Principles of Retrospective Decision Analysis

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Motivation

- How do we evaluate management responses to forecast information?
- What is the best response to a forecast?
- How do we factor the inherent uncertainty of seasonal forecasts into recommendations?
- How to we attribute value to a forecast system, or compare forecast systems?

Model-based vs. Descriptive Analysis

- *Ex-ante*, model-based valuation
  - Assess potential impacts before they are realized.
  - Based on:
    - models of what decision makers are expected to do
    - elicited rules of what they think they would do
- *Ex-post*, descriptive valuation
  - Estimate observed impacts
  - May require model-based analyses to supplement observation

Why Retrospective Analysis?

- Climate and impacts are probabilistic
- Uncertainty is a characteristic of decisions
  - Does a good outcome = a good decision?
  - Does a poor outcome = a poor decision?
- Must understand uncertainty of forecast climate and agricultural impacts
- Must understand decision outcomes over a range of variability

Optimal Climate Information Use

Some Notation

- Utility function $U(w)$
- Climate distributions $f(2)$ (climatology C) & $g(2|F_j)$ (conditioned on forecast F_j)
  2 is a realization of weather or seasonal mean
- Strategy, or vector of decisions $\mathbf{x}$
  $\mathbf{x}^*$ denotes the optimal strategy
- Environment (everything else) $\mathbf{e}_t$
- Returns $w_i(\mathbf{x}, 2_i, \mathbf{e}_i) = w_{i-1} + A_i(\mathbf{x}, 2_i, \mathbf{e}_i)$,
  a function of decisions, weather, environment

Optimal Climate Information Use

Decision Rule, Climatology

- Maximize

$$E\{U(w)\} = \int U(w(\mathbf{x}, 2, \mathbf{e}_{now}))\, f(2)\, d2 \qquad \text{general}$$

$$\approx n^{-1} \sum U(w_i(\mathbf{x}, 2_i, \mathbf{e}_{now})) \qquad \text{hindcast or retrospective}$$

...subject to constraints

- Equivalently, maximize w_{CE}
- Single (fixed) optimal strategy / $\mathbf{x}^*|C$

Optimal Climate Information Use

Decision Rule: Forecast

- For each F_j, maximize

$$E\{U(w|F_j)\} = \int U(w(\mathbf{x}, 2, \mathbf{e}_{now}))\, g(2|F_j)\, d2$$

$$\approx n_j^{-1} \sum_i U(w_i(\mathbf{x}_j, 2_i|F_j, \mathbf{e}_{now}))$$

...subject to constraints

- Multiple (flexible) optimal strategies $\mathbf{x}^*|F_j$
  - must evaluate for every F

Value of Forecast Information

“Climate forecasts have no intrinsic value” (Graeme Hammer).

Value of Forecast Information

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Outcomes of improved decisions do.

Value of Forecast Information

Economists define the value of information as expected outcome of best decisions using the new information minus expected outcome of best decisions in the absence of the new information.

Value of Forecast Information

- *Objective*: difference in expected returns:

  $V = E\{W(\mathbf{x}^*|F)\} - E\{W(\mathbf{x}^*|C)\}$

  $\approx n^{-1} \sum (W_i(\mathbf{x}^*|F_i, \theta_i) - W_i(\mathbf{x}^*|C, \theta_i))$

- *Subjective*: difference in *CE*:

  $V = W_{CE}(\mathbf{x}^*|F) - W_{CE}(\mathbf{x}^*|C)$

  $\approx U^{-1}(n^{-1} \sum U(W_i(\mathbf{x}^*|F_i, \theta_i))) - U^{-1}(n^{-1} \sum U(W_i(\mathbf{x}^*|C, \theta_i)))$

- Can consider value realized in a particular season, can be positive or negative

Value of Forecast Information

Assumptions

- "Value" assumes:
  - Optimal use of forecast and climatology
  - Utility function captures relevant goals
  - Realistic constraints
  - Ability to predict outcome distribution as a function of forecast or observed climatological distribution
  - Subjective uncertainty = "objective" distribution
- Potential value of optimal use of climate information in the model system

Applying Forecast Value

- Basis for answering:
  - What decisions are most sensitive to forecasts?
  - Relative value of forecast systems or formats?
  - Relative importance of various components of forecast quality, e.g., skill vs. lead time?
- Optimal strategies an entry point for stakeholder discussion or further research
- Only way to estimate potential benefit before aksing stakeholders to risk livelihoods.

Applying Forecast Value

The formulation presented here is only a generic framework. Several methods are available for analyzing decisions. The method should be appropriate for the nature of the decision and the system being managed.

Nature of the Decision

- Discrete or continuous decision variables?
- Determined by continuous climatic states or thresholds?
- Static or dynamic?
- Profit maximizing or risk averse?
- Single or multiple objectives?
- Single or multiple decision makers?
- Are are climate and outcomes closely linked?

System Levels

- Field level, e.g., crop management
- Farm level, e.g., resource allocation
- Household level, e.g. livelihood decisions
- Community level, e.g. Florida potato farmers clearing drainage canals
- Watershed level, e.g., irrigation distribution
- Sub-national level, e.g., food reserves
- National level, e.g., requests for food aid

Levels of Analysis

Use the simplest analytical framework that captures the important determinants of the decision problem.