International Research Institute for Climate and Society
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Connecting Agriculture Stress Index Systems at the Sub-National Level to the Next Generation of Seasonal Climate Forecasts: A General Approach to Transition from Monitoring to Forecasting

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Introduction

Agriculture for food production remains a major contributor to the national economies of many developing countries. Often, these countries are characterized by agricultural landscapes that are heavily or even primarily dependent upon rainfall for crop irrigation and watering pastures for cattle. In the face of climate variability and change, decision-making processes at both the institutional and farm level are becoming more complex. Anticipating a potential agricultural drought and the associated impacts on food production could facilitate an informed risk-management strategy in climate-vulnerable agricultural landscapes. Systems for monitoring vegetation stress around the world have been successfully implemented at different geographical scales and are used by leading global developmental and humanitarian agencies. Yet, these systems could benefit from the incorporation of a combination of seasonal (3-9 months) and sub-seasonal (2-6 weeks) forecasts, to transition from monitoring to a more proactive approach of forecasting agricultural droughts months in advance. This approach can, in turn, inform risk-management strategies at the farm and institutional level.

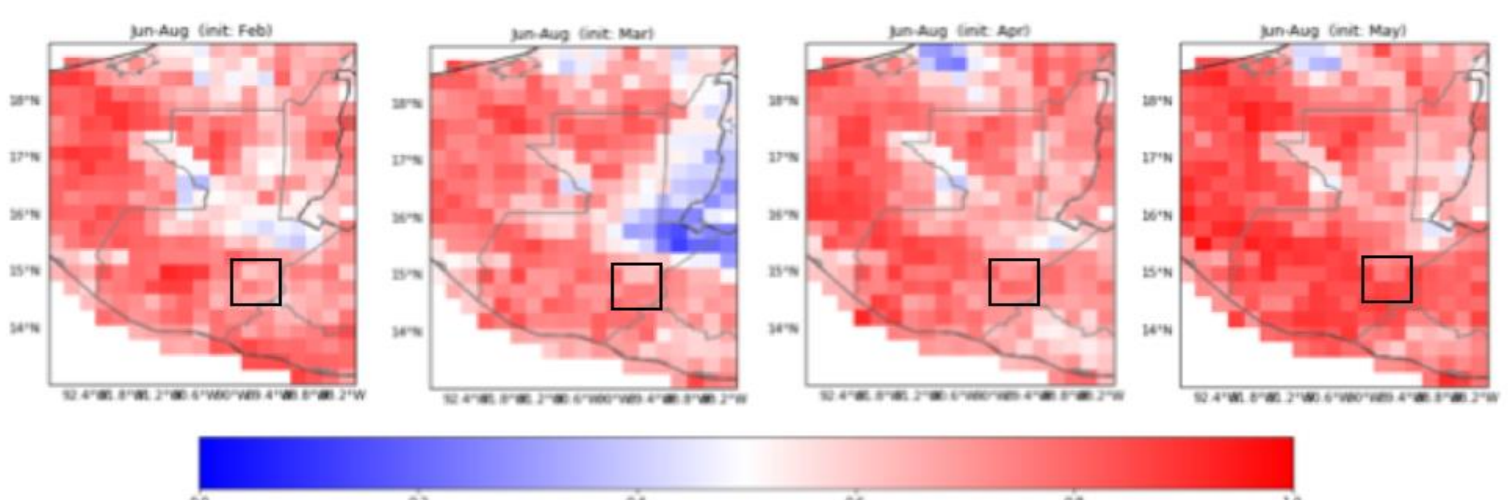

Figure 1. ROC values for the NextGen precipitation forecast initialized in Feb-May for the June-July-August season. Dry Corridor area highlighted

The next generation of climate forecasts—hereinafter "NextGen"—developed by the International Research Institute for Climate and Society (IRI) and implemented by several National Meteorological Services around the world, opens new avenues for state-of-the-art research and applied science that has the potential to transform policy-making processes, and help local governments and developmental and humanitarian agencies achieve their goals (Figure 1). This research shows the advantages of using a pattern-based-calibrated, multi-model ensemble, derived from the North American Multi-Model Ensemble (NMME), to forecast vegetation stress at subnational level. It also demonstrates how this approach (Model Output Statistics –MOS- using Canonical Correlations Analysis –CCA-) could be implemented by all the main agricultural monitoring systems worldwide based on the Normalized Difference Vegetation Index (NDVI). This general approach could be used to transform the current agricultural stress monitoring systems from one of monitoring of agricultural stress to one incorporating forecasts at temporal and spatial scales relevant to smallholder farmers, governments and humanitarian and developmental agencies using and *objective*, and *transparent* method.

Methods

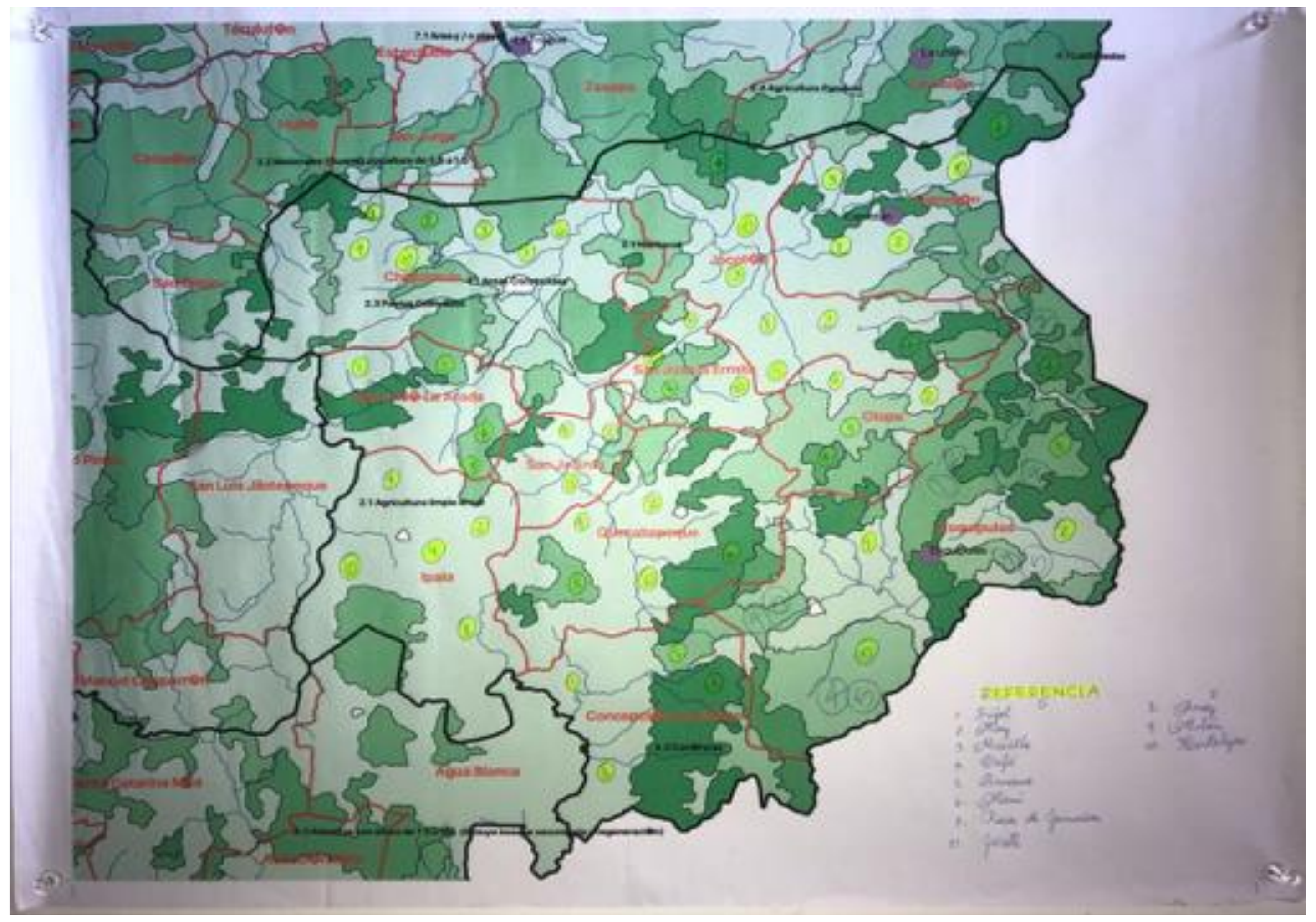

Figure 2. Example of crowdsourcing mapping of crops in the study region.

We started this process by visiting the locations on the ground in Guatemala's dry corridor (Figure 2) There, we worked with all the agricultural extension service agents to identify the current and historical crop allocation and agricultural calendars the municipal level. Noting the proper sowing and harvesting dates, we determined the phenological stages sensitive to changes in precipitation. We then evaluated the retrospective skill of the NNME-based NextGen for precipitation and temperature as predictors and several satellite-derived vegetation indices as predictands (Table 1). The training period for the cross-validation is 1982-2010. The goodness of fit was evaluated for each of the predictor-predictand combinations using spatially-averaged Kendall's Tau values. We then used canonical correlation analysis to build linear regressions between combinations of EOFs in the predictor and the predictand that maximize the correlation among them, tending to decrease systematic biases in the mean, variance, and spatial distribution (Tippet & Barnston 2008). CCA also implicitly works as a statistical downscaling method (Karamouz et al., 2010), thus producing corrected fields at the same spatial resolution of the predictand field. Hence, in this study CCA produced hindcasts at a resolution of 0.1o x 0.1o.

Table 1. Kendall's Tau values for each predictor-predictand experiment

Predictor	Predictand	Goodness Index (Kendall's Tau)
NextGen Precipitation anomalies	NDVI	0.182
NextGen Precipitation anomalies	SMN	0.139
NextGen Precipitation anomalies	VCI	0.147
NextGen Precipitation anomalies + Temperature anomalies	NDVI	0.186
NextGen Precipitation anomalies + Temperature anomalies	SMN	0.214
NextGen Precipitation anomalies + Temperature anomalies	VCI	0.185

Results

In this study we demonstrate the applicability of the Next Generation of Climate Forecast (NextGen) to anticipate agricultural drought for the most relevant crop season and locations identified by farmers and extension service agents using crowdsourcing methods. NextGen uses an integrated assessment of the forecast's capabilities to reproduce precipitation and temperature associated with hydrological supply and demand for ground level vegetation, expressed by multiple satellite-derived vegetation indices. The results suggest that the NextGen system can be used to forecast agricultural drought up to four months in advance by producing a categorical and deterministic forecast of the Normalized Difference Vegetation Index (NDVI) based on precipitation and temperature as predictors (Figure 3). This advancement in agricultural stress forecasting could help observing systems to move from monitoring vegetation stress to forecasting vegetation stress which in turn can help humanitarian and development agencies to anticipate catastrophic agricultural droughts months in advance. In addition, the study shows the advantages of incorporating local knowledge to overcome some of the current information gaps that kept these systems from providing relevant, timely information to small-holder agriculturalists at the sub-country level. Overall, the NextGen approach using CCA as the MOS method could help institutions to determine potential predictors and predictands (e.g. precipitation and NDVI) in an objective and transparent manner at scales relevant for decision-making processes for farmers.

Figure 3. Reliability diagrams for the model using precipitation and temperature for the above (blue), normal (green), below (red) and all categories (black) for NDVI.