Towards Improved Seasonal Rainfall Forecasting: Some Key Issues

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SUMMARY

Seasonal rainfall forecasts prepared under the PRESAO programme of the African Centre for Meteorological Applications to Development (ACMAD) are reviewed in terms of their accuracy and clarity, and the potential of such forecasts as a decision-support tool for natural resources managers and economic operators.

INTRODUCTION

In the last four years, seasonal rainfall forecasts expressed in probabilistic terms, have been issued by several West African countries including the Gambia, under the banner of the PRESAO programme of the African Centre for Meteorological Applications to Development (ACMAD). We observe however that forecasts are not rigourously verified.

The purpose of this paper is to highlight key aspects of seasonal rainfall forecasts that may very well define the potential of such forecasts as a decision-support tool for water resources allocation to competing uses (including agriculture), and between riparian member states of trans-boundary river basin organisations. Discussions are centred on two broad issues: (i) accuracy; and (ii) clarity of forecasts.

ACCURACY OF FORECASTS

We briefly recall that forecasts are based on regression between sea surface temperature (SST) anomalies and rainfall (ACMAD, 2001). Forecast rainfall, with associated probabilities, is described as (i) below normal; (i) normal; and (iii) above normal, corresponding to the lower, middle and upper tercile of underlying probability distribution. On the issue of verification, observed rainfall is compared to a single category of the forecast.

We take issue with prevailing forecast and verification methods on four fronts: (i) spatial resolution of forecasts; (ii) definition of forecast categories; (iii) verification scores; and (iv) use of other predictors.

Spatial resolution

Our understanding is that seasonal forecasts are made on a national or regional basis (ACMAD, 2001). The question which arises is how one may transfer probabilities assigned to an areal unit to points contained within that area. As far as the author is aware, such a task, embodying considerable theoretical work, is yet to be performed. Observe that the question only loses its pertinence when one is using lumped parameter models, or when rainfall characteristics are relatively uniform over the spatial unit associated with the seasonal forecast.

Forecast categories

Our investigations show that forecast categories are often in contradiction with rainfall statistics computed from parent probability distribution. Table 1 shows the discrepancies arising from 'ad hoc' definition of forecast categories in the Gambian context.[1]

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[1] Annual rainfall is described by the normal probability distribution with a mean of 796.2 mm, and standard deviation of 146.7 mm

Table 1: *Ranges associated with rainfall forecasts (mm) using ad hoc and statistical definitions.*

Categories	ad hoc	statistical
Below Normal	< 600	< 730
Normal	600 – 800	730 – 860
Above Normal	> 800	> 860

The change in boundaries of forecast categories and ramifications for forecast probabilities is self-evident.

Verification scores

The major point to note here is the absence of a quantitative score for assessing seasonal forecasts. Indeed, the suppression of 'false' forecasts gives a misleading account of forecast accuracy. What is needed is a verification score that takes account of noncommittal forecast (i.e. probabilities of occurrence uniformly distributed across all forecast categories), the PRESAO forecast for a particular year, and rainfall actually measured in the year under reference.

To this end, we recommend a composite score that rewards accuracy and precision of forecasts, and penalises 'false' forecasts according to their departure from the actual situation.

Using the type of information presented table 2 below, we give an example of such a score – NWFS (Normalised Weighted Forecast Score) that reads

$$\text{NWFS} = \text{PRECIS} - \text{PENALTY}$$

in which

$$\text{PRECIS} = \frac{b_i\big|_{c_i=1} - a_i\big|_{c_i=1}}{1 - a_i\big|_{c_i=1}}, \quad b_i\big|_{c_i=1} \geq a_i\big|_{c_i=1}$$

Table 2: *Table of probabilities associated with different categories of seasonal rainfall forecast*

Categories	Noncom.	PRESAO	Obs.
Below Normal	a_1	b_1	c_1
Normal	a_2	b_2	c_2
Above Normal	a_3	b_3	c_3

Note:
Noncom. = Noncommittal forecasts (i.e., $a_1 = a_2 = a_3 = 0.3333$ ad infinitum), Obs. = Observed event, translated as mutually exclusive forecast categories with probability of 1 if rainfall is in a particular category, and 0 for the other two categories. All probabilities sum up to 1, thus

$$\sum a_i = \sum b_i = \sum c_i = 1$$

When $b_i\big|_{c_i=1} < a_i\big|_{c_i=1}$, PRECIS is assigned a value of zero, for the simple reason that outperformance of PRESAO forecasts by trivial ones (i.e. noncommittal forecasts) should be treated with great severity.

For, $b_i\big|_{c_i=0} > 0$,

$$\text{PENALTY} = \sum w_i \left| b_i\big|_{c_i=0} - a_i\big|_{c_i=0} \right|$$

in which $w_i > 0$ are multiplicative factors applied to 'false' forecasts.

In order to obtain consistent and coherent results, worse departures from the true situation are assigned bigger weights.

Other predictors

Although SST correlation with rainfall has some theoretical merit, use of other predictors in combination with SST or separately should not be excluded. Jury et al. (1996) point to outgoing long wave radiation (OLR) [2] as an important indicator of convective patterns.

Landscheidt (undated) makes an equally compelling case for solar activity as a major forcing factor of climate dynamics. Examples cited by the author include the prediction, some years in advance, of the end of successive drought years in the Sahel in 1985, and El Niño events of 1995 and 1998.

Research into factors behind the late recovery of the 2002 rainy season in the Gambia (Njie, 2002) may also provide some useful insights into short timescale processes that have a big impact on the outcome of seasonal rainfall forecasts.

CLARITY OF FORECASTS

Whilst a 'below normal' forecast suggests water deficits, this is not necessarily true. Notice that water demand for crops grown in the Gambia (Doorenboos et al., 1979) lie in the range 450 – 700 mm, coincident with the upper half of the 'below normal' range. On the other hand, 'above normal' rainfall forecasts, fail to bring out the adverse effects of rainfall above a certain threshold. Extensive crop damage as a result of excessive rainfall and water-logged soils floods in the URD[3], in 1999, expose the fallacy associating "above normal" rainfall with positive impacts on agriculture and other sectors.

Subject to a re-definition of forecast ranges therefore, seasonal rainfall forecasts are not likely to fulfil their potential within the framework of integrated early warning systems (IEWS).[4]

Due to the dissociation of forecast ranges from economic indicators, one is also missing the opportunity to evaluate and properly plan for droughts and floods. In this respect, forecasts could be presented in the form of 2 x 2 contingency tables relative to drought and/or flood risks, similar to the example given in Table 3.

Table 3: *Example of contingency table for drought forecast. Probabilities* b_1 , b_2 , and b_3 *are synonymous with values in Table 2, after re-definition of class range*

Observed Forecast	YES	NO
YES	b_1	$b_2+ b_3$
NO	$b_2+ b_3$	b_1

In the specific case of drought, forecast accuracy is evaluated as

$$DFS = \frac{b_1^2 - (b_2 + b_3)^2}{(b_1 + b_2 + b_3)^2} \ .$$

Recalling that $\sum b_i = 1$, we have $b_2 + b_3 = 1 - b_1$, whence the expression for DFS (Drought Forecast Score) reduces to

$$DFS = 2b_1 - 1$$

From the foregoing, one may therefore conclude that successful forecasts need to have a minimum probability of 0.5 to be considered statistically significant.

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[2] OLR measurements are obtained from AVHRR mounted on meteorological satellites.

[3] URD: Upper River Division of the Gambia.

[4] boundaries of forecast categories are likely to be different for different water-sensitive sectors and/or industries

CONCLUSIONS

The potential benefits of seasonal forecasts for decision-support in natural resources management, and water-sensitive economic decisions is beyond debate. Owing however to limitations in current practice, further work is needed to improve the accuracy and clarity of forecasts issued at the start of the rainy season. In particular, one should be mindful that that accuracy of forecasts based on SST anomalies alone has its limits, and contemplate using other readily available predictors, in combination with SST, to improve overall forecasting skill (i.e. NWFS).

Concerning seasonal flow forecasts brought to our attention (ACMAD, 2001), we can only sound a note of caution on the utmost importance of cause and effect relationship in flow forecasting. SST-based regressions should really be seen as be a stopgap measure for providing seasonal flow forecasts. The goal of water resources managers and climatologists alike should be one of improving rainfall forecasts, which amounts to reducing errors in the input of rainfall-runoff and/or catchment water balance models. Clearly, accurate forecasts assigned sufficiently high probabilities (i.e. high precision) should be the aim of seasonal forecasting.

ACKNOWLEDGEMENT

This paper was written at the kind invitation of Mr. John Peacock, Coordinator Local Organising Committee for the CAgM Workshop, Banjul, 9 – 13 December 2002.

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