Risk and Nitrogen Application Decisions in Florida Potato Production

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Abstract

This study focuses on development of agricultural best management practices (BMPs) for potato production areas in Northeast Florida, and presents the results of the initial situation assessment. BMP implementation is the primary strategy used by agencies and farmers to improve the efficiency and to ensure environmental sustainability of agricultural production. Although BMPs are defined as "economically feasible" and "cost-effective", economic analysis conducted as a part of BMP development has been limited, leaving the room for disagreement about economic impacts of specific BMPs. As a part of the situation assessment, we used interviews, group discussions, a survey, and a field trip to collect information about farmers' production practices and to examine farmers' opinions about BMP development process. Then, partial budget analysis was used determine the relative impacts of various factors (including the implementation of nitrogen fertilization management BMP) on production returns. Finally, an economic model is proposed to incorporate production risk analysis in BMP evaluation process.

Keywords: Florida potato production, partial budget analysis, risk analysis, best management practice, nitrogen fertilization.

Introduction

Florida potato production is an important component of the state and national economy, accounting for about 24% of total harvested potato production area in the U.S. for the spring market season (USDA Potatoes 2009 Summary, 2010; VanSickle et al. 2009). Most of Florida potato production is concentrated in northeastern Florida, in the region referred to as the Tri-County Agricultural Area (TCAA). Recently, a Total Maximum Daily Load (TMDL) plan was adopted for the area to address surface water quality problems, making best management practices (BMPs, including nutrient management) mandatory for the potato producers (Section 403.067 (7) (d), Florida Statutes). By definition, agricultural BMPs should be "practical and cost-effective" (FDACS 2005). However, there is an ongoing discussion among agencies, growers, university researchers, and other watershed stakeholders about the BMP definition, and specifically, about the nutrient management BMP that can be defined as "practical" and "economical".

This study focuses on the BMP development process in TCAA, discusses potential effects of nutrient management on production risks, costs and returns, and proposes an economic model for BMP development and evaluation. A combination of qualitative methods is employed for this study. First, to better understand producers' fertilizer use decisions, a situation assessment was conducted that included informal interviews with a producer and extension faculty members, survey of potato producers, and the review of policy documents and research reports. Based on the situation assessment, the following growers concerns with BMP program have been identified. First, growers question the results of the pollution loading modeling conducted as a part of TMDL development for the region, and hence, they doubt that the effectiveness of their BMP implementation efforts can be adequately assessed. Secondly, the growers argue that the current fertilizer BMP rate is not economical, and it will force producers out of production. They also question the results of the field production experiments used to develop the nutrient management BMP, and they are supportive of the new field trials designed to refine the BMP recommendations. Finally, the growers recognize that the mission of the land-grant university is to produce unbiased research, but they also emphasize that their collaboration with the researcher should result in benefits that outweigh the opportunity costs of their time "invested" in the collaboration.

Furthermore, the following determinants of growers' nutrient management decisions were identified: a) weather (rainfall in particular); b) fertilizer prices; c) availability of nutrients in the soils; d) potato variety grown, and e) the type of the target market (i.e., table-stock or chipping potato). Overall, increased fertilizer application is perceived by the producers as an insurance against yield reduction in the case of unfavorable weather conditions. To further explore the sensitivity of production costs and returns to key economic parameters, a partial budget analysis was conducted using production budgets for representative potato growers supplying chipping potato target markets (Smith and VanSickle, 2009). The analysis confirms the findings from the situation assessment that, variability in potato yields is a key determinant of the growers' costs and returns, and even a small increase in yield can make the increased fertilizer use profitable.

The data on growers' production practices, BMP development process, and growers' and researchers attitudes toward BMP program collected through the survey and informal interviews was used to formulate an economic model to define an "economically feasible" best management practice for nutrient management.

The paper is organized as follows. We review existing literature on fertilizer use and risks. Next, we describe the study area, the methodology, and the results of the analysis.

Literature Review

Producers' Fertilizer Use Decisions. Nitrogen application is a key production decision that have a direct effect on the crop yield and hence, profitability and economic viability of the farms. Babcock (1992) developed a theoretical model that explains the decision criterion frequently used by farmers: "apply a little extra fertilizer just in case it is needed". Farmers apply additional nitrogen fertilizer because the growing conditions after the application are not known (while the opportunities for additional fertilizer application later in the season are limited). During a rainy season, nutrients from fertilizers can be lost due to runoff or leaching process, reducing the nutrient availability to the crop and overall fertility of the soils. High nutrient rates can also be needed during the season with plentiful sunshine and optimal rainfall, to insure the vigorous plant growth. In other words, applying more fertilizer would guarantee that the lack of nutrients would not be limiting for the plants growth given any weather conditions that occur later in the season. This rule holds only if the costs of additional fertilizer applied *every year* are paid off by the gains in yields (and revenues) in the *few years* when such additional fertilizer is critical (Babcock 1987, Rajsic et al. 2009).

Farmers' fertilizer use decisions are also influenced by uncertainty about the site-specific soil nutrient content. Specifically, farmers increase fertilizer rates to make sure that the parts of the fields with the low fertility levels have enough nutrients to maintain healthy crops (Babcock and Blackmer 1994).This logic only holds if the price of nitrogen is low compared with the increase in the yield/returns on low-fertility soils (Babcock et al.1987, Babcock and Blackmer 1994). Better soil tests are becoming available to the farmers to reduce the uncertainty about soil fertility, and such tests can help reduce fertilizer rates and costs. Babcock and Pautsch (1998) compared two corn production technologies for 12 Iowa counties: single rate (i.e. applying nitrogen at the same rate to all farm lands) and variable rate (i.e. applying different fertilizer amounts based on soil nitrogen levels). The study showed that the variable rate application increases yield ranging from 0.05 to 0.50 bushels per acre, and decreases the fertilizer costs ranging from $1.19 to $6.83 per acre.

Economic literature also suggests that expected agricultural profits can change very little for a wide range of the fertilizer rates (referred to as "flat payoff function" by Pannell (2006) and Rajsic et al. (2009)). Hence, the farmers may not have strong incentives to change fertilizer use, given that the associated changes in profits are relatively small.

Since the fertilizer use influences yield variability and hence, production risks, the fertilizer application decisions depend on the degree of farmers' risk aversion (Isik 2002, Pope and Kramer 1979). Specifically, if the increase in fertilizer use leads to higher yield variability, then farmers who dislike the risks (i.e. more risk-averse) apply less fertilizer, in comparison with those who enjoy risky enterprises (i.e. less risk-averse or risk-loving). Given that nitrogen and phosphorus are found by many studies to *increase* the variability of yield (at least for corn), more risk-averse farmers should apply less fertilizer. For example, in a study of corn production experiments in Canada, Rajsic et al. (2009) found that it is economically optimal for a risk-neutral farmer to apply 14% more nitrogen than the current Canadian agronomic recommendations, while for a very risk-averse farmer it is optimal to apply 37% less nitrogen than the agronomic recommendations. Interestingly, in his study of twelve Texas grain sorghum producers, SriRamaratnam et al. (1987) found that the absolute majority of the growers believed that fertilizer reduces yield variability (contrary to conclusions of many existing studies), and hence, their risk aversion would drive the fertilizer use up.

Published studies have also modeled producers' fertilizer use decisions given the uncertainty of future input and output prices. For example, Feinerman et al. (1990) showed that the output price uncertainty lowers the levels of fertilizer use, while the expected increase in fertilizer prices lead to higher fertilizer application rates. Published studies have also considered the effects of uncertainty of weather and soil fertility on the substitution between nitrogen and land (Babcock and Blackmer 1994), as well as the link between fertilizer use and crop choices (Babcock and Pautsch 1998).

Producers' BMP Implementation Decisions. Nutrient management is one of the agricultural BMPs recommended by USDA/NRCS (USDA 2006), along with many state-level programs. Several sociological and economic studies have examined the factors that influence farmers' decisions to implement specific BMPs (Prokopy et al. 2008). These studies found that BMP implementation rate can depend on farm topography, soil texture and fertility, and crops produced, as well as typical rainfall and temperature in the specific geographic areas (Houston and Sun 1999). In addition, BMP implementation rate depends on BMP implementation and maintenance costs, perceived benefits of BMP, as well as the farm's financial performance (e.g., farm's debt-to-asset ratio) (Paudel et al. 2008). The presence of nearby subdivision usually leads to high value of land in alternative (non-farm) use, thus increasing the opportunity cost of farming, and reducing the likelihood of BMP implementation (Paudel et al. 2008). Furthermore, farmers' attitudes and perceptions about the process of BMP development and implementation, severity of water quality problems, and the effectiveness of BMPs in reducing potential environmental impacts can also change the likelihood of BMP implementation (FDACS 2005). Finally, BMP implementation rate can depend on the type of information available to the farmers, as well as on the sources of information (Feather and Amacher 1994). Involvement in producers' or community organizations can increase access to information about BMP programs, and hence, increase the rate of BMP implementation (Feather and Amacher 1994).

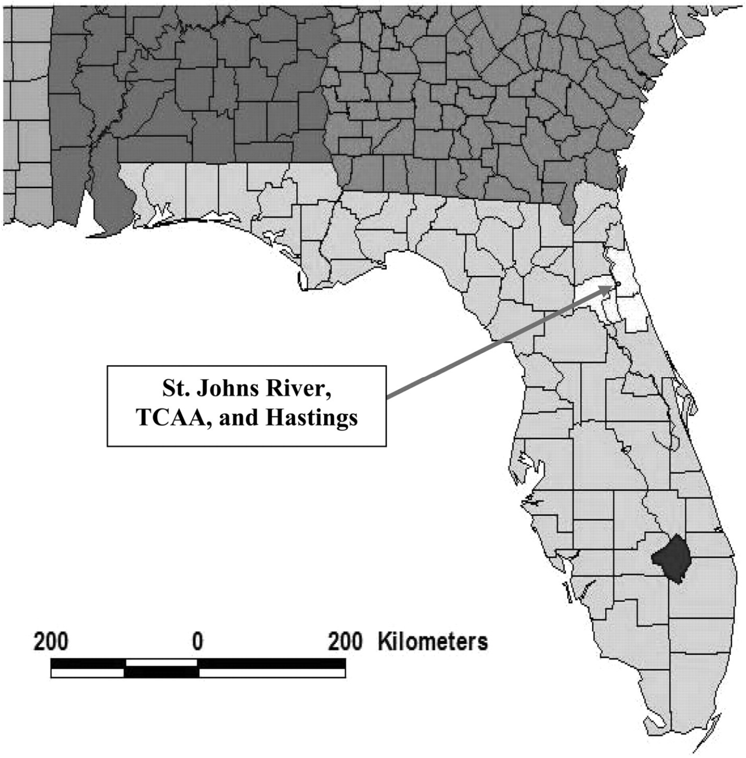
Policies to encourage BMP implementation. Various policies and programs have been proposed to increase the rate of BMP implementation. Labeling of sustainably-produced agricultural products (e.g., Czarnezki 2011), performance-based payments (Shortle et al.

1998; Winsten 2009), and payments for environmental services (PEPA 2011) are the strategies that can increase the rate of BMP implementation without affecting agricultural profits. Other policies to encourage BMP implementation include taxes or restrictions on fertilizer use (Shortle and Laughland 1994; Horan et al. 1999). Overall, Sheriff (2005) stated that there is no one policy appropriate for all crops and locations, and a policy mechanism should be designed based on specific characteristics of a particular region.

Study Area: Tri-County Agricultural Area, Northeast Florida

Most of the Florida potato production is concentrated in the Tri-County Agricultural Area (TCAA) that includes St. Johns, Flagler, and Putnam Counties (Fig. 1). Agricultural production in this area can be traced back to the 1890s when Thomas Hastings established the Prairie Garden Farm at what was to become the town of Hastings (St Johns County, Florida). By 1901, 22,790 cwt of Irish potatoes and 12,190 cwt of sweet potatoes were shipped from the Hastings area, so that it became known as the Potato Capital of Florida (Town of Hastings, no date).

Figure 1. Tri-County Agricultural Area



Source: Munoz-Arbodela et al. (2008)

Most of the potatoes grown in TCAA are harvested in May and June (spring planting) (Hochmuth and Cordasco, 2000). There approximately 30 potato growers in the area, and the majority of them target processed (chipping potato) market, while a few target the fresh market (table-stock potato). The aggregate average prices received by Florida potato producers are reported in Table 1. The prices for chipping potatoes are determined at the beginning of the production season through contracts with the processing plants, while the prices in table-stock potato market are more uncertain and could not be easily foreseen. In turn, the production and marketing costs are about $11.50/cwt (or $3,450/acre) for chipping potatoes, and approximately $17.79/cwt (or $4,450/acre) for table-stock potatoes (Smith and VanSickle, 2009). The biggest cost items are seeds (14-18% of total cost), fertilizer (12-16%[1]), and machinery (9-14%).

Table 1. Monthly Average Potato Prices Received by Farmers in Florida ($/cwt)

	Jan	Feb	Mar	Apr	May	Jun
2005		25.50	27.60	13.50	10.80	11.80
2006			40.00	18.70	11.90	12.20
2007		40.50	41.50	34.00	13.30	12.90
2008		18.80	21.50	18.00	16.40	12.30
2009	17.00	25.60	28.90	18.20	15.30	15.40

Source: USDA Potato Summary Reports 2007-2010.

Nitrogen is extremely important for optimal potato growth. The level of nitrogen in soil depends on weather, crop rotation, and production practices. The low water- and nutrient-holding capacity of the sandy soils (typical of northeast Florida) favors nitrogen leaching. Therefore, nitrogen fertilizer is applied in the beginning of potato production seasons and after periods of heavy rainfall (Hochmuth and Cordasco, 2000). Over the years, the potato growers have been reducing the nitrogen rates (Lands, personal communications), and the typical rate currently used in TCAA is 180-240 lb of nitrogen per acre (Cantliffe et al. 2009, Zotarelli et al. 2011).

Large part of TCAA is located in the Lower St. Johns River Basin. The main stem of the River was classified as impaired by nutrients, and the Total Maximum Daily Load plans

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[1] Assuming the average urea price of $600/ton is applied at the UF-recommended rate per acre.

(TMDLs) for total nitrogen and total phosphorus in the freshwater section, and for total nitrogen in the marine section of the River have been established (Magley and Joyner 2008). The state and regional agencies identify nutrient and sediment discharge from agricultural operations as the main cause of nonpoint source pollution in the middle and southern portions of the Basin (Magley and Joyner 2008). However, the effect of agricultural production on water quality has been questioned by the growers (Johns, personal communications), and additional research, monitoring, and educational projects to address growers' concerns are currently being implemented.

Florida has unique institutional framework for the water quality management. According to the Florida Watershed Restoration Act (FWRA, s. 403.067 F.S.), once a TMDL is adopted, Florida Department of Environmental Protection (FDEP) may develop and adopt a TMDL implementation plan, referred to as Basin Action Management Plan (BMAP). A BMAP describes the strategies and actions to achieve TMDL pollutant reduction goals, and contains a monitoring program and BMAP re-evaluation process (FDEP 2008). The FWRA also authorizes the Florida Department of Agriculture and Consumer Services (FDACS) to develop and adopt by rule BMPs to assist agriculture in reducing pollutant loads in TMDL watersheds and other areas. When BMPs are adopted by FDACS, FDEP must verify at representative sites that BMPs are effective in achieving pollutant reductions. Prior to rule adoption by FDACS, FDEP may provide "initial verification" of the BMPs, based on best professional judgment. The FWRA directs FDACS to re-evaluate and, if appropriate, revise BMPs, in consultation with FDEP, where water quality problems are demonstrated despite their appropriate implementation, operation, and maintenance.

Agricultural producers operating in the BMAP basins are required to either implement BMPs adopted by FDACS, or conduct monitoring to show that their production activities do not affect water quality. If an agricultural producer in a BMAP area does not either implement agency-adopted BMPs or conduct monitoring, he/she may be subject to enforcement by FDEP or a regional agency (i.e. a Water Management District, WMD).

To formally participate in an FDACS BMP program, agricultural producers should use the FDACS-adopted BMP manual(s) appropriate to their operations and geographical regions, identify the applicable BMPs on a notice of intent (NOI) to implement the BMPs, and submit the NOI to FDACS. Agricultural producers also must maintain records, such as fertilizer use, and allow FDACS staff to inspect the BMPs (Migliaccio and Boman 2008). Farmers who submit an NOI and implement and maintain FDACS-adopted BMPs have a presumption of compliance with state water quality standards. Growers also become eligible to apply for state cost-share funding.

BMAP to implement the Lower St. Johns River Basin TMDL has been adopted in 2008, making agricultural BMP mandatory for the potato producers in TCAA (Lower St. Johns River TMDL Executive Committee, 2008). Reduction in the fertilizer application rates is one of the best management practices (BMP) recommended by FDACS to address nutrient water pollution issues in TCAA. Current nutrient recommendation for potatoes specifies maximum rates of 200 lb of nitrogen per acre (Zotarelli et al. 2011), which is below the rate currently used by some growers (Cantliffe et al. 2009). In addition to the application rates, changes in timing of fertilizer application, and the use of control release fertilizers have been suggested (FDACS 2005).

The rate of implementation of nutrient management BMPs has been relatively low in TCAA (Cantliffe et al. 2009). Moreover, there is an on-going discussion among potato growers, agencies, extension faculty, and other watershed stakeholders about the definition of a "best management practice". FDACS defines BMPs as practices that are "economically and technically feasible" (FDACS 2005); however, comprehensive analysis of the economic implications of nutrient management is rarely a part of BMP research.

This study focuses on (a) describing the process of development the nutrient BMP and resulting disagreement among the stakeholder about what practice constitutes a BMP; (b) developing an economic model that can be used in future BMP research; and (c) defining the issues related to the role of extension as both serving agricultural community and also generating information for water quality policy development. Although many existing studies have examined economic factors driving producers' nutrient management decisions, we found no study that would propose an economic model for the development and evaluation of agricultural BMP recommendations. Most of the Florida BMP development studies are based on horticultural research and are largely focused on the average yield given different nutrient rates. No consideration for input and output prices, production risks, or input substitution is given. Limitations of such approach are discussed in this study. Finally, we discuss the challenging task faced by the extension service to conduct an objective BMP research while at the same time satisfying informational needs of the specific clientele group (agricultural producers). These at times contradictory demands faced by extension have not been adequately described in the existing economic literature.

Methodology

This study uses a combination of qualitative research methods to conduct situation assessment and stakeholder analysis (Ramirez, 1999). Qualitative data were collected using the following methods: (a) a field trip and four meetings and informal interviews with extension faculty and a potato producer; (b) a survey of potato producers in TCAA; and (c) review of the BMP production manuals, regional and state water quality reports and policies, and published research studies related to BMP and TMDL/BMAP development.

The meetings and the field trip were organized during the fall of 2011. Specifically, the authors met with a potato grower, Mr. Danny Johns, the president of North Florida Growers Exchange. Mr. Johns also provided comments for the initial drafts of the partial budget analysis (which is discussed below). We also met with two local extension agents, and two extension faculty members involved in the development of the BMP. The meetings and informal interviews were focused on determinants of the profitability of a potato farm, growers' perceptions of BMP program, and growers' opinions of the nutrient management BMP.

The survey instrument was developed by a multi-disciplinary research team working with potato producers TCAA. The instrument included 40 questions focused on current production practices used by the growers, targeted markets, and producers' attitudes about the factors affecting economic viability of potato industry in the area. The survey instrument was distributed to the potato growers who attended 2011 Florida Potato School (Hastings, Florida). Out of approximately 30 producers in TCAA, approximately 20 growers attended the School, and of them 10 completed the survey.

In addition to the meetings and the survey, we also reviewed 37 papers and reports related to the development of the fertilizer rate BMP recommendation, and 21 papers and reports about agricultural water quality policy in Florida, and the growers' opinion about it.

The results of the situation assessment were used to conduct the partial budget / sensitivity analysis of production costs and returns to changes in a) fertilizer prices and application rates; b) potato yields; and c) potato sale prices. We also propose an economic model to conceptualize BMP development. In future, we plan to expand the analysis and evaluate the BMP implementation using the results from current on-farm BMP trials.

Analysis and Results

Situation Assessment

Based on the interview and meeting results, the growers' opinions about agricultural BMPs can be summarized as follows. First, growers question the effect of agricultural operations on water quality in the region. The growers argue that fertilizer application rates have been going down over the past years (largely driven by the increase in fertilizer costs), while the area devoted to agricultural operations has been shrinking. However, no associated improvements in water quality have been observed. Further, growers argue that the water quality models used to estimate agricultural loading as a part of TMDL development process by the regional water agency leave unanswered questions related to the variations in water quality between geographical locations[2]. Finally, the growers argue that it is neither economical, no ethical for them to over-apply nutrients and cause water quality deterioration. Fertilizers account for a significant portion in potato production budget, and over-application of fertilizers would increase production costs. In addition, growers enjoy water-based recreation in the region, and they are motivated to avoid any impacts on surface water quality.

Secondly, for the production experiments that were used to develop the nitrogen application rate BMP, producers questioned the concept of "statistical significance." The past production experiments were conducted on five TCAA farms for three years. One farm was the property of the University of Florida Extension Service, and the field strips on the other four farms were voluntarily donated for the production experiments by the local producers. On each farm, a side-by-side comparison was used to examine potato yields given the growers' typical

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[2] As a part of this study, we have not interviewed agency representatives about the TMDL modeling. However, the University of Florida Water Institute is currently implementing a research / extension project focused on the review of the hydrologic modeling conducted as a part of TMDL development. Exploring growers' concerns and facilitating information sharing between the growers and the agencies is an important component of that project (Graham, Clark and McKee 2011).

nitrogen fertilizer rate and reduced nitrogen rates. Statistical analysis showed no significant difference in potato yields between typical and reduced nitrogen fertilizer rates. However, growers argue that the mean yield received with the typical growers' nitrogen rates were higher than the yield for the reduced rates. And even if the difference was not statistically significant, this difference still represented a respectable income, and growers interpreted such results as one that favored higher N rates.[3]

Thirdly, the growers argue that the current fertilizer BMP rate is not economical, and it will force growers out of production. The growers also disagree with the "one size fits all" approach used to set limits for fertilizer application rates for several crops and production systems in Florida. Different recommendations should be developed for different crops and soil types. Overall, agricultural production is an art; there are no two production seasons that are similar, and it is almost impossible to design BMP recommendations that would fit every grower, every production condition, or every weather condition.

Finally, producers believe that cooperation between agricultural producers and university should focus on research to produce information that can benefit growers (e.g., testing new production methods / technologies / varieties, developing production budgets, risk analysis, etc). Agricultural producers also realize that the mission of land-grant universities is to produce objective and unbiased research. Overall, the topic of nitrogen fertilizer application and BMPs is an uncomfortable topic for the producers, and they prefer to wait for the results of the field trials before commenting on this topic any further.

Survey results: production practices

Ten completed surveys were received for the potato growers' survey. Given that there are approximately thirty potato producers in the region, the survey response rate is respectable 30%. Summary of the relevant survey responses is provided below.

Eight out of ten respondents were from St Johns County. Average reported size of the potato farm was approximately 670 acres (ranging from 300 to almost 1200 acres). Sixty percent of respondents both owned and leased the land. Eighty two percent of respondents produce

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[3] To address the growers' concerns, additional on-farm BMP trials are currently being conducted to test the effects of alternative fertilizer rates on potato yield.

primarily for chipping potato market, while seventeen percent targeted table-stock potato market, and one percent targeted other markets.

Majority of respondents broadcasted the fertilizer at the pre-plant stage (30 to 40 days before potato planting), and either broadcasted or use banded method of application at plant emergence and to side-dress. Only four respondents answered the question about the percentage of nitrogen fertilizer they use at every stage of potato production. For these four respondents, on average, the largest proportion of nitrogen (35% of total nitrogen fertilizer applied during potato season) is applied at plant emergence (with the range from 0% to 70% among the respondents). In addition, on average, 26% of nitrogen is applied at pre-plant stage (with the range from 0% to 60%), and 18% - at planting (ranging from 0% to 70%). Finally, 21% of nitrogen is applied as sidedress (ranging from 0 to 50%). Among the factors that influence fertilizer application timing, the growers mention weather, planting dates, and the stage of plant growth.

Among the factors that influence fertilizer rate decisions, nine out of ten respondents indicated soil test results, and they also stated that soil tests are conducted every year. In addition, at least two-third of respondents mentioned rainfall volume and intensity, as well as the potato variety produced, as important factors for their fertilizer rate decisions. Thirty percent of respondents used control-released fertilizers in 2010/11 production season. Eighty percent of respondents do not perform crop rotation on their lands (i.e. potato is planted in the same area every year), but 100% use summer cover crops (mostly sorghum sudangrass), which is frequently fertilized to guarantee good plant establishment and growth.

For the question “What are the top challenges for the future success of your farm?”, 9 out of 10 respondents mentioned environmental regulation, and 8 out of 10 mentioned costs of fertilizer, pesticides, and other chemicals. Seven respondents also answered the open-ended question about “the biggest threat to the industry” as a whole. Five of them mentioned low prices of the output and/or high costs of production, and two explicitly mentioned regulations. The same seven respondents also answered the open-ended question about the strategies growers use to stay in business. Reduction in production costs and increased economic efficiency were mentioned by two out of seven respondents. Two respondents also mentioned effective competition strategies as a way to stay in business (which may imply reduction in production costs and / or competitive pricing strategy). Other strategies mentioned included pre-season contracts and money outlay.

For a typical year, the average reported yield for chipping potato is 258 cwt / acre (with the range from 240 to 280 cwt/acre). Weather is definitely a significant determinant of the yield, which can increase or decrease the yield by 19% (on average). Specifically, for a wet and cold year, average reported yield of chipping potato is equal to 208 cwt / acre (ranging from 175 to 250 cwt / acre). In turn, for a year with optimal weather conditions, average yield of chipping potato is 308 cwt / acre (with the range between 250 and 350 cwt/acre). These responses generally confirm with the values reported in Zotarelli et al. (2011) that states that the typical yield for chipping potato production is 275 – 400 cwt/acre.

Partial Budget Analysis

A simple sensitivity/partial budget analysis of costs and returns from potato production is conducted to explore the economic reasons driving the growers' fertilizer application decisions. The goal is to identify potential effects of changes in fertilizer application rates on costs and returns from potato production. The cost estimates are based on UF-IFAS potato production budgets (see Table 2). Returns are defined as the difference between total sale revenues (sale price multiplied by sale quantity) and total production costs (excluding loan interest on variable costs and, overhead and management costs). Since large part of potato production in TCAA targets chipping potato market, we focus on chipping potato only.

Table 2. Chipping Potato Production Budget 2008-09 in TCAA (Estimated Yield 300 cwt/acre)

	$/Acre	$/cwt
Pre-Harvest Variable Costs		
Seed/Transplants (26 cwt, @$24 / cwt)	$624.00	$2.08
Fertilizer, mixed and Lime (K, P and Water Soluble N – $600/ton – applied)	$550.90	$1.84
Crop Insurance	$35.00	$0.12
Cover Crop Seed	$20.00	$0.07
Herbicide	$22.48	$0.07
Insecticide and Nematicide	$147.36	$0.49
Fungicide	$131.55	$0.44
Tractors and Equipment	$414.07	$1.38
Farm Trucks (88.67 miles - driver cost included in overhead expense) (@$0.51 /mile)	$45.90	$0.15
General Farm Labor	$123.72	$0.41
Tractor Driver Labor	$160.43	$0.53
Aerial Spray	$19.50	$0.07
Predatory Mites	$0.00	$0.00

	$/Acre	**$/cwt**
Scouting	$0.00	$0.00
Interest on Operating Capital	$157.54	$0.53
Total Pre-Harvest Variable Costs INCLUDING Interest on Variable Costs	***$2,452.47***	***$8.17***
Pre-Harvest Fixed Costs		
Tractors and Machinery	$100.93	$0.34
Land Rent	$150.00	$0.50
Overhead and Management	$445.70	$1.49
Total Pre-Harvest Fixed Costs	**$697.63**	**$2.33**
Harvest and Marketing Costs		
Dig and Haul	$210.00	$0.70
Grading	$90.00	$0.30
Containers	$0.00	$0.00
Other Harvest and Marketing Costs	$0.00	$0.00
Total Harvest and Marketing Costs	***$300.00***	***$1.00***
Total Cost per Acre	**$3,450.10**	**$11.50**

Source: Smith and VanSickle, 2009 – IFAS Interactive Budget and seed prices revised for 2011 after the interview with IFAS experts.

For the baseline scenario, the average potato yield is assumed to be 300 cwt/acre. The potato sale price estimate is based on USDA Potato Summary Reports (2007-2010) and ERS (2007). Based on the price ratio between the chipping potato producer price ($6.53/cwt) and table-stock potato producer prices ($11.55/cwt) for all U.S. production in May – June of 2007 (ERS, 2007), a price index has been generated to differentiate sale prices received on the table-stock and chipping potato markets. Specifically, based on the responses to the growers' survey (see above), 20% of potato produced in TCAA was assumed to be sold in the table-stock potato market, and 80% in chipping potato market. Based on this sales split and the prices reported in ERS (2007), a price ratio has been generated. This price ratio was then applied to the USDA monthly prices for Hasting area (Table 1) to evaluate chipping potato price variability from year to year. For 2008 – 2009, the average producer price for the Hastings area is calculated as $12.92/cwt (with the range from $9.84/cwt to $16.00/cwt).

Total production costs for this baseline scenario are $3,450.10/acre (Smith and VanSickle, 2009). We assumed that producers apply 200 lbs N/acre in the form of a water soluble fertilizer (urea). Approximately 3.2 acres can be fertilized with one ton of urea, and the price of urea is assumed to be $600/ton (resulting in nitrogen fertilizer price of $187.5/acre).

Partial budget analysis was used to examine the sensitivity of production costs to the changes in potato yield, fertilizer prices, and fertilizer application rate. We also examine sensitivity of returns to the changes in yield and sale prices. It is assumed that the yield for Florida chipping potato ranges between 275 and 400 cwt/acre (Zotarelli et al. 2011). Next, the range of fertilizer price is based on the personal interviews with IFAS experts and online market search (American Cristal Sugar Company, undated): from \$540 to \$660/ton, or \$168.75 - \$206.25 / acre (given application rate of 200 lb of nitrogen per acre). In turn, the application rate of nitrogen is assumed to vary from 150 to 300 lbs N/acre (Hochmuth and Cordasco 2000). This analysis is based on an assumption that changes in fertilizer application rate do not influence yield. This assumption is a significant over-simplification; however, the information about fertilizer-yield relationship is currently not available.

The partial budget analysis shows that the production costs are not sensitive to the changes in fertilizer application rate. For example, a 12.5% increase in fertilizer application rate (from 200 lb/acre to 225 lb/acre) results in only a 1% increase in production costs (from \$11.50/acre to \$11.58/acre, assuming the yield of 300 lb/acre) (Table 3). In contrast, variations in yields have a much more significant effect on the production costs. Specifically, reduction in the yield from 300 lb/acre to 270 lb/acre (10%) would increase production costs from \$11.50/lb to \$12.67/lb (10%) (Tables 3).

Table 3. The sensitivity of production costs (\$/100 lb) to changes in yield and fertilizer application rate[1]

Fertilizer Application Rate (lbN/acre)	The Yield Range of the Chipping Potatoes (cwt/Acre)																		
	220	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**	**310**	**320**	**330**	**340**	**350**	**360**	**370**	**380**	**390**	**400**
150	15.11	14.49	13.93	13.41	12.94	12.49	12.08	11.70	11.34	11.01	10.70	10.40	10.13	9.87	9.62	9.39	9.17	8.96	8.76
175	15.21	14.59	14.03	13.51	13.03	12.58	12.17	11.78	11.42	11.09	10.77	10.47	10.20	9.93	9.69	9.45	9.23	9.02	8.82
200	15.32	14.70	14.13	13.60	13.12	12.67	12.25	11.86	11.50	11.16	10.84	10.55	10.26	10.00	9.75	9.51	9.29	9.08	8.88
225	15.43	14.80	14.22	13.69	13.21	12.75	12.33	11.94	11.58	11.24	10.92	10.62	10.33	10.07	9.82	9.58	9.35	9.14	8.93
250	15.53	14.90	14.32	13.79	13.30	12.84	12.42	12.02	11.66	11.31	10.99	10.69	10.40	10.13	9.88	9.64	9.41	9.20	8.99
275	15.64	15.00	14.42	13.88	13.39	12.93	12.50	12.10	11.73	11.39	11.06	10.76	10.47	10.20	9.95	9.70	9.47	9.26	9.05
300	15.74	15.10	14.52	13.98	13.48	13.01	12.59	12.19	11.81	11.46	11.14	10.83	10.54	10.27	10.01	9.77	9.54	9.32	9.11

[1] Note: for this analysis, we assume that changes in fertilizer application rate does not significantly affect yield.

[2] The price of the urea (fertilizer containing 46% of N) is assumed to be 600\$/ton.

Contrary to our expectations, the sensitivity of production costs to fertilizer prices is low. For example, given the yield of 300 lb/acre, a 10% increase in fertilizer price (from \$600/ton to

$660/ton) results in less than 1% increase in production costs (from $11.50 to $11.56/cwt). The sensitivity depends on potato yield, and if the yield is low (e.g., due to unfavorable weather conditions), the effect of changes in fertilizer prices on the total costs is slightly higher. In this analysis, we also assume that changes in fertilizer price do not influence the fertilizer application rates.

Table 4. The sensitivity of production costs ($/100 lb) to changes in yield and the fertilizer price

Fertilizer Prices[1] ($/ton)	The Yield Range of the Chipping Potatoes (cwt/Acre)																		
	220	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**	**310**	**320**	**330**	**340**	**350**	**360**	**370**	**380**	**390**	**400**
540	15.23	14.61	14.05	13.53	13.04	12.60	12.18	11.80	11.44	11.10	10.79	10.49	10.21	9.95	9.70	9.46	9.24	9.03	8.83
570	15.28	14.66	14.09	13.56	13.08	12.63	12.22	11.83	11.47	11.13	10.81	10.52	10.24	9.97	9.72	9.49	9.27	9.05	8.85
600	15.32	14.70	14.13	13.60	13.12	12.67	12.25	11.86	11.50	11.16	10.84	10.55	10.26	10.00	9.75	9.51	9.29	9.08	8.88
630	15.36	14.74	14.16	13.64	13.15	12.70	12.28	11.89	11.53	11.19	10.87	10.57	10.29	10.03	9.78	9.54	9.31	9.10	8.90
660	15.40	14.78	14.20	13.68	13.19	12.74	12.32	11.93	11.56	11.22	10.90	10.60	10.32	10.05	9.80	9.56	9.34	9.13	8.92

[1] Fertilizer price is taken for urea ($/ton) and the material would fertilize 3.2 acres/ton.

In turn, the returns are highly dependent on both the yields and the sale prices (Table 5). For example, change in sale prices from $9.84/cwt to $16.00/cwt (60%) results in variations in growers' returns from $0.35/cwt to positive $6.51/cwt at the base level. The returns are also highly sensitive to yield changes. Given the sale price of $9.84/cwt, 10% decrease in yield from 300 cwt/acre to 270 cwt/acre can turn farmers' (modest) returns (of $0.35/cwt) into losses of $0.59/cwt.

Table 5. The sensitivity of production profit ($/100 lb) to changes in yield and potato sale price

Potato Prices Received by Farmers ($/cwt)	The Yield Range of the Chipping Potatoes (cwt/Acre)															
	250	**260**	**270**	**280**	**290**	**300**	**310**	**320**	**330**	**340**	**350**	**360**	**370**	**380**	**390**	**400**
9.84	-1.35	-0.96	-0.59	-0.26	0.06	0.35	0.62	0.88	1.12	1.35	1.56	1.76	1.95	2.14	2.31	2.47
11.38	0.19	0.58	0.95	1.28	1.60	1.89	2.16	2.42	2.66	2.89	3.10	3.30	3.50	3.68	3.85	4.01
12.92	1.73	2.12	2.49	2.82	3.14	3.43	3.70	3.96	4.20	4.43	4.64	4.85	5.04	5.22	5.39	5.55
14.46	3.27	3.67	4.03	4.36	4.68	4.97	5.25	5.50	5.74	5.97	6.18	6.39	6.58	6.76	6.93	7.09
16.00	4.81	5.21	5.57	5.91	6.22	6.51	6.79	7.04	7.28	7.51	7.72	7.93	8.12	8.30	8.47	8.63

Overall, this analysis implies that even modest increases in yields (which may or may not be caused by increased fertilizer use) can significantly increase farmers' profits. As stated above, this analysis is subject to all limitations associated with partial budget analysis, and most importantly, it is based on assumption that changes in fertilizer application rate do not lead to changes in yield.

BMP development: an economic model

Best management practices are defined in Florida as "cost-effective" and "economically and technically feasible" (FDACS 2005). However, this definition can be hard to apply in practice. One possible interpretation of this definition is that BMP should improve economic efficiency of an agricultural operation, and bring the growers closer to the efficiency frontier. Alternatively, BMP cost-effectiveness can be defined within the context of water pollution reduction. Within this context, agricultural BMPs are cost-effective if they allow society to achieve pollution reduction goal at the lowest costs (as compared with other strategies). In this case, estimation of BMP cost-effectiveness should include both the analysis of the growers' BMP costs, and the effectiveness of the BMP in reducing water pollution (which is not currently a part of the fertilizer rate BMP development process).

Given that agricultural BMPs are widely interpreted by Florida stakeholders as strategies to improve economic efficiency of agricultural production, we adopt the model that is widely used in economic literature to examine the economically-optimal agricultural fertilizer use decisions. Potato production function can be defined as follows:

$$Y = f(N, W, S) \qquad 1$$

where yield (Y) is a function of nitrogen application (N), weather condition (W) and site specific soil conditions (S). W (weather) and S (site-specific soil characteristics) are random variables with probability distributions pr_W and pr_S. Given this production function, the farmer's profit can be defined as:

$$\pi = P_O Y(N, W, S) - P_n N - C \qquad 2$$

where P_o refers to the price of output, P_n denotes the price of nitrogen fertilizer, and C refers to other costs. Given the uncertainty of weather conditions and soil fertility, the nitrogen fertilizer rate decision of a risk-averse (or risk-loving) farmer is based on the utility maximization:

$$Max_N E[U(\pi)] = E\left[U\left(P_O Y(N, W, S) - P_n N - C\right)\right] \qquad 3$$

Denote the optimal level of nitrogen use as N^*.

Given that the BMP is widely interpreted as the strategy that does not affect farmers' profits, BMP should recommend the level of nitrogen application, N_{BMP} , which is equal to N^*.

$$N_{BMP} = N^* \qquad 4$$

Then, growers profit maximization problem becomes:

$$Max_N E[\pi] = P_O E(Y) - P_n N - C \qquad 5$$

Subject to

$$N \le N_{BMP} \qquad 6$$

Denote the optimal nitrogen rate that satisfies (5) – (6) as N^{**}, and if the BMP recommendation is chosen according to (4), then the following condition should hold:

$$N^{**} = N_{BMP} = N^* \qquad 7$$

As discussed above, in the northeast Florida, potato producers state that nitrogen rate recommended in BMP manuals, N_{BMP}, is below the economic optimum for their farms, that is condition (4) is not satisfied. Possible reasons can be identified for this mismatch between BMP recommendations and farmers' practices:

- BMP recommendations are developed based on the goal of yield maximization, as opposed to profit maximization (3);
- The differences in optimal nitrogen application rates among the growers with different degree of risk aversion are disregarded;
- Production experiments do not allow accurate evaluation of the probability distributions for weather and soil characteristics (pr_w and pr_S) and the shape of production function (1);
- A uniform BMP rate of 200 lb of nitrogen per acre has been set for all producers in the region. Such a uniform BMP rate can satisfy (4) only if the expected profit maximization problem (3) is exactly the same for all producers in the area. However, this is highly unlikely, given that soil characteristics likely vary from farm to farm, which would influence the distribution of the random variable S.

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