Is Strawberry Advisory System (SAS) Feasible for Farmers of All Risk Preference Profiles?

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Introduction

In the past decade, changing dynamics of weather patterns have affected global agricultural production. Climate change causes increased fluctuations in weather patterns, creating a variety of negative effects on agricultural operations. Some of the effects can be mitigated by the use of technology and expert systems such as Strawberry Advisory System (SAS).

SAS is a weather-dependent system of fungicide application. It was developed to improve temporal precision of fungicide application and to adjust it to weather conditions conducive for fungal diseases development. Based on Net Present Value (NPV) analysis, it outperforms the traditional, calendar-based fungicide application method given weather and market conditions typical for Florida (Vorotnikova et al., 2014). However, the analysis of the simulated yields and profits indicate that although SAS outperforms the traditional fungicide application method based on NPV maximization criterion, SAS also increases risks since the variability and the range of outcomes for both yield and profit increase in comparison with those under the traditional method. This discovery begs the following question: is the increased risk worth the increase in average yields and revenues? and would the answer be the same for all farmers or not? Accounting for the variability in yields and profits, as well as farmers' risk preferences, in the valuation of SAS performance is important because it allows researchers to target SAS recommendations to the farmers with appropriate risk aversion levels, thus making the advisories more accurate.

In this paper we analyze and compare the performance of SAS and traditional fungicide application method using stochastic efficiency with respect to a function

(SERF) criteria. SERF is a valuable tool because it incorporates a utility function and a range of decision-maker risk preferences. SERF criteria is used to rank ten-year NPV for SAS-based and traditional fungicide application methods, given a range of farmers' risk preferences. Thus, we are able to identify the thresholds of risk bearing preferences of farmers for which the increase in variability is worth the increase in yield.

We find that although the use of the SAS expert system increases the variability of yield and profit, stochastic efficiency with respect to a function (SERF) ranking, applied to the ten-year NPV, indicates that the SAS-based fungicide application method is preferred for the farmers with various risk-aversion levels for the management of two diseases (Anthracnose and Botrytis) and given two cultivar types (more- and less- disease resistant).

Background

Strawberry is the most significant berry crop by production value in Florida. In 2013 the production value was $260 million. In 2014, a record 207.1 million pounds of strawberry was harvested in Florida from approximately 10,100 acres (NASS, 2015).

Fungal diseases pose a special challenge for strawberry growers in humid and warm climates conducive for disease development, such as the climate in the southeastern United States. Losses from fruit rot, such as anthracnose and Botrytis fruit rots, can exceed 50% when conditions favor disease development (Ellis and Grove 1982).

Growers commonly use fungicides to fight the diseases, applying them on a calendar-based, once a week schedule (Mertely and Peres, 2012). However, this type

of application method introduces an array of issues. First, when/if the conditions are not conducive for disease development, unnecessary fungicide application causes chemical and labor waste, which are neither cost effective nor environmentally optimal. Second, if weather conditions have the potential to deteriorate unexpectedly, the farmer is unable to be proactive (Ellison et al., 1997). Third, the more fungicide farmer applies, the more fungicide-resistant the disease can become. Fourth, there are rising public concerns about possible health and environmental effects of fungicide use (Peres et al., 2010b).

Pre-harvest disease prevention strategies could have a significant impact on strawberry input use, production costs, and environmental sustainability. The Strawberry Advisory System (SAS) has been developed to assist producers in the southeastern U.S. to manage weather- and climate-related risks (Pavan et al., 2009). Florida was selected as the first state to launch the SAS web-based expert system, and in 2009, it was launched by the Southeast Climate Consortium (SECC), Florida Climate Institute, and Florida Cooperative State Extension Service (Pavan et al., 2011).

The system can be accessed on-line (at www.AgroClimate.org), or strawberry producers can subscribe for location-specific SAS-issued alerts via text or e-mail messages. In 2012 the web-site was accessed 3,099 times by 617 people (interview Natalia Peres, 2013). Based on a 2012 survey of Florida strawberry producers, 55% of respondents (45 growers) were subscribed for text or e-mail alerts from SAS (Borisova et al. 2014). Currently, SAS is being tested in other strawberry-producing U.S. states (Peres, 2012). For details of SAS operation see Vorotnikova et al. 2014.

Data

We heavily rely on the dataset used by Vorotnikova et al. (2014) and comprised from the records from 2006-2012 production experiments conducted at the University of Florida's farm. For each production season, the trials followed a randomized complete block design, with four replications randomly assigned to each fungicide application method: SAS-based, calendar-based, and no fungicide application. The experiment included two diseases, anthracnose and Botrytis, and two cultivar types, more- and less-disease resistant.

The strawberry production costs were based on the University of Florida strawberry production budgets, with projected increase in costs of 2% per year (Smith and Taylor, 2003; VanSickle et al., 2009). Florida strawberry sale prices and statewide yields for 1984–2012 were obtained from the National Agricultural Statistical Service (NASS, 2015). More details on original data can be found in Vorotnikova et al. (2014).

The Problem Definition

Vorotnikova et al. (2014) showed that based on NPV simulations, SAS-based method outperforms the traditional, calendar-based fungicide application method. Assuming a Florida strawberry farm of 26 acres, the value of SAS was estimated on average to be $1.76 million for anthracnose and $0.89 million for Botrytis management, over a ten-year horizon of use. It was concluded that SAS was a viable and practical decision-support/expert system for choosing the timing of fungicide application that can increase profit, and potentially reduce the environmental footprint from strawberry production.

Yet in Vorotnikova et al. (2014) it was observed that both the range and the variability of simulated NPV and strawberry yield distributions under SAS-based method were larger than that for traditional, calendar-based fungicide application method. When the NPV and yield distributions for no fungicide, SAS-based, and traditional methods were compared, no fungicide method was characterized with the widest distribution, and the distributions for SAS-based method were second widest. In contrast, the distributions under the traditional method of application were the narrowest, implying the smallest variation. This means that SAS-based method introduced more risk than that of traditional method (see the coefficient of variation measures in Tables 1 and 2).

Ultimately, the most important question is whether taking slightly more risk associated with the SAS-based fungicide application method is outweighed by the higher expected profits. To test this question, we use the data from the simulations conducted in Vorotnikova et al. (2014).

Table 1. Yield Summary Statistics after Monte Carlo Simulation for Anthracnose

	Name	Mean (lbs/acre)	Std Dev	Coef Var
More-Resistant Cultivar				
1	Control	19,017.61	8,588.02	45.16
2	Calendar	24,018.12	8,211.71	34.19
3	SAS based	30,968.59	11,310.99	36.52
Less-Resistant Cultivar				
1	Control	11,586.97	6,379.48	55.06
2	Calendar	19,566.59	5,946.78	30.39
3	SAS based	27,981.94	8,685.44	31.04

Table 2. Yield Summary Statistics after Monte Carlo Simulation for Botrytis

	Name	Mean (lbs/acre)	Std Dev	Coef Var
More-Resistant Cultivar				
1	Control	22,462.28	4,437.46	19.75
2	Calendar	24,357.75	3,481.39	14.29
3	SAS based	30,559.50	4,609.44	15.08
Less-Resistant Cultivar				
1	Control	20,306.48	3,457.70	17.02
2	Calendar	22,021.44	2,777.85	12.61
3	SAS based	25,113.97	3,439.42	13.70

Method: Stochastic Efficiency with Respect to a Function

To account for producers' risk preferences, stochastic efficiency with respect to a function (SERF) criterion was used to compare the NPVs for the two fungicide application methods. We assume negative exponential producer's utility function with absolute risk aversion coefficients of the following form (Richardson and Outlaw, 2008): $U(\pi, r) = 1 - e^{-r(\pi)\pi}$. In this study, the absolute risk aversion coefficient (ARAC) is $a(\pi_m) = \frac{b(\pi_m)}{x_m}$, where *m* signifies the risky alternatives (that is, the method of fungicide application), $b(\pi_m)$ is the relative risk aversion coefficient with respect to annual profit, π, under the method of application, *m*. SERF calculates the certainty equivalence (CE), that is, the fixed amount of money a producer would accept as an equal exchange for a distribution of potential risky returns. SERF is estimated for various risk aversion levels, $a(\pi_m)$, using the inverse utility function:

$$CE\big(\pi_m, a(\pi_m)\big) = U^{-1}\big(\pi_m, a(\pi_m)\big) \tag{1}$$

The advantage of SERF is that it does not require knowing a farmer's risk aversion coefficient, instead it uses a range of absolute risk aversion coefficients (ARAC) describing a range of risk preferences, from risk neutral (ARAC = 0) to extremely risk-averse (ARAC = 4) (Anderson and Dillon, 1992).

Existing studies (Nyangito et al., 1996) perform whole farm economic feasibility analyses of precision agriculture and expert systems using stochastic dominance ranking criterion, and we contribute to that literature by extending the risk analysis to SERF. We find SERF to be a valuable risk analysis tool because it incorporates a utility function and a range of decision-maker's risk preferences whereas stochastic dominance criterion does not.

Results

The certainty equivalence is estimated given the ten-year NPV distributions for the alternative fungicide application methods and different levels of producers' risk-aversion. We find that for both diseases and cultivars, the SAS-based application ranks as the most preferable given all values of the producers' absolute risk-aversion coefficients considered. This result is consistent for both diseases and cultivar types.

As it can be seen on Figures 1 and 2, certainty equivalence is the highest for SAS-based method for both cultivars for any risk aversion coefficient. Being that the certainty equivalent is the guaranteed amount of money that an individual would view as equally desirable as the risky alternative, the farmers would view risk adjusted return under SAS-based method as the most preferred.

Figure 1. SERF of Profit in case of Botrytis disease for two different cultivars

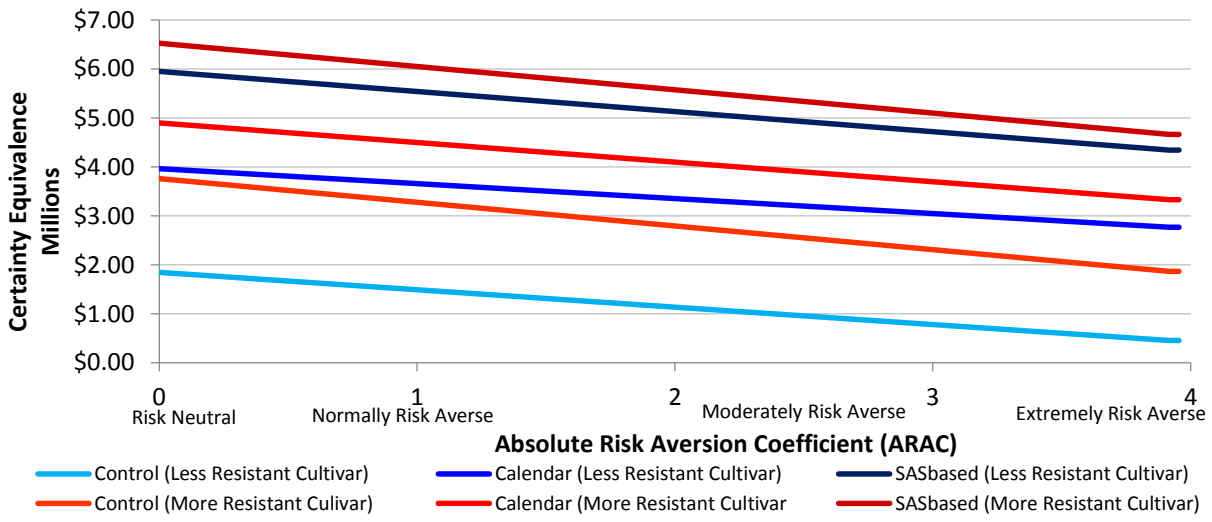
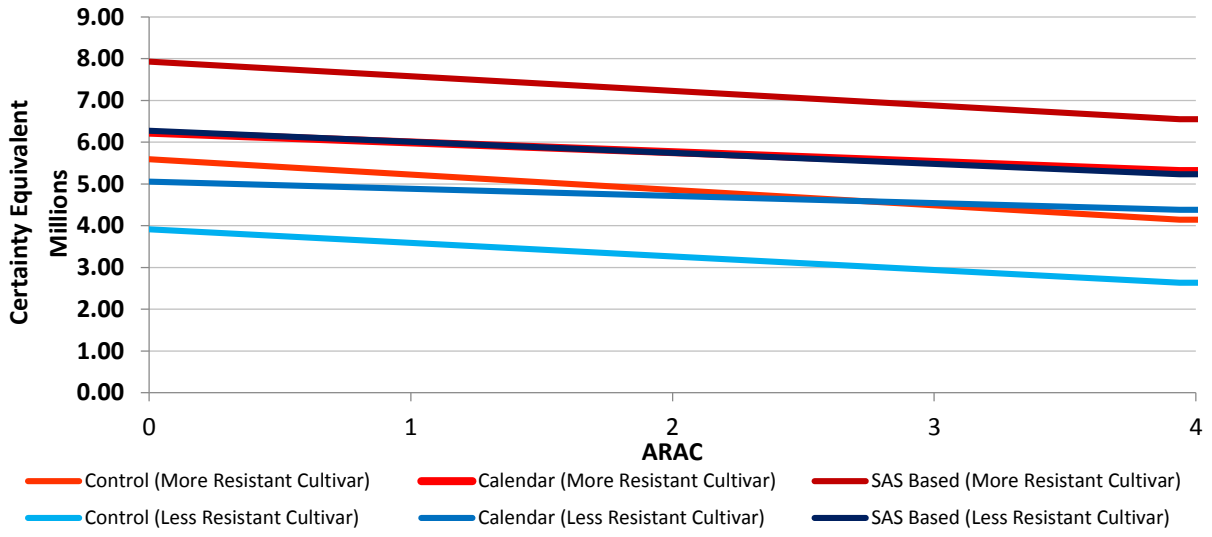


Figure 2. Stochastic efficiency of NPV function in case of Anthracnose



Discussion

This study examines the profitability of a precision agriculture (PA) expert system that optimizes agricultural input use over time. Specifically, we comprehensively evaluate the risk of SAS, which improves temporal precision of

fungicide application in strawberry production based on weather information. We show that SAS-based application is more profitable than the traditional method for all possible weather conditions, market price scenarios, and risk aversion levels of producers.

The results based on research trials show that for both diseases and cultivars, the SAS-based method is the most preferred given any farmers' risk aversion levels. This result can be explained by increased cost-effectiveness in fungicide applications, improved yields, and increased profits, compared to the traditional calendar-based application method. The PA disease management system increases profits while compensating the farmer for the additional risk associated with higher yield and profit variability.

Overall, SAS fungal disease management is a viable and practical decision-support system for fungicide application that can increase profit, and potentially reduce the environmental footprint from strawberry production. It can add significant economic value to the strawberry producer in the United States and in other countries. Furthermore, similar systems can be adopted for production of other high value crops like grapes, blueberries, and blackberries.

References

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