

ARID - Agricultural Reference Index for Drought

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INTRODUCTION

Drought index is a measure of drought, the shortage of water for a specific need. Although a number of drought indices are available for agricultural use, no drought index exists that takes into account all the agriculturally important aspects, namely, crop physiology, soil processes, land use/cover, drought-induced yield loss, high spatio-temporal resolution, genericness, and simplicity. As an attempt to account for all these aspects, Agricultural Reference Index for Drought (ARID) was developed recently. ARID is calculated as the ratio of transpiration (T) to the potential evapotranspiration of a reference crop (ET_o), namely, a grass of uniform height and full ground cover:

$$ARID = 1 - \frac{T}{ET_o}$$

The basic concept behind ARID is that because water requirement of a crop is highest and the crop is most sensitive to drought at full ground cover, a drought index that is based on this stage can approximate water stress of all crops in general.

This study was conducted to evaluate ARID on the basis of comparison with the water stress factor (WSPD) calculated by the DSSAT, a widely-used and reliable crop growth model, and estimation of soil moisture; to assess the yield estimation ability of ARID-based crop yield models; and to explore the potential of forecasting ARID based on ENSO phases and climate indices.

METHODS

To evaluate ARID based on comparison with WSPD and other drought indices, average values of each of eight drought indices – Crop Moisture Index, Keetch and Byram Drought Index, Lawn and Garden Moisture Index, Palmer Drought Severity Index, Palmer Z-index, Standardized Precipitation Index, Water Requirement Satisfaction Index, and ARID – and WSPD were computed for each of three developmental phases for maize: *planting-silking*, *silking-anthesis*, and *anthesis-maturity* for each of sixteen locations in the SECC region. Using these phase-wise average values, the drought indices were compared with WSPD.

To evaluate ARID based on soil moisture, daily values of ARID-estimated and field-observed soil moisture contents were compared for Citra, FL, using the data of one year.

To assess ARID-yield relationships, rainfed yields of cotton, maize, peanut, and soybean from various locations in the SECC region over a number of years were compared with the corresponding yields estimated by the ARID-based yield model:

$$\hat{Y} = \bar{Y}_L \left[Y_p \prod_{i=1}^n (1 - ARID)_i^{\lambda_i} \right]$$

where, \hat{Y} is estimated yield, \bar{Y}_L is location-specific mean yield, Y_p is potential yield, Y_p is relative potential yield (Y_p/\bar{Y}_L), and λ_i is the relative sensitivity of a crop to water stress during the i th stage.

To explore the possibility of forecasting drought using ARID, ENSO-based and climate indices-based approaches were used. While in the former approach, monthly ARID values were separated into three ENSO categories and averaged by phases; in the latter approach, regression was done to estimate 1-, 2-, and 3-month lead time monthly values of ARID from the past values of some significant climate indices. Finally, errors of prediction with each approach were compared across months and five locations in the SECC region.

RESULTS

Among the eight drought indices compared, ARID showed the highest correlation with WSPD after full canopy development in all locations (Figure 1).

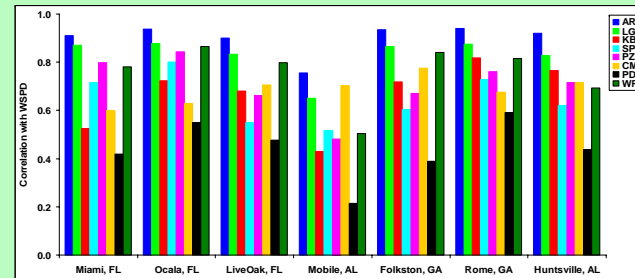


Figure 1. Correlation of various drought indices with WSPD after full canopy development of maize in various locations.

Similarly, ARID had the least departure from WSPD among the drought indices compared (Figure 2), suggesting that the water stress estimations of ARID for maize were better than those of the other drought indices. These results further indicated that ARID has the potential of working as a generic drought index.

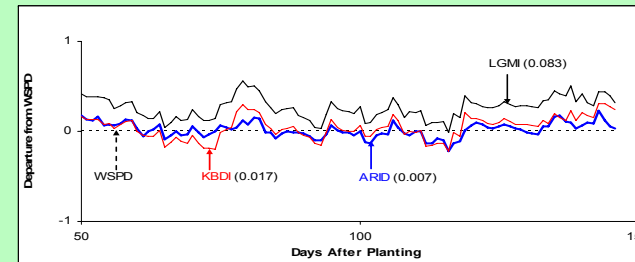


Figure 2. Departure of daily time series values of various drought indices from those of the WSPD after full canopy development of maize. Figures in parentheses are RMSE values.

A good agreement was found between the ARID-estimated and field observed soil moisture contents (Willmott d-index = 0.90, RMSE = 0.014, percent error = 10), indicating ARID can provide good estimations for soil moisture status (Figure 3).

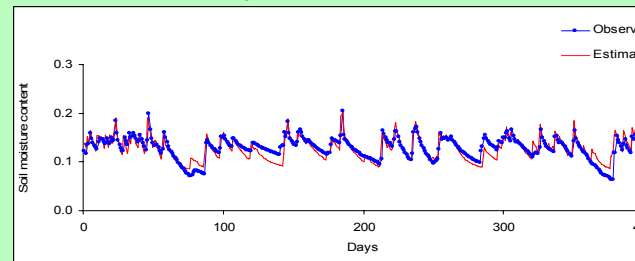


Figure 3. Daily time series values of observed and ARID-estimated soil moisture contents (v/v) at the Citra Experimental Station in year 2007/2008.

RESULTS

The ARID-based crop yield models performed reasonably well (Figure 4). Relative percent errors (RMSE/ \bar{Y}) of maize, cotton, peanut, and soybean yield models were 13, 20, 21, and 22%, respectively.

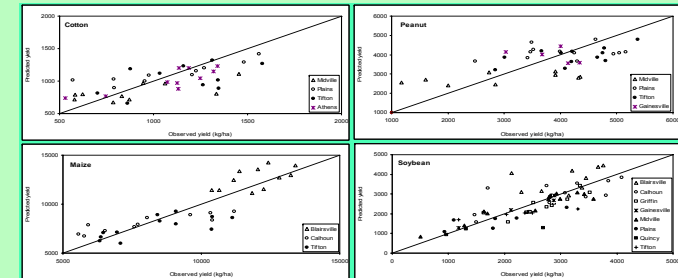


Figure 4. Observed and ARID-estimated yields of cotton, maize, peanut and soybean in various locations in the SEC region.

Predicting abilities of climate indices-based and ENSO phase-based methods varied depending on months and locations (Figure 5). For instance, prediction errors of the former method for Jan, Feb, Aug, and Sep were less than those of the latter method for Liveoak, FL, suggesting the possibility of improving predictions for these months using climate indices.

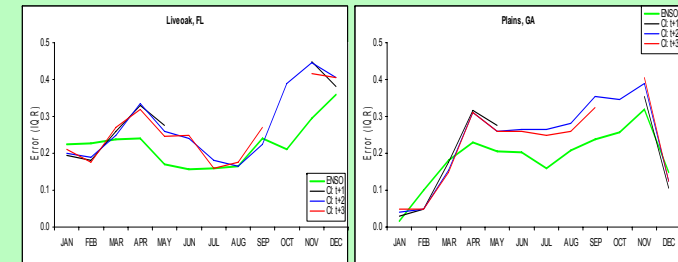


Figure 5. Prediction errors (inter-quartile range) of ENSO-based and climate indices-based models across months in two locations.

CONCLUSIONS

- Values of ARID were closer to WSPD than those of the other drought indices after full canopy development.
- ARID provided good estimations for soil water status.
- ARID-estimated crop yields were in good agreement with observed yields, indicating ARID-based yield models may provide reasonable prediction of crop yields.
- ARID has a good potential to quantify agricultural droughts.
- The possibility of forecasting ARID based on climate indices exists for some months and locations.

ACKNOWLEDGEMENTS

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