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The Emperor's New Clothes: Software, Wetware, or Nowhere? The Thorny Road to Adoption: Climate-Product Dissemination for Agriculture in the United States.

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INTRODUCTION

Practical applications of climate forecasts require software to calculate climate indices, simulate impacts on agriculture, and evaluate profitability, risk and decision options. But the mere availability of such software packages does not guarantee adoption and use of forecast and prediction products by the agricultural end-user. The broader adoption issue also hinges on effective dissemination and communication of agriculture-specific decision information and its integration into the end-user's decision process.

SOFTWARE FOR FORECASTS AND PREDICTION PRODUCTS

Software is defined as computer simulation tools that calculate forecasts and prediction products. For the purposes of this discussion, software is classified into climate-forecast, downscaling, impact-prediction, and decision-support software.

Forecast software: Seasonal climate forecasts are developed by use of General Circulation Models (GCM) and statistical forecast models. GCMs are complex and resource intensive models that simulate the major physical processes controlling the state of the earth's oceans, atmosphere and land surface. Statistical forecast models produce forecasts based on teleconnections between ocean/atmospheric indices or states, and regional climate conditions.

Downscaling software: The mismatch between the large scale of regional climate forecasts and the local scale for agricultural impact studies is resolved by statistical-empirical or dynamical downscaling software. Spatial and temporal downscaling software generates local weather data that reflect the climate-forecast characteristics.

Impact-prediction software: Impact-prediction software provides the linkage between downscaled climate forecasts and local agricultural applications. Prediction software includes complex process-based rainfall-runoff models, crop growth and productivity models, grazing models, disease and pest models, and environmental impact models.

Decision-support software: Decision support integrates forecasts and forecast impacts with economic, management, risk and marketing considerations, and places these factors into a systems context. Decision support provides the end-user with alternative options that increase profitability under favorable forecasts, reduces losses for adverse forecasts, or results in other economic, environmental, and societal benefits. Decision-support software may include optimization routines, cost-return calculations, enterprise budgets, and evaluation of risk factors. Educational software, such as visualization, gaming and scenario analysis also fall into this category.

In the United States, as well as in many other countries, software packages in the above categories have been developed by government agencies, research institutions and consulting companies. Many of these software packages are or have evolved out of research models. Providing a review of existing software packages is beyond the scope of this study. Validation and operation of these sophisticated models, as well as data preparation and result interpretation, is generally beyond the reach of the typical farmer, rancher and operator of small- to medium-size farm enterprises. To date, agricultural applications have mostly been conducted by research agencies as demonstration projects, and existing software and prediction products have not been broadly adopted by the agricultural end-user for a number of practical reasons.

ADOPTION IMPEDIMENTS

Adoption impediments are not necessarily due to any shortcomings in hydrologic or agricultural application models and their linkage with the climate. Established hydrologic and agricultural models have been successfully used in agricultural and water resource planning and management. Adoption impediments are primarily associated with (1) limitations in forecasting ability and associated prediction products; (2) constraints related to the decision process and decision maker; and (3) lack of relevant and accessible prediction products and decision information for agricultural applications.

In the first kind of impediment, limited skill of forecasts affects user confidence, low frequency of useful forecasts dampens expectations for routine applications, and generalized presentation of regional forecast lack the specificity often required for local and practical applications. Also, downscaling and impact assessment may degrade the predictive value of the forecast, an undesirable side effect that is rarely quantified. Development of significant improvements in forecast skill is a considerable challenge and is unlikely to be forthcoming soon. These issues have been addressed in the published literature and are not discussed further in the context of this paper.

In the second kind of impediment, end users have difficulties formally dealing with probabilistic concepts and integrating these into the overall decision system. Agricultural users traditionally account for risk and uncertainty by relying on intuition and experience. Training, education and consulting services can alleviate these difficulties. Other impediments include legal, contractual, financial and market constraints. These constraints, while important to the decision process, are driven by non-climatic issues and are not discussed further herein.

The third kind of impediment addresses the lack of relevant and application-specific agricultural prediction products, and lack of an effective and affordable delivery system that reaches and resonates with the agricultural end-user. Demonstration projects have illustrated the usefulness of climate forecasts for selected agricultural applications. However, application-specific prediction information for a range of agricultural applications, along with an effective delivery mechanism, is not available at this time. This reflects the gap between science-driven development of prediction products and practical decision information needed for problem-specific applications. This gap is narrowed when forecast users are government agencies and large corporations that have in-house resources and expertise to interpret technical forecast information and provide problem-specific decision support. However, the gap remains wide for small to medium size agricultural enterprises that generally cannot afford consulting service fees to interpret the forecasts, develop farm-specific prediction information and provide related decision support. This raises the question of how and by whom climate forecasts, impact predictions and decision information should be prepared for effective transfer and adoption by typical agricultural decision makers.

TECHNOLOGY TRANSFER APPROACHS

The prevalent technology-transfer approaches for climate forecasts, impact predictions and decision information to end-users are the "loading-dock" and the "end-to-end" approaches. The advantages and limitations of each are discussed and a hybrid approach more suitable for agricultural applications is proposed.

Loading-dock approach: In the "loading-dock" technology transfer approach, a forecast product is made available in a top-down fashion to the public with little input from the end-user (for example, seasonal climate forecasts). This transfer mechanism is often used by government organizations to deliver products for public consumption or to other agencies which in turn provide a public service. The products tend to reflect the mission and mandate of the government organization producing them. The products are generally free of charge and enjoy wide dissemination potential. However, they lack application-specific details and users have to figure out for themselves how to best make use of them for their particular application.

End-to-end approach: In the "end-to-end" technology transfer approach, all aspects of the decision process from the initial forecast development, to downscaling, impact assessment, design and communication of products, and end-user decisions support are considered in an integrated fashion. The end-to-end approach requires interdisciplinary collaboration and close interaction between users, their intermediaries, and the application scientists. Applications are generally demand driven and are provided for a fee. The end-to-end approach is very effective at targeting forecast and prediction products to address decision criteria of specific end-user applications. This effectiveness, however, comes at a cost. The effort and resources brought to bear on an individual application must be justified by the expected benefits. Cost-benefit considerations of the end-to-end approach suggest that the typical customer for this service are large irrigation projects, commodity groups, and agribusiness that can defray the cost of the service. This full end-to-end service is generally not cost effective for individual ranchers and small- and medium-size farm enterprises.

Hybrid Approach: The hybrid approach provides affordable prediction and decision information for agricultural applications. It combines the top-down "loading-dock" approach for the development and dissemination of the resource intensive components of climate forecasting and impact prediction, and a bottom-up consulting approach for the site- and problem-specific interpretation of the prediction products and development of end-user decision information.

On the climate side, the technically complex and resource intensive development of regional climate forecasts and downscaling to month and county scales is performed by a government or research institution and delivered using the "loading-dock" approach. In the Unites States, the Climate Prediction Center (CPC) of the National Weather Service provides seasonal climate forecasts, and CPC and local Weather Service offices are contemplating downscaling forecasts to monthly and local scales.

On the agricultural side, forecast impact assessment is preferably performed by agricultural specialists that are familiar with local and regional agronomic practices, farm issues and likely management and cropping alternatives for various climate forecast scenarios. Impact assessment involves stochastic generation of daily weather that reflects the forecast, and simulation of corresponding impacts on hydrology, crop and plant production, pests, grazing capacity, erosion, nutrient transport, etc. Impact assessment is conducted at the county scale and for dominant crops, typical physiographic conditions and likely agronomic alternatives for forecasts under consideration. The assessment may also include qualitative recommendations for agronomic management practices that appear best suited for the given climate forecast. This impact assessment can be integrated into services already provided by State Agricultural Extension Services using a top-down "loading-dock" approach.

The agricultural end-user gets primarily involved at the decision support stage. The user can either utilize the county level assessments and recommendations, or subscribe to a consulting service for decision support. The consulting service would provide enterprise-specific interpretation of the county level impact assessment, quantification of critical decision variables (risk, benefits, etc.), integration of these variables into an overall decision matrix, economic evaluation of decision options, and tailored recommendations for action. The service provider could be a for-profit business, or possibly a government supported service. Limiting the scope and cost of the personalized consulting to interpretation, application of county-level prediction products and decision support reduces cost and makes the service accessible to small agricultural users.

DISCUSSION

Investments in prediction products and decision support for agriculture depends on a number of factors. First, regions of potential applications should have skillful and actionable forecasts, i.e. forecasts should depart sufficiently from average conditions (climatology) to lend themselves to alternative agronomic actions. Such actionable forecasts should also occur, if not every year, at least every second or third year to generate user interest in prediction products and justify the cost and effort of implementation. Second, regions considered for application should be agriculturally active and support crops that are sensitive to climate variations, and timing of related agronomic decisions and activities should coincide with seasons that display predictable climate patterns. Third, agricultural end-users of forecast products, affected commodity groups, and related agribusiness should promote the use of prediction products and generate political and financial support that encourages agricultural service agencies to include forecast-based decision support in their services. In regions where these conditions are met, demonstrated forecast-application methodologies and existing software packages can be used to conduct impact assessments, develop agricultural prediction products, and provide related decision support on an operational basis. Development, implementation and communication of farm-specific prediction products and decision support should be the result of a participatory approach that includes all interested parties. The realization of such a prediction system could increase productivity, enhance profitability, and reduce economic risk for agricultural enterprises.