer between species and 3) random genetic mutation. The second mechanism is one of interest and can give rise to herbicide resistant weeds by hybridization with or gene flow between a GMO and a closely related species (Sandermann 2006). The topic of transgenic introgression has been extensively documented for genetically modified crops. In many cases, genetically modified crops have wild relatives that occur in the same region and will likely exchange genetic material with them (Fig. 1). For example, the sunflower

(*Helianthus annuus*) has been genetically modified to be resistant to both herbicides and insects. A close relative, *Heliantus petiolaris* also occurs in many of the same areas across the U.S as *H. annuus*. Other crop species commonly used in agriculture that have a transgenic variety and a wild relative that have been documented as exchanging genetic material are sorghum (*Sorghum bicolor*), canola (*Brassica napus*), wheat (*Triticum aestivum*) and alfalfa (*Medicago sativa*).

Transgene introgression can happen not only between cultivars and wild relatives, but also between nonagronimic species. Reichman et al. (2006) studied the ability of genetically modified creeping bent grass (*Agrostis stolonifera*) to transfer genetic material to any of the 12 species that it can hybridize with. Since creeping bent grass is intended to be used on golf courses, its one of the first transgenic, perennial, wind pollinated crops with sexual and asexual methods of reproduction to ever be studied and experimented with. Three species in the Oregon study area were capable of hybridizing with the GM creeping bent grass (Reichman et al 2006). As expected, genetically modified material from the GM bent grass was found in the three other species in the study area and was generally located downwind of the prevailing winds. This study represents one of the first documented cases of gene flow between wild and non wild populations outside of the agricultural realm (Reichman et al. 2006). This study is also an example of the growing amount of data showing that the escape of genetic material is actually possible. Studies on the effects of transgene introgression on biodiversity however, have not been as well documented. Therefore, one can begin to see the complexity of this issue and how it is unlikely that this will not effect biodiversity in someway or another. Biodiversity in an area is likely to be affected as wild relatives of

GM crops gain a competitive advantage over other naturally occurring species through the development of resistances to things including pesticides, herbicides and insects.

Genetic Random mutation is the third possible mechanism for the development of herbicides and pesticides. Randomly occurring mutation in a species genome can cause weeds to form resistances to herbicides at one or more of the steps that an herbicide uses to kill a plant. Random genetic mutation will not be discussed in detail because of its complexity and difficulty with measuring random changes in a population. This process is the reason for pre-existing resistances in weedy plants, mentioned in mechanism number one and the development of new tolerances.

Another problem associated with the use of genetically modified crops is that pests could develop a resistance to the pesticides that crops are modified to produce and thereby create "super pests". Many crops are now being modified to contain a gene from the bacterium *Bacillus thuringiensis*. This gene allows the crops to produce endotoxins which act as a naturally produced pesticide (Ives 1996). However, it has already been shown that there is potential for pests to develop resistance to these genetically modified Bt crops. A study in 2004, showed the effects that Bt corn can have on a major pest, the corn borer (*Ostrinia nubilalis*) (Farinos et al 2004). The researchers performed field and laboratory tests and although no resistance was shown to develop in the field tests, significant levels of resistance did develop in the laboratory tests. The proposed reason for the differences between the field tests and the lab test was due to the natural variability in the soil of the corn fields. The laboratory results showed that over the course of 8 generations, the corn borer populations were able to develop resistances to the Bt corn. These corn borers developed resistances to the Bt toxin between 10 and 21

times as strong as their original resistance (Farinos et. al 2004). Although this study was not able to prove that corn borers in the field would develop resistance to Bt corn, it did show that the potential to develop resistance exists. Another study which showed the development of resistance to a Bt crop in a laboratory was done by Zhao and others in 2000. This study dealt with the development of resistance by the diamondback moth to Bt broccoli. After 24 generations the diamondback moths in the study had developed a resistance to the Bt broccoli. Similarly to the case of corn borers no resistance has yet been established to Bt broccoli in field populations (Zhao et. al. 2000).

One important reason that resistance to Bt crops has not been recorded in populations in the wild may be that refuges still exist for non resistant pests. Currently there are still many areas where Bt crops are not in use. These areas act as refuges to pests such as the diamondback moths or corn borers. Refuges are areas either within or outside an agricultural field where naturally occurring populations are not exposed to the same conditions as populations being affected by the Bt crops. Individual pests who do not have a resistance to Bt crops are able to survive in these refuge areas and their survival allows their non-resistant genes to remain in the gene pool. Oftentimes, the gene which provides resistance to Bt crops is recessive, meaning that other genes which do not provide resistance are dominant (Tabashnik et. al. 2003). The dominance of non-resistant genes allows them to once again be reestablished into the population even though large numbers of non-resistant individuals may be killed off. For Bt corn, it is mandated that 20% of the field cannot have the gene which allows them to create Bt toxin (Bordeau Bros. 2007). This 20% can be spatially distributed anyway a farmer wants but this practice still allows for some refuges in a Bt corn field.

Herbicide resistant crops and a subsequent increase in herbicide use could lead to herbicide resistant weeds (Barney Personal Communication). Weeds develop resistance to herbicides through selection in the same way that arthropod pests develop a resistance to pesticides. GM herbicide resistant crops allow farmers to blanket spray their crops with herbicides, effectively killing off any weeds in a field that aren't resistant to the pesticides. Since the blanket spraying doesn't leave any surviving weeds that aren't resistance to the herbicides weed populations can quickly develop a resistance. This would not be a problem if herbicide use was kept to a minimum because un-resistant weeds could survive and reestablish their genes in the population.

Another issue with GM cops is that humans have only a very limited understanding of ecosystems and human related factors that may affect ecosystems. We often disregard the ecological services that ecosystems provide for us. When we genetically engineer organisms there are sometimes unintended repercussions on the structure of our biotic communities. One issue with genetically modified crops that is beginning to come to the forefront is the unforeseen effect on non target organisms. While engineering genes that encode for insecticidal proteins may have positive benefits to agriculture, there are many direct and indirect effects on the species that rely on them for survival and biological control agents (Schuler et al. 1999).

Plants that are insect resistant can have profound effects on arthropods and their natural enemies (Schuler et al. 1999). All GM insect-resistant plants express a toxin gene copied from the bacterium *Bacillius thuringinesis* (Bt), which binds and causes severe damage to the midgut epithelium of many herbivorous insects (Peferoen 1997). When the toxin binds to the midgut of the insects it lowers the survival and health of the insects

that eat these plants. In turn, the parasitoids that use these insects as larval host are also affected because the insects do not die immediately but are still used as hosts (Schuler et al. 1999). This can lower the total biodiversity of insects in an area and potentially reduces abundance of species that act as pollinators. In a review of the effects of Bt plants on insect interactions, Schuler et al. (1999) found that these interactions are often unexpected and complex but most studies found a disruption in trophic systems and community structure.

The decline in insect populations may not seem like a serious issue to some people because there are so many insects out there, but sometimes these GM crops harm beneficial insects. The Swiss government found that Bt crops killed lacewings (*Chrysoperla* spp.), which eat cottonworms (*Anomis xylixa*). Cotton worms damage cotton plants (Grote 1874) and by reducing their natural predators, it will allow for higher populations of these worms and further damage. In a study shown in the New Scientist, honeybees can be harmed be feeding on proteins in GM canola flowers (Batalion 2000). Pollination by insects is a huge ecosystem service. A decline population of some insects is worrisome because they are invaluable to the agricultural industry. Again we see that as more and more data piles up, our understanding of ecosystems is very limited. The relationship between GM crops and ecosystem services is complex and not well documented but sometimes disruption in the natural ecosystem are evident.

Another problem that can result from the use of transgenic crops is an increase in toxicity of the soil. This problem originates from the creation of genetically modified crops that are resistant to herbicides. The creation of crops which are resistant to herbicides allows farmers to apply more chemical herbicides to their fields without

harming their crops. Farmers will no longer have to selectively spray individual weeds and instead will be able to blanket spray entire fields. Many of these herbicide resistant crops have actually been created by herbicide companies in an attempt to sell more herbicides. Produces including and similar to Round-up, could have negative effects on 74 endangered species within the United States due to increased soil toxicity (Batalion 2000).

Gyamfi et al. (2002) studied the effects herbicide resistant crops could have on the soil community structure. This study looked at the effects of the use of genetically modified herbicide resistant oilseed rape, a crop used as feed for animals as well as to produce vegetable oil. This particular line of oilseed rape had been modified to be resistant to the herbicide Basta. The study measured the effects that the altered plant structure as well as the increased use of the herbicide Basta had on the environment. Use of the herbicide resistant oilseed rape decreased the complexity of microorganism communities in the soil. These microorganisms in the soil are favorable for plant growth and therefore altering their community structure could have negative impacts on soil fertility (Gyamfi et. al. 2002).

Strandberg et al. (2005) compared weed and arthropod diversity in fields of genetically modified crops and in fields of non-genetically modified crops. At the start of the study the fields containing genetically modified crops showed higher biodiversity of weeds and arthropods. However, after applying herbicides, biodiversity had been reduced significantly in the GM fields and GM fields contained much less weed and arthropod diversity than the conventional fields (Strandberg et. al. 2005). This study shows how biodiversity decreases after applying herbicides, which relates to the issue of

increased herbicide use in GM crops. As more and more GM crops are being planted in the North Country there will be an increase in herbicide use. This could potentially lead to further biodiversity loss in Northern New York.

A final problems associated with the use of GMOs is that farming and biotech corporations are driven by economics. Issues of supply and demand have a huge effect on the livelihoods of farmers in the North Country. Most farmers are just trying to make a living and feed their families so they are willing to do anything that can increase there revenues and yields. Some farmers believe that they can increase yields through the use of genetically modified crops. Farmers can sometimes see an increase from 12 tons per acre with non-genetically modified crops to as much as 22 tons per acre (Bordeau Bros. 2007). One problem that we are interested in is the loss of seed diversity due to hybridization and the formation of large monocultures leading to a loss in overall biodiversity. In one study, hybrid between GM radishes and wild radishes showed that the hybrid had 22% higher survival and 270% more seeds in some areas than wild versions and had equal or less survival in other areas across the U.S. (Cambell et al. 2006). One possible explanation for these differences is because the hybrids inherited the broad environmental tolerances of the cultivated relative and are adapted to survive in new environments (Cambell et al. 2006). Through the combination of inherited genetic material from the GM plants and already being adapted to living in the wild these hybrid can potentially do much better than the wild versions. A similar study found that crop-wild sunflower hybrids produced far fewer seeds than wild sunflowers and fitness of crop-wild radish hybrids was lower than wild species (Snow et al. 2002; Snow et al. 2001). These hybrids may be doing worse for similar reasons as to why they can do

better. It is possible that these hybrid inherited genetic material that put them at a disadvantage compared to wild populations. This last study may be showing that hybrids will do worse out in the wild. From a preservation of biodiversity standpoint this seems positive because species will not be lost due to hybridization.

Stakeholders:

The first group of stakeholders in this issue is the farmers. Both large and small scale farmers will be affected by the use of genetically modified crops. Small scale farmers could stand to lose the most from the use of transgenic crops because they will be the ones that will be put at a disadvantage. The first reason that small scale farmers could potentially be put at a disadvantage is that the large corporations that produce and sell the genetically modified seeds are patenting the crops that they produce. Because these companies hold patents they are able to control the price of GMO seeds (Whitman 2000). Genetically modified seeds are far more expensive then non-GM seeds because farmers pay for the price of the seeds but then have to pay for the additional cost of the genetic upgrades. If a farmer wants to purchase corn seeds that are Round-up ready and Corn Borer resistant, they will have to pay for the cost of regular corn seeds plus the additional cost of each upgrade (Barney Personal Communication). With higher prices it may be difficult for the less wealthy small scale farmers to afford seeds, especially for those who live in impoverished or third world areas (Whitman 2000). Small scale farmers stand to be hurt more by this increased cost, not only because they are not as wealthy as large scale farmers, but also because GMO seeds are sold at lower cost when they are purchased in bulk. Small scale farmers purchase far fewer seeds than large scale farmers

and therefore do not receive the benefits from buying in bulk (Batalion 2000). Another issue with the high price of GMO seed is that often times the seeds are sterilized. Although sterility is beneficial in preventing the flow of transgenes, it could be devastating to small scale and third world farmers. Sterile crops would not produce their own seeds and therefore farmers would be forced to buy seeds yearly from the seed corporations. Small scale farmers not only would not be able to afford these seeds at a high cost, but by being forced to by seeds yearly they could become depended on the corporations for their livelihood (Whitman 2000). Originally North Country farmers could not afford to purchase GM crops because of their high costs. However, because of reduced competition in the seed industries North Country farmers are left with no choice but to purchase the expensive seeds that the seed corporations sell. Since, these farmers can't replant the GM seeds from year to year North Country farmer's have become locked in and are dependent on the seed companies (Barney Personal Communication). There are some possible issues with transgenes jumping into other non-GM farms. Since large seed companies have patents on their gene, if this was to happen, small scale farmers face potential law suits.

Small scale farmers are also put at a disadvantage by the ability of GM crops to increase production. Although it would seem that increased production is a good thing in reality it can be detrimental to small scale farmers. Increased production leads to a surplus of food, which in turn forces food prices to drop. Although this decrease in prices could be good for the average consumer, it is not good for small scale farmers. With decreased prices small scale farmers fail to make a profit and are potentially forced out of business (Batalion 2000).

Organic farmers also stand to lose from the production and use of GM crops. One potential hazard to organic farmers is that pollen from transgenic crops could escape and pollinate organic crops. Once organic crops are pollinated by GM crops they are by definition no longer organic. Organic farmers could also be affected by the wide use of Bt crops. As mentioned earlier, many crops are now being modified to contain a gene from the bacterium *Bacillus thuringiensis*. This gene allows the crops to produce endotoxins which act as a naturally produced pesticide (Ives 1996). However, the bacterium Bacillus thuringiensis, or Bt, is used by organic farmers as a natural pesticide. Organic farmers cannot use chemical pesticides and therefore are left with few options for pest control. The wide scale use of genetically modified Bt crops may lead to an increase in resistance in pests. The pests would not only become resistant to the Bt crops, but would also become resistant to the bacterium itself which is used by the organic farmers (Batalion 2000).

Organic and small scale farmers will also be put at a disadvantage by the development of GM technology that will allow large corporations to produce crop products without the need for farming. This technology would eliminate the need for small scale farmers by allowing food to be produced in labs. One example of this would be a new form of GM vanilla which grows in tubs in a lab without the need for any farming. Batalion writes, "far beyond hydroponics, scientists are developing processes to grow foods in solely laboratory environments – eliminating the need for seeds, shrubs, trees, soil and ultimately the farmer (Batalion 2000)." This new technology would be devastating for small scale farmers and especially those in the third world who depend on people buying their crops.

In contrast to small scale farms, large scale farmers could benefit greatly from the production and use of transgenic crops. Large scale farmers will be put at an advantage by the lower cost of buying seeds in bulk. This would also give competitive advantage over small scale farmers because large scale farms have the means to pay higher prices for seeds, and to pay those prices yearly. Large scale farmers would also stand to gain from the excess production, due to GM crops, that could be detrimental to small scale farmers. Large scale farms that can produce a large amount of crops can afford to sell them at lower prices. The use of Bt crops, while harming organic farmers, could actually benefit large scale farmers, if resistance in pests does not develop, because Bt crops would control pests without the need to purchase more pesticides. Crops that provide herbicide resistance also put organic farms at a disadvantage because controlling weed populations in GM fields by spraying, is time efficient. Finally, large scale farmers could potentially benefit from the use of GM crops that could be produced in the lab, because large scale farms could have the means to switch over to this new way of producing crops (Batalion 2000).

All farmers could be affected by the reduction in the number of seeds producers caused by increased use of GM crops. The list of seed distributors is shrinking because smaller distributors are unable to compete with the large scale GM seed companies. Chemical companies have been buying up the seed distributors in order to produce GM crops which are resistant to their particular brand of herbicide. This reduction in the number of seed companies is a problem because it reduces competition. Reduced competition causes prices to go up which forces farmers to pay more for their seeds. The issue of reduced competition in the seed industry has a large impact on many farmers in

the North Country who cannot afford to pay higher costs for seeds (Barney Personal Communication).

A second group of stakeholders that could be impacted by the use of GM crops is the wildlife in the North Country. The first way that wildlife could be affected by the use of transgenic crops is if the genes from these crops escaped into the environment, as shown in the study conducted by Reichman et al. (2006) on creeping bent grass . The GM herbicide resistant creeping bent grass genes were able to escape into wild populations of similar grass species in the *Agrostis* Genus (Reichman 2006). These grass species are a weed and therefore disrupt the natural ecosystem which could have widespread effects on local wildlife. All of the issues listed in the problem definition section, i.e. escape of transgenes, super pest etc. can be related back to the larger issue of potential loss in biodiversity.

Wildlife could also be affected directly by feeding on GM crops and also by eating pests which have accumulated GM crops in their bodies. An example of how a non-target wildlife species is affected by the use of a GM crops is the effect on aphid populations. Three different aphids, which feed on GM crops, were shown to have accumulated a material produced by GM plants called snowdrop lectin in their stomachs (Hogervorst et al. 2006). This material is produced by genetically modified crops to control pest populations, however this does not always killing these pests and it accumulates in their bodies. Aphid predators then eat these insects and snowdrop lectin further bioaccumulates in the next trophic level. The accumulation of snowdrop lectin in the bodies of these aphid predators was shown to negatively affect their health and reproduction (Hogervorst et. al. 2006). Since aphid predators act as natural pest

controllers, affects on their health may have repercussions not only for natural wildlife but also for farming. These affects to non-target species could drastically affect natural systems and must be investigated further.

Another stakeholder is the government and in the case of the North Country, it is the U.S. government. The federal government is responsible for regulating the use of GMO foods and ensuring that they are safe not only for the consumer but also for the environment. The EPA, FDA, and USDA are all involved in the regulation discussed in a later section (Whitman 2000). The government is also responsible for determining whether corporations can establish patents and other business practices which could lead to monopolies (Batalion 2000). There are laws against the formation of monopolies and the government is in charge of determining if a monopoly has been formed. This will take action on behalf of the government to pursue these issues. Finally, the government subsidizes farms and will have to decide which farms to subsidize. The decision is in the hands of the government whether to choose farms that use GM crops or those that do not or, chose between large or small scale farms.

Another group of stakeholders in this issue is corporations. There are over 1,500 companies that produce and sell GM seeds globally but control over the market is not evenly distributed. Of the 1,500 GM crop companies, 12 companies control more than 50% of the commercial seed rights. By 1999 in the corn seed production section, the top three companies controlled 88% of the sale and production of seeds (Batalion 2000). Monsanto, Pioneer Hi-Bred, Delta and Land Pine Company are all major players in this fast growing global industry. Through competitive practices many of these larger companies have been able to out compete smaller seed companies. The smaller

companies cannot stay in business so they are bought up and incorporated in to larger companies, allowing larger companies to take further control over the market. The attempt to monopolize the seed market by these larger corporations has resulted in little price competition and fewer seed outlets (Batalion 2000).

Reducing competition by buying up smaller companies is just the tip of the iceberg. Many of these larger corporations use other tactics to increase their revenues and increase the dependency of farmers on GM seeds. For example, Monsanto establishes licensing agreements with farmers which forces farmers to use only Monsanto brand herbicides (Batalion 2000). Some companies even incorporate a "suicide gene" into their crops making the GM plants unable to produce seeds, so farmers have to buy fresh seeds every year (Whitman 2000). Others make farmers agree not to collect seeds and even send out field detectors to monitor the farms (Batalion 2000). These corporations are the suppliers of GM crops and represent one of the major groups that stand to gain or lose from decisions made about the use of GMOs.

Consumers are another large stakeholder group. The first thing that is at stake when dealing with consumers is their health. There has been growing attention concerning the introduction of foreign genes into the food that we eat and the potential for negative human health effects (Whitman 2000). For example, in 1989 L-tryptophan, an essential amino acid used in some food supplements, cause 37 deaths and impaired thousands of Americans with eosinophilia-myalgia syndrome (EMS) (Batalion 2000; U.S.F.D.A. 2001). This outbreak was traced back to a Japanese company who paid a 2 billion dollar settlement for the damages. The Japanese company has very little regulation on the GM bacteria that they used to synthesize L-tryptophan and in the

purification process, bacterial metabolites were not completely remover. An increasing number of children in the U.S. and Europe have developed life threatening allergies to proteins in genetically modified peanuts (Whitman 2000). Some researchers believe the introduction of new genes into plants is responsible for a number of new allergens. Similarly, due to fear of unexpected allergic reactions, idea of splicing Brazil nut genetic material into soy beans was abandoned (Batalion 2000; Whitman 2000).

Another issue concerning consumers is the insufficient regulation and safety testing for GMOs. There is much confusion in the government on how to efficiently regulate tGM products because GM crops fall under the jurisdiction of three different government agencies. The EPA regulates GM crops for environmental safety and is responsible for the regulation of pesticides and putting maximum limits on toxins. The USDA determines if plants are safe to grow and regulates GM crops that do not fall under the EPAs jurisdiction such as drought-tolerant crops and crops grown for feed. The FDA determines if a product is safe to eat but the FDA is generally concerned with food products and additives, not whole foods (Whitman 2000). This separation of the monitoring of GMOs is problematic and leads to substandard safety testing and complete gaps in regulation. The FDA officials even admit that the agency does not have enough time or resources to carry out extensive research on every GM product (Whitman 2000).

Human impacts, organizations and attitudes:

Economic and social factors greatly influence the way humans interact with the environment and what activities they choose to pursue will influence many of the problem with GM crops. Farming is driven by economics most of the time. Most farmers in the northern New York are trying to make a living to feed their families and

pay their bills. This alone will determine the methods farmers use. Something that affects the environment will not be a high priority for farmers and corporations because the environment is not generally considered in the principals of supply and demand. Many corporations, as mentioned earlier, will create herbicide resistant crops that only work with their brand of herbicide or form licensing agreements to not collect seeds (Batalion 2000). These decisions are driven strictly by economics and turning a profit, with environmental impacts not incorporated into their economic principles.

Social concerns are also a high priority. Even though the goals of using GMOs (curing world hunger, increasing nutrients in food, etc.) are optimistic, the methods being used to produce them are not always socially acceptable. There are also human values of preservation of cultural and biological diversity that are not being considered in the GM global market. Then there is the issue of creating a dependency on GMO corporations and foreign governments in third world countries.

Since the release of the first commercially available GM crop in 1996, farmer's attitudes have remained relatively constant and split. In a state wide study conducted by Cornell University, researches found that New Yorker's attitudes about the use of GMOs are split almost fifty-fifty. Three annual surveys of 850 people found that, on a 1 to 10 scale, the use of biotechnology had a mean rank of 5.6 and the perceived risk of GMOs had a mean rank of 6.1 (GMO food for thought 2006). Interestingly, this study found that women and minorities perceived a higher risk from the use of GM crops and republicans showed more support overall for genetically modified foods. Also, individuals who ranked themselves as paying more attention to the news supported genetically modified

foods more than individuals who do not pay attention to the news (GMO food for thought 2006).

Most farmers in the North Country understand that GMOs are trying to enhance health and nutritional values of food. The issue is not that biotechnology's overall goals are wrong, the issue of concern in northern New York is how are GMOs being regulated, ecological and human health effects and the ethics involved in bioengineering. One farmer in Jefferson County believes that with proper testing and controls to limit out crossing, GMOs should be safely developed and used in Northern New York (Lenihan 1998). This farmer stresses the importance of being careful. Just because studies have not shown any adverse human health effects does not mean all farmers should go out and buy them.

Also, the cost of GM crops may also prohibit farmers from using them. On average GM crops cost $15 more per acre than conventional crops, which has stopped some farmers from using GM corn to feed their cows (Lenihan 1998). On the other hand, GM crops do have the potential to save money for farmers who use them. High-oil corn and GM alfalfa are two crops that have potential to save farmers indirectly. High-oil corn has been shown to increase the growth rates of chickens and cows. This could reduce the need for dietary supplements, saving the farmer some money. High-oil corn also has a more oil per ear of corn. According to the farmer in Jefferson County "we need to look at where the world is going and where the world economy is going" (Lenihan 1998). For this reason, he believes that farmers should look into GM corn and GM soybeans. This farmer and many others have a positive outlook on where GMOs can take the economy in Northern New York. It is believed that upstate New York can be the

perfect cross road for agriculture and bioengineering. The development of more biotechnology industries could be a helpful strategy for solving the problem of job and population loss in Northern New York.

Environmental and human health concerns are the main focus for organizations and people who are on the opposite side of the spectrum. Groups like Earth Save, Organic Trade Association promote organic farming because it does not involve the use of GMOs. From their point of view, we just do not know what we are getting ourselves into and it is better to be safe than sorry. As studies that show potential negative effects of GM crops continue to be reported, fuel is added to the fire. Related to our hesitancy of using GMOs, "Food scares" have increased very rapidly in recent years. In 1986, there was 1 "food scare" reported in the English language media, due to possible contamination by the Chernobyl disaster. By 1999, there was over 1,400 "food scare" related media reports (Fitzgerald and Campbell 2001). A majority of these reports are likely related to food made from GMOs, which further illustrates the point that we do not really know what we are getting ourselves into went we genetically alter organisms.

Governmental issues:

The US federal government is responsible for regulating the use and production of GM crops. There are three government agencies that regulate these issues; the EPA, the FDA, and the USDA. The EPA (Environmental Protection Agency) is responsible for ensuring the environmental safety of GM crops. The FDA (Food and Drug Administration) is responsible for regulating the safety to human health. Finally, the

USDA (United States Department of Agriculture) is responsible for specific crops that aren't dealt with by the EPA by the EPA.

The EPA is already responsible for regulating the use of pesticides and although they do not regulate the use of Bt crops, they have established precautions to ensure that pests did not become resistant to these crops. These precautions include, requiring farmers to create refuges within fields that are not made up of Bt products (Whitman 2006). GM crops could possible affect the EPA because the use of GM crops could lead to a decrease in the need to apply pesticides to crops. Genetically modified herbicide resistant crops could also lead to increased use of herbicides which may force the EPA to increase regulations on these chemicals.

The second government agency responsible for dealing with the use of GM crops is the FDA. The FDA's responsibilities deal with making sure that GM products, not crops, are safe for human consumption. This means that although the FDA does not regulate directly the crops directly they do regulate foods and medicines which are produced using these crops. According to Whitman, "the FDA (admits) that the agency currently does not have the time, money, or resources to carry out exhaustive health and safety studies of every proposed GM food product (Whitman 2000)."

The third government agency responsible for regulating the use of GM crops is the USDA. The USDA deals with the GM crops that are not under the jurisdiction of the EPA, these include, "drought-tolerant or disease-tolerant crops, crops grown as animal feeds, or whole fruits, vegetables and grains for human consumption (Whitman 2000)." The USDA is also responsible for regulating environmental issues resulting directly from the growth of GM crops (Whitman 2000). The USDA would be responsible for dealing

with the issues mentioned earlier such as escape of transgenes into the environment. They would also be responsible for dealing with effects to non-target organisms.

With the regulation of GM crops falling between all three of these organizations there could be potential for confusion. Sometimes the duties of these organizations seem to overlap or are not clearly defined, as in the case of the EPA and USDA. Furthermore, as in the case of the FDA there may not be enough resources to properly ensure the safety of GM products. There is also currently no regulated health and safety testing for the direct consumption of GM crops (Batalion 2000).

Development of solutions: Parameterizing the solutions:

There are several issues that must be kept in mind when developing possible solutions. Any solution should address the needs of all of the stakeholders. The importance of food production as well as the potential of the effects on the environment must also be taken into account. Economic issues should also be taken into account, so as not to put small scale farmers at a significant disadvantage because small scale farms are largely the type of farm in St. Lawrence County.

Food production is a matter of huge importance around the world. There are many people in third world as well as in developed nations who suffer from malnourishment. Since, food is a vital human need, no solution should reduce the amount of food that can be produced or force people to go without food. If a solution is needed to reduce the use of GM crops and also at the same time reduces the amount of crops produced, then an alternative should be found that allows for the reduction of

malnourishment. This alternative could be another means to produce more food, or some kind of program which redistributes food surplus.

Another area that must be taken into account in developing solutions is that the environment should not be further degraded by the use of GM crops. Small scale Agriculture is already one of the major causes for habitat degradation and any further effects from farming should be mitigated. The means that escape of genes into the environment should be prevented. Also, effects on non-target species should be eliminated or reduced significantly. The development of resistance in pests must also be taken into account when developing solutions, because if pests become resistant to Bt then farmers would be forced to turn to other pest control methods, such as chemical pesticides. The possible increase of soil toxicity should also be taken into account because this could affect not only farming but also natural ecosystems.

The final area that must be taken looked in to while developing solutions to problem related to GM crops is that small scale farmers should not be affected negatively by the increased use of GM crops. Therefore, our solutions mainly focus on keeping prices low on GM seeds and maybe some kind of subsidy program should be established so that small scale farmers can afford them. Also, corporations which produce GM seeds should be controlled or regulated in some way so that they are unable to establish a monopoly.

Potential solutions:

The first potential solution to prevent all the potential dangers of using GM crops would be to ban the use and creation of GM crops. GM crops could be banned all

together or could potentially be banned in just the North Country. By banning the use of GM crops all of the ecological problems would be prevented. Genetically modified crops would quickly and easily become a small problem. However, the solution of banning the use and creation of GM crops would not take into account all of the stakeholders because it would ignore the interests of corporations as well as large scale farmers. This solution would also ignore the potential benefits that could be gained from a democratic and safe use of GM crops. Banning GM crops in the North Country brings in other problems. The first problem with banning GM crops in the North Country is that farmers in the North Country would be put at a competitive disadvantage. Also, there would be resistance from farmers and other people in the North Country who are in support of the use of GM crops. Since, it is probably not realistic or even a good solution to ban all GM crops, some solutions for a safe and democratic use of GM crops must be developed.

In order to solve the problem of pests developing a resistance to crops, such as Bt corn which is genetically modified to produce its own pesticides, a regulated management system should be established. The refuges method establishes areas within farming fields that do not use Bt crops. These areas act as refuges which allow some pest individuals that are not resistant to Bt to survive. These individuals are able to breed with the individuals who are resistant to Bt and since the genes which allow pests to be resistant to Bt and other pesticides are often recessive, the dominant trait (non-resistance) is able to establish back into the population. The refuge method prevents populations of pests from developing widespread resistance to Bt (Tabashnik et. al. 2003). The EPA already requires farmers to establish refuges for pests in Bt corn fields (Whitman 2000). However, further regulations should be established to create some kind of management

strategy that can be used for all forms of Bt crops. There have been many studies done to develop ways of managing for pest resistance in Bt crops. One study done on the effectiveness of managing pest resistance through the use of refuges predicted that, "it may be economically feasible for farmers to maintain effective refuge percentages in excess of 20% (Gould 1998)." This solution could effectively prevent pests from developing resistance to Bt as well as any other GM produced natural pesticides, such as snowdrop lectin.

The similar problem of the evolution of herbicide resistance in weeds could be solved by changes in herbicide use. It is recommended that farmers alternate yearly between herbicide resistant and non-herbicide resistant crops. Through the rotation of different types of crops, no herbicide resistant weed will be able to establish populations larger enough that dominate (non-resistant) traits cannot be incorporated back into weed genomes. If farmers do not use GM crops consistently and the large amounts of herbicides that come with them every year, then weeds will be less likely to develop a resistance. It is also recommended that farmers mix there herbicides (Barney Personal Communication). By mixing herbicides weeds which have a resistance to one form of herbicide, such as the widely used Round-up, will not be able to survive. Since, no weeds will be able to survive the genes which have resistance to one form of herbicide will not be passed on and weed populations will not be able to establish herbicide resistance.

One potential solution to the problem of increased toxicity to the soil would be through the education of farmers. Farmers would be less likely to apply large amounts of herbicides to their soils if they were educated that herbicides are harmful, not only to the environment, but also to the fertility of their soils. Farmers could be educated by a

warning that could come with their seeds or through community outreach programs. In Saint Lawrence County the Cornell Cooperative Extension provides advice to local farmers. This organization could increase its efforts to educate farmers about the dangers of using large amounts of herbicides.

The problem of toxicity to the soil could also be solved by government regulations. Since the main issue causing toxicity to the soil is not the GM crops themselves, but the actions of the farmers, their behaviors may be easy to regulate. Genetically modified herbicide resistant plants give farmers the ability to use greater quantities of herbicide, which leads to toxicity in the soil. Since the use of herbicide is the problem, the best solution may be to establish strict regulations on how much herbicide can be used on a plot of land or how much herbicide is sold to one farm. Another solution could be to prevent corporations from producing herbicide resistant GMOs. There is no reason to produce these crops except to allow farmers to use herbicides easily and some would argue that herbicide resistant crops do not need to be produced. Farmers can take the extra time and effort to carefully apply herbicides to their field. Biotech Corporation's production can also lead to other problems, because many corporations who produce GM crops only make them resistant to their own brand of herbicide (Batalion 2000). Therefore, the regulation of the production of herbicide resistant crops may be the best solution to the problem of soil toxicity.

There are many potential solutions for the problem of gene flow into populations of wild crop relatives. The first potential solution for the problem of gene flow is to have spatial separation between cultivated and wild populations. This method includes the process of separating GM crops by a large enough distance so as to prevent cross-

pollination with barriers and buffer zones. If plants are unable to pollinate each other then their can be no escape of transgenes. The spatial separation can also be assured by planting crops which do not have wild relatives in the area. However, sometimes it can be difficult to ensure enough spatial separation because plants can be pollinated at large distances by wind, animals and insects (Lu 2003). It may also be difficult to ensure that there are no wild relatives with the potential for cross pollination in an area.

The second potential solution for the problem of gene flow into populations of wild crop relatives is by creating GM crops with male sterility. By inducing male sterility in GM crops they will be unable to pollinate wild relatives because of this inability to of male flower to produce pollen (Lu 2003). Inducing male sterility in tobacco and oil seed rape has been achieved by using the barnase gene (Al-Ahmad and Gressel 2005). Male sterility is more difficult in fruit producing crops, because these crops need to be pollinated in order to produce fruit. However, male sterility can be used in some types of fruit producing crops because of a process called parthenocarpy. Parthenocarpy is when fruits produce fruit with out being pollinated. Parthenocarpy can be induced through the use of hormones or through genetic engineering (Schenkelaars 2006). Inducing male sterility is affective in preventing GM crops from directly pollinating wild relatives, but may not in itself totally solve the problem of gene outflow. Genetically modified crops with induced male sterility can themselves still be pollinated by wild relatives. These crops would still be able to create hybrids which would have genes from the wild and crops species and could become super weeds (Lu 2003).

Since, male sterile GM crops can still receive pollen another step needs to be taken to prevent gene flow with the environment. In order to prevent the possible hybrids

from becoming super weeds, “Transgenic Mitigation” is could be used. Mitigation makes the offspring of GM crops unable to survive in the wild, by splicing in genes that make it more difficult for offspring to compete (Lu 2003). In one example of mitigation, GM tobacco was introduced with a gene that causes dwarfism in offspring and this process effectively prevents the tobacco from competing in the wild (Al-Ahmad and Gressel 2005). “Transgenic Mitigation” and induced male sterility used together could be an effective way to prevent escape of transgenes into the environment.

Another possible solution to the problem of gene flow into the wild populations is cleistogamy. Cleistogamy creates flowers which do not open and pollinate within the closed flower. This may be an effective way of preventing the flow of genes into wild populations by preventing out pollination, but this process may not be always be practical. It is possible that inducing cleistogamy in plants could prevent them from developing as many seeds as non-GM crop and therefore potentially reducing harvest in grain plants. Cleistogamy may also not be possible in plants such as corn that require cross-pollination (Lu 2003).

A final solution to the problem of gene flow into wild populations is terminator technology. Terminator technology genetically alters plants to produce seeds which are not viable. This technology is often referred to as a “suicide gene” (Batalion 2000). Terminator technology helps prevent transgenic crops from producing offspring, hybrid or otherwise (Lu 2003). The issue of creating non-viable seeds can create unfavorable situations for farmers because they would be forced to purchase seeds yearly. Having to buy fresh seeds annually increases dependence of farmers on seed corporations. This yearly sale of fresh seeds by seed corporation may not be the only issue that increases the

dependency of farmers on sees corporations. Many farmers in the North Country are already required to sign contracts stating that they will not save or replant GM seeds. (Barney Personal Communication). Another issue is the potential for GM crops to cross-pollinate with organic and other non-GM crops. As discussed earlier GM crops could potentially pollinate the fields of organic farmers (Batalion 2000). Genetically modified crops with terminator technology still can produce pollen and therefore have the potential to pollinate organic crops leaving organic farmers with seeds that are not viable and preventing them from harvesting seeds for next year's crop.

The major problem with the pollination of non-GM crops by GM crops can be solved by the same spatial separation that is a potential solution for the escape of genes into wild populations. In order to prevent this cross pollination of GM and non-GM plants, laws and mandates should be established to regulate the distance between these fields. Further research needs to be done to establish proper distance regulations for specific crops and specific areas. However, it is possible for pollination to occur at distances of more than a kilometer and therefore spatial separation may become more and more difficult with the intensification of agriculture in the North Country (Bordeau Bros. 2007) and especially as more farmers switch over to GM crops (Lu 2003).

Another possible solution deals with the role government plays in regulating GMOs. The confusion among government agencies about control over GM products has lead to a serious concern from consumers due to the possibility of insufficient regulation and safety testing. Since the biotechnology industry is becoming quite large, one way to solve this problem is to create a new agency that is responsible for the control over the entire operation or consolidate all responsibilities to one agency. If a new agency was

set up it would be responsible for setting limits on pesticide and other toxins use and determine if plants are safe to grow and eat. By consolidating the responsibilities that used to fall under the jurisdiction of the three government agencies that currently regulate GMOs, this new agency would free up valuable resources in FDA, EPA and USDA and eliminate any cross talk and gaps in current regulations. It might not be feasible however to create a new government agency or assign all responsibilities to one agency when they are currently not allocated enough funds to do their jobs effectively anyway. As mentioned earlier, the FDA admits to not having enough funds to extensively monitor every GM product (Whitman 2000) and for this reason, the creation of a new agency may not be feasible.

Another way to get around the problem of confusion within the government is to get the seed companies involved in the process. This would involve some government oversight but would not be as extensive as creating a new agency or reassigning agency jurisdictions. The Institute for Social, Economic and Ecological Sustainability (ISEES) is currently trying to find methods that combine the actions of business, government, consumers. This new approach named the safety first approach, is intended to increase public involvement in designing and overseeing the formulation and implementation of reliable and socially acceptable safety standards for GMOs (Kapuscinski et al. 2001). ISEES' main goals with their "safety first" approach is to develop an industry wide, industry run program that monitors from when the seed is first sown into the ground until it arrives at your dinner table. This will happen through the use of both public and private research facilities and better communication between academia, public interest groups and government (Kapuscinski et al. 2001). This approach will increase public

involvement, public awareness of issues with GM crops and help government agencies because this method is largely funded by the biotech industry. Considering the recent boom in the biotechnology industry and increasing concerns with GMOs if a program like safety first were mandated by the government, only the companies might not agree.

Another possible solution involves GM seed corporations, such as Monsanto, patenting their seeds. The ability of these corporations to form patents has reduced competition in the seed market allowed the few seed corporations to control prices. Patents also increase dependency on corporations because patents take away the right of the farmers to harvest and replant GM seeds from year to year (Whitman 2006). In order to deal with the problem of patents, one potential solution if for the U.S. government to not allow patenting of genetically modified crops or specific genes used in these crops. If corporations could not patent seeds it would allow for more seed companies to sell GM seeds and it would increase competition among seed producers. With increased competition prices would drop, seeds would become more affordable to farmers and more diverse (Barney Personal Communication). Farmers would also be less dependent on corporations, because ownership of the seeds would transfer away from corporations to farmers, which would be again able to plant them from year to year. The issue with patenting genes that are created in nature is a cause of concern for many people. Many feel that large corporations should not be able to claim that they have the right to control something that was actually invented naturally.

Another problem which prevents farmers from being able to harvest and plant seeds from year to year are contracts. Farmers are forced to sign contracts when they purchase GM seeds, which state that they will not replant or harvest seeds (Barney

Personal Communication). After signing these contracts farmers become locked in to the use of GM seeds and become dependent on corporations. In order to solve this problem, the government should pass a law which makes it illegal to form these contracts. If corporations were not allowed to form these contracts then farmers could purchase GM seeds without becoming locked in and dependent on corporations.

Another similar problem is the issue of licensing agreements. Licensing agreements apply to the herbicide resistant crops. When corporations, such as Monsanto, sell farmers GM herbicide resistant seeds they force them to sign a licensing agreement. In these licensing agreements farmers agree that they will purchase and use only the brand of herbicide produced by the corporation selling the seed. These licensing agreements apply not only to the year that farmers purchase the seeds but continue to apply even in subsequent years (Batalion 2000). These licensing agreements are just another way that farmers get locked into the use of GM crops. In order to solve this problem the government should illegalize these licensing agreements. By illegalizing the licensing agreements the corporations would be less likely to be able to form monopolies over the seed and herbicide markets. The illegalizing of licensing agreements would also prevent farmers from getting locked in to using GM crops and chemical herbicides.

Feasible Solutions:

Feasibility of solutions is a big issue because some of the potential solutions sound like they would work well but in actuality they would not be beneficial in the North Country. Not all of the possible solutions listed earlier are actually feasible, although most of them could be. The first solution, to ban the use of GM crops altogether,

is not feasible for many reasons. The first reason it is not very feasible is that it does not take into account all the stakeholders. It does not look at the benefits to North Country farmers and the lobbying power that these large corporations have with the government. The second reason that banning the use of GM foods is not feasible is because they are already so prevalent. There are 8.5 million farmers in 21 different countries, which have devoted over 90 million hectares to GM crops and these numbers are consistently growing. We see that today, over 2/3 of all processed food in the U.S. contains GM crops and 25% of all arable land in the U.S. is used for GM crops (Sanvido 2006). Since, GM foods are so prevalent it would require huge costs to ban GM crops and there would be a large resistance from North County farmer. Banning GM crops just in the North Country would also be infeasible because it would put local farmers at a competitive disadvantage from the rest of the country and would also require large costs.

Another potential solution which is not feasible is the spatial separation of GM and non-GM fields. Agricultural fields are already in place and as farmers switch over to GM crops it would require a large amount of time and resources to move and cultivate new fields. Spatial separation will also become increasingly difficult as more and more farmers switch over to GM crops, which is the current trend (Bordeau Bros. Personal Communication). With increasing areas coming under the cultivation of GM crops it will become increasingly difficult to spatially separate GM and non-GM crops (Lu 2003). Therefore, because of the huge cost involved in spatial separation and the increasing difficulty of implementing spatial separation it is not a feasible solution.

Aside from the total banning of GM crops the other possible solutions mentioned are feasible. The following section justifies the feasibility of the remaining potential

solutions. The first potential solution is the refuges method, which is feasible for a variety of different reasons. The first reason that the refuges method is possible is that it is already in use in Bt corn fields. The EPA currently requires that 20 percent of the corn in a Bt corn field be unmodified (Whitman 2000). Since, the refuges method is already in regulation for corn it is a feasible solution for corn and has potential as a solution for other Bt crops. Another reason that the refuges method is feasible is that, "it may be economically feasible for farmers to maintain effective refuge percentages in excess of 20% (Gould 1998)." Since, it is an economically feasible solution and can easily be regulated for use in the North Country without too much resistance.

The next potential solution was the alternation from year to year of various herbicides combined with the mixing of herbicides. The reason that the mixing and alternation of herbicides is a feasible solution is that it will not increase prices to the farmers. This solution requires farmers to purchase more varieties of herbicide, but they can still apply the same quantity of herbicide and therefore cost should not be increased. Since, the solution does not come with an increased cost over current methods it is an economically feasible method for the farmers. Therefore, if farmers can simply be convinced that that mixing and alternating herbicides is necessary or beneficial it has some serious potential.

The next solution which also deals with herbicides is the education of farmers so as to avoid increasing toxicity to the soil. Community organizations are already in place, which educate farmers on issues with agriculture. In the North Country, the Cornell Cooperative Extension, educates and advices farmers on agricultural issues (Barney personal communication). With community organizations already in place for the

education and advisement of farmers it will be fairly cheap and easy to implement education on the dangers of blanket spraying of herbicides. The solution of education of farmers on herbicide use and increasing toxicity to the soil has good potential in the North Country.

The third solution dealing with herbicides is government regulation of herbicides, which deals with increased soil toxicity. Increased government regulation of herbicides is a feasible solution because the EPA already regulates herbicides (EPA 2006). This solution would not require implementing a new law, it would only require the strengthening current regulations. Therefore, because regulations of herbicides by the EPA are already in place further regulation is a feasible solution.

Next is a group of solutions which deal with the prevention of gene flow from GM crops into the environment. These solutions are the introduction of male sterility, transgenic mitigation, cleistogamy, and terminator technology to plants. All of these solutions are genetic alterations that can be introduced to plants. The cost of these alterations could be covered by the seed corporations which are making huge profits off the sale of GM crop seeds anyway. Since, these companies already alter the genetic structure of the crops to make them GM in the first place, they will be able to also add in these alterations to make the plants environmentally safe. Therefore, male sterility, transgenic mitigation, cleistogamy, and terminator technology are all feasible solutions for the prevention of gene flow from GM crops into the environment.

The next possible solution is the consolidation of government responsibility to monitor and regulate GM crops and foods. Currently funding for monitoring and regulating GM crops and foods is spread between the USDA, FDA, and EPA. This

solution would not necessarily imply any increase in funding only a consolidation of the funding and responsibility. Funding to change these regulations will be very minimal but recourses will have to be redistributed. Furthermore, although consolidating responsibility in the short term may require a lot of work, in the long term it would save time and effort by centralizing the regulation of GM crops. Since, consolidating is cost effective and not very time intensive it is a feasible solution for North Country farmers.

The other solution for dealing with the consolidating of responsibility of monitoring of GM crops is the "safety first approach." This approach puts the burden of the proof on the seed corporations not on the government organizations. Since, these seed corporations are the ones receiving most of the economic benefits of the use of GM crops they can afford to pay to monitor the possible dangers associated GM crops. Although this monitoring may be time intensive, it is better than the current system of monitoring. Since the cost of this solution would be covered mostly by the corporations who will be benefiting from GM foods and because of the importance of monitoring the "safety first" approach is a feasible solution. This approach also increases public involvement and public awareness on the issues of GM crops and processed foods. This is important because GMOs tend to fly under the radar most of the time and with this new approach in place, North Country citizens will have more say and a better idea of what is going on around them.

The next potential solution is to make the use of patents illegal, which deals with the problems of reduced competition in the seed company market as well as farmer dependency. This solution is feasible because it is a matter of altering policy and is very beneficial to small scale farmers. Currently farmers are allowed to patent the GM seeds

that they create (Batalion 2000). The decision to make patents illegal could be made by the government at little increased cost of current practice. This solution would require a great deal of time in lobbying on the behalf of small scale farmers. However, this time would be divided amongst a large number of people and if enough people supported the issue then it would be a feasible solution.

The next potential solution is to make contracts and licensing agreements between farmers and seed companies illegal. This change in regulation is similar to the previous solution of illegalization of patents. Similarly to making patents illegal it is also a matter of altering an already existing policy and therefore would not require a huge amount of money. However, this solution would again require a great deal of time from small scale farmers to push this issue and would only be feasible if there were enough people in support of illegalizing these contracts and licensing agreements.

Best Solutions:

Although there is a large list in the previous section of feasible solutions there are some solutions that are better than others. However, because the topic of GM crops and the problems associated with it are multiple and widespread, a combination of several solutions is needed to constitute a best solution and cover all of the stakeholders. There are many feasible solutions that can be eliminated from the best solutions. The first solution that is feasible but that is not a best solution is the increased governmental regulation of herbicides. This solution is not one of the best solutions to the problem of increased toxicity to soil because it takes some choice and power away from the farmers.

Although this solution would be effective it is simply not as good a solution as increasing farmer education on the dangers of herbicides.

The second feasible solution that can be eliminated from the list of best solutions is terminator technology. Terminator technology involves altering crops to have a "suicide gene" in their seeds so that they do not produce viable offspring (Lu 2003, Whitman 2000). This technology would not be in the best solutions because it would increase the problems of dependency of farmers on seed corporations. By creating seeds that are not viable farmers become more dependent on seed corporations, because they have to purchase new seeds every year (Whitman 2000). Male sterility, mitigation, and cleistogamy all prevent the escape of genes just as well as terminator technology without increasing farmer dependency as much.

Another group of feasible solutions that can be eliminated from the list of best solutions is the illegalization of patents, contracts, and licensing. All of these solutions have good potential but they require a great deal of effort and lobbying on the small scale farmer's behalf. It is not feasible that there will be enough support for these new regulations just in the North Country and farmers have to spend their time doing other things. It would be very difficult to compete with the lobbying and political power of the large seed corporations. Therefore simply because of the political, economic, and lobbying power that the seed corporations currently have, eliminating contract, patents and licensing agreements just would not work. If in the future however, support for illegalizing patents, contracts, and licensing grows than this could become one of the better solutions.

The final feasible solution that does not make it on the list of best solutions is to consolidate regulating and monitoring of GM crops and foods to one branch of the government. This solution, although possible and effective simply is not as good a solution as the "safety first approach." The consolidation of regulating and monitoring to one government organization would still keep the burden of proof on the government and therefore taxpayer money would be going to the funding. Since, the burden of proof should be on the potential polluter and not on the government this is not one of the best solutions.

Now that many of the feasible solutions have been eliminated, the best solutions can be discussed. The best solution for the problems associated with GM crops in the North Country is a combination of the following solutions. The first solution that should be incorporated into the best solution is the refuges method. This method is already in place and will be easily extended to all Bt crops. The next solution that should be included in the best solution is alternating and mixing herbicides and incorporating crop rotation. The Cornell Cooperative Extension already recommends to farmers that they should alternate and mix herbicides in their fields (Barney personal communication). This solution is also already being used and will be effective if more effort is put forth to educated North Country farmers.

Male sterility, mitigation, and cleistogamy should also be incorporated into any best solution. These solutions are cost effective because they will be paid for by the seed corporations and are also effective in preventing the escape of genes. Farmer education on herbicides should also be incorporated into the best solution because into the best

solution because it is cost effective and for reasons mentioned earlier a better solution than government regulation. The final piece of the best solution is the "safety first approach," this approach is of great importance in ensuring current and future safety of the use of GM crops.

Ease of Implementation:

The combination of best solutions discussed previously will be relatively easy to implement. Most of the best solutions outlined involve either education or regulations that are already in place. The solutions that involve education of farmers are in the farmers' best interest and so it should not be too hard to convince North Country farmers to begin to abiding by these solutions. Therefore most of the best solutions will be easily implemented.

We believe that one of the more difficult parts of the solution to implement would be forcing seed corporations to alter their seeds to include male sterility, mitigation, and cleistogamy. Forcing seed companies to introduce genes for male sterility, mitigation, and cleistogamy may be difficult because it is not necessarily in the best interest of the corporations. These large corporations are likely more interested in the economic value of GM crops then the potential for the escape of genes. Corporations will most likely resist pressure to add these alterations and therefore it may be difficult to persuade them to change their practices. It will also require a lot of scientific proof to persuade policy makers to regulate that corporations incorporate these regulatory genes into their GM seeds. Therefore, the introduction of male sterility, mitigation, and cleistogamy although necessary and a best solution may be difficult to implement.

The other relatively difficult part of the solution to implement would be to switch to the "safety first approach" to regulating GM crops. Since, human health, little regulation of GM crops and gaps in coverage are becoming an issue of increasing concern, it would be in the best interest of the government to implement these practices, no matter the cost. The "safety first" approach will require a lot of restructuring of the monitoring systems currently used for GM crops. This approach will be a huge shift in the responsibility of the USDA, FDA, and EPA. The approach would shift the responsibility of who is monitoring GM crops to the corporation rather than the government.

Environmental and conservation minded individuals are usually resistant to having large companies responsible for control because many of these companies usually report what is in their best interest. Similarly, to the solutions for gene containment, the "safety first" approach will most likely be met with a lot of resistance from the corporations, because it is not in their best interest either. Although it may be difficult to implement the "safety first" approach is part of the best solution because it will involve government oversight and public involvement. This will not allow companies to report whatever is in their best interest, which will please many North Country citizens concerned about the health effects of GM foods. The Rio Declaration on the Environment and Development of 1992 emphasizes the importance of the "precautionary principle" and shifting the burden of proof to the potential polluter (Dresner 2002). This is precisely what the "safety first" approach is trying to do.

Implementation Plan:

A list of best solutions is not very useful without a plan of implementation. In order to implement all of the various parts of the best solutions to the problem of GM crops, many things will have to be done. The first major part of the plan of implementation is farmer education. Farmers should be educated on the dangers of herbicides leading to increased soil toxicity and on the advantages of rotating and mixing herbicides. If farmers are educated on these topics they will see the advantages to their own livelihoods of not overusing herbicides and of mixing and rotating herbicides. Farmer education can be provided by community agriculture outreach programs that are already in place. The Cornell Cooperative Extension already provides education to farmers in St. Lawrence County on the issues with herbicides and recommending that they alternate herbicides yearly as well as mixing herbicides and rotating crops (Barney Personal Communication). The Cooperative extension is funded by Cornell University as well as by grants from other organizations (CCE 2007). With some help, it would be possible to form other outreach groups that will be able to educate a larger number of farmers in Northern New York.

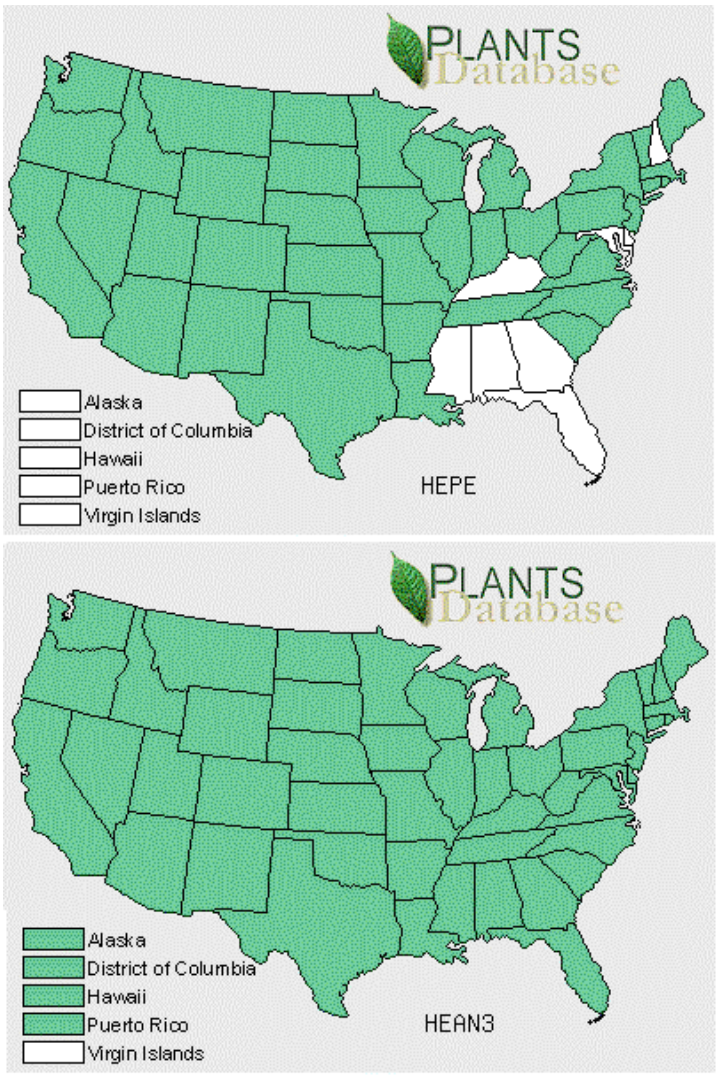
The next major part of the plan of implementation involves introducing male sterility, mitigation, and cleistogamy into GM crops. These three mechanisms for gene containment would be under the jurisdiction of EPA laws. The EPA is responsible for regulating environmental safety related to growing GM crops (Whitman 2000). Therefore the EPA would have to be responsible for implementing and regulating these new mechanisms. A combination of the various mechanisms should be established for various crops. Cleistogamy works better on fruits then male sterility so it should be

introduced into GM fruit crops. Whereas with crops that require cross pollination, male sterility is more effective then cleistogamy and therefore male sterility should be used for these crops. Neither cleistogamy nor male sterility are totally effective for any type of crop so some type of mitigation method would have to be combined with these other mechanisms (Lu 2003). The funding to create crops with a combination of these three gene containment mechanisms will be mandated to come from the seed corporations because they are the ones receiving the main economic benefits of GM crops.

The next major part of the implementation plan is implementing the refuge system. The refuge system is already in place in Bt corn (Whitman 2000) and there is potential to expand refuge areas past 20% (Gould 1998). However, increasing past this threshold is most likely not necessary since resistance is yet to be shown outside the lab (Farinos et. al 2004, Zhao et. al. 2000). Instead of increasing the refuge size past 20% the EPA should regulate refuge requirements in all Bt crop fields as well as for fields of crops modified with other forms of pest resistance. The funds to implement the regulation of this refuge system as well as enforcement of these regulations will come from the EPA.

The next and most difficult part of the overall implementation plan is implementing the "safety first" approach. With this approach it is necessary to include involvement of seed corporations, the government and the public to benefit wildlife and human health. In order to get this started, it must be first mandated by the government, which, because of the importance of this issue, should be done anyway. Once mandated, public and private research institutions would have to be created to monitor each other and exchange information (Kapuscinski 2001). Like mentioned earlier, there is a need

for government oversight to control both of these groups. But since government oversight is only a small portion of this plan, it will be much easier than creating a new government agency. One of the current government agencies can monitor this process and since the seed companies are fronting the money for this project, the other two government agencies will have more time and resources to keep up with the rest of their responsibilities. Also since, public research institutes are involved, information will be able with flow freely to the rest of the public to increase their involvement and awareness of GMOs. This, along with the other best solutions will be able to support farming more sustainable in the North Country. There will have to be some give and take between the stakeholders but we believe that once our best solutions are implemented, it will increase the quality of living for citizens, control biodiversity loss and help the livelihoods of the many farmers in the North Country.



Distibution of H. petiolaris (top) and H. annuus (bottom).
Images from http://plants.usda.gov

Fig. 1. Distribution of Wild Sunflower (top) and a species of GM sunflower that has been genetically modified to have herbicide and pest resistance.

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