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Strategy of Soybean Management (*Glycine max* L.) to Cope with Extreme Climate Using CropSyst© Model

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ABSTRACT

This research was carried out to verify the CropSyst© plant model from experimental data in a soybean field and to predict planting time along with its potential yield. The researches were divided into two stages. First stage was a calibration for model on field from June to September 2015. Second stage was the application of the model. The required data models included climatic, soil and crop's genetic data. There were relationship between the obtained data in field and the simulation from CropSyst© model which was indicated by 0.679 of Efficiency Index (EF) value. This meant that the CropSyst© model was well used. In case of Relative Root Mean Square Error (RRMSE), it was shown at 2.68 %. RRMSE value described that there was a 2.68% error prediction between simulation and actual production. In conclusion, CropSyst© can be used to predict the suitable planting time for soybean and as the result, the suitable planting time for soybean on the dry land is the end of rainy season (2nd June 2015). Tanggamus variety is the most resistant variety based on slow planting time, because the decreased percentage of production was lower (8.3%) than Wilis (26.3%) and Anjasmoro (43.0%).

Keywords: calibration; CropSyst©; Efficiency Index; RRMSE; soybean

INTRODUCTION

Soybean is one of food crops with high protein content (ca. 39%) consequently highly enthused by consumers. In addition, soybean has a great prospect of market and it can help farmers to increase their income. Year by year, soybean's demand increases because of the increasing of human population, however, the domestic production of soybean is only possible to reach 998.870 ton (Statistics Indonesia, 2016) or 37 % of national demand. Finally to cover the lack of production, import is the only reasonable effort.

There are some environmental factors related to the lower productivity of soybean. Drought and flooding as results of climatic anomaly and climate change are the main causal factors. Many sectors are affected by climate changes, and agriculture is the most susceptible sector related to extreme climate change. Ecosystem of rice and other food crops such as soybean are the common examples that impacted by the extreme climate changes (Kaimuddin, Kamaluddin, & Sasmono, 2013).

To solve environmental problems, there are some desires to find integrated software or models that combined some variables from interdisciplinary approaches as solution models (Donatelli, Bregaglio, Confalonieri, de Mascellis, & Acutis, 2014). Models or software which can simulate plant growth and development on the varied crop management are opportunity in the global modernization of agricultural production. Some models can describe the plant responses on the different environment and crop management (Singh, Tripathy, & Chopra, 2008; Evett & Tolk, 2009).

CropSyst© is one of models that can describe some concepts in the agriculture for future (Stöckle et al., 2014). This model was used to predict or simulate the growth and development of the selected plants or crops on the selected soil. It produces model that can estimate the potential crop production on the specific climatic and soil condition (Radovanović & Šovljanski, 2013) and it is the first step for crops to adapt on the cropping system (Stöckle et al., 2012). This model has been applied on some crops and in some areas of the world (Singh, Tripathy, & Chopra, 2008; Palosuo et al., 2011; Rotter et al., 2012). Calibration and validation are needed as preliminary procedure before applying CropSyst© on the various environmental conditions.

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Based on that condition, it is deemed necessary to get a better strategy of soybean management to cope the extreme climate change by using CropSyst©. This research was needed because mitigation and adaptation of climate change on agriculture sectors are the latest issues in the world, especially food crops are very susceptible to climate change.

MATERIALS AND METHODS

This research was divided into two stages based on the use of CropSyst© models. The first stage was calibration stage and the next stage was field application (preparation and test of *Relative Root Mean Square Error*; RRMSE). Calibration stage was conducted in the field from June to September 2015, at the Bureau of Meteorology, Climatology and Geophysics (BMKG) in Maros District. Split-plot design was adopted in the research that consisted of treatments; variety (V) as the main plot and planting time (W) as sub-plot. Three varieties, such as Tanggamus (V1), Wilis (V2) and Anjasmoro varieties (V3) were used. Planting times were divided into four periods, namely 2 June (W1), 12 June (W2), 22 June (W3) and 2 July 2015 (W4). Growth Degree Days (GDDs) were observed from planting to harvest period. Plant phenological variables such as *emergence, end canopy growth, early flowering, early seed filling, early senescence, maturity* and *completed senescence* were also recorded. Application model was conducted after calibration stage. In this stage, the data obtained from calibration/verification in the field were then used in CropSyst© models. The required data models were daily climatic data (such as precipitation, radiation, air temperature, and humidity), physical soil (pH, bulk density, field capacity, permanent wilting point, cation exchange, sand, silt and clay contents), and the plant genetic data.

RESULTS AND DISCUSSION

Calibration Stage

Calibration is a process of selecting the combination of variables or to change the plant and soil variables for fixing of variables in the model and then collecting plant variables that is needed for the model. On calibration stage (parameterization of CropSyst© model) was done by comparing the simulation and current values that were obtained on the field, and then changing the sensitive variables to get the best results that were close to the actual results on field.

On calibration activities, data of plant genetic (Table 1) and soil variables (Table 2) were obtained from the observation results in Laboratory of Soil Science, Faculty of Agriculture, University of Hasanuddin, Makassar, Indonesia.

Table 1. Values of soybean genetic data were obtained on the field

Treatments (Varieties-planting time)	Plant Genetic Variables						
	D1	D2	D3	D4	D5	D6	D7
Tanggamus-2 June 2015	108	931	931	1440	1845	2095	2226
Tanggamus-12June 2015	107	956	956	1492	1877	2064	2201
Tanggamus-22 June 2015	135	985	985	1531	1852	2016	2152
Tanggamus-2 July 2015	151	956	956	1504	1885	2058	2199
Wilis-2 June 2015	80	906	906	1412	1816	2012	2148
Wilis-12 June 2015	80	928	928	1492	1824	2011	2149
Wilis-22 June 2015	79	985	985	1531	1852	1990	2125
Wilis-2 July 2015	102	1012	1012	1531	1885	2003	2143
Anjasmoro-2 June 2015	80	906	906	1412	1735	1927	2068
Anjasmoro-12 June 2015	80	958	958	1518	1824	1877	2011
Anjasmoro-22 June 2015	107	958	958	1531	1825	1908	2042
Anjasmoro-2 July 2015	102	984	984	1478	1885	1974	2112

Remarks: D1=degree day of emergence; D2=degree day of end canopy growth; D3=degree day of early flowering; D4=degree day of early seed filling; D5=degree day of early senescence; D6=degree day of maturity and D7=degree day of completed senescence

Table 2. Observation results of soil variables in Bureau of Meteorology, Climatology and Geophysics, Maros District

Soil variables	Values
Bulk Density (g cm^{-3})	1.24
pH (H_2O)	6.90
Field capacity (%)	2.01
Cation Exchange Capacity	25.63
Base Saturation (%)	56.00
Permanent Wilt Point (cm cm^{-3})	0.26
Sand content (%)	22.00
Dust content (%)	32.00
Clay content (%)	46.00
Thickness (m)	0.20

The purpose at this stage was to see the accuracy of the model related to the condition of growth and development stages of soybean (from emergence to harvesting phases). Seven phases of soybean growth and development were observed in this research such as: 1) emergence, 2) end of canopy growth, 3) early flowering, 4) early seed filling, 5) early senescence, 6) maturity and 7) completed senescence phases. The relationship of data between observation result in field/current and simulation result on every treatment were described in Table 3.

Based on the validation, CropSyst© was suitable to be used as a simulation tool for soybean. It has been showed by Efficiency Index (EF) with value 0.679 that was obtained from actual production in field and simulation CropSyst© model result. This model can be used to predict the production based on suitable planting time. RRMSE resulted 2.684%, it showed that there was 2.684% prediction error between actual and simulating results.

Wijayanto (2010) reported that the lowest prediction error was produced by simulating model using variable`s values which were obtained from previous research (Bellocchi et al., 2000). According to his result, the lowest prediction error obtained the high value of EF (0.97). High value of EF and the lowest value of prediction error were the main indicators that CropSyst© could be used to predict crop production based on Nitrogen (N) application. However, this research was applied in the small area (ca. 40 Ha) only, where there are differences related to the differences in management.

Table 3. Relationship production data between simulation and actual observation for all treatment`s combinations of soybean

Treatments	Simulation/ Actual	Plant variables	
		Production (t ha^{-1})	Stover Results (t ha^{-1})
Tanggamus-2 June 2015	S	1.059	2.119
	A	1.140	2.358
Tanggamus-12 June 2015	S	0.714	1.428
	A	1.09	1.943
Tanggamus-22 June 2015	S	0.507	1.014
	A	0.840	1.773
Tanggamus-2 July 2015	S	0.356	0.711
	A	0.810	1.008
Wilis-2 June 2015	S	1.052	2.105
	A	1.130	2.133
Wilis-12 June 2015	S	0.749	1.497
	A	1.090	1.516
Wilis-22 June 2015	S	0.614	1.228
	A	0.890	1.886
Wilis-2 July 2015	S	0.540	1.080
	A	0.570	1.116
Anjasmoro-2 June 2015	S	1.074	2.147
	A	1.180	2.182
Anjasmoro-12 June 2015	S	0.803	1.606
	A	0.980	1.598
Anjasmoro-22 June 2015	S	0.510	1.020
	A	0.800	1.175
Anjasmoro-2 July 2015	S	0.483	0.965
	A	0.590	1.001
RRMSE (%)		2.684	2.712

Remarks: S=Simulation and O=Actual Observation

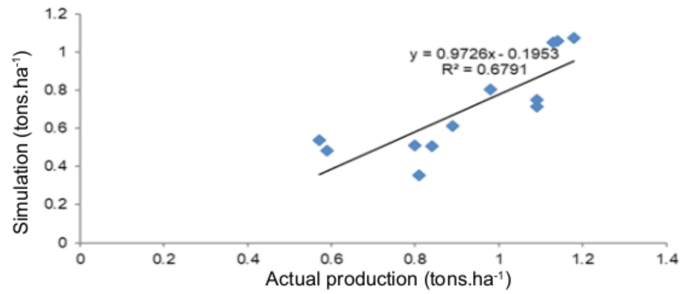

Fig. 1. Verification result between simulation and actual productions for three varieties of soybean on the four planting times in Maros District

Application Model

In this stage, verification was conducted by using soybean as plant model on the CropSyst© program to predict the production of soybean for each treatment. After result of simulation was obtained, the comparison between simulation and actual productions for each treatment were then compared. Relationship between simulation and actual productions for each treatment are described in Table 3.

Result showed that model of soybean production can predict actual production of soybean and there was a correlation between simulation and actual production, with the value 0.679 (Fig. 1). This means that this model was suitable for soybean.

Based on the verification between actual and prediction data, the high production was resulted at the first planting time (2 June 2015), and production decreased at longer planting time. This condition was related to rainfall intensity, where the first planting time received the highest intensity of rainfall. The second (12 June 2015), third (22 June 2015) and fourth (2 July 2015) planting times had no rain. In addition, the highest production was a result from treatments of soybean varieties such as Tanggamus, Wilis and Anjasmoro at the first planting time. As conclusion, growth, development and production of soybean were related to the planting time. If soybean plants are planted at unsuitable planting time, it will cause some problems, such as:

1. Pest attack, for example: the fly nut will be an outbreak if soybean is planted at 2-4 weeks different than others. To solve the problem, it is better to plant soybean at the same planting time. In case of disease, Hong et al. (2012) reported that delayed planting time up to 15 days reduced the intensity of bacterial disease on soybean. Related to this condition, it is better to use the resistant cultivar if the planting time are on the different planting times. If susceptible cultivar is used, a delayed planting time with fungicide application is suggested to reduce the bacterial disease intensity on soybean.
2. Drought as result of delayed planting time. Hu & Wiatrak (2011) reported that the delayed planting time on the unsuitable climatic condition contribute to the lower quality in soybean growth, development and production. In addition, lower quality of seed will ensue because of the changes in oil and protein contents.
3. Water also contributed to growth, development and production of soybean. Aminah et al. (2013) reported that the sufficient water during vegetative stage and the lower volume of water during generative stage (flowering and ripening of seed stages) increased the production of soybean.

CONCLUSION

CropSyst© can be used to predict the suitable planting time for soybean and as a result, the suitable planting time for soybean on the dry land is in the end of rainy season (2 June 2015). Tanggamus variety was the most resistant variety based on slow planting time, because the decreased percentage of production was the lowest (8.3%) than Wilis (26.3%) and Anjasmoro (43.0%).

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