A Report on CRAFT Implementation for In-season Wheat Yield Forecasting (Winter 2014/15) in Nepal

CGIAR Research Project on Climate Change, Agriculture and Food Security (CCAFS) Regional Agriculture Forecasting Toolbox (CRAFT)

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Acknowledgment

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MoAD and WFP would like to acknowledge the recent collaboration with CCAFS South Asia to strengthen early warning for better food security planning in Nepal, especially under the present and anticipated changing climatic conditions. The results of this collaboration are presented in this report.

This report relies on information provided through different agencies, including the International Centre for Integrated Mountain Development (ICIMOD), International Water Management Institute (IWMI), International Research Institute for Climate and Society, Columbia University, Nepal Agriculture Research Council (NARC), Department of Agriculture, MoAD and WFP. Hence, all contributing agencies and their staff are gratefully acknowledged for their support and cooperation.

The Nepal Food Security Monitoring System (NeKSAP) collects, analyzes and presents information on household food security, emerging crises, markets and nutrition from across Nepal. Initiated by WFP in 2002, NeKSAP is now jointly operated by the Ministry of Agricultural Development and WFP under the strategic guidance of the National Planning Commission and with support from the European Union.

http://www.neksap.org.np

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Table of Contents

Background

Crop yield forecasting refers to the prediction of crop yield or production prior to harvesting. Reliable, timely and accurate crop yield forecasts can provide crucial information for food security planning, particularly in the context of climate variability, change, and extremes. Crop yield forecasting uses meteorological data, cultivar specific genotype data, soil properties, and various management practice data to simulate plant-weather-soil interactions in quantitative terms and predict the crop yield over a given area, prior to the harvest. These models try to mimic fundamental mechanisms of plant growth and related processes in the soil-plant-atmospheric continuum to simulate specific outcomes. For any soil, cultivar and management conditions weather is a prime driver of inter-annual variations in the crop yield.

So far crop yield estimation in Nepal is based on traditional crop cuts, surveys and reports from the District Agricultural Development Offices (DADOs). Additionally, representatives from MoAD, WFP, FAO and other agencies undertake field verifications and consultations to collect additional information on crop performance and issues and challenges related to production and marketing of key cereals. Based on MoAD's preliminary estimates and field verification outcomes, MoAD, WFP and FAO issue crop situation updates twice a year, i.e., after harvesting of summer and winter crops. These crop situation updates rely on sample crop-cutting, which is used to verify the yield for key cereal crops (paddy, wheat, maize, and millet).

Though this process has its own advantages, it is a time consuming and costly exercise and there can be delays in processing the results. The crop cut results can take from six months to over one year to provide a basis for the area and production estimates and the results only become available after the crops are actually harvested. On the other hand, the Government of Nepal (GoN) and other agencies working on food security require estimates of food production in advance for various policy and programme decisions relating to pricing, marketing, export/import, distribution, and overall food security management. In this context, crop modeling tools can provide GoN and other agencies with production estimates well in advance to support better food security planning and programme decisions.

A systematic yield forecasting model is, however, not yet developed for Nepal. In the absence of a country specific model, a robust crop yield forecasting tool based on real-time climate information can serve the same purpose, providing accurate, precise, scientific estimates of crop yields for food security and early warning purposes. Once the simulation model is built, seasonal crop yields can be estimated by periodically updating climatic data and other information in the model.

Under its research theme on Climate Risk Management, CCAFS has developed a crop yield forecasting tool customized for the South Asia Region, the CCAFS Regional Agriculture Forecasting Toolbox (CRAFT). The CGIAR Research Project on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT), which conducts research to identify and address the most important interactions, synergies and tradeoffs between climate change, agriculture and food security.

CRAFT incorporates a crop simulation model (DSSAT), weather and seasonal forecast module (CPT) and a GIS mapping module (Map Win GIS). This tool provides the support for spatial input data, spatial crop simulations, integration of seasonal climate forecasts, spatial aggregation, probabilistic analysis of forecast uncertainty, and calibration of model predictions from historical agricultural statistics, analysis and visualization. This tool helps to provide advance information to farmers and policy makers allowing them to manage within-season climate risks to agriculture. The model has been used in Nepal for a pilot study and is being currently used in Bangladesh, Sri Lanka and India as well. **Figure 1** presents the flow diagram of CRAFT with four major steps (e.g. crop model, statistical model, aggregation and calibration).

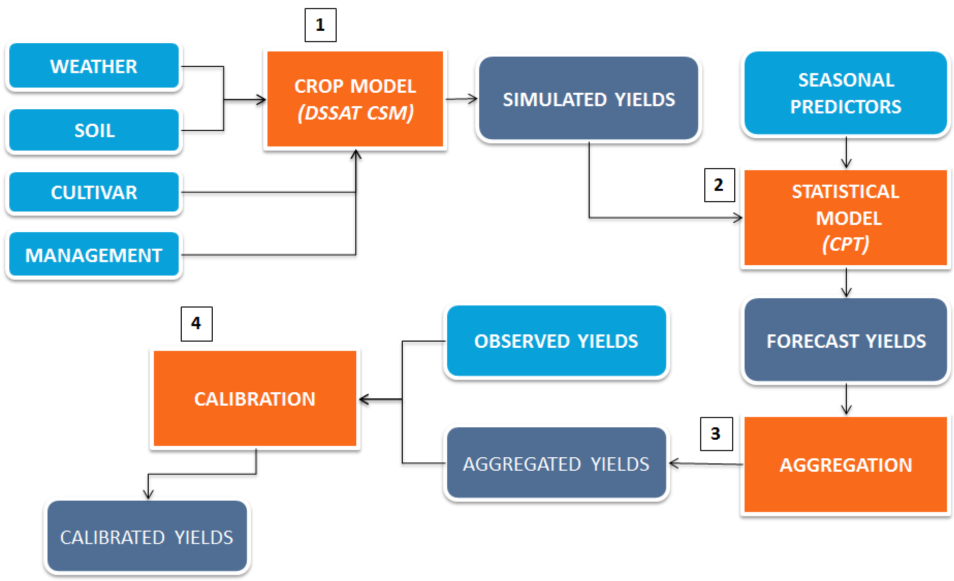

Figure 1: Flow diagram of CRAFT

Methods

Weather

Weather is the major driver of the CRAFT model, and the reliability of climatic parameters determine the reliability of model outcomes, i.e., the yield and production forecasts. Near-real time data is a prerequisite to get reliable yield forecasts. In the absence of the near real time data, ground measured station data were used in conjunction with the satellite based climatic estimates. Department of Hydrology and Meteorology (DHM) ground station data for precipitation and temperature for a time period of 1981 to 2009 were used in the model run. The precipitation data was taken from 163 stations and temperature from 45 stations across Nepal.[1] The stations were selected based on the availability of the weather parameters. These data were interpolated in 5' x 5' schema grids using the nearest neighborhood method[2]. Beyond 2009, the weather data was supplemented using other satellite

[1] http://www.dhm.gov.np/hydrological-station, http://www.dhm.gov.np/meteorological-station

[2] The nearest neighborhood method calculates the distance and additional proximity information between the schema grids and the weather stations around it and picks the closest weather station for each grid.

precipitation and temperature estimates. The supplementary precipitation data used was 0.1° RFE v 2.0 data (Love, 2002), which was accessed through the IRI/LDEO Climate Data Library[3].

Wheat crop mask

The wheat crop mask was created using the Ministry of Agricultural Development's national statistics on wheat grown area for the year 2013/14. Since the DHM's weather outlook predicts 'normal or above normal' rainfall this winter season, it was assumed that the wheat grown area will remain more or less the same. The ratio of wheat grown area to the total area for each district was calculated and this proportion was uniformly distributed to each grid within a district to get the distributed wheat mask.

Irrigated area mask

Similarly, MoAD statistics on the irrigated area were used and distributed to grids based on districts. It was also assumed that the irrigated areas will not change from 2013/14.

Soil data

The Soil and Terrain Database (SOTER) for Nepal was used as the soil source and the respective properties, such as texture, depth, soil moisture content, bulk density, infiltration capacity, and organic matter content (Dijkshoorn and Huting, 2009), were added to the CRAFT database and used for modeling. The SOTER database, at a scale of 1:1 million, is supported by the Food and Agriculture Organization of the United Nations (FAO), ISRIC-World Soil Information and the United Nations Environmental Programme (UNEP) under the umbrella of the International Union of Soil Science (IUSS) to create a global Soil and Terrain cover.

Crop varieties

RR-21 for the hills ecological belt and NL-297 varieties for the plains (Terai) ecological belt were selected as the popular wheat cultivars. Calibrated genotypes obtained from the Nepal Agricultural Research Council (NARC) were used as the cultivar coefficients.

Crop management

The planting dates for the hills ecological belt were assumed to be December 1 and for the plains (Terai) to be November 22. Similarly, it was also assumed that nitrogen fertilizer use was 60 kg/ha for both the hills and plains (Terai). Total irrigation application was assumed to be 600 mm for the hills and 800 mm for the plains (Terai). The assumptions were based on the studies conducted by Gautam et al. (2011), Hobbs et al. (1996), Adhikari et al. (1999), and Amgain and Timsina (2005).

Results

Preliminary wheat outlook 2014/15 season (with climate data to 10 February 2015)

Once the aforementioned spatial-temporal inputs were prepared and entered into the model, CRAFT was used to forecast the wheat production for 2014 /15 season. Prior to forecast, the model was run to simulate production for each year from 1983 to 2013 and the simulated values were compared against the reported production from MoAD. The preliminary model run showed a strong correlation between the observed and the simulated yields in Nepal. A coefficient of determination (R^2) value of 0.92 shows a

[3] http://iridl.ldeo.columbia.edu/

very good predictive capability of the model. However, a closer look into the model prediction shows an overestimation of the production in most of the years. Apart from 1989, 1994 and 2000, the differences in production are well within 30 percent, with the lowest being 2 percent in 1993. This result was assumed to be satisfactory and CRAFT was run to get a preliminary wheat outlook for the 2014/15 season. The outlook suggests an estimated production of 2,230,660 mt (within a range of 1,896,061 to 2,565,259 mt).

Final wheat outlook 2014/15 season (with climate data to 10 March 2015)

The model was rerun with updated climate data to 10 March 2015 and the model calibration was further improved to get the updated outlook for the winter season. The updated results show that the results have been improved considerably with the predicted values much closer to the reported ones (**Figure 3**). The scatter plot between the observed and simulated production and coefficient of determination (R^2) of 0.90 also indicate that the model performance is satisfactory (**Figure 2**). The final wheat production outlook estimated was 1,994,598 mt (**Figure 4**), with an average prediction uncertainty of ±12 percent.

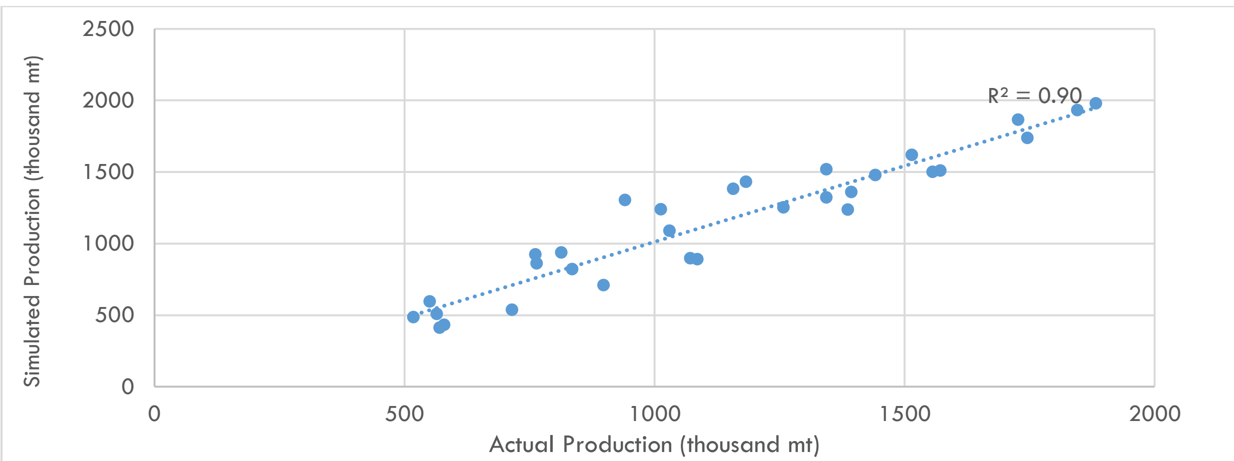

Figure 2: Scatter plot of actual and simulated wheat production (final run)

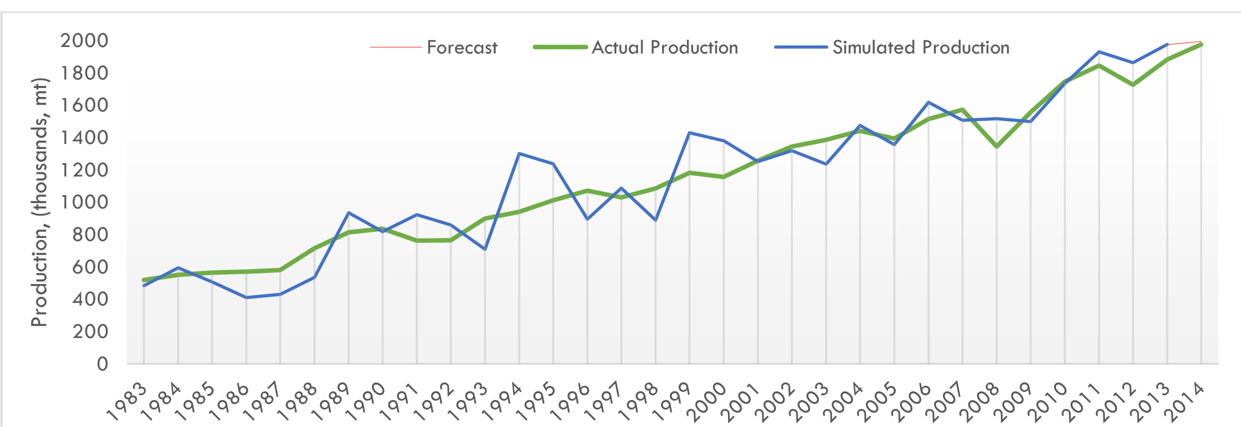

Figure 3: Observed*, simulated and forecasted wheat production, mt (final run)

*2014 production statistics are advanced estimates of MoAD; Model: DSSAT CSM in CRAFT framework

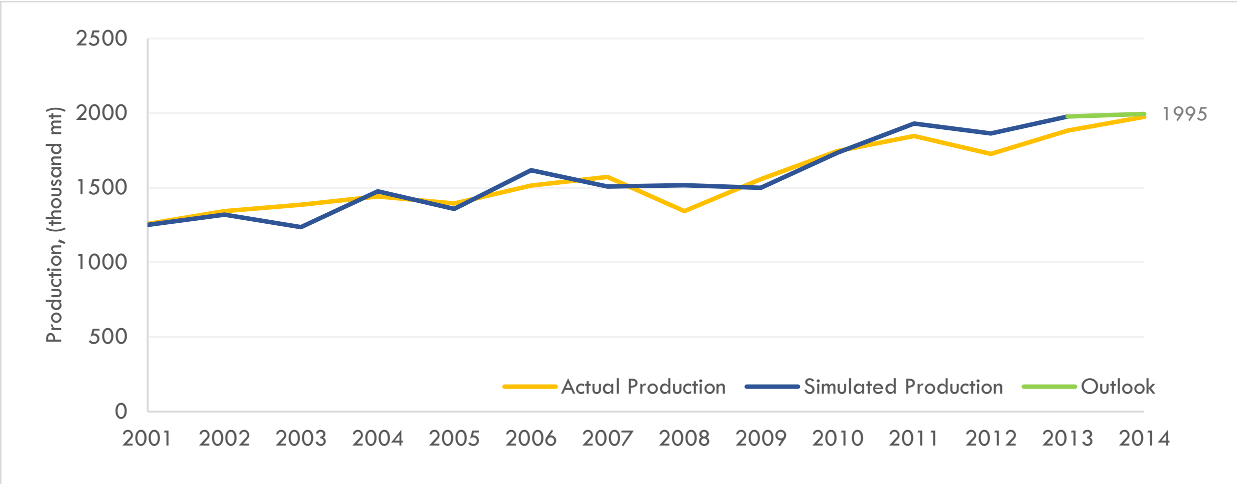

Figure 4: Observed*, simulated and forecasted wheat production, mt

*2014 production statistics are advanced estimates of MoAD; Model: DSSAT CSM in CRAFT framework

Conclusion

Yield forecasting outcomes

The CCAFS Regional Agriculture Forecasting Toolbox (CRAFT) was piloted as a part of the Nepal Food Security Monitoring System (NeKSAP) and is a new initiative to incorporate crop yield forecasting in Nepal with the technical support from CCAFS South Asia. CRAFT was used to estimate wheat production in Nepal over the 2014/15 season. Once spatial inputs were included in the model, CRAFT was used to forecast the wheat production. The forecasted yield of **1,994,598 mt** closely matches the MoAD estimate of **1,975,607 mt** with a prediction error of less than 1 percent. These results show that there is the potential for crop yield modeling to be incorporated in the crop yield estimation process in Nepal and can thus make a significant contribution to food security planning and early warning.

Dissemination of results

The CRAFT modeled outlook for wheat production was published through the Nepal Food Security Bulletin (Issue 43) and Crop Situation Update (2014/14 winter crops).[4] In addition, the updated wheat outlook was disseminated through the digital information board at MoAD. A poster on CRAFT implementation for in-season crop yield forecasting in Nepal was also presented at the 3rd Global Science Conference on Climate-Smart Agriculture in Montpellier, France in March 2015.[5]

Improving model prediction

In order to improve the model prediction and to improve the spatial inputs, including crop management data, revisions were made to the crop assessment community interaction questionnaire. Likewise, the International Centre for Integrated Mountain Development (ICIMOD) provided cropped and irrigated area maps.

[4] http://neksap.org.np/food-security-bulletins, http://neksap.org.np/crop-situation-update
[5] http://csa2015.cirad.fr/

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