Statistical seasonal rainfall forecasts for south west Australia

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KEY MESSAGES

Climate change projections indicate that south-west Australia (SWWA) will experience a drying climate with declining growing season rainfall and rising temperatures. However, seasonal variability will remain the dominant driver of adaptation at the farm level. Forecasts of seasonal rainfall made at managerially relevant times of year should enable farmers to modify farm management to maximise returns in good seasons and minimise losses in bad seasons. However, current use of seasonal forecasts is limited by perceived low levels of skill and limited availability of long-lead forecasts at appropriate times of year.

We present a system for forecasting growing season rainfall in SWWA that uses novel predictors derived from global climate data within sophisticated statistical models. The predictors have been selected based on measurable relationships with SWWA rainfall. The forecasts take the form of probability distributions that describe the most likely rainfall total as well as the predicted variability around it.

Uncertainty in seasonal forecasts arises from uncertainty in the observational data, uncertainty arising from the choice of model structure and uncertainty due to the chaotic nature of atmospheric processes. When making forecasts, it is important to produce and effectively communicate information about the uncertainty of the forecast.

We demonstrate a range of products designed to enable farmers and policy makers to use the forecasts appropriately to make decisions about how to manage the coming season. The products emphasise the forecast uncertainty and varying forecast accuracy at different times of year.

Forecasts and products will be available on the DAFWA Internet site from April 2011.

AIMS

1. To present DAFWA's new statistical seasonal forecasting (SSF) system.
2. To demonstrate and discuss forecast products that will enable farmers and policy makers to use the forecasts appropriately to make decisions about how to manage the coming season.
3. To present forecasts for the 2011 growing season made using currently available predictor data.

METHOD

Overview

Statistical forecasting systems derive relationships between rainfall and the drivers or influences of rainfall, called *predictors*, using historical data and then use those relationships to forecast future rainfall given the current states of the predictors. We first identified a range of predictors to trial in the system.

Predictors of rainfall

Sea surface temperatures

Because changes in sea surface temperatures (SSTs) occur more slowly than changes in the atmosphere, sea surface temperatures are often used in statistical forecasting systems, including the operational three-month outlooks produced by the Bureau of Meteorology (Drosdowsky and Chambers, 2001). Because the global SST data sets are very large, the dimension of the data must be reduced before they can be used in a statistical approach. We use the method of partial least squares (PLS) to find linear combinations of the global SSTs at any given time that maximise the covariance between the SSTs and future rainfall in SWWA.

Long wave features of the circulation in the Southern Hemisphere

The atmosphere in the Southern Hemisphere exhibits large, slowly moving features known as long wave troughs and ridges that together form the Southern Annular Mode. The Indian Ocean trough is a quasi-permanent region of low pressure south-west of WA. When the Indian Ocean trough is in a more northerly position, we get more rain. The Australian ridge is a region of high pressure located over the south-east of Australia. Northerly shifts in the Australian ridge are also related to higher rainfall in SWWA, most likely due to the formation of isolated low-pressure systems, called *cut-off lows*, that break away from the blocking ridge. We use measures of the locations of the long wave features as well as the overall measure of the Southern Annular Mode, the Antarctic Oscillation Index (Gong and Wang, 1999).

El-Nino Southern Oscillation (ENSO)

ENSO has a strong influence on rainfall in eastern Australia but a weaker relationship with SWWA rainfall. We use ENSO indices developed as part of the ENSO Sequence System (Stephens *et al.*, 2007).

Air pressure

In SWWA, rainfall in SWWA is highly correlated with concurrent mean sea level pressure (MSLP). Including MSLP improves forecasts made at one-month lead time.

Blocking

A simple blocking index derived from wind data provides an alternate predictor with concurrent correlations to rainfall from cut-off lows (Pook *et al.*, 2006). We use the index applied at 125ºE.

Forecast models

Monthly rainfall for each cell is log-transformed and modelled using a linear model with the above predictors. The best set of predictors is found by a stepwise algorithm that removes and adds predictors to minimise the Akaike information criterion. The forecasts are in the form of probability distributions that may represent a shift from climatological probabilities. Forecasts for more than one month are made using the Fenton and Wilkinson lognormal approximation to a sum of lognormal distributions (Fenton, 1960). The models are run on a 0.5 degree grid across SWWA.

Forecast accuracy depends on the amount of lead time, the forecast months and the strength of relationships between the climate drivers and rainfall. Forecasts should therefore be carefully interpreted using the accompanying skill information.

Forecast skill

Forecast validation is the assessment of forecast accuracy using data measured prior to the forecast being made. Artificial skill, or over-fitting, can occur when the data used to create the forecasting model are also used for its assessment. Cross-validation can be used to obtain a better assessment of how well the model will forecast in the future. We have calculated forecast skill using leave one out cross-validation of data from 1950 to 2009.

Forecast presentation

We have designed a range of products to enable farmers and policy makers to use the forecasts appropriately to make decisions about how to manage the coming season. The products emphasise the forecast uncertainty and varying forecast accuracy at different times of year. The products include forecast and skill maps for SWWA (Figure 1) as well as more detailed plots showing the forecast results for particular locations (Figure 2).

Forecasts and products will be available on the DAFWA Internet site from April 2011. The user will be able to select the type of forecast and skill maps displayed, and the range of months that are being forecasted.

Potential yield

Rainfall is the principal limitation of cropping systems in Western Australia. Potential yield is the maximum yield possible given the rainfall received. Good estimates of potential yield are obtained using a modified French and Schultz algorithm that (1) accounts for stored soil water at the start of the season, and (2) limits the amount of growing season rainfall that contributes to yield according to the plant available water capacity (PAWC) of the soil (Oliver *at al.*, 2009). We assume a duplex soil type with PAWC equal to 81mm.

Because rainfall forecasts take the form of probability distributions, we use the forecasts to produce a distribution of potential yield for any given year. Year to date rainfall and 10000 simulations from the forecast distribution for rainfall to the end of the growing season are used to simulate 10000 potential yield samples. The skill of rainfall forecasts should also be considered when interpreting these results.

RESULTS

2010 Hindcast

Using data up to and including December 2009, the forecast of April to October rainfall over most of SWWA indicated a less than 60% chance of above median rainfall, where 1970 to 2009 is used as the reference climatology. A less than 40% chance of above median rainfall was indicated in the northern agricultural region. However, when making forecasts that far in advance, the percent consistent skill is poor, ranging between 0.5 and 0.6. The percent consistent (PC) skill measures the rate at which the system correctly predicts above or below median rainfall, where values greater than 0.5 indicate that the forecast contains more information that the climatological median.

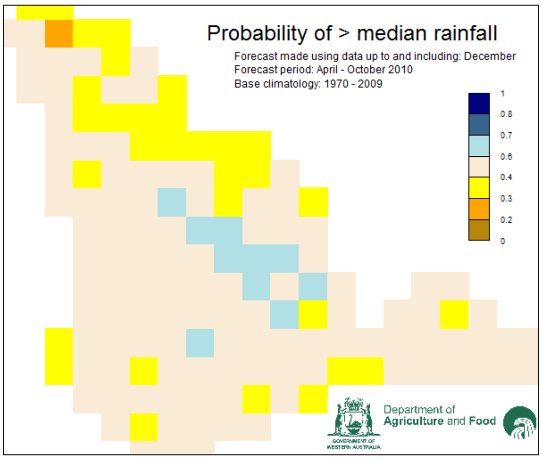
Using data up to and including March 2010, the forecasts showed lower probabilities of receiving above median rainfall. After collecting one more month of data, forecasts of May to October rainfall made using data up to and including April 2010 showed that more than half of SWWA had less than 40% chance of receiving above median rainfall, and half of that area had less than 30% chance of receiving above median rainfall. The PC skill for making forecasts at these times ranges between 0.6 and 0.7 over most of SWWA, making the forecasts a useful tool for within-season decision making.

As the 2010 season progressed, the system forecasted low probabilities of exceeding median rainfall in May, June, July and August. However, forecasts made for September indicated high probabilities of above median rainfall in the eastern agricultural region, which did not ensure. The forecast for spring rainfall was similar to forecasts made by most climate models at the time, when the developing La Nina pattern suggested that wetter conditions could be expected in the spring.

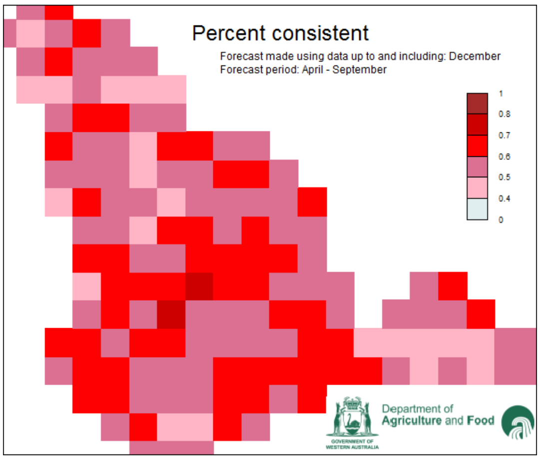
2011 Forecast

Forecasts of January to March rainfall in 2011 using the latest available data, December 2010, indicate a greater than 80% chance of exceeding median rainfall, with PC skill of greater than 0.6 for most of SWWA. This forecast is consistent with most global climate models. It does not necessarily mean high rainfall totals are expected over SWWA, as this region usually has low rainfall at this time of year. However, there may be opportunities for gaining stored soil water or improving above ground storage.

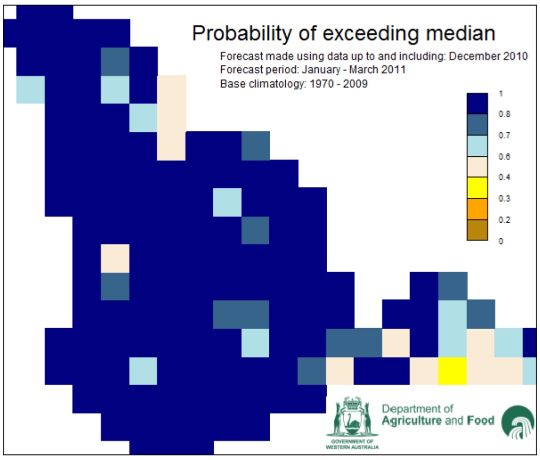
Forecasts of April to October rainfall in 2011 must be considered in context of the poor skill of the system at forecasting this far ahead. Over SWWA the forecast varies spatially across the full range of probabilities of above median rainfall (this compares to a spatially consistent pattern in 2010). Forecasts for May to July show low probabilities of higher than median rainfall, which is consistent with the drying trend evident since the turn of the century. Forecasts for spring show higher probabilities of above median rainfall in the northern agricultural region.



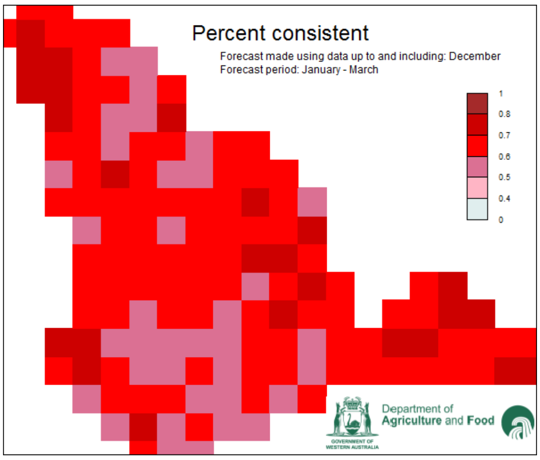
a) Forecast of April to October 2010 rainfall made using data to December 2009.



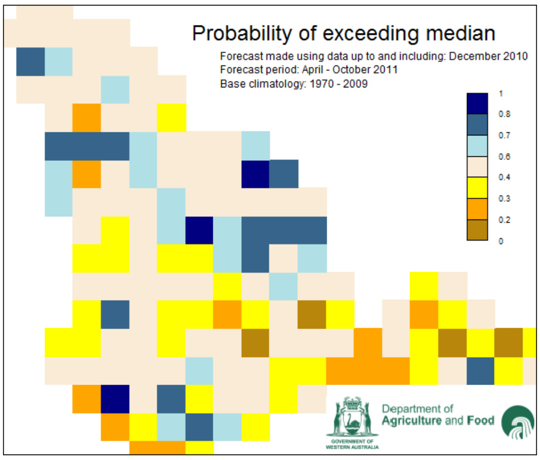
b) PC skill at forecasting April to October rainfall using data to December.



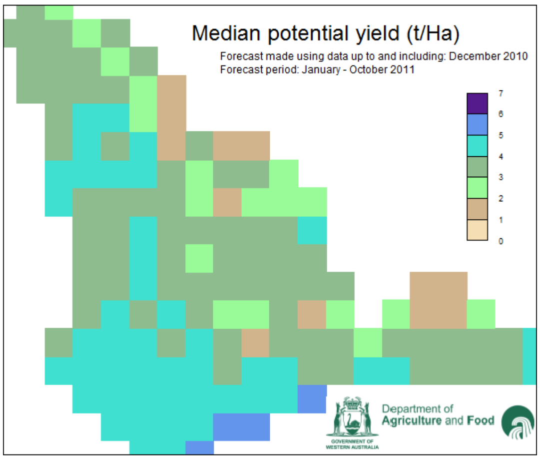
c) Forecast of January to March 2011 rainfall made using data to December 2010.



d) PC skill at forecasting January to March rainfall using data to December.

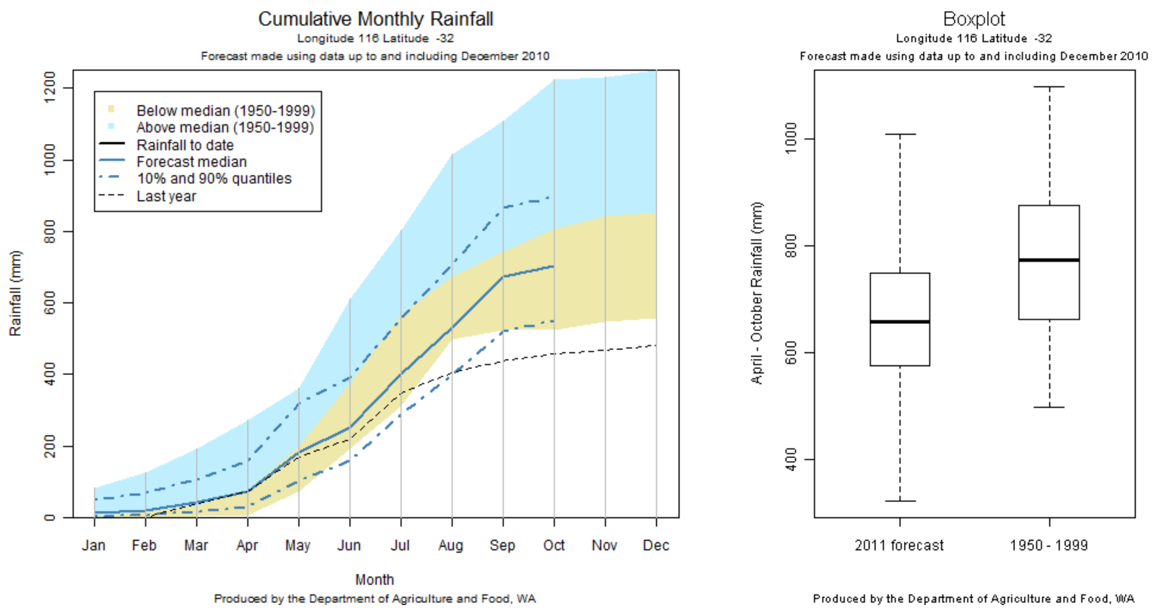


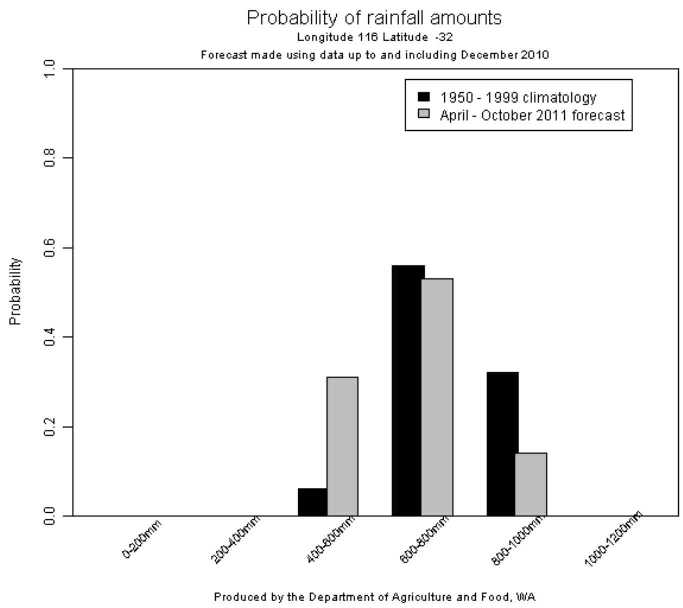
e) Forecast of April to October 2011 rainfall made using data to December 2010.



f) Forecast of 2011 median potential yield based on rainfall forecasts made using data to December 2010.

Figure 1: Forecasts and accompanying skill maps for periods in 2010 and 2011.





2011 Potential yield forecast quantiles
Longitude 116 Latitude -32

Forecast of January - October rainfall made using data up to and including December 2010

Quantile	Tonnes/Ha
0.10	3.38
0.25	3.47
0.50	3.63
0.75	3.85
0.90	4.17

Figure 2. Examples of location-specific forecast plots and information.

CONCLUSION

The new statistical seasonal forecasting system will provide useful information for onfarm and regional agronomic planning.

KEY WORDS

Seasonal rainfall forecast, seasonal variability, SSF

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Paper reviewed by: ???