Agricultural Systems 146 (2016) 103–110

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Review

Imperfect forecasts and decision making in agriculture

Yoko Kusunose [a,*], Rezaul Mahmood [b]

[a] Department of Agricultural Economics, University of Kentucky, 400 C.E. Barnhart Building, Lexington, KY 40546-0276, USA
[b] Department of Geography and Geology, Western Kentucky University, 304 Environmental Science and Technology 1906 College Height Blvd., Bowling Green, KY 42101-1066, USA

A R T I C L E I N F O

Article history:
Received 30 October 2014
Received in revised form 12 April 2016
Accepted 17 April 2016
Available online xxxx

Keywords:
Forecast accuracy
Weather
Climate
Agricultural decision making
Imperfect information

A B S T R A C T

The past few decades saw tremendous advances in weather and climate forecasting ability. These advances opened up the possibility of strategic adaptation of agricultural management in anticipation of weather and climate outcomes, resulting in a profusion of studies estimating the value of weather and climate forecasts. Estimated values from this literature were, in many cases, substantive, implying that farmers could significantly benefit from forecasts. Yet the response from farmers, it appears, was not commensurate with the values suggested by the studies. In this article we make the case that forecast quality, both real and perceived, may still pose a significant obstacle; despite recent gains in forecasting ability, forecasts—especially seasonal climate forecasts—are far from certain. Unless this uncertainty is explicitly and more realistically incorporated into models of forecast use, a gap will always exist between expectations of forecast use and actual forecast use by farmers. We conclude by establishing the need for 1) making imperfect forecasts a standard feature in models of forecast use and 2) informing these models with empirical research on farmer use of imperfect forecasts.

Contents

1. Introduction

Agricultural production is subject to much uncertainty, a large part of which stems from day-to-day weather variability, and seasonal variability linked to inter-annual climate fluctuations. In theory, the availability of better weather and climate forecasts should improve the economic welfare of growers, whether through increased revenue and/or reduced volatility in revenue. As climate change increases both the variability and uncertainty of weather and climate patterns, the value of forecasts to growers should also increase. Under an ideal management scenario, growers should rapidly and fully assimilate improved forecasts into their crop management decisions.

* Corresponding author.
E-mail addresses: yoko.kusunose@uky.edu (Y. Kusunose), rezaul.mahmood@wku.edu (R. Mahmood).

http://dx.doi.org/10.1016/j.agsy.2016.04.006

This assertion is based on a large body of studies that model producer decisions (and corresponding returns) in response to forecasts. In these models, given a forecast, a regionally-representative farmer chooses the management alternative that he/she expects will yield the greatest return.[1] The value of a forecast source is the average difference between the resultant stream of returns and that which would result in its absence. A meta-analysis of such studies by Mjelde et al. (1998) places the value of forecasts to US agriculture between $0/acre and $3.40/acre. For a relatively recent, comprehensive review of value-of-seasonal-forecast studies, please see Meza et al. (2008).

In reality, reliance on improved weather and climate forecasts is limited and not commensurate with the estimated benefits of doing so. This is especially true of longer-term climate information, in contrast to daily or weekly weather forecasts. For a novel source of weather information to have any real marginal value, it must lead to changes in management choices that result in improved outcomes. Clearly, many factors stand between information availability and information use. Limited reliance on new information sources can be a function of multiple factors, including the following: grower objectives and risk preferences, enrollment in risk-management programs (e.g. crop insurance), the inability (financial, physical, or perceived) of changing practices in response to forecasts, the format and quality of the forecasts themselves, and the process by which decision makers assimilate these forecasts (Sonka et al., 1987; Artikov et al., 2006; Cabrera et al., 2007; Klockow et al., 2010; Carriquiry and Osgood, 2012). However, the observation that farmers are less responsive to longer-term weather and climate forecasts—combined with the fact that forecasts with longer lead times are generally of lower quality—implies that forecast quality may be a critical factor.

This review focuses on the quality (or uncertainty) of forecasts. First, it provides a general sense of the current quality of forecasts. Second, it summarizes the main modeling approaches used to depict forecast quality in value-of-seasonal-forecast studies to date. Here we find that, while some models of seasonal forecast use allow for imperfect forecasts, they are not nearly as numerous as the ones that assume perfect forecasts. Moreover, the modeling of the assimilation process for imperfect forecasts appears to be somewhat ad hoc and driven entirely by theory, rather than any empirical tests or observations. Third, this study provides a simple example of a typical model and uses the results of this example to explain the commonly reported observation of many farmers 'paying attention' to forecasts while, at the same time, not 'using' them. This simple model suggests the existence of a critical 'minimum accuracy threshold' that forecasts must surpass in order to be of any practical use. We conclude by establishing the need for i) making uncertainty a standard feature of forecast-use-(and-value) models and ii) improving communication with extension agents and farmers themselves so that basic model assumptions can be vetted and refined.

2. The current state of weather and climate forecasts

Over the past two decades, the meteorological and climate community has made steady progress in the accuracy and lead-time of weather and climate forecasts. Yet despite these gains, forecast quality (real and perceived) may still be the primary limitation in forecast use (Hu et al., 2006). In this section we discuss the availability, actual quality, and perceived quality of weather and climate forecasts.

2.1. Forecast availability

Some of the most common sources of forecasts in the U.S. include products developed by two entities within the National Oceanic and Atmospheric Administration (NOAA): the National Weather Service (NWS) and the Climate Prediction Center (CPC). Both the NWS and CPC provide interactive, on-line, map-based forecast products. For example, on the NWS website (www.weather.gov), users can select any point on a U.S. map and obtain location-specific forecasts, including maximum and minimum temperatures and precipitation, for the next seven days. Users can also view maps of precipitation forecasts extending up to five days ahead, and hazardous weather outlooks extending up to three days. The CPC website (www.cpc.ncep.noaa.gov) provides 6-to-10-day, 8-to-14-day, monthly, and seasonal outlooks. These forecasts are also presented as color-coded maps showing the probability of above or below-normal occurrences. It also presents a 'Weekly Weather and Crop Bulletin,' a joint publication by NOAA and USDA. Additionally, the two websites provide contextual information for their forecasts, which may be useful to the more weather- and climate-attuned users, and informative for average users as well.

In addition to forecasts disseminated via the NWS and CPC, NOAA provides current-state reports on Pacific Ocean sea surface temperature, as well as outlooks related to El Niño and La Niña events. These are helpful for weather- and climate-attuned farmers in the regions affected by El Niño and La Niña. NOAA also offers seasonal drought outlooks. Finally, an additional source for forecasts covering North America is the European Center for Medium Range Weather Forecasts (ECMWF). Forecasts from these sources are based on models that incorporate the physics and chemistry of the atmosphere, as well as modulation by land surface and oceans. Monthly and seasonal forecasts are the statistical predictions of such models. The scientific background of these forecasts, models, and resultant products is extensively documented in the published literature (For the most recent examples, please see Baars and Mass (2005); McEnery et al. (2005); Saha et al. (2006); Yussouf and Stensrud (2006); Ebert et al. (2007); O'Lenic et al. (2008); Ruth et al. (2009); Stensrud et al. (2009); Charba and Samplatsky (2011); Magnusson and Källén (2013).

Anecdotally, farmers increasingly report using other sources of weather and climate forecasts such as AccuWeather, The Weather Channel, and The Climate Corporation. At this point in time, these sources generate forecasts by aggregating weather and climate data from existing networks maintained by the federal, state, and local governments, as well as private citizens. The main drawback associated with data from such sources is that they are typically collected by a diverse set of instruments. When a single network uses instruments that produce data of differing quality—due to differences in manufacturer, model, measurement methodology, maintenance schedules and/or exposure[2]—the quality of data produced by the entire network can no longer be gauged. In other words, inhomogeneity of instruments within a meteorological network renders the quality of its forecasts 'unknowable.'

2.2. Forecast quality

The quality of a forecasts depends on many factors. As one would expect, forecasts with longer lead times (i.e. forecasts of conditions that are farther in the future) are generally less accurate than those with shorter lead times. In general, precipitation forecasts are less accurate than temperature forecasts. And, by construction, forecasts of lower resolution (e.g. those that predict the likelihood of three categorical events—above average, average, and below average temperatures) are more accurate than those of higher resolution (e.g. those that predict the likelihood of events across five categories).

The quality of forecasts can be described using many, inter-related, general metrics such as accuracy, skill, reliability, sharpness, resolution,

[1] Examples of commonly modeled management alternatives are crop choice, varietal choice, planting dates, input application rates and input timing.

[2] Instrumentation exposure is affected by the presence of manmade or natural objects near the observing equipment. For example, if there is a large tree close to wind and precipitation measuring instruments, the tree will obstruct the natural flow of wind, causing inaccuracies in wind speed and direction measurements. As another example, a temperature sensor located close to a building or an asphalt road would record higher temperature than actual air temperatures, introducing bias (Mahmood et al., 2006; Pielke et al., 2007).