



## Calibration, validation and application of CERES-Maize model for climate change impact assessment in Abuan Watershed, Isabela, Philippines

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### Abstract

Recently, corn farmers in Abuan Watershed and Isabela Province are experiencing declining crop yields caused by insufficient amount of rainfall. To increase crop yields and reduce production risks, research on better use of available rainfall and better understanding on effects of climate variability, and soil and field management on crop production is imperative. Simulation models, driven by daily climatic data, can be used to predict the impact of long-term climate variability on the probability of success of a range of crop, and water and soil management strategies.

Calibration of the model was based on field data from Cagayan Valley Research Center at Ilagan, Isabela during two growing seasons in 2013-2015. Model validation of phenology, yield and biomass was undertaken on-station and at farmer fields. Results showed acceptable accuracy between actual and simulated data. Specifically, the model yields high efficiency of 0.86 in predicting yield of participating farmers. It also demonstrated the possibility of simulating production of other hybrid varieties.

Projected yield as affected by temperature and rainfall changes indicated a sharp reduction by up to 44% in 2020 and 35% in 2050. The model can be used as important input in developing decision support system by the Department of Agriculture and local government units.

**Keywords:** CERES-Maize Model · calibration · validation · Abuan Watershed

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## Introduction

It is well accepted in the scientific community that our climate is changing due to rising anthropogenic greenhouse gas emission. According to Intergovernmental Panel on Climate Change (IPCC), the future degradation of soil and water resources will be a major challenge facing global agriculture (IPCC, 2001).

Climate change poses serious threats to Abuan Watershed's ecological services and to livelihoods of farmers (Tongson, 2014). The increasing frequency of inter-annual anomalies from both typhoons and drought in recent years foretell the impacts from global warming. In the early half of 2010, prolonged dry spells caused wilting of rice and corn crops. Yield reductions of corn were recorded at 66% from normal yield. With climate change, anomalies occurring the same year are becoming more common and are likely to get worse. According to PAGASA (2011), the 2050 scenario for Isabela will result in a 1.9 to 2.1 °C increase in temperature, a 29% decrease in mean rainfall for dry months, and a 1.7 to 25.1% increase in rainfall during wet months. This rise in temperature will increase atmospheric demand for water through evaporation and transpiration. The redistribution of rainfall will translate to frequent and more intense flooding during wet months and prolonged dry spells during summer.

In recent years, several dynamic crop simulation models have been developed as information technology tools to support strategic decision-making in research, crop production and land planning (Hoogenboom et al., 1992; Penning de Vries et al., 1993; Hoogenboom et al., 2004). These crop models can be used to evaluate agricultural production risk as a function of climatic variability, to assess regional crop yield potential across a wide range of environmental conditions and to determine suitable planting dates and other management factors for increasing crop yield (Egli & Bruening, 1992; Meinke et al., 1993; Aggarwal & Kalra, 1994; Meinke & Hammer, 1995; Hunt et al., 1996; Chapman et al., 2000).

Crop simulation models would help in investigating climate change impacts on crops. It will help in identifying and prioritizing the management options for adapting to and mitigating climate change effects. It will assess variability in yield or effects of water deficits. Bridging yield gaps and attaining potential yield will inspire farmers to achieve best results in spite of climate change effects.

This study aims to develop a localized Decision Support System for Agrotechnology Transfer - Crop Environment Resource Synthesis (DSSAT-CERES) Maize model using field data and assess future corn production under climate change scenarios. It is intended to support the government initiatives to mitigate climate change impacts to corn production and build resilient corn farms in the province of Isabela.

## Methodology

### Study Site

Located in the province of Isabela, the Northern Sierra Madre Natural Park hosts the last remaining old-growth dipterocarp

forests in the country. In its western buffer zone lies in the Abuan Watershed, a 63,754 hectare ecosystem that supports the livelihoods of some 2,900 farming households. The higher catchment comprises 44,000 hectares (69%) of the Northern Sierra Madre Natural Park.

The lower sub-catchments consist of farm lands, residual forests and brush lands with an area of 19,000 hectares (31%) of the watershed area. The watershed is named after the Abuan River, which, together with the smaller Bintacan River, drains into the Pinacanauan de Ilagan River, before merging with the Cagayan River. Most of the rice and corn areas are planted at the lowest sub-catchment of the watershed. Rice areas in the watershed are 133 hectares while corn areas constitute 2,779.5 hectares (Figure 1).

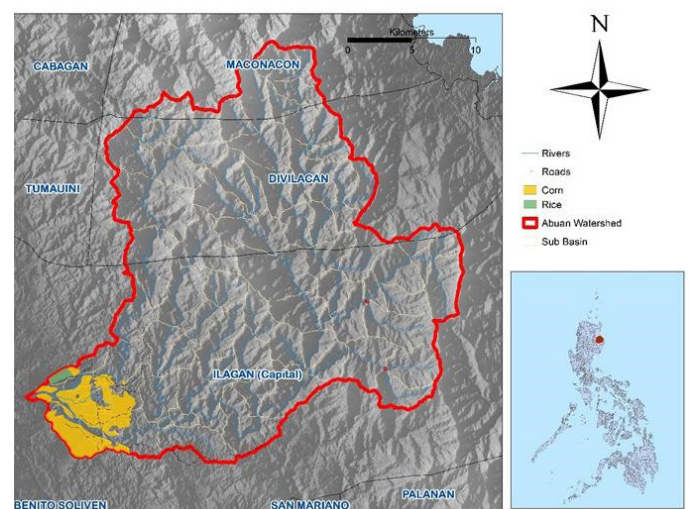


**Figure 1.** Rice and corn areas in Abuan Watershed

### Weather

A 26-year weather data (1988-2014) from the Cagayan Valley Research Center (CVRC) was used for the study area. Average annual rainfall is 2,176 mm and rainy season starts in the month of May and ends in December. Highest rainfall occurs in the month of November with 319.16 mm and lowest during the month of March with 56.99 mm. The hottest month was observed in June with an extreme value of 35.64 °C while coldest month is January with a minimum value of 19.88 °C. Sunshine duration is highest in the months of April, May and June with 6.9, 7.0 and 6.7 hours, respectively.

### Soil Characteristics of Experimental Areas

The soil at CVRC site is characterized as alluvial plain with slope of more or less 1%, a soil depth is 100 cm and silty clay loam texture of surface and subsoil. Cabisera 10 is also located in alluvial plain with slope of more or less 1%. Soil depth is more than 100 cm and soil texture of surface soil and subsoil is loam. At Villa Imelda site, the area is situated in rolling terrain with slopes ranging from 8 to 18%. Soil depth is more than 100 cm and soil texture of surface

soil and subsoil is clay. Sindon Bayabo is a hilly area with slope ranges from 18 to 30%. Soil depth is 65 cm and soil texture of surface soil is sandy clay loam, while subsoil is clay.

Table 1 shows some physical and soil characterization of the study areas. Agro-zone is classified based on percent slope. Information on soil characteristics includes soil depth, texture and some chemical properties. As shown, typical corn soil in the watershed are acidic with low contents of organic matter, phosphorus and potassium.

**Table 1.** Physical and soil characteristic of the study areas

| Location            | CVRC               | Cabisera 10                 | Villa Imelda                | Sindon Bayabo               |
|---------------------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Corn Farmer         | Research Center    | Charlito Servilla           | Eulalio Paredes             | Amado Bolda                 |
| Agro-zone           | Flood plain        | Flood plain                 | Rolling                     | Hilly                       |
| Slope (%)           | ≥ 1                | ≥ 1                         | 8-18                        | 18-30                       |
| Soil depth (cm)     | >100               | >100                        | >100                        | 65                          |
| Texture             | Silty clay loam    | Loam                        | Clay                        | Sandy clay loam over clay   |
| Soil reaction (pH)  | 5.60 (medium acid) | 4.84 (very strongly acidic) | 4.66 (very strongly acidic) | 5.00 (very strongly acidic) |
| Organic matter (%)  | 0.41 (very low)    | 0.16 (very low)             | 0.59 (very low)             | 0.05 (very low)             |
| Phosphorus (mg/kg)  | 8.30 (low)         | 6.99 (low)                  | 15.96 (medium)              | 0.40 (very low)             |
| Potassium (cmol/kg) | 0.18 (very low)    | 0.24 (low)                  | 0.30 (low)                  | 0.36 (low)                  |

## Crop Management

In the CVRC site, planting is usually done in the months of December or January with a spacing of 0.75 m by 0.20 m and fertilizer application followed the package of technology for corn. In Cabisera 10, Villa Imelda and Sindon Bayabo, farmers wait when soil moisture is wet enough to commence land preparation and planting. As practiced, planting usually takes place during the months of October and November. Plant population is approximately 60,000 per hectare and fertilizer application rates largely depend on the financial capability of farmers.

## Field Experimental Data

Field experiments were conducted for two cropping season under various agro-ecological zones namely: floodplains, rolling

and hilly croplands. Figure 2 shows the locations of these field sites as follows:

1. Villa Imelda - rolling terrain, farmers field, rainfed
2. Sindon Bayabo - hilly terrain, farmers field, rainfed
3. Cabisera 10 - flood plain, farmers field, rainfed
4. CVRC - formerly Cagayan Valley Integrated Agricultural Research Center (CVIARC), flood plain, rainfed and irrigated

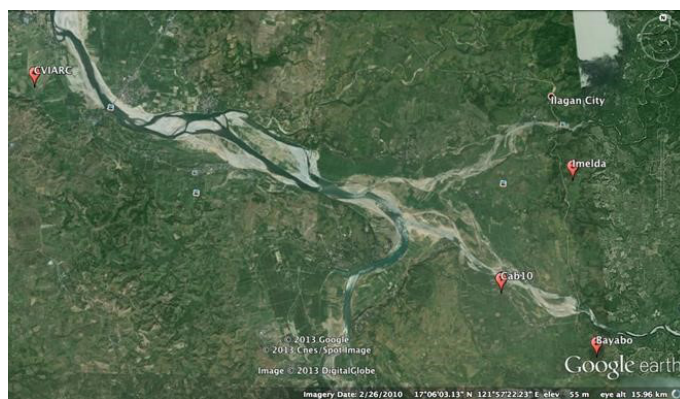


**Figure 2.** Location of field sites

Maize hybrid, Dekalb 9132, a long season hybrid yellow corn was selected being the preferred choice of most farmers in the Abuan Watershed. Local daily climate data and soil information from each site were gathered and monitored. Phenological events were recorded in reference to date of planting. Biomass data were gathered after every 10 days from emergence to harvest through destructive sampling. Ten plants are chosen in random as samples and were oven dried for 48 hours at 70°C. A harvest area of 5 m by 3 m was designated in the middle of each plot for yield data collection.

## Model Description

Advance crop production management support systems need appropriate process-based crop simulation model which utilizes site specific parameters such as weather, physical and chemical properties of soil, water management, and agronomic practices (Penning de Vries et al., 1989). O' Toole and Stockle (1987) described the potential of simulation models in assessing trait benefits of winter cereals and their capacity to survive and reproduce in stress-prone environment. Crop growth models have been used in plant breeding to simulate the effects of changes in the morphological and physiological characteristics of crops which aid in identifying ideotypes for different environments (Hunt, 1993; Kropff et al., 1995).

A process-oriented Cropping System Model (CSM) - Ceres-Maize Model has been developed to simulate vegetative and reproductive development, growth and yield as a function of crop characteristics, climatic factors, soil characteristics and crop management. These models are part of suite of crop growth models that encompass DSSAT (Hoogenboom et al., 2004).

The CERES-Maize model was first introduced by Jones and Kiniry (1990). Over the years, the model has been improved and included as a module in the software package (Ritchie et al., 1989; Hoogenboom et al., 2003; Jones et al., 2003). CSM-CERES-Maize simulates corn growth on a daily basis in response to weather, soil, and environmental conditions, fertilizer rates, and other field management strategies. It simulates plant phenological development, biomass accumulation and partitioning, and final yield production. The CSM-CERES-Maize model can provide a prompt assessment to support decisions in crop production systems that involve risk (Jagtap et al., 1999). Modeled processes include phenological development, i.e., duration of growth stages, growth of vegetative and reproductive plant parts, extension growth of leaves and stems, senescence of leaves, biomass production and partitioning among plant parts, and root system dynamics.

DSSAT software integrates the effects of soil, crop phenotype, weather, and management options. It allows users to ask “what if” questions and simulate results by conducting, in minutes on a desktop computer, experiments which would consume a significant part of an agronomist’s career. It also provides for validation of crop model outputs; thus allowing users to compare simulated outcomes with observed results. Crop model validation is accomplished by inputting the user’s minimum data, running the model, and comparing outputs. By simulating probable outcomes of crop management strategies, DSSAT offers users information with which to rapidly appraise new crops, products, and practices for adoption. The DSSAT package incorporates models of 27 different crops with new tools that facilitate the creation and management of experimental, soil, and weather data files. DSSAT v4.5 includes improved application programs for seasonal and sequence analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer and nutrient management, climate change, soil carbon sequestration, climate variability and precision management.

In the Philippines, Lansigan et al. (2004) used CERES-Maize in the analysis of corn yield gaps in major corn growing areas where crop genetic coefficients specific for the local corn variety IPB 911 was derived.

The localized model input data was taken from the first cropping experimental set up for all the five sites. Model calibration was undertaken using DSSAT utility program called Generalized Likelihood Uncertainty Estimation (GLUE). The GLUE program was used to estimate genotype-specific coefficients for the local crop model using data from the field experiments i.e., biomass and yield. Information for cultivar specific genetic coefficients is normally not readily available for certain local cultivars. In the first step, a model calibration was conducted to determine the cultivar coefficients for cultivar of corn that is normally grown in the Abuan Watershed.

Using the set of actual data inputs, the GLUE uses an inverse engineering technique to calculate the six coefficients for corn. GLUE iterates the simulation until it determines the coefficients that will give the best goodness of fit between the actual and simulated biomass, phenological events and yield. The derived genetic coefficients will then be copied to the DSSAT database which can be properly named and used to validate the model (Figure 3). The uncertainty of the coefficients is reflected as statistical indicators which are also a measure of the accuracy of the model.

### Model Validation

Simulation models are thought to be an indispensable tool for supporting scientific research, crop management, and policy analysis (Fischer et al., 1999; Hammer et al., 2002; Hansen, 2002). However, validation of such models needs to be conducted because these are developed under very specific edaphic and climatic conditions that do not necessarily prevail in other regions of the world. Therefore, before the model can be adopted or used in other locality, evaluation or validation study must be undertaken to establish its credibility (Balderama & Bareng, 2009).

The accuracy of the procedure, used to estimate the genetic coefficients, was determined by comparing the simulated values for the development and growth characteristics with their corresponding observed values and by calculating the values for coefficient of determination ( $R^2$ ), root mean square error (RMSE)

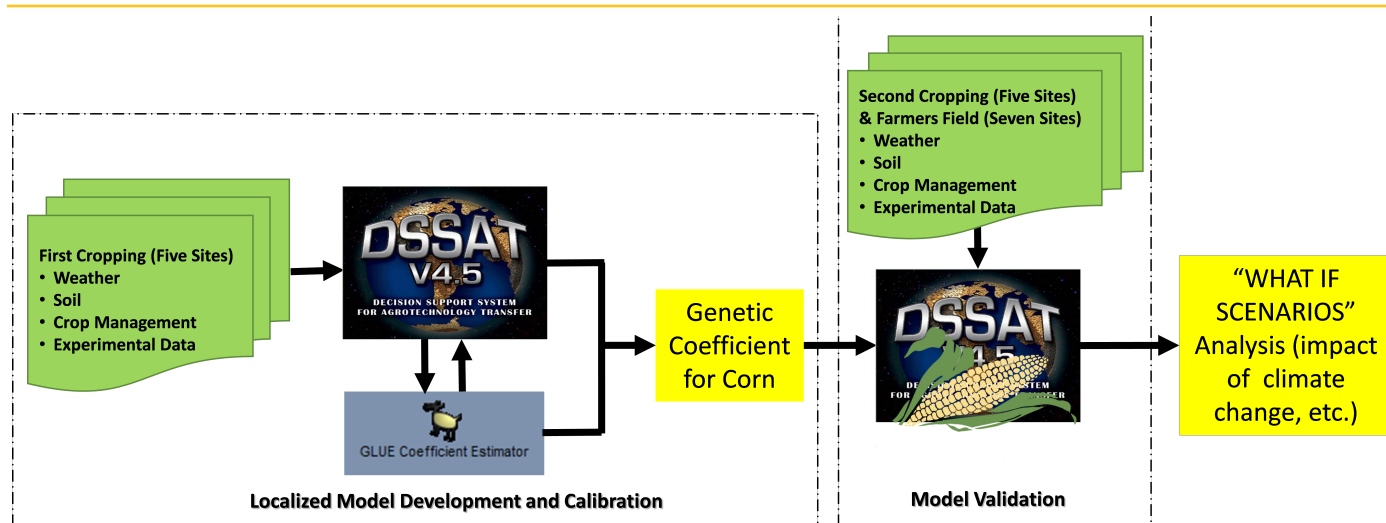


Figure 3. Localized model development, calibration and validation flow chart

as well as the index of agreement (d value). In the results and discussion, the term d-stat will be used instead of d value to follow the term used in DSSAT. The values of R<sup>2</sup>, RMSE and d value indicate the degree of agreement between the predicted values with their corresponding observed values. A low RMSE value and a d value approaching unity are desirable. The R<sup>2</sup> describes the proportion of the variance in measured data explained by the model. R<sup>2</sup> ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Santhi et al., 2001; Van Liew et al., 2003). The d value was developed by Willmott (1981) as a standardized measure of the degree of model prediction error and varies between 0 and 1. A computed value of 1 indicates a perfect agreement between the measured and predicted values, and 0 indicates no agreement at all (Willmott, 1981). RMSE is one of the commonly used error index statistics (Chu & Shirmohammadi, 2004; Singh et al., 2004; Vasquez-Amabile & Engel, 2005). It is commonly accepted that the lower the RMSE, the better the model performance.

The derived genetic coefficient for corn, actual data from the second cropping season for all the five sites, and the actual data from the farmers were used to validate the model. Model validation for phenological events, biomass and yield was undertaken on same five field sites and twenty four farmer's field sites.

### Assessment of Climate Change

Projections are important as basis for adaptation interventions. Table 2 shows the 2020 and 2050 projected weather data from PAGASA which was also used to capture the effect of rise in temperature and change in rainfall amounts in rainfed corn yield. These were produced through downscaling of relatively coarse resolution information from Global Climate Model (GCM) to regional scale. The data are given in percent change of the normal for a three-month period. Normal years identified by PAGASA (2011) were from 1991 to 2000. The normal years climate data used in the simulations were taken from the Agrometeorology station in CVRC, Ilagan City, Isabela. The 2020 climate projection is centered from 2006-2035 and the 2050 from 2036-2065. The emissions considered in this study for the climate data both for 2020 and 2050 were medium range emissions scenario for the province of Isabela. The DSSAT program has a utility for environmental modifications where the projections were inputted as percent change of the normal.

**Table 2.** Projected temperature and rainfall changes in 2020 and 2050 (PAGASA, 2011)

| Simulated year   | % change in Rainfall |         |         |         | Increase in Temperature |         |         |         |
|------------------|----------------------|---------|---------|---------|-------------------------|---------|---------|---------|
|                  | Dec-Feb              | Mar-May | Jun-Aug | Sep-Nov | Dec-Feb                 | Mar-May | Jun-Aug | Sep-Nov |
| 2020 Projections | 3.90                 | -8.60   | 5.10    | 13.5    | 0.80                    | 0.90    | 0.90    | 0.80    |
| 2050 Projections | 25.10                | -29.20  | 8.70    | 1.70    | 2.00                    | 2.10    | 2.10    | 1.90    |

## Results and Discussion

### Calibration of Genetic Coefficients

Calibration was undertaken in the five sites during the first cropping season. Table 3 shows the genetic coefficients of Dekalb 9132 as result of model calibration.

**Table 3.** Estimated genetic coefficient of Dekalb 9132

| Definition                                                                                                                                                                                          | Variable | Unit                                                                                       | Coefficient |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------------------------------------------------------------------------------------------|-------------|
| 1 Thermal time from seedling emergence to the end of the juvenile phase                                                                                                                             | P1       | degree days above TBASE during which the plant is not responsive to changes in photoperiod | 287         |
| 2 Extent to which development is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours) | P2       | expressed as days                                                                          | 1.32        |
| 3 Thermal time from silking to physiological maturity                                                                                                                                               | P5       | expressed in degree days above a base temperature of 8°C                                   | 986.70      |
| 4 Maximum possible number of kernels per plant                                                                                                                                                      | G2       | number                                                                                     | 528.90      |
| 5 Kernel filling rate during the linear grain filling stage and under optimum conditions                                                                                                            | G3       | mg/day                                                                                     | 16.43       |
| 6 Phylochron interval; the interval in thermal time between successive leaf tip appearances                                                                                                         | PHINT    | degree days                                                                                | 45          |

There are six coefficients derived using local conditions and actual data. Results showed high goodness of fit between simulated and actual above ground biomass. Maize growth reflected through the biomass accumulations was accurately predicted with R<sup>2</sup> ranging from 0.91 to 0.99 with a d-stat ranging from 0.70 to 0.97 for the five sites.

Also, RMSE values are low which ranged from 1,201 to 2,950 kg/ha of biomass (Table 4).

**Table 4.** Statistical analysis result between observed and simulated dry aboveground biomass

| Site             | Standard Deviation |           | R <sup>2</sup> | RMSE     | d-Stat. |
|------------------|--------------------|-----------|----------------|----------|---------|
|                  | Observed           | Simulated |                |          |         |
| Cabisera 10      | 3,543.86           | 3,419.42  | 0.93           | 1,201.07 | 0.97    |
| CVRC (Irrigated) | 3,899.12           | 5,159.72  | 0.93           | 2,950.31 | 0.90    |
| CVRC (Rainfed)   | 2,537.70           | 1,937.85  | 0.99           | 2,223.02 | 0.69    |
| Villa Imelda     | 3,033.28           | 1,627.94  | 0.94           | 1,846.86 | 0.85    |
| Sindon Bayabo    | 3,981.63           | 2,592.47  | 0.99           | 2,386.39 | 0.88    |

Furthermore, Table 5 shows the close agreement of observed and simulated phenological events.

**Table 5.** Observed and predicted phenological events

| Site             | Emergence |      | Silking |      | Beginning of Grain Filling |      | Physiological Maturity |      |
|------------------|-----------|------|---------|------|----------------------------|------|------------------------|------|
|                  | Obs.      | Sim. | Obs.    | Sim. | Obs.                       | Sim. | Obs.                   | Sim. |
| Cabisera 10      | 3         | 5    | 61      | 63   | 72                         | 74   | 115                    | 122  |
| CVRC (Irrigated) | 5         | 6    | 66      | 68   | 74                         | 78   | 110                    | 111  |
| CVRC (Rainfed)   | 5         | 6    | 66      | 68   | 74                         | 78   | 110                    | 111  |
| Villa Imelda     | 3         | 5    | 61      | 66   | 80                         | 80   | 115                    | 111  |
| Sindon Bayabo    | 3         | 5    | 61      | 65   | 74                         | 79   | 115                    | 91   |

*Note: Obs. = Observed; Sim. = Simulated*

### Model Validation during the Second Cropping

The calibrated genetic coefficients were evaluated using actual data taken from the five sites during the wet cropping season of 2015. The validation process was successful as manifested by the goodness of fit between actual and simulated biomass from the five validation sites. The R<sup>2</sup> ranged from 0.86 to 0.97 with d-stat ranging from 0.71 to 0.98. Also, RMSEs were low which ranged from 1,718 to 5,725 kg/ha of biomass (Table 6).

**Table 6.** Statistical analysis result between observed and simulated dry aboveground biomass in the five sites for the model validation

| Site             | Standard Deviation |           | R <sup>2</sup> | RMSE     | d-Stat. |
|------------------|--------------------|-----------|----------------|----------|---------|
|                  | Observed           | Simulated |                |          |         |
| Cabisera 10      | 3,543.86           | 3,419.42  | 0.93           | 1,201.07 | 0.97    |
| CVRC (Irrigated) | 3,899.12           | 5,159.72  | 0.93           | 2,950.31 | 0.90    |
| CVRC (Rainfed)   | 2,537.70           | 1,937.85  | 0.99           | 2,223.02 | 0.68    |
| Villa Imelda     | 3,033.28           | 1,627.94  | 0.91           | 1,846.86 | 0.85    |
| Sindon Bayabo    | 3,981.63           | 2,592.47  | 0.99           | 2,386.39 | 0.88    |

The differences between observed and predicted phenological dates in these three sites were not significant. Table 7 shows the observed and predicted phenological dates from Cabisera 10, CVRC Irrigated, CVRC Rainfed, Villa Imelda and Sindon Bayabo.

**Table 7.** Observed and predicted phenological events from the five plots in days

| Site             | Emergence |      | Silking |      | Beginning of Grain Filling |      | Physiological Maturity |      |
|------------------|-----------|------|---------|------|----------------------------|------|------------------------|------|
|                  | Obs.      | Sim. | Obs.    | Sim. | Obs.                       | Sim. | Obs.                   | Sim. |
| Cabisera 10      | 3         | 4    | 57      | 52   | 66                         | 66   | 115                    | 106  |
| CVRC (Irrigated) | 5         | 6    | 66      | 68   | 74                         | 78   | 110                    | 111  |
| CVRC (Rainfed)   | 5         | 6    | 66      | 68   | 74                         | 78   | 110                    | 111  |
| Villa Imelda     | 3         | 4    | 58      | 58   | 69                         | 66   | 115                    | 109  |
| Sindon Bayabo    | 3         | 4    | 58      | 56   | 65                         | 69   | 114                    | 106  |

*Note: Obs. = Observed; Sim. = Simulated*

### Harvest Yield

Table 8 shows the actual and simulated grain yield from the five plots. Actual and simulated yield showed high goodness of fit with R<sup>2</sup>, RMSE and d-stat of 0.82, 1,118.40 kg/ha, and 0.89, respectively.

**Table 8.** Simulated and observed grain yield during the first and second cropping

| Site             | Planting Date | Observed | Simulated |
|------------------|---------------|----------|-----------|
| First Cropping   |               |          |           |
| CVRC (Irrigated) | January 7     | 5,687    | 6,096     |
| CVRC (Rainfed)   | January 7     | 2,431    | 1,915     |
| Cabisera10       | October 23    | 5,500    | 4,784     |
| Villa Imelda     | November 13   | 2,520    | 1,423     |
| Sindon Bayabo    | November 11   | 4,620    | 2,594     |
| Second Cropping  |               |          |           |
| CVRC (Irrigated) | June 12       | 8,800    | 9,163     |
| CVRC (Rainfed)   | June 12       | 8,213    | 8,777     |
| Cabisera10       | June 2        | 9,867    | 10,202    |
| Villa Imelda     | July 3        | 5,190    | 5,024     |
| Sindon Bayabo    | June 27       | 7,167    | 7,566     |

Cabisera 10 yielded the highest due to the right timing of rainfall. Also, CVRC irrigated plots yielded high due to the supplemental irrigation applied. Villa Imelda yielded very low due to waterlogging. The grain yield from the Sindon Bayabo site was a rough estimate given by the farmer. The actual yield during the first cropping considered the harvest reported by the farmer cooperators in Sindon Bayabo and Villa Imelda instead of the final harvest data gathered from the 3 m by 15 m due to inconsistencies brought about by the terrain in the area. The variability in the two sites was corrected in the second cropping through representative sampling at the top, middle and bottom of the slopes.

Similarly, the model predicted the second cropping season harvest yield very close from the actual yield with 3.20 to 6.87% difference. It showed better agreement between actual and simulated yield compared to the calibration experimental set ups. The validation experiment yielded a low RMSE of 387 kg/ha while it had high R2 and d-stat with both value of 0.99.

### Model Validation from Farmers' Field

Twenty-four farmers in the watershed participated in the validation of the model in the wet season period of 2015. Table 9 shows the profile of farms, date of planting, variety actual yield and simulated yield.

**Table 9.** Profile of farmer participants

| Name             | Agro Ecozone | Date of Planting | Variety                     | Yield    |           |
|------------------|--------------|------------------|-----------------------------|----------|-----------|
|                  |              |                  |                             | Observed | Simulated |
| Anthony Bernabe  | Flood-plain  | 12-May-15        | DEKALB 6819                 | 6,533    | 7,101     |
| Arman Bolda      | Hilly        | 08-May-15        | NK 8850                     | 5,560    | 5,411     |
| Arsenio Caeliong | Rolling      | 14-May-15        | NK 8840                     | 1,000    | 1,775     |
| Bong Pangalina   | Rolling      | 28-Apr-15        | NK 8840                     | 3,248    | 3,669     |
| Charlie Servilla | Flood-plain  | 09-May-15        | DEKALB 9132                 | 3,689    | 3,900     |
| Clarita Magudang | Flood-plain  | 15-May-15        | DEKALB 6819                 | 3,919    | 6,119     |
| Clemente Lorenzo | Flood-plain  | 13-May-15        | NK 8850                     | 5,795    | 5,517     |
| Elidior Morales  | Flood-plain  | 12-May-15        | DEKALB 9132                 | 4,000    | 4,511     |
| Franklin Cortez  | Flood-plain  | 18-May-15        | DEKALB 9132                 | 3,600    | 4,419     |
| Freddie Crispin  | Hilly        | 03-Jun-15        | DEKALB 9132, PIO-NEER 3774  | 2,800    | 3,096     |
| Isagani Bueno    | Flood-plain  | 23-May-15        | DEKALB 6919                 | 4,960    | 5,363     |
| Jessa Pascua     | Hilly        | 13-May-15        | PIONEER 3774                | 2,987    | 3,218     |
| Jessie Ramiscal  | Flood-plain  | 11-May-15        | NK 8840                     | 7,760    | 7,412     |
| Juan Bajo        | Hilly        | 26-May-15        | DEKALB 9132, PIO-NEER 30T80 | 4,800    | 4,975     |
| Lolita Quitola   | Flood-plain  | 12-May-15        | DEKALB 9132                 | 4,060    | 3,794     |
| Luz Dumalag      | Rolling      | 23-May-15        | DEKALB 9132                 | 2,005    | 2,725     |
| Maxvel Benzal    | Hilly        | 12-May-15        | PIONEER 9047                | 4,640    | 3,796     |
| Me-anne Gamiao   | Hilly        | 12-May-15        | Not Specified               | 3,093    | 3,213     |
| Myrna Lung Ayan  | Flood-plain  | 27-May-15        | NK 8840                     | 6,480    | 6,322     |
| Regie Turqueza   | Hilly        | 28-May-15        | NK 8840                     | 2,700    | 2,817     |

**Table 9.** Continued...

|                 |             |           |                               |       |       |
|-----------------|-------------|-----------|-------------------------------|-------|-------|
| Relina Torres   | Rolling     | 23-May-15 | DEKALB 9132, NK 8850, NK 8840 | 1,456 | 3,857 |
| Vilma Paredes   | Rolling     | 13-May-15 | DEKALB 9132                   | 1,880 | 1,685 |
| Violeta Briones | Flood-plain | 14-May-15 | DEKALB 9132                   | 4,410 | 4,978 |

Seven farmers planted DEKALB 9132 and seventeen farmers planted other hybrid varieties. Simulated and actual yield showed high goodness of fit for DEKALB 9132 farmers actual and simulated yield with high R2 of 0.86, low RMSE of 524 kg/ha and high d-stat value 0.87 (Figure 4).

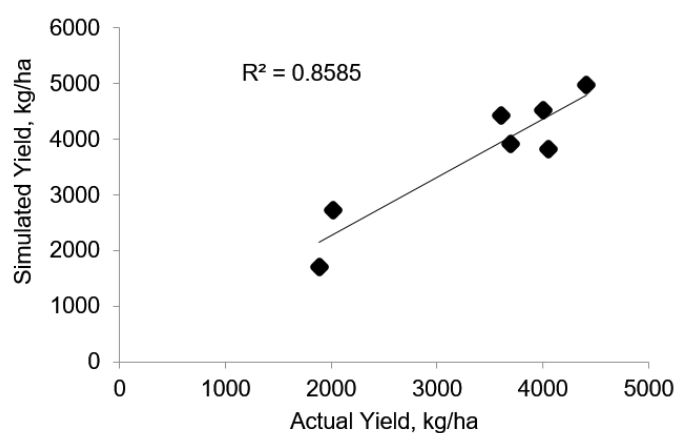


**Figure 4.** Simulated vs actual yield of the participants who planted DEKALB 9132 in Abuan

Moreover, outputs showed the possibility of the model to be used for other hybrid varieties. Actual farmers yield for other hybrid varieties had high R2 of 0.81, low RMSE of 875 kg/ha and high d-stat of 0.93 (Figure 5).

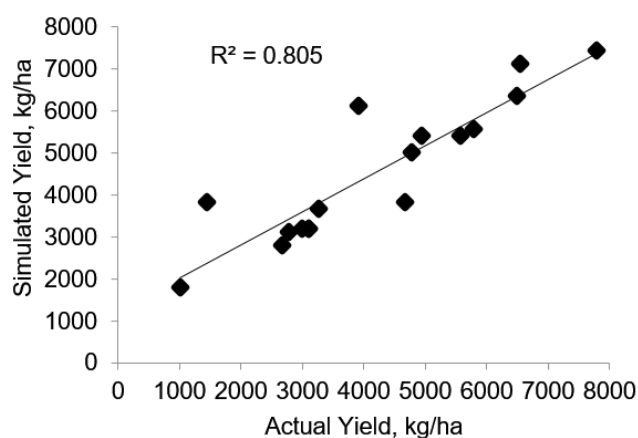


**Figure 4.** Simulated vs actual yield of the participants who planted other hybrid varieties in Abuan

## Impact of Climate Change

Assumed planting date is January 1 which is a dry season. Yield reduction is highest during this season. Recommended fertilizer application rate and a CO<sub>2</sub> emission level of 380 volumes per million (vpm) were used in the crop simulations. Results showed that corn yield would sharply reduce by 44% in 2020 and by 35% in 2050 (Figure 6).

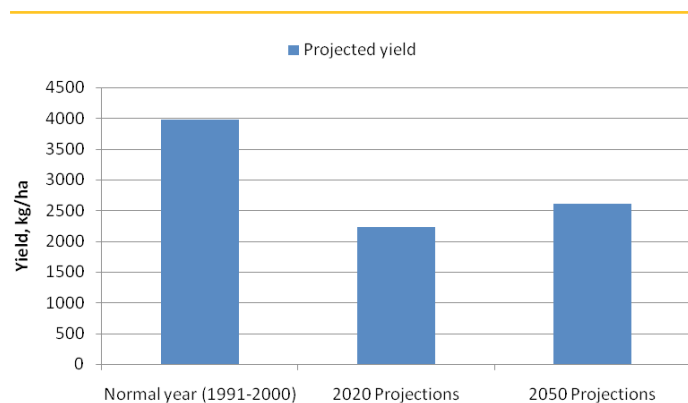


**Figure 6.** Yield projections for the year 2020 and 2050

These predictions are helpful in formulating strategies to alleviate the effects of extreme drought brought about by climate change. Introduction of drought-resistant corn varieties; provision of irrigation projects; selection of the best date to plant, best date and amount of irrigation, best date and amount of fertilizer application; and crop diversification are among the intervention options to build resilience in corn farms. Moreover, the localized DSSAT-CERES Maize Model can be used to create farmers' decision support system which is a platform for crop forecasting

The policy management is one very useful application of crop simulation models. The issues range from global (impacts of climate change on crops) to field level (effect of crop rotation on soil quality) issues. Thornton et al. (1997) showed that in Burkina Faso, crop simulation modeling using satellite and ground-based data could be used to estimate millet production for famine early warning which can allow policy makers the time they need to take appropriate steps to ameliorate the effects of global food shortages on vulnerable urban and rural populations.

## Conclusion

This study was conducted to estimate the genetic coefficient of hybrid corn cultivar in 2013-2015 using Ceres-Maize Model of DSSAT software. Calibration was done to estimate the six genetic coefficients for corn with input data taken from the dry season cropping. The estimated genetic coefficients are the following: (1) thermal time from seedling emergence to end of the juvenile phase is 287 degree days; (2) 1.315 days of which development is delayed for each hour increase in photoperiod; (3) 986.7 degree days from silking to physiological maturity; (4) maximum possible number of kernels per plant is 528.9; (5) kernel filling rate during the linear grain filling stage and under optimum conditions is 16.43 mg/day; and (6) Phylchron

interval—the interval in thermal time between successive leaf tip appearances—is 45 degree days. Calibration of these coefficients was successful as manifested by close agreement between actual and simulated biomass, yield and occurrence of phenological events.

Using the genetic coefficient estimated from the data observed during the first cropping, validation was conducted using the data set observed from the same five plots during the second cropping. Results showed that these genetic coefficients accurately predicted the actual corn yield, biomass production and phenological stages. Yield data was also gathered from 22 farmers for further validation. The model yields high efficiency of 0.81 in predicting the yield of participating farmers in the watershed. The model also showed possibility of simulating corn production for other hybrid varieties.

Application of the Maize Model was also used to assess the impact of climate change in corn production. Results indicated that corn yield would be reduced by up to 44% in 2020 and 35% in 2050 due to changes in rainfall amount and rise in temperature.

The model can be used as primary input in developing farmers decision support system in response to the need for more effective extension program of the Department of Agriculture and local government units.

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