Efficiency Measure in Nitrogen Management under U.S. Trade Induced Corn Production

Osei Yeboah
Department of Agribusiness, Applied Economics and Agriscience Education
N.C.A&T State University, A-25 C.H. Moore Agricultural Research Facility
1601 E. Market Street. Greensboro, NC 27411, Phone 336.285.4727, Fax 336.334.7658
E-mail oyeboah@ncat.edu

Cihat Gunden
Department of Agribusiness, Applied Economics and Agriscience Education
N.C.A&T State University, A-25 C.H. Moore Agricultural Research Facility, 1601 E. Market Street. Greensboro, NC 27411, Phone 336.256 2260, Fax 336.334.7658
E-mail cgunden@ncat.edu

Albert Allen
Mississippi State University, Department of Agricultural Economics, 205 Howell Hall, Howell Engineering Building, 823 College view Street, Mississippi State, MS 39762,
Phone: 662-325 2883, Fax: 662-325-6614
Email: allen@agecon.msstate.edu

Akua S. Akuffo (Graduate Research Assistant)
Department of Agribusiness, Applied Economics and Agriscience Education
N.C.A&T State University, A-25 C.H. Moore Agricultural Research Facility
1601 E. Market Street. Greensboro, NC 27411, Phone 336.285 4727, Fax 336.334.7658
E-mail: asakuffo@ncat.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, TX, February 5-8, 2011

Efficiency Measure in Nitrogen Management under U.S. Trade Induced Corn Production

Osei Yeboah, Cihat Gunden, Albert Allen and Akua Akuffo

Abstract

The overall objective of this paper is to measure the impact of the undesirable outputs from NAFTA (agricultural production and trade) on the environment by years in post-NAFTA period. Data Envelopment Analysis (DEA) was used to measure environmental efficiency by considering desirable (corn production) and undesirable (nitrogen) outputs in fifteen states. DEA allowed us to measure the level of nitrogen pollution to be reduced by modeling undesirable output in efficiency evaluation. Data from 15 states (Colorado, Illinois, Iowa, Indiana, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Carolina, Ohio, South Dakota, Texas and Wisconsin) on corn production, land use and nitrogen fertilizer from 1994-2008 (post-NAFTA) were considered. The results indicated environmental inefficiency, nitrogen pollution and land use inefficiency were increasing over the years in the post-NAFTA period.

Keywords: Data Envelopment Analysis, Environmental Efficiency, Nitrogen Pollution, NAFTA

Introduction

The relationship between trade and environment has become one of the hottest topics for debates in politics since the 1990s. Although the link has not been fully established between trade and pollution, many environmental communities stand by the idea that increased trade will increase environmental problems (Thompson*, et al*; 1996). As countries globalize, they tend to increase their production some of which are pollution intensive and have negative impacts on the environment. It is also clear that the environment has become increasingly important to trade negotiations. Environmental groups have long protested trade agreements, partly out of concern that producers will relocate to countries with weak pollution regulations, avoiding strict regulations in developed countries and damaging the environments of developing countries (Levinson, 2008). With the movement of hazardous wastes and toxic materials, the environmental risks increase the further the goods are transported, since spillage is always possible (Environment and Trade handbook, 2000). Such commodities may end up being dumped in technologically less endowed countries that cannot dispose of them.

Dean (1999) has shown that there is a connection between increasing income and pollution, that the level of pollution in a country at any point in time is connected to the level of income. This means that as the economic activity of the country increase, there is a rise in demand for goods and services this leads to an increase in production and emissions.

Under the NAFTA agreement, trade between the US and Mexico has increased particularly in corn and this has been reported to have a lot of undesirable environmental impacts. Including; high chemical and fertilizer use, land and water pollution and soil erosion. The level of nutrients such as nitrates and phosphorous in freshwaters is a problem worldwide (Shiklomanov, 1997). This is as a result of the increased use of fertilizer and organic manure in global agriculture. In the United States, for example, agriculture is the single greatest source of pollution degrading the quality of surface waters like rivers and lakes, with croplands alone accounting for nearly 40 percent of the nitrogen pollution and 30 percent of the phosphorous (Ackerman, *et al*; 2003).

International trade does not always have a negative impact on the environment, there are some positive effects including spreading of new technologies for protecting the environment, such as microbial techniques for cleaning up oil spillage. Or it may more rapidly spread goods or technologies that have less environmental impact; example, solar power technology, wind power technology or the manufacture of more fuel-efficient vehicles. Openness to trade and investment can aid in facilitating transfer of new management systems and improved technologies (Environmental and Trade handbook, 2000).

One of the largest and most environmentally significant changes since the implementation of NAFTA was the shift in the corn trade between the US and Mexico. US exports to Mexico rose from 3.1 million metric tons in 1994 to 5.2 million tons in 2000 or from 1.2% to 2.1% of the US corn crop. From Mexico's perspective, imports from the US rose from 14% to 24% of total corn consumption between 1994 and 2000. In monetary terms, US corn exports to Mexico were worth just over $500 million in 2000, which is 0.5% of all exports, or 8% of agricultural exports, from the US to Mexico (Ackerman, *et al*; 2003).

Theoretically, the impact of trade liberalization on pollution levels is not clear, even though a useful framework for thinking about trade and the environment has been proposed (Grossman and Krueger, 1993). They identify three mechanisms by which trade and investment liberalization affect the environment: scale, composition, and technique effects. Other research works on the impact of trade and economic development on the environment have used the Inverted U

Hypothesis (Grossman and Krueger, 1995; Selden and Song, 1994) and the pollution haven hypothesis .The EKC hypothesis states that pollution levels increase as a country develops, but begin to decrease as rising incomes pass beyond a turning point. In EKC analysis, the relationship between environmental degradation and income is usually expressed as a quadratic function with the turning point occurring at a maximum pollution level. The pollution haven hypothesis predicts that under the free trade, international firms will relocate their pollution- intensive production to countries that are developing, and take advantage of the low environment monitoring system in those countries (Temurshoev, 2006).

The overall objective of this paper is to measure the impact of the undesirable outputs from NAFTA (agricultural production and trade) on the environment.

The specific objectives to be pursued are:

1. To measure corn production efficiency by considering desirable (corn production) and undesirable (nitrogen) outputs in fifteen states: a) to measure production efficiency; and, b) to measure the level of nitrogen pollution to be reduced by modeling undesirable output in efficiency evaluation.
2. To estimate targets of input use and nitrogen pollution level in terms of the current corn production.
3. To observe the changes in the efficiency measures (considering corn production and nitrogen pollution) by years in post-NAFTA period

Corn Production in the United States

Corn is widely cultivated throughout the world, and a greater weight of it is produced each year than any other grain. The United States produces almost half of the world's harvest (42.5%); other top producing countries include China, Brazil, Mexico, Argentina, India, Pakistan and France. Worldwide production was around 800 million tonnes in 2007—just slightly more than rice (650 million tonnes) or wheat (600 million tonnes). In 2007, over 150 million hectares of maize were planted worldwide, with a yield of 4970.9 kilogram/hectare. Production can be significantly higher in certain regions of the world; 2009 forecasts for production in Iowa were 11614 kg/ha. It is one of the country’s most important crops, with annual sales around $17 billion, or 9% of the value of all agricultural output (NASS, 2000). Corn production today is very different from what it was in the early 1900's or even the 1950's. Corn production is mechanized, with farmers using tractors and implements to till the ground rather than horses and moldboard plows.

Corn exports account for roughly 20% of the corn crop, or $5 billion in sales (FATUS, 2001). The US is by far the world's largest corn producer and exporter, accounting for 40% of world production and 66% of world exports in 1999; in the same year Mexico accounted for 3% of world production and 7% of world imports (FAOSTAT, 2001).

Nitrogen Fertilization in Corn Production

Fertilizing corn is on the most essential and critical parts about growing corn. If you don't use the right type of fertilizer when you are growing corn, your corn won't grow right, it won't grow in as large of a quantity, and nor will it taste as good as it could of. When growing corn, you need to pick the right type of fertilizer. There are many corn fertilizers out there and the right fertilizer depends on a lot of factors, most important of which is soil type. In 1995, agricultural producers in America used 36 billion pounds of nitrogen to the environment; 23 billion pounds of nitrogen fertilizer and 13 billion pounds as animal manure (www.ewg.org).

Fertilizing corn should be done on the basis of soil tests and yield goals. Corn requires approximately 1.25 lbs. of elemental nitrogen (N), 0.6 lbs. of phosphate (P_2O5) and 1.4 lbs. of potash (K_2O) to produce one bushel of grain corn. Total N fertilizer applications are governed by the yield potential of individual soil series. Soils that enable deeper rooting depths and have high water-holding capacities will produce greater corn yields than soils with physical properties that restrict root growth, or soils that have sandy textures with low water-holding capacities.

US agriculture in general and corn production in particular, rely on intensive application of fertilizers, herbicides, and insecticides. While these chemicals make a major contribution to agricultural productivity, they also create problems of water pollution, with risks to human health and natural ecosystems. In particular, runoff of excess nitrogen and phosphate fertilizer contaminates surface and groundwater supplies, by promoting algal growth which reduces the dissolved oxygen content in the water making it difficult for fish or other wildlife to survive. The great quantities of nitrogen carried by the Mississippi River have been implicated in the large "dead zone" in the Gulf of Mexico where ocean life has been killed off (Keeney *et al;* 2000, Goolsby *et al*. 1999). Corn production is a major contributor to this effect through direct nitrogen runoff from fertilizer application on farms.

Corn growers in the US use more nitrogen fertilizer than producers of any other crop. Since the mid-1970s, at least 95 percent of the US corn acres have received nitrogen fertilizer each year, and in 1994 a total of 7.9 billion pounds of nitrogen was applied to 62.5 million acres of corn, at an average rate of 129 pounds per acre (http://www.ers.usda.gov). Illinois, Ohio, and Indiana recorded the highest levels of fertilizer application.

Nationwide, nitrogen application rates on corn have remained virtually unchanged since 1989 -- although between 1993 and 1994, application rates increased by six pounds per acre. But in four major corn-producing states, Ohio, Indiana, Missouri, and Michigan, nitrogen fertilizer application rates increased between 1989 and 1994 (www.ewg.org). Nitrogen fertilizer use in the Corn Belt between 1985 and 1993 decreased from 3.4 million tons to 3.0 million tonnes, but then it increased in 1994 to 3.5 million tonnes due to the flood incidence in 1993. N 1995, the Corn Belt had a nitrogen fertilizer consumption of 3.2 million tonnes (www.ers.usda.gov).

In Illinois, Indiana, and Nebraska, application rates exceeded the national average by at least ten pounds per acre. The experience of Iowa farmers, meanwhile, provides strong empirical evidence that corn producers in these states can significantly reduce their use of nitrogen fertilizer (Iowa State University 1993; Hallberg, et al. 1991; updated, 1995). The second highest users of nitrogen fertilizer in the United States; North Dakota, South Dakota, Nebraska and Kansas had an increase from 1.8 million tons to 2.3 million tons from 1985 to 1998 (www.ers.usda.gov).

In 1985, nitrogen fertilizer application rates in Iowa were 145 pounds per acre -- on the same level with those of farmers throughout the Corn Belt. However, between 1985 and 1994, average application rates in Iowa dropped by 16 percent, to 122 pounds of nitrogen fertilizer per acre. Meanwhile, fertilizer application rates for farmers in the remaining Corn Belt states remained at the same high rates.

In spite of major statewide decline in nitrogen fertilizer use, Iowa's corn yields remained higher than those of farmers throughout the Corn Belt. In an average year between 1989 and 1994, Iowa farmers used sixteen percent less fertilizer than farmers in other Corn Belt states -- and still achieved higher yields. In fact, Iowa farmers obtained record yields in 1992 and 1994, while significantly reducing fertilizer use. As a result, Iowa farmers reduced their costs by 31-39 million dollars per year, and reduced the threat to water supplies considerably (Hallberg et al; 1991). Unfortunately, farmers in most other states have not followed Iowa's lead. For most farmers throughout the Corn Belt, fertilizer use can be dramatically and easily reduced.

Nitrogen is the key element in increasing productivity. It is an integral component of many compounds essential for plant growth processes including chlorophyll and many enzymes. Nitrogen also mediates the utilization of potassium, phosphorus and other elements in plants. The optimum amounts of these elements in the soil cannot be utilized efficiency if nitrogen is deficient in plants. Therefore, nitrogen deficiency or excess can result in reduced maize yields.

Nitrate Pollution

Nitrate is a problem as a contaminant in drinking water (primarily from groundwater and wells) due to its harmful biological effects. High concentrations can cause methemoglobinemia. Methemoglobinemia is the condition in the blood which causes infant cyanosis, or blue-baby syndrome. It has been cited as a risk factor in developing gastric and intestinal cancer. Due to these health risks, a great deal of emphasis has been placed on finding effective treatment processes to reduce nitrate concentrations to safe levels. An even more important aspect to reduce the problem are preventive measures to stop the leaching of nitrate from the soil. Some suggest that reducing the amount of fertilizers used in agriculture will help alleviate the problem, and may not hurt crop yields. Nitrate is a wide spread contaminant of ground and surface waters worldwide (NECi, 2007).

The accumulation of nitrate in the environment results mainly from: non-point source runoff from the over-application of nitrogen fertilizers, point-sources such as Concentrated Animal Feeding Operations and point-sources from poorly or untreated human sewage (NECi, 2007).

Other new developments in leach pits and slurry stores help to control the nitrate that comes from stored manure. By putting in place these preventive methods and reducing the amount of fertilizer used, the concentration of nitrate in the groundwater can be reduced over time (www.reopure.com). Although there are many sources of nitrogen (both natural and artificial) that could potentially lead to the pollution of the groundwater with nitrates, the artificial sources are really the ones that most often cause the amount of nitrate rise to dangerous levels. One potentially large source of nitrogen pollution of groundwater is the application of nitrogen-rich fertilizers to turf grass. The main source of nitrate pollution in the groundwater results from the actions of farmers. Farming alone pollutes more of our groundwater resources than anything else (www.reopure.com). It is generally believed that the main source of nitrate-nitrogen in water bodies is from agriculture. One example of proof that farming is a major cause of groundwater pollution is that nitrate problems are most common in the spring, which is the time that farmers apply nitrogen fertilizer to their fields. Also, in a study (Burkart *et al;* 1993) it is found that samples of water from wells surrounded by more than 25% land in corn and soybean have a dramatically larger frequency of excess nitrate (30%) than wells with approximately 25% of the surrounding land in corn or soybean (11%).

Agriculture is the chief cause of widespread groundwater and surface water contamination with nitrate in the United States (Hallberg 1986a, Bouchard 1992).

A 1990/91 nationwide water quality summary analyzed nitrate transport in surface waters and land use and found that the highest transfer rates occurred in soybean and corn production areas. This research found that the average annual yield of nitrate contamination on agricultural land was 0.93 tons per square mile. In contrast, the average yield in urban areas is significantly lower, 0.55 tons per square mile. The impact of this irregularity between urban and agricultural land as a source of nitrogen is even more dramatic when one considers how much more land is used in crop production than for urban space. Corn alone accounts for 12 times more land area than all urban land in the United States. Agricultural regions nationwide contribute approximately 20 times more nitrate contamination to surface waters than urban lands. Similarly, corn and soybean acreage is responsible for 11 times more nitrate contamination than land used as rangeland.

In most regions, agriculture is also the major source of groundwater pollution with nitrate. In many areas where groundwater is heavily contaminated, there are few other significant sources of nitrate besides agriculture (Hallberg 1986). Intensive studies over 40 years in the Corn Belt have shown that increases in groundwater contamination by nitrate correspond closely with increases in nitrogen fertilizer use (Hallberg 1984). The United States Geological Survey in their most recent survey found that groundwater wells in agricultural regions are much more heavily contaminated than wells in urban, forest, or rangeland regions (Mueller, 1995).

Although a variety of factors, from urban sewage to atmospheric fallout, may be responsible for localized instances of nitrate contamination, on regional and national scale nitrogen inputs from agricultural activities are the single most important source of ground and surface water problems.

A recent authoritative study of the problem concurred: Solving the nitrate contamination problem will require reducing and refining agricultural use of nitrogen fertilizer, as well as vastly improved management of manure, both as a point source of pollution and when used as a fertilizer in the field. Instead of reducing their use of nitrogen fertilizers, America's farmers continue to increase nitrogen fertilizer use, thereby increasing production costs, environmental risks and the costs to taxpayers to solve contamination problems.

Trade and the Environment

Agricultural trade is important, especially that between the U.S. and Mexico since the U.S. accounts for around 70 percent of Mexico's agricultural exports and 70 percent of its agricultural imports; in addition to the effects related to production there are environmental consequences of the transportation of products, especially since most of this is by truck. U.S. foreign direct investment (FDI) in the Mexican agricultural sector, especially food processing, has increased and has implications for the environment (Colyer, 2002).

Corn being one of the more important staple crops in Mexico where it is grown solely for food, has had increases in both area and production. However, average yields are relatively low, only around two metric tons per hectare, indicating a relatively low level of technology (Colyer, 2002).

Fertilizers and chemical inputs, such as pesticides and herbicides, can have unfavorable environmental consequences like water pollution, food contamination, farm worker exposure to chemicals, etc.

Nearly 85% of all Mexican water usage is for agriculture (Vaughan, 2003). Shifts in the dynamics of agricultural trade between the US and Mexico has resulted in the concentration of certain high yield crops in farming sectors of Mexico to meet export demands. Export-oriented fruit farms "use greater amounts of groundwater per yield, compared to smaller farms" (Vaughan, 2003). A desire for increased yield has also led to an increase in the use of fertilizer which aggravates the scarcity of portable drinking water. The Great Lakes region is also home to a lot of water disputes. "Farming is the leading source of pollution in Canada, Mexico, and the United States" (Vaughan, 2003). Nitrogen, a central component of fertilizer, is the main culprit. It pollutes groundwater, creates algae blooms, acidifies waterways, and helps to increase ground-level ozone.

Mexico's participation in the free trade agreement has created a market for large industrial scale farms that focus on exports. Fertilizer consumption has remained relatively static since 1994, but the concentration of high intensity farms in certain regions has built up effects. Information on use of other agricultural chemicals is not complete, but data indicates that use of insecticides has increased during the post-NAFTA era. Similarly, FAO data on imports of chemicals by Mexico indicate that they have increased since the implementation of the free trade agreement (Colyer, 2002).

Biodiversity in agriculture is another important policy area. Mexico banned the use of GM corn in 1998, but a study in 2001 found GM crops to be growing throughout Mexico. This worries many who take note of the significance of corn as an extremely diverse crop in Mexico. Mexico is said to be the home of thousands of varieties (Nadal, 2002).

Another area of concern is the air quality. Transportation has had an enormous impact on air quality. Liberalization in trade, as a direct effect of international trade, has increased automobile shipment throughout the member states, in turn increasing emissions through these high impact transportation corridors (Kirton, 2001). A study conducted found that increased shipment traffic in five distinct corridors increases air pollution concentration into hot spots in urban areas, and especially at border crossings known for delays. Cross-border shipment accounts for up to 11% of all mobile source nitrous-oxide and up to 16% of all mobile source fine particulate matter emissions (CEC, 2001).

The North American Free Trade Agreement (NAFTA) was signed in 1992 and entered into force on January 1st, 1994, creating what was at the time the largest free trade zone in the world. One of the salient features of NAFTA was the inclusion of a rapidly developing country (Mexico) in a free trade zone with two industrialized partners. This new situation gave rise to several concerns regarding the effects that the Agreement would have on the environment. These concerns fuelled an intense political debate, mostly in the United States, that became one of the central elements in the discussions surrounding NAFTA's endorsement by the US Congress (Paquin et al; 2003). Prior to NAFTA, US maize exports to Mexico represented 0.8% of US production. In the post-NAFTA period, this share rose to 2.1%, two-and-a-half times the previous level.

U.S. agriculture in general and corn production in particular, rely on intensive application of fertilizers, herbicides, and insecticides. While these chemicals make a major contribution to agricultural productivity, they also create problems of water pollution, with risks to human health and natural ecosystems. In particular, runoff of excess nitrogen and phosphate fertilizer contaminates groundwater supplies in farm areas. The great quantities of nitrogen carried by the Mississippi River, coming heavily from corn-growing areas, annually kills ocean life throughout a huge "dead zone" in the Gulf of Mexico (Keeney, et al; 2000). USDA's National Agricultural Statistical Service (NASS, 2000) publishes annual reports on the use of agricultural chemicals by state, with coverage varying by crop and year. For 2000, the report covered the 18 top corn-growing states, accounting for 93% of production. It found that nitrogen fertilizer was applied to 98% of planted corn acreage, compared to 84% for phosphates and 66% for potash, the three major varieties of fertilizer. Herbicides were applied to 97%, and insecticides to 29%, of corn acreage (Ackerman, *et al*; 2003).

Interestingly, fertilizer usage has increased in both Canada and the United States since the implementation of the Canada-U.S. Free Trade Agreement (CFTA) in 1989, which suggests that agriculture is becoming more intensive in these two countries. In contrast, fertilizer usage in Mexico has changed very little since NAFTA's implementation in 1994, except for a steep drop in fertilizer usage in 1995, on the heels of the peso crisis of December 1994(ERS/USDA, 2005).

Reviewed Literature Studies on Environmental Efficiency Measurements

An agricultural study, (Reinhard et al; 2000) studied the side effects of nitrogen pollution on intensive dairy farm in Netherlands. The nitrogen pollution variable was obtained by using a materials balance equation. They used three efficiency models which yielded three different efficiency scores; a)an environmental efficiency score, b) an output-oriented technical efficiency score and c) an input-oriented technical efficiency score (Reinhard et al; 2003).

Research was carried out in Bangladesh to explain the influence of the economic performance of wheat farmers. The study set out to investigate the possibility of improving the economic efficiency of wheat farms and also to apply DEA to empirical evidence of 150 farmers in a region of the country. The DEA was used to investigate the economic efficiency of the sample of wheat growers. The wheat farms which were the DMUs consume varying amounts of inputs to produce different levels of output. A production possibility frontier was constructed consisting of all possible combinations of efficient production units.

The results obtained after the analysis showed that medium sized farms were more efficient in terms of production than small and large farms. This is due to the lack of limitations as found in small and large farms. Medium farms use inputs efficiently and they are operated by family members with their own lands. A non-parametric analysis of economic efficiency was performed on the wheat produced. The results showed the scores and they reflected that the farms needed to adjust the levels of inputs in order to achieve economic efficiency. The small farms had an average score of 0.90, meaning that they had to reduce their input levels by about 9%. Overall, 11 farms had a score of 1.00, meaning they are most efficient with the remaining 21 farms not being able to achieve the efficiency score of 1.00 (Kamruzzaman et al; 2002).

A study in Netherlands was to estimate the environmental efficiency measures for dairy farms. These scores were based on nitrogen surplus, phosphate surplus and total energy use of unbalanced panel on the farm (that direct and indirect source). In this study environmental efficiency is defined as the ratio of the minimum feasible to observed use of environmentally detrimental inputs. So this measure will allow for a reduction of environmentally detrimental inputs applied. The detrimental outputs; nitrogen and phosphorous surplus and the energy are treated as inputs as was done by Cooper and Oates and Boggs. They treated water emissions as a factor of production instead of an output. The methodology used was that each score was calculated yearly and it was compared to the efficiency frontier for that year. The estimated technical and environmental efficiencies obtained at the end for the input-oriented technical efficiency showed a radial reduction. And these scores were higher due to the presence of increasing returns to scale. The output-oriented technical efficiency scores seemed very possible. And the environmental efficiency scores obtained were non radial. The nitrogen scores were low because it was applied inefficiently and the levels have not been sanctioned yet in Netherlands. Output oriented scores were constant throughout the study (Reinhard et al; 2003).

The Parametric Model

In accordance with the global environmental conservation awareness, undesirable outputs of productions and social activities, e.g., air pollutants and hazardous wastes, are being increasingly recognized as dangerous and undesirable. Thus, development of technologies with less undesirable outputs is an important subject of concern in every area of production (Seiford *et al;* 2007).

The non-parametric approach or the data envelopment analysis (DEA) has the advantage of no prior parametric restrictions on the technology, therefore less sensitive to model mis-specification. DEA method is not subject to assumptions on the distribution of the error term and imposes minimal assumptions on production behavior. Furthermore, estimation of DEA method is based on a piecewise production frontier, making the estimated frontier close to real activity. However, because DEA is a deterministic approach, all deviations from the frontier are considered as inefficiencies, making it sensitive to measurement errors and data noises (Linh, 2006).

Charnes, Cooper and Rhodes (1978) proposed a model which had an input orientation and assumed constant return to scale (CRS). Banker, Charnes and Cooper (1984) also proposed a variable return to scale (VRS) model. The CRS model is only appropriate when all the DMU’s are operating at an optimal scale but the VRS model is used when the DMU’s are not operating at the optimal scale. So the use of the CRS model when not all DMU’s are operating at the optimal scale will result in measures of technical efficiency which are confounded by scale inefficiencies. The

VRS model will allow the calculation of technical efficiency devoid of these scale efficiency effects (Coelli, 2008). DEA has been applied to several benchmarking research works and to the performance analysis of public institutions like schools, hospitals and also of private institutions especially banks, (Bosetti *et al*; 2006).

Researchers have studied on how economic and ecological issues are considered together and concluded that new indicators are needed to measure the economic performance of a production unit and the national economy, which take into account environmental aspects as well (Cooper et al; 2007).

Data Envelopment Analysis is commonly used to evaluate the efficiency of Decision Making Units (DMUs). DEA, a non-parametric mathematical programming method is derived from Farrel (1957) definition of efficiency. It involves the use of linear programming to construct an efficiency frontier (piece-wise). The frontier provides a relative measurement of each unit. The frontier that comprises efficient units is the expected target for other units which are inefficient. Inefficient DMUs can improve their performance to reach the efficient frontier by either increasing their current output levels or decreasing their current input levels.

However, both desirable (good) and undesirable (bad) factors may be present. DEA model can be used to improve the performance via increasing the desirable outputs and decreasing the undesirable outputs (Seiford and Zhu, 2002). The problem is that the conventional DEA models assume that outputs should be increased and the inputs should be decreased to improve the efficiency or to reach the efficient frontier. If one treats the undesirable outputs as inputs so that the bad outputs can be reduced, the resulting DEA model does not reflect the true production process (Zhu, 2009).

The recent environmental movements and environmental conservation issues require evaluating the relative efficiency of production units within the framework that includes both desirable and undesirable outputs. Undesirable outputs of productions and social activities, e.g., air pollutants and hazardous wastes, are being increasingly recognized as dangerous and undesirable. Thus, development of technologies with less undesirable outputs is an important subject of concern in every area of production. Data Envelopment Analysis usually assumes that producing more outputs relative to less input resources is a criterion of efficiency. In the presence of undesirable outputs, however, technologies with more good (desirable) outputs and less bad (undesirable) outputs relative to less input resources should be recognized as efficient (Cooper, Seiford and Tone, 2007).

The Undesirable Output Model deals with applying a slacks-based measure of efficiency (SBM). The SBM is non-radial and non-oriented, and utilizes input and output slacks directly in producing an efficiency measure. In this model, SBM is modified so as to account for undesirable outputs. This model has Bad Output Model which deals with good (desirable) and bad (undesirable) outputs independently.

Bad Output Model classifies output items into good (desirable) and bad (undesirable) outputs. Let us decompose the output matrix Y into (Y^g, Y^b) where Y^g and Y^b denote good (desirable) and bad (undesirable) output matrices, respectively. For a DMU, the decomposition is denoted as (x_0, y_0^g, y_0^b).

We consider the production possibility set defined by:

$$P = \left\{(x, y^g, y^b) \mid x \geq X\lambda, y^g \leq Y^g\lambda, y^b \geq Y^b\lambda, L \leq e\lambda \leq U, \lambda \geq 0\right\}$$

where λ is the intensity vector, and L and U are the lower and upper bounds of the intensity vector, respectively. We define the efficiency status in this framework as follows.

A DMU (x_0, y_0^g, y_0^b) is efficient in the presence of bad outputs, if there is no vector $(x_0, y_0^g, y_0^b) \in P$ such that $x_0 \geq x, y_0^g \leq y^g, y_0^b \geq y^b$ with at least one strict inequality. Then, SBM is modified as follows:

$$\rho^* = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_{i0}^-}{x_{i0}}}{1 + \frac{1}{s}\left(\sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}^g} + \sum_{r=1}^{s_2} \frac{s_r^g}{y_{r0}^g}\right)}$$

subject to

$$x_0 = X\lambda + s^-$$
$$y_0^g = Y\lambda - s^g$$
$$y_0^b = Y\lambda + s^b$$
$$L \leq e\lambda \leq U$$
$$s^-, s^g, s^b, \lambda \geq 0.$$

The vectors s^- and s^b correspond to excesses in inputs and bad outputs, respectively, while s^g expresses shortages in good outputs. s_1 and s_2 denote the number of elements in s^b and s^g, and $s = s_1 + s_2$. Let an optimal solution of the above program be (ρ^*, s^{-*}, s^{g*}, s^{b*}). Then we can demonstrate that the DMU (x_0, y_0^g, y_0^b) is efficient in the presence of undesirable outputs if and only if $\rho^*=1$, i.e., $s^{-*}=0$, $s^{g*}=0$, $s^{b*}=0$. If the DMU is inefficient, i.e., $\rho^*<1$, it can be improved and become efficient by deleting the excesses in inputs and bad outputs and augmenting the shortfalls in good outputs by the following projection.

$$x_0 \Leftarrow x_0 - s^{-*}$$
$$y_0^g \Leftarrow y_0^g + s^{g*}$$
$$y_0^b \Leftarrow y_0^b - s^{b*}$$

The above fractional program can be transformed into an equivalent linear program. By considering the dual side of the linear program, we have the following dual program in the variable v, u^g, u^b for the CRS case, i.e. $L=0$, $U=\infty$.

$$\max u^g y_0^g - v x_0 - u^b y_0^b$$
$$subject\ to$$
$$u^g Y^g - vX - u^b Y^b \le 0$$
$$v \ge \frac{1}{m}\left[1/x_0\right]$$
$$u^g \ge \frac{1 + u^g y_0^g - v x_o - u^b y_0^b}{s}\left[1/y_0^g\right]$$
$$u^b \ge \frac{1 + u^g y_0^g - v x_o - u^b y_0^b}{s}\left[1/y_0^b\right]$$

The dual variables v and u^b can be interpreted as the virtual prices (costs) of inputs and bad outputs, respectively, while u^g denotes the price of good outputs. The above dual program aims at obtaining the optimal virtual costs and prices for the DMU so that the profit $u^g y^g - vx - u^b y^b$ does not exceed zero for every DMU and maximizes the profit $u^g y^g - vx - u^b y^b$ for the DMU concerned. Apparently, the optimal profit is at best zero and this identifies the DMU as efficient.

In our Bad Output Model, we set weights to bad and good outputs through keyboard before running the model. If we supply $w_1(\ge 0)$ and $w_2(\ge 0)$ as the weights to good and bad outputs, respectively, then the model calculates the relative weights as $W_1=sw_1/(w_1 + w_2)$ and $W_2=sw_2/(w_1 + w_2)$, and the objective function will be modified to

$$\rho^* = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_{i0}^-}{x_{i0}}}{1 + \frac{1}{s}\left(W_1 \sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}^g} + W_2 \sum_{r=1}^{s_2} \frac{s_r^g}{y_{r0}^g}\right)}$$

The defaults are w_1=1 and w_2=1. In accordance with the degree of emphasis on bad outputs evaluation, we can put a large w_2 against w_1, and vice versa.

In this study, two output variables are used in the analysis as desirable and undesirable to measure the environmental efficiency in corn production. The desirable output is total corn production, while the undesirable output is the nitrogen fertilizer. The efficiency measurement considers one input variable: land, which includes corn production area used in corn production.

Data

To measure the impact of increased trade under NAFTA on the environment, data from 15 growing states (Colorado, Illinois, Iowa, Indiana, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Carolina, Ohio, South Dakota, Texas and Wisconsin) on corn production, land use and nitrogen fertilizer from 1994-2008 (post-NAFTA). The land, which includes area planted to corn over these periods in acres for each state; the nitrogen which covers the amount consumed in tons by each state in corn production. The data were obtained from the National Agricultural Statistical Service (NASS)-USDA (www.nss.usda.gov) and U.S. Geological Survey (USGS) (www.usgs.gov).

Results and Discussion

Table 1 shows basic descriptives statistics for the environmental efficiency score by the years over which the data was taken; 1994 to 2008. In all fifteen states were used and the number of efficient states just shows how many states used the inputs that is land and nitrogen proficiently. 1996 had the highest number of efficient states followed by 2006 with 4 states. 1998, 1999 and 2005 had the highest number of inefficient states; 14 implying they had just one proficient states those years. The average score just captures on the average the rating of the states on a scale of 1.00. 2002 had the least score of 0.562 meaning that year the land and nitrogen were used inefficiently. The states can reduce the land and nitrogen consumption by 43.8% without causing a decrease in current corn production. On the other hand 1996 was the most efficient year with an average score of 0.774 implying that the consumption of nitrogen and land usage have to be reduced by 22.6% to make the states efficient and maintain current production of corn. The environmental efficiency as shown in the average scores was decreasing slightly on the whole.

Table 1: Descriptive statistics of the environmental efficiency scores for fifteen states in 1994-2008

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Number of States	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Minimum	0.381	0.499	0.449	0.427	0.308	0.328	0.495	0.477	0.359	0.530	0.369	0.502	0.319	0.440	0.336
SD	0.181	0.144	0.205	0.169	0.195	0.167	0.164	0.192	0.175	0.161	0.186	0.143	0.212	0.203	0.218
Average Scores	0.711	0.724	0.774	0.772	0.725	0.692	0.714	0.719	0.562	0.721	0.574	0.695	0.743	0.693	0.662
Number of efficient States	3	2	5	3	1	1	2	3	1	2	2	1	4	3	3
Number of inefficient States	12	13	10	12	14	14	13	12	14	13	13	14	11	12	12

Figure 1 below shows the average environmental efficiency measures by years. It shows the efficiency started to reduce from 2000 to 2004 then begun to increase up till to 2007 then down in 2008. The average efficiency score for 1994 was 0.71; in 1995 was 0.72 which was an increase from the previous year. In 1996 it went up to 0.77 and stayed there until it decreased to 0.73 in 1998 then to 0.69 in 2000. In 2001 the average score was 0.72 then it came down to 0.56 in 2002 then up again to 0.69. From 2003 to 2008 it kept on decreasing generally from 0.72 down to 0.66. The figure shows a decrease in efficiency overall. The efficiency score in 1994 implies corn producers were 71% efficient in managing nitrate pollution and land use whereas in 2008 producers were 66% efficient.

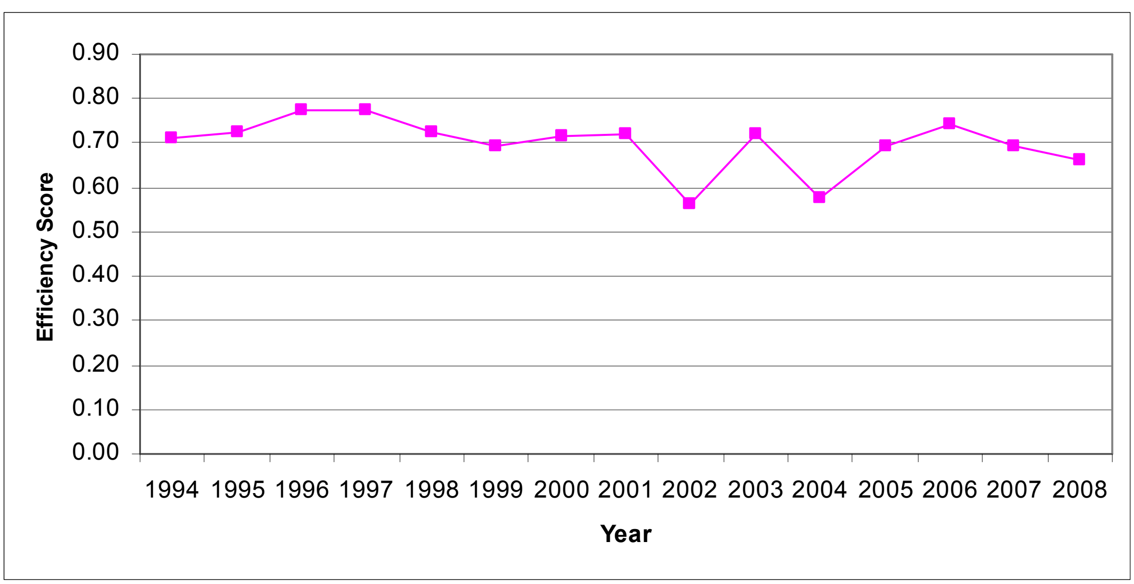

Figure1: Average environmental efficiency scores by years (1994-2008)

The Table 2 shows the results of efficiency scores in total by states and years.

From the analysis, three states were efficient in the year 1994; Illinois, Wisconsin and Iowa; this means that they had a score of 1.00. Texas and North Carolina were found to be the least efficient with scores of 0.50 and 0.38 respectively.

In 1995, the number of efficient states was also two, Iowa and Wisconsin. The least efficient states were still Texas and North Carolina with scores of 0.60 and 0.56 respectively.

Results from the year 1996, shows the increase in the number of efficient states to five since 1995; Iowa, Kansas, Missouri, Nebraska and South Dakota. Texas (0.48) and North Carolina (0.45) were still the least efficient.

In 1997 Iowa, Kansas and Missouri were the most efficient states. Texas and North Carolina were still the least efficient with scores of 0.63 and 0.43 respectively.

Iowa was the only efficient state in 1998 and 1999. The least efficient states Texas and North Carolina had a score of 0.38 and 0.31 respectively in 1998 and 0.56 and 0.33 respectively in 1999.

The analysis of the data from the year 2000 showed two efficient states, Illinois and Missouri with Iowa ranking third in efficiency this year. Texas and North Carolina were still the least efficient with scores of 0.53 and 0.50 respectively.

In 2001, there were three efficient states, Illinois, Indiana and Missouri each having a score of 1.00. Texas and North Carolina were still the least efficient with scores of 0.48 and 0.55 respectively.

There was only one efficient state, Iowa in 2002. In this year the least efficient state was Ohio with a score of 0.38 and Texas with a score of 0.47.

Illinois and Iowa were the efficient states in 2003. The least efficient states, Missouri and Kansas had scores of 0.54 and 0.54 respectively.

Illinois and Indiana were the efficient states with scores of 1.00 each in 2004 whiles North Carolina and Texas still remained inefficient with scores of 0.40 and 0.48 respectively.

Results for 2005 showed only one efficient state, Iowa. The least efficient states were Missouri and Texas with scores of 0.51 and 0.50 respectively.

Illinois, Iowa, Missouri and Texas were the efficient states in 2006, with scores of 1.00.Kansas and Kentucky took the positions of Texas and North Carolina with scores of 0.45 and 0.62.

In 2007, Illinois, Missouri and Iowa were the most efficient states. Colorado and Kansas were inefficient with high percentages by which their nitrogen input had to be reduced. They had scores of 0.53 and 0.55 respectively. Illinois, Missouri and Iowa all had scores of 1.00 making them efficient states. Kansas and Kentucky had the same score of 0.52.

Iowa, Illinois and Missouri were the efficient states in with a score of 1.00 each in 2008. Kansas and Kentucky were the least efficient with a score of 0.52 each.

Table 2: Environmental efficiency scores for states by years (1994-2008)

State	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
CO	0.67	0.61	0.74	0.78	0.74	0.72	0.56	0.72	0.46	0.64	0.44	0.70	0.62	**0.53**	0.46
IL	**1.00**	0.84	0.92	0.88	0.91	0.88	**1.00**	**1.00**	0.69	**1.00**	**1.00**	0.75	0.91	**1.00**	**1.00**
IN	0.85	0.82	0.88	0.82	0.86	0.80	0.89	**1.00**	0.59	0.82	**1.00**	0.80	**1.00**	0.94	0.87
IA	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	0.89	0.96	**1.00**	**1.00**	0.67	**1.00**	**1.00**	**1.00**	**1.00**
KS	0.62	0.68	**1.00**	**1.00**	0.73	0.68	0.59	0.55	0.46	0.54	0.52	0.67	**0.45**	**0.55**	0.52
KY	0.58	0.61	0.66	0.52	0.55	0.48	0.62	0.67	0.47	0.70	0.54	0.61	**0.62**	**0.51**	0.52
MI	0.54	0.72	0.50	0.62	0.57	0.65	0.61	0.48	0.55	0.68	0.44	**0.68**	0.66	0.50	0.55
MN	0.76	0.80	0.78	0.79	0.94	0.90	0.81	0.71	0.89	0.87	0.56	0.95	0.89	0.73	0.80
MO	0.70	0.62	**1.00**	**1.00**	0.70	0.56	**1.00**	**1.00**	0.50	0.54	0.60	0.51	**1.00**	**1.00**	**1.00**
NE	0.77	0.79	**1.00**	0.86	0.90	0.82	0.69	0.89	0.58	0.88	0.60	0.82	0.81	0.84	0.80
NC	**0.38**	**0.56**	**0.45**	**0.43**	**0.31**	**0.33**	**0.50**	**0.55**	**0.36**	0.53	0.40	0.58	0.60	0.44	**0.34**
OH	0.69	0.72	0.59	0.85	0.83	0.63	0.79	0.66	**0.38**	0.84	0.55	0.68	0.73	0.66	0.57
SD	0.62	0.50	**1.00**	**0.63**	0.73	0.65	0.59	0.53	0.40	0.61	0.44	0.56	**0.32**	0.51	0.57
TX	**0.50**	**0.60**	**0.48**	**0.63**	**0.38**	**0.56**	**0.53**	**0.48**	**0.47**	0.58	0.48	0.50	**1.00**	0.67	0.47
WI	**1.00**	**1.00**	0.61	0.77	0.74	0.72	0.65	0.60	0.61	0.59	0.37	0.63	0.55	0.52	0.48

Figure 2 below shows the average efficiency scores by states from 1994 to 2008. Iowa is the most efficient state in terms of nitrogen management in corn production, with an efficiency score of 0.97 followed by Illinois with 0.92. As can be observed North Carolina and Texas were the least efficient states with average scores of 0.45 and 0.56 respectively. The overall trend was decreasing with noticeable changes between 2002 and 2004.

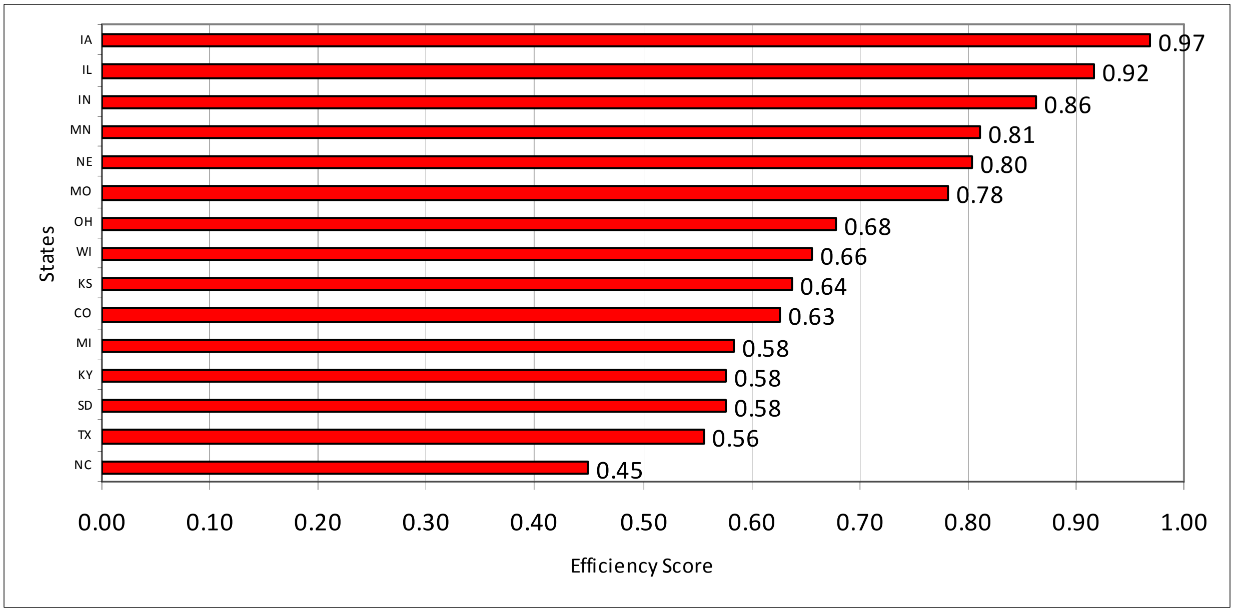

Figure 2: Average efficiency scores by states for all period (1994-2008)

Table 3 shows the percentages by which inefficient states are to reduce the nitrogen they use in corn production. These percentages were calculated by the difference between actual and projected nitrogen pollution by the states. The higher the value, the less efficient the state was in managing its nitrogen use in that year. From 1994 to 2004 North Carolina and Texas were the least efficient states. Iowa was the most efficient state followed by Illinois, Missouri and Kansas. In 2005, Missouri was the least efficient and had to remove 48.51% of total nitrogen in order to be environmentally efficient. In 2006, 2007 and 2008 Kansas was the least efficient and was required to reduce the nitrogen usage levels by 80.01%, 75.49% and 78.13% respectively

Table 3: Nitrogen Reduction in percentage required of states for all periods (1994-2008)

State	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO	58.55	63.78	52.07	48.58	50.89	46.90	57.28	27.14	49.71	15.64	99.53	14.83	66.44	**69.09**	73.16
IL	**0.00**	21.03	15.32	14.48	16.25	16.85	**0.00**	**0.00**	42.38	**0.00**	**0.00**	24.41	20.66	**0.00**	**0.00**
IN	15.25	26.77	2.40	15.97	14.40	23.22	24.28	**0.00**	50.30	10.62	0.00	21.86	**0.00**	**0.00**	0.29
IA	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	24.24	**0.00**	**0.00**	**0.00**	94.97	**0.00**	**0.00**	**0.00**	**0.00**
KS	74.36	77.05	**0.00**	**0.00**	69.43	68.56	72.42	67.30	55.28	**35.86**	99.59	26.14	**80.01**	**75.49**	**78.13**
KY	58.89	62.68	59.29	66.11	67.76	70.47	60.67	59.73	57.71	24.03	99.43	43.43	**68.08**	70.00	**75.22**
MI	45.55	37.41	41.05	42.55	46.42	43.20	43.39	53.59	38.64	10.53	99.13	20.90	42.14	51.72	53.95
MN	23.45	28.09	19.56	28.31	13.61	14.03	38.17	22.10	7.60	3.99	98.34	4.48	21.89	24.53	18.71
MO	12.06	45.57	**0.00**	**0.00**	17.29	30.32	**0.00**	**0.00**	54.61	**39.15**	98.30	**48.51**	**0.00**	**0.00**	**0.00**
NE	25.88	25.83	**0.00**	20.48	20.47	25.21	30.88	9.80	41.90	7.55	98.28	16.45	34.52	23.91	24.67
NC	**78.93**	78.66	74.51	80.72	87.91	86.35	75.64	**66.21**	54.53	27.07	**99.87**	29.04	55.33	43.27	43.35
OH	48.02	62.50	59.14	19.76	25.45	54.62	32.06	60.73	69.55	13.72	99.53	35.60	52.23	46.13	54.10
SD	**0.00**	30.95	0.00	2.20	13.64	16.84	42.95	45.57	17.16	10.91	99.36	24.78	67.42	49.84	46.63
TX	**86.58**	**84.64**	**83.68**	**84.54**	**88.90**	**86.36**	**86.25**	**87.32**	62.49	27.72	**99.66**	**42.83**	**0.00**	33.39	66.68
WI	**0.00**	**0.00**	7.22	2.22	9.70	15.59	29.06	17.20	20.62	20.05	99.47	13.86	43.80	42.96	48.19

Figure 3 shows the average in average percentage by how much these states are to reduce their nitrogen consumption in order to be environmentally efficient in corn production. . The higher the percentage, the least environmentally efficient the state is. Since Texas and North Carolina are the least efficient states, they are required to reduce their nitrogen use by 68.07 % and 65.43% for all periods. Iowa was most efficient followed by Illinois and these states had to reduce their nitrogen usage by 7.95% and 11.43% in order to be environmentally efficient.

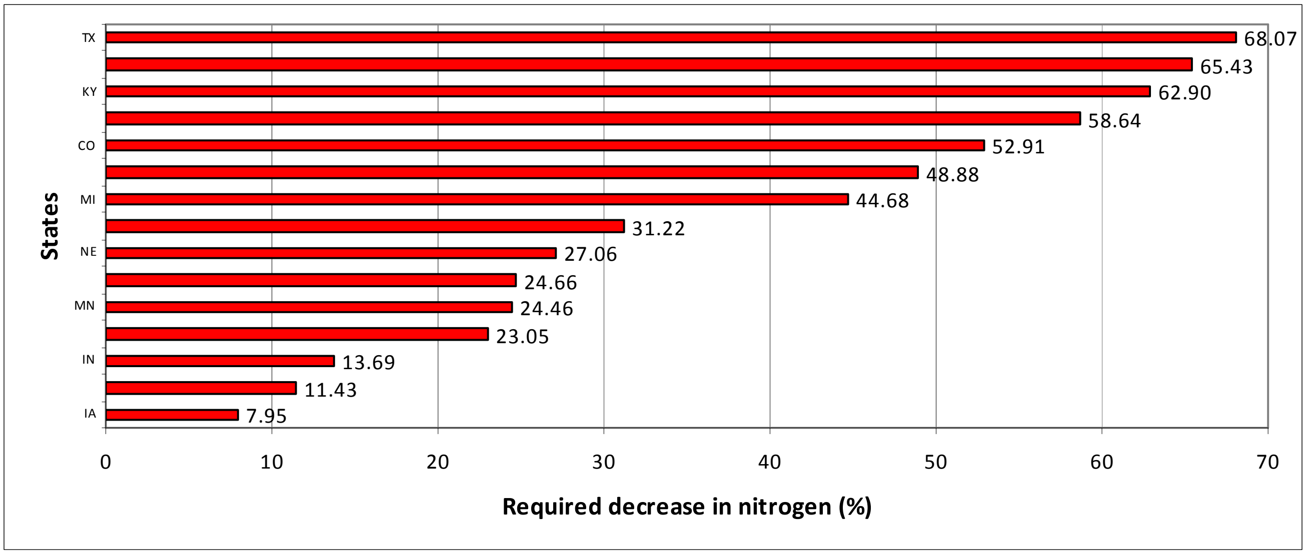

Figure 3: Average Projected Nitrogen Reductions (%) for all States (1994-2008)

Figure 4 just shows the percentages by which the states were to reduce their nitrogen consumption each year. In 2004 all states had to reduce the amount by almost 90% which is the highest so far. The year 2003 had the least reduction of about 14%.

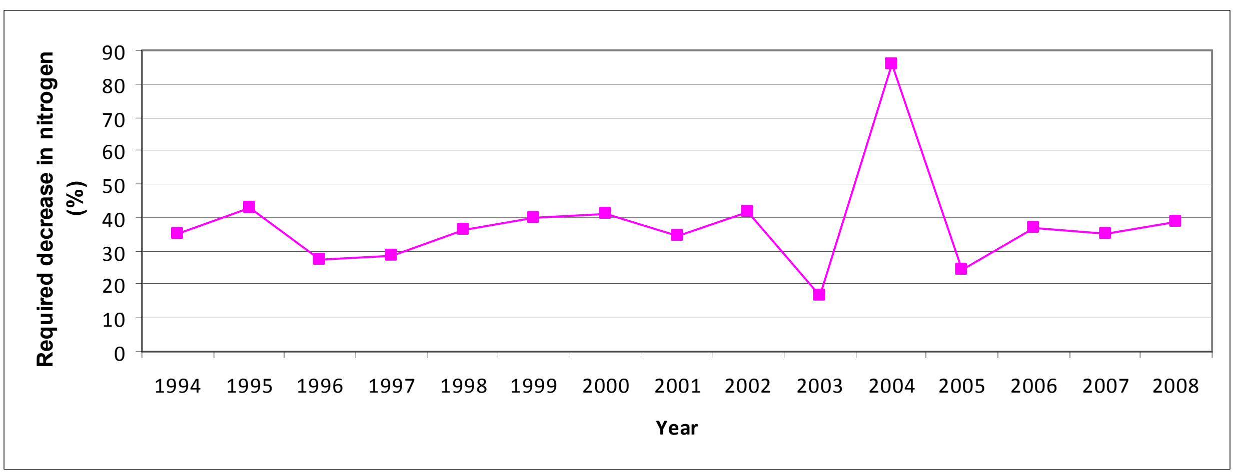

Figure 4: Average Projected Nitrogen Reductions (%) by years (1994-2008)

Table 4 shows by how much each state was to reduce its acreage of land to make it efficient, these percentages just as in the nitrogen case, and show by how much these states have to reduce their land use to make it efficient. Iowa was the most efficient state in the use of land. In 1994, 1996, 1997, 1998, 1999, 2000 and 2003, North Carolina was the least efficient state and was required to reduce its land usage by 46.81%, 38.40%, 40.08%, 55.71%, 53.02%, 31.74% and 39.80% respectively in order to be efficient in corn production.

Table 4: The percentage of land usage required to decrease for states by years (1994-2008)

State	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO	13.87	19.12	6.20	2.48	7.09	11.01	27.95	18.10	43.15	31.24	34.16	24.34	17.54	28.52	37.12
IL	**0.00**	7.60	0.90	5.45	1.78	4.99	**0.00**	**0.00**	16.27	**0.00**	**0.00**	16.41	**0.00**	**0.00**	**0.00**
IN	8.63	7.50	11.16	11.67	7.37	11.19	**0.00**	**0.00**	26.12	13.15	**0.00**	10.85	**0.00**	5.64	12.94
IA	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	4.44	**0.00**	**0.00**	0.55	**0.00**	**0.00**	**0.00**	**0.00**
KS	15.21	5.24	**0.00**	**0.00**	1.32	8.20	19.82	26.38	41.39	36.07	21.58	24.47	36.70	24.74	28.23
KY	24.88	19.78	15.05	30.71	26.24	35.40	19.30	13.18	39.41	21.84	19.41	26.24	16.68	31.15	28.49
MI	33.74	15.05	39.63	24.21	30.09	20.70	26.22	**39.52**	34.31	28.63	34.19	24.39	19.92	37.22	30.10
MN	15.03	8.90	14.03	9.64	0.03	4.04	3.64	20.94	7.72	11.22	15.89	3.36	1.63	18.49	12.89
MO	25.94	24.21	**0.00**	**0.00**	24.01	35.76	**0.00**	**0.00**	36.05	35.55	11.00	37.05	**0.00**	**0.00**	**0.00**
NE	13.40	10.89	**0.00**	5.24	0.45	7.68	19.90	6.19	29.26	8.63	9.98	11.53	5.30	6.45	10.04
NC	**46.81**	21.91	**38.40**	**40.08**	**55.71**	**53.02**	**31.74**	26.82	54.30	**39.80**	40.58	33.71	24.01	46.44	59.14
OH	14.61	5.20	23.11	7.00	6.26	19.57	8.28	14.18	48.63	10.31	17.46	20.26	8.17	18.71	27.50
SD	38.14	**42.35**	**0.00**	36.19	22.17	29.79	28.79	34.95	**56.18**	36.06	34.71	37.48	57.34	36.70	30.02
TX	27.90	13.98	31.99	10.29	**45.53**	19.42	24.69	31.33	37.68	34.25	28.19	**39.11**	**0.00**	21.62	**37.33**
WI	**0.00**	**0.00**	36.63	22.31	22.82	22.09	25.38	35.22	32.25	35.46	**44.73**	33.15	32.58	36.81	41.02

Figure 5 is a graphical representation of the percentage by how much the states were to reduce their land to make it efficient. Colorado was the least efficient in terms of land use, was required to decrease by 40.83% followed by Kentucky with 34.72%. Missouri was the most successful state in managing land use and had to decrease its land use on the average by 0.33%, followed by Illinois with 3.56% in order to make them efficient in land use for corn growth

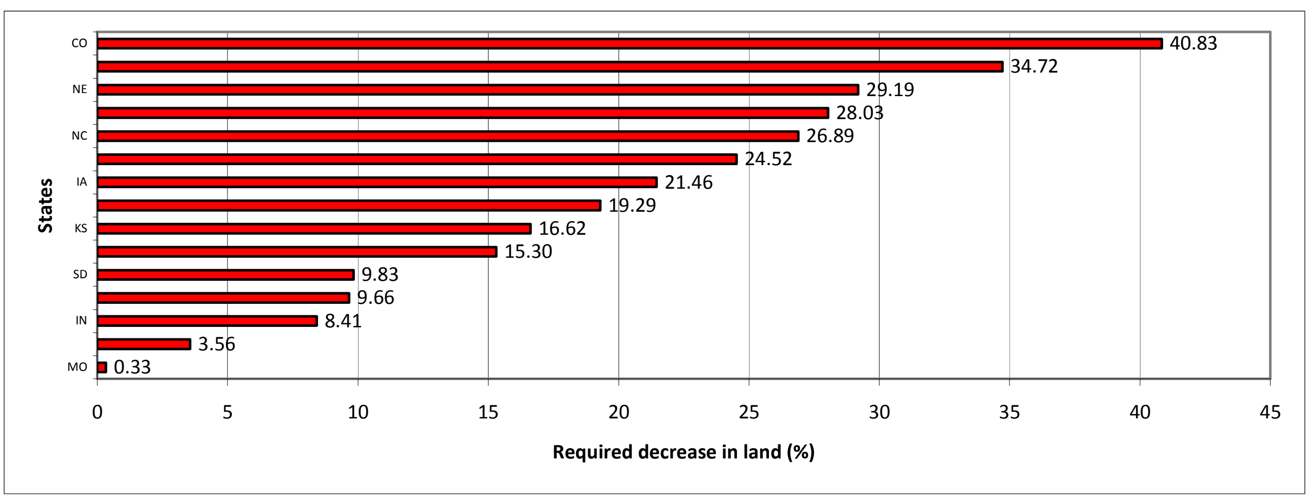

Figure 5: Average Projected Land Reductions (%) for all States by years (1994-2008

Figure 6 shows that the most inefficient land use occurred in 2002 with all states required to decrease land area by 33.51% on the average. 2006 was the most efficient year with an average required reduction value of 14.66% to make it efficient in the use of corn propagation. The trend shows inefficient land use in corn production like nitrogen consumption.

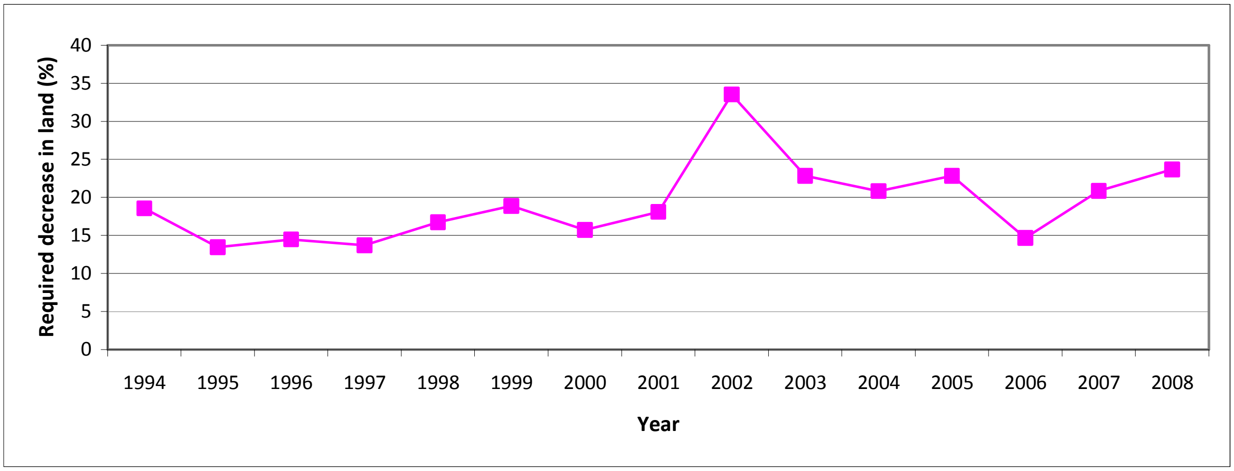

Figure 6: Average percentage of land usage required to decrease by years (1994-2008)

Conclusion

Average environmental efficiency is decreasing for all states in the period considered due to the increase in nitrogen pollution. Corn producers are also using land inefficiently. Nine of the top eleven nitrogen using states -- Iowa, Illinois, Nebraska, Minnesota, Kansas, Indiana, North Dakota, Ohio, and Missouri -- are in the Corn Belt, and 50% of the nation's fertilizer use occurs in these nine states (www.ewg.org). Iowa coming up as the most efficient state confirms the reduction in nitrogen fertilizer application by farmers between 1985 and 1994. Levels of nitrogen fertilizer have continued to be reduced as can be seen in the results making it the most efficient state. Texas according to literature ranks first in the United States fertilizer use so it is not surprising that it is coming up as one of the least efficient in the management of nitrogen use in corn production from the results. The increase in the use of nitrogen in corn production can also be attributed to the push to grow more corn for ethanol production.

REFERENCES

Ackerman, Frank, Luke Ney, Kevin Gallagher and Regina Flores, 2003. Environmental Impacts of the Changes in US.-Mexico Corn Trade under NAFTA. Global Development and Environment Institute, Tufts University.

Agricultural Resources and Environmental Indicators (AREI): Production Inputs. Available online at http://www.ers.usda.gov/publications/arei/ah712/ah712_3.pdf

Alpha Water Systems Incorporated. "N.d.". Available online at http://www.reopure.com.

Banker, R.D., Charnes A. and Cooper W.W., 1984. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, Management Science, 30; 1078-1092

Bossetti, Vallentina and Gianni Locatelli, 2006. A Data Envelopment Analysis Approach to the Assessment of Natural Economic Efficiency and Sustainability. The Case of Italian National Parks.

Bouchard, 1992. Nitrate contamination of groundwater: sources and potential health effects. Journal AWWA. September. 85-90.

Bukart, Michael R. and Koyoin Dana W., 1993. Hydrologic and Land Use Factors Associated with Herbicides and Nitrate in Near-Surface Aquifers, Journal of Environmental Quality, Vol 22, page 646-656

Charnes A., W. W. Cooper, J. Rousseau and J. Semple, 1987. Data Envelopment Analysis and Reference Sets, Research Report CC5 558, Centre for Cybernetic Studies. The University of Texas, Austin.

Charnes A., W.W. Cooper and E. Rhodes, 1978. Measuring the Efficiency of Decision Making Units, European Journal of Operations Research: 429-444

Coelli T. J., 2008. A Guide to DEAP Version 2.1: Data Envelopment Analysis (Computer) Program. Center for Efficiency and Productivity Analysis (CEPA) No. 8196

Commission for Environmental Cooperation, CEC, 2001. Available online at www.cec.org.

Cooper, William, and Lawrence M. Seiford and Kaoru Tone, 2007, Data Envelopment Analysis: A Comprehensive Text and Models an Applications, References and DEA-Solver Software. Available online at www.infibeam.com

Coyler, David 2002, Environmental Impacts of Agricultural Trade under NAFTA. Available online at www.ageconsearch.umn.edu.

Dean, Judith M. 1999. How Does Trade Liberalization Harm the Environment? A New Test, John Hopkins University.

Economic Research Service (ERS) Fact Sheets 2001. Available online at http://www.ers.usda.gov/StateFacts

Economic Research Services, (ERS /USDA), 2005. Effects of NAFTA on Agriculture and the Rural Economy, WRS 02-1. Available online at www.ers.usda.gov/StateFacts/

Environmental and Trade Handbook, 2000. United Nations Environment Programme (UNEP). Available online at ww.iisd.org

Fare R., S. Grosskopf and C.A.K. Lovell, 1994. Productivity Frontiers. Cambridge University Press.

Farrell M. J. 1957. The Measurement of Productive Efficiency, Journal of the Royal Statistical Society. A CXX Part 3, 253-290

Food and Agriculture Organization of the United Nations, (FAOSTAT) 2001. Available online at www.faostat.fao.org

Foreign Agricultural Trade of the United States (FATUS), 2001, Database search. Available online at http://www.ers.usda.gov/db/fatus

Foreign Agricultural Trade of the United States, (FATUS) 2001. Available online at www.ers.usda.gov/DATA/FATUS

Gehl, Ronald J., John P. Schmidt, Larry D. Maddux and W. Barney Gordon. 2005. Corn Yield Response to Nitrogen Rate and Timing in Sandy Irrigated Soils. Available online at www.ces.nscu.edu

Goolsby, D. A., W.A. Battaghn, G. B. Lawrence, R.S. Artz, B.T. Anlenbach, R.P. Hooper and G.J. Stensland, 1999. Flux and Source of Nutrients in the Mississippi- Atchafalaya River Basin: Topic 3 Report. NOAA Report on Web at http;//www.nos.noaa.gov/pdflibrary.hypoxt3final.pdf

Grossman, M. and A.B. Kruger. (1995). Economic growth and the environment. Quarterly Journal

Hallberg, 1986. From hoes to herbicides: Agriculture and groundwater quality. Journal of Soil and Water Conservation. November-December. pp 357-364. Available online at http://www.ewg.org

Hallberg, 1986a. Agrichemicals and Water Quality. Proc. Colloquium on Agrichemical Management to Protect Water Quality. Board of Agriculture, National Research Council. Washington, DC.

Hallberg, 1991. A progress review of Iowa's agricultural-energy-environmental initiatives: Nitrogen management in Iowa. Technical Information Series 22. Iowa Department of Natural Resources. Available online at http://www.ewg.org http://www.nass.usda.gov/census/census97/volume1/volpubs.html.

International Journal of Food, Agriculture and Environment, 2009. 7, No 1. Available online at world-food.net/scientific journal/2009/issue31/pdf/agric/58.pdf.

Kamruzzaman, Mohammed, Basil Manos and Moss Anjuman Ara Begun, 2002. Evaluation of Economic Efficiency of Wheat Farms in a Region of Bangladesh under the Input Orientation Model, Department of Agricultural Economics, Aristotle University of Thessaloniki, Greece.

Keeney Dennis and Mark Muller, 2000. Nitrogen and the Upper Mississippi River; Minneapolis: Institute of Agriculture and Trade Policy. Available online at www.iatp.org/foodsec/library/admin/uploadedfiles/showfile.ctm

Kirton John and Alan M. Rugman, 2001. Regional Environmental Impacts of NAFTA on the Automotive Sector. Canadian Journal of Regional Science 21-22, 227-254.

Levinson, Arik. 2008. Pollution International in Trade Services.

Linh Houng Vu, 2006. Efficiency of Rice Farming Households in Vietnam: A DEA with Bootstrap and Stochastic Transfer Application. Available online at www.cid.harvard.edu

Mueller, D., 1995. Nutrients in Ground Water and Surface Water of the United States -- an Analysis of data through 1992. United States Geological Survey Water Resources Investigation Report 95-4031. Washington, DC.

Nadal Alejandro, 2002, “Zea mays” Effects of Trade Liberalization of Mexico’s Corn Sector. Greening the Americas, MASSIMIT. 143-162.

National Agricultural Statistics Services (NASS), 2000. Available online at www.usda.nass.gov

Nitrate Elimination Co. Inc., NECi 2007.

Paquin, Marc and Mayrand, Karel. 2003. The CEC and NAFTA Effects on the Environment: Discussion Paper, Rep Montreal; Unifera International Center.

Pouring it On: Nitrogen Use and Sources of Nitrate Contamination. “n.d.”, Available online at www.ewg.com.

Reinhard, Stjin and Alfons Oude Lansink, 2003. Investigating Technical Efficiency and Potential Technological Change in Dutch Pig Farming, Wageningen University.

Same as it ever Was, 2010. Available online at http://www.thoughtcontrol.us/same-as-it-ever-was/2010/06/nafta-and-its-impacts-on-the-environment-across-member-states

Seiford L.M. and Zhu Joe, 2007. Modeling Undesirable Factors in Efficiency Evaluation, European Journal of Operational Research, 142, No. 16-20

Seiford, L. M. and R. M. Thrall, 1984. Recent Developments in Analysis. Management Science 30, 1078-1092

Selden, T.M. & D.S. Song. (1994). Environmental quality and development: is there a Kuznets

Temurshoev, Umed, 2006. Pollution Haven Hypothesis of Factor Endowment Hypothesis: Theory and Empirical Examination for the US and China. Available online at www.cerge-uicz

Thompson, Peter and Laura A. Strohm, 1996. Trade and Environmental Quality: A Review of Evidence, Journal of Environment and Development. 5, No 4.

Vaughn Scott, 2003. The Greenest Trade Agreement Ever? Rep. Carnegie Endowment for International Peace, Print.