

# **Modeling Farm-Level Costs of the Yield Reserve Program**

By

Todd Metcalfe

Virginia Polytechnic Institute and State University

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Agricultural and Applied Economics

Darrell J. Bosch, Co-Chair

James W. Pease, Co-Chair

Mark M. Alley

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**Abstract**

Nonpoint Source (NPS) pollution, pollution that comes from diffuse sources that are difficult to trace back to a single point such as farm fields, is a major concern affecting America's water ways. Nationally, agriculture is the leading source of water impairment and has also been identified as the largest source of pollution affecting the Chesapeake Bay.

There are proposals now for a program that would pay farmers to use 15 percent less than the extension recommended amount of fertilizer. Known as the Yield Reserve Program, or Enhanced Nutrient Management, this policy could possibly help to reduce the nutrient loads.

The objective of this study was to evaluate the effects of a Yield Reserve Program on farm yields and net revenues. Costs were estimated for different policy implementations for the Virginia Coastal Plain to better understand problems with this type of program. The effects of Yield Reserve on enterprise net returns, yields, and N applications for corn under varying weather and soil conditions were estimated.

Based on experimental trials from North Carolina and Virginia from 2000 to 2004, yield response functions were calculated for corn. The costs of the Yield Reserve Program vary depending on its implementation, but under current proposals these costs were estimated at \$113 per hectare, and \$10,855,000 for the coastal plain. This proposal is a

more costly program than would be necessary to compensate farmers for yield losses based on estimates in this study.

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## **Chapter 1 Nitrogen Nonpoint Source Pollution**

### **Introduction**

Nonpoint Source (NPS) pollution, pollution that comes from diffuse sources that can not be traced to a single point such as a farm field, is a major water quality concern. Farms are a major source of NPS pollution. Nationally, agriculture is the leading source of water impairment, “degrading 60 percent of the impaired river miles and half of the impaired lake acreage” (EPA). Agriculture has also been identified as the largest source of pollution affecting the Chesapeake Bay (Chesapeake Bay Foundation). Nitrogen (N) and phosphorus that leave fields as runoff promote eutrophication, algal blooms, in water bodies creating anoxic conditions that can kill fish (EPA MAIA).

The Clean Water Act (CWA) was enacted in 1972 to clean up impaired surface water ways in the United States. The CWA originally focused on “point sources” of pollution. Point source pollution was legally defined as “any discernible, confined and discrete conveyance” ... “from which pollutants are or may be discharged” (CWA). Agricultural pollution was excluded from being defined as a “point source” of pollution, with the notable exception of Confined Animal Feeding Operations (CAFO). Since its inception, the CWA has managed to reduce pollution to waterways from point source pollution (ESA).

However, treatment of water impaired by nonpoint source pollution (NPS) has lagged behind. It was not until 2000, in the case of *Pronsolina v. Marcus*, that it was ruled that the Clean Water Act (CWA) allowed the Environmental Protection Agency (EPA) to

establish Total Maximum Daily Loads (TMDLs) for water ways only impaired by NPS pollution (Stephens and Dias). The EPA has not been able to effectively enforce CWA provisions for NPS, due to legal precedent (until 2000) and political will (Geyer).

Because of pressure from agricultural interest groups, Congress is not keen on seeing the EPA regulate farmers for NPS (Geyer). Other agricultural programs have been used to help clean up waters impaired by NPS pollution, and agreements have been made at the state level to improve regional water quality. One of these compacts is the Bay Program 1987 agreement in which Virginia, Maryland, Pennsylvania, and the District of Columbia pledged to work towards a forty percent reduction in sediment and nutrient loads to the Chesapeake Bay (Chesapeake Bay Program).

Nutrients are required for proper plant growth. N is a nutrient that is needed in “relatively large quantities” for proper plant growth (Arnold et. al.). N can reach water ways through one of two means. Either N it is directly deposited to water by leaching and/or run off or the N can be volatilized and re-deposited on the ground or be washed into water as either “acid rain or dry pollutants” (ESA).

Locally and nationally there are many programs in place to mitigate runoff originating from farms. One type of program involves giving payments to farmers for practices that mitigate pollution. Cost sharing programs that help to pay for the implementation of Best Management Practices (BMPs) would be an example of this type of program. The Conservation Reserve Program, or CRP, bidding program is an example of a program that uses market determined land rental rates to pay for a fixed practice to mitigate

pollution. In the CRP the government pays farmers up to a fixed rental rate to remove highly erodible lands from production (USDA FSA).

The programs which are in place and that have been proposed to reduce N runoff have many problems associated with them. These problems include uncertainties about the effectiveness of the recommended practices, uncertainties about whether the practices are adopted and implemented as intended by policymakers, and imperfect information about the effectiveness of the programs. Trading programs are policy instruments that seek to create markets for limited rights to pollute and let the market allocate the lower levels of pollution in the most efficient manner. However, there are other problems that are more specific to trading programs such as defining eligible reductions, time length of trades, coordinating multiple parties, and high cost of trades.

N is a nutrient that is vital to plant growth and is widely used by farmers for non-legume crops. There is evidence that shows N has an inelastic demand (Choi and Helmberger), meaning that farmers value extra units of N very highly, and that inducing a relatively small reduction in N use will take a relatively high increase in the real price of fertilizer. The crop's need for N fertilization is uncertain depending on the growing conditions. There is evidence that farmers may apply more N than needed in many years to avoid yield reductions in years of high N need (Babcock; Babcock and Blackmer; Yadav, Peterson, and Easter). Insurance programs could act as a substitute to higher levels of N fertilizer applications, if excess N is being used as "insurance" against being "caught short" on fertilizer, and hence could mitigate N use (Babcock and Hennessy).

In his 2002 paper, Huang empirically tested the concept of using insurance to induce farmers to split the application of fertilizer. Split application of fertilizer consists of two or more fertilizer applications during the growing season. Split application is considered more risky due to the possibility of not being able to apply fertilizer due to weather conditions during the growing season, but split application can use less total fertilizer to achieve the desired yield because less fertilizer is leached from the soils before the crops can utilize it. Huang showed, conceptually and empirically using corn data from Iowa, that this approach could have higher net returns for farmers from lower fertilizer applications. This type of insurance would also have better environmental outcomes due to a lowered potential of nutrient runoff or leaching losses from lowered applications.

A few programs have been put into effect that seek to reduce fertilizer applications on fields by providing insurance (or a “warranty”) to farmers (Sheriff, Brandt). These approaches provide farmers with an insurance policy that will compensate them if the conservation practice causes a lowered yield. This type of approach avoids many of the problems associated with trading and other program approaches. Uncertainty in models used to assess NPS pollution will almost always be a problem with programs that address NPS pollution due to the very high cost associated with monitoring runoff directly.

Insurance programs would give farmers financial incentives to reduce N use without suffering financial losses when yields are reduced by insufficient fertilizer application. This type of program is dependent on insurance being viewed as a partial substitute to fertilizer applications by farmers.

Recently, the Federal Crop Insurance Act included funding for a pilot program called the Nutrient Management/Best Management Practices Insurance (USDA RMA 2003). This was started as a pilot program in 2003 in Iowa, Minnesota, Pennsylvania, and Wisconsin, and provides insurance for farmers to reduce their nutrient applications to those levels called for in Best Management Practices (BMP) guidelines. Farmers are compensated if their yields are lowered due to reduced fertilizer applications. In order to determine if a farmer's yields are lower due to following BMP guidelines, each enrolled farmer plants a control strip that is fertilized based on the farmer's previous fertilization plan. This plan is intended to get farmers to switch to using BMPs by removing the financial risk, which is a barrier for BMP adoption (USDA RMA 2003).

Moral hazard, the effect of insurance reducing a person's incentives to avoid losses (Arrow, Nicholson), is a major problem for agricultural insurance (Chambers). In the Nutrient Management/Best Management Practices Insurance, Mitchell points out that farmers' have an incentive to care for check strips preferentially to increase their yields compared to the rest of the fields. Adverse selection, the idea that those who know that they need insurance the most are more likely to be insured, while those who need insurance the least are less likely to be insured thereby diluting the positive effect of pooling risks (Nicholson), is another problem that can affect insurance programs. The Nutrient Management/Best Management Practices Insurance, had potential for adverse selection, because its premiums were based on a state average yield, so farmers with

typically lower yields, would be more inclined to join the program, than farmers with typically higher yields (Mitchell).

One of the problems confronting insurance programs is yield variations. Under typical growing conditions, yields can vary even within fields (Scharf, et. al.). Near the optimal N application rates, the variations in yields are hard to measure statistically because other site factors are more influential near the optimal rate (Mitchell). To be able to better distinguish variations in yield due to localized versus other effects, the federal government has implemented programs based on yields over areas (counties) such as the Group Risk Plan (Skees, Black, and Barnett). These programs were implemented after the 1996 Farm Bill ended deficiency payments and other subsidy programs that had been implemented in 1973 (Skees et. al.). Deficiency payments lowered the variability of a farmer's income that could result from yield variations. Hence with the end of deficiency payments a farmer's net returns are likely to vary more (Skees et. al.). Area-wide insurance programs can help to reduce the effects of moral hazard and adverse selection, since a farmer's payments are not based on his/her own management practices but the aggregate of returns of their area (Skees, Black, and Barnett).

The notion that farmers over anticipate yield potentials and hence have a tendency to over fertilize (apply more fertilizer than needed by the crop) is not supported for all crops in all regions (Pease, Bosch et al.). For farmers who are not over fertilizing, the Nutrient Management/Best Management Practices program would not be effective. There are proposals now for a program that would pay farmers to use 15 percent less than the

Cooperative Extension Service recommended amount of fertilizer (Sweeney, Simpson). The Yield Reserve Program, also known as Enhanced Nutrient Management, has been proposed as a policy that could help to reduce the nutrient loads that are currently negatively impacting the Chesapeake Bay. In August 2002, Maryland, Pennsylvania, Virginia, and the District of Columbia proposed to have four practices included in the Farm Bill at a cost of \$100 million dollars over five years. About half of this money was requested to support a pilot Yield Reserve Program (MWCOG). The program costs are estimated at \$99 per hectare (\$40 per acre) with a \$74 per hectare (\$30 per acre) incentive payment to farmers, a \$21 per hectare (\$8.50 per acre) insurance fee, and \$3.70 per hectare (\$1.50 per acre) technical administration fee annually (Chesapeake Bay Commission, Sweeney). However, the cost of the program will depend on details of program administration. Simpson has stated that in the “worst case scenario” the program would probably cost \$5 to \$7.50 per hectare (\$2 to \$3 per acre) for administrative costs, \$25 to \$30 per hectare (\$10 to \$12 per acre) for insurance cost, and \$74 per hectare (\$30 per acre) for the incentive cost, for a total of \$104 to \$111 per hectare (\$42 to \$45 per acre).

Currently, policy makers lack information on the costs and benefits of the Yield Reserve Program. Policy makers need to have as much information as possible to be able to design programs that will achieve their goals and be cost effective. Proper policy design is also very important to farmer and farm industry profitability. Policymakers would benefit from cost estimates for specific methods of implementing the program. Four alternative options are a yearly incentive payment, a one time easement payment,

deficiency insurance payments in years where yields are negatively impacted by Yield Reserve, and a mixture of incentive payments and insurance. Analysis of these options will help farmers, policymakers, and program administrators assess the costs and potential benefits of this proposed program.

### **Objectives of the Study**

This study will evaluate the effects of a Yield Reserve Program on farm yields and reductions in N applications. Further, costs will be estimated for different policy implementations for the Virginia Coastal plain to better understand the problems associated with this type of program. Specific objectives are to:

1. Estimate the effects of a Yield Reserve Program on corn yields, N applications, and enterprise net returns under incentive payments, deficiency insurance payments, and mixed incentive and insurance payments.
2. Estimate the expected costs to taxpayers of Yield Reserve Program for the Virginia Coastal Plain under incentive payments, deficiency insurance payments, and mixed incentive and insurance payments.

### **Hypotheses**

1. Farmers' average net returns will increase, that is the program will compensate farmers more than the plan will cost farmers, under the proposed Yield Reserve Program with mixed incentive and insurance payments.
2. A Yield Reserve Program will require yield indemnity payments to farmers in at least 50 percent of years.

## **Study Approach**

The farm level responses to Yield Reserve are estimated based on an expected net returns model at the county level. Based on experimental trials from North Carolina and Virginia from 2000 to 2004, yield response functions are calculated for corn. These curves show how corn responded to N over these years and allow estimates to be made on the range of costs (reductions in yields) that would occur for each field with the Yield Reserve change in N use. The calculated response curves are adapted to different soil types to be able to approximate responses over a broad region.

Historic county yields are regressed as a time series against seasonal rainfall for the Virginia Coastal plain for the last 47 years. This regression is done to de-trend the data and allow groupings for years with similar rainfall to the experimental data that are available. These groups are used to estimate probabilities of weather, associated crop – N responses, and overall costs of the program.

Soil management group data are used as a measure of the differences in corn response to N for the soils that fall into groups I, II, and III inside of each county (Virginia Department of Conservation and Recreation). Data on the soil types in each county in the sample are obtained. Then percentages of the three soil groups are estimated and multiplied times the total harvested acreage for corn to obtain overall county estimates for yields.

Weather states (dry, average, and above average), soils data, estimated yield response to N, and price and cost data are combined in a model of expected net returns from corn production to estimate farmer returns and estimated costs of the program with different designs. These program designs allow comparisons among alternative methods of implementing a proposed Yield Reserve Program.

Chapter 2 of this study covers the history of Yield Reserve and other similar programs. Chapter 3 presents the theory used in the study to examine Yield Reserve costs. Chapter 4 explains the methods used in the analysis. Chapter 5 presents the results, and chapter 6 gives the conclusions of the study.

## **Chapter 2 History of Yield Reserve and Similar Programs**

### **N Policy Design Issues**

From a public policy perspective the environmental effect of N use is a complex problem. Excess amounts of N can have adverse environmental consequences (ESA). However, finding appropriate policy programs that reduce N use is complex and difficult. This task is complicated by the uncertainty about the fate of N, from application to its eventual use by crops, leaching or runoff from fields, or volatilization to the atmosphere. For programs to have the possibility of being cost effective, policies must be carefully tailored to individual regions and crops (Sheriff).

A farmer's simple decision to use fertilizer on his/her fields creates the potential for N runoff from agriculture. This decision also creates information issues from a policy perspective. There are economic reasons why farmers would utilize more nutrients than would seemingly be economically optimal. These include specialized information about his/her own fields, and uncertainties surrounding the potential yields due to uncertain weather (Babcock, Sheriff). Some farmers apply more fertilizer than the crops can use (Brown; Iowa Soybean Association; Lucht; Scharf; Simpson; Yadav, Peterson, and Easter). However, other evidence suggests that some farmers under apply fertilizer, that is use less than the ideal amount, where marginal cost equals marginal revenue, of fertilizer for crop growth (Pease, Bosch et al). If farmers are applying fertilizer at above economically optimal rates, there exists a win-win situation from a policy perspective for lower application rates (Sheriff). Peng and Bosch found that N runoff reduction could be

achieved at the lowest cost for N over applicators where over application is defined as application at the point where marginal cost of nitrogen exceeds its marginal return.

Once fertilizer has been applied to fields other problems with incomplete information arise. The economically optimal rate of N use can vary greatly even inside individual fields (Scharf et al.). In-field variability is an important consideration for policies that require a test strip to measure the effects of N reduction (Simpson). Site factors (slope and distance to surface water) for different fields can greatly affect the likelihood of runoff and the relative costs to reduce runoff (Peng and Bosch; Carpentier, Bosch and Batié). The differences in runoff potential from different areas, based on site factors specific to each field, make it difficult, if not impossible, to determine specific runoff from N applications to different locations. Because of this problem, programs that are implemented often estimate reductions based on practices implemented, or they target decreases in inputs. Ribaud et al. estimated that for the Mississippi Basin a 10 percent reduction in N inputs was required for a 5 percent reduction in N deliveries to the Gulf of Mexico.

Effective policy design requires that the above uncertainties surrounding N usage and runoff be taken into consideration. Program cost and effectiveness are greatly affected by the choices made to address and balance the complexities involved, such as the diffuse nature of NPS pollution. The tradeoffs that need to be made to address these often conflicting complexities can be seen in the types of programs that are in existence today, and programs that have been proposed.

## **Types of Policies Programs**

The types of policies that have been proposed or implemented, for reducing NPS pollution, can be classified into 4 main categories. These categories are 1. Fixed payments for practice adoption (or a fixed tax charged for not adopting the practice); 2. Variable payments for practice adoption (or a variable tax tied to not adopting a practice); 3. Fixed payment tied to performance (or a fixed tax that is tied to performance); 4. Variable payment tied to performance (or a variable tax that decreases as performance increases); and 5. Insurance Programs. Insurance programs tend to be a special case of variable payments for practice adoption, but are separated out due to their unique approach. Political realities and economic principles determine how each of these categories performs and whether or not they are adopted.

### *Fixed Payments (Tax) for Practice Adoption*

The first category, fixed payments (tax) for practice adoption, is one that is easier to implement, and thus has been more widely used. These types of programs consist of a payment being made to farmers to get them to either adopt the use of a pollution reducing method, create/install a pollution mitigating resource, or adopt other Best Management Practices (BMPs) to reduce effluent. Most typical agricultural cost-share programs fit into this category, an example being the Virginia Agricultural Best Management Practices Cost-Share Program. In these programs, pollution mitigating practices or improvements are partly paid for (up to 75 percent in the Virginia Program) by the regulating agency. The Conservation Reserve Program's (CRP) continuous signup program is an example of

a program in this category. Through the continuous signup, farmers can be paid a fixed amount to remove land from production. Land is put in conserving uses such as installing riparian buffers.

Two special cases of “fixed payments for practice adoption” are those in which the government directly regulates practices and farmers voluntarily adopt practices for a zero payment. These types of programs pass costs onto the farmers. Mandatory regulation could be expensive to enforce because regulatory agencies would have to monitor potentially large amounts of data over large areas, and they would have to strike a proper balance between penalties strong enough to deter cheating and ones that are politically viable (Sheriff). Voluntary programs depend on farmers receiving either altruistic or economic gains by implementing the practice.

#### *Variable Payments (Tax) for Practice Adoption*

The next type of program, variable payments for practice adoption, is characterized by a more competitively determined payment that may vary by farm, for the adoption of a practice that does not reduce runoff in an easily measurable manner. The CRP bidding program would be an example of this type of program.

In the CRP bidding program, the government will pay farmers up to a fixed rental rate, based on the “relative productivity of soils within each county and the average dryland cash rent or the cash-rent equivalent” (USDA FSA), to remove highly erodible land from production. To enroll, farmers submit bids for the lowest amount they would accept for

taking their lands out of production. These bids are ranked by the USDA's Environmental Benefit Index (EBI). The EBI score is based on wildlife habitat potential, water quality, benefits the farm receives, durability of the benefits, and air quality, all compared to the cost to rent the land (USDA FSA). The EBI has been shown to be effective largely due to increased competition in the bidding process by landowners (Ribaud, et al.). The eligible lands with the best EBI are selected for inclusion into the program and are eligible for cost share funds for improvements on the land.

#### *Fixed Payment (Tax) Tied to Performance*

Programs could also be set up that would have a fixed payment (tax) tied to performance. In the ideal case, this type of program would require pollution reduction performance to be directly measured. A fixed per unit payment (tax) on pollutants would fall into this category. This classification would be similar to the Connecticut point source trading program. This program has a fixed price for N credits (in 2003 it was set at \$2.14 per pound), with the state buying the excess credits that municipalities do not need (Connecticut Department of Environmental Protection). A subsidy program that would include NPS pollution would operate in a similar manner. Basically the state would establish a fixed price per pound of pollutant released. However, due to the complexities involved with direct measurement of runoff, input taxes and subsidies could be used instead. Input taxes and subsidies are problematic, though, because the demand for fertilizer is considered to be very inelastic (Choi and Helmberger). This would indicate that per unit subsidies (taxes) would have to be very high to achieve their goals.

### *Variable Payment (Tax) Tied to Performance*

The last category of program, variable payment (tax) tied to performance is not generally measured at the individual farm level. Because of the difficulties of directly measuring nonpoint source pollution, the trading programs that are put into place tend to fit more into the previous category than this one. Morgan, Coggins, and Eidman propose an auction method for implementing a program for trading nitrate emissions between farms. The model they propose entails measurement at wells and modeling of farm level activities, soil behavior, and ground water interactions to estimate individual farm compliance.

An example of a program that incorporates aspects from this category is the Agricultural Privilege Tax charged in the Everglades region of Florida. This tax is a per-acreage charge on agricultural land that escalates from its inception level in 1994 of \$61.48 per hectare (\$24.89/acre) to its top level in 2013 of \$86.45 per hectare (\$35.00/acre). There is an area-wide tax incentive that will lower the tax if the “phosphorus load reduction exceeds 25 percent” for the area (South Florida Water Management District). Also, individual farmers can lower their tax burden by taking actions to reduce their individual discharges, which are “quantified using site-specific calibration equations” and utilize “flow measurements, collection and compositing of discharge water samples and analysis for [total phosphorus]” (South Florida Water Management District).

## *Insurance*

Insurance programs to reduce N use are a relatively new policy approach for environmentally focused agricultural programs. The proposals for insurance programs to reduce N usage fall into different categories above depending on how the payments are implemented. Huang proposes providing insurance for farmers using split timing applications of fertilizer (practice) against the possibility of missing the second application due to poor weather conditions. This would be an example of variable payments for practice adoption, because the insurance payment would vary by year depending on yield reductions. In 2003, a pilot program began to provide farmers insurance against yield loss in order to have them reduce their fertilizer applications to values called for in BMPs. This insurance was called the Nutrient Management, Best Management Practices Insurance NM/BMPI (Mitchell).

## **Yield Reserve Program**

The Yield Reserve Program is a “hybrid” program of the types described above. The current proposal for the program can be classified as either fixed payment for practice or variable payment for practice depending on how it is implemented. The program involves payment for fixing the level of inputs. Hence, it is not directly paying for a measurable impact on runoff. The fixed incentive payment that is currently proposed puts the program in the fixed payment for practice category, while the variable insurance payment puts the program in the variable payment for practice category.

### *History of the Yield Reserve Program*

In 2001, a pilot program for a Yield Reserve Program that would have an incentive payment for participating farmers and insurance for potential reductions in yields was recommended (Henry A. Wallace Center). The CRP program had been successful at removing marginal land from production, but there were still problems with excess nutrients which have potential to pollute ground and surface waters (Simpson). To address nutrient concerns, paying farmers to use lower levels of fertilizer was felt to be a better alternative than taking land out of use entirely even if such reductions led to sub-optimal applications of fertilizer, where marginal cost is less than marginal revenue from using an extra unit (Simpson).

Senator Sarbanes of Maryland and Senator Harkin of Iowa supported the inclusion of the Chesapeake Bay Nutrient Reduction Pilot Program in the Agriculture, Conservation, and Rural Enhancement Act of 2001. The states of Maryland, Pennsylvania, Virginia, and the District of Columbia supported the proposed pilot program. Senator Sarbanes described the program as a win-win proposition that would benefit the Bay and help farmers by lowering their operating costs (US Senate February 2002). Approximately \$50 million was requested to support a pilot Yield Reserve Program (MWCOG). The provision passed the Senate, and failed by a narrow margin in the House. Later, it was stripped out of the final bill that passed conference (Simpson). Later that year, Senator Sarbanes expressed his dismay that the version of the Farm Security and Rural Investment Act of 2002 that came out of conference did not contain the proposal for the program (US Senate May 2002).

Criticism of the program has come from some farmers and from industries with an interest in agricultural input use and output. Some of this criticism has focused on a conviction that it is wrong to grow less than a “full crop.” Further, some attack the programs as coming from environmentalist and “anti-ag” forces. In an article entitled “Defending Nitrogen,” in *Croplife*, the author asked, “What insanity is it to limit the American farmers' ability to produce food just to satisfy these anti-ag voices politically[?]” (Angstadt). It has further been argued that this program comes from the “environmentalist” camp, is “backwards”, “convoluted”, and “smacks of socialism” (Anonymous). Further, in a University of Maryland Law report, a “stakeholder”, was quoted as saying, “we don’t like to get paid for growing bad crops.” There has also been some concern that the program would eventually create a cap on N use (Simpson).

### *The Background of Yield Reserve*

While the program has been attacked as coming from “anti-ag” voices, the reality is that the program developed from experiences and studies from agricultural-minded academics. Some of the concepts behind the Yield Reserve Program came out of Simpson’s work on the Virginia Agronomic Land Use Evaluation System (VALUES), which has recommendations that will not limit crop yields in good years (Simpson). In drought years, farmers will not lose anything, and it is estimated that over the long term a 15 to 25 percent reduction in N will have only a 2 to 5 percent reduction in average yields (Simpson).

In a 2001 paper, Mitsch et al recommended lower N usage and switching away from row crops to alternative cropping systems as two ways to reduce N loading in the Gulf of Mexico. Further, it was determined that reducing fertilizer usage was more cost effective than wetland restorations for a reduction goal of up to 1.2 million tons of N in the Gulf of Mexico (Ribaud et al.). There are also indications that farmers use fertilizer at rates that are higher than many fields need (Brown; Iowa Soybean Association; Lucht; Scharf; Simpson; Yadav, Peterson, and Easter).

In December of 2001 the Risk Management Agency approved the Nutrient Management/Best Management Practices Insurance. The approval cited that farmers tended to over-fertilize crops so reducing nutrients to agronomic recommendations would not limit production (RMA 2001). This program utilizes a representative test strip in fields that farmers treat with their previous application rates, while the rest of the field receives the lower recommended rate of fertilizer. If the rest of the field has less production than the test strip, the insurance will make a payment to the affected farmer minus a 5 percent deductible of losses (RMA 2001).

In 2005, the RMA discontinued the NM/BMPI program because it was no longer certain that the “interests of producers are protected and that the rates are actuarially sound” (FCIC). This leaves two programs currently in place that are similar. These are the BMP Challenge and the Corn Nutrient Demonstration Project, run by American Farmland Trust (Brandt). The BMP Challenge gets farmers to reduce their fertilizer usage to university-recommended rates and provides a “warranty” payment if yields are negatively

impacted (Lucht). There have been about 40 participants in the BMP Challenge in the last 4 years (Brandt). This year there are about 1,600 hectares (4,000 acres) enrolled, approximately 650 hectares (1,600 acres) in Pennsylvania, 400 to 600 hectares (1,000 to 1,500 acres) in Ohio, and 400 to 600 hectares (1,000 to 1,500 acres) in Iowa, Wisconsin, and Minnesota (Brandt). However, it has been challenging to get farmers to sign up for the program (Brandt).

There has so far been mixed results from the BMP Challenge. On average, farmers have reduced their application rates of N by approximately 20 percent. There have been a few larger payouts, of approximately \$49 per hectare (\$20 an acre), but about 40 to 50 percent of the payouts made have been in the \$15 to \$17 per hectare range (\$6 to \$7 per acre) (Brandt). Returns have tended to be \$2.50 to \$5 per hectare (\$1 to \$2 per acre) better than returns earned with the higher rate of fertilizer for participants (Brandt).

The Corn Nutrient Demonstration Project (CNDP) is paid for partly with a Chesapeake Bay Small Watershed Grant of \$85,000 (National Fish and Wildlife Foundation). This program has approximately 17 producers enrolled in Pennsylvania this year covering approximately 600 hectares (1,500 acres) (Brandt). The program pays farmers approximately \$5 per hectare (\$2 per acre) for each percentage of reduced fertilizer up to 15 percent. All of the farmers who signed up for the program elected to go with the full 15 percent reductions (Brandt). Agflex, a private corporation, provides the insurance in case farmers' yields are lower due to the lowered N application rate. The insurance cost is approximately \$39.50 per hectare (\$16 per acre) for fields enrolled in the CNDP.

While the Nutrient Management/Best Management Practices Insurance provided insurance to farmers to reduce their fertilizer usage to recommended levels, the Yield Reserve Program would pay farmers to go below the recommended levels like the CNDP. Hence, the Yield Reserve would be implemented in a similar manner to these other programs. The Yield Reserve Program, like NMBMPI, the BMP Challenge, and CNDP would utilize check strips to determine if there is any significant difference in yields between the strips and the rest of the fields. The test strip would create an estimated cost for the program of between \$5 to \$7.40 per hectare (\$2 to \$3 per acre), for the cost of a consultant to make sure that the strip is appropriately placed, and to document any losses (Simpson).

Like the NMBMPI there would be provisions for reducing moral hazard for the Yield Reserve Program. Moral hazard is an incentive created by insurance for individuals to change their behavior in a way that increases the chance of and magnitude of a loss occurring (Arrow, Nicholson). Moral hazard that could be present for these strips would be that the farmer preferentially treats the test strip in comparison to the rest of the field (Mitchell). To prevent moral hazard, farmers would be required to maintain records and allow them to be inspected which is currently done in other agricultural programs (Simpson). To help mitigate losses if farmers preferentially treat their test strips, payments could be capped at 15 percent of the yield from the test strip. The basis for a 15 percent cap is that a 15 percent reduction in N application is not going to create more than a one-to-one yield reduction (Simpson).

Other costs for covering the potential losses due to the implementation of the Yield Reserve Program would consist of the price of insurance and incentive payments to get farmers to adopt the practice. Insurance cost for this type of program has currently been set at \$40 per hectare (\$16 per acre) (Brandt). On top of this cost, it is believed that an incentive policy would be necessary to coax farmers into adopting the program, it is estimated that in the long term a \$74 per hectare (\$30 per acre) payment per year is needed (Chesapeake Bay Commission 2004, Simpson, Sweeney).

## Chapter 3 Theoretical Considerations

### Fertilizer Use Under Uncertainty

The notion that farmers “over fertilize”, is an oversimplification. Because fertilizing is an ex ante decision, and it is not known what the profit maximizing level of fertilizer use is until after the season, farmers might use more fertilizer than is optimal, i.e., necessary to maximize profits from an ex post analysis. The uncertainty surrounding the optimal level of nutrient use is why an insurance approach has potential to decrease nutrient runoff to waterways. Further, uncertainty can explain why from an environmental perspective, in an ex post analysis, farmers “over fertilize.” Due to uncertainty farmers find it profitable to apply more fertilizer than will be used in many years. This excess fertilizer means that there is a greater amount of N in the system that has the potential to leach or run off to water ways. Since farmers do not bear any costs for pollution, they will use more fertilizer than “optimal” from a social point of view in which pollution costs are considered.

To simplify the problem, assume that there are only two states of nature, wet and dry. Wet represents growing seasons in which there are plentiful amounts of water and dry represents seasons in which water is a limiting factor for growth.  $N_w^*$  is defined as the optimal amount of N in wet conditions and  $N_d^*$  is defined as the optimal amount of N for dry growing seasons. Here optimal is defined as the N level where marginal cost is equal to marginal revenue for each state.

A farmer has no way of telling if the upcoming season will be wet or dry. However, since there is a perception by some farmers that if the expected weather is a dry season they should not plant at all (Alley), it will be assumed that a farmer is expecting a wet season and will fertilize at the optimal level for a wet season. Now if a wet season occurs, the farmer has fertilized properly. However, if it is a dry season there is excess fertilizer in the system from an environmental standpoint (see figure 1), defined as:

$$(3) N_{\text{excess}} = N_w - N_d$$

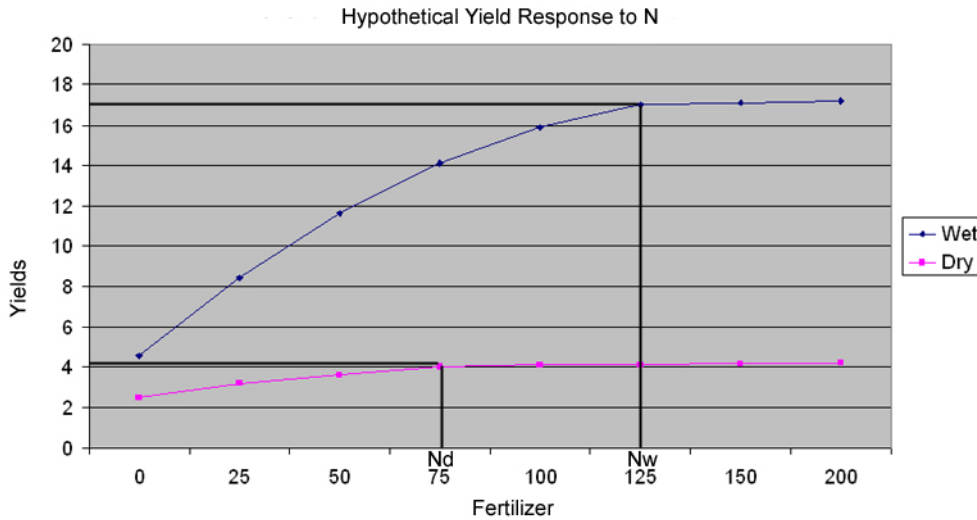


**FIGURE 3.1. Hypothetical Yield Response to N in Wet and Dry Years**

From the farmer's perspective this "excess" fertilizer contributes to achieving his/her goals. Let  $P_c$  = Price/Mg of corn,  $P_N$  = Price/kg of N, and let yield be a function of lbs/N and weather,  $Y = \text{Yield}(N, W)$ . Assume that  $P_c$  is constant for wet and dry years, and that a farmer's only cost is  $P_N$ . Weather has been assumed to have two states, dry and wet, with below average rainfall and above average rainfall. Then we can simplify the expected net return of the farmer to a function involving the above components.

$$(5) E(\pi) = \text{pr(dry)}(P_c * Y_{\text{dry}} - P_N N) + \text{pr(wet)} (P_c * Y_{\text{wet}} - P_N N)^1$$

The expected profit depends on the probability of each state occurring multiplied by the profit that results from each state.

If we let dry and wet seasons have equal probabilities, we get

$$(6) E(\pi) = \frac{1}{2}(P_c * Y_{\text{dry}} - P_N N) + \frac{1}{2}(P_c * Y_{\text{wet}} - P_N N)$$

The necessary condition for maximum profit is:

$$(7) \frac{1}{2} (P_c * \frac{\partial Y_{\text{dry}}}{\partial N} - P_n) + \frac{1}{2} (P_c * \frac{\partial Y_{\text{wet}}}{\partial N} - P_n) = 0$$

A farmer's decision to fertilize is going to be based on the price of a Mg of corn, the behavior of the yield functions and the price of N. One bushel of corn (.063 Mg/ha) uses approximately 1 lb (.45 kg) of N (Baker 2006). The price for 1 Mg of corn is \$102 (\$2.58/bu) and a pound of N is approximately \$.28 (\$.62 per kg). The cost to haul a Mg of corn was approximated by using the Virginia Cooperative Extension's corn budget for 2001 (\$.15/bu) and indexing the price using the Virginia Agricultural Statistics Service price of fuel for 2001 and 2004, and was estimated at \$7.22 per Mg (\$.18/bu). These are the five year average prices for 2000 to 2004 adjusted to 2005 dollars (National Agricultural Statistics Service, Virginia Agricultural Statistics Service). Corn's price is

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<sup>1</sup> Variable harvest costs are deducted from the reduced yield price, and other costs such as land preparation, etc. are assumed fixed and disregarded.

far greater than the cost of a pound of N, and marginal response to N for a wet year is far greater than for a dry year. So the right term,  $\frac{1}{2}(P_C * \partial Y_{\text{wet}} / \partial N - P_N)$ , drives the profit function. This means that to achieve profit maximization a farmer will fertilize more towards an optimum for wet years than for dry years.

A more formal way to approach risk in a farmer's decision to fertilize was developed by Babcock. In his paper "The Effects of Uncertainty on Optimal Nitrogen Applications", he develops a way to look at N applications under three distinct types of uncertainty: estimation uncertainty (based on the true versus estimated output function); weather uncertainty; and N availability uncertainty. Weather uncertainty will be the only type focused on for this study.

Babcock explains his rationale by using a linear response plateau function of the form:

$$(8) y = \min\{\alpha + \beta N, y_p(W)\}$$

"where  $y_p(W)$  is the random plateau yield with  $\frac{\partial y_p}{\partial W} > 0$ " (Babcock, p. 274) and W represents growing conditions, or weather. Babcock demonstrates that the optimal N application is:

$$(9) N^* = [P_n(b-a) - \beta (b-\alpha)] / -\beta^2$$

Babcock then demonstrates that uncertainty about weather can induce using more N when  $\beta_2 > P_N$ . “If the price of nitrogen is less than half the marginal product of nitrogen when nitrogen is limiting, then optimal nitrogen rates under uncertainty will be greater than those under certainty” (Babcock, p. 274). So as long as there is more than a 50 percent chance that an extra unit of fertilizer would increase yields the extra yield of  $\beta$  is worthwhile, since it is greater than the certain cost of  $P_N$  (Babcock). Babcock (p. 275) uses this to state, “farmers find it profitable to apply extra fertilizer to reduce the risk of being caught short in good growing years.” Further, increasing yield per acre reduces the cost per bushel. Farmers may be attracted to higher yields because they allow machinery costs to be spread over more bushels of yield (Alley).

### **Model for Analyzing Yield Reserve**

Fertilizer use under uncertainty leads to the following net returns maximization model for analysis of the Yield Reserve Program for corn. The model is based on the following assumptions, which allow the variables of production in the model to be estimated and the analysis to proceed:

1. Acreage of corn is fixed at the five-year average for the region.
2. Crop sale prices are constant and determined outside of the model.
3. The N applied each year is fixed, since the decision to apply it comes before the growing season is known. (Fertilizing is an ex ante decision.)
4. The price of N is constant.
5. Yield trends are constant.
6. There are no rotation effects on yield.

7. Weather probabilities can be estimated from previous years' weather.
8. Non-N costs are fixed.
9. Variable harvest and drying costs are deducted from the sale price.

### **Without Yield Reserve**

Corn net return maximization problem is stated as follows:

$$(10) \max(\pi_c) = \text{pr}(W_1)(P_c * Y_1 * A - P_n * N * A) + \text{pr}(W_2)(P_c * Y_2 * A - P_n * N * A) + \dots + \text{pr}(W_n)(P_c * Y_n * A - P_n * N * A)$$

Where  $\text{pr}(W_j)$  is the probability of weather state  $j$  occurring and  $Y_j$  is the corresponding yield response to that state of weather, for  $j = 1, 2, \dots, n$ .  $P_c$  and  $P_n$  are the price of corn per Mg/ha and  $N$  per kilogram, respectively,  $A$  is the number of hectares of corn planted, and  $N$  is the amount  $N$  applied to each acre in kilograms. The form of  $Y_j$  is estimated empirically.

### **Expected Net Return under Yield Reserve**

The methods of implementing the policy considered are incentive payments, insurance, mixed incentive payments and insurance, and  $N$  easements on the property.

#### *Case I: Incentive payment*

Under Yield Reserve the farmer loses the ability to optimize  $N$  rates, so this problem is no longer one of maximization. Instead, the expected profit function for corn is

$$(11) E(\pi) = \text{Inc}_p + \text{pr}(W_1)(P_c * Y_{yr1} * A - P_n * N_{yr} * A) + \text{pr}(W_2)(P_c * Y_{yr2} * A - P_n * N_{yr} * A) \\ + \dots + \text{pr}(W_n)(P_c * Y_{yrn} * A - P_n * N_{yr} * A)$$

Where  $\text{pr}(W_j)$  is the probability of weather state  $j$  occurring,  $Y_{yrj}$  is the corresponding yield response to that state of weather, for each state  $j$ , for  $j = 1, 2, \dots, n$ .  $\text{Inc}_p$  is an annual incentive payment to farmers to get them to participate in the program.  $N_{yr}$  is the fixed amount of  $N$  applied to each acre based on a 15 percent reduction of recommended fertilizer rates.

The average incentive payment needed per hectare to induce farmer participation ( $\text{Inc}_p$ ) is calculated.

$$(12) \text{Inc}_p = [\max(\pi_c) - \text{pr}(W_1)(P_c * Y_{yr1} * A - P_n * N_{yr} * A) + \text{pr}(W_2)(P_c * Y_{yr2} * A - P_n * N_{yr} * A) + \dots + \text{pr}(W_n)(P_c * Y_{yrn} * A - P_n * N_{yr} * A)] / A$$

In order to get farmers to join the program, the incentive payment will need to compensate farmers for at least the amount of net returns that is lost due to reduced yields. Lost revenue is defined as the difference between the maximum net return, calculated above, and the expected net revenue under different states of weather using the Yield Reserve  $N$  levels.

The main difference between insurance and an incentive payment in this case is that insurance is an ex post payment based on realized losses in yield from participating in the Yield Reserve Program, and an incentive payment is an ex ante payment to farmers based on projected losses in yield. Incentive payments based on expected profits would lower the volatility of farmers' income, because they would increase profits in bad (low yield) years, and lower them in good (high yield) years (compared to baseline N applications), but maintain the same expected profit level.

### *Case II: Insurance*

The insurance payments are assumed to pay the “total” loss to farmers during years where yields fall short due to participating in the Yield Reserve Program. To approximate the insurance payments needed in each state that there is a loss we can set:

$$(15) \text{Netins}_i = \sum_1^n pr(W_i)P_c \bullet (Y_i - Y_{yr_i}) \bullet A$$

For every weather state  $i$  taking on the values  $i = 1, 2, \dots, n$ . By using weather data averages for the growing season months for previous years, we can estimate the approximate likelihood of each classification of weather year occurring.

### *Case III: Mixed Incentive payments and Insurance*

The program, as currently proposed, calls for a \$74 yearly incentive payment per hectare (\$30 per acre) and insurance payments in years where yields are limited due to the

decreased use of fertilizer (Sweeney). This would yield the following expected profit function for farmers:

$$E(\pi) = Inc_p + pr(W_1)(P_c * Yyr_1 * A + Netins_1 - P_n * N_{yr} * A_c) + \\ (16) \quad pr(W_2)(P_c * Yyr_2 * A + Netins_2 - P_n * N_{yr} * A) + \dots + \\ pr(W_n)(P_c * Yyr_n * A + Netins_n - P_n * N_{yr} * A)$$

with  $Inc_p = \$74$ , and all the other variables defined as before. The expected value of payments under this situation would depend on the relative weights of the weather probabilities and calculated annual payments. The insurance payments under this method would be the same as calculated above for the insurance payment only method.

#### *Case IV: N Reduction Easement*

A special case of the incentive payment approach would be a simple calculation of an easement on properties for a permanent reduction of N use. In this approach a farmer would be paid a lump sum for the yield costs imposed by reducing N to 15 percent below extension recommendations every year in the future. The cost of this approach would be similar to calculating the price of a perpetual bond, which is  $Price = \text{Yearly payment} / \text{interest rate}$  (Mishkin). The price of the easement value becomes

$$(17) \text{ Easement Value} = [Inc_{p\_caseI} / Discount_{rate}]$$

where  $Inc_{p\_caseI}$  is the value of the incentive payment calculated in the first case analyzed and the discount rate is the value of the money used for other investments.

## **Chapter 4 Methods and Procedures**

To estimate the cost of a Yield Reserve Program, corn yield response curves were estimated for data from sites in North Carolina and Virginia. These curves allowed for yields to be predicted under Cooperative Extension recommended levels and at 15 percent less than recommended levels. Weather probabilities and associated yields were based on historical weather and yield data and the estimated yield response curves for different weather years. Next, historic yields in Eastern Virginia for forty-seven years were regressed against rainfall amounts and de-trended. Yields were de-trended to control for advancements that were made allowing for greater yields. This regression allowed for groupings to be made for similar years into three different categories of rainfall. Then soil management group data were used to adjust estimated yield across different groups of soil. These data were used to adjust the yield response curves for soil type across seasonal rainfall categories. Finally, the probability-weighted yield response curves were used to estimate farm level costs of a Yield Reserve Program.

### **Yield Response Curve Regressions**

Dry land corn data, representing 16 site years in North Carolina and 9 site years in Virginia, were used to estimate yield response curves for corn to N. The North Carolina data were from 4 sites in 2000, 3 sites in 2001, and 1 site in 2002 (Sripada et al.). The Virginia data are from 5 sites for 2004 and from one site for 2002 and 2003 (Phillips). The sites for the data for North Carolina were The Peanut Belt Research Station (Lewiston), Denton Farms (Denton), Haslin Farms-Organic Ridge (HSOR) located in Belhaven, Haslin Farms-Sandy Ridge (HSSR) also in Belhaven, and the Tidewater

Research Station (TRS) located in Plymouth (Sripada et al.). Data are available in 2000 for Lewiston, Denton, HSOR, HSSR, and TRS. In 2001, the North Carolina data are available for HSOR, Lewiston, and TRS. In 2002, data are available for Lewiston and TRS, and in 2003 data are available for three fields at both Lewiston and TRS. The Virginia data are from locations in Accomack, Augusta, Charles City, Essex, and Westmoreland for 2004, and Accomack for 2002 and 2003. However, the 2002 and 2003 data are only available for a limited number of repetitions up to 168 kg per hectare (150 lbs of N per acre). This is not ideal but these data still provide extra information on the possible behavior of response curves.

The data were regressed with SAS using both quadratic linear regression and nonlinear regression utilizing the Mitscherlich function. These curves take the following forms:

Quadratic: 
$$(11) Y_{C_j} = \alpha + \beta N - \gamma N^2$$

Mitscherlich: 
$$(12) Y_{C_j} = \alpha[1 - \beta * \exp(-\gamma * N)]$$

The parameters  $\alpha$ ,  $\beta$  and  $\gamma$  are determined through regression for each yield response curve. N is the amount of N applied.

All of the regressions for the North Carolina data produced significant models except for 2002 TRS-ORG, which had a model significance of .25. A specific example of the equations produced for 2000 is from the Lewiston data:

$$\text{yield} = 13.07[1-.44*\exp(-.0073*N)] \text{ (Mitscherlich)}$$

$$\text{yield} = 22.28+8.11*N-.000035*N^2 \text{ (Quadratic)}$$

The  $R^2$  values, the proportion of variation explained by the model (Montgomery, Peck, and Vining) for the two equations are .706 and .694, respectively (SAS). Both models are significant at the 99% confidence level, and all of the regressors are significant at the 99% confidence level. The tables below summarize the quadratic equations for all of the regressions run for the North Carolina data (Table 4.1) and the Virginia data (Table 4.2). The models for the North Carolina data are all significant, though not necessarily well fitting, except for 2002 TRS-ORG. It should be noted that 2002 was a drought year, so insignificance of the model and the low  $R^2$  of the 2002 Lewiston experiment is consistent with expectations for a drought year producing low to no response to N.

**Table 4.1 Summary of Quadratic Regressions of Corn Yields and N rates for North Carolina Data**

| Year                                                                                                                                                                                                                                                                           | Location  | R <sup>2</sup> <sup>a</sup> | Model Sig. <sup>b</sup> | Intercept | Intercept Sig. | N <sup>c</sup> | N Sig. | N <sup>2</sup> | N <sup>2</sup> Sig. |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-----------------------------|-------------------------|-----------|----------------|----------------|--------|----------------|---------------------|
| 2000                                                                                                                                                                                                                                                                           | Lewiston  | 0.69                        | <.0001                  | 7.78      | <.0001         | 0.03           | <.0001 | -3.5E-05       | <.0001              |
| 2000                                                                                                                                                                                                                                                                           | Denton    | 0.36                        | <.0001                  | 3.50      | <.0001         | 0.02           | 0.0004 | -2.5E-05       | 0.0315              |
| 2000                                                                                                                                                                                                                                                                           | Hsor      | 0.43                        | <.0001                  | 8.20      | <.0001         | 0.02           | 0.0002 | -2.2E-05       | 0.0432              |
| 2000                                                                                                                                                                                                                                                                           | Hssr      | 0.45                        | <.0001                  | 3.63      | <.0001         | 0.02           | 0.001  | -1.8E-05       | 0.1499              |
| 2000                                                                                                                                                                                                                                                                           | TRS       | 0.70                        | <.0001                  | 1.90      | 0.0083         | 0.03           | <.0001 | -2.6E-05       | 0.0599              |
| 2001                                                                                                                                                                                                                                                                           | Hsor      | 0.72                        | <.0001                  | 4.85      | <.0001         | 0.04           | <.0001 | -4.8E-05       | 0.0022              |
| 2001                                                                                                                                                                                                                                                                           | Lewiston  | 0.80                        | <.0001                  | 3.11      | <.0001         | 0.04           | <.0001 | -4.6E-05       | <.0001              |
| 2001                                                                                                                                                                                                                                                                           | TRS       | 0.38                        | <.0001                  | 5.45      | <.0001         | 0.02           | 0.0273 | -1.5E-05       | 0.3714              |
| 2002                                                                                                                                                                                                                                                                           | Lewiston  | 0.19                        | <.0001                  | 2.80      | <.0001         | 0.01           | <.0001 | -2.0E-05       | 0.0007              |
| 2002                                                                                                                                                                                                                                                                           | TRS-ORG   | 0.05                        | 0.2459                  | 3.55      | <.0001         | 0.004          | 0.1016 | -7.6E-06       | 0.1409              |
| 2003                                                                                                                                                                                                                                                                           | Lewiston1 | 0.64                        | <.0001                  | 5.20      | <.0001         | 0.02           | 0.0002 | -1.4E-05       | 0.1252              |
| 2003                                                                                                                                                                                                                                                                           | Lewiston2 | 0.56                        | <.0001                  | 5.37      | <.0001         | 0.02           | <.0001 | -2.8E-05       | 0.006               |
| 2003                                                                                                                                                                                                                                                                           | Lewiston3 | 0.51                        | <.0001                  | 5.31      | <.0001         | 0.02           | 0.0004 | -2.3E-05       | 0.0504              |
| 2003                                                                                                                                                                                                                                                                           | TRS1      | 0.58                        | <.0001                  | 4.87      | <.0001         | 0.03           | <.0001 | -3.1E-05       | 0.0023              |
| 2003                                                                                                                                                                                                                                                                           | TRS2      | 0.56                        | <.0001                  | 5.09      | <.0001         | 0.03           | <.0001 | -3.9E-05       | 0.0003              |
| 2003                                                                                                                                                                                                                                                                           | TRS3      | 0.52                        | <.0001                  | 5.33      | <.0001         | 0.02           | <.0001 | -2.6E-05       | 0.0112              |
| <sup>a</sup> R <sup>2</sup> value of the fit for each model                                                                                                                                                                                                                    |           |                             |                         |           |                |                |        |                |                     |
| <sup>b</sup> If the model significance is good (close to 0) then the null hypothesis, that there is no relationship between the independent and dependent variables, can be rejected                                                                                           |           |                             |                         |           |                |                |        |                |                     |
| <sup>c</sup> N is the amount of nitrogen fertilizer in kg                                                                                                                                                                                                                      |           |                             |                         |           |                |                |        |                |                     |
| The locations were the Peanut Belt Research Station (Lewiston), Denton Farms (Denton), Haslin Farms-Organic Ridge (HSOR) located in Belhaven, Haslin Farms-Sandy Ridge (HSSR) also in Belhaven, and the Tidewater Research Station (TRS) located in Plymouth (Sripada et al.). |           |                             |                         |           |                |                |        |                |                     |

**Table 4.2 Summary of Quadratic Regressions of Corn Yields for Virginia Data**

| Year                                                                                                                                                                                 | Location     | R <sup>2</sup> <sup>a</sup> | Model Sig. <sup>b</sup> | Intercept | Intercept Sig. | N <sup>c</sup> | N Sig. | N <sup>2</sup> | N <sup>2</sup> Sig. |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------------------------|-------------------------|-----------|----------------|----------------|--------|----------------|---------------------|
| 2002                                                                                                                                                                                 | Accomack     | 0.04                        | 0.8637                  | 3.05      | 0.0629         | 0.09           | 0.7422 | -4.4E-05       | 0.6918              |
| 2003                                                                                                                                                                                 | Accomack     | 0.57                        | 0.0226                  | 3.13      | 0.0497         | 0.07           | 0.0157 | -2.6E-04       | 0.0281              |
| 2004                                                                                                                                                                                 | Accomack     | 0.97                        | <.0001                  | 4.59      | <.0001         | 0.06           | <.0001 | -8.9E-05       | 0.0389              |
| 2004                                                                                                                                                                                 | Augusta      | 0.55                        | 0.0263                  | 9.82      | <.0001         | 0.05           | 0.0583 | -1.9E-04       | 0.2103              |
| 2004                                                                                                                                                                                 | Charles City | 0.90                        | <.0001                  | 7.32      | <.0001         | 0.04           | 0.0002 | -8.8E-05       | 0.0268              |
| 2004                                                                                                                                                                                 | Essex        | 0.05                        | 0.7482                  | 10.00     | <.0001         | 0.0002         | 0.9911 | 1.3E-05        | 0.8389              |
| 2004                                                                                                                                                                                 | Westmoreland | 0.20                        | 0.2593                  | 7.67      | <.0001         | 0.02           | 0.2541 | -6.1E-05       | 0.4444              |
| <sup>a</sup> R <sup>2</sup> value of the fit for each model                                                                                                                          |              |                             |                         |           |                |                |        |                |                     |
| <sup>b</sup> If the model significance is good (close to 0) then the null hypothesis, that there is no relationship between the independent and dependent variables, can be rejected |              |                             |                         |           |                |                |        |                |                     |
| <sup>c</sup> N is the amount of nitrogen fertilizer in kg                                                                                                                            |              |                             |                         |           |                |                |        |                |                     |

The Virginia data produced only two models significant at .0001 in 2004 Accomack and 2004 Charles City, these years also had good  $R^2$  values of .97 and .90 respectively. The models that were not significant at the .0001 level were not considered, and all had lower  $R^2$  values.

The quadratic and the Mitscherlich equations produced similar results. In all cases the  $R^2$  values were similar, and neither approach produced consistently higher  $R^2$  values than the other. Both approaches produced  $R^2$  values that were generally low. The quadratic equation was selected for use because it is simple to apply and interpret compared to a non-linear regression approach. Further, the quadratic equations always produced non-zero values for all of the parameters, which was not the case for all of the Mitscherlich equations.

### **Predicted Corn Yields**

Next, the regression equations were used to determine predicted corn yields at each experiment location utilizing fertilizer recommendations from the Virginia Nutrient Management Standards and Criteria guide. The Virginia Nutrient Management Standards and Criteria Guide were updated (Baker), with the base fertilizer levels being set at 1 pound of N per Bu/Ac compared to 1.1 lb N/bu/Ac used in the Virginia Nutrient Management Standards and Criteria Guide. Utilizing the recommended rates of N, predicted yields were obtained utilizing the yield response curves (See table 4.3 and 4.4).

**Table 4.3. Predicted and Experimental Yields in Mg/ha for Recommended N Applications for North Carolina Data**

| Year                                                                                                                                                                                                                                                                           | Location  | N Recommendations kg/ha <sup>a</sup> | Predicted Yields Mg/ha | Experimental Yields Mg <sup>b</sup> | Experimental Rate Kg of N <sup>c</sup> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------|------------------------|-------------------------------------|----------------------------------------|
| 2000                                                                                                                                                                                                                                                                           | Lewiston  | 157                                  | 12.81                  | 11.3                                | 168                                    |
| 2000                                                                                                                                                                                                                                                                           | HSOR      | 112                                  | 10.71                  | 10.3                                | 112                                    |
| 2000                                                                                                                                                                                                                                                                           | HSSR      | 179                                  | 7.75                   | 7.1                                 | 224                                    |
| 2000                                                                                                                                                                                                                                                                           | TRS       | 191                                  | 8.96                   | 8.0                                 | 224                                    |
| 2001                                                                                                                                                                                                                                                                           | HSOR      | 112                                  | 8.88                   | 8.7                                 | 112                                    |
| 2001                                                                                                                                                                                                                                                                           | Lewiston  | 157                                  | 7.91                   | 8.5                                 | 168                                    |
| 2001                                                                                                                                                                                                                                                                           | TRS       | 191                                  | 8.40                   | 9.2                                 | 224                                    |
| 2002                                                                                                                                                                                                                                                                           | Lewiston  | 157                                  | 5.30                   | 4.7                                 | 168                                    |
| 2002                                                                                                                                                                                                                                                                           | TRS-ORG   | 191                                  | 4.64                   | 3.7                                 | 224                                    |
| 2003                                                                                                                                                                                                                                                                           | Lewiston1 | 191                                  | 9.28                   | 9.0                                 | 224                                    |
| 2003                                                                                                                                                                                                                                                                           | Lewiston2 | 191                                  | 10.88                  | 9.5                                 | 224                                    |
| 2003                                                                                                                                                                                                                                                                           | Lewiston3 | 191                                  | 10.36                  | 9.1                                 | 224                                    |
| 2003                                                                                                                                                                                                                                                                           | TRS1      | 191                                  | 10.78                  | 8.7                                 | 224                                    |
| 2003                                                                                                                                                                                                                                                                           | TRS2      | 191                                  | 11.94                  | 9.7                                 | 224                                    |
| 2003                                                                                                                                                                                                                                                                           | TRS3      | 191                                  | 10.41                  | 8.6                                 | 224                                    |
| <sup>a</sup> N recommendations from the updated Virginia Nutrient Management Standards and Criteria Guide                                                                                                                                                                      |           |                                      |                        |                                     |                                        |
| <sup>b</sup> The experimental yields are the average yields for the N application rate closest to the recommended rates.                                                                                                                                                       |           |                                      |                        |                                     |                                        |
| <sup>c</sup> The experimental rate is the N application rate in Kg of observed N used in the experiment closest to the recommended rate per hectare.                                                                                                                           |           |                                      |                        |                                     |                                        |
| The locations were the Peanut Belt Research Station (Lewiston), Denton Farms (Denton), Haslin Farms-Organic Ridge (HSOR) located in Belhaven, Haslin Farms-Sandy Ridge (HSSR) also in Belhaven, and the Tidewater Research Station (TRS) located in Plymouth (Sripada et al.). |           |                                      |                        |                                     |                                        |

**Table 4.4. Predicted and Experimental Yields in Mg/ha for Recommended N Applications for Virginia Data**

| Year                                                                                                                                        | Location     | N Recommendation kg/ha <sup>a</sup> | Predicted Yields Mg/ha | Experimental Yields Mg <sup>b</sup> | Experimental Rate Kg of N <sup>c</sup> |
|---------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------------------------------|------------------------|-------------------------------------|----------------------------------------|
| 2002                                                                                                                                        | Accomack     | 146                                 | 3.475217               | 11.5                                | 168                                    |
| 2003                                                                                                                                        | Accomack     | 146                                 | 8.481269               | 7.6                                 | 168                                    |
| 2004                                                                                                                                        | Accomack     | 146                                 | 10.8278                | 3.2                                 | 168                                    |
| 2004                                                                                                                                        | Augusta      | 112                                 | 12.68875               | 11.91                               | 112                                    |
| 2004                                                                                                                                        | Charles City | 134                                 | 10.62452               | 11.2                                | 168                                    |
| 2004                                                                                                                                        | Essex        | 146                                 | 10.23417               | 10.4                                | 168                                    |
| 2004                                                                                                                                        | Westmoreland | 157                                 | 9.165434               | 9.6                                 | 168                                    |
| <sup>a</sup> N recommendations from the updated Virginia Nutrient Management Standards and Criteria Guide                                   |              |                                     |                        |                                     |                                        |
| <sup>b</sup> The experimental yields are the average yields for the observed N application rate closest to the recommended rates.           |              |                                     |                        |                                     |                                        |
| <sup>c</sup> The experimental rate is the N application rate in Kg of N used in the experiment closest to the recommended rate per hectare. |              |                                     |                        |                                     |                                        |

Next, yield losses under Yield Reserve were estimated from the response curves using 15 percent less than the recommended N rate (see tables 4.5 and 4.6).

**Table 4.5. Predicted Yields for North Carolina Quadratic Regressions Under Recommended and Yield Reserve Program N Applications**

| Year                                                                                                                                                                                                                                                                           | Location  | Predicted Yields (Mg/ha)<br>Based on Recommended<br>N Applications | Predicted Yields (Mg/ha)<br>Based on N Applications<br>Under Yield Reserve |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------------------------------|----------------------------------------------------------------------------|
| 2000                                                                                                                                                                                                                                                                           | Lewiston  | 12.81                                                              | 11.94                                                                      |
| 2000                                                                                                                                                                                                                                                                           | HSOR      | 10.71                                                              | 10.30                                                                      |
| 2000                                                                                                                                                                                                                                                                           | HSSR      | 7.75                                                               | 7.06                                                                       |
| 2000                                                                                                                                                                                                                                                                           | TRS       | 8.96                                                               | 7.78                                                                       |
| 2001                                                                                                                                                                                                                                                                           | HSOR      | 8.88                                                               | 8.35                                                                       |
| 2001                                                                                                                                                                                                                                                                           | Lewiston  | 7.91                                                               | 7.33                                                                       |
| 2001                                                                                                                                                                                                                                                                           | TRS       | 8.40                                                               | 8.03                                                                       |
| 2002                                                                                                                                                                                                                                                                           | Lewiston  | 5.30                                                               | 4.86                                                                       |
| 2002                                                                                                                                                                                                                                                                           | TRS-MIN   | 4.64                                                               | 4.44                                                                       |
| 2002                                                                                                                                                                                                                                                                           | TRS-ORG   | 9.28                                                               | 8.60                                                                       |
| 2003                                                                                                                                                                                                                                                                           | Lewiston1 | 10.88                                                              | 9.92                                                                       |
| 2003                                                                                                                                                                                                                                                                           | Lewiston2 | 10.36                                                              | 9.50                                                                       |
| 2003                                                                                                                                                                                                                                                                           | Lewiston3 | 10.78                                                              | 9.75                                                                       |
| 2003                                                                                                                                                                                                                                                                           | TRS1      | 11.94                                                              | 10.73                                                                      |
| 2003                                                                                                                                                                                                                                                                           | TRS2      | 10.41                                                              | 9.53                                                                       |
| 2003                                                                                                                                                                                                                                                                           | TRS3      | 12.81                                                              | 11.94                                                                      |
| The locations were the Peanut Belt Research Station (Lewiston), Denton Farms (Denton), Haslin Farms-Organic Ridge (HSOR) located in Belhaven, Haslin Farms-Sandy Ridge (HSSR) also in Belhaven, and the Tidewater Research Station (TRS) located in Plymouth (Sripada et al.). |           |                                                                    |                                                                            |

**Table 4.6. Predicted Yields for Virginia Quadratic Regressions Under Recommended and Yield Reserve Program N Applications**

| Year | Location     | Predicted Yields (Mg/ha)<br>Based on<br>Recommended N<br>Applications | Predicted Yields<br>(Mg/ha) Based on N<br>Applications Under<br>Yield Reserve |
|------|--------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------------|
| 2002 | Accomack     | 3.48                                                                  | 3.51                                                                          |
| 2003 | Accomack     | 8.48                                                                  | 8.24                                                                          |
| 2004 | Accomack     | 10.83                                                                 | 10.08                                                                         |
| 2004 | Augusta      | 12.69                                                                 | 12.50                                                                         |
| 2004 | Charles City | 10.62                                                                 | 10.62                                                                         |
| 2004 | Essex        | 10.23                                                                 | 10.23                                                                         |
| 2004 | Westmoreland | 9.17                                                                  | 9.17                                                                          |

Costs (gains) of reducing N application for each calculated yield response curve were estimated by subtracting the savings associated with each yield response curve for reduced N usage and transportation costs from the lost revenue associated with reductions in yields under Yield Reserve (see Table 4.7). The five year average, from 2000 to 2004, price of corn and fertilizer were used, \$102 per Mg (\$2.58/bu) for corn and \$.62 per kg (\$.28 per pound) of N, respectively. Transportation costs were set at \$7.22 per Mg (\$.18/bu).

**Table 4.7. Estimated Costs of Yield Reserve Program per Hectare Based on Estimated Yield Response Functions**

| Year                                                                                                                                                                                                                                                                           | Location     | Lost Revenue | Savings from Lower N | Transportation Costs | Farmer's Net Cost <sup>a</sup> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|--------------|----------------------|----------------------|--------------------------------|
| 2000                                                                                                                                                                                                                                                                           | Lewiston     | \$88.53      | \$14.49              | \$6.24               | \$67.79                        |
| 2000                                                                                                                                                                                                                                                                           | HSOR         | \$42.23      | \$10.35              | \$2.98               | \$28.90                        |
| 2000                                                                                                                                                                                                                                                                           | HSSR         | \$70.84      | \$16.56              | \$4.99               | \$49.28                        |
| 2000                                                                                                                                                                                                                                                                           | TRS          | \$120.83     | \$17.60              | \$8.52               | \$94.71                        |
| 2001                                                                                                                                                                                                                                                                           | HSOR         | \$54.14      | \$10.35              | \$3.82               | \$39.97                        |
| 2001                                                                                                                                                                                                                                                                           | Lewiston     | \$58.94      | \$14.49              | \$4.16               | \$40.29                        |
| 2001                                                                                                                                                                                                                                                                           | TRS          | \$38.30      | \$17.60              | \$2.70               | \$18.00                        |
| 2002                                                                                                                                                                                                                                                                           | Lewiston     | \$44.89      | \$14.49              | \$3.17               | \$27.23                        |
| 2002                                                                                                                                                                                                                                                                           | TRS-ORG      | \$20.34      | \$17.60              | \$1.43               | \$1.31                         |
| 2003                                                                                                                                                                                                                                                                           | Lewiston1    | \$69.24      | \$17.60              | \$4.88               | \$46.76                        |
| 2003                                                                                                                                                                                                                                                                           | Lewiston2    | \$97.84      | \$17.60              | \$6.90               | \$73.34                        |
| 2003                                                                                                                                                                                                                                                                           | Lewiston3    | \$88.40      | \$17.60              | \$6.23               | \$64.57                        |
| 2003                                                                                                                                                                                                                                                                           | TRS1         | \$105.36     | \$17.60              | \$7.43               | \$80.33                        |
| 2003                                                                                                                                                                                                                                                                           | TRS2         | \$123.62     | \$17.60              | \$8.72               | \$97.31                        |
| 2003                                                                                                                                                                                                                                                                           | TRS3         | \$90.18      | \$17.60              | \$6.36               | \$66.22                        |
| 2002                                                                                                                                                                                                                                                                           | Accomack     | (\$3.25)     | \$21.65              | (\$0.23)             | (\$24.67)                      |
| 2003                                                                                                                                                                                                                                                                           | Accomack     | \$24.87      | \$13.46              | \$1.75               | \$9.65                         |
| 2004                                                                                                                                                                                                                                                                           | Accomack     | \$76.15      | \$13.46              | \$5.37               | \$57.32                        |
| 2004                                                                                                                                                                                                                                                                           | Augusta      | \$19.39      | \$10.35              | \$1.37               | \$7.67                         |
| 2004                                                                                                                                                                                                                                                                           | Charles City | \$34.25      | \$12.42              | \$2.42               | \$19.42                        |
| 2004                                                                                                                                                                                                                                                                           | Essex        | \$6.59       | \$13.46              | \$0.46               | (\$7.33)                       |
| 2004                                                                                                                                                                                                                                                                           | Westmoreland | \$7.45       | \$14.49              | \$0.53               | (\$7.57)                       |
| <sup>a</sup> Negative Costs are actually a gain to farmers                                                                                                                                                                                                                     |              |              |                      |                      |                                |
| The locations were the Peanut Belt Research Station (Lewiston), Denton Farms (Denton), Haslin Farms-Organic Ridge (HSOR) located in Belhaven, Haslin Farms-Sandy Ridge (HSSR) also in Belhaven, and the Tidewater Research Station (TRS) located in Plymouth (Sripada et al.). |              |              |                      |                      |                                |
| In years with no or low response to N, i.e. 2002, there will be net gains to farmers.                                                                                                                                                                                          |              |              |                      |                      |                                |

### Selecting Yield Response Curves

Ideally the costs of the program would be calculated based on estimated yield response curves for each soil type and each location for each year. However, there are limited data available so an approach needs to be utilized to capture the range of likely yield

responses to N reductions (Alley). This approach requires looking at the high and low extremes of yield response curves based on each type of rainfall year. The “best curve” from each category of rainfall year from the sample can be used to get an approximation of a “well responding” curve for each year (Alley). The best curve is defined as the curve that has a relatively high  $R^2$  value compared to the other curves in those years, and produces realistic estimates of yield outputs based on comparison with the historic data for those years. However, because of the small sample size it is not possible to be certain that we have a good representation of the high end extreme for yield responses to N for each year (Alley). The low end extreme for yield response to N is no response due to moisture stress, high amounts of residual N, disease, and other local field/weather conditions.

The yield response to N for each category is estimated based on the best yield response curve, defined as the best  $R^2$  value with realistic yield predictions. For 2000 and 2001, the best curve was from the data for Lewiston in 2001, which had an  $R^2$  value of .80, and produced a curve that behaved as expected (Figure 4.1). The field for the Lewiston 2001 data had Norfolk Loamy soil which is classified in corn management group III. Further, the yields under recommended levels of fertilizer for this curve were 10.4 Mg/ha, 9.1 Mg/ha, and 7.8 Mg/ha for soil groups I, II, and III, respectively. Procedures for yield adjustments for soil groups are described in a later section.

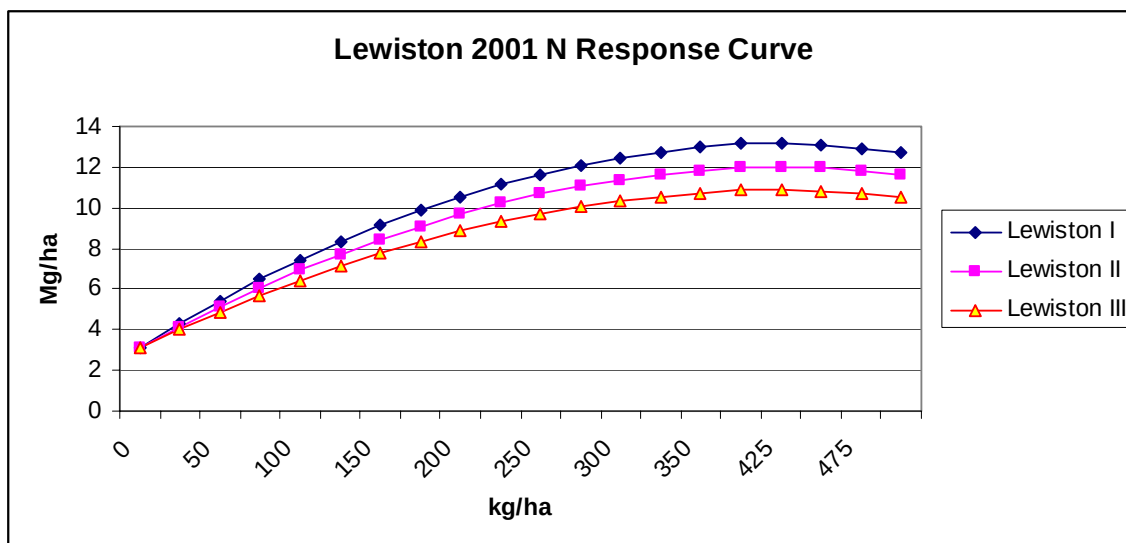


**Figure 4.1. Yield Response to N for Lewiston 2001 for Soil Management Groups I, II, and III**

For 2002, which was a drought year, the yield response curves show no response to N. Because the curves from this year did not produce good fits, the highest statistical fit being an  $R^2$  value of .24 from 2002, and because there is no or minimal response to N during drought, a zero yield response is assumed in low-yield years (Alley).

The data for Accomack in 2004 (Figure 4.2) provided the best fit of all the calculated yield response curves and were used to represent the yield response in good growing years. This curve had an  $R^2$  value of .9663. The corn in this field was grown on Bojac soil which is classified in soil group III on the Eastern Shore of Virginia where Accomack is located.

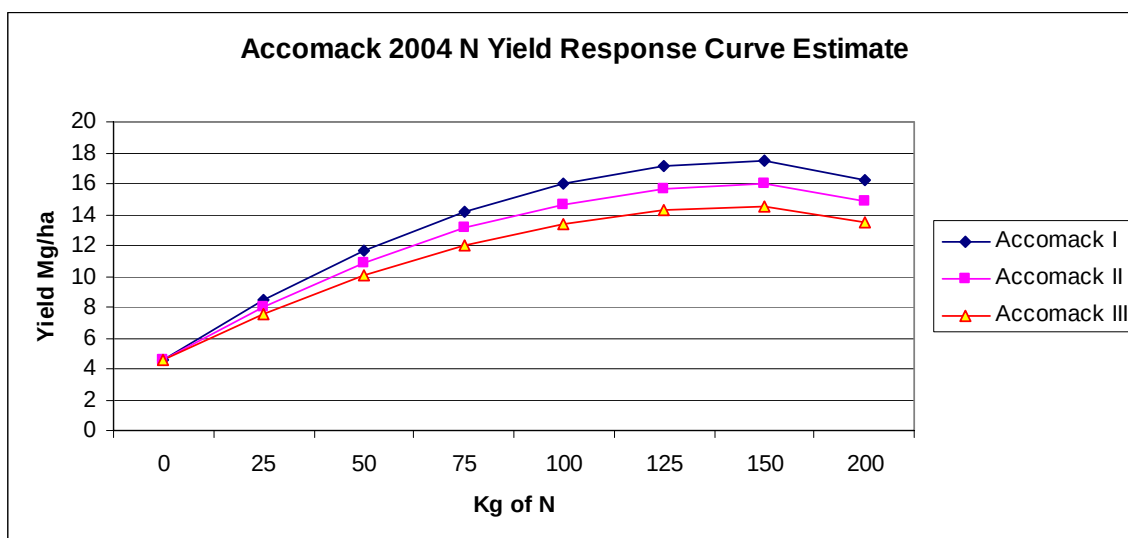


**Figure 4.2. Yield Response to N for Accomack 2004 for Soil Groups I, II, and III**

The other curves and costs that have been calculated are very important because they provide additional examples of observed yield response to N. These responses will be used to provide more information about the potential results of Yield Reserve, and to help demonstrate the potential for variability for each year.

### Seasonal Rainfall Probabilities

Rainfall data were compared to corn yields for the last 47 years in order to assign probabilities to yield response curves. Forty-seven years were used due to availability of rainfall data. Corn yield data were obtained from the National Agricultural Statistics Service, from 1958 to 2004 for 31 counties and independent cities in the Virginia Coastal plain (See Appendix A Table A.1). Rainfall data were obtained from the Southeast Regional Climate Center's web site for the corresponding years.

Weighted average corn yield data were determined by summing up the total acreage of corn harvested for all of the reporting counties for each year, summing up the total production of corn in Mg, and then dividing the production in Mg by the hectares harvested. Rainfall data were obtained for five weather stations on the Virginia Coastal Plain. The weather stations were chosen based on their geographic location and the completeness of their records over the 47 years of corn yields. The weather stations chosen were, “Williamsburg 2 N”, “Warsaw 2 N” in Richmond County, “Suffolk Lake Kilby” in Suffolk City, “Richmond WSO Airport” in Henrico County, and “Painter 2 W” in Accomack County. There were two data points that were missing for the months needed from the regression. Data for July 2001 for “Warsaw 2 N” and July 2003 for “Painter 2 W” were substituted with the corresponding months from “Walkerton 2 NW” in King and Queen, and “Wallops Island,” respectively. In order to mitigate variability in rainfall amounts, the five rainfall totals for each month were averaged (See Appendix A Table A.2 for the Average Total Rainfall for Each Month). Averaging is necessary because there can be significant spatial variability in rainfall amounts even in large fields (Alley).

To be able to predict yields with current practices from historic weather, yields were analyzed using a time series regression analysis against rainfall totals from growing months. There is a strong upwards trend over the sample years in yield rates due to reduction in the number of hectares that are farmed and a concentration of corn production on better soils, and because of improved hybrids and management practices (Alley) (see figure 4.3). Further, the strong linear trend is reflected in the fact that the

linear trend variable for year, yearnum, is the regressor that explains the most variability in the data. It has an individual  $R^2$  value of .3928 when regressed against yield. In order to account for trend, the variable yearnum with values of 1 to 47 was added to the model.

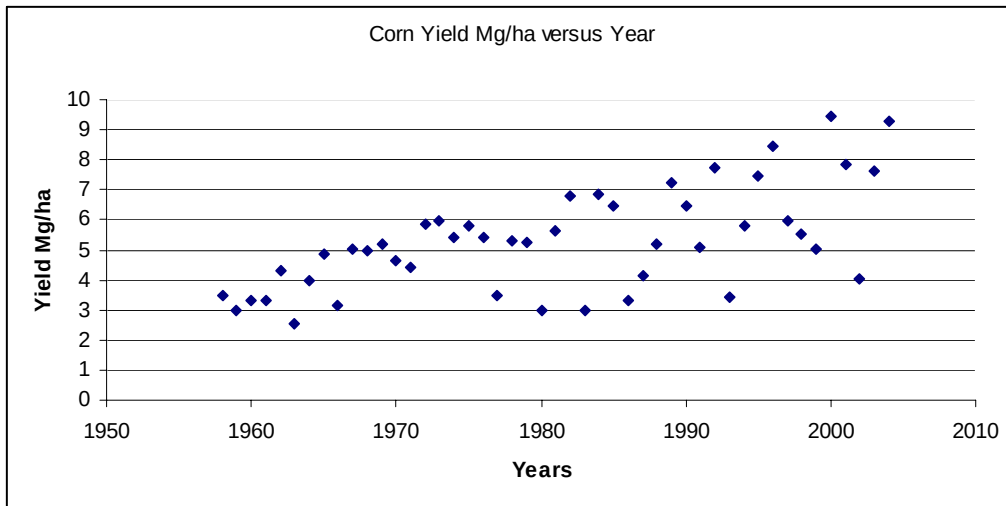


**Figure 4.3. Eastern Virginia Corn Yield versus Year**

The regressors, the yearnum and the rainfall for each month in the growing season, were each individually plotted against the response variable. The plots suggested that the regressors would have a better fit if natural log was taken (Figures 4.4 and 4.5).

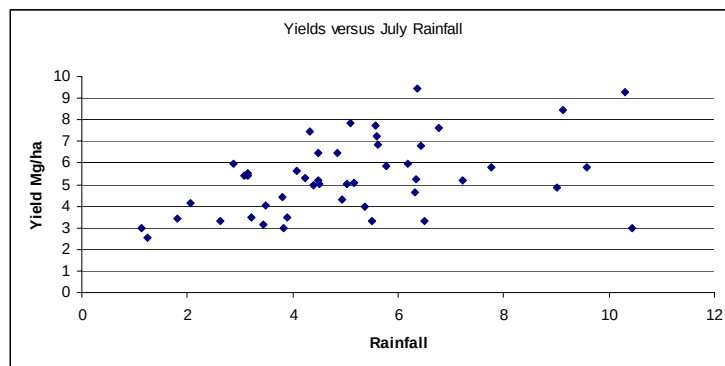


**Figure 4.4. Yields Versus July Precipitation**

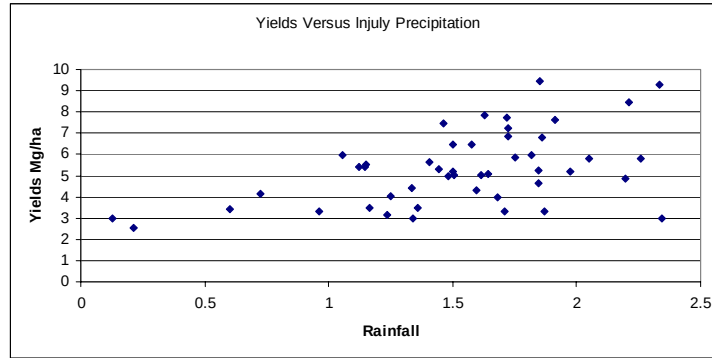


**Figure 4.5. Yield Versus Natural Log of July Precipitation**

After the transformations were completed, a regression was run using R-square and the C(p), encyclopedic (using all combinations of the variables), selection criteria in SAS. The best model defined as the most parsimonious, having highest  $R^2$ , and having all regressors significant, was the four regressor model, with the variables sqrtyear (the square root of the variable used for the yearly trend, which was used because it had a better fit), lnmay, lnjune, and lnjuly (natural logarithm of rainfall for each month). As can be seen from Table 4.8 below, all of the variables are significant at the 99 percent confidence level.

**Table 4.8. Summary Statistics of Rainfall Regression<sup>a</sup>**

| Sum of Mean                                                                                                |          |          |           |         |         |                       |        |
|------------------------------------------------------------------------------------------------------------|----------|----------|-----------|---------|---------|-----------------------|--------|
| Source                                                                                                     | DF       | Squares  | Square    | F Value | Pr > F  |                       |        |
| Model                                                                                                      | 4        | 26717    | 6679.27   | 36.26   | <.0001  |                       |        |
| Error                                                                                                      | 42       | 7735.63  | 184.18    |         |         |                       |        |
| Corrected Total                                                                                            | 46       | 34453    |           |         |         |                       |        |
| Root MSE                                                                                                   | 13.57    |          | R-Square  | 0.78    |         |                       |        |
| Dependent Mean                                                                                             | 84.45    |          | Adj. R-Sq | 0.75    |         |                       |        |
| Coeff Var                                                                                                  | 16.07    |          |           |         |         |                       |        |
| Parameter Estimates                                                                                        |          |          |           |         |         |                       |        |
| Parameter                                                                                                  | Standard |          |           |         |         |                       |        |
| Variable                                                                                                   | DF       | Estimate | Error     | t value | Pr >  t | 95% Confidence Limits |        |
| Intercept                                                                                                  | 1        | -54.27   | 12.58     | -4.32   | <.0001  | -79.65                | -28.89 |
| Sqrtyear                                                                                                   | 1        | 10.72    | 1.27      | 8.47    | <.0001  | 8.17                  | 13.28  |
| Lnmay                                                                                                      | 1        | 14.76    | 4.47      | 3.3     | 0.002   | 5.74                  | 23.78  |
| Lnjune                                                                                                     | 1        | 20.5     | 4.33      | 4.74    | <.0001  | 11.77                 | 29.24  |
| Lnjuly                                                                                                     | 1        | 29.32    | 4.2       | 6.98    | <.0001  | 20.84                 | 37.8   |
| <sup>a</sup> Regression was performed with 47 years of corn yields and rainfall data for Eastern Virginia. |          |          |           |         |         |                       |        |

The corresponding model for predicting yield response compared to rainfall is:

$$(13) \text{ Yield} = -54.272 + 10.72239\text{sqrtyear} + 14.760\text{lnmay} + 20.504\text{lnjune} + 29.321\text{lnjuly}$$

Yield refers Mg of corn per hectare, and lnmay, lnjune, and lnjuly refer to the natural logarithms of rainfall for May, June, and July, respectively. The residuals of the regression are distributed randomly (as can be seen in the figure 4.6).

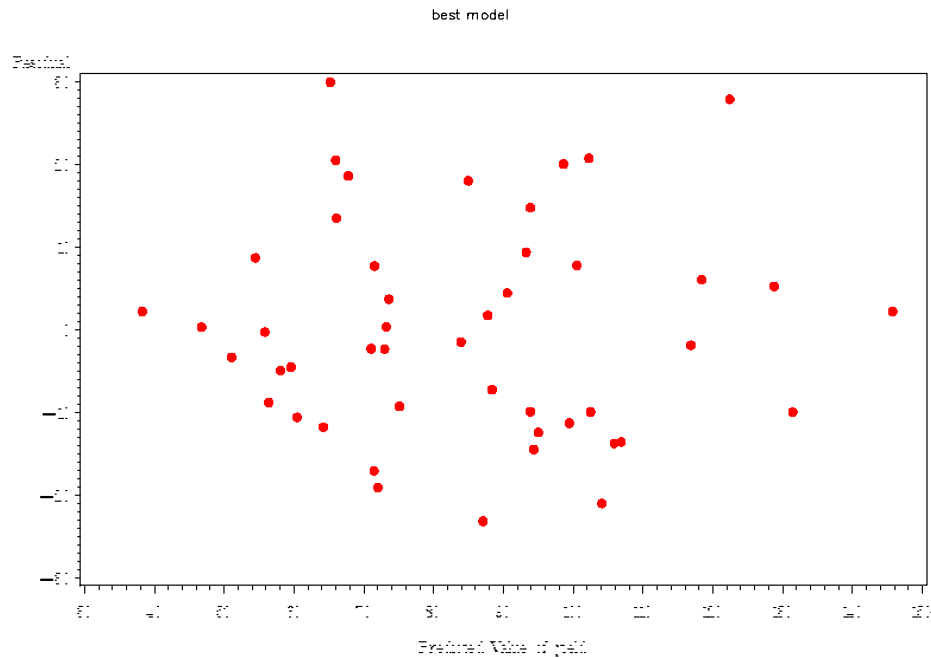


**Figure 4.6. Residual Distribution of Yields Predicted by Rainfall and Time Trend**

The model was used to predict yields based on current practices for the 47 years of data. The projected yields from the model are used to determine the likelihood of good and bad years in terms of rainfall for corn production. The predicted yield values for the data can be found in Table A.3 in Appendix A.

### **Rainfall Probabilities**

Three categories of yield responses were determined for the detrended historic data corresponding to each year of rainfall data (see Table A.1 in Appendix A). The data from 2003 and 2004 were very closely grouped, and were used to form the high-yield group, because these years gave the highest response to N. The average-yield was based on the 2000 and 2001 data, and low-yield years were based on the 2002 data. The division lines between each group were calculated by taking the average of the lowest value from the

“upper” group, and highest value of the “lower” group yields corresponding to each year and are taken from the detrended historic yield (see Figure 4.7 below). The division line between good and average years was 8.1 Mg/ha, which was the average of the lowest yield for 2003 and 2004, the high yield years, of 8.3 Mg/ha and the high yield of 2000 and 2001, the average years, which was 7.9 Mg/ha. The lower division line for the yields was 6.6 Mg/ha, which was the average of the low end of the average year estimates of 7.6 Mg/ha and the low estimate for the low yield year of 2002 of 5.6 Mg/ha, the only year available for no to low response to N. The good growing year group consisted of all years with de-trended estimates above 8.1 Mg/ha, the middle group was all values between 6.6 Mg/ha and 8.1 Mg/ha, and the lowest group was composed of all years with a de-trended yield estimate of less than 6.6 Mg/ha. There were 6 years that fell into the highest yield groups, 23 years in the average yield groups, and 18 years in the low yield group. The corresponding probabilities of these types of years occurring are 13 percent for a good year (high response to N), 49 percent of an average year (average response to N), and 38 percent of a bad year, little or no response yield years.

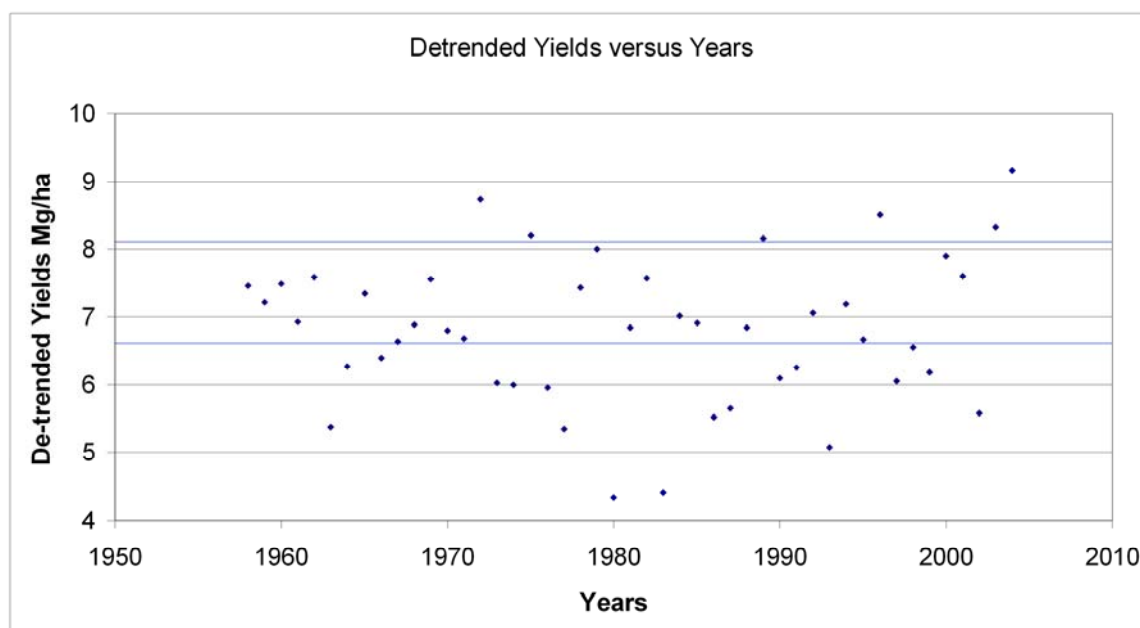


**Figure 4.7. Yield Classification Groups, Good (Top), Average (Middle), and Low to No Response (Bottom)**

### **Soil Profiles and Yield Adjustments Based on County Soil Types**

The soil profiles for Virginia Coastal Plain counties were obtained from the USDA Natural Resource Conservation Service's Soil Data Mart (see Table 4.9 for Accomack's data). The jurisdictions that had corn acreage and hence were used in this study were, Accomack, Charles City, Caroline, Dinwiddie, Essex, Gloucester, Hanover, Henrico, Isle of Wight, James, King and Queen, King George, King Williams, Lancaster, Mathews, Middlesex, New Kent, Northampton, Northumberland, Prince George, Prince William, Richmond County, Southampton, Stafford, Spotsylvania, Suffolk City, Surry, and Westmoreland. In order to adjust yield predictions for each county to better represent actual conditions, estimated yield response curves were adjusted for soils in each county using information on soil productivity from the Virginia Nutrient Management and Standards Criteria information. Since the Virginia Nutrient Management and Standards

Criteria provide approximate fertilizer recommendations by soil type, the criteria can be used to normalize yield responses to N by soil type.

**Table 4.9. Accomack County Soils in Corn Management Groups**

| <b>Soil Series</b>                                                                                                     | <b>Acres</b> | <b>Percent</b> | <b>Soil Manag. Group<sup>b</sup></b> | <b>Corn Mgmt<sup>b</sup></b> |
|------------------------------------------------------------------------------------------------------------------------|--------------|----------------|--------------------------------------|------------------------------|
| Arapahoe mucky loam, 0 to 2 percent slopes, rarely flooded                                                             | 8,600        | 4.26%          | EE                                   | IVb                          |
| Assateague fine sand, 2 to 35 percent slope, rarely flodded                                                            | 1,510        | 0.75%          | QQ                                   | V                            |
| Bojac loamey sand, 2 to 6 percent slopes                                                                               | 15,330       | 7.60%          | T                                    | IIIb                         |
| Bojac sandy loam, 0 to 2 percent slopes                                                                                | 44,040       | 21.83%         | T                                    | IIIb                         |
| Bojac fine sandy loam, 0 to 2 percent slopes                                                                           | 6,470        | 3.21%          | T                                    | IIIb                         |
| Dragston fine sandy loam, 0 to 2 percent slopes                                                                        | 15,225       | 7.55%          | EE                                   | Ila                          |
| Fisherman-Assateague complex, 0 to 35 percent slopes, rarely flooded                                                   | 970          | 0.48%          | QQ                                   | V                            |
| Molena loamy sand, 0 to 6 percent slopes                                                                               | 3,385        | 1.68%          | II                                   | V                            |
| Molena loamy sand, 6 to 35 percent slopes                                                                              | 7,100        | 3.52%          | II                                   | V                            |
| Munden sandy loam, 0 to 2 percent slopes                                                                               | 31,580       | 15.66%         | F                                    | Ila                          |
| Nimmo sandy loam, 0 to 2 percent slopes                                                                                | 67,230       | 33.33%         | E                                    | Ila                          |
| Seabrook loamy fine sand, 0 to 2 percent slopes                                                                        | 265          | 0.13%          | EE                                   | IVb                          |
| Total with groupings                                                                                                   | 201,705      | 100.00%        |                                      |                              |
| <sup>a</sup> From USDA Natural Resource Conservation Service's Soil Data Mart                                          |              |                |                                      |                              |
| <sup>b</sup> Soil Management Group and Corn Management groups from Virginia Nutrient Management Standards and Criteria |              |                |                                      |                              |

The soil survey of each county in the sample was obtained, and each county's area of soil fitting into corn soil management groups was summarized. Any land that was not assigned a management group, or was in management groups IV and V was removed. In general, these management groups are not suitable for economically viable corn production. The management groups were combined into the major groups (i.e. Ia and Ib were combined to just I) by averaging their recommended levels of fertilizer. Next, the percentage of the remaining soils in management groups I, II, and III of the type of soil in the county was calculated (see Table 4.10 for Accomack and Appendix B for area of soil groups I, II, and II for the entire Coastal Plain). The number of hectares of each soil

management group producing corn, was assumed to be proportional to the total number of hectares of each corn soil management group.

**Table 4.10. Five Year Average Accomack Soils Groups I, II, and III in Hectares for Corn**

| Soil Group                                                                                                                                                                                             | 2000 | 2001 | 2002 | 2003 | 2004  | Average | Percent <sup>a</sup> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|-------|---------|----------------------|
| I                                                                                                                                                                                                      | 0    | 0    | 0    | 0    | 0     | 0       | 0                    |
| II                                                                                                                                                                                                     | 5390 | 5647 | 6160 | 5903 | 6365  | 5893    | 63%                  |
| III                                                                                                                                                                                                    | 3112 | 3260 | 3557 | 3408 | 3675  | 3403    | 37%                  |
| <b>Total</b>                                                                                                                                                                                           | 8502 | 8907 | 9717 | 9312 | 10041 | 9296    |                      |
| The five year averages of hectares planted with corn. Data from NASS                                                                                                                                   |      |      |      |      |       |         |                      |
| <sup>a</sup> Assignment of corn to soil groups was based on the percentage of the total number of hectares in each county for the soil type compared to the entire area in groups I, II, and III soils |      |      |      |      |       |         |                      |

The information on corn soil management groups was used to adjust the estimated yield response curves to predict yields for the productivity groups not represented in each category. The adjustment percentages (Table 4.11) were multiplied by the linear and quadratic terms in each yield response curve, so that the estimated curves yield responses to N for the other productivity groups could be determined based on the basic shape of the curve. The intercepts were not adjusted.

**Table 4.11. Soil Productivity Adjustments**

| Soil Productivity Groups                                                                                                                                                                                                                                                   | Estimated Likely Grain Yield, Mg/ha <sup>a</sup> | Percent of Soil Management group Ib | Percent of Soil Management group II | Percent of Soil Management group III |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-------------------------------------|-------------------------------------|--------------------------------------|
| I                                                                                                                                                                                                                                                                          | 11.00                                            | 100%                                | 113%                                | 130%                                 |
| II                                                                                                                                                                                                                                                                         | 9.75                                             | 89%                                 | 100%                                | 115%                                 |
| III                                                                                                                                                                                                                                                                        | 8.49                                             | 77%                                 | 87%                                 | 100%                                 |
| <sup>a</sup> Likely Grain Yield based on Virginia Nutrient Management Standards and Criteria Guide                                                                                                                                                                         |                                                  |                                     |                                     |                                      |
| <sup>b</sup> Percentage of adjustment of realistic yields for the top three soil management groups, these were derived by calculating the ratio between each soil group's estimated likely grain yields from the Virginia Nutrient Management Standards and Criteria Guide |                                                  |                                     |                                     |                                      |

### **Economically Optimal Rate**

The economically optimal level of fertilizer that would be derived from the data may not be the same as the actual levels recommended by Cooperative Extension Service. The economically optimal rate of fertilizer is the point at which  $MR = MC$ , and the maximum level of profit is reached. If the economically optimal level is higher than the recommended level, then farmers would be at a disadvantage using programs that are linked to the lower value. If, however, the economically optimal rate of fertilizer usage is below the recommended rate, then farmers' net revenues would not be as greatly affected by programs based on extension recommended rates, and if optimal rates are significantly lower than recommended rates, farmers' net revenues could increase under programs with lower than recommended levels of fertilizer.

The economically optimal rate for the data in this study can be derived by using the price of corn, transportation, and N, and the yield functions derived from the regression of the data. The net revenue function for farmers is:

$$(14) \text{ netrevenue} = (\text{Yield}_n)(P_c - P_t) - P_n * N$$

Net revenue equals yield based on the level of N times the price of corn minus the price of transportation minus the cost of fertilizer. Fixed costs are not included in this analysis.

To determine the economically optimal level of fertilizer for the data in this study, the above equation was used to calculate the net revenue for levels of fertilizer in 9 kg (20lb)

increments up to 400 kg of N for 2001 Lewiston and 2004 Accomack, the curves used for average and good growing years, respectively. For poor growing years 2002 TRS-ORG was used, since it had the lowest response to N and hence fit the assumption of low to no response the best.

Individual net revenue levels were estimated for 47 N applications, 0 to 360 kg/ha in intervals of 9kg/ha. The individual economically optimal level of fertilizer varied greatly between the different fields. Surprisingly, the economically optimal rate was higher in the average years than in the good years (Tables 4.12, 4.13, and 4.14). However, at the calculated economically optimal rates of fertilization in good years still produced greater revenues for farmers than did the fields from the average years (Tables 4.12, 4.13, and 4.14).

**Table 4.12. Net Revenue Responses to N Applications Soil Group I**

| <b>N Applied</b>                                                                                                                                                                                                             | <b>Good Year<sup>a</sup></b> | <b>Average Year<sup>a</sup></b> | <b>No to Low Response Year<sup>a</sup></b> | <b>Total Expected Net Return<sup>b</sup></b> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|---------------------------------|--------------------------------------------|----------------------------------------------|
| <b>0</b>                                                                                                                                                                                                                     | \$436.48                     | \$295.99                        | \$337.91                                   | \$329.98                                     |
| <b>9</b>                                                                                                                                                                                                                     | \$579.16                     | \$331.97                        | \$335.97                                   | \$365.06                                     |
| <b>18</b>                                                                                                                                                                                                                    | \$713.02                     | \$367.02                        | \$333.91                                   | \$398.51                                     |
| ...                                                                                                                                                                                                                          |                              |                                 |                                            |                                              |
| <b>144</b>                                                                                                                                                                                                                   | \$1,661.98                   | \$761.32                        | \$292.87                                   | \$696.89                                     |
| <b>153</b>                                                                                                                                                                                                                   | \$1,663.69                   | \$782.59                        | \$289.07                                   | \$706.06                                     |
| <b>162</b>                                                                                                                                                                                                                   | \$1,656.58                   | \$802.94                        | \$285.14                                   | \$713.61                                     |
| ...                                                                                                                                                                                                                          |                              |                                 |                                            |                                              |
| <b>180</b>                                                                                                                                                                                                                   | \$1,615.93                   | \$840.89                        | \$276.94                                   | \$723.85                                     |
| <b>189</b>                                                                                                                                                                                                                   | \$1,582.39                   | \$858.49                        | \$272.66                                   | \$726.54                                     |
| <b>198</b>                                                                                                                                                                                                                   | \$1,540.04                   | \$875.17                        | \$268.27                                   | \$727.61                                     |
| <b>207</b>                                                                                                                                                                                                                   | \$1,488.88                   | \$890.93                        | \$263.75                                   | \$727.07                                     |
| ...                                                                                                                                                                                                                          |                              |                                 |                                            |                                              |
| <b>333</b>                                                                                                                                                                                                                   | (\$152.49)                   | \$1,015.07                      | \$188.31                                   | \$549.39                                     |
| <b>342</b>                                                                                                                                                                                                                   | (\$335.81)                   | \$1,017.05                      | \$182.05                                   | \$524.56                                     |
| <b>351</b>                                                                                                                                                                                                                   | (\$527.94)                   | \$1,018.11                      | \$175.66                                   | \$498.10                                     |
| <b>360</b>                                                                                                                                                                                                                   | (\$728.88)                   | \$1,018.24                      | \$169.16                                   | \$470.03                                     |
| <sup>a</sup> Net Revenue for soil group I for each year type, note maximum revenue comes at 153 kg N/ha for good years, 360 kg n/ha for average years, and 0 kg N/ha for No to low response years.                           |                              |                                 |                                            |                                              |
| <sup>b</sup> The total expected net return is calculated by taking the weighted average of net returns for each year type, weighted by likelihood of the year occurring. This weighting produce a maximum at 198 kg of N/ha. |                              |                                 |                                            |                                              |

**Table 4.13. Net Revenue Responses to N Applications Soil Group II**

| <b>N Applied</b>                                                                                                                                                                                                   | <b>Good Year</b> | <b>Average Year</b> | <b>No to Low Response Year</b> | <b>Total Expected Net Return</b> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------|--------------------------------|----------------------------------|
| <b>0</b>                                                                                                                                                                                                           | \$433.66         | \$295.99            | \$337.91                       | \$329.62                         |
| <b>9</b>                                                                                                                                                                                                           | \$560.02         | \$327.22            | \$335.56                       | \$360.13                         |
| <b>18</b>                                                                                                                                                                                                          | \$678.59         | \$357.64            | \$333.10                       | \$389.21                         |
| ...                                                                                                                                                                                                                |                  |                     |                                |                                  |
| <b>144</b>                                                                                                                                                                                                         | \$1,519.10       | \$698.00            | \$287.88                       | \$645.76                         |
| <b>153</b>                                                                                                                                                                                                         | \$1,520.61       | \$716.21            | \$283.88                       | \$653.32                         |
| <b>162</b>                                                                                                                                                                                                         | \$1,514.31       | \$733.60            | \$279.77                       | \$659.46                         |
| ...                                                                                                                                                                                                                |                  |                     |                                |                                  |
| <b>180</b>                                                                                                                                                                                                         | \$1,478.31       | \$765.95            | \$271.23                       | \$667.42                         |
| <b>189</b>                                                                                                                                                                                                         | \$1,448.61       | \$780.90            | \$266.81                       | \$669.25                         |
| <b>198</b>                                                                                                                                                                                                         | \$1,411.10       | \$795.04            | \$262.28                       | \$669.65                         |
| <b>207</b>                                                                                                                                                                                                         | \$1,365.78       | \$808.36            | \$257.66                       | \$668.61                         |
| ...                                                                                                                                                                                                                |                  |                     |                                |                                  |
| <b>333</b>                                                                                                                                                                                                         | (\$88.00)        | \$909.45            | \$181.97                       | \$503.50                         |
| <b>342</b>                                                                                                                                                                                                         | (\$250.37)       | \$910.57            | \$175.78                       | \$480.95                         |
| <b>351</b>                                                                                                                                                                                                         | (\$420.55)       | \$910.87            | \$169.50                       | \$456.97                         |
| <b>360</b>                                                                                                                                                                                                         | (\$598.52)       | \$910.36            | \$163.10                       | \$431.55                         |
| <sup>a</sup> Net Revenue for soil group I for each year type, note maximum revenue comes at 153 kg N/ha for good years, 351 kg n/ha for average years, and 0 kg N/ha for No to low response years.                 |                  |                     |                                |                                  |
| <sup>b</sup> The total expected net return is calculated by taking the weighted average of net returns for each year type, weighted by likelihood of the year occurring. This produce a maximum at 198 kg of N/ha. |                  |                     |                                |                                  |

**Table 4.14. Net Revenue Response Soil Group III**

| <b>N Applied</b>                                                                                                                                                                                                   | <b>Good Year</b> | <b>Average Year</b> | <b>No to Low Response Year</b> | <b>Total Expected Net Return</b> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------|--------------------------------|----------------------------------|
| <b>0</b>                                                                                                                                                                                                           | \$433.66         | \$295.99            | \$337.91                       | \$329.62                         |
| <b>9</b>                                                                                                                                                                                                           | \$543.72         | \$322.48            | \$335.14                       | \$355.57                         |
| <b>18</b>                                                                                                                                                                                                          | \$646.98         | \$348.25            | \$332.29                       | \$380.28                         |
| ...                                                                                                                                                                                                                |                  |                     |                                |                                  |
| <b>144</b>                                                                                                                                                                                                         | \$1,379.04       | \$634.68            | \$282.89                       | \$594.98                         |
| <b>153</b>                                                                                                                                                                                                         | \$1,380.36       | \$649.82            | \$278.69                       | \$600.95                         |
| <b>162</b>                                                                                                                                                                                                         | \$1,374.87       | \$664.26            | \$274.39                       | \$605.66                         |
| ...                                                                                                                                                                                                                |                  |                     |                                |                                  |
| <b>180</b>                                                                                                                                                                                                         | \$1,343.52       | \$691.00            | \$265.53                       | \$611.35                         |
| <b>189</b>                                                                                                                                                                                                         | \$1,317.64       | \$703.31            | \$260.96                       | \$612.32                         |
| <b>198</b>                                                                                                                                                                                                         | \$1,284.97       | \$714.91            | \$256.30                       | \$612.05                         |
| <b>207</b>                                                                                                                                                                                                         | \$1,245.51       | \$725.80            | \$251.56                       | \$610.52                         |
| ...                                                                                                                                                                                                                |                  |                     |                                |                                  |
| <b>333</b>                                                                                                                                                                                                         | (\$20.69)        | \$803.83            | \$175.62                       | \$457.98                         |
| <b>342</b>                                                                                                                                                                                                         | (\$162.11)       | \$804.08            | \$169.52                       | \$437.71                         |
| <b>351</b>                                                                                                                                                                                                         | (\$310.33)       | \$803.63            | \$163.33                       | \$416.20                         |
| <b>360</b>                                                                                                                                                                                                         | (\$465.34)       | \$802.47            | \$157.05                       | \$393.44                         |
| <sup>a</sup> Net Revenue for soil group I for each year type, note maximum revenue comes at 153 kg N/ha for good years, 342 kg n/ha for average years, and 0 kg N/ha for No to low response years.                 |                  |                     |                                |                                  |
| <sup>b</sup> The total expected net return is calculated by taking the weighted average of net returns for each year type, weighted by likelihood of the year occurring. This produce a maximum at 189 kg of N/ha. |                  |                     |                                |                                  |

After each group of optimal rates and revenues were calculated, a composite economically optimal rate was estimated at each interval by taking the weighted average of each curves net revenue and searching for the maximum revenue. This produced recommendations of 198 kg/ha (178 lbs/kg), 198 kg/ha (718 lbs/ac), and 189 kg/ha (170 lbs/ac) for soil management groups I, II, and III, respectively (figure 4.8). These rates were close to the recommended rates of 196 kg/ha (175 lbs/ac), 174 kg/ha (155 lbs/ac), and 151 kg/ha (135 lbs/ac) per hectare for soil management groups I,II, and III respectively. Losses from Yield Reserve are estimated under Cooperative Extension recommended N applications.

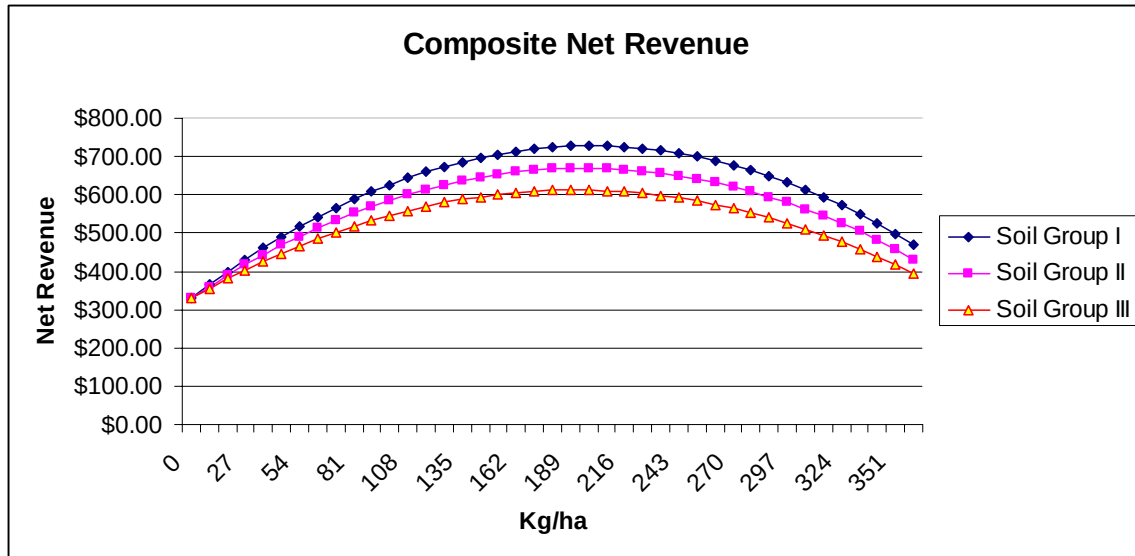


**Figure 4.8. Composite Net Revenue Functions for Soil Groups I, II, and III<sup>a</sup>**

<sup>a</sup> Revenue is maximized at 198 kg of N per ha for soil groups I and II, and at 189 kg of N per ha for soil group III.

### Expected Net Revenue

The estimated costs of the Yield Reserve Program for each county, and the Virginia Coastal Plain as a whole are estimated by inserting the calculations made in this chapter into the expected profit model presented in Chapter 3. The results for Essex were derived first, and then the model was expanded to every county in the Virginia Coastal Plain. The results for Essex County are presented here for illustrations. Results for the entire Virginia Coastal Plain are presented in the next chapter.

## Calculations for Essex County

Projected costs for Essex County are described in detail to illustrate the calculations.

Essex County was selected as a representative county, because it has a significant level of corn acreage and each of the corn management soil types used in the study, I, II, and III, is represented in the county.

### *Essex Average Years*

For Essex County under average rainfall, Yield Reserve produced an estimated average cost of approximately \$43 per hectare (see Table 4.15). Under Yield Reserve there would be an average yield penalty of approximately .6 Mg/ha, with 23.7 kg/ha less N applied to the fields in the county. This yield reduction would correspond to a total estimated cost to farmers for average years of approximately \$296,000 for a total reduction of 164,000 kg of N applied to the fields. The cost per kg of N reduced would be approximately \$1.80 not counting administration costs.

**Table 4.15. Average Year Cost and Yield Calculations for Corn Grown in Essex County**

| Soil Management Group                                                                                                                             | Yield (MG) <sup>a</sup> | YRP Yield (MG) <sup>b</sup> | Yield Differences (MG) <sup>c</sup> | Farmer Net Cost <sup>d</sup> | N Reductions (kg) <sup>e</sup> |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------|-------------------------------------|------------------------------|--------------------------------|
| I                                                                                                                                                 | 1,926                   | 1,777                       | 149                                 | \$10,813                     | 5,431                          |
| II                                                                                                                                                | 15,463                  | 14,287                      | 1,176                               | \$84,550                     | 44,473                         |
| III                                                                                                                                               | 39,128                  | 36,281                      | 2,847                               | \$200,634                    | 114,143                        |
| <b>Total</b>                                                                                                                                      | 56,518                  | 52,345                      | 4,172                               | \$295,997                    | 164,048                        |
| <b>per ha</b>                                                                                                                                     | 8.2                     | 7.6                         | 0.60                                | \$43                         | 23.7                           |
| <sup>a</sup> Yield under Cooperative Extension Recommended N application rates                                                                    |                         |                             |                                     |                              |                                |
| <sup>b</sup> Yield under Yield Reserve Program N application rates                                                                                |                         |                             |                                     |                              |                                |
| <sup>c</sup> Extension recommended fertilizer rate yield minus YRP yield.                                                                         |                         |                             |                                     |                              |                                |
| <sup>d</sup> Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue from lowered yields. |                         |                             |                                     |                              |                                |
| <sup>e</sup> N reductions are the lowered amount of N applied under YRP application rates compared to extension recommended rates.                |                         |                             |                                     |                              |                                |

The costs to farmers came from average projected lost revenue for the reduction in yields of almost \$62 per hectare. This loss is mitigated by lower projected N costs of approximately \$15 per hectare and lower transportation costs of about \$4 per hectare. The total lost revenue for Essex County for an average year is estimated as approximately \$427,000. The total gain from Yield Reserve for Essex County during an average year is estimated as approximately \$101,000 for reductions in fertilizer, and approximately \$30,000 for lowered transportation costs (see table 4.16)

**Table 4.16. Changes in Costs and Revenues for Essex County Under Yield Reserve levels of N in Average Years**

| Soil Group            | Loss in Revenue | Changes in N Costs | Transportation Costs | Farmer's Net Cost |
|-----------------------|-----------------|--------------------|----------------------|-------------------|
| I                     | \$15,230        | \$3,346            | \$1,074              | \$10,813          |
| II                    | \$120,430       | \$27,395           | \$8,492              | \$84,550          |
| III                   | \$291,500       | \$70,312           | \$20,554             | \$200,634         |
| <b>Total</b>          | \$427,170       | \$101,053          | \$30,120             | \$295,997         |
| <b>Average per ha</b> | \$62            | \$15               | \$4                  | \$43              |

#### *Essex Bad Years*

For bad years in Essex, the savings per hectare of corn is equal to the cost of the 15 percent less N fertilizer relative to the base recommendation level for each soil type. Farmers would save about \$18, \$16, and \$14 per hectare in corn soil management groups I, II, and III, respectively. The overall average per hectare savings is approximately \$15. The Yield Reserve Program in a bad year would provide farmers in Essex with an estimated savings of approximately \$101,000 for 164,000 kg of lower N fertilizer applications.

### *Essex Good Years*

The best growing seasons should have the highest potential for significant yield penalties.

The yield response curve used to represent this category was the curve with the second highest associated yield penalty in the study, Accomack 2004. Data from this curve produced an average cost of approximately \$62 per hectare, with costs of \$81, \$70, and \$56, for soil groups I, II, and III respectively.

Of the other nine yield response curves for the good years, the highest cost for any soil management group was \$101 per hectare. However, this cost was associated with the curve from 2003 TRS2, and this curve had an  $R^2$  value of only .56. The second highest cost was associated with TRS1, but TRS1 had a low  $R^2$  value of only .58. These curves show that there is a very large range of possible losses from reduced N but these losses are likely to be less than those estimated with the curve from Accomack 2004.

The total predicted yield penalty based on Accomack 2004 was estimated to be .80 Mg/ha. This yield penalty had a total cost of \$62. In good years there will be a total reduction in N of approximately 164,000 kg, or roughly 23.7 kg/ha (see table 4.17).

**Table 4.17. Yields, Costs, and N Reductions Associated with Good Rainfall Years for Essex County with Extension Recommended and YRP Levels of N Fertilization**

| Soil Group                                                                                                                                                       | Yield (MG) <sup>a</sup> | YRP Yield (MG) <sup>b</sup> | Yield Differences (MG) <sup>c</sup> | Farmer Net Cost <sup>d</sup> | N Reductions (kg) <sup>e</sup> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------|-------------------------------------|------------------------------|--------------------------------|
| I                                                                                                                                                                | 2,690                   | 2,497                       | 193                                 | \$ 15,019                    | 5,431                          |
| II                                                                                                                                                               | 21,740                  | 20,189                      | 1550                                | \$120,124                    | 44,473                         |
| III                                                                                                                                                              | 55,380                  | 51,578                      | 3801                                | \$291,480                    | 114,143                        |
| <b>Total</b>                                                                                                                                                     | 79,810                  | 74,265                      | 5545                                | \$426,625                    | 164,048                        |
| <b>per ha</b>                                                                                                                                                    | 11.53                   | 10.73                       | 0.80                                | \$ 61.62                     | 23.70                          |
| <sup>a</sup> Predicted yields for Essex County in good years under extension recommended N rates                                                                 |                         |                             |                                     |                              |                                |
| <sup>b</sup> Predicted yields for Essex County in good years under Yield Reserve Program N rates                                                                 |                         |                             |                                     |                              |                                |
| <sup>c</sup> Yield differences are determined by subtracting predicted yields under Yield Reserve Program N rates from those under extension recommended N rates |                         |                             |                                     |                              |                                |
| <sup>d</sup> Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue from lowered yields.                |                         |                             |                                     |                              |                                |
| <sup>e</sup> N reductions are the lowered amount of N applied under YRP application rates compared to extension recommended rates.                               |                         |                             |                                     |                              |                                |

The costs to farmers came from projected lost revenue for the reduction in yields of \$82 on average per hectare. This loss of revenue is mitigated by lower projected N costs of \$15 per hectare and lower transportation costs of \$6 per hectare. The total lost revenue to corn growers in Essex County for a good year is estimated to be approximately \$568,000. The gains to farmers from Yield Reserve in Essex County during a good year were estimated as approximately \$101,000 from reductions in fertilizer used and approximately \$40,000 for lowered transportation costs (see table 4.18). The net costs to farmers in Essex would be approximately \$427,000.

**Table 4.18. Changes in Costs and Revenues for Essex County Under Yield Reserve levels of N in Good Years**

| Soil Group         | Lost Revenue | Lower N Costs | Transportation Costs | Farmer's Net Cost |
|--------------------|--------------|---------------|----------------------|-------------------|
| I                  | \$19,760     | \$3,350       | \$1,390              | \$15,020          |
| II                 | \$158,710    | \$27,400      | \$11,190             | \$120,120         |
| III                | \$389,240    | \$70,310      | \$27,450             | \$291,480         |
| <b>Total</b>       | \$567,700    | \$101,050     | \$40,030             | \$426,620         |
| <b>Per ha Avg.</b> | \$82         | \$15          | \$6                  | \$62              |

### *Essex Overall*

Based on the estimated costs for each category of year and the likelihood of each year category occurring, the costs of Yield Reserve for corn growers in Essex County can be estimated. The estimated probabilities of each type of year occurring are 48.9 percent, 38.3 percent, and 12.8 percent, for the average, bad, and good years, respectively. These probabilities were calculated using the method described in this chapter and produced an estimated average cost, after deducting savings for lower N applications and transportation costs, for Yield Reserve of approximately \$161,000 a year for Essex County, or about \$23 per hectare.

### *Essex Sensitivity Analysis of Weather Probabilities*

The method to categorize years into the three groups was described above. This probability set estimates the actual costs of Yield Reserve. However, there is evidence that suggests that farmers over estimate the response of yields to N (SriRamaratnam et. al., Pease). If farmers “forget the bad years,” incentives to get farmers to adopt Yield Reserve will have to be higher than the level based on probabilities used in the study. To account for the possibility of farmers feeling the costs are higher, two additional weather probability scenarios are considered.

The first scenario considered assumes that farmers forget most of the bad years. Only years with yields lower than 2002’s de-trended yield, are considered bad years. The resulting probability set is 72 percent, 15 percent, and 13 percent chance of average, bad, and good years, respectively (2002 was the most recent drought year with poor yields).

This set produced a cost of \$37 per hectare, for a total cost of approximately \$253,500 average per year for Essex. Further, this probability set, has an associated projected yield penalty of approximately .54 Mg/ha, or a total of approximately 3,700 Mg for Essex.

A second scenario, which assumes that where farmers forget all of the bad years, is considered. All bad years are reclassified as average years resulting in a 87 percent chance of average years and a 13 percent chance of good years. The estimated costs for Essex with all of the bad years being re-classified as average years, comes to \$45 per hectare, for an approximate total average yearly cost of \$313,000. The associated yield penalties with all bad years reclassified as average years was approximately .63 Mg/ha per hectare, for an overall estimated penalty of approximately 4,300 Mg/ha (see Table 4.19).

**Table 4.19. Costs and Yield Penalties Based on Weather Probability for Essex County**

| Scenario <sup>a</sup>                                                                                                                             | Probability of Average Rainfall Year | Probability of Low Rainfall Year | Probability of Good Rainfall Year | Cost Per ha <sup>b</sup> | Overall Cost | Yield Penalty Mg/ha <sup>c</sup> | Total Yield Penalty Mg <sup>d</sup> |
|---------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------|-----------------------------------|--------------------------|--------------|----------------------------------|-------------------------------------|
| <b>Baseline</b>                                                                                                                                   | 49%                                  | 38%                              | 13%                               | \$23                     | \$160,600    | 0.40                             | 2,750                               |
| <b>Sensitivity I</b>                                                                                                                              | 72%                                  | 15%                              | 13%                               | \$37                     | \$253,540    | 0.54                             | 3,726                               |
| <b>Sensitivity II</b>                                                                                                                             | 87%                                  | 0.00%                            | 13%                               | \$45                     | \$312,670    | 0.63                             | 4,348                               |
| <sup>a</sup> The scenarios are the likelihood of Average, Bad, and Good growing seasons to occur.                                                 |                                      |                                  |                                   |                          |              |                                  |                                     |
| <sup>b</sup> Cost per ha is the predicted net cost to farmers associated with lowered yields, N applications, and transportation costs.           |                                      |                                  |                                   |                          |              |                                  |                                     |
| <sup>c</sup> Yield Penalty is the estimated per hectare yield difference between extension recommended rates and Yield Reserve Rates.             |                                      |                                  |                                   |                          |              |                                  |                                     |
| <sup>d</sup> Total Yield Penalty is the overall reduction in yield in Mg for Essex County under Yield Reserve versus extension recommended rates. |                                      |                                  |                                   |                          |              |                                  |                                     |

## **Chapter 5 Results**

The costs of Yield Reserve for the Virginia Coastal Plain were calculated based on the methods described in Chapter 4. Yield responses to N by soil management group and type of rainfall year were estimated as a basis for estimating costs of Yield Reserve. Next, farmers' net revenues were estimated after adding government payments calculated using each of the four approaches described in chapter 3, Incentive Payment, Insurance, Mixed Incentive Payment and Insurance, and Easement Payment for the entire study area<sup>2</sup>. The results were based on the different categories of years, bad, average, and good. Bad years were years with a very low yield response to N (defined as no to low response for this study). Average years are years that produce a good response, but not the best possible response, and good years are the years that have the highest yield response to N.

### **Overall Costs of Yield Reserve**

The costs and gains associated with Yield Reserve in each county were calculated and the aggregate was used to estimate the cost of the program for the Virginia Coastal Plain. Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue due to lowered yields. These costs (gains) have the potential to vary greatly from year to year depending on the type of growing season.

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<sup>2</sup> The jurisdictions in the study area were Accomack, Charles City, Caroline, Dinwiddie, Essex, Gloucester, Hanover, Henrico, Isle of Wight, James, King and Queen, King George, King Williams, Lancaster, Mathews, Middlesex, New Kent, Northhampton, Northumberland, Prince George, Prince William, Richmond County, Southampton, Stafford, Spotsylvania, Suffolk City, Surry, and Westmoreland.

### *Overall Costs of Yield Reserve in Average Years*

In average growing seasons, Yield Reserve would create a net cost to farmers in the Virginia Coastal Plain. These costs would be approximately \$47 per hectare, and would correspond to a yield penalty of .65 Mg/ha. There would be an overall cost of approximately \$4,477,500 for the Coastal Plain. These costs are the sum of costs of \$855,200, \$1,875,100, and \$1,747,200 for soil groups I, II, and III, respectively. (See Table 5.1 for the overall average costs, and Appendix C.1 for each county's cost).

**Table 5.1. Average Year Cost and Yield Reductions from Yield Reserve Program for Virginia Coastal Plain**

| Soil Group                                                                                                                                       | Yield (Mg) <sup>a</sup> | YRP Yield (Mg) <sup>b</sup> | Yield Differences (Mg) <sup>c</sup> | Farmer Net Cost <sup>d</sup> |
|--------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------|-------------------------------------|------------------------------|
| I                                                                                                                                                | 152,328                 | 140,561                     | 11,767                              | \$855,200                    |
| II                                                                                                                                               | 342,942                 | 316,853                     | 26,089                              | \$1,875,100                  |
| III                                                                                                                                              | 340,745                 | 315,951                     | 24,795                              | \$1,747,200                  |
| <b>Total</b>                                                                                                                                     | 836,016                 | 773,365                     | 62,651                              | \$4,477,500                  |
| <b>Per ha</b>                                                                                                                                    | 8.68                    | 8.03                        | 0.65                                | \$47                         |
| <sup>a</sup> Yield in Mg under extension level of N fertilizer                                                                                   |                         |                             |                                     |                              |
| <sup>b</sup> Yield in Mg under YRP level of N fertilizer                                                                                         |                         |                             |                                     |                              |
| <sup>c</sup> Yield differences in Mg that occur due to lower fertilizer application of YRP versus extension recommendations                      |                         |                             |                                     |                              |
| <sup>d</sup> Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue from lowered yields |                         |                             |                                     |                              |

In average growing years the estimated costs to farmers will be an average of \$47 per hectare, for a total estimated cost in the Virginia Coastal Plain of approximately \$4,477,500. Farmers will lose approximately \$6,414,300 in revenue from yield reductions. However, they will gain approximately \$1,484,500 in lower fertilizer costs, and about \$452,300 from lowered transportation costs (see Table 5.2)

**Table 5.2. Cost (Gain) Breakdown of Yield Reserve Program for Virginia Coastal Plain in an Average Year**

| <b>Soil Group</b>                                                                                                                                  | <b>Loss of Revenue</b> | <b>Lower N Costs</b> | <b>Transportation Costs</b> | <b>Farmer's Net Cost<sup>a</sup></b> |
|----------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----------------------|-----------------------------|--------------------------------------|
| <b>I</b>                                                                                                                                           | \$1,204,800            | \$264,600            | \$84,900                    | \$855,200                            |
| <b>II</b>                                                                                                                                          | \$2,671,000            | \$607,600            | \$188,300                   | \$1,875,100                          |
| <b>III</b>                                                                                                                                         | \$2,538,500            | \$612,300            | \$179,000                   | \$1,747,200                          |
| <b>Total</b>                                                                                                                                       | \$6,414,300            | \$1,484,500          | \$452,300                   | \$4,477,500                          |
| <b>Per ha avg.</b>                                                                                                                                 | \$67                   | \$15                 | \$5                         | \$47                                 |
| <sup>a</sup> Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue due to lowered yields |                        |                      |                             |                                      |

*Overall Costs of Yield Reserve in Bad Years*

In a bad year the projected estimated gains to farmers are savings on fertilizer and are an average of \$15 per hectare, for a total savings to farmers in the Virginia Coastal Plain of approximately \$1,484,500. In the bad year there is no yield penalty, and transportation and fuel costs to farmers do not change.

*Overall Costs of Yield Reserve in Good Years*

In good growing seasons, Yield Reserve would create a larger net cost to farmers on the Virginia Coastal Plain than the average years. These costs would be nearly \$20 more per hectare than average years or approximately \$66 per hectare. The yield penalty that would occur in good years would average .9 Mg/ha (Table 5.3).

**Table 5.3. Estimated Cost and Yield Reductions from Yield Reserve Program for Virginia Coastal Plain in Good Years**

| Soil Group                                                                                                                                         | Yield (Mg) <sup>a</sup> | YRP Yield (Mg) <sup>b</sup> | Yield Difference (Mg) <sup>c</sup> | Farmer Net Cost <sup>d</sup> | N Reductions (kg) |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------|------------------------------------|------------------------------|-------------------|
| I                                                                                                                                                  | 212,760                 | 197,490                     | 15,260                             | \$1,187,900                  | 429,600           |
| II                                                                                                                                                 | 482,140                 | 447,760                     | 34,380                             | \$2,664,00                   | 986,300           |
| III                                                                                                                                                | 482,270                 | 449,160                     | 33,110                             | \$2,538,300                  | 994,000           |
| <b>Total</b>                                                                                                                                       | <b>1,177,160</b>        | <b>1,094,410</b>            | <b>82,750</b>                      | <b>\$6,390,400</b>           | <b>2,409,900</b>  |
| <b>Per ha</b>                                                                                                                                      | <b>12.2</b>             | <b>11.4</b>                 | <b>0.86</b>                        | <b>\$66</b>                  | <b>25.0</b>       |
| <sup>a</sup> Yield in Mg under extension recommended level of N fertilizer                                                                         |                         |                             |                                    |                              |                   |
| <sup>b</sup> Yield in Mg under YRP level of N fertilizer                                                                                           |                         |                             |                                    |                              |                   |
| <sup>c</sup> Yield differences in Mg that occur due to lower fertilizer application of YRP versus extension recommendations                        |                         |                             |                                    |                              |                   |
| <sup>d</sup> Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue due to lowered yields |                         |                             |                                    |                              |                   |

In good growing years the cost of the program is approximately \$6,390,400 for the Virginia Coastal Plain. Good years will have estimated total yield penalties for the Virginia Coastal Plain of approximately 204,400 Mg/ha and an average yield penalty of approximately .86 Mg/ha (see Table 5.3). In good growing years there is a total loss revenue of approximately \$8,472,200. Gains will come from lowered N costs of approximately \$1,484,500 and transportation costs of \$597,400. There will be a total cost for the Virginia Coastal Plain of approximately \$6,390,400 (see table 5.4).

**Table 5.4. Change in Revenues and Costs from Yield Reserve for Virginia Coastal Plain in Good Years**

| Soil Management Group | Lost Revenue       | Lower N Costs      | Transportation Costs | Farmer's Net Cost  |
|-----------------------|--------------------|--------------------|----------------------|--------------------|
| I                     | \$1,562,700        | \$264,600          | \$110,200            | \$1,187,900        |
| II                    | \$3,519,900        | \$607,600          | \$248,200            | \$2,664,00         |
| III                   | \$3,389,600        | \$612,300          | \$239,000            | \$2,538,300        |
| <b>Total</b>          | <b>\$8,472,200</b> | <b>\$1,484,500</b> | <b>\$597,400</b>     | <b>\$6,390,400</b> |
| <b>Per ha avg.</b>    | <b>\$88</b>        | <b>\$15</b>        | <b>\$6</b>           | <b>\$66</b>        |

#### *Overall Costs for the Virginia Coastal Plain*

The above calculations for the costs (gains) of each type of year were multiplied by the estimated probabilities of each type of weather year category to arrive at an estimate of

overall costs for Yield Reserve for the Virginia Coastal Plain. The base projections used for the rainfall probabilities were 49 percent, 38 percent, and 13 percent for the average, bad, and good year types of rainfall years, respectively. These probabilities produced an estimated average cost of Yield Reserve of approximately \$2,438,400 a year for the Virginia Coastal Plain, or about \$31 per hectare (Table 5.5 and See Appendix C.3 for the counties in the Coastal Plain).

**Table 5.5. Summary of Changes in Revenues and Costs from Yield Reserve to Farmers in Virginia Coastal Plain**

|                                                                                                                                                                            | Low Rainfall Year | Average Rainfall Year | Good Rainfall Year | Total <sup>a</sup> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-----------------------|--------------------|--------------------|
| <b>Total Cost (Gain)</b>                                                                                                                                                   | (\$1,484,491.79)  | \$4,477,534.09        | \$6,390,353.08     | \$2,438,394.69     |
| <b>Cost (Gain) per ha</b>                                                                                                                                                  | (\$15.42)         | \$46.50               | \$66.37            | \$25.33            |
| <b>Total Yield Penalty (Mg/ha)<sup>b</sup></b>                                                                                                                             | 0                 | 996,478               | 1,316,182          | 655,661            |
| <b>Yield Penalty (Mg/ha)</b>                                                                                                                                               | 0                 | 10.3                  | 13.7               | 6.8                |
| <b>Predicted Probability<sup>c</sup></b>                                                                                                                                   | 38%               | 49%                   | 13%                |                    |
| <sup>a</sup> The total costs of the program was computed by using the predicted probability of each year type occurring multiplied by the associated costs with each year. |                   |                       |                    |                    |
| <sup>b</sup> Yield Penalty is the difference between predicted yields under extension recommended rates and Yield Reserve Program rates                                    |                   |                       |                    |                    |
| <sup>c</sup> Predicted Probability is the estimated likelihood of the given weather state of occurring                                                                     |                   |                       |                    |                    |

### *Sensitivity Analysis*

With weather probabilities redefined based on classifying bad years as only those years with yields lower than 2002's de-trended yield, there is a 72 percent, 15 percent, and 13 percent chance of average, bad, and good years, respectively. As a result, the average cost of Yield Reserve is \$40 per hectare, for a total cost of approximately \$3,837,900 average per year for the Virginia Coastal Plain. These probabilities produce an associated projected yield penalty of approximately .59 Mg/ha, or a total of approximately 139,200 Mg/ha for the counties in the study area (See Table 5.6).

Lastly, the estimated costs with all of the bad years being re-classified as average years giving average years an 87 percent chance of occurring comes to \$49 per hectare, for an approximate average yearly cost of \$4,726,700 for the Virginia Coastal Plain. The associated yield penalties with all bad years reclassified as average years are approximately .68 Mg/ha, for an overall estimated penalty of approximately 162,500 Mg/ha (Table 5.6).

**Table 5.6. Effects of Changing Weather Probabilities on YRP Costs and Yield Penalties for the Virginia Coastal Plain**

| Scenario <sup>a</sup>                                                                                                                                              | Probability of Average Rainfall Year | Probability of Low Rainfall Year | Probability of Good Rainfall Year | Cost Per ha <sup>b</sup> | Overall Cost | Yield Penalty Mg/ha <sup>c</sup> | Total Yield Penalty Mg <sup>d</sup> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------|-----------------------------------|--------------------------|--------------|----------------------------------|-------------------------------------|
| <b>Baseline</b>                                                                                                                                                    | 49%                                  | 38%                              | 13%                               | \$25.35                  | \$2,441,190  | 0.43                             | 102,620                             |
| <b>Sensitivity I</b>                                                                                                                                               | 72%                                  | 15%                              | 13%                               | \$39.86                  | \$3,837,860  | 0.59                             | 139,220                             |
| <b>Sensitivity II</b>                                                                                                                                              | 87%                                  | 0%                               | 13%                               | \$49.09                  | \$4,726,650  | 0.68                             | 162,510                             |
| <sup>a</sup> The scenarios are the likelihood of Average, Bad, and Good growing seasons occurring.                                                                 |                                      |                                  |                                   |                          |              |                                  |                                     |
| <sup>b</sup> Cost per ha is the predicted net cost to farmers associated with lowered yields, N applications, and transportation costs.                            |                                      |                                  |                                   |                          |              |                                  |                                     |
| <sup>c</sup> Yield Penalty is the estimated per hectare yield difference between extension recommended rates and Yield Reserve rates.                              |                                      |                                  |                                   |                          |              |                                  |                                     |
| <sup>d</sup> Total Yield Penalty is the overall reduction in yield in Mg for Essex County under Yield Reserve versus extension recommended rates of N application. |                                      |                                  |                                   |                          |              |                                  |                                     |

### **Other Yield Responses to N**

The estimated yield responses from sites that were not selected as the best for each category provide information on variable yield response to N that will occur in different fields. Because the curves used for average and good years are the ones with the second highest and highest costs, respectively, the estimates produced are considered conservative. In every year there were curves estimated for sites that had low yield penalties. Even in 2003 and 2004, which were good growing seasons, there are projected to be fields with low yield penalties or even positive economic gains from lower N applications. The information to properly test how many fields might have lower yield penalties is not available (Alley).

### **Cost of Yield Reserve to Taxpayers**

#### *Administrative Costs*

There would be a \$7.40 per hectare administrative cost for paying a consultant to set up the check strip in the field and to verify yield differences from lower N applications

(Simpson, Brandt). Under every scenario considered, the cost for the yield strip is assumed to be the same. For the Virginia Coastal Plain this cost is approximately \$713,000.

### *Incentive Payment*

The annual incentive payment that would equate expected net returns under Yield Reserve and based on Cooperative Extension N recommendations would be the average estimated yearly cost of Yield Reserve (Table 5.5). This payment would need to vary depending on the soil type. These payments would be approximately \$32, \$27, and \$22 per hectare for soils in management groups I, II, and III, respectively, approximately \$25 per hectare as calculated above. With the administrative cost added, there would be an approximate cost of \$29 to \$39 per hectare, and a total cost of the program of \$3,151,900 per year for the entire Virginia Coastal Plain (table 5.7).

**Table 5.7. Cost for Incentive Payment for Yield Reserve for the Virginia Coastal Plain by Soil Group**

| Soil Management Group                                                                                                                  | Incentive Payment Cost <sup>a</sup> | Administration Cost | Soil Management Group (ha) | Overall Cost |
|----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|---------------------|----------------------------|--------------|
| I                                                                                                                                      | \$32                                | \$7.40              | 14,600                     | \$478,100    |
| II                                                                                                                                     | \$27                                | \$7.40              | 37,900                     | \$1,239,500  |
| III                                                                                                                                    | \$22                                | \$7.40              | 43,800                     | \$1,434,200  |
| <b>Total</b>                                                                                                                           |                                     |                     | 96,300                     | \$3,151,900  |
| <sup>a</sup> Incentive Payment Cost is the amount that would be required to compensate farmers for expected losses from Yield Reserve. |                                     |                     |                            |              |

### *Easement Payment*

A special case of the incentive payment scheme is paying for an easement to permanently reduce N applications by 15 percent. The cost of the incentive payment, assuming a discount rate of 7 percent, would simply be the discounted value in perpetuity of the

estimated average cost per acre with the \$7.40 administration cost included. In the baseline scenario, the easement value would be approximately \$470 per hectare, and would cost approximately \$45,026,500 to implement for the Virginia Coastal Plain (See Table 5.8). As the likelihood of bad years occurring declines, the cost of easements increases greatly, because the expected returns from the 15 percent N removed by Yield Reserve increases. The estimated cost with no bad years is approximately \$800 per hectare, or approximately \$77,645,500 for the entire Virginia Coastal Plain.

**Table 5.8. Cost for Yield Reserve Easements for the Virginia Coastal Plain**

| Scenario                                                                                                                                                                                  | Average | Bad | Good | Easement Value Per ha (7%) <sup>a</sup> | Total Cost for Virginia Coastal Plain |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-----|------|-----------------------------------------|---------------------------------------|
| <b>Baseline</b>                                                                                                                                                                           | 49%     | 38% | 13%  | \$470                                   | \$45,026,500                          |
| <b>Sensitivity I<sup>b</sup></b>                                                                                                                                                          | 72%     | 15% | 13%  | \$670                                   | \$64,960,300                          |
| <b>Sensitivity II<sup>c</sup></b>                                                                                                                                                         | 87%     | 0%  | 13%  | \$800                                   | \$77,645,500                          |
| <sup>a</sup> The easement value of per ha was determined by taking the discounted value in perpetuity of the estimated average cost per acre with the \$7.40 administration cost included |         |     |      |                                         |                                       |
| <sup>b</sup> Scenario Sensitivity I was determined by classifying years with yields below 2002 as bad, and all years that were previously defined as bad above 2002 as average            |         |     |      |                                         |                                       |
| <sup>c</sup> Scenario Sensitivity II was determined by classifying all bad years as average years instead                                                                                 |         |     |      |                                         |                                       |

### *Insurance Payment*

For the insurance payment method the total payout made will vary each year. Because there will be no payout for bad (low-yield) years, the approximate cost per hectare for Yield Reserve under an insurance scheme would be the cost of average and good years multiplied by their likelihood of occurring, approximately \$31.00 per hectare. The administrative costs would raise the cost for Yield Reserve under an insurance scheme to \$39 per hectare, and \$3,720,400 for the Coastal Plain. This cost does not take into

account savings that farmers would receive from reduced N applications in bad years of \$15.

### *Mixed Payments*

The current proposal of the Yield Reserve Program has an incentive payment of \$30 a year per acre, or approximately \$74 per hectare, being paid to farmers, and a “warranty” or insurance payment being made in years where there is a yield penalty associated with the reduction in fertilizer use (Sweeney). The yearly average cost, between the incentive payment and the insurance would be \$74 plus the average calculated cost of insurance of \$31 per hectare, and the administration costs of \$7.40 per hectare. The total program cost would be \$112 per hectare. For the Virginia Coastal Plain, not counting administration costs, the total average expense of the program would be approximately \$10,141,500 per year. With the administration costs added in, the total cost of the proposed programs would come to approximately \$10,855,000.

The costs of the Yield Reserve Program will vary by county, soil management group, year, and method of implementation. The current proposal for the program as a mixed incentive payment and insurance program will be the most expensive method, because the incentive payment is higher than that calculated for them to be economically indifferent between participating in the program and not. The actual and perceived probability of types of growing seasons occurring will also greatly impact the costs of the program. As the likelihood of bad years occurring goes down, the cost of the program will go up.

The hypothesis that Yield Reserve would require deficiency payments in at least fifty percent of years was proven correct, since only bad years will not have payments and have less than a fifty percent likelihood. Assuming that farmers are using Cooperative Extension recommendations, the hypothesis that farmers average net returns will increase under the proposed Yield Reserve Program with associated incentives and insurance payments was proven to be correct. The combination of incentive payment and insurance payment of the proposed program is estimated to be greater than costs of Yield Reserve to farmers.

## **Chapter 6 Summary and Conclusions**

### **Summary**

Agriculture has been identified as the largest source of pollution affecting the Chesapeake Bay (Chesapeake Bay Foundation). Recently there has been an increase in interest in reducing nutrient (nitrogen (N) and phosphorus (P)) run off from agricultural fields. There have been different approaches proposed to reduce nutrient runoff including the Yield Reserve Program.

N is a critical nutrient for plant growth and is widely applied to agricultural fields in the Virginia Coastal Plain. Currently, it is believed that farmers view fertilizer as a risk reducing input, and hence use more of it than might be economically optimal (Babcock, Babcock and Blackmer). Because of this perception, insurance policy approaches have recently been proposed to encourage farmers to use lower amounts of nutrients (Huang, Sheriff, Brandt, Mitchell, Simpson, USDA RMA 2001). Insurance programs would give farmers financial incentives to reduce N use without suffering financial losses when yields are reduced by insufficient fertilizer application. In general the proposed insurance programs call for farmers to reduce their N use to recommended levels. However, there have also been calls for programs to reduce N to a level 15 percent below the recommendations (Brandt, Simpson).

There is currently a lack of information available for policy makers to support decisions relating to costs and to environmental benefits of reducing fertilizer usage. The objective of this study is to evaluate the effects of a Yield Reserve Program on farm yields and

reductions in N applications. The effects of Yield Reserve on corn yields, N applications, and enterprise net returns were quantified, and the costs to taxpayers of Yield Reserve for the Virginia Coastal Plain were estimated. Four policy options, a yearly incentive payment, a one time easement payment, insurance payments when yields are inversely impacted, and a mixture of incentive payments and insurance, were investigated in this study to explore the costs associated with Yield Reserve.

Data from North Carolina and Virginia were used to estimate the effects of Yield Reserve on yields. Historic yields were used in conjunction with seasonal rainfall data to estimate the likelihood of a year's weather occurring. Lastly, soil management group data were used to adjust estimates to be specific to soils in each county in the Virginia Coastal Plain. Weather probabilities, soils data, and estimated yield response to N were then used to analyze Yield Reserve costs.

Curves were selected to represent good, average, and bad, growing years by dividing the five site years of data into three groups, bad, average, and good growing seasons, based on historic yield data. The years 2000 and 2001 were selected as the average growing years, these years had historic yields in between the other two groups, 2002 was a drought year and selected as the bad growing season as it had the lowest historic yields, and 2003 and 2004 were selected as the good growing years, based on them having the highest historic yields. After the groups were selected, the curves with the best fit, highest  $R^2$  value, for the average and good years were used to represent these groups.

The bad growing years were assumed to have no to low response to N, and were assumed to have no response to N for the purposes of this study.

## **Results**

The overall cost of Yield Reserve was estimated for each of the counties in the Coastal Plain with reported corn acreage<sup>3</sup>. In average growing seasons, years with average rainfall during the corn growing season, Yield Reserve would create a net cost to farmers of approximately \$47 per hectare, or \$4,477,500 for the entire Coastal Plain, and would correspond to a yield penalty of .65 Mg/ha. In bad years, years with low rainfall during the corn growing season, farmers would gain approximately \$15 per hectare (\$1,484,500 for the entire Coastal Plain), and there would be no yield penalties. In good growing seasons, years with plentiful rainfall during the corn growing season, farmers on the Virginia Coastal Plain would lose approximately \$66 per hectare and have a yield penalty of .86 Mg/ha.

The expected net revenue effects of Yield Reserve over all types of weather years and soil management groups would be a reduction of \$25 per hectare. There would be an average yield penalty of .43 Mg/ha. N applications per year would be reduced by approximately 25 kg per ha or about 164,000 kg. The overall estimated cost of insurance payments to farmers would be \$31 per hectare, which is comparable to the Agflex rate for insurance in the Corn Nutrient Demonstration Project of \$40 per hectare (\$16 per acre)

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<sup>3</sup> The counties are Accomack, Charles City, Caroline, Dinwiddie, Essex, Gloucester, Hanover, Henrico, Isle of Wight, James, King and Queen, King George, King William, Lancaster, Mathews, Middlesex, New Kent, Northampton, Northumberland, Prince George, Prince William, Richmond County, Southampton, Stafford, Spotsylvania, Suffolk City, Surry, and Westmoreland

(Brandt). The cost of insurance payment to farmers will be higher than the expected net revenue reductions, because the insurance payment would only be made in years when yields are reduced by YRP N applications. The reduced cost of N in years of no yield penalty is not included in the insurance costs.

The perception of how likely bad, average, and good growing seasons are to occur will affect the potential costs of Yield Reserve. The numbers above are based on the probabilities of good, average, and bad years based on from historical rainfall data for the Virginia Coastal Plain. Assuming that only years with yield levels lower than those observed in 2002 are considered bad years, that is with 72, 15, and 13 percent chances for average, bad, and good years, respectively, the cost per hectare rises to \$47, and the total effect on farmer net return would be \$3,833,800. If all bad years are reclassified as average years, then there becomes an 87 percent likelihood of average years, and a 13 percent likelihood of good years and the effect on farmers' net return would be an average loss of \$56 per hectare, or approximately \$4,721,700 yearly.

The yield curves that were not used to estimate what could happen in each year still provided valuable information. With one exception, these curves demonstrate that costs estimated for Yield Reserve are likely to be conservatively high. The one exception showed that it would be possible for larger impacts on net returns than estimated here, but this exception was based on limited data and a poorly fitted curve.

The cost to taxpayers would vary depending on the mechanism used to implement Yield Reserve. There would always be an approximate administration cost of \$7.40 per hectare

to pay for the yield check strip and to verify any yield differences from reduced N application. Under an incentive payment only scenario, there would be a total expected cost to tax payers of approximately \$33 per hectare, or \$3,151,900 on average per year for Yield Reserve for the entire Virginia Coastal Plain. If an easement were to be used, the cost would be a one time payment for the easement, and a continuing payment for the defined administration cost. The one time cost would come to approximately \$470 per hectare, or approximately \$45,026,500 for the coastal plain. An insurance payment would have an average cost of \$39 per hectare, and approximately \$3,720,400 for the Coastal Plain. The insurance cost would be higher than the incentive payment because it would not account for bad years, when farmers receive net benefits from the program.

The current proposals for Yield Reserve include an incentive payment of approximately \$74 per hectare, and calls for an insurance (warranty) payment, in years where there is a yield penalty (Sweeney; Simpson). The cost of this mixed scheme for Yield Reserve with administration costs included would come to \$113 per hectare and \$10,855,000 for the Coastal Plain.

## **Potential Limitations of Yield Reserve**

### *Weather Risk*

The type of growing seasons that occur when the Yield Reserve Program is implemented could have very important impacts on the perceived costs of the program. If the first year or two of the program were drought years, then the program could seem to have low costs to taxpayers. However, if the program were to see a few good growing years in a row,

such as 2003 and 2004, or even average growing years such as 2000 and 2001, the perception could become that the program is too costly from a tax payer perspective if an insurance approach was used. If an incentive payment approach was used and drought years occurred early, farmers could feel very positively about the Yield Reserve payments. However, if good or average growing years occurred, then farmers could be discouraged from continuing with Yield Reserve unless they are adequately compensated with insurance.

#### *Recommended Fertilizer Rates*

The fact that Yield Reserve is pegged to a 15 percent reduction in fertilizer applications from the extension recommended levels has the potential to create other problems. If new hybrids of corn have a greater yield response to N, and the optimal (net revenue maximizing) levels of fertilization increase without the extension recommendations also increasing, the program's costs could increase. In Virginia there were approximately 10 years between updates in the extension recommendations (1995 to 2006). Outdated extension recommendations could create greater costs to farmers, and participation rates could drop. The Yield Reserve Policy would have to address the possibility of updating extension recommendations more regularly.

### *Residual N*

There is evidence that there is a high level of residual N in many crop fields (Brown; Yadav, Peterson, and Easter). If there is a high level of residual N in fields where Yield Reserve is practiced, then it is possible that there will not be a great reduction in yields at first. However, when the residual levels of N are used up, there could be potential for much larger yield penalties (Alley, Brandt). Residual N build up means that costs could be lower than expected in the first few years of Yield Reserve and could increase after a few years when the residual levels of N are depleted. If the costs of Yield Reserve were to increase dramatically as residual levels of N are used up, then it would be necessary to make sure that extra funds are set aside to be able to cover the increased costs, or that the policy be re-evaluated later in time.

### *Uncertain Runoff Reduction*

It is not certain how much reducing N applications will affect N runoff. It is likely that a 1 kg reduction in inputs will result in less than a 1 kg reduction in outputs. Ribaud et al. estimated that for the Mississippi Basin a 10 percent reduction in N inputs was required for a 5 percent reduction in N deliveries to the Gulf of Mexico. The implication is that to be certain that runoff reduction policies are successful, reductions in “outputs” (runoff) from the fields need to be considered, not reductions in inputs to a field. Further, it is likely that costs per kg of runoff reduction will be higher than costs per kg of reduced N application.

## **Conclusions**

The proposed mixed incentive and insurance scheme for implementation of Yield Reserve, the Yield Reserve Program is a more costly program than would be necessary to compensate farmers for yield losses. The proposal for Yield Reserve is more costly from the taxpayer's perspective than the program could be and still have an economic benefit for farmers to join. The proposals for and the current test implementation of the Yield Reserve Program would likely result in gains to farmers. Still there has not been much of a clamor for farmers to join similar programs (Mitchell).

Currently, the proposal is to give farmers \$74 per hectare as an incentive payment, and to cover any potential costs they may incur through insurance. This means that expected costs of the Yield Reserve Program, including administration costs, \$113 per hectare, are more than twice the net losses to farmers in the worst case scenario analyzed, where only good and average years are considered (\$49 per hectare).

## **Future Research**

Information gained from the Corn Nutrient Demonstration Project will be very beneficial for policy design and consideration on whether to proceed with Yield Reserve or not. This project provides a payment of approximately \$5 for each percent that farmers reduce their N applications up to 15 percent per hectare and insurance for any resulting losses. Further, as this program proceeds, farmers' acceptance of the concept behind Yield Reserve will be able to be determined.

However, due to the high expected costs of Yield Reserve other policy initiatives should be investigated further. Precision agriculture may be able to reduce overall N applications to fields. It may prove to be less expensive in the long run to subsidize farmers' adoption of precision agriculture methods, due to the fact that farmers may be more willing to accept precision agriculture. Further, insurance programs like split timing application insurance as suggested by Huang, may be more likely to be adopted by farmers, who may perceive it more favorably, than "not growing a full crop." Policy studies should be done on these types of program to determine their costs and potential to reduce N applications. These programs may be less costly from taxpayers' perspectives. Further, farmer acceptance of these programs should be taken into account. In order to be effective, any policy implemented has to be adopted by farmers.

The Yield Reserve Program has the potential to help reduce nutrient pollution in waterways. There is more than one manner to implement Yield Reserve, and the costs, and gains to taxpayers and farmers will vary based on the method selected. There are some potential limitations with Yield Reserve including weather risks, the necessity of timely updates to the recommended fertilization rates, residual N depletion, and uncertain reductions in N losses to runoff and leaching from reduced N applications. However, farmers would benefit from Yield Reserve through higher expected net returns, and lowered income variance and taxpayers would benefit from Yield Reserve through improvements to water quality. These benefits mean that Yield Reserve and other environmental programs to reduce NPS pollution should be explored more.

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## Appendix A – Historic Corn Yield and Rainfall Data

Table A.1. Historic Average Corn Yields for the Virginia Coastal Plain

| Year | Corn<br>(Mg/ha) | Year | Corn<br>(Mg/ha) |
|------|-----------------|------|-----------------|
| 1958 | 3.5             | 1982 | 6.8             |
| 1959 | 3.0             | 1983 | 3.0             |
| 1960 | 3.3             | 1984 | 6.8             |
| 1961 | 3.3             | 1985 | 6.5             |
| 1962 | 4.3             | 1986 | 3.3             |
| 1963 | 2.5             | 1987 | 4.1             |
| 1964 | 4.0             | 1988 | 5.2             |
| 1965 | 4.9             | 1989 | 7.2             |
| 1966 | 3.1             | 1990 | 6.5             |
| 1967 | 5.0             | 1991 | 5.1             |
| 1968 | 5.0             | 1992 | 7.7             |
| 1969 | 5.2             | 1993 | 3.4             |
| 1970 | 4.6             | 1994 | 5.8             |
| 1971 | 4.4             | 1995 | 7.5             |
| 1972 | 5.9             | 1996 | 8.4             |
| 1973 | 6.0             | 1997 | 6.0             |
| 1974 | 5.4             | 1998 | 5.5             |
| 1975 | 5.8             | 1999 | 5.0             |
| 1976 | 5.4             | 2000 | 9.5             |
| 1977 | 3.5             | 2001 | 7.8             |
| 1978 | 5.3             | 2002 | 4.0             |
| 1979 | 5.2             | 2003 | 7.6             |
| 1980 | 3.0             | 2004 | 9.3             |
| 1981 | 5.6             |      |                 |

Table A.2. April to July Average Rainfall for Virginia Coastal Plain

| Year | Average April Rain (cm) | Average May Rain (cm) | Average June Rain (cm) | Average July Rain (cm) | Total Rain (cm) |
|------|-------------------------|-----------------------|------------------------|------------------------|-----------------|
| 1958 | 12.8                    | 14.0                  | 13.5                   | 9.9                    | 50.3            |
| 1959 | 12.0                    | 6.0                   | 5.1                    | 26.5                   | 49.5            |
| 1960 | 7.6                     | 14.7                  | 6.5                    | 16.5                   | 45.3            |
| 1961 | 5.9                     | 15.8                  | 14.5                   | 6.6                    | 42.8            |
| 1962 | 10.8                    | 8.5                   | 15.3                   | 12.5                   | 47.1            |
| 1963 | 1.8                     | 9.0                   | 19.1                   | 3.1                    | 33.0            |
| 1964 | 8.2                     | 4.2                   | 8.1                    | 13.6                   | 34.1            |
| 1965 | 6.6                     | 2.6                   | 12.4                   | 22.9                   | 44.5            |
| 1966 | 5.0                     | 9.9                   | 9.2                    | 8.7                    | 32.8            |
| 1967 | 3.3                     | 8.8                   | 7.0                    | 12.8                   | 31.8            |
| 1968 | 6.6                     | 8.3                   | 10.7                   | 11.2                   | 36.7            |
| 1969 | 8.2                     | 8.1                   | 9.1                    | 18.3                   | 43.7            |
| 1970 | 8.1                     | 6.0                   | 7.5                    | 16.1                   | 37.6            |
| 1971 | 5.1                     | 17.0                  | 6.7                    | 9.6                    | 38.5            |
| 1972 | 8.3                     | 16.4                  | 18.5                   | 14.7                   | 57.9            |
| 1973 | 10.3                    | 8.6                   | 9.8                    | 7.3                    | 36.0            |
| 1974 | 4.9                     | 8.6                   | 8.4                    | 8.0                    | 29.9            |
| 1975 | 7.7                     | 8.6                   | 9.5                    | 24.3                   | 50.2            |
| 1976 | 2.4                     | 10.3                  | 7.3                    | 7.8                    | 27.8            |
| 1977 | 6.1                     | 10.0                  | 4.4                    | 8.2                    | 28.7            |
| 1978 | 10.0                    | 16.6                  | 10.4                   | 10.8                   | 47.8            |
| 1979 | 10.3                    | 16.2                  | 9.3                    | 16.1                   | 51.9            |
| 1980 | 8.3                     | 8.0                   | 1.8                    | 9.7                    | 27.8            |
| 1981 | 7.6                     | 11.7                  | 9.0                    | 10.3                   | 38.6            |
| 1982 | 7.4                     | 9.4                   | 9.6                    | 16.3                   | 42.8            |
| 1983 | 16.1                    | 8.6                   | 10.4                   | 2.9                    | 38.0            |
| 1984 | 14.2                    | 13.7                  | 5.8                    | 14.2                   | 48.0            |
| 1985 | 1.5                     | 7.1                   | 10.7                   | 12.3                   | 31.6            |
| 1986 | 3.4                     | 4.4                   | 4.2                    | 14.0                   | 26.1            |
| 1987 | 10.4                    | 7.3                   | 13.3                   | 5.2                    | 36.2            |
| 1988 | 7.2                     | 13.7                  | 7.0                    | 11.4                   | 39.2            |
| 1989 | 12.1                    | 11.3                  | 16.2                   | 14.2                   | 53.8            |
| 1990 | 7.0                     | 18.7                  | 3.1                    | 11.4                   | 40.2            |
| 1991 | 6.6                     | 2.8                   | 11.2                   | 13.1                   | 33.7            |
| 1992 | 5.8                     | 11.7                  | 6.8                    | 14.2                   | 38.4            |
| 1993 | 9.4                     | 11.8                  | 7.1                    | 4.6                    | 33.0            |
| 1994 | 5.0                     | 7.6                   | 6.3                    | 19.7                   | 38.7            |
| 1995 | 6.6                     | 11.2                  | 7.4                    | 11.0                   | 36.2            |
| 1996 | 9.6                     | 9.1                   | 12.4                   | 23.2                   | 54.3            |
| 1997 | 8.8                     | 4.3                   | 5.5                    | 15.7                   | 34.3            |
| 1998 | 9.4                     | 11.7                  | 10.3                   | 8.0                    | 39.5            |
| 1999 | 7.1                     | 3.9                   | 10.3                   | 11.5                   | 32.7            |

| Table A.2 Continued                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |      |      |      |      |      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|------|
| <b>2000</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 11.3 | 9.6  | 12.4 | 16.2 | 49.4 |
| <b>2001</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 5.1  | 9.0  | 14.1 | 12.9 | 41.2 |
| <b>2002</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 9.4  | 8.8  | 5.2  | 8.8  | 32.2 |
| <b>2003</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 12.9 | 16.6 | 10.6 | 17.2 | 57.3 |
| <b>2004</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 11.8 | 8.4  | 18.2 | 26.2 | 64.7 |
| <p>The weather stations used were Williamsburg 2 N, Warsaw 2 N in Richmond County, Suffolk Lake Kilby in Suffolk City, Richmond WSO Airport in Henrico County, and Painter 2 W in Accomack County. There were two data points that were missing for the months needed from the regression. Data for July 2001 for Warsaw 2 N and July 2003 for Painter 2 W were substituted with the corresponding months from Walkerton 2 NW in King and Queen, and Wallops Island, respectively.</p> |      |      |      |      |      |

Table A.3. De-Trended Predicted Yields for the Virginia Coastal Plain

| <b>Year</b> | <b>Yield<br/>Mg/ha</b> | <b>Year</b> | <b>Yield<br/>Mg/ha</b> |
|-------------|------------------------|-------------|------------------------|
| <b>1958</b> | 7.5                    | <b>1982</b> | 7.6                    |
| <b>1959</b> | 7.2                    | <b>1983</b> | 4.4                    |
| <b>1960</b> | 7.5                    | <b>1984</b> | 7.0                    |
| <b>1961</b> | 6.9                    | <b>1985</b> | 6.9                    |
| <b>1962</b> | 7.6                    | <b>1986</b> | 5.5                    |
| <b>1963</b> | 5.4                    | <b>1987</b> | 5.7                    |
| <b>1964</b> | 6.3                    | <b>1988</b> | 6.8                    |
| <b>1965</b> | 7.3                    | <b>1989</b> | 8.2                    |
| <b>1966</b> | 6.4                    | <b>1990</b> | 6.1                    |
| <b>1967</b> | 6.6                    | <b>1991</b> | 6.2                    |
| <b>1968</b> | 6.9                    | <b>1992</b> | 7.1                    |
| <b>1969</b> | 7.6                    | <b>1993</b> | 5.1                    |
| <b>1970</b> | 6.8                    | <b>1994</b> | 7.2                    |
| <b>1971</b> | 6.7                    | <b>1995</b> | 6.7                    |
| <b>1972</b> | 8.7                    | <b>1996</b> | 8.5                    |
| <b>1973</b> | 6.0                    | <b>1997</b> | 6.1                    |
| <b>1974</b> | 6.0                    | <b>1998</b> | 6.6                    |
| <b>1975</b> | 8.2                    | <b>1999</b> | 6.2                    |
| <b>1976</b> | 5.9                    | <b>2000</b> | 7.9                    |
| <b>1977</b> | 5.4                    | <b>2001</b> | 7.6                    |
| <b>1978</b> | 7.4                    | <b>2002</b> | 5.6                    |
| <b>1979</b> | 8.0                    | <b>2003</b> | 8.3                    |
| <b>1980</b> | 4.3                    | <b>2004</b> | 9.2                    |
| <b>1981</b> | 6.8                    |             |                        |

## Appendix B Corn Area in Hectares for the Virginia Coastal Plain

Table B.1 Area of Soil Groups I, II, and III for Accomack, Charles City, Caroline, Dinwiddie, Essex, Gloucester, and Hanover

| Soil Type    | Accomack | Charles City | Caroline | Dinwiddie | Essex | Gloucester | Hanover |
|--------------|----------|--------------|----------|-----------|-------|------------|---------|
| I            | 0        | 4,068        | 1,080    | 80        | 185   | 807        | 657     |
| II           | 5,893    | 15,135       | 4,750    | 950       | 1,707 | 358        | 1561    |
| III          | 3,402    | 3,757        | 4,450    | 1,510     | 5,031 | 1,410      | 2528    |
| <b>Total</b> | 9,296    | 22,960       | 10,280   | 2,540     | 6,923 | 2,575      | 4745    |

Table B.2 Area of Soil Groups I, II, and III for Henrico, Isle of Wight, James, King and Queen, King George, King Williams, and Lancaster

| Soil Type    | Henrico | Isle of Wight | James | King and Queen | King George | King Williams | Lancaster |
|--------------|---------|---------------|-------|----------------|-------------|---------------|-----------|
| I            | 185     | 1,766         | 102   | 255            | 600         | 951           | 228       |
| II           | 307     | 1,768         | 636   | 862            | 602         | 1,360         | 1,418     |
| III          | 375     | 288           | 3,084 | 3,822          | 393         | 2,207         | 653       |
| <b>Total</b> | 866     | 3,822         | 3,822 | 4,939          | 1,595       | 4,518         | 2,300     |

Table B.3. Area of Soil Groups I, II, and III for Mathews, Middlesex, New Kent, Northampton, Northumberland, Prince George, and Prince William

| Soil Type    | Mathews | Middlesex | New Kent | Northampton | Northumberland | Prince George | Prince William |
|--------------|---------|-----------|----------|-------------|----------------|---------------|----------------|
| I            | 1       | 279       | 439      | 0           | 1,136          | 311           | 149            |
| II           | 361     | 336       | 490      | 918         | 2,797          | 723           | 116            |
| III          | 43      | 1,620     | 828      | 1,778       | 1,864          | 836           | 261            |
| <b>Total</b> | 405     | 2,235     | 1,757    | 2,696       | 5,798          | 1,870         | 526            |

Table B.4 Area of Soil Groups I, II, and III for Richmond County, Southampton, Stafford, Spotsylvania, Suffolk City, Surry, and Westmoreland

| Soil Type    | Richmond County | Southampton | Stafford | Spotsylvania | Suffolk City | Surry | Westmoreland |
|--------------|-----------------|-------------|----------|--------------|--------------|-------|--------------|
| I            | 561             | 996         | 89       | 115          | 1,051        | 639   | 989          |
| II           | 682             | 2,202       | 349      | 399          | 1,631        | 1,005 | 946          |
| III          | 3,154           | 810         | 112      | 458          | 1,075        | 761   | 3,086        |
| <b>Total</b> | 4,397           | 4,008       | 551      | 972          | 3,757        | 2,405 | 5,020        |

## Appendix C Cost by County of Yield Reserve

All of the tables use estimated yields under Extension recommendations (Yield) and Yield Reserve Program (YRP Yield) levels to allow for yield differences to be estimated and for the net costs to farmers and N reductions to be calculated. Net cost is derived by subtracting savings from lower N applications and transportation costs from lost revenue due to lowered yields.

### Appendix C.1. Cost of Yield Reserve in Average Rainfall Years

Appendix C.1. Cost of Yield Reserve by Soil Management Group for Average Rainfall Years

|               | Yield (Mg) | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost | N Reductions (KG) |
|---------------|------------|----------------|------------------------|-----------------|-------------------|
| I             | 152,300    | 140,600        | 11,700                 | \$855,200       | 429,570           |
| II            | 342,900    | 316,900        | 26,100                 | \$1,875,100     | 986,317           |
| III           | 340,700    | 316,000        | 24,800                 | \$1,747,200     | 994,002           |
| <b>Total</b>  | 836,000    | 773,400        | 62,700                 | \$4,477,500     | 2,409,889         |
| <b>Per ha</b> | 8.68       | 8.03           | 0.65                   | \$47            | 25                |

Table C.1.1. Average Rainfall Year Cost and Yield Reductions for Accomack

|              | Yield (Mg) | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|------------|----------------|------------------------|-----------------|
| I            | 0          | 0              | 0                      | \$0             |
| II           | 53,374     | 49,314         | 4,060                  | \$291,840       |
| III          | 26,462     | 24,537         | 1,926                  | \$135,687       |
| <b>Total</b> | 79,836     | 73,850         | 5,986                  | \$427,527       |

Table C.1.2. Average Rainfall Year Cost and Yield Reductions for Charles City

|              | Yield (Mg) | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|------------|----------------|------------------------|-----------------|
| I            | 17,174     | 996            | 83                     | \$96,418        |
| II           | 55,498     | 51,276         | 4,222                  | \$303,451       |
| III          | 11,831     | 10,970         | 861                    | \$60,665        |
| <b>Total</b> | 84,503     | 78,093         | 6,410                  | \$460,534       |

Table C.1.3. Average Rainfall Year Cost and Yield Reductions for Caroline County

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 4,559             | 264                   | 22                            | \$25,592               |
| <b>II</b>    | 17,417            | 16,092                | 1,325                         | \$95,233               |
| <b>III</b>   | 14,013            | 12,994                | 1,020                         | \$71,854               |
| <b>Total</b> | 35,989            | 33,292                | 2,697                         | \$192,680              |

Table C.1.4. Average Rainfall Year Cost and Yield Reductions for Dinwiddie County

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 337               | 20                    | 2                             | \$1,894                |
| <b>II</b>    | 3,483             | 3,218                 | 265                           | \$19,044               |
| <b>III</b>   | 4,755             | 4,409                 | 346                           | \$24,383               |
| <b>Total</b> | 8,576             | 7,939                 | 637                           | \$45,321               |

Table C.1.5. Average Rainfall Year Cost and Yield Reductions for Gloucester County

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 8,413             | 488                   | 41                            | \$47,232               |
| <b>II</b>    | 3,240             | 2,994                 | 247                           | \$17,717               |
| <b>III</b>   | 10,969            | 10,171                | 798                           | \$56,247               |
| <b>Total</b> | 22,623            | 20,928                | 1,695                         | \$121,196              |

Table C.1.6. Average Rainfall Year Cost and Yield Reductions for Hanover County

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 6,847             | 397                   | 33                            | \$38,439               |
| <b>II</b>    | 14,135            | 13,059                | 1,075                         | \$77,286               |
| <b>III</b>   | 19,659            | 18,229                | 1,431                         | \$100,805              |
| <b>Total</b> | 40,641            | 37,606                | 3,035                         | \$216,531              |

Table C.1.7. Average Rainfall Year Cost and Yield Reductions for Henrico County

|              | Yield (Mg)   | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|--------------|----------------|------------------------|-----------------|
| I            | 1,925        | 112            | 9                      | \$10,805        |
| II           | 2,782        | 2,571          | 212                    | \$15,213        |
| III          | 2,914        | 2,702          | 212                    | \$14,941        |
| <b>Total</b> | <b>7,621</b> | <b>7,048</b>   | <b>572</b>             | <b>\$40,959</b> |

Table C.1.8. Average Rainfall Year Cost and Yield Reductions for Isle of Wight

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 18,413        | 1,068          | 89                     | \$103,374        |
| II           | 16,012        | 14,794         | 1,218                  | \$87,551         |
| III          | 2,243         | 2,080          | 163                    | \$11,500         |
| <b>Total</b> | <b>36,668</b> | <b>33,864</b>  | <b>2,804</b>           | <b>\$202,425</b> |

Table C.1.9. Average Rainfall Year Cost and Yield Reductions for James City

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 1,069         | 62             | 5                      | \$6,000          |
| II           | 5,757         | 5,319          | 438                    | \$31,477         |
| III          | 23,983        | 22,238         | 1,745                  | \$122,977        |
| <b>Total</b> | <b>30,809</b> | <b>28,543</b>  | <b>2,266</b>           | <b>\$160,455</b> |

Table C.1.10. Average Rainfall Year Cost and Yield Reductions for King and Queen

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 2,656         | 154            | 13                     | \$14,910         |
| II           | 7,811         | 7,217          | 594                    | \$42,710         |
| III          | 29,726        | 27,563         | 2,163                  | \$152,424        |
| <b>Total</b> | <b>40,193</b> | <b>37,231</b>  | <b>2,962</b>           | <b>\$210,044</b> |

Table C.1.11. Average Rainfall Year Cost and Yield Reductions for King George

|              | Yield         | YRP Yield     | Yield Differences | Farmer Net Cost |
|--------------|---------------|---------------|-------------------|-----------------|
| I            | 6,260         | 363           | 30                | \$35,142        |
| II           | 5,454         | 5,039         | 415               | \$29,823        |
| III          | 3,054         | 2,832         | 222               | \$15,662        |
| <b>Total</b> | <b>14,768</b> | <b>13,647</b> | <b>1,121</b>      | <b>\$80,626</b> |

Table C.1.12. Average Rainfall Year Cost and Yield Reductions for King William

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 9,923             | 576                   | 48                            | \$55,708               |
| <b>II</b>    | 12,318            | 11,381                | 937                           | \$67,354               |
| <b>III</b>   | 17,162            | 15,913                | 1,249                         | \$88,000               |
| <b>Total</b> | 39,403            | 36,451                | 2,952                         | \$211,062              |

Table C.1.13. Average Rainfall Year Cost and Yield Reductions for Lancaster

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 2,379             | 138                   | 12                            | \$13,354               |
| <b>II</b>    | 12,846            | 11,869                | 977                           | \$70,240               |
| <b>III</b>   | 5,080             | 4,710                 | 370                           | \$26,048               |
| <b>Total</b> | 20,305            | 18,774                | 1,531                         | \$109,642              |

Table C.1.14. Average Rainfall Year Cost and Yield Reductions for Mathews

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 12                | 1                     | 0                             | \$67                   |
| <b>II</b>    | 3,271             | 3,022                 | 249                           | \$17,884               |
| <b>III</b>   | 331               | 307                   | 24                            | \$1,699                |
| <b>Total</b> | 3,614             | 3,340                 | 274                           | \$19,649               |

Table C.1.15. Average Rainfall Year Cost and Yield Reductions for Middlesex

|              | <b>Yield</b> | <b>YRP Yield</b> | <b>Yield Differences</b> | <b>Farmer Net Cost</b> |
|--------------|--------------|------------------|--------------------------|------------------------|
| <b>I</b>     | 2,909        | 169              | 14                       | \$16,331               |
| <b>II</b>    | 3,040        | 2,809            | 231                      | \$16,621               |
| <b>III</b>   | 12,601       | 11,684           | 917                      | \$64,615               |
| <b>Total</b> | 18,550       | 17,177           | 1,373                    | \$97,566               |

Table C.1.16. Average Rainfall Year Cost and Yield Reductions for New Kent

|              | <b>Yield (Mg)</b> | <b>YRP Yield (Mg)</b> | <b>Yield Differences (Mg)</b> | <b>Farmer Net Cost</b> |
|--------------|-------------------|-----------------------|-------------------------------|------------------------|
| <b>I</b>     | 4,583             | 266                   | 22                            | \$25,731               |
| <b>II</b>    | 4,438             | 4,100                 | 338                           | \$24,265               |
| <b>III</b>   | 6,437             | 5,968                 | 468                           | \$33,005               |
| <b>Total</b> | 15,458            | 14,298                | 1,160                         | \$83,001               |

Table C.1.17. Average Rainfall Year Cost and Yield Reductions for Northampton

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 0             | 0              | 0                      | \$0              |
| II           | 8,315         | 7,682          | 633                    | \$45,464         |
| III          | 13,831        | 12,824         | 1,006                  | \$70,917         |
| <b>Total</b> | <b>22,145</b> | <b>20,506</b>  | <b>1,639</b>           | <b>\$116,381</b> |

Table C.1.18. Average Rainfall Year Cost and Yield Reductions for Northumberland

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 11,851        | 688            | 58                     | \$66,534         |
| II           | 25,335        | 23,407         | 1,927                  | \$138,526        |
| III          | 14,497        | 13,442         | 1,055                  | \$74,333         |
| <b>Total</b> | <b>51,683</b> | <b>47,785</b>  | <b>3,898</b>           | <b>\$279,393</b> |

Table C.1.19. Average Rainfall Year Cost and Yield Reductions for Prince George

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|---------------|----------------|------------------------|-----------------|
| I            | 3,247         | 188            | 16                     | \$18,227        |
| II           | 6,552         | 6,054          | 498                    | \$35,827        |
| III          | 6,500         | 6,027          | 473                    | \$33,327        |
| <b>Total</b> | <b>16,298</b> | <b>15,076</b>  | <b>1,222</b>           | <b>\$87,380</b> |

Table C.1.20. Average Rainfall Year Cost and Yield Reductions for Prince William

|              | Yield (Mg)   | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|--------------|----------------|------------------------|-----------------|
| I            | 1,557        | 90             | 8                      | \$8,742         |
| II           | 1,050        | 971            | 80                     | \$5,744         |
| III          | 2,030        | 1,882          | 148                    | \$10,409        |
| <b>Total</b> | <b>4,638</b> | <b>4,290</b>   | <b>348</b>             | <b>\$24,895</b> |

Table C.1.21. Average Rainfall Year Cost and Yield Reductions for Richmond County

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 5,846         | 339            | 28                     | \$32,821         |
| II           | 6,181         | 5,711          | 470                    | \$33,797         |
| III          | 24,528        | 22,743         | 1,785                  | \$125,768        |
| <b>Total</b> | <b>36,555</b> | <b>33,848</b>  | <b>2,707</b>           | <b>\$192,385</b> |

Table C.1.22. Average Rainfall Year Cost and Yield Reductions for Southampton

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 10,388        | 603            | 50                     | \$58,323         |
| II           | 19,947        | 18,430         | 1,517                  | \$109,069        |
| III          | 6,296         | 5,838          | 458                    | \$32,285         |
| <b>Total</b> | <b>36,632</b> | <b>33,854</b>  | <b>2,778</b>           | <b>\$199,676</b> |

Table C.1.23. Average Rainfall Year Cost and Yield Reductions for Stafford

|              | Yield (Mg)   | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|--------------|----------------|------------------------|-----------------|
| I            | 929          | 54             | 5                      | \$5,214         |
| II           | 3,162        | 2,922          | 241                    | \$17,291        |
| III          | 874          | 811            | 64                     | \$4,483         |
| <b>Total</b> | <b>4,965</b> | <b>4,589</b>   | <b>376</b>             | <b>\$26,987</b> |

Table C.1.24. Average Rainfall Year Cost and Yield Reductions for Spotsylvania

|              | Yield (Mg)   | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|--------------|----------------|------------------------|-----------------|
| I            | 1,198        | 69             | 6                      | \$6,725         |
| II           | 3,614        | 3,339          | 275                    | \$19,761        |
| III          | 3,560        | 3,301          | 259                    | \$18,255        |
| <b>Total</b> | <b>8,372</b> | <b>7,746</b>   | <b>627</b>             | <b>\$44,741</b> |

Table C.1.25. Average Rainfall Year Cost and Yield Reductions for Suffolk City

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 10,957        | 636            | 53                     | \$61,516         |
| II           | 14,772        | 13,648         | 1,124                  | \$80,771         |
| III          | 8,364         | 7,755          | 609                    | \$42,887         |
| <b>Total</b> | <b>34,093</b> | <b>31,514</b>  | <b>2,579</b>           | <b>\$185,174</b> |

Table C.1.26. Average Rainfall Year Cost and Yield Reductions for Surry

|              | Yield (Mg)    | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost  |
|--------------|---------------|----------------|------------------------|------------------|
| I            | 6,660         | 386            | 32                     | \$37,393         |
| II           | 9,106         | 8,413          | 693                    | \$49,788         |
| III          | 5,917         | 5,487          | 431                    | \$30,341         |
| <b>Total</b> | <b>21,683</b> | <b>20,046</b>  | <b>1,638</b>           | <b>\$117,523</b> |

Table C.1.27. Average Rainfall Year Cost and Yield Reductions for Westmoreland

|              | Yield (Mg) | YRP Yield (Mg) | Yield Differences (Mg) | Farmer Net Cost |
|--------------|------------|----------------|------------------------|-----------------|
| I            | 10,312     | 598            | 50                     | \$57,892        |
| II           | 8,567      | 7,915          | 652                    | \$46,843        |
| III          | 23,998     | 22,251         | 1,746                  | \$123,049       |
| <b>Total</b> | 42,876     | 39,682         | 3,195                  | \$227,785       |

### Appendix C.2 Costs of Yield Reserve in Bad Rainfall Years

Farmers costs in bad years are negative because of lowered fertilizer costs, due to the reduced applications from Yield Reserve.

Table C.2.1. Bad Rainfall Year Costs to Farmers for Accomack, Charles City, Caroline, Dinwiddie, and Gloucester

| Soil Type    | Accomack    | Charles City | Caroline   | Dinwiddie  | Gloucester |
|--------------|-------------|--------------|------------|------------|------------|
| I            | \$0         | (\$29,834)   | (\$7,919)  | (\$586)    | (\$14,614) |
| II           | (\$94,560)  | (\$98,322)   | (\$30,857) | (\$6,171)  | (\$5,741)  |
| III          | (\$47,551)  | (\$21,260)   | (\$25,181) | (\$8,545)  | (\$19,712) |
| <b>Total</b> | (\$142,112) | (\$149,416)  | (\$63,957) | (\$15,302) | (\$40,067) |

Table C.2.2. Bad Rainfall Year Costs to Farmers for Hanover, Henrico, Isle of Wight, James, and King and Queen

| Soil Type    | Hanover    | Henrico    | Isle of Wight | James      | King and Queen |
|--------------|------------|------------|---------------|------------|----------------|
| I            | (\$11,894) | (\$3,343)  | (\$31,986)    | (\$1,857)  | (\$4,613)      |
| II           | (\$25,042) | (\$4,929)  | (\$28,368)    | (\$10,199) | (\$13,839)     |
| III          | (\$35,327) | (\$5,236)  | (\$4,030)     | (\$43,097) | (\$53,417)     |
| <b>Total</b> | (\$72,263) | (\$13,509) | (\$64,384)    | (\$55,153) | (\$71,869)     |

Table C.2.3. Bad Rainfall Year Costs to Farmers for King George, King Williams, Lancaster, Mathews, and Middlesex

| Soil Type    | King George | King Williams | Lancaster  | Mathews   | Middlesex  |
|--------------|-------------|---------------|------------|-----------|------------|
| I            | (\$10,874)  | (\$17,237)    | (\$4,132)  | (\$21)    | (\$5,053)  |
| II           | (\$9,663)   | (\$21,824)    | (\$22,759) | (\$5,795) | (\$5,385)  |
| III          | (\$5,489)   | (\$30,840)    | (\$9,128)  | (\$595)   | (\$22,644) |
| <b>Total</b> | (\$26,025)  | (\$69,900)    | (\$36,019) | (\$6,411) | (\$33,083) |

Table C.2.4. Bad Rainfall Year Costs to Farmers for New Kent, Northampton, Northumberland, Prince George, and Prince William

| Soil Type    | New Kent          | Northampton       | Northumberland    | Prince George     | Prince William   |
|--------------|-------------------|-------------------|-------------------|-------------------|------------------|
| I            | (\$7,962)         | \$0               | (\$20,587)        | (\$5,640)         | (\$2,705)        |
| II           | (\$7,862)         | (\$14,731)        | (\$44,884)        | (\$11,608)        | (\$1,861)        |
| III          | (\$11,567)        | (\$24,853)        | (\$26,050)        | (\$11,679)        | (\$3,648)        |
| <b>Total</b> | <b>(\$27,391)</b> | <b>(\$39,584)</b> | <b>(\$91,521)</b> | <b>(\$28,927)</b> | <b>(\$8,214)</b> |

Table C.2.5. Bad Rainfall Year Costs to Farmers for Richmond County, Southampton, Stafford, Spotsylvania, and Suffolk City

| Soil Type    | Richmond County   | Southampton       | Stafford         | Spotsylvania      | Suffolk City      |
|--------------|-------------------|-------------------|------------------|-------------------|-------------------|
| I            | (\$10,155)        | (\$18,046)        | (\$1,613)        | (\$2,081)         | (\$19,034)        |
| II           | (\$10,951)        | (\$35,340)        | (\$5,603)        | (\$6,403)         | (\$26,171)        |
| III          | (\$44,075)        | (\$11,314)        | (\$1,571)        | (\$6,397)         | (\$15,030)        |
| <b>Total</b> | <b>(\$65,181)</b> | <b>(\$64,700)</b> | <b>(\$8,787)</b> | <b>(\$14,881)</b> | <b>(\$60,235)</b> |

Table C.2.6. Bad Rainfall Year Costs to Farmers for Surry and Westmoreland

| Soil Type    | Surry             | Westmoreland      |
|--------------|-------------------|-------------------|
| I            | (\$11,570)        | (\$17,913)        |
| II           | (\$16,132)        | (\$15,178)        |
| III          | (\$10,633)        | (\$43,123)        |
| <b>Total</b> | <b>(\$38,335)</b> | <b>(\$76,213)</b> |

### Appendix C.3 Costs of Yield Reserve in Good Rainfall Years

All of the tables use estimated yields under Extension recommendations (Yield) and

Yield Reserve Program (YRP Yield) levels to allow for yield differences to be estimated

and for the net costs to farmers and N reductions to be calculated.

Table C.3.1. Good Rainfall Year Cost and Yield Reductions for Accomack

|              | Yield (Mg/ha)  | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|----------------|-------------------|---------------------------|------------------|
| I            | 0              | 0                 | 0                         | \$0              |
| II           | 75,038         | 69,687            | 5,351                     | \$414,633        |
| III          | 37,453         | 34,882            | 2,571                     | \$197,125        |
| <b>Total</b> | <b>112,491</b> | <b>104,569</b>    | <b>7,922</b>              | <b>\$611,758</b> |

Table C.3.2. Good Rainfall Year Cost and Yield Reductions for Charles City

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 1,508         | 1,400             | 108                       | \$133,930        |
| II           | 4,906         | 4,556             | 350                       | \$431,129        |
| III          | 1,053         | 981               | 72                        | \$88,134         |
| <b>Total</b> | <b>7,466</b>  | <b>6,936</b>      | <b>530</b>                | <b>\$653,193</b> |

Table C.3.3. Good Rainfall Year Cost and Yield Reductions for Caroline

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 400           | 372               | 29                        | \$35,549         |
| II           | 1,540         | 1,430             | 110                       | \$135,303        |
| III          | 1,247         | 1,161             | 86                        | \$104,389        |
| <b>Total</b> | <b>3,187</b>  | <b>2,963</b>      | <b>224</b>                | <b>\$275,242</b> |

Table C.3.4. Good Rainfall Year Cost and Yield Reductions for Dinwiddie

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 739           | 686               | 53                        | \$65,608         |
| II           | 286           | 266               | 20                        | \$25,172         |
| III          | 976           | 909               | 67                        | \$81,715         |
| <b>Total</b> | <b>2,001</b>  | <b>1,861</b>      | <b>140</b>                | <b>\$172,495</b> |

Table C.3.5. Good Rainfall Year Cost and Yield Reductions for Gloucester

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 739           | 686               | 53                        | \$65,608         |
| II           | 286           | 266               | 20                        | \$25,172         |
| III          | 976           | 909               | 67                        | \$81,715         |
| <b>Total</b> | <b>2,001</b>  | <b>1,861</b>      | <b>140</b>                | <b>\$172,495</b> |

Table C.3.6. Good Rainfall Year Cost and Yield Reductions for Hanover

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 601           | 558               | 43                        | \$53,395         |
| II           | 1,249         | 1,160             | 89                        | \$109,805        |
| III          | 1,749         | 1,629             | 120                       | \$146,449        |
| <b>Total</b> | <b>3,600</b>  | <b>3,348</b>      | <b>252</b>                | <b>\$309,649</b> |

Table C.37. Good Rainfall Year Cost and Yield Reductions for Henrico

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 169           | 157               | 12                        | \$15,009        |
| II           | 246           | 228               | 18                        | \$21,614        |
| III          | 259           | 241               | A18                       | \$21,706        |
| <b>Total</b> | 674           | 627               | 47                        | \$58,329        |

Table C.3.8. Good Rainfall Year Cost and Yield Reductions for Isle of Wight

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 1,617         | 1,501             | 116                       | \$143,593       |
| II           | 1,415         | 1,314             | 101                       | \$124,388       |
| III          | 200           | 186               | 14                        | \$16,707        |
| <b>Total</b> | 3,232         | 3,001             | 231                       | \$284,689       |

Table C.3.9. Good Rainfall Year Cost and Yield Reductions for James City

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 94            | 87                | 7                         | \$8,335         |
| II           | 509           | 473               | 36                        | \$44,722        |
| III          | 2,134         | 1,988             | 147                       | \$178,660       |
| <b>Total</b> | 2,737         | 2,547             | 190                       | \$231,717       |

Table C.3.10. Good Rainfall Year Cost and Yield Reductions for King and Queen

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 233           | 216               | 17                        | \$20,711        |
| II           | 690           | 641               | 49                        | \$60,681        |
| III          | 2,645         | 2,464             | 182                       | \$221,441       |
| <b>Total</b> | 3,569         | 3,321             | 248                       | \$302,833       |

Table C.3.11. Good Rainfall Year Cost and Yield Reductions for King George

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 550           | 510               | 39                        | \$48,814        |
| II           | 482           | 448               | 34                        | \$42,371        |
| III          | 272           | 253               | 19                        | \$22,753        |
| <b>Total</b> | 1,304         | 1,211             | 92                        | \$113,938       |

Table C.3.12. Good Rainfall Year Cost and Yield Reductions for King William

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 871           | 809               | 63                        | \$77,382        |
| II           | 1,089         | 1,011             | 78                        | \$95,693        |
| III          | 1,527         | 1,422             | 105                       | \$127,847       |
| <b>Total</b> | 3,487         | 3,242             | 245                       | \$300,921       |

Table C.3.13. Good Rainfall Year Cost and Yield Reductions for Lancaster

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 209           | 194               | 15                        | \$18,549        |
| II           | 1,135         | 1,055             | 81                        | \$99,794        |
| III          | 452           | 421               | 31                        | \$37,842        |
| <b>Total</b> | 1,796         | 1,669             | 127                       | \$156,185       |

Table C.3.14. Good Rainfall Year Cost and Yield Reductions for Mathews

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 1             | 1                 | 0                         | \$93            |
| II           | 289           | 268               | 21                        | \$25,409        |
| III          | 29            | 27                | 2                         | \$2,468         |
| <b>Total</b> | 320           | 297               | 23                        | \$27,969        |

Table C.3.15. Good Rainfall Year Cost and Yield Reductions for Middlesex

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 255                  | 237                      | 18                               | \$22,685               |
| <b>II</b>    | 269                  | 250                      | 19                               | \$23,614               |
| <b>III</b>   | 1,121                | 1,044                    | 77                               | \$93,872               |
| <b>Total</b> | 1,645                | 1,531                    | 114                              | \$140,170              |

Table C.3.16. Good Rainfall Year Cost and Yield Reductions for New Kent

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 402                  | 374                      | 29                               | \$35,743               |
| <b>II</b>    | 392                  | 364                      | 28                               | \$34,474               |
| <b>III</b>   | 573                  | 533                      | 39                               | \$47,949               |
| <b>Total</b> | 1,368                | 1,271                    | 96                               | \$118,166              |

Table C.3.17. Good Rainfall Year Cost and Yield Reductions for Northampton

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 0                    | 0                        | 0                                | \$0                    |
| <b>II</b>    | 735                  | 683                      | 52                               | \$64,593               |
| <b>III</b>   | 1,231                | 1,146                    | 84                               | \$103,028              |
| <b>Total</b> | 1,966                | 1,829                    | 137                              | \$167,621              |

Table C.3.18. Good Rainfall Year Cost and Yield Reductions for Northumberland

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 1,041                | 966                      | 75                               | \$92,420               |
| <b>II</b>    | 2,239                | 2,080                    | 160                              | \$196,811              |
| <b>III</b>   | 1,290                | 1,201                    | 89                               | \$107,991              |
| <b>Total</b> | 4,570                | 4,247                    | 323                              | \$397,222              |

Table C.3.19. Good Rainfall Year Cost and Yield Reductions for Prince George

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 285           | 265               | 20                        | \$25,318         |
| II           | 579           | 538               | 41                        | \$50,901         |
| III          | 578           | 539               | 40                        | \$48,417         |
| <b>Total</b> | <b>1,443</b>  | <b>1,341</b>      | <b>101</b>                | <b>\$124,636</b> |

Table C.3.20. Good Rainfall Year Cost and Yield Reductions for Prince William

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost |
|--------------|---------------|-------------------|---------------------------|-----------------|
| I            | 137           | 127               | 10                        | \$12,144        |
| II           | 93            | 86                | 7                         | \$8,160         |
| III          | 181           | 168               | 12                        | \$15,122        |
| <b>Total</b> | <b>410</b>    | <b>381</b>        | <b>29</b>                 | <b>\$35,426</b> |

Table C.3.21. Good Rainfall Year Cost and Yield Reductions for Richmond County

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 513           | 477               | 37                        | \$45,590         |
| II           | 546           | 507               | 39                        | \$48,017         |
| III          | 2,183         | 2,033             | 150                       | \$182,715        |
| <b>Total</b> | <b>3,242</b>  | <b>3,017</b>      | <b>226</b>                | <b>\$276,322</b> |

Table C.3.22. Good Rainfall Year Cost and Yield Reductions for Southampton

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 912           | 847               | 65                        | \$81,014         |
| II           | 1,763         | 1,637             | 126                       | \$154,960        |
| III          | 560           | 522               | 38                        | \$46,903         |
| <b>Total</b> | <b>3,236</b>  | <b>3,006</b>      | <b>230</b>                | <b>\$282,876</b> |

Table C.3.23. Good Rainfall Year Cost and Yield Reductions for Stafford

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 82                   | 76                       | 6                                | \$7,242                |
| <b>II</b>    | 280                  | 260                      | 20                               | \$24,566               |
| <b>III</b>   | 78                   | 72                       | 5                                | \$6,512                |
| <b>Total</b> | 439                  | 408                      | 31                               | \$38,321               |

Table C.3.24. Good Rainfall Year Cost and Yield Reductions for Spotsylvania

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 105                  | 98                       | 8                                | \$9,342                |
| <b>II</b>    | 319                  | 297                      | 23                               | \$28,076               |
| <b>III</b>   | 317                  | 295                      | 22                               | \$26,521               |
| <b>Total</b> | 741                  | 689                      | 52                               | \$63,938               |

Table C.3.25. Good Rainfall Year Cost and Yield Reductions for Suffolk City

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 962                  | 893                      | 69                               | \$85,449               |
| <b>II</b>    | 1,306                | 1,213                    | 93                               | \$114,756              |
| <b>III</b>   | 744                  | 693                      | 51                               | \$62,306               |
| <b>Total</b> | 3,012                | 2,799                    | 213                              | \$262,511              |

Table C.3.26. Good Rainfall Year Cost and Yield Reductions for Surry

|              | <b>Yield (Mg/ha)</b> | <b>YRP Yield (Mg/ha)</b> | <b>Yield Differences (Mg/ha)</b> | <b>Farmer Net Cost</b> |
|--------------|----------------------|--------------------------|----------------------------------|------------------------|
| <b>I</b>     | 585                  | 543                      | 42                               | \$51,941               |
| <b>II</b>    | 805                  | 747                      | 57                               | \$70,737               |
| <b>III</b>   | 527                  | 490                      | 36                               | \$44,080               |
| <b>Total</b> | 1,916                | 1,781                    | 136                              | \$166,758              |

Table C.3.27. Good Rainfall Year Cost and Yield Reductions for Westmoreland

|              | Yield (Mg/ha) | YRP Yield (Mg/ha) | Yield Differences (Mg/ha) | Farmer Net Cost  |
|--------------|---------------|-------------------|---------------------------|------------------|
| I            | 906           | 841               | 65                        | \$80,416         |
| II           | 757           | 703               | 54                        | \$66,552         |
| III          | 2,135         | 1,989             | 147                       | \$178,765        |
| <b>Total</b> | <b>3,798</b>  | <b>3,533</b>      | <b>266</b>                | <b>\$325,734</b> |