Evaluation of the CropSyst Model on Soybean (*Glycine max* L.) in the Tropics

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Abstract— *South Sulawesi is one of the soybean producer provinces in Indonesia. As in other tropical areas, South Sulawesi season comprises is dry and rainy seasons, so modeling of crops such as CropSyst can be very helpful in predicting planting time, providing irrigation, and applying the right fertilizer to get maximum soybean productivity. To apply the CropSyst model in the tropics such as South Sulawesi, calibration and validation of several plant parameters are required. Further calibration and validation results need to be tested to see the accuracy of predicting models. The results of soybean evaluation in South Sulawesi showed that RMSE (0.09 and 0.11), MBE (-0.01 and 0.11), MAE (0.08 and 0.11), and d (0.92 and 0.81) had values showing that CropSyst model accurately to predict grain yield of soybean in South Sulawesi.*

Keywords— ***soybean, CropSyst, calibration, validation, evaluation.***

I. INTRODUCTION

CropSyst is a friendly crop simulation model used. The CropSyst model is used to look at the effects of climate, soil, and crop management systems on productivity and the environment. CropSyst simulates soil, nitrogen, plant growth and development, crop yields, residual production, soil erosion by water, and salinity [1]. The current developments that are heavily caused by the development of climate change will be a challenge for crop modeling to update the model [2]. Several studies have been done to see the level of accuracy of CropSyst model. Some of these studies suggest that CropSysts can predict convincingly the results of barley and irrigated rescue on plant yields [3], CropSyst models can be used as a means to regulate irrigation water to improve productivity with poor water quality [4], CropSyst model simulation with predictive climate can summarize the predicted outcomes going forward [5], calibration and validation of the CropSyst model for rice can precisely determine irrigation and proper fertilization [6], and evaluation of the CropSyst model on yields for cluster bean in India also shows the proximity between simulation and observation data [7].

South Sulawesi is a province in Indonesia, at $0^0$12' North Latitude - 8^0 South Latitude and $116^0$48' - $122^0$36' East Longitude. South Sulawesi which has an area of 46,083.94 km^2 divided into 21 districts and 3 cities. South Sulawesi is one of the soybean producer provinces in Indonesia, with an average productivity of 1.5 t ha^{-1} grain yield [8].

II. MATERIAL AND METHOD

The research was conducted at Jenetaesa Village, Simbang Sub-district, Maros District which is one of soybean producer in South Sulawesi, Indonesia. This study used 2 varieties of soybeans that were Anjasmoro (90 days), and Argomulyo (80 days). The experiment was made by making a plot of 2 x 3 m with 3 replications. Fertilization is done with Ponska fertilizer (N 15%, P 15%, K 15%) dose 250 kg ha^{-1} with irrigation 50 mm with interval every 10 days as much 8 times for Anjasmoro variety and 7 times for Argomulyo varieties. Other studies were conducted at Sawakong (Takalar District), Attangsalo (Soppeng District), and liliriawang (Bone District) in the form of data collection of soybean productivity. Soil attributes at the research sites are presented in Table 1, while monthly rainfall data during 2016 is presented in Table 2.

TABLE 1
SOIL ATTRIBUTES AT FOUR RESEARCH LOCATIONS

Districts	Sand	Clay	Silt	Bulk Density	Cation Exchange	pH
Jenetaesa (Maros)	24	41	35	1.270	21.28	6.80
Sawakong (Takalar)	29	17	54	1.410	17.50	6.67
Attangsalo (Soppeng)	27	40	33	1.280	33.92	7.11
Liliriawang (Bone)	42	5	53	1.610	25.68	7.8

TABLE 2
MONTHLY RAINFALL IN THE YEAR 2016 AT FOUR RESEARCH LOCATIONS

Districts	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jenetaesa (Maros)	729	606	420	251	164	167	93	0	91	231	310	417
Sawakong (Takalar)	158	507	238	31	19	23	11	0	15	9	131	514
Attangsalo (Soppeng)	158	108	83	201	90	133	196	1	219	288	120	67
Liliriawang (Bone)	118	182	191	313	191	216	191	2	159	244	172	33

Treatment of irrigation is done every 10 days since sowing date with the amount of 50 mm for each time of administration. The irrigation interval along with the timetable and the amount of irrigation are presented in Table 3.

TABLE 3
MANAGEMENT IRRIGATION DURING RESEARCH

Management	Anjasmoro		Argomulyo	
	Description	Quantity	Description	Quantity
Sowing date	7 August 2016		7 August 2016	
Line spacing (cm)	20 x 40		20 x 40 cm	
1st irrigation date	7 August 2016		7 August 2016	
Irrigation (mm)		50		50
2nd irrigation date	17 August 2016			
Irrigation (mm)		50		50
3rd irrigation date	27 August 2016			
Irrigation (mm)		50		50
4th irrigation date	6 September 2016			
Irrigation (mm)		50		50
5th irrigation date	16 September 2016			
Irrigation (mm)		50		50
6th irrigation date	26 September 2016			
Irrigation (mm)		50		50
7th irrigation date	6 October 2016			
Irrigation (mm)		50		50
8th irrigation date	16 October 2016			
Irrigation (mm)		50		
Harvest date	4 November 2016		25 October 2016	
Total irrigation (mm)		400		350

For Calibration, data are used in research area at Maros District, while validation is done in 3 other locations, at Takalar, Soppeng , and Bone District with the same management. As for the evaluation of cropsyst model to see the relationship between the simulation with observation by statistically calculating Root Mean Square Error (RMSE), Mean Bias Error (MBE), Mean Absolute Error (MAE), and Index of Agreement (*d*) [9], [10], [11].

$$\text{RMSE} = \sqrt{\frac{1}{n}\Sigma(S-O)^2} \quad (1)$$

$$\text{MBE} = \frac{1}{n}\Sigma(S-O) \quad (2)$$

$$\text{MAE} = \frac{1}{n}\Sigma|S-O| \quad (3)$$

$$d = 1-\left[\frac{\Sigma(S-O)^2}{\Sigma(|S-\bar{O}|+|O-\bar{O}|)^2}\right] \quad (4)$$

explanation:

n = amount of data

S = Simulation

O = Observation

The evaluation was conducted to see if the CropSyst model can be applied to the research area for prediction. Evaluation of CropSyst model is done by performing calibration and validation on some parameters [12], [13], [14].

III. RESULTS AND DISCUSSION

3.1 Plant parameters for evaluation

For the purpose of the model, evaluation it is necessary to calibrate some aspects of crop varieties, that is in thermal time, phenology, transpiration, attainable growth, canopy growth, root, harvest, and senescence as in Table 4.

TABLE 4
PARAMETERS USED IN CROPSYST MODELS FOR SIMULATION SOYBEAN

Parameters	Anjasmoro	Argomulyo	Source
	Value	Value	
Thermal time accumulation			
Base temperature(^{0}C)	8	8	L
Cutoff temperature(^{0}C)	25	25	L
Phenology			
Degree-days emergence (^{0}C-days)	100	100	M
Degree-days begin flowering (^{0}C-days)	760	720	M
Degree-days begin filling (^{0}C-days)	1296	1235	M
Degree-days begin senescence (^{0}C-days)	1622	1478	M
Degree-days maturity (^{0}C-days)	1740	1563	M
Degree-days full senescence (^{0}C-days)	1842	1641	M
Transpiration			
Canopy extinction coefficient for total solar radiation	0.5	0.5	L
Evapotranspiration crop coefficient at full canopy	1	1	L
Leaf water potential at the onset of stomatal closure (J kg^{-1})	-1,000	-1,000	D
Wilting leaf water potential (J kg^{-1})	-1,500	-1,500	D
Maximum water uptake (mm d^{-1})	10	10	L
Attainable growth			
Above ground biomass transpiration coefficient (kPa kg m^{-3})	5	5	L
Radiation use efficiency PAR (g MJ^{-1})	2.5	2.5	C
Mean daily temperature (^{0}C)	22	22	C
Canopy growth			
Specific leaf area at optimum temperature (m^2 kg^{-1})	28	28	C
Stem/leaf partition coefficient	3	3	L
Root			
Maximum root depth (m)	1.5	1.5	M
Harvest			
Unstressed harvest index	0.3	0.3	M
Senescence			
Leaf area duration (^{0}C-days)	900	900	L

C=Calibrated, D=Default, L=literature, M=Measured [15]

3.2 CropSyst Calibration

For calibration used data of plant parameters that have been got in research during 2016, especially grain yield. The difference between the simulation and observations result is minimized by a trial and error approach. After the grain yield results between the simulation and observation being closed, then next will be validated for each calibration results in some other areas. The results of the field research (observation) along with the simulated results from CropSyst models that have been calibrated are presented in Table 5.

TABLE 5
OBSERVATION AND SIMULATION OF GRAIN YIELD CALIBRATION RESULT IN ANJASMORO AND ARGOMULYO VARIETIES

Soybean Varieties	Grain Yield (t ha^{-1})	
	Measured	Simulated
Anjasmoro	1.86	1.79
Argomulyo	1.44	1.50

Table 5 shows that in Anjasmoro variety the result of grain yield simulated is lower than the observation result, while in Argomulyo show the opposite is higher grain yield simulation compared with observation result.

3.3 Cropsyst Validation

To validate the data that has been got from field research, thus calculation of the simulation results with the observation results in three other areas. This validation result will determine whether the model can accurately predict the grain yield of the soybean or not. Validation results in the three districts in South Sulawesi are presented in Table 6.

TABLE 6
OBSERVATION AND SIMULATION OF GRAIN YIELD VALIDATION RESULT IN ANJASMORO AND ARGOMULYO VARIETIES IN SOUTH SULAWESI

Districts	Soybean Varieties	Grain Yield (t ha^{-1})	
		Measured	Simulated
Takalar	Anjasmoro	2.00	1.96
	Argomulyo	1.70	1.85
Soppeng	Anjasmoro	1.70	1.64
	Argomulyo	1.50	1.56
Bone	Anjasmoro	2.00	2.14
	Argomulyo	1.50	1.65

Table 6 shows that simulation results of Anjasmoro varieties in Takalar and Soppeng are lower than field observations, but in Bone District, the result of the simulation is higher than observation result. While for the Argomulyo variety, the simulation results are higher than the observations for the three districts.

3.4 Cropsyst Evaluation

Evaluation of CropSyst model for Anjasmoro and Argomulyo varieties was done by calculating RMSE, MBE, MAE, and *d* from each variety. The results of statistical calculations for each variety are presented in Table 7.

TABLE 7
EVALUATION PERFORMANCE CROPSYST MODEL ON GRAIN YIELD SOYBEAN IN SOUTH SULAWESI

Soybean Varieties	Parameter	Mean		RMSE	MBE	MAE	*D*
		Measured	Simulated				
Anjasmoro	Grain Yield (t ha^{-1})	1.89	1.88	0.09	-0.01	0.08	0.92
Argomulyo	Grain Yield (t ha^{-1})	1.54	1.64	0.11	0.11	0.11	0.81

The results of the evaluation in Table 7 show that the RMSE (0.09 and 0.11) and MAE (0.08 and 0.11) are so small that the CropSyst model can accurately predict the productivity of both the research site and the validation sites. RMSE and MAE are two approaches to see the difference between simulation and observation [16], [17], [18]. MBE is used to view the simulated averages below or above observation. In Anjasmoro MBE has a negative value, it shows that the simulation value is less than the observed value [19], while in Argomulyo is opposite. In the *d* (Index of Agreement) values show that both Anjasmoro (0.92) and Argomulyo (0.81) have a value close to 1, showing that the CropSyst model is suitable [20] to applied in tropical regions such as South Sulawesi, Indonesia.

IV. CONCLUSION

The results of the evaluation on the grain yield of soybean show that CropSyst model has a tiny RMSE and MAE value (close to 0), thus accurately to predict the grain yield. While the value of *d* is close to 1 which means that the model (simulation) accurately predicts the results of field research (observation). Thus it can be concluded that the CropSyst model accurately predicts grain yields in different regions of South Sulawesi, which have a tropical climate. So that, it can be concluded that the CropSyst model can be applied to tropical regions by doing calibration and validation.

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