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ASSESSMENT OF POTENTIAL YIELD AND CLIMATE CHANGE SENSITIVITY OF SELECTED DRYLAND CROPS IN CAGAYAN VALLEY, PHILIPPINES USING SIMULATION MODELS

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ABSTRACT

Corn and peanut are major upland crops in Cagayan Valley. Emerging food and biofuel crops like sweet sorghum requires less water were recently introduced to increase the productivity in the rainfed ecosystem. However, little information is available on the potential productivity of these upland crops and analysis on the production constraints including climate change sensitivity. This study aimed to determine potential yield, yield gap, production constraints and climate change sensitivity of peanut, sweet sorghum and corn crops in Cagayan Valley through the use of Decision Support System for Agrotechnology Transfer (DSSAT) simulation modeling. Simulation results using DSSAT model showed highest potential yield of peanut, corn and sweet sorghum is 2267 kg/ha when planted in October 15, 7,734 kg/ha when planted in June 15, and 6,570 kg/ha when planted in February 1 respectively, under rainfed condition. Under non-stressed conditions, the highest obtainable yield is 4805 kg/ha when planted in December 15; peanut is 7,953 kg/ha planted in May 1 for corn and 7,380 kg/ha planted in February 1 forsweet sorghum. Large yield gaps exist between actual farmers yield and potential yield. Overall, the average yield gap is 1000 kg/ha for peanut; 2,460 kg/ha for maize; and 1700 kg/ha for sweet sorghum, indicating the potential for future yield improvements. Low rates of nitrogen application, pests and diseases were the main factors causing yield gaps of these crops. Climate variability is another factor as DSSAT was able to capture the effect of drought periods, which resulted to underestimated yield result. The study demonstrated the potential of using dynamic crop simulation model in assisting with strategic decision-making for crop production and land use planning. It indicated the possibility of using DSSAT model as an information technology tool to increase yield of dryland crops for the agricultural production areas.

Keywords: simulation modeling, decision support system, climate change

1 INTRODUCTION

Corn and peanut are the major upland crops in Cagayan Valley. Recently, emerging food and biofuel crops like sweet sorghum that requires less water were recently introduced to increase productivity in the rainfed ecosystem. Peanut is a priority crop under the High Value Crop Development Program of DA-Bureau of Agricultural Research and a banner R&D program of the Cagayan Valley Agriculture Resources Research and Development Consortium. It is considered a major upland crop in the region and an important leguminous crop that requires less water to increase productivity in the upland and rainfed ecosystem. Corn is an important crop in the Cagayan Valley. The region ranked first in corn production for many years. Corn productivity over the last 5 years is said to be low at an average of

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1.98 tons per hectare. There are almost a million corn farmers in the country. Many of them are mostly smallholders and marginal and dependent totally on rainfall.Sweet sorghum crop is a banner R&D program of the Isabela State University (ISU) for Cagayan Valley. A very significant breakthrough is ISU's forging of partnership agreement with Green Future Innovations, Inc. (GFII) on R&D in August 4, 2010 on the commercial use of sweet sorghum as feedstock for biofuel production in Isabela. GFII is a multinational firm who owned and operates a large-scale bioethanol and cogeneration plant located in San Mariano, Isabela.

Little information is available on the potential productivity of the crop and analysis on the production constraints including climate change sensitivity. Quantifying yield and identifying yield gaps for various growing conditions could provide valuable information for designing strategic crop management plans to increase productivity in the upland and rainfed areas. However, this process is time consuming and expensive, as it may involve many years of experimental data collection. Dynamic crop simulation models provide an alternative option to determine yield for a range of growing conditions and crop management scenarios. User-oriented simulation models greatly facilitate the task of optimizing crop growth, deriving recommendations concerning crop management and it can also be used to determine the potential impact of climate change on crop production, long-term soil carbon sequestration, or provide management scenarios for adapting to climate variability since simulation models are designed to mimic the natural process of crop growth in response to the different environmental conditions.

2 OBJECTIVES

Overall goal of the study is to quantify yield potential and sensitivity to climate change environment of peanut, sweet sorghum and corn crops in Cagayan Valley using simulation models to generate strategic information in improving productivity and in developing adaptation strategies and approaches for upland, water-scarce and rainfed ecosystems in Cagayan valley in particular and the country in general.

Specific objectives are as follows:

1. Determine yield potential and production constraints through the use of simulation modeling of groundnut, maize and sweet sorghum;
2. Analyze yield gaps between simulated and actual yield level of the above crops;
3. Evaluate the sensitivity of peanut, maize and sorghum crop under various climate change scenarios;
4. Develop regional yield productivity map of these crops.

3 REVIEW OF LITERATURE

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. Emerging issues on climate change and dryland agriculture has been at the center of discussions and interests among top policy makers as manifested by the recently concluded conference National Dryland Conference and the eventual creation of the Philippine Dryland Institute (PhilDri). A result of GIS analysis showed that 43% or 13 million hectares of the country will be under dryland environment as a consequence of climate change (Obien 2008). Isabela and Cagayan provinces are on the top of the list registering

432,916 and 319,102 hectares respectively.

4 RESEARCH FRAMEWORK

4.1 Potential Yield

Potential yield is the yield of a given crop planted at the optimal level of climatological elements and physiological characteristics of the crop. Estimation of the potential yield is accomplished with the use of Decision Support System for Agro-Technology Transfer (DSSAT).

4.2 On-Station Yield (Attainable)

On-station yields refers to the yield which will be obtained from the experimental stations of an improved cultivar under good care and supervision wherein factors other than water availability and nutrient are not limiting crop growth and development. Primary yield data refers to the newly acquired yield through the establishment of a series of experiments under the different area of concern while secondary yield data is the long-term available yield data from the different experimental stations representative of the Cagayan Valley Region.

4.3 Farmer's Yield (Actual)

This is the yield obtained from farmers' field wherein they adopted all the elements of improved/updated production technology for a particular crop. On-farm yield will be obtained directly from the farmers' field through sets of experimentation. Secondary data will also be considered and be obtained from the LGU's of each selected/and or representative provinces of the Cagayan Valley Region. Yield reducing factors or yield constraints will be determined by comparing the potential, experimental and actual/on-farm yields.

4.4 Predicting yield under various management and climate scenarios

The modeling tool will provide analysis on the effect of climate changes, cultural management practices and introduction of improved germplasm.

5 METHODOLOGY

The following general methodology was followed in the project implementation.

5.1 Site Selection and setting up of field experiment

As a representation of the Cagayan valley region, site of experiment is located on-station at Isabela State University, Echague, Isabela and Qurino State University at Diffun, Quirino. The soil is typical clay and peanut, corn and sorghum production is widely adapted in nearby communities and municipalities. Soil properties were collected prior to planting and included bulk density, soil texture, soil moisture, organic matter and pH. To observe phenological events and gather biomass data, a 500 square meter plot for each site was prepared, subdivided into four sub-plots as replication. Phenological events such as flowering, pegging and podding were recorded in reference to date of planting. Biomass data were gathered every 10 days after emergence until harvest by random from the sampling area, oven dried for 48 hours and weighed. A harvest area of 1 meter by 1 meter was delineated in the middle of each plot. Plant development data that were measured included the dates on which 50% of the plants in a plot reached the critical developmental stages: plant with first flower, plant with a pod 2.0 cm long and when seed growth begins in at least one pod and plant with one pod yellowing. Dates of these stages were obtained by daily observations of all plants in the plot.Crop care and maintenance followed the recommended cultural management practice.Crop management details included planting date, row and plant spacing, plant density, dates and rates of fertilizer, irrigation, herbicide and pesticide applications.

5.2 Setting up of weather monitoring station

Real time data is required for the modeling experiment hence, the necessity of installing a weather station on-site. Rainfall and other climatic variables were monitored using a HOBO® weather station (Automatic Weather Station) which is strategically installed inside experimental zone. This kit is composed of a rain gauge, air temperature, relative humidity, soil moisture, and wind speed and direction sensors all connected to an automatic data-logger and set-up in a tripod. The meteorological information is useful in the studies of the interactions between climate and key physical and biological processes. Meteorological observation will be useful in the study of the influence of climate change and variability on crop yields and gap. Daily weather data, i.e., minimum and maximum temperatures, rainfall and solar radiation, were obtained from the weather station.Under collaborative projects with DA-Bureau of Agricultural Research, PhilRice and Green Future Innovations, Inc., eight weather stations were installed by Isabela State University in 2010-2011 at strategic locations in Cagayan Valley to monitor spatial variability of weather systems in the region.

5.3 Overall description of theDecision Support System for Agrotechnology Transfer (DSSAT) cropping system model

DSSAT is a software package integrating the effects of soil, crop phenotype, weather and management options that 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, it 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.

5.4 Model Calibration

Inputs required to run the CSM model include information on soil and weather conditions, crop management practices and cultivar specific genetic coefficients. The information for cultivar specific genetic coefficients is normally not readily available for certain local cultivars. In the first step, therefore, a model calibration was conducted to determine the cultivar coefficients for certain peanut, corn and sweet sorghum cultivars that are normally grown in Cagayan Valley. Crop growth and yield simulation modeling was undertaken using the DSSAT for small seeded peanut (Pn9), maize (Pioneer 30T80), and sweet sorghum (SPV-422). The said varieties are considered best adaptable in the region and popularly used by farmers in the dry season.The research adapted the standard procedure of model validation and calibration. Genetic coefficient is cultivar specific and therefore often not available for local varieties. In this case, DSSAT has a utility program called GLUE whichwas used to estimate genotype-specific coefficients for the DSSAT crop models. It is a Bayesian estimation method that uses Monte Carlo sampling from prior distributions of the coefficients and a Gaussian likelihood function to determine the best coefficients based on the data that are used in the estimation process. The GLUE program allows users to select a crop, then a cultivar to be estimated. It will then identify all experiments and treatments in the DSSAT data files for the crop that have measurements for that cultivar. The user then can select one or more experiments and treatments that will actually be used in the coefficient estimation process. To do this, data from actual experiments in terms of biomass and yield should be inputted.

5.5 Model Validation

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 root mean square error (RMSE) as well as the index of agreement (*d* value). Values of RMSE and *d* indicate the degree of agreement between the predicted values with their corresponding observed values and a low RMSE value and a *d* value approaching unity are desirable.

5.6 Yield Gap Analysis

Yield gap analysis at a given site have three components of yield; the potential (simulated), achievable (experimental) and actual farmer's data (i.e. reports by Dept. of Agriculture and BAS) and based on actual experimentation for each representative areas of concern. The analysis will provide information on production constraints due to physical and technology limitations.

5.7 Analysis of production performance under various climate change scenario in the region

Analysis of production performances under various climate change scenarios and cultural management practices i.e. reduction of rainfall in rainfed areas, changing of planting dates, adaption of short duration crops, applications of water-saving technologies and provision of supplemental irrigation. A regional spatial analysis was undertaken to show the potential yields of the three dryland crops under wet and dry season.

6 RESULTS AND DISCUSSION

6.1 Climate and Weather in Cagayan Valley

Climate in Cagayan Valley consists of two tropical monsoons, i.e., the Southwest Monsoon and the Northeast Monsoon. The valley falls under Type III and Type IV of the Corona's Climate Classification System. These climate types (expressed mainly in terms of rainfall distribution) are characterized by not very pronounced seasons with relatively dry weather from November to April while the rest of the year is noted as wet season. Monthly mean air temperature ranges from 23.1°C in January to 29.0°C in May. The hottest month is May or June, while the coldest month is January. Solar radiation ranges between 9 MJ/m2/day in December to a high of 24 MJ/m2/day.

6.2 Location of Automatic Weather Stations

Through this project, eight automatic weather stations were installed in various locations in the Cagayan River basin to serve as network of weather stations to monitor variabilities of weather pattern such as rainfall distribution on a temporal and spatial scale.Rainfall distribution on a one-year period showed a clear distinction of rainfall differences such that areas close to the Sierra Madre in the eastern side and northern town of Cagayan are relatively wetter than other areas. Dryer places in the region are Qurino and Ifugao.

6.3 Crop Simulation Modeling

6.3.1 CSM-CROPGRO PEANUT MODEL

Model calibration and evaluation

For the peanut study, PN9, a small seeded peanut variety was selected being a popular variety widely used by farmers in the region. To determine the genetic coefficient of PN9 peanut cultivar, data set collected from the experimental set up was used as inputs in the standard format of DSSAT Version 4.5. Genetic coefficients of the peanut cultivar were determined by iteration of model simulation against the experimental data, following the procedures described by Hoogenboom et. al. (1999). PN9 coefficients are presented in Table 1.

Table 1: Cultivar coefficients of PN9 peanut variety

Definition		Variable	Unit	Value
1	Critical Short Day Length below which reproductive development progresses with no daylength effect (for shortday plants)	CSDL	hour	11.84
2	Slope of the relative response of development to photoperiod with time (positive for shortday plants)	PPSEN	1/hour	0
3	Time between plant emergence and flower appearance (R1)	EM-FL	photothermal days	21
4	Time between first flower and first pod (R3)	FL-SH	photothermal days	8
5	Time between first flower and first seed (R5)	FL-SD	photothermal days	20.3
6	Time between first seed (R5) and physiological maturity (R7)	SD-PM	photothermal days	73
7	Time between first flower (R1) and end of leaf expansion	FL-LF	photothermal days	88
8	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO2, and high light	LFMAX	mg CO2/m2-s	1.36
9	Specific leaf area of cultivar under standard growth conditions	SLAVR	cm2/g	270
10	Maximum size of full leaf (three leaflets)	SIZLF	cm2	18
11	Maximum fraction of daily growth that is partitioned to seed + shell	XFRT		0.94
12	Maximum weight per seed	WTPSD	g	1
13	Seed filling duration for pod cohort at standard growth conditions	SFDUR	photothermal days	38
14	Average seed per pod under standard growing conditions	SDPDV	#/pod	1.65
15	Time required for cultivar to reach final pod load under optimal conditions	PODUR	photothermal days	30
16	The maximum ratio of (seed/(seed+shell)) at maturity. Causes seed to stop growing as their dry weights increase until shells are filled in a cohort	THRSH	Threshing percentage	80
17	Fraction protein in seeds (g(protein)/g(seed))	SDPRO	g(protein)/g(seed)	0.27
18	Fraction oil in seeds	SDLIP	g(oil)/g(seed)	0.51

For model evaluation, recommended cultural management for peanut was adapted were used including plant growth and development, soil surface and profile characteristics, local weather conditions and crop management. The model was evaluated in the estimation of potential yield of the crop under rainfed condition and low-nitrogen application.To assess the accuracy of the cultivar coefficients derived from model calibration, simulated values for Pn9 cultivar at February 10 in Echague site and January 25, 2013 in Quirino site planting dates was compared with the corresponding observed values. A close agreement between observed and simulated values was obtained in the cropping periods. The simulated and observed values for dry weights of total biomass and pod biomass were in good agreementat the different growth stages. Based on the computed values for RMSE and *d*, it was also assessed that the model predicted dry weights for total biomass at different growth stages. RMSE and *d* values for crop biomass at the given planting date is 493.2 kg per hectare and 0.996 respectively. The difference between simulated and observed values for dry weight of crop biomass is 1.18%. For the final harvest weight, simulated and actual were in close agreement at 1142 kg/hectare and 1084 kg/hectare respectively.

Yield Gap Analysis

Time series simulations were conducted to determine the reduction in peanut yield due to nitrogen limitation and poor crop management conditions prevalent at field level. Simulation was conducted using 10 years of yield data for peanut under rainfed condition. Simulated result of yield was compared with data published by the Bureau of Agricultural Statistics (BAS) in 2011 for peanut production. As expected, with the exception of 2005 and 2009, simulated results are significantly higher than the average yield data. The years 2005 and 2009 yielded lower potential production than actual. On further analysis, 2005 was recorded by NASA as the warmest year of century. The unusual event resulted to 50% decline in potential productivity. The year 2009 is one of the most intense El Nino event recorded which started in the last quarter of 2009 up to the middle of 2010. Comparison of actual rainfall data during the El Nino event compared to long-term average further showed a substantial reduction of rain recorded from December 2009 to April 2010. Yield gap between farmer's yield to that of rainfed potential ranges from 153 kg per hectare to 2116 kg per hectare with an average of about 1 ton per hectare for peanut. Given the use of right technology and improving farmer's practice, productivity of peanut in rainfed areas of Cagayan Valley can obtain 2.5 tons per hectare for peanut.

Simulation of Planting Date and Irrigation Applications

Yield potential for peanut limited only by temperature and solar radiation and no-water and nutrient stress, ranged from 3274 to 4805 kg per hectare for the six planting dates. The highest yield potential was found for the December 15 planting date due to moderate temperature and a moderate level of radiation. Compared to rainfed farming, yield reduction of peanut caused by water limitation ranges from 10% to 1041% of potential yield.

Simulating Regional Peanut Yield in Cagayan Valley

The DSSAT is equipped with an extra feature providing linkage between the CSM-CROPGRO-Peanut model and the GIS ArcView which was used for spatial yield analysis of peanut production areas in the Cagayan River basin. Inputs required for the spatial application of the model include local soil and weather conditions, cultivar specific coefficients and crop management regimes.Climatic data were obtained from PAGASA and Automatic Weather Stations. Scenarios for crop management were defined as; rain-fed conditions were used for two planting dates on wet and dry season, June 1 and November 1, respectively; Fertilizer applications is low nitrogen at 11 kg/ha and soil is typical clay. Regional analysis of peanut yield, presented in *Figure 1* showed that central eastern part is a more productive area for rain-fed conditions during dry season, whereas southern part including Quirino and Ifugao is more suitable to produce peanut during the wet season due to cooler temperature.

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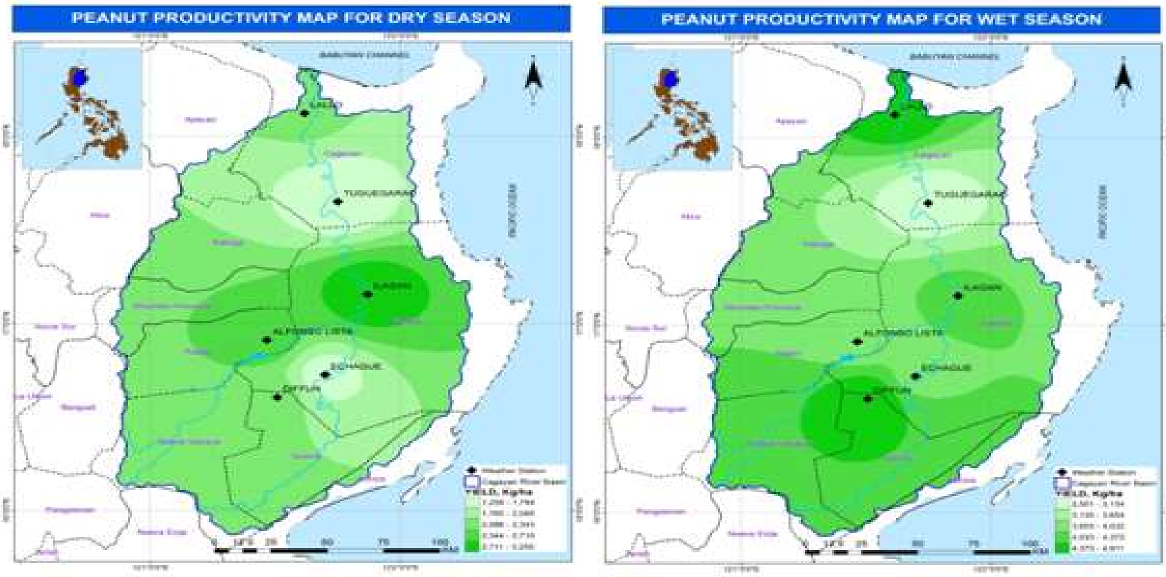

Figure 1: Spatial variation of average peanut yield (kg ha-1) for cultivar Pn9 for two planting season

6.3.2 CSM-CERES SORGHUM MODEL

Calibration and evaluation of CSM-CROPGRO-Sorghum model

Using the input data taken from the experimental set up in QSC, Diffun, Quirino site planted on January 25, 2012, calibration was made by running the Generalized Likelihood Uncertainty Estimation (GLUE), a program integrated in the DSSAT Version 4.5. The SPV-422 sorghum cultivar resulted from this calibration process is presented in Table 2.

The sorghum model was further evaluated to assess the accuracy of the SPV-422 cultivar coefficients calibration. It was found out that the degree of agreement indicated from RMSE is 973 kg/ha and the d value is 0.96 which means that the model can be used to simulate "what if" scenarios for sorghum crop management. There is 1.76% difference between observed and simulated yield. The observed value, 3,157 kg per hectare, was underestimated by the simulated yield with 3,270 kg per hectare.

Yield gap analysis

The average yield gap for sweet sorghum during dry season is 2.4 tons per hectare and 0.78 tons per hectare during wet season with the overall average yield gap of 1.7 tons per hectare. It can also be observed that during the occurrence of natural phenomenon such as La Niña and El Niño, the actual yield underestimates the simulated yield. This is due to the capability of the DSSAT program to simulate and capture the effect of these phenomena.

Simulation of Planting Date and Irrigation Applications

On the average, the rainfall during the simulation period of potential sweet sorghum yield during dry season under irrigated condition contributes 47% of water used during the growing seasons and supplied with supplemental irrigation. This amount of rainfall accounts for 47% higher yield in irrigated condition compared to that of rainfed. The potential yields between the two water management schemes during wet season does not differ which means that rainfall is sufficient to provide the water requirements of the crop.

Yield potential for sweet sorghum under rainfed condition limited by water ranged from 987 to 3,765 kg per hectare during dry season and 2,905 to 4,747 kg per hectare on wet season. Under irrigated condition, it ranges from 3,255 to 5,797 kg per hectare during dry season and 4,724 to 3,156 kg per hectare during wet season. The highest yield potential was found for the February 1 planting date in irrigated condition.

Table 2. Cultivar coefficients of SPV-422 Sweet sorghum

Definition		Variable	Unit	Values
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	345
2	Thermal time from the end of the juvenile stage to tassel initiation under short days	P2	degree days above TBASE	102
3	Critical photoperiod or the longest day length at which development occurs at a maximum rate. At values higher than P2O, the rate of development is reduced	P2O	Hours	13.5
4	Extent to which phasic development leading to panicle initiation is delayed for each hour increase in photoperiod above P2O	P2R	degree days	20
5	Thermal time from the end of tassel initiation to anthesis	PANTH	degree days above TBASE	617.5
6	Thermal time from to end of flag leaf expansion to anthesis	P3	degree days above TBASE	152.5
7	Thermal time from anthesis to beginning grain filling	P4	degree days above TBASE	81.5
8	Thermal time from beginning of grain filling to physiological maturity	P5	degree days above TBASE	640
9	Phylochron interval; the interval in thermal time between successive leaf tip appearances	PHINT	degree days	49
10	Scaler for relative leaf size	G1		3
11	Scaler for partitioning of assimilates to the panicle (head)	G2		5.5

Productivity Map of SPV 422 in Cagayan Valley Region

Weather data covering 2011 to 2012 were used in the model simulation under clay soil and rainfed condition, optimal cultural management and 120 kg/ha of nitrogen fertilizer. Figure 2 shows the potential productivity of SPV 422 variety during wet and dry season. Wet season planting indicated higher productivity in the southern part of the province with values 5718, 5024 and 4049 kg/ha for Echague, San Mariano and Cabagan respectively. Computed values are realistic since results of study made by Demafeliz (2012) shows that seed yield average is up to 4 tons/hectare.

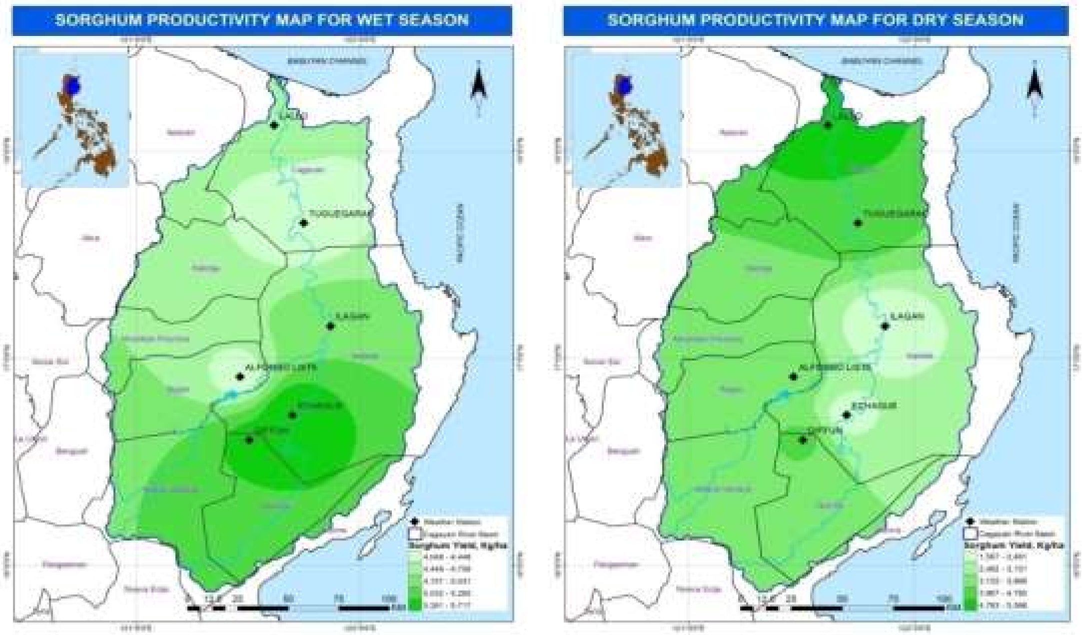

Figure 2: Productivity maps of SPV 422 sweet sorghum for dry and wet season

6.3.3 CSM-CERES MAIZE MODEL

Calibration and Evaluation of Pioneer 30T80

Most of the data used in the calibration, evaluation and simulation of CERES-Maize model was taken from the Calibration of Fertilizer Recommendation for N, P, K. Using Yield Response to Corn, a project implemented by the Department of Agriculture (DA) Region 2. Seed variety used was Pioneer 30T80, which is commonly adapted in the Cagayan Valley. Genetic coefficient of Pioneer 30T80 required by the model were derived from yield data in the calibration of fertilizer recommendation project of the DA at Echague, Isabela during the 2011 wet season, weather data from the ISU-DOST-PAGASA Agromet Station and the local soil and crop management data. Genetic coefficients are shown in Table V. Result of the calibration shows 4% difference between the observed and simulated maize yield, which are 8,135 kg per hectare, and 8,809 kg per hectare respectively.

Table 3: Cultivar coefficients of Pioneer 30T80 Maize

Definition		Variable	Unit	Values
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	140
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	1.200
3	Thermal time from silking to physiological maturity	P5	expressed in degree days above a base temperature of 8øC	670
4	Maximum possible number of kernels per plant	G2		470
5	Kernel filling rate during the linear grain filling stage and under optimum conditions	G3	mg/day	13.4
6	Phylochron interval; the interval in thermal time between successive leaf tip appearances	PHINT	degree days	38.90

<u>Yield Gap Analysis</u>

Time series simulation was conducted in four consecutive cropping seasons in 2010-2011 at Echague, Isabela. There was 6.5% rainfall reduction during the 2010 wet season where 24% or 3.8 tons per hectare yield difference was accounted. On another occasion, the dry season of 2010 have 26% or 1.7 tons per hectare yield difference with 26% rainfall reduction. Timing of rainfall affected the production performance of maize as can be observed during 2010 cropping seasons. Given the right timing of planting, the yield of maize may obtain up to 9 tons per hectare for Pioneer 30T80 under rainfed condition. The higher value of observed against simulated during the 2010 wet season may be attributed to supplemental irrigation used.

<u>Simulation of Planting Date and Irrigation Applications for Maize</u>

Usual planting dates of maize in the Cagayan Valley are October to December during dry season and May to July during wet season. These months were used in the simulation of maize yield to determine the date that will give the highest rainfed potential yield. Rainfed condition, 140 kg/ha nitrogen, clay loam soil, the weather data covering dry season of 2011 and wet season of 2012 and the genetic coefficient and crop management for pioneer 30T80 were inputted in the maize model to simulate maize rainfed potential yield. There was no pronounced difference in yield between the rainfed and irrigated condition except for the December 15 planting date in dry season. This is due to the simulation management option of automatic irrigation when needed under irrigated management. Rainfall under irrigated management was enough for maize production and the supplemental irrigation used did not significantly contribute in terms of increase in production. The yield potential for pioneer 30T80 cultivar of maize ranged from 4,818 to 6,532 kg per hectare during dry season and 4,674 to 7,953 kg per hectare during wet season. November 15 and June 15 planting dates for dry and wet season respectively give the highest maize potential yield. In terms of crop water productivity, the December 15 for dry season and May 1 for wet season planting dates used rainfall efficiently for production for both rainfed and irrigated condition.

<u>Regional Productivity Analysis of Maize Production</u>

Figure 3 shows the simulated regional yield map of pioneer 30T80 cultivar of maize. Weather data from seven stations for 2011 to 2012, clay loam soil, cultivar coefficients and maize crop management for pioneer 30T80 were used to simulate the spatial maize yield in Cagayan Valley under rainfed condition. It can be observed that Cagayan valley’s northern and central eastern partsare more productive during dry season while central and western parts are more productive during wet season (Figure 3).

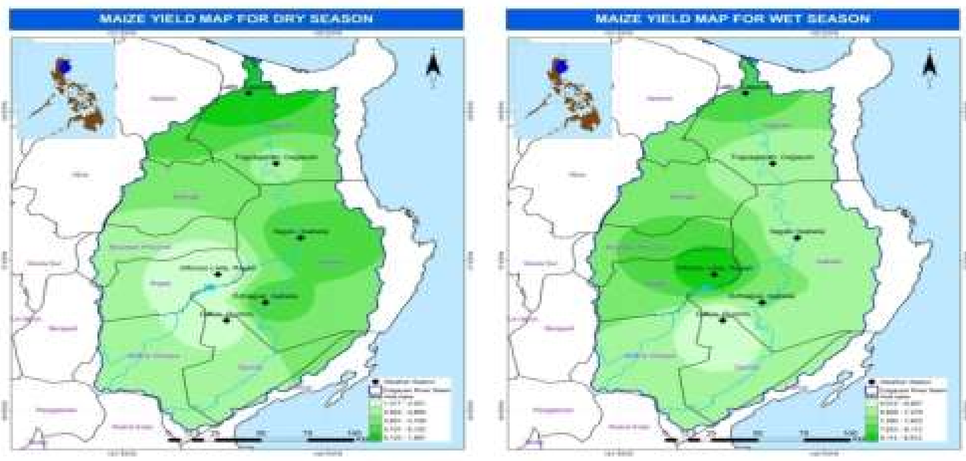

Figure 3. Regional maize yield of pioneer 30T80 cultivar in Cagayan Valley in kg per hectare.

7 SUMMARY, CONCLUSION AND RECOMMENDATION

This research clearly demonstrated the potential of using crop simulation model to support strategic decision-making to ensure climate-smart crop production system and sustainable land use planning. It also indicated the usefulness of using crop simulation model as an information technology tool to increase yield of peanut and other upland crops for the other agricultural production areas in the Philippines.Further study is needed to evaluate potentials of new germplasm releases as well as on crop rotation and intercropping simulations.

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