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Graduate Research Assistant, College of Pharmacy, mockj@mail.rx.uga.edu, and
Professor, Department of Agricultural and Applied Economics, epperson@uga.edu,
respectively, The University of Georgia, Athens, GA 30602

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Dept. of Agricultural & Applied Economics
College of Agricultural & Environmental Sciences
University of Georgia

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J.N. Mock and J.E. Epperson

Department of Agricultural and Applied Economics

University of Georgia

Athens, GA 30602-7509

mockj@mail.rx.uga.edu

ABSTRACT---While the population of the world is continually growing, there are doubts that the food supply will be sufficient to keep pace. Although 14% of the world is undernourished today, an exponentially increasing population could be catastrophic if agricultural production lags too far behind. This paper attempts to forecast agricultural yield given the recent advent of genetically modified crops as a means to see whether this technology has the potential to help supply the world with food in the future. Through regression, a model was developed to make predictions of corn yields as a case study on how biotechnology might affect future agricultural production.

Key Words: Yield, Future, Prediction, Model

During the 20ᵗʰ Century the world went through countless changes resulting in a lifestyle and global society that would have been previously unimaginable. While many of the changes have been beneficial some will have resounding effects for generations to come. For example, the global population is currently estimated to be approximately 6.7 billion according to the U.S. Census Bureau, a stark increase from 1950 when the world was estimated to have roughly 2.5 billion people.

So what does a growing population mean? What are the possible ramifications of having too many people and too little planet? These questions are not only relevant, but also relatively pressing, as the population is expected to continue growing for the next several decades and is not expected to peak until 2050. However, concerns about the potential of overpopulation are not new, having roots back to the 1700s. On the other hand, our knowledge of the world has changed drastically since that time, making it interesting to compare and contrast the differences between projections of the future then and now.

Thus, the primary research question to be addressed is whether or not we will be able to feed the population 40 years from now, specifically in light of the emergence of biotechnology as a means to produce genetically modified (GM) crops. In the past there have been leaps in agricultural yields as a result of the green revolution and innovations in fertilizers, pesticides, and breeding; but at current production levels, all else equal, there will be extreme shortages if the population increases by three billion people.

Beginning with a look at the Malthusian Catastrophe, we follow with the situation regarding current GM crops and the growing population. Then, an examination of yield

data over the past 80 years is conducted in order to make a prognostication about the ability to feed the world in the future.

The Malthusian Catastrophe

Three centuries ago, there were those who were already worrying that humans were populating the world at a rate that would outpace resources, specifically food. The most noteworthy of these individuals was Thomas Robert Malthus, a social economist with a pessimistic outlook on the future. Born in 1766, by 1789 he published the first of six editions of his paramount work, *An Essay on the Principle of Population as it Affects the Future Improvement of Society*. Malthus describes how a certain section of society will always be relegated to poverty as a result of the population expanding beyond its means (Dupâquier, 2004).

Malthus considered the only constraints on population to be misery (i.e., starvation and disease), vices like murder, and in later editions of his *Essay*, morality like sexual abstinence. However, he predicted that these factors would not be enough to suppress the constantly growing human population, and eventually something devastating would occur (Dupâquier, 2004).

From these predictions, the "Malthusian Catastrophe" was born. Simply stated, the catastrophe would occur when the population finally grew so large that an epic famine would kill a large proportion of the population, the only real check for population growth.

Since Malthus first published his *Essay*, many have debated whether a global famine of this scale would be possible or even when it would occur (Trewavas, 2002). Of course, we have yet to see a catastrophe like this, but considering the current situation

with food needs and an ever increasing population, this sort of scenario should be given some thought.

Biotechnology

Until the mid 1990's, the genetic profile of production crops was altered only via traditional breeding techniques. By breeding dwarf varieties of cereal crops like wheat and rice, producers were able to increase yields threefold. With the addition of increasingly sophisticated fertilizers and pesticides, farmers have continued to increase yields steadily since the "Green Revolution" of the 1950's (Trewavas, 2002).

However, current technology is beyond that of the previous Green Revolution, and we are looking towards a new Gene Revolution (De Oliveira, 2005). Genetically modified crops were first planted in 1996, and the acreage planted globally has continued to increase. There are several species of crops that have been modified including corn, soybeans, cotton, canola, squash, papaya, alfalfa, and tomatoes, all of which have been transformed with genes that either produce insect resistance or herbicide tolerance (James, 2007). While both of these traits were meant to lower costs to farmers, studies have shown that there are yield increases related to insect resistance ranging from 5% in America to upwards of 30% in other parts of the world (Brookes, 2006).

It is important to note that there was no expected affect on yield. These observed increases are a positive externality of the emerging technology.
However, there are GM products in the pipeline that actually aim to increase yield by conferring traits that would help crops to grow in drought conditions or low quality soil

(De Oliveira, 2005). While there are no available field data on crops like these, yield

increases should be higher than those of current GM generations.

Growing Population

While the Green Revolution of the 1950's allowed farmers to significantly

increase yields, there has been more than a doubling of the world population since that

time (United Nations, 2007). Thus, current agricultural practices are barely keeping pace.

Even so, 14% of the world population still does not have access to a regular food supply

(De Oliveira, 2005). Unfortunately, the problem could get worse before it gets better as

recent UN estimates predict that the world population will not peak until 2050, with an

estimated population of 9.2 billion (United Nations, 2007).

This exponential population growth is the primary reason why this study is

looking at the potential of biotechnology to increase yields. In previous times of

prosperity, many countries considered the potential risks of GM crops to far outweigh the

benefits, but in light of world food conditions, the GM alternative is looking more

acceptable (Pollack, 2008). As the population continues to expand, the world will

undoubtedly need to find a way to increase yields and production in order to provide food

to everyone.

Method of Analysis

The use of biotechnology in agriculture has grown since the technology was first

introduced in 1996. Using data from commercial cultivation over the last 80 years and

select studies on the effectiveness of biotechnology, we attempt to calculate the effect of

using biotechnology on the potential to feed a growing global population. Using

regression analysis we estimate the increase in yield that can be expected by 2050 as a result of the adoption of biotechnology.

All such studies have limitations. The primary limitation here is that relatively few GM crops have been commercialized. Thus, our commodity focus is limited to Bt corn with ramifications for other crops.

Different versions of Bt corn have been widely adopted around the world (James, 2007). Moreover, when considering the foundation of the human diet, corn is a staple. Of the roughly 300 cultivated crops widely consumed in the world, three staples – corn, rice, and wheat – make up more than half of the average diet (Chrispeels, 2003). Thus, increases in the production of any of these three crops would be much more significant than an increase in the production of a less utilized crop. Commercialization of GM rice and wheat has yet to occur.

Further, although GM technology is becoming more widely accepted, particularly in developing nations, few countries have really planted significant quantities of any one GM crop, save the United States. Other than herbicide tolerant soybeans, which have not proven to increase yield, Bt corn is the only food crop that has been grown on a sizeable scale (James, 2007). As a result, the data being analyzed include only yields from U.S. grown corn.

Yield Increases

While Bt corn was first planted in 1996, it was not cultivated on a large scale until 1998 when the total planted acreage of Bt corn surpassed 15% of total field corn acreage. The planted acreage of Bt corn in the United States between 1996 and 2000 was estimated by NCFAP and can be found in table 1. According to the ISAAA, planted

acreage has continued to increase since that time (James, 2007). Official statistics from USDA, NASS are not available. For our purposes, it is only important to note that significant planting of Bt corn began in 1998.

Knowing when Bt corn began to be adopted at a considerable rate is important because in order to see any impact on U.S. corn yield, a large percentage of the overall acreage must have been planted from Bt varieties. With an estimated increase in yield of approximately 5% in the United States (Carpenter, 2001) there would be little noticeable impact on yield in 1996 or 1997 with only 1% and 6%, respectively, of the overall acreage composed of Bt crops.

In order to predict the longer reaching effects of Bt corn into the future, a regression model was developed from corn yields in the United States from 1930-2007. The yields for these years are presented in figure 1. A cursory examination reveals a dramatic jump in yield growth circa 1960. This is attributed to the Green Revolution of the 1950's and is accounted for by including a dummy variable (x_1) in the regression model.

The overall yield trended up over the study period and is captured by the time variable (x_2). This reflects normal increases in technology like better breeding processes, advances in fertilizers and pesticides, and the incorporation of better farming practices. It is important to note that this steady increase in yield is not associated with increased land area devoted to corn production. U.S. corn acreage has trended fairly flat since 1950 (Trewavas, 2002; USDA NASS, 2008).

Of course, the goal of this model is to determine whether or not the introduction of Bt corn has an effect on U.S. corn yield. The Bt corn era was shown to begin in a substantial way in 1998 and is captured with the dummy variable, x_3.

Taking all three variables into account, the developed model that predicts U.S. corn yield to 2050 follows:

(1) $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3,$

where y is yield, x_1 is the dummy variable for the green revolution, x_2 is the time variable, and x_3 is the dummy variable for the Bt era. Regression analysis resulted in the following equation:

(2) $y = 12.16471 + 9.75015\ x_1 + 1.51554 x_2 + 10.54868 x_3,$

table 2.

All of the parameter estimates are significant at the 0.05 level or greater. The adjusted R^2 of 0.96 and F value of 570.71 indicate that the model fits the data extremely well, table 2. Using this model, projections of future yields can be made, assuming that progress continues according to the data. Projections are made through the year 2050, culminating with a yield of about 214 bushels per acre. Figure 2 provides a visual representation of the projections, and table 3 provides selected values of actual and predicted yields.

Figure 3 provides visual evidence of how well the model fits the data. Unforeseen events aside, the model appears to be a suitable tool for peering into the future. However, with the current pace of biotechnology and considering other products in the pipeline, there could be one or more structural yield jumps before 2050. From a statistical perspective, confidence intervals are usually provided, at some statistical level

of significance, along with forecasts. However, in this case confidence intervals have little or no meaning when gazing so far into the future.

Discussion

If these projections are accurate, yield will increase more than 40% by 2050, while the UN estimates that the population will increase by a lesser amount, approximately 27% over the same period. Thus, as far as averting a Malthusian Catastrophe is concerned, this is very good news.

Nevertheless, as mentioned before, there are limitations to the application of this model. This study focused on GM corn only, grown in the United States. Thus, it would be incorrect to assume that all crop yields will increase according to the predictions of the regression model developed herein.

On the other hand, the results support the idea that biotechnology can increase yields, despite the fact that current GM crops were designed solely to reduce the cost of production. Even so, GM yield increases from insect resistance should not come as a surprise since pests are credited with destroying half of world food production annually (Herrera-Estrella, 2001).

Furthermore, while corn is one of a few staple cereal crops, the vast majority of corn grown in the United States, roughly 60%, is used to feed poultry and livestock (Carpenter, 2001). As the developing world grows more affluent, the demand for meat increases requiring more feed for livestock (Trewavas, 2001).

Overall, the model developed in this study suggests that agricultural biotechnology will provide a positive structural shift in yield that likely will be important

in the future. Our primary purpose has been to illustrate that in order to meet the needs of a growing world population, agricultural technology must progress with all due haste.

Conclusions and Implications

The ability to produce enough food in the future is a problem relevant to us all. However, those that will be affected most by a global food shortage are in developing countries. Biotechnology has the potential to impact these countries in a way that previous agricultural innovations have not. Over a third of the total acreage of GM crops grown today is being grown in developing countries where farmers are not only benefiting from increased yields but also increased incomes (James, 2007). This kind of success is vital in the fight to feed the world, especially when the population is expected to top nine billion within the next 40 years (United Nations, 2007).

One common argument often broached during discussions of preventing world hunger is that we currently have the ability to feed the world but lack infrastructure and distribution means. While this may be true, starvation and malnourishment even occur in developing countries that are net exporters of agricultural goods (Herrera-Estrella, 2001). Yield and quality enhanced biotech crops in countries like this would not only help to feed the population but also serve to bolster agrarian economies.

Future GM varieties for protection from drought and other abiotic stresses could offer significant gains particularly in developing countries that may not be naturally suited to produce certain agricultural staples. The ability to grow in less suitable conditions while increasing yields might also protect the environment. While virtually all increases in yield in the developed world have resulted from increases in technology, expanding production onto virgin land via slash and burn techniques has been the major

12

method of increasing production in Africa and South America (De Oliveira, 2005;Trewavas, 2002). GM crops with the ability to increase yields in these areas would feed more people and perhaps help maintain the natural biodiversity.

In conclusion, biotechnology will likely be the key to feeding an ever increasing population and contribute to protection of the environment. In the long run, it appears as though Malthus's predictions may have been too dire, and hopefully, in spite of localized shortages in certain parts of the world, innovation will prevail.

References

Brookes, G., and P. Barfoot. 2006. "Global Impact of Biotech Crops: Socio-Economic and Environmental Effects in the First Ten Years of Commercial Use." *AgBioForum* 9(3):139-151.

Carpenter, J.E., and L.P. Gianessi. 2001. *Agricultural Biotechnology: Updated Benefits Estimates*. National Center for Food and Agricultural Policy. Washington, D.C.

Chrispeels M.J., and D.E. Sadava. 2003. "Development, Productivity, and Sustainability of Crop Production." In *Plant, Genes and Crop Biotechnology*. USA: Jones and Bartlett Publishers.

de Oliveira, D.E., and M. Van Montagu. 2005. "GMOs and Organic Farming: Friends or Foes for Sustainable Agriculture?" In Tuberosa, R., R.L. Phillips, and M. Gale, eds. *In the Wake of the Double Helix from the Green Revolution to the Gene Revolution*. Proceedings of an International Congress, University of Bologna, Italy, May 27-31 (2003). Bologna: Edizioni Avenue Media, pp. 689-698.

Dupâquier, J. 2004. "Malthus, Thomas Robert." *International Encyclopedia of Social and Behavioral Sciences*, pp. 9151-9156.

Herrera-Estrella, L., and A. Alvarez-Morales. 2001. "Genetically Modified Crops: Hope for Developing Countries?" *European Molecular Biology Organization Reports* 2(4): 256-258.

James, C. 2007. *Global Status of Commercialized Biotech/GM Crops: 2007*. ISAAA Brief No. 37. Ithaca, NY: ISAAA.

Pollack, A. 2008. "In Lean Times, Biotech Grains Are Less Taboo." *International Herald Tribune*. April 21.

Trewavas, A. J. 2002. "Malthus Foiled Again and Again." *Nature* 418:668-670.

Trewavas, A. J. 2001. "The Population/Biodiversity Paradox, Agricultural Efficiency to Save Wilderness." *Plant Physiology* 125, 174–179.

United Nations. 2004. *World Population to 2300*. Populations Division. New York: United Nations.

United Nations. 2007. *World Population Prospects - The 2006 Revision*. Populations Division. New York: United Nations.

U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS). 2008. *Quick Stats*. Washington, DC. http://www.nass.usda.gov/QuickStats/

Table 1. Bt Corn Acreage as a Percentage of U.S. Corn Acreage

	1996	1997	1998	1999	2000
Bt Corn %	1	6	18	26	19

Source: Carpenter, 2001.

Table 2. Data Description and Model Coefficient Estimates

Variable[a]	Definition	Coefficient	t Value
Intercept		12.16471**	5.60
x_1	Green revolution dummy, equal 1 for 1960 on, 0 otherwise	9.75015*	2.38
x_2	Time, 0, 1, 2, …	1.51554**	14.65
x_3	Bt dummy, equal 1 for 1998 on, 0 otherwise	10.54868**	2.68

Observations: 78

F value**: 570.71

Adjusted R-Square: 0.9569

[a] The dependent variable is U.S. corn yield in bushels per acre from 1930 to 2007. Note: * indicates significance at the 0.05 level and ** indicates significance at the 0.01 level.

Table 3. Projected and Actual U.S. Corn Yields for Selected Years, Bushels per Acre

U.S. Corn	1950	1975	2000	2007	2020	2030	2040	2050
Projected	42.5	90.1	138.6	149.2	168.9	184.0	199.1	214.3
Actual	38.2	86.4	136.9	151.1	-	-	-	-

Figure 1. U.S. Corn Yield in Bushels per Acre

Yield, bushels

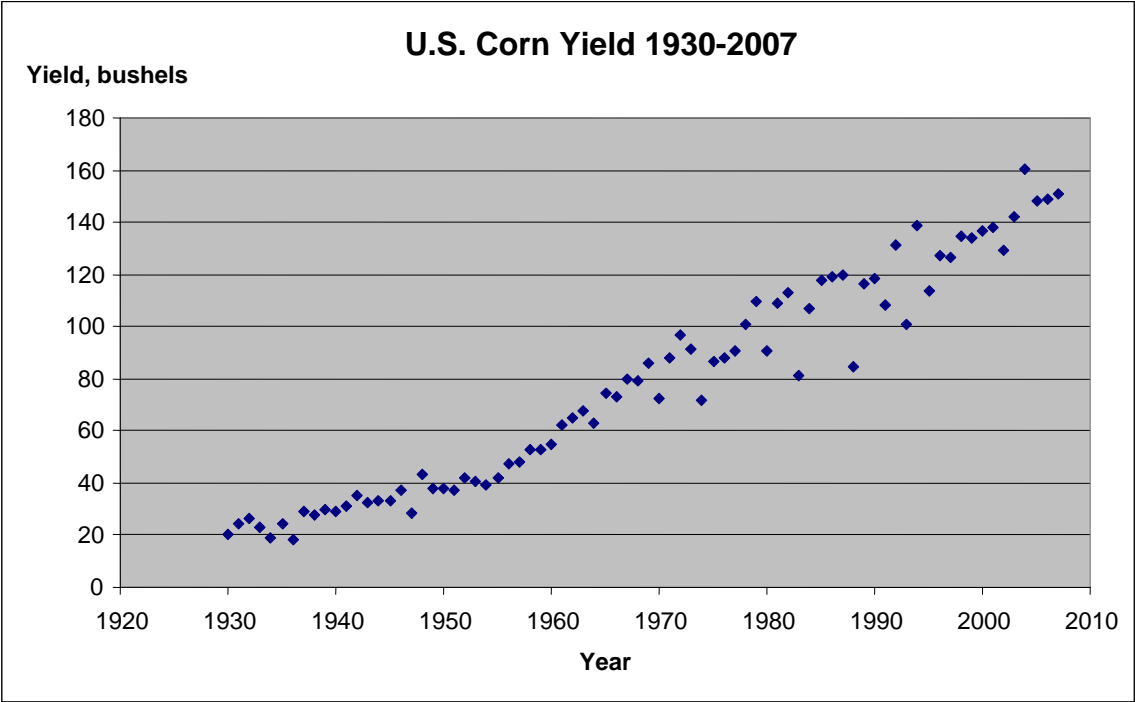U.S. Corn Yield 1930-2007

Year

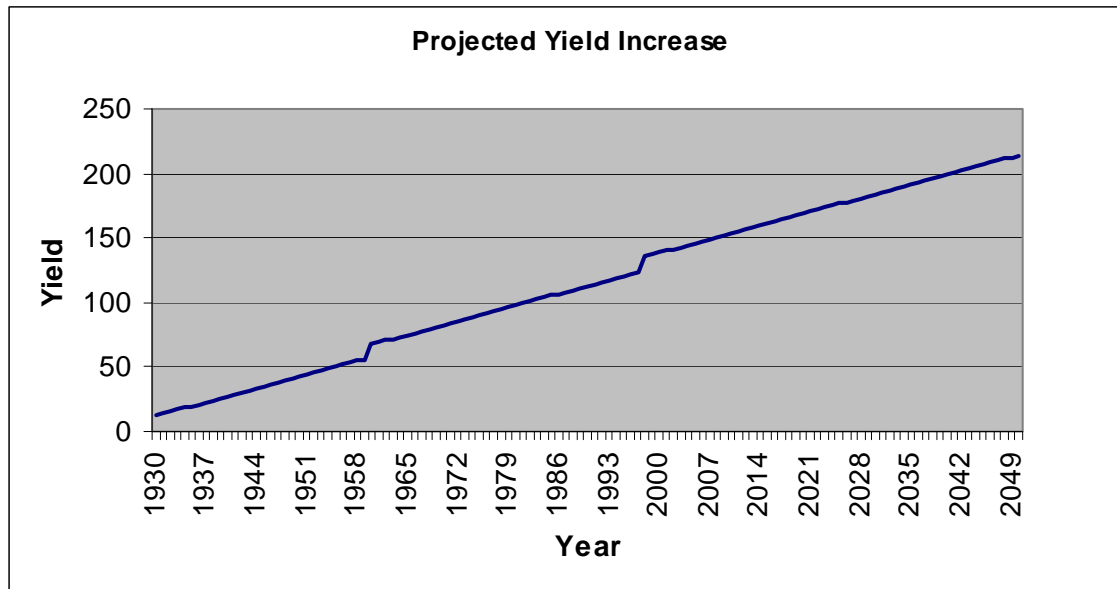**Figure 2. U.S. Per Acre Corn Yield Increase According to Model**

Figure 3. Regression Model Predictions vs. Historic Yields, U.S. Corn