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

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association's 2016 Annual Meeting, San Antonio, Texas, February 6-9, 2016

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The Abstract

The implementation of the TPP is going to impact the US cotton production and export to member nations and this would invariably have impact on the environment. A baseline study on the environmental impact of the undesirable outputs from pre-TPP free trade induced cotton production in the southern U.S. (Arkansas, Arizona, California, Mississippi, Louisiana, and Texas) was conducted. Data Envelopment Analysis (DEA) was used to measure environmental efficiency by considering the desirable (cotton outputs) and the undesirable (nitrogen outputs) in six southern states. Data on cotton production, land use and nitrogen fertilizer for 30 years (1980 – 2010) were collected and analyzed. The overall analysis of the data shows that farmers in the six selected states combined are using nitrogen and land inefficiently for cotton production to the detriment of the environment. The state of Texas was the most inefficient state with 0.29 environmental efficiency score. Cotton producers in the state of Arizona had the highest environmental efficiency score of 0.96; implying that they used land and nitrogen most efficiently in the period investigated. State by state data analysis of resource management shows that Mississippi had no single efficient score while Texas had only one.

Keywords: Nitrogen Pollution, Data Envelopment Analysis, TPP, Environmental efficiency

INTRODUCTION

The relationship between trade, agriculture, and the environment has been the focus of domestic and international discussions for more than two decades ago. International policy forums such as the United Nations Conference on Environment and Development, the Committee on Trade and Environment (CTE) under the auspices of the new World Trade Organization (WTO), and the Organization for Economic Cooperation and Development (OECD) have all been discussing trade and environmental issues(Anderson, 1992a). WTO and OECD discussions have focused on topics such as: (1) the effects of environmental policies on trade and competitiveness, (2) how agricultural trade liberalization affects environmental quality, (3) to what extent international harmonization of environmental policies and product standards should exist, and (4) what economic justifications exist for using trade measures for environmental quality (Barry Krissoff, 1996).

The discussion on the correlation between trade and environmental conditions has not reached a consensus in the literature (Taskin & Zaim, 2001). The debate on the effect of trade on environment focused on the following two opposite views. One view argues that freer and increased trade will have detrimental effects on environmental conditions. The first concern of the advocates of this view is that, open trade may cause an overall decline in the international environmental standards when countries engage in competitive deregulation to alleviate the cost of environmental regulation (Taskin & Zaim, 2001). Less strict environmental regulations in a country, distorts the relative cost of production across trading partners and creates comparative advantage in the production of polluting commodities which would lead to a specialization in exports of those goods. Another concern has been the transfer of dirty industries to the countries where environmental policies are less restrictive. The re-location hypothesis elaborates on the possibility that environment regulations may have a dynamic influence on capital flows, giving incentive for polluting industries to migrate towards countries where environmental regulations are not strict. Concerns were also raised that export led growth that results from free trade agreements can encourage rapid and unsustainable extraction of natural resources and that increased production and trade volumes exacerbate the use of energy associated with the transportation of goods(Taskin & Zaim, 2001).

The other view on the relationship between trade and environment argues that an increase in trade promotes environmental quality in developing countries. Proponents of this view claim that, freer trade, leads to a more efficient allocation and use of resources, enables countries to specialize in production of goods and services in which they possess a comparative advantage and hence resulting in the production of maximum level of output for a given level of energy and materials. A related argument emphasizes the ability of freer trade in increasing the financial resources available for environmental protection by promoting output expansion(Taskin & Zaim, 2001). This argument is further extended as a justification for the existence of an environmental Kuznets curve which states that there is a critical level of per capita income above which environmental quality increases(Temurshoev, 2006).

The Trans-Pacific Partnership (TPP) is a proposed free trade agreement (FTA) among 12 Asia Pacific countries(Australia, Brunei Darussalam, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, United States, and Vietnam), with both economic and strategic significance for the United States. The 12 countries announced the conclusion of the TPP negotiations on October 5, 2015, after several years of ongoing talks. If approved, it would be the largest FTA in which the United States participates(Ian F. Fergusson, 2015).

Through the TPP, the participating countries seek to liberalize trade and investment and establish new rules and disciplines in the region beyond what exists in the World Trade Organization (WTO). The FTA is envisioned as a living agreement that will be open to future members and may become a vehicle to advance a wider Asia-Pacific free trade area(Ian F. Fergusson, 2015). The trade agreement that will open markets, set high-standard trade rules, and address 21st-century issues in the global economy. Arguably, TPP will promote jobs and growth in the United States and across the Asia-Pacific region(USTR, 2014).

The implementation of Trans-Pacific Partnership (TPP) is likely to bring an abrupt surge in US cotton export. Vietnam, the third largest importer of cotton behind China and Bangladesh, will eliminate all tariffs within four years. Arguably, preferential access to the Vietnamese market under a TPP agreement could result in new business opportunities for U.S. fiber, yarn, and fabric producers. To date, however, Vietnam is not a significant market for U.S. yarn and fabric exporters, importing only $59 million of such products in 2013. The United States' main textile-related export to Vietnam is raw cotton: U.S. exports supply about 60% of the cotton used in Vietnamese textile mills(Platzer, 2014).

Theoretically, the impact of trade liberalization and the likely impact of TPP on pollution levels is still not clear, even though useful framework for thinking about trade and the environment has been proposed (Grossman & Krueger, 1993). Grossman and Krueger identified three mechanisms by which trade and investment liberalization affect environment: scale, composition, and technique effects. The environmental Kuznets curve (EKC) states that there is a critical level of per capita income above which environmental quality increases. In the EKC analysis, the correlation between environmental degradation and income is usually expressed as a quadratic function with the turning point occurring at a maximum pollution level(Temurshoev, 2006).

The implementation of the TPP is going to impact the US cotton production and export and this would invariably have impact on the environment. The main objective of this paper is to measure the environmental impact of the undesirable outputs from pre-TPP free trade induced cotton production in the southern U.S.

The specific objectives are: (1) to measure cotton production efficiency by considering desirable output (cotton production) and undesirable output (nitrogen), (2) to measure production efficiency and the level of nitrogen pollution to be reduced by modelling undesirable output in efficiency evaluation, and (3) to estimate targets of input use and nitrogen pollution level in terms of the current cotton production.

REVIEW OF LITERATURE

Trade in Goods to TPP Countries

The United States ships more than $1.9 billion in goods to TPP countries every day. In today's highly competitive global marketplace, even small increases in a product's cost due to tariffs or non-tariff barriers can mean the difference between success and failure for a business. That is why the United States is working to negotiate in TPP comprehensive and preferential access across an expansive duty-free trading region for the industrial goods, food and agricultural products, and textiles, which will allow our exporters to develop and expand their participation in the value chains of the fastest-growing economies in the world(USTR, 2014).

Twenty percent of U.S. farm income comes from agricultural exports and those exports support rural communities. In fact, U.S. food and agricultural exports to the world reached an all-time high in 2013 of over $148 billion. Of that total, US exported more than $58 billion to TPP countries – a figure that would increase as a result of tariff elimination under TPP. As just one example: U.S. poultry currently faces a 40-percent tariff in Malaysia. U.S. poultry would become more affordable in Malaysia under a TPP agreement that reduces these duties to zero(USTR, 2014).

U.S. textile and apparel manufacturers sold more than $10 billion worth of products to TPP countries in 2013, an increase of 5.4 percent from the previous year. Many U.S. yarns, fabrics, and apparel currently face tariffs as high as 20 percent upon entering some TPP countries. TPP negotiations seek to remove tariff and non-tariff barriers to textile and apparel exports to enhance the competitiveness of our producers in the Asia-Pacific region(USTR, 2014).

Cotton Production in United States

Cotton production is an important economic factor in the United States as the country leads, worldwide, in cotton exportation. The United States is ranked third in production, behind China and India(USDA-ERS, March 5, 2015).

Almost all of the cotton fiber growth and production occurs in southern and western states, dominated by Texas, California, Arizona, Mississippi, Arkansas, and Louisiana. More than 99 percent of the cotton grown in the US is of the Upland variety, with the rest being American Pima(USCOTA, 1987). Cotton production is a $25 billion-per-year industry in the United States, employing over 200,000 people in total(USDA-ERS, March 5, 2015), as against growth of forty billion pounds a year from 77 million acres of land covering more than eighty counties(Yafa, 2004). The final estimate of U.S. cotton production in 2012 was 17.31 million bales(http://www.cotton.org/news/av/newsline130515.cfm, May 15, 2013), with the corresponding figures for China and India being 35 million and 26.5 million bales, respectively (http://www.cotton.org/econ/cropinfo/cropdata/rankings.cfm, March 13, 2011). U.S. producers planted 11.0 million acres of cotton in 2014, an increase of 6.1% from the previous spring. The added acreages were the result of cotton prices maintaining a stronger appearance relative to grains and oilseeds. The United States will remain the largest exporter of cotton with 2014 shipments estimated at 10.2 million bales. Although down from 10.5 million bales in the previous year, the current export number represents a gain in overall U.S. trade share(Adam, 2015).

Nitrogen Fertilization in Cotton Production

Nitrogen is an agricultural input that is essential for crop production. Human induced production and release of reactive nitrogen has greatly affected the Earth's natural balance of nitrogen, contributing to changes in ecosystems, both beneficial and harmful, including increased agricultural productivity in nitrogen-limited areas, ozone-induced injury to crops and forests, over enrichment of aquatic ecosystems, biodiversity losses, visibility-impairing haze, and global climate change. Incentives for encouraging farmers to adopt improved nitrogen management can take many forms, from purely voluntary to regulatory(Marc Ribaudo & Roberto Mosheim, 2011)**.**

Cotton is one of many agricultural industries that relies heavily on nitrogenous fertilizers to maintain high levels of production; it is therefore a potentially high-risk agricultural system with respect to nitrogen losses through denitrification and nitrate leaching. On average, more than one third of applied N is lost and this loss may exceed 100 kg N/ha each season. As well as environmental concerns with greenhouse gas emissions (from nitrous oxide) and nitrate leaching, N losses also have a significant economic impact on farm income. Denitrification is the process where soil nitrate N is converted into N gases (including nitrous oxide, the most potent greenhouse gas) and returned to the atmosphere. Denitrification is encouraged by high soil temperatures and saturated soil conditions so is normally the most significant form of N loss in irrigated cotton production. Nitrate leaching occurs when nitrates are washed through the soil profile with water (http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/03/Nitrogen_losses.pdf). Nitrate is mobile in wet soil and has the potential to move beyond the root zone following large rainfall events or if too much irrigation water is applied. Where there are high levels of soil nitrogen, cotton makes limited use of applied fertilizer N and a greater proportion of applied N is lost through denitrification and leaching. Cotton crops use less than half of the N applied during that season, obtaining most of their nitrogen from soil N rather than applied N. An average of 33% of applied N is recovered, 25% remains in the soil at crop maturity and the remainder (approximately 42%) is lost from the system. Figure 1 shows that ideal N uptake in cotton crops increases with lint yield, but this is not a linear relationship. Higher yielding crops do not necessarily take up more nitrogen as improved soil N conversions and recovery rates facilitate higher yields with less fertilizer. Cotton crops need to accumulate approximately 250-300kg N/ha to achieve maximum yield potential. While crops can take up more N than this, N uptake greater than 300kg N/ha will not increase lint yield; and nitrogen fertilizer recovery and nitrogen use efficiency will be reduced. These figures of amount of N uptake per hectare represent soil N uptake, not the amount of applied N(http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/03/Nitrogen_losses.pdf).

Nitrogen Pollution Cost

Nitrogen from fertilizers and manures washed off farmland costs Americans $157 billion a year in damages to human health and the environment(Weir, 2015). The median cost of nitrogen pollution damages inflicted by fertilizing crops, burning fossil fuels, manufacturing industrial products and all other human-induced sources is $210 billion a year. Agriculture accounts for roughly 75 percent of the problem(Daniel J Sobota, 2015).

Within the agricultural sector, corn production uses the lion’s share of nitrogen fertilizer and manures and generates a lot of the nitrogen pollution. The cost in human and environmental health problems caused by nitrogen pollution from agriculture is more than twice the $76.7 billion total value of corn produced for grain in the U.S. in 2011, when prices of corn and other agricultural commodities were high. According to Daniel J. Sobota et al 2015, for each kilogram of nitrogen used in the U.S. costs an average of $23.10 for increased incidence of respiratory disease and $16.10 for aggravating conditions that cause toxic algal blooms in waterways.

Definitions of Nitrogen Use Efficiency

Researchers calculate nitrogen use efficiency (NUE) to assess the effectiveness of nitrogen management. The NUE of a cropping system is the proportion of all nitrogen inputs that are removed in harvested crop biomass, contained in recycled crop residues, and incorporated in soil organic and inorganic nitrogen pools(Kenneth G. Cassman, 2002). Nitrogen not recovered in these nitrogen sinks is lost to the environment. Increases in NUE reduce the share of nitrogen left in the soil and available for loss to water or the atmosphere(Marc Ribaudo & Roberto Mosheim, 2011).

Reviewed Literature Studies on Environmental Efficiency Measurements

Lansink & Reinhard (2004) studied the impact of nitrogen pollution on intensive dairy farm in Netherlands. The nitrogen pollution variable was obtained by using a materials balance equation. The authors 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(Lansink & Reinhard, 2004).

Research was carried out in Bangladesh to explain the influence of the economic performance of wheat farmers(Osei Yeboah, 2011). The study was designed 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, 2006).

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 (Joe, 2007; Lansink & Reinhard, 2004; Osei Yeboah, 2011).

The Parametric Model

In line with the global environmental conservation awareness, undesirable outputs of productions and social activities, e.g., air pollutants and hazardous wastes, are 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 (Joe, 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 (Vu, 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 (William, 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 (J., 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 (Joe, 2007). 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 (Joe, 2007).

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(William, 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:

$P = \{ (x,y^g,y^b) \mid x \geq X\lambda,\ y^g \leq Y^g\lambda,\ y^b \geq Y^b\ y_0^g,\ L \leq e\lambda \leq U,\ \lambda \geq 0\}$

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:

$$\max u^g y_0^g - v x_0 - u^b y_0^b$$

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

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. $L=0$, $U = \infty$.

subject to

$$u^gY^g - vX - u^bY^b \leq 0$$

$$v \geq \frac{1}{m}\left[\frac{1}{x_0}\right]$$

$$u^b \geq \frac{1 + u^g y_0^g - vx_0 - u^b y_0^b}{s}\left[\frac{1}{y_0^b}\right]$$

$$u^g \geq \frac{1 + u^g y_0^g - vx_0 - u^b y_0^b}{s}\left[\frac{1}{y_0^g}\right]$$

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 $w_1(\geq 0)$ and $w_2(\geq 0)$ 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 cotton production. The desirable output is total cotton production, while the undesirable output is the nitrogen fertilizer. The efficiency measurement considers one input variable: land, which includes cotton production area used in cotton production.

Data

To assess the environmental impact of trade under pre-TPP trade agreement era, data from 6 cotton growing states (Arkansas, Arizona, California, Louisiana, Mississippi, and Texas) on cotton production, fertilizer and acre of land used from 1980-2010 were analyzed. The land used includes the area planted i.e. the acres used in cotton production for each state; the amount of nitrogen consumed in tons by each of the states in cotton production. The data used were all collected from United State Department for Agriculture (USDA) under National Agricultural Statistical Service (NASS) and National Cotton Council (NCC).

Results and Discussion

Appendix (Table 1) shows the basic descriptive statistics for the environmental efficiency scores by the years over which the data were collected. Column seven of the table shows the number of states that used their inputs (land and nitrogen) effectively in a given year for cotton production. The highest number efficient score obtained from the six cotton producing states under the years of study is 3 with 1 as the least. This implies that for the years where only 1 state was efficient in using their inputs, the remaining 5 states were inefficient for the same years. The average scores captures the average rating of the states on a scale of 1.00. The year, 1986 had the least average score of 0.501, this means that in this particular year land and nitrogen fertilizer were most inefficiently used compare to the other years. In this case, the states can decrease nitrogen application and reduce land used by 49.9% without cutting down the cotton production in this particular period. The most efficient year was 1988 with an average score of 0.788 meaning that the nitrogen application and land usage have been decreased by 21.2% in order for the state to be efficient and continue in cotton production.

The average environmental efficiency measures (AEEM) by years is shown in appendix (figure 1.) The plot shows how AEEM fluctuated over the period of study. In 1980 it started with an AEEM rise from 0.520 to 0.741 in 1983 before dropping in the subsequent years; the efficiency scores continue to rise and fall. The highest efficiency score between1980 to 2010 was attained in 1988 with the average efficiency score of 0.788 and the lowest average efficiency score of 0.501 in 1986 for the period. This indicates that cotton farmers from the six states were 78.8% efficient in managing nitrate pollution and land use in 1988 against the least efficiency score of 50.1% in 1986. The overall AEEM for the period of study stands at 0.648 (i.e. 64.8%)

Appendix (Table 2) illustrates the environmental efficiency scores by states; this table contains the total results for the six states selected for the period (1980-2010) under investigation.

Results from the analysis shows that in 1980 we have two efficient states: Arizona and California with the score of 1.00 each, which indicates that the states were efficient. The inefficient states in this period are Arkansas, Louisiana, Mississippi, and Texas with the score of 0.22, 0.40, 0.15, and 0.35 respectively; Texas having the least score. Arizona and California were still found to be the only efficient states in 1981. For the entire period under investigation, the state of Mississippi did not have any efficient score; while the State of Texas had only one efficient score in 1988. The State of Arizona had 25 years of efficient scores from 1980 to 2010 while California achieved 22 years of efficient scores.

The average efficiency scores for the six states from 1980-2010 in appendix (figure 2) shows that the state of Arizona is the most efficient state in terms of nitrogen pollution management (among the six selected states) with the efficiency score of 0.96. The state of California was the next with an efficiency score of 0.94. The least efficient states after Arkansas (with 0.66) are Mississippi, Louisiana, and Texas with an average efficiency scores 0.54, 0.49, and 0.29 respectively.

The percentages by which the inefficient states are to reduce the amount of nitrogen application on cotton production to attain efficiency is found in appendix (table 3). The percentages were calculated by subtracting the actual amount of nitrogen used from the projected amount of nitrogen, the difference gives the percentages that has to be reduced in order for these states to be efficient in cotton production. In this calculation the states with higher percentage values are the less efficient states in the management of nitrogen application by year.

The percentage by which these states are to reduce their nitrogen intake in order to be efficient in cotton production is shown in appendix (figure 3). The lower the percentage the higher the environmental efficiency and vice versa. Appendix (Figure 3) points out that the state of Texas is the least efficient state with the highest need of reducing the nitrogen consumption by 32.43%, followed by Louisiana with 26.58% of nitrogen required to decrease. Arizona is the most efficient state with the least required nitrogen reduction of 4.83%. These reductions are required by all these states in order to be an environmentally efficient.

Appendix (Figure 4) shows the percentages by which the states are to reduce their nitrogen consumption each year. In year 2010 all the states had to reduce the amount of their nitrogen intake by 60.8%, which is the highest seen within these period (1980-2010). The least reduction requirement by the states is in year 1995 with 0.55%

Appendix (Table 4) shows by how much each state was to reduce its acreage of land to make it efficient as in the nitrogen case. The state of Texas was the least efficient state among the six selected states, with 66.65% of land usage that required reduction, followed by Louisiana with 45.70% in the period under investigation.

The percentages of acres of land that each of these six states were to decrease in order to make the land use efficient is also shown in appendix (figure 5.) The state of Arizona was the most efficient state with the least (1.72%) acres of land reduction requirement, followed by California with 2.77%.

Appendix (Figure 6) shows that most inefficient land use by all the states occurred in 1980 where the states had to reduce land use by 46.01% on the average to attain efficiency. 2005 was the most efficient year with an average required land reduction value of 18.26%. The two inputs (nitrogen and land), both show similar pattern of inefficiency in resource management.

CONCLUSION

The overall analysis of the data using DEA shows that farmers in the six selected states combined are using nitrogen and land inefficiently for cotton production to the detriment of the environment. The state of Texas was the most inefficient state with 0.29 environmental efficiency score. Cotton producers in the state of Arizona had the highest environmental efficiency score of 0.96; implying that they used land and nitrogen most efficiently in the period investigated. State by state data analysis of resource management shows that Mississippi had no single efficient score while Texas had only one from 1980 to 2010.

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Appendix

Table 1: Descriptive statistics of the environmental efficiency scores for six states in 1980-2010

Year	Number of States	Maximum Scores	Minimum Scores	Average	SD	No. of efficient states	No. of inefficient states
1980	6	1	0.146	0.520	0.349	2	4
1981	6	1	0.301	0.581	0.300	2	4
1982	6	1	0.168	0.720	0.331	3	3
1983	6	1	0.230	0.741	0.261	2	4
1984	6	1	0.252	0.625	0.290	2	4
1985	6	1	0.299	0.706	0.308	3	3
1986	6	1	0.156	0.501	0.303	1	5
1987	6	1	0.301	0.631	0.280	2	4
1988	6	1	0.346	0.788	0.256	3	3
1989	6	1	0.205	0.591	0.308	2	4
1990	6	1	0.340	0.608	0.246	1	5
1991	6	1	0.237	0.613	0.273	1	5
1992	6	1	0.163	0.525	0.267	1	5
1993	6	1	0.289	0.530	0.279	1	5
1994	6	1	0.359	0.784	0.242	3	3
1995	6	1	0.323	0.747	0.267	3	3
1996	6	1	0.254	0.755	0.257	2	4
1997	6	1	0.317	0.739	0.250	2	4
1998	6	1	0.218	0.602	0.232	1	5
1999	6	1	0.272	0.629	0.261	1	5
2000	6	1	0.169	0.568	0.319	2	4
2001	6	1	0.231	0.694	0.317	3	3
2002	6	1	0.277	0.631	0.278	2	4
2003	6	1	0.230	0.741	0.261	2	4
2004	6	1	0.409	0.705	0.231	2	4
2005	6	1	0.378	0.735	0.224	2	4
2006	6	1	0.246	0.689	0.265	2	4
2007	6	1	0.451	0.689	0.225	2	4
2008	6	1	0.228	0.587	0.319	2	4
2009	6	1	0.231	0.553	0.321	2	4
2010	6	1	0.349	0.569	0.219	1	5

Table 2: Environmental efficiency scores for states by year (1980-2010)

State	Arkansas	Arizona	California	Louisiana	Mississippi	Texas	Average
1980	0.22	1.00	1.00	0.40	0.35	0.15	**0.52**
1981	0.37	1.00	1.00	0.36	0.46	0.30	**0.58**
1982	1.00	1.00	1.00	0.38	0.77	0.17	**0.72**
1983	0.71	0.83	1.00	1.00	0.67	0.23	**0.74**
1984	0.56	1.00	1.00	0.34	0.59	0.25	**0.63**
1985	1.00	1.00	1.00	0.35	0.59	0.30	**0.71**
1986	0.39	1.00	0.82	0.29	0.35	0.16	**0.50**
1987	0.59	1.00	1.00	0.30	0.55	0.35	**0.63**
1988	1.00	1.00	0.84	0.35	0.54	1.00	**0.79**
1989	0.51	1.00	1.00	0.32	0.51	0.21	**0.59**
1990	0.55	0.86	1.00	0.35	0.54	0.34	**0.61**
1991	0.60	0.86	1.00	0.31	0.67	0.24	**0.61**
1992	0.57	0.65	1.00	0.30	0.48	0.16	**0.52**
1993	0.32	0.83	1.00	0.39	0.34	0.29	**0.53**
1994	1.00	1.00	1.00	0.62	0.72	0.36	**0.78**
1995	1.00	1.00	1.00	0.57	0.59	0.32	**0.75**
1996	0.70	1.00	0.89	1.00	0.69	0.25	**0.75**
1997	1.00	1.00	0.89	0.56	0.66	0.32	**0.74**
1998	0.50	1.00	0.66	0.66	0.57	0.22	**0.60**
1999	0.53	1.00	0.95	0.54	0.48	0.27	**0.63**
2000	0.47	1.00	1.00	0.39	0.38	0.17	**0.57**
2001	1.00	1.00	1.00	0.42	0.51	0.23	**0.69**
2002	0.59	1.00	1.00	0.41	0.52	0.28	**0.63**
2003	0.71	0.83	1.00	1.00	0.67	0.23	**0.74**
2004	0.72	1.00	1.00	0.48	0.62	0.41	**0.70**
2005	0.71	1.00	0.76	1.00	0.56	0.38	**0.74**
2006	1.00	1.00	0.72	0.65	0.52	0.25	**0.69**
2007	0.58	1.00	1.00	0.59	0.51	0.45	**0.69**
2008	0.60	1.00	1.00	0.23	0.46	0.23	**0.59**
2009	0.41	1.00	1.00	0.37	0.31	0.23	**0.55**
2010	0.52	1.00	0.67	0.38	0.49	0.35	**0.57**
Average	**0.66**	**0.96**	**0.94**	**0.49**	**0.54**	**0.29**	

Table 3: Nitrogen reduction in percentage required for states from 1980-2010

State	Arkansas	Arizona	California	Louisiana	Mississippi	Texas	Average
1980	29.69	0.00	0.00	5.22	29.35	35.68	**16.66**
1981	5.14	0.00	0.00	16.01	14.28	0.00	**5.91**
1982	0.00	0.00	0.00	26.76	0.00	38.46	**10.87**
1983	0.00	25.45	0.00	0.00	9.11	47.23	**13.63**
1984	0.00	0.00	0.00	27.41	9.87	13.95	**8.54**
1985	0.00	0.00	0.00	23.87	7.69	2.80	**5.73**
1986	33.91	0.0	2.46	52.44	48.32	47.52	**30.78**
1987	0.00	0.00	0.00	26.61	12.34	0.00	**6.49**
1988	0.00	0.00	1.71	33.79	21.41	0.00	**9.49**
1989	15.36	0.00	0.00	43.56	30.22	37.59	**21.12**
1990	6.97	15.79	0.00	26.85	22.27	13.82	**14.28**
1991	2.73	22.12	0.00	46.92	11.02	42.49	**20.88**
1992	11.17	44.91	0.00	40.38	34.46	58.17	**31.52**
1993	46.34	16.08	0.00	26.94	47.49	28.26	**27.52**
1994	0.00	0.00	0.00	18.55	0.00	3.32	**3.65**
1995	0.00	0.00	0.00	3.28	0.00	0.00	**0.55**
1996	0.00	0.00	18.16	0.00	0.00	42.90	**10.18**
1997	0.00	0.00	14.35	4.95	15.40	26.00	**10.12**
1998	16.28	0.00	20.14	20.14	17.64	40.42	**19.10**
1999	11.06	0.00	5.50	3.16	26.98	27.91	**12.44**
2000	22.97	0.00	0.00	31.87	47.28	55.87	**26.33**
2001	0.00	0.00	0.00	0.54	4.96	18.89	**4.07**
2002	7.60	0.00	0.00	46.07	23.59	27.73	**17.50**
2003	0.00	25.45	0.00	0.00	9.11	47.23	**13.63**
2004	11.02	0.00	0.00	46.50	25.86	14.80	**16.36**
2005	20.44	0.00	42.99	0.00	37.32	80.75	**30.25**
2006	0.00	0.00	58.85	6.60	24.19	51.63	**23.55**
2007	26.71	0.00	0.00	11.50	37.02	24.23	**16.58**
2008	31.38	0.00	0.00	73.60	69.96	56.70	**38.61**
2009	62.06	0.00	0.00	71.89	84.40	62.21	**46.76**
2010	63.21	0.00	91.70	88.57	62.82	58.71	**60.84**
Total	**424.04**	**149.80**	**255.86**	**823.98**	**784.36**	**1005.27**	
Average	**13.68**	**4.83**	**8.25**	**26.58**	**25.30**	**32.43**	

Table 4: Percentage of acre of land used required to be reduce by the states from 1980-2010

State	Arkansas	Arizona	California	Louisiana	Mississippi	Texas	Average
1980	74.24	0.00	0.00	59.38	59.63	82.82	**46.01**
1981	61.80	0.00	0.00	61.44	50.94	69.93	**40.69**
1982	0.00	0.00	0.00	56.99	22.71	79.98	**26.61**
1983	29.39	5.89	0.00	0.00	29.74	71.55	**22.76**
1984	43.53	0.00	0.00	60.8	38.11	73.04	**35.91**
1985	0.00	0.00	0.00	61.21	38.85	69.66	**28.29**
1986	54.5	0.00	16.85	62.96	56.79	80.64	**45.29**
1987	41.47	0.00	0.00	65.84	41.56	65.22	**35.68**
1988	0.00	0.00	15.36	59.54	39.96	0.00	**19.14**
1989	44.95	0.00	0.00	60.54	41.56	75.65	**37.12**
1990	43.52	6.77	0.00	59.77	39.49	63.68	**35.54**
1991	39.38	4.06	0.00	61.54	29.72	71.25	**34.33**
1992	40.33	20.81	0.00	64.50	43.96	78.93	**41.42**
1993	60.24	10.04	0.00	55.32	58.06	66.97	**41.77**
1994	0.00	0.00	0.00	31.98	27.93	63.49	**20.57**
1995	0.00	0.00	0.00	41.67	41.39	67.71	**25.13**
1996	30.35	0.00	3.23	0.00	30.96	69.14	**22.28**
1997	0.00	0.00	4.47	42.24	29.06	64.14	**23.32**
1998	45.97	0.00	27.51	27.51	37.50	73.80	**35.38**
1999	44.49	0.00	2.33	44.75	45.60	69.04	**34.37**
2000	47.46	0.00	0.00	54.58	53.41	78.41	**38.98**
2001	0.00	0.00	0.00	57.70	47.36	74.73	**29.97**
2002	39.02	0.00	0.00	50.16	41.99	68.43	**33.27**
2003	29.39	5.89	0.00	0.00	29.74	71.55	**22.76**
2004	23.80	0.00	0.00	41.24	29.84	56.08	**25.16**
2005	21.57	0.00	7.37	0.00	33.64	46.95	**18.26**
2006	0.00	0.00	6.59	33.22	41.46	69.03	**25.05**
2007	33.86	0.00	0.00	37.40	40.09	49.49	**26.81**
2008	30.32	0.00	0.00	68.78	37.63	70.33	**34.51**
2009	46.37	0.00	0.00	50.33	55.46	69.76	**36.99**
2010	31.02	0.00	2.04	45.22	35.46	54.84	**28.10**
Average	**30.87**	**1.72**	**2.77**	**45.70**	**40.31**	**66.65**	

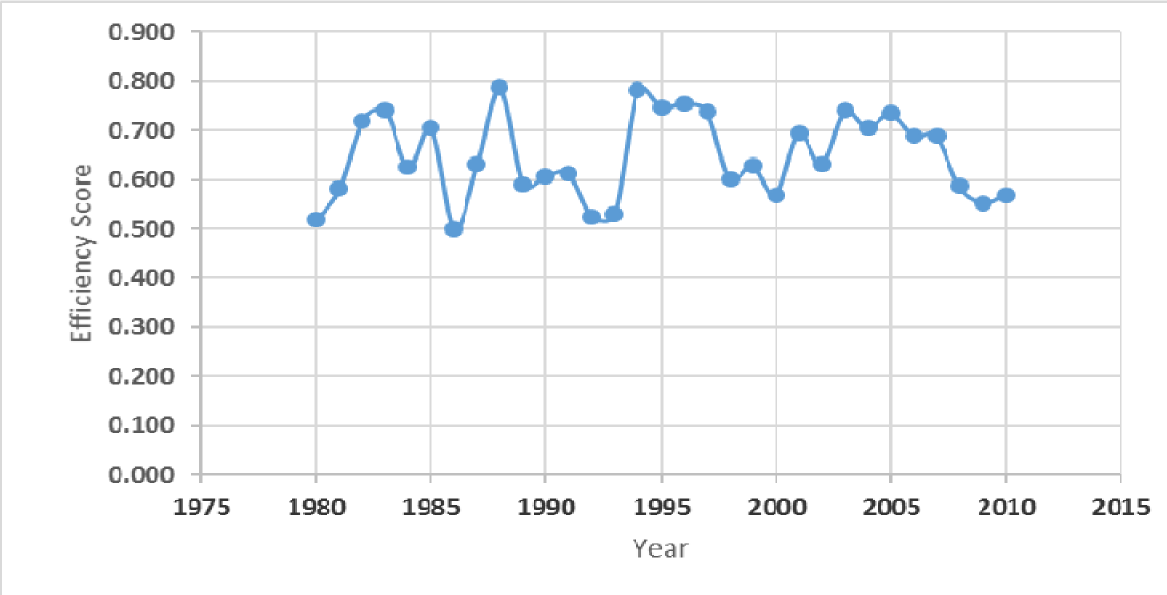

Figure 1: Average environmental efficiency scores by years (1980-2010)

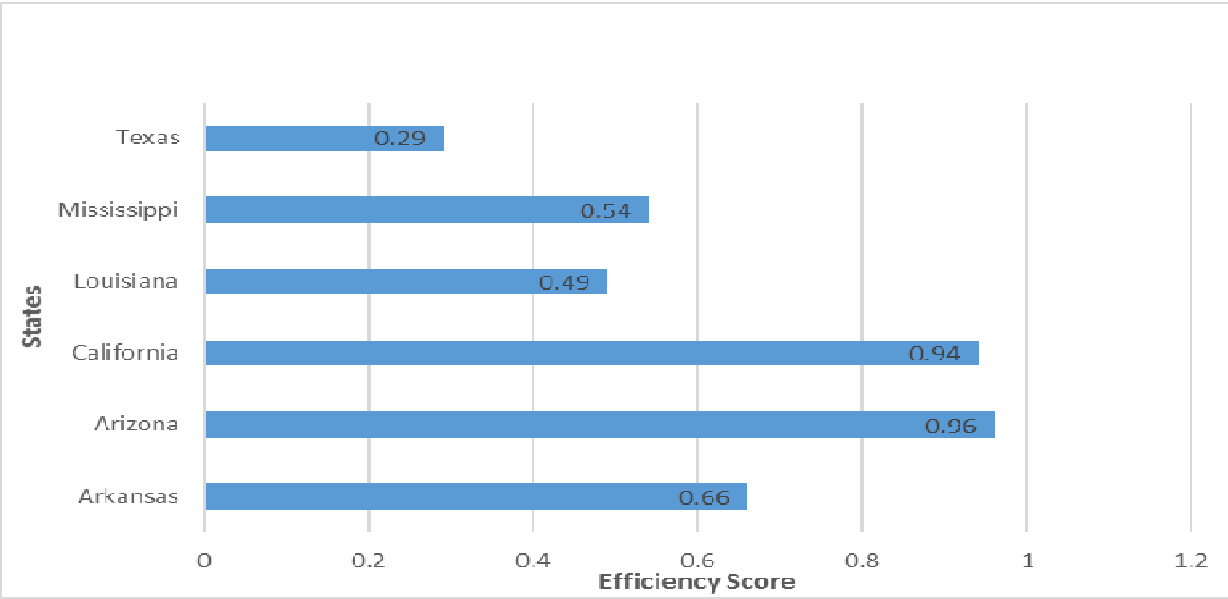

Figure 2: The average efficiency scores from the states (1980-2010)

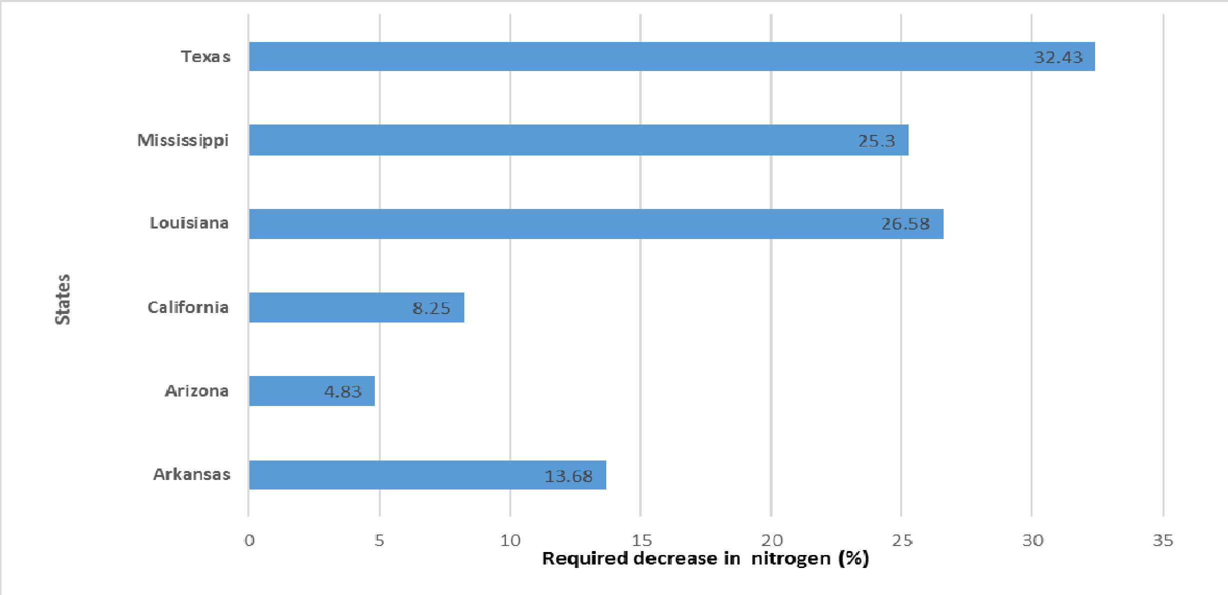

Figure 3: The average projected nitrogen reduction (%) for all states (1980-2010)

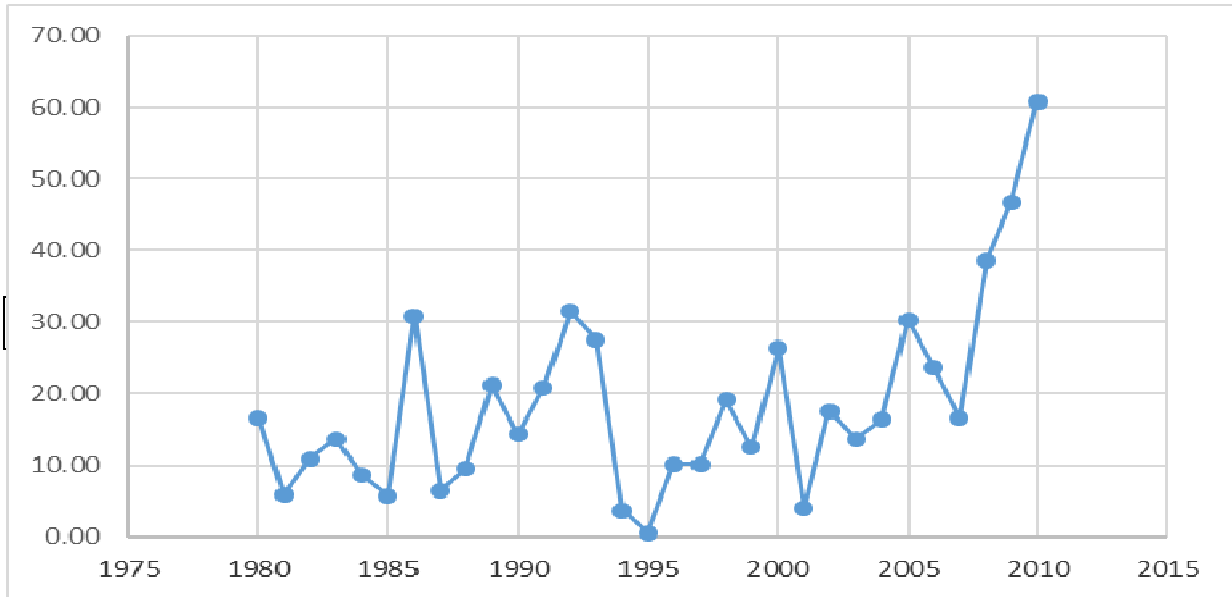

Figure 4: Average projected nitrogen reduction in percentage by years (1980-2010)

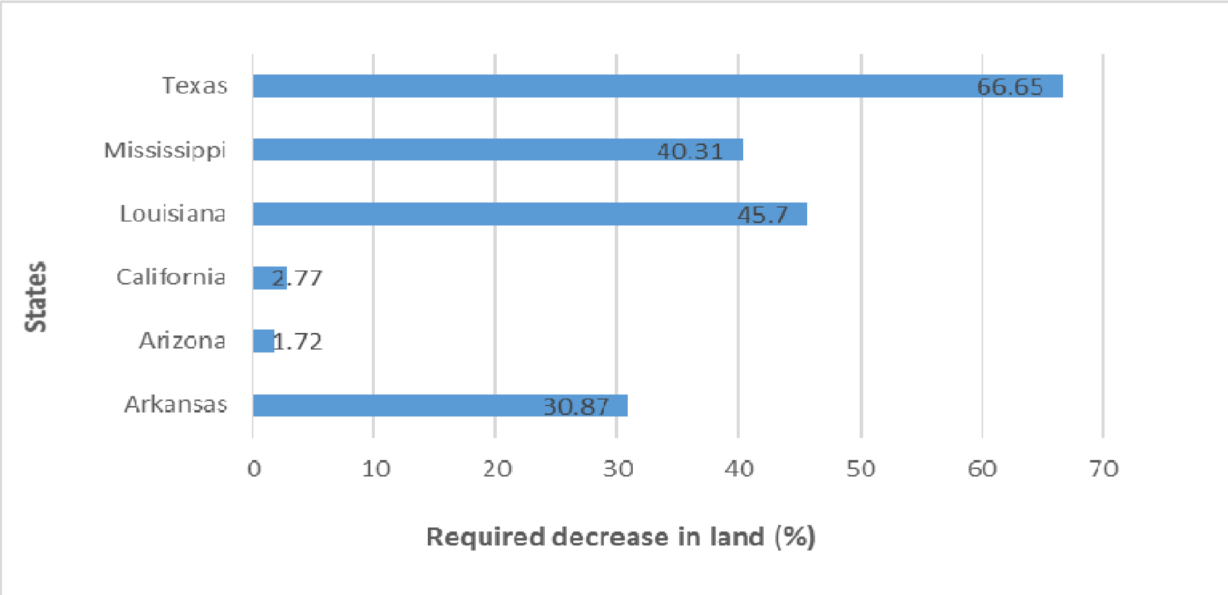

Figure 5: Average projected land reductions (%) for states by years (1980-2010)

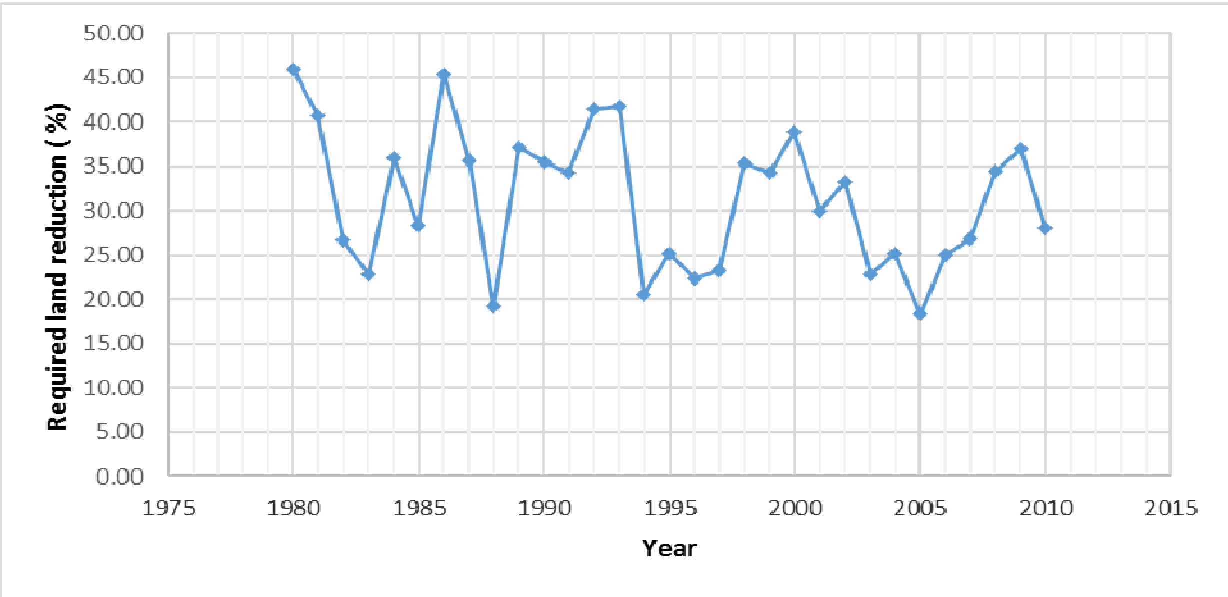

Figure 6: Average percentage of land usage required to reduce by years (1980 2010)