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Economic Approach to Valuing Information with Applications to Climate Information[1]

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Introduction

When we make decisions, often we rely on imperfect information about the complex world around us to predict the possible outcomes of those decisions. To make better decisions, we seek better information to reduce uncertainty and to more accurately predict outcomes. Information is valuable to us only insofar as it allows us to improve our decisions. This EDIS publication gives a basic introduction to the economic approach to valuing information. Specifically, it discusses a way to evaluate the information in Florida climate forecasts in order to improve agriculture decisions and thereby produce more reliable economic outcomes.

Economic Approach to Valuing Information

Information collection improves decision-makers' predictions about the outcomes of a decision. The value of information (VOI) is the expected gain in a decision outcome from using additional information measured in monetary terms. Once the benefits of improved information are estimated, they can be compared with the information collection costs to reach an appropriate balance (Lawrence 1999).

Consider a simplified example of measuring the value of climate information in tomato production. Florida climate varies depending on the phase of El Niño Southern Oscillation (ENSO). Specifically, El Niño years are usually characterized by 30 percent to 40 percent higher precipitation and lower temperatures during fall and winter in comparison with Neutral years. In contrast, La Niña years usually bring lower precipitation and warmer average temperatures than Neutral years. Each El Niño, La Niña, or Neutral year runs from October through September of the next calendar year, with approximately 50 percent of the years as Neutral, 25 percent El Nino, and 25 percent La Nina (for more information see Fraisse et al. 2006 and 2004). Predictions of ENSO phases could benefit Florida tomato producers by helping them to adjust their planting dates and select appropriate fertilizer types (Breuer et al. 2004a). Consider a hypothetical example when a tomato farmer is deciding on *high* versus *low* fertilizer application rates. A decision tree

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representing the farmer's decision options and hypothetical returns from every decision for each ENSO phase is presented in Figure 1.

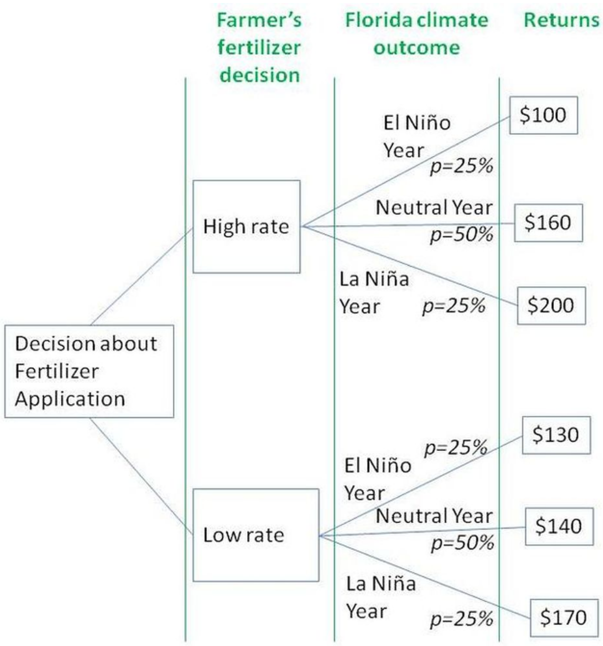

Figure 1. Hypothetical decision tree for fertilizer application rate.

If no climate forecast is available, based on the past frequencies, the farmer may assume that the probability of the coming year being Neutral, La Niña, or El Niño is 50 percent, 25 percent, and 25 percent, respectively. If this is the case, the expected return from applying the fertilizer at the high application rate is $155 (based on the fact that a return of $160 is expected, with a 50 percent probability for a Neutral year, and returns of $100 and $200 are expected, with a 25 percent probability for either a La Niña or El Niño year). The expected return from applying the fertilizer at the low application rate is $145. In this situation, it is more beneficial for the farmer to apply the fertilizer at the high application rate, which is associated with a higher expected return ($155).

What if a perfect forecast about the ENSO phase can be acquired by the farmer? Based on the hypothetical decision tree in Figure 1, the optimal choice in an El Niño year is to apply the fertilizer at the low application rate (an expected return of $130 versus $100 for the high application rate). Alternatively, in a La Niña year, the high application rate of the fertilizer is more beneficial for the hypothetical farmer (an expected return of $200 versus $160 for the low application rate). The high application rate of the fertilizer is most profitable for the farmer in the Neutral year as well (compare the returns of $160 and $140 for the Neutral year and different fertilizer application rates). Given the probability of having a Neutral, El Niño, or La Niña year, we obtain $162.50 as the expected return value for the fertilizer application decision with perfect information [130(0.25) + 200(0.25) + 160(0.5)= 162.5].

The value of perfect information is the difference between the expected returns for the decisions with and without perfect information. In our hypothetical example, the value of perfect information is $7.50 [$162.50 – $155.00 = $7.50]. If there are 1,000 growers in the region, making the same type of decision, the aggregate value of information for them would be $7,500.

What if the acquired information is imperfect? In other words, what if the forecast improves the farmer's ability to predict the ENSO phase in the coming year, but it does not result in perfect knowledge? To estimate the value of such information, one would need to know the accuracy of the forecast (e.g., the probability of El Niño conditions given a La Niña forecast), as well as the expected probabilities of the different forecast messages (El Niño, La Niña, and Neutral) for any given year. The value of imperfect information will always be less than the value of perfect information.

Determinants of the Value of Information (VOI)

In addition to the accuracy of the forecast, the value of information depends on a variety of other factors. The prior information available to the decision-maker can influence the value of any additional information the decision-maker may acquire. Furthermore, the value of different types of information differs. For example, if a decision outcome depends on several uncertain factors (summer maximum temperature and winter rainfall), then any additional information collected for each of these factors has a different value. On the other hand, the same information can be valued differently by farmers facing unalike decisions. For example, the same climate forecast can be valued differently by the farmer selecting fertilizer types as opposed to the farmer selecting irrigation rates. In addition, the same information can have different values for the two farmers if one of them focuses on maximizing profits while the other minimizes loss risks.

The value of information also depends on the ability and skills of the decision-maker to apply the information to modify his/her actions. Timing of the information delivery is important because information has no value if it is delivered too late in the decision-making process. This concept is especially important for agricultural decision making.

VOI Methodology and Examples of Agricultural Management Decisions

The phase of ENSO has significant influence on the value of agricultural production in Florida. The mean average winter yields in Florida decrease significantly during El Niño years (wet-cold fall and winter) in comparison with Neutral years: the decrease is 77 percent for tomatoes, 77 percent for bell pepper, 83 percent for sweet corn, and 83 percent for snap beans. As a result, increased prices for snap beans and bell pepper would be reported during the El Niño phase. El Niño conditions that follow a La Niña phase increase the mean average sugarcane yield by 7 percent. Two consecutive El Niño phases increase the yield of grapefruits and tangerines by 9 percent and 16 percent, respectively, but decrease lime yields by 14 percent (Hansen 2002; Hansen, Hodges, and Jones 1998; Hammer et al. 2001; Jagtap et al. 2002).

Scientists at several Florida universities have implemented projects focused on identifying the types of climate and weather information needed by Florida agricultural producers, the best format in which to deliver this information, and the potential uses of climate information in producers' decision-making. A review of weather and climate management tools available for Florida agricultural producers can be found in Miller and Migliaccio (2008).

Field crop producers can use pre-season climate information to make decisions about variety selection, acreage allocation, fungicide and herbicide expenditures, amount of fertilizer to apply, whether to sell or to hold grain stocks, and what marketing strategies to choose. *Livestock producers* can use climate information in their decisions about planting and fertilizing winter forage, estimating feed purchases to avoid high prices, and selecting optimal stocking rates. For a *forestry producer*, climate information can be used to decide whether to plant drought-resistant seedlings, when to schedule seedling planting and timber harvesting, what planting location and density to select, and how to best allocate resources for forest fire monitoring (Fraisse et al. 2004; Breuer et al. 2004a,b).

For example, El Niño / La Niña predictions may help in the selection of seasonal management strategies for tomato production in south Florida (Breuer et al. 2004a; Messina, Letson, and Jones 2006). In response to climate information, producers can select specific fields for growing tomatoes (avoiding lowlands during wet El Niño years), decide on irrigation frequency (irrigation frequency can decrease during wet El Niño years), and manage fertilizer application (using slow-release fertilizers and drip irrigation techniques during El Niño years).

Information about the ENSO phase can have value for peanut farmers. Adjusting planting dates depending on the ENSO phase can potentially increase mean peanut yield by 1 percent to 8 percent (Mavromatis, Jagtap, and Jones 2002). Using a computer model, Fraisse et al. (2005) estimated that the best peanut planting window for peanut producers in Jackson (Florida), Henry (Alabama), and Mitchell (Georgia) Counties is the second half of May. Planting at that time reduces the risk of crop failure. If planting must occur outside this best planting window, a higher level of insurance coverage may be advisable, and information about the ENSO phase can be used in crop insurance purchasing decisions. For example, for Jackson County (Florida), the El Niño phase (cooler-wet fall and winter) carries a higher risk of crop failure for early planting dates. Hence, if El Niño conditions are predicted, the grower planting outside the best planting window may consider higher insurance coverage. In contrast, the risk of crop failure is lower during La Niña years (warmer-dry fall and winter) for almost all planting dates in comparison with El Niño and Neutral years (Cabrera et al. 2006; Fraisse et al. 2005).

Information about ENSO seasonal changes also can have value for cow-calf production. Producers can use climate information in stocking decisions (the herd may be expanded during El Niño years which are generally characterized by good forage production) and in decisions about winter forage (Jagtap et al. 2002; Breuer et al. 2005). Using a computer model of a representative cow-calf production operation, with a bahiagrass forage system for summer and a mixture of rye and ryegrass for winter, Breuer et al. (2005) showed that the estimated pasture production was significantly lower for La Niña years (hot-dry fall and winter) in comparison with El Niño (cool-wet fall and winter) and Neutral years, which leads to significant reductions in the number of cattle that can be carried over the winter. Information about an expected ENSO climate phase can have value for a cattle producer if it helps reduce the cost of winter feed purchases. For example, if a La Niña year is expected, the producer can purchase the feed ahead of time (during the summer when hay costs about half as much as in winter). In addition, if a La Niña year is predicted, the producers can anticipate a lower chance of forage establishment and therefore stock fewer cattle in comparison with the Neutral or El Niño conditions.

Forage crop simulations by Cabrera et al. (2005) show that climate-based decision-making in dairy farms in northern Florida would allow farmers to identify the forage systems that result in the lowest nitrate leaching. If annual nitrogen leaching is predicted to be higher for El Niño years in comparison with Neutral or La Niña years (for most of the months), mostly due to a higher frequency and intensity of rainfall, an informed decision can reduce potential nitrate losses (Cabrera et al. 2005).

More information about the value of information for agricultural production can be found in Mjelde, Hill, and Griffiths (1998), Katz (2009), and Katz and Murphy (1997). Management options can be adjusted in response to climate information for many agricultural crops and plants.

Discussion and Limitations

Assigning value to weather and climate forecasts for agriculture is a complex proposition. Uncertainties exist at every level of forecast development, including monitoring of climate conditions, developing ocean-atmospheric and crop models, and in communicating the information to decision-makers. In this document, we considered known outcome uncertainties (linked to frequency of ENSO phase) and rational decision making on the part of a hypothetical farmer who is neither a risk-taker nor a risk-avoider. The methodology of valuing imperfect information (which can be complex) was not discussed in this document. Similarly, we did not discuss the costs of information acquisition. Decision-makers should compare the costs with the value of information to decide if it is worth investing in information acquisition.

Furthermore, we focused on a competitive industry and assumed that individual farmers cannot influence input or output prices in the industry. In contrast, Messina et al. (2006) and Jagtap et al. (2002) observed that climate information value caused tomato farmers to fear that increasing their production levels based on climate predictions might elicit lower crop prices. Using a computer simulation model, Jagtap et al. (2002) showed that "if only one [tomato] grower with 500 hectares adopted the optimal transplanting dates, she or he could expect to benefit by an average of $892 per hectare, per year. However, if all producers in the region adopted the same optimal practice, each producer and the industry as a whole would lose money." Coordinated production schedules among farmers may help mitigate the problem of possible overproduction (and adverse price effects) of climate information provision (Breuer et al. 2004a).

Conclusions

The value of information concept allows us to estimate the effect information collection can have on decision outcomes. If aggregated to the state of Florida, for a given crop, the value of information on seasonal climate would likely be quite high.

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