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PREDICTABILITY OF MAY TO AUGUST (MJJA) SEASONAL RAINFALL IN NORTHERN PHILIPPINES

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ABSTRACT – A study on the predictability of May-August (MJJA) seasonal rainfall over northern Philippines was conducted by regressing it with sea surface temperature (SST) over the Niño3.4 region. Here, the skill of a probabilistic climate forecast three months ahead of the rice and maize growing season to inform better agricultural management was examined. The climate predictability tool (CPT) was used for evaluating the skill of observed SST and global circulation model (GCM) SST (Climate Forecasting System v2 (CFSv2) and ECHAM4.5) as predictors of MJJA rainfall at 6 selected weather stations consisting of 32-year reliable rainfall data. Results show that the predictive skills of the developed climate forecast models are satisfactory with an average goodness index (Pearson's correlation) of 0.62. The obtained average canonical correlation of 0.73 is also very sufficient. The skill of predictors comes mainly through the skillful rainfall anomaly forecasts during significant ENSO events. CFSv2-SST model, having a goodness index of 0.63 and canonical correlation of 0.79 provided the strongest rainfall predictor patterns that considerably mirror the rainfall characteristics of the 6 stations. Forecasted rainfall produced from this model is comparable with the actual rainfall from three diagnostic stations. The skill of seasonal climate forecast provides a basis on the utility of the advanced climate information for assessing and managing climate related risks in crop production using agricultural impact models.

Keywords: foecast skill, Climate Predictability Tool, SST, GCM, climate forecast, canonical correlation analysis, decision support

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INTRODUCTION

Background of the Study

Seasonal climate forecasts are potentially very useful for planning agricultural activities and as a starting point for early warning and response planning (Hansen et al., 2004).

Much of the premise of seasonal prediction is based on predictability of large-scale tropical SST anomalies at seasonal lead times. Climate forecasts are very much associated with varying tropical ocean conditions. Measurements of SSTs in the tropical Pacific Ocean are especially useful. By measuring these conditions, particularly sea temperatures, it is possible to predict the climate up to several months into the future. The El Niño–Southern Oscillation (ENSO) which is in the form of El Niño (warmer temperatures) or La Niña (cooler ones), represent one of the most important sources of predictability for climate forecasting. Their effects are very predictable which on the average, happens every three to seven years. Fluctuations in temperatures can create large changes in evaporation off the sea surface. This event then starts and propagates a process that affects rainfall patterns in the particular region (Moron, V., et. al., 2007).

ENSO is the most significant source of seasonal climate variability globally, with rainfall over the Philippines being strongly influenced by it. Whether based on empirical relationships or GCM simulations, seasonal climate predictions are usually expressed in terms of the seasonal amount of rainfall at regional or gridpoint scales (Goddard et al. 2001).

Meanwhile, limited work has been done regarding predictability of rainfall over Northern Philippines, There is a significant opportunity to reduce the production risks inherent to rainfed rice and maize production in these areas by means of the timely dissemination of seasonal crop yield predictions to farmers as well as local government officers. When reliable climate forecasts are available, farmers may appropriately decide when and how and where to plant accordingly. They may also use this information to decide on the type of management practices that needs to be applied. This in turn is expected to lower the production risks imposed by climate variability and result in increased agricultural output (http://www.ciatnews.cgiar.org/wp-content/uploads/2013/04/AGENDA_EN.pdf).

Significance and Objectives of the Study

The Philippines' persistent exposure to highly variable climate and extremes is immensely contributing significantly to its development problems. Agriculture, currently the key and primary development sector that is contributing more than 20% of the gross domestic product (GDP), is particularly sensitive to climate variability and change. The impact of climate-related events such as intense rainfall and prolonged drought have enormous social and economic impacts at the farmer's level that could categorically multiply into negative impacts on the national economy. These scenarios could threaten development gains and negate years of development efforts (World Bank/NDCC, 2004).

Climate variability and extremes are very much a part of life in the Philippines. But where people are poor and vulnerable as in farming communities, these climatic factors can add greatly to the drudgery of their lives that limit their choices. If crops fail or when crop production is drastically reduced due to extreme climatic events, subsistence farmers have few or no alternative means to provide food for their families. This leads to economic devastations on their part, in particular, and to poor food security outlook of the country, in general (Hellmuth, M.E. et. al., 2007).

Managing therefore impacts of climate variability and change in agriculture is of utmost importance not only to minimise risk associated with the bad years, but also to maximise opportunities during the good years. In order to manage better climate related risk in agriculture, one must be equipped with useful information in advance to plan ahead in time. Advances in climate science using sophisticated physical models of the earth system combined with statistical models have paved the way to predict climate in advance of the growing season (Goddard et al., 2001; Goddard and Mason, 2002). This advanced climate information can help farmers make prudent decisions concerning farming activities that aim to minimise climate risks and exploit climate opportunities when they are given climate information ahead of the growing season.

This study seeks to understand and assess the predictability of the May – August (MJJA) seasonal average rainfall over northern Philippines using three predictors (observed SST, two GCM SSTs) with 3-month leadtime. The MJJA season is the major rice and maize growing season in some regions of the study area.

METHODOLOGY

Data sources

The predictand data (station rainfall, 32-year record) were gathered from six (6) agromet and synoptic stations of PAGASA within the study area. On the other hand, the predictor data (observed and GCM SSTs) were downloaded directly from CPT with the predetermined domain (Niño3.4 region). The observed SSTs are raw values from the monthly extended reconstructed SST (ERSSTv3) data. The forecast CFSv2 and ECHAM4.5 SSTs are the mean of an ensemble of 24 members forming a 3-month seasonal SST values.

Analysis

In this study, the CPT was used to perform canonical correlation analysis (CCA) between the pre-determined set of predictors (SSTs) and predictands (MJJA station rainfall).

The CPT developed by the International Research Institute for Climate and Society (IRI) at Columbia University, is a package that facilitates the construction of seasonal climate forecast models, investigations into model validation and producing forecasts given updated data. The CPT design has been tailored to produce seasonal climate forecasts using model output statistic (MOS) corrections to climate predictions from general circulation models, or to produce forecasts using fields of sea-surface temperatures (Mason, S. et al., 2014).

CCA is used to produce probabilistic forecasts of tercile-based precipitation categories (below-, near-, and above-normal). CCA is a way of making sense of cross-covariance matrices. If we have two vectors X = (X1, ..., Xn) and Y = (Y1, ..., Ym) of random variables, and there are correlations among the variables, then canonical-correlation analysis will find linear combinations of the Xi (predictor) and Yj (predictand) which have maximum correlation with each other. It is a multivariate regression, involving patterns on both the predictor and predictand sides. One combination of predictor coefficients and its corresponding combination of predictand coefficients constitutes one canonical mode, describing the preferred coupled spatial patterns relating predictor and predictand (Hardle and Simar, 2007).

CCA is seen to represent an advance in climate-forecasting method that is applicable to the study areas. The tool is then used to develop seasonal probabilistic rainfall forecasts that are essential for decision making ahead of the growing season.

In CCA, the number of empirical orthogonal functions (EOFs) for the predictor and predictand fields used to fit the model was chosen. The predictor (X) domain at the Niño3.4 region (120 ° W -170 ° W and 5 ° S -5 ° N) was set with 6 CCA modes. The predictand (Y), on the other hand, was set at 14 ° N -20 ° N and 118 ° E -124 ° E with 4 CCA modes. A 5-year cross validation window for both variables was set which is needed to avoid artificial skill. Also, the Y values are transformed to ensure that they are normally distributed. CPT was then driven to make cross-validated forecasts using all possible combinations of modes. Goodness indices were calculated at each combination with the highest goodness index. Once the CCA-based prediction model that optimized the relationships between the patterns in the predictor and predictor was built, a probabilistic forecast for a desired year was then made.

CPT was executed to determine the probabilistic rainfall forecast with 3-months lead-time onto the MJJA season. Both the model with observed and GCM SSTs were time-lagged to represent a predictive relationship with the predictand. In this study, the predictor was the February-May (FMA) SST initialized in January and the predictand covered the MJJA season. Experiments were done to determine which of the three SST predictors (i.e., observed and GCM-based) tend to result in the greatest cross-validated hindcast skill and which predictor shows the strongest SST-versus-rainfall relationships.

Pearson’s correlations, goodness index and skill maps were then analyzed to derive and generate conclusions between the association of the predictor and predictand. Pearson's correlation coefficient, normally denoted as r, is a statistical value that measures the linear relationship between two variables. It ranges in value from +1 to -1, indicating a perfect positive and negative linear relationship respectively between two variables. On the other hand, goodness index indicates how good all the forecasts are (the closer to 1.0 the better).

RESULTS AND DISCUSSION

Table 1 show the spatial average of cross-validated rainfall forecast skills. The canonical correlation values show the strength of the spatial and temporal association between the predictor and predictands. It reflects the spatial patterns as well sources of skill in the model predictions that tend to be associated with patterns in the verifying observations over the hindcast period. On the other hand, Pearson’s correlation measures association of the trend of the forecasts associated with the trend in the observations.

Results show that of the three predictors, CFSv2 SST exhibited the strongest SST-Rainfall relationship as shown by its canonical correlation (CC) of 0.79 (Figure 1) with goodness index (GI) of 0.63. This reflects that SST loading pattern in the Niño3.4 region predicted by CFSv2 SST was skillful in predicting rainfall for the MJJA season in the study area. The ECHAM4.5 SST produces slightly lower but comparable CC of 0.76 with a GI of 0.61. The observed SST predictor yields the lowest CC of 0.65 and GI of 0.55. The skill differences between the models maybe due in part to their inherent attributes such as their response to nonlinear dynamics relating SST to rainfall. Generally, the SST conditions in the Niño3.4 region influences and matters most in northern Philippines rainfall. Visualization of the Pearson’s correlation of the individual stations is shown in Figure 2.

The MJJA season is the wet cropping season for rice and corn in Nueva Ecija and Isabela sites, respectively. Focusing on CFSv2 SST, the Pearson’s correlation of the selected sites indicate sufficient skills, which could be used for decision support for rice and corn production by linking it to crop models.

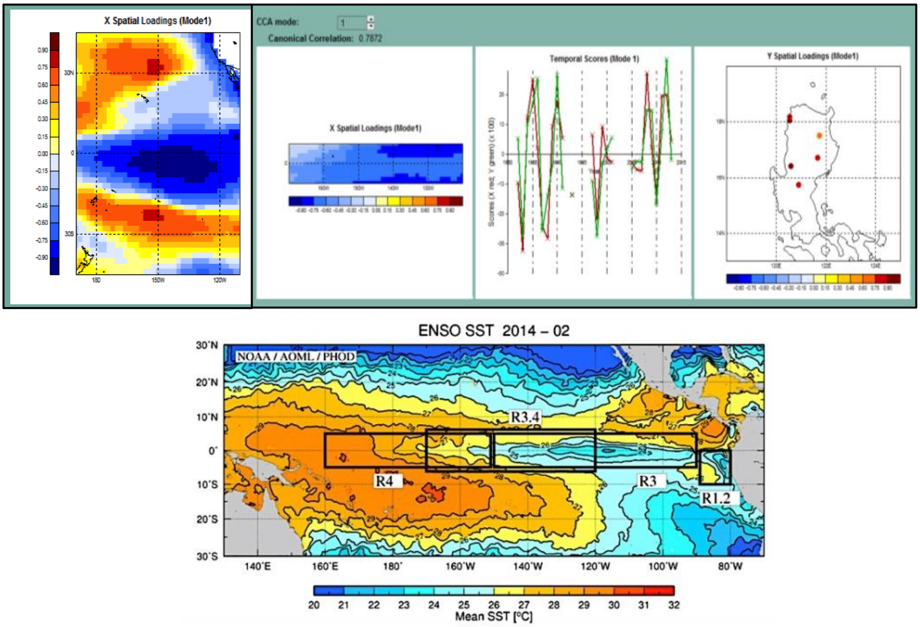

Figure 1. Spatial loadings of the predictor (SSTs) and predictand (MJJA Station rainfall

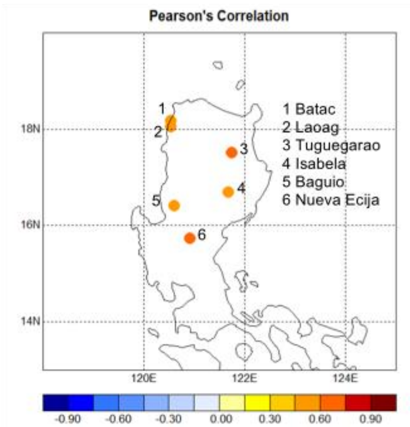

Figure 2. Skill map of the CFSv2 SST predictor.

The model correlation in Nueva Ecija site is 0.68, which means about 45% of variance of the observed rainfall is successfully predicted by the model. On the other hand, Isabela's correlation of 0.50 indicates that 26% of the variance of the observed rainfall was successfully predicted by the model. Table 2 shows the probabilistic forecast of the CFSv2 SST-rainfall model. Observed MJJA rainfall of Batac (324.80 mm) in 2014 was comparable with the forecasted rainfall of 325.53 mm, showing the remarkable ability of the model to predict MJJA rainfall for that year.

Diagnostic results using a wider domain have features that were similar to those of the Niño3.4 region but predictive skills were slightly lower. This finding suggests that SST variability outside of the Nino region does not provide additional valuable information for predicting rainfall in the study area.

MEASURES	PREDICTOR (FMA)	PREDICTAND (MJJA season)					
		BATAC	BAGUIO	N. ECIJA	ISABELA	LAOAG	TUGUEGARAO
	CFSv2 SST						
Goodness Index (r)	0.63						
Canonical Correlation	0.79						
Pearson's Correlation		0.47	0.59	0.68	0.50	0.49	0.67
	ECHAM4.5 SST						
Goodness Index (r)	0.61						
Canonical Correlation	0.76						
Pearson's Correlation		0.55	0.64	0.72	0.41	0.50	0.51
	OBSERVED SST						
Goodness Index (r)	0.55						
Canonical Correlation	0.65						
Pearson's Correlation		0.45	0.71	0.59	0.29	0.40	0.32

Table 1. Goodness indices, canonical correlation and and station correlations (Pearon's r) using three predictors.

STATION	FORECAST (mm)	PROBABILITY (%)	BELOW-NORMAL (mm)	PROBABILITY (%)	ABOVE-NORMAL (mm)	PROBABILITY (%)	ACTUAL (mm)
BATAC	325.53	36.00	239.75	37.00	538.87	27.00	324.80
BAGUIO	611.36	37.00	395.39	36.00	726.17	27.00	-
NUEVA ECIJA	318.81	41.00	259.32	34.00	353.32	25.00	284.70
ISABELA	184.78	38.00	151.53	35.00	233.19	27.00	-
LAOAG	331.86	38.00	282.43	35.00	497.72	27.00	351.06
TUGUEGARAO	162.25	41.00	127.08	33.00	222.27	26.00	-

Table 2. Probabilistic MJJA average rainfall for 2014 using the CFSv2 SST model as predictor

SUMMARY AND CONCLUSION

CPT was used to assess and estimate predictability of the MJJA seasonal rainfall over northern Philippines based on a 32-yr historical data. The experiments include three sets of predictors (observed, CFSv2, ECHAM4.5 SSTs) at Niño3.4 region for time-lagged (3-month leadtime) forecasts. Within CPT, canonical correlation analysis was performed to determine the best model that describes the coupled spatial patterns relating the predictor to the predictand.

Results show that the CFSv2 SST model produced the highest goodness index (GI) of 0.63 with canonical correlation (CC) of 0.79 for the target season. This model provided strongest rainfall predictor patterns that considerably mirror the rainfall characteristics of the 6 stations. Forecasted rainfall produced from this model was found comparable with the actual rainfall from two diagnostic stations.

ECHAM4.5 model, on the other hand, showed a slightly lower rainfall prediction skill as compared to CFSv2 SST with GI of 0.61 and CC 0.76. The observed SST predictor generated the least GI of 0.55 and CC of 0.65. The skill differences between the models maybe due in part to their inherent attributes. In the context of rainfall forecasting ahead of the growing season, the obtained goodness indices indicate considerable predictive skill in all portions of the study areas. The ENSO phenomenon was found to play a dominating role in creating and enabling skillful predictions of northern Philippines rainfall. Thus, years with the strongest ENSO conditions were expected to produce the strongest rainfall anomaly forecasts.

Overall findings suggest that MJJA seasonal rainfall predictions were favorable and skillful enough for decision support in farming activities to be able to substantially reduce economic losses associated with excessive rain and drought in the study area. Generally, skill levels may provide considerable basis to reasonably link the probabilistic rainfall forecasts with crop models for decision support in rice and maize production.

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STATEMENT OF AUTHORSHIP

The first author prepared the capsule study, lead the gathering of needed station and GCM data, conducted the literature search, processed and translated the data into required format, ran the pre-determined CCA-based prediction model experiments, analyzed the data and discussed results, formulated recommendations, and undertook the writing up. The second author elucidated the concept, identified some issues, formulated recommendations, and reviewed the paper.

REFERENCES

Goddard, L., Mason, S.J. 2002. Sensitivity of seasonal climate forecasts to persisted SST anomalies. Clim. Dyn. 19, 619-632.

Goddard, L., Mason, S.J., Zebiak, S.E., Ropelewski, C.F., Basher, R., Cane, M.A. 2001. Current approaches to seasonal to interannual climate predictions. Int. J. Climatol. 21, 1111–1152.

Hansen, J.W., Indeje, M. 2004. Linking dynamic seasonal climate forecasts with crop simulation for maize yield prediction in semi-arid Kenya. Agric. For. Meteorol. 125:143-157.

Hansen, J.W., Ines, A.V.M. 2005. Stochastic disaggregation of monthly rainfall data for crop simulation studies. Agric. For. Meteorol. 131: 233-246.

Hardle, W., Simar, L. 2007. "Canonical Correlation Analysis". Applied Multivariate Statistical Analysis. pp. 321–330.

Hellmuth, M.E., Moorhead, A., Thomson, M.C., and Williams, J. 2007. Climate Risk Management in Africa: Learning from Practice. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.

Mason, S.J. 2014. Seasonal Forecasting Using the Climate Predictability Tool (CPT). International Research Institute for Climate and Society, The Earth Institute of Columbia University, Palisades, NY

Moron, V., Robertson, A.W., Ward, M.N., and Ward, and N'Diaye, O. 2007. Weather types and rainfall in Senegal. Part II: Downscaling of GCM Simulations. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA. i

Seasonal climate and crop forecasts for agricultural risks management training related to the Crop Predictability Tool (CPT). Available at: http://www.ciatnews.cgiar.org/wp-content/uploads/2013/04/AGENDA_EN.pdf

World Bank/NDCC. 2004. Natural Disaster Risk Management in the Philippines: Enhancing Poverty Alleviation through Disaster Reduction. Manila, Philippines.

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