# Analysis of Climate Risk Level on Soybean Productivity (*Glycine max L.*) Using Cropsyst Model

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***Abstract*—The aims of this research is to predict the planting time and the potential of soybean yield in Pangkep Regency as one of South Sulawesi's soybean production centers in extreme climate conditions using Cropsyst model. This research consist of several steps: (1) Step of validation, conducted to validate calibrated model (calibrated in Maros regency) with condition in Pangkep regency, (2) Step of model application, and (3) Step of strategy determination. The result of validation of soybean plant production in Pangkep regency shows the correlation between observation of production data and simulation of production data namely 0,933. It means that the model is suitable to predict the appropriate production for soybean planting at the research locations. RRMSE calculation result (Relative Root Mean Square Error) of the production data is 2.501%. Simulation results on climate risk analysis show that the potential production in the normal year is higher than El Nino extreme year while the production potential in La Nina year is higher than normal year and El Nino year. The strategy that can be offered in terms of the use of varieties and the best planting time for Pangkep regency in the case of el nino is Tanggamus varieties with the first planting time on April 4 (V1W1) due to it's rate of yield reduction is 36.67%, while in the case of La Nina is Tanggamus varieties with the third planting time (V1W3) due to the rate of yield increasing is the highest one, namely 42.98%.**

***Index Terms*—Cropsyst, El Nino, La Nina, RRMSE, soybean, and validation**

## I. Introduction

Consumption of soy in Indonesia is increasing with increasing of population and prosperity of people who pay more attention to health. They are more looking for a source of protein from vegetable that consist of low cholesterol. The increasing of consumption cannot be fulfilled by domestic production. Domestic consumption is around 2.2 to 2.5 million [tons/ha] while national production only reaches 998,999 [kg/ha]. So it still has to be filled by imported soybeans (BPS, 2016) "Ref. [1]".

The low production of soybean in Indonesia compared to other soybean producing countries is caused by two factors namly climate and technology. The climate factor included the extreme climate of drought and flood. The sectors most vulnerable to the effects of changes in this extreme climate are the agricultural sector, particularly the rice and palawija ecosystems including soybean crops (Kaimuddin *et al.*, 2013) "Ref. [2]".

Anomalies or climate aberrations are predicted to continue to threaten agricultural production systems. It affects farmers' cropping patterns and crop damage caused by floods, pests and other attacks. To anticipate the climate anomalies can be done by adjusting input modifications to minimize climate risk and behavior by conducting accurate analysis of forecasts, flood and drought early warning systems, and timing of cultivation, with the ability to rapidly and precisely disseminate climate prediction and anticipatory technology to users (Kaimuddin *et al.*, 2005) "Ref. [3]".

Based on the above description, this research is needed in accordance with current issues that are developing today namely mitigation and adaptation.

## II. Materials and Method

The research was conducted from March 2017 until July 2017. It was conducted in Pangkep regency as one of soybean production center in South Sulawesi. The materials used in this research were soybean varieties of Tanggamus, Wilis and Anjasmoro, manure, NPK, Decis.

This research method was done based on previous research result that was calibrated in area of Maros Regency as preliminary research. Data obtained in area of Maros regency then validated in Pangkep regency. Furthermore, the research was continued with application/model simulation to risk climate analysis over the normal year, el nino and la nina. The last step was strategy determination.

## III. Results

### *A. Validation of the Model*

Validation was done to measure the suitability of model calibrated in area of Maros Regency (Meteorology Agency Office, Climatology and Geophysics with condition in South Sulawesi represented by Pangkep Regency).

Furthermore, to know the suitability between the observation results obtained in the area with the simulation results that analyzed using Effiency Index

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(EF). The closer the value of EF to one the more valid this model (Moriasi *et al.*, 2007) "Ref. [4]".

The comparison between observation of production and simulation of production in Pangkep Regency is presented in Table I.

TABLE I. RESULT OF DATA VALIDATION BETWEEN SIMULATION AND OBSERVATION FOR ALL TREATMENT'S COMBINATIONS OF SOYBEAN

| Treatments | Simulation/ Observation | Plant variables | |
|---|---|---|---|
| | | Production [ton/ha] | Stover Results [ton/ha] |
| V1W1 | S | 1.097 | 3.65 |
| | O | 1.80 | 3.79 |
| V1W2 | S | 1.64 | 3.21 |
| | O | 1.75 | 3.54 |
| V1W3 | S | 1.42 | 2.74 |
| | O | 1.69 | 2.99 |
| V1W4 | S | 0.96 | 2.05 |
| | O | 1.12 | 2.46 |
| V2W1 | S | 1.052 | 2.105 |
| | O | 1.13 | 2.33 |
| V2W2 | S | 1.32 | 3.07 |
| | O | 1.57 | 3.32 |
| V2W3 | S | 0.98 | 2.96 |
| | O | 1.06 | 2.35 |
| V2W4 | S | 0.84 | 2.09 |
| | O | 0.98 | 2.27 |
| V3W1 | S | 1.075 | 2.39 |
| | O | 1.18 | 2.41 |
| V3W2 | S | 1.39 | 2.99 |
| | O | 1.52 | 3.30 |
| V3W3 | S | 1.01 | 2.21 |
| | O | 1.28 | 2.51 |
| V3W4 | S | 0.91 | 2.56 |
| | O | 1.39 | 2.98 |
| RRMSE (%) | | 2.501 | 1,902 |

Note: V1 = Tanggamus, V2 = Wilis, V3 = Anjasmoro, W1 = 4 April, W2 = 14 April, W3= 24 April and W4= 3 Mei.

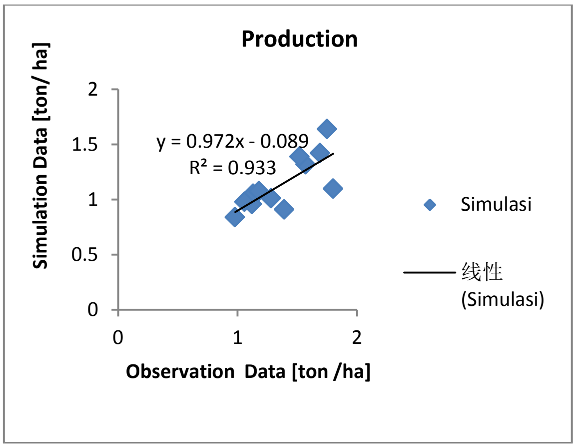


Figure 1. Correlation between observation of production and simulation of production on Pangkep regency

The result of soybean production validation in Pangkep regency shows that soybean production model that has been prepared can predict soybean production well. Correlation between observation production data and simulation production data is 0,933 shown in Fig. 1. This means that both models are suitable to use to simulate the production of soybean cultivation in Pangkep regency.

## B. *Application of the Model*

The application of the model consists of two stages, namely:

Stage 1: Preparation of the Plant Simulation Model

In this stage, verification was done using the soybean plant model on the cropsyst program to estimate the potential outcome of each treatment. After obtained the result of simulation result of potency then it was compared between result of observation to result of simulation in the area.

Once we have obtained all the data from the planting site in Maros Regency as calibrated data and data from Pangkep Regency as data to be validated, then the data will be included in the simulation model of the plant using Cropsyst.

Stage 2: Test RRMSE

The formula of Relative Root Mean Square Error (RRMSE) which has the value 0 - ~ was used to measure the level of difference between the simulation model and the observation used (Hopkins, 1997) "Ref. [5]". The smaller the RRMSE value the smaller the level of difference between the actual model.

$$\text{RRMSE} = \sqrt{\sum_{i=1}^{n} \frac{(Si - Ai)^2}{n}} x \frac{100}{A} \quad (1)$$

Note:

RRMSE: Relative Root Mean Square Error (%)
Si: simulated value (prediction) of the i-th data
Ai: actual value (observation) of the i-th data
n: amount of data
A: average actual value (observation)

The RRMSE calculation for component of production obtained result 2,501% that means difference of result between production observation and production of simulation is only 2,501% while for heavy component of berangkasan obtained result equal to 1,901%.

## C. *Implementation of the Model*

The analysis of climate risk level on soybean production in Pangkep regency in the normal year (2014), El Nino (2015) and La Nina (2016) can be seen in Table II. In this case a simulation was conducted to estimate the potential outcome of each treatment (planting time and variety) over normal years and extreme years (el nino and la nina)

The result of simulation of climate risk analysis at Pangkep regency toward normal year and extreme year is found that in the event of extreme weather conditions in this case there is drought (el nino) hence the decreasing of yield / production at V1W1 treatment (Tanggamus variety with time of planting date 4 April) is the lowest is 36.67%, this means that in Pangkep region should be in the dry season (el nino) planting varieties that are resistant to drought that is Tanggamus varieties with planting time around 4 April. At the time of extreme weather of la nina, the highest varieties showed an increase in yield compared to the normal year was Tanggamus variety with the first planting time on April 4 (V1W1) with an increase of approximately 42.98% of the normal year.

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TABEL II. CLIMATE RISK ANALYSIS RESULTS ABOUT DECREASING AND INCREASING OF POTENTIAL SOYBEAN PRODUCTION CAUSED BY NATURAL PHENOMENA EL NINO AND LA NINA IN PANGKEP REGENCY

| Treatments | Potential results (ton ha$^{-1}$) | | | Decrease Hasil (El Nino) and Increase results (La Nina) (%) | |
|---|---|---|---|---|---|
| | Normal Tahun 2014 | El Nino Tahun 2015 | La Nina Tahun 2016 | El Nino Tahun 2015 | La Nina Tahun 2016 |
| V1W1 | 1.608 | 0.822 | 2.82 | 36.67 | 34.72 |
| V1W2 | 1.761 | 0.729 | 2.70 | 42.87 | 34.78 |
| V1W3 | 1.980 | 0.886 | 3.033 | 46.70 | 42.98 |
| V1W4 | 2.169 | 1.041 | 3.354 | 52.00 | 35.33 |
| V2W1 | 1.774 | 0.946 | 2.971 | 48.88 | 40.29 |
| V2W2 | 1.889 | 0.797 | 2.855 | 57.81 | 33.83 |
| V2W3 | 2.058 | 0.974 | 3.144 | 52.67 | 34.54 |
| V2W4 | 2.305 | 1.111 | 3.456 | 51.80 | 33.30 |
| V3W1 | 1.773 | 0.945 | 2.969 | 55.25 | 40.28 |
| V3W2 | 1.888 | 0.797 | 2.854 | 57.78 | 33.85 |
| V3W3 | 2.057 | 0.906 | 3.033 | 55.95 | 32.18 |
| V3W4 | 2.304 | 1.109 | 3.455 | 51.96 | 33.31 |

Note : V1 = Tanggamus, V2 = Wilis, V3 = Anjasmoro, W1 = 4 April, W2 = 14 April, W3= 24 April dan W4= 3 Mei.

The analysis of climate risk level for soybean crops against production in normal years (2014), El Nino (2015) and La Nina (2016) can be seen in Fig. 2. In this case simulations were performed using the cropsyst plant model to predict the potential outcome each of the treatments (planting time and variety) of the normal year as well the extreme years (el nino and la nina) so that other inputs are considered equal in affecting potential outcomes.

The simulation results show that the production potential in the normal year (2014) is higher compared to the El Nino extreme years (2015) and the production potential in La Nina (2016) is higher than the normal year (2014) and El Nino (2015) .

From the simulation results it is seen (Fig. 2) that between Normal year and El nino year generally have almost the same pattern while for the year of LA Nina the pattern is somewhat different.

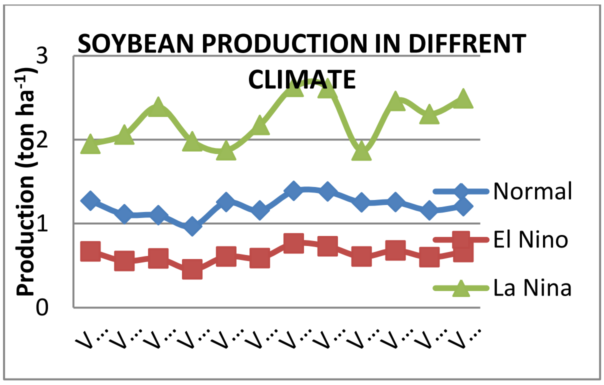


Figure 2. Soybean production in normal year, El Nino, and La Nina.

From the results of climate risk analysis, it was found that adequate water in la nina condition resulted in a significant increase in yield compared to normal conditions, especially el el nino / drought conditions

While the potential for large production in the normal year compared to el nino year (on rainfed) is possible because at the beginning of the rainfall is sufficient and the radiation is high enough so that during the growth of the plant does not experience water stress, so for the next phases plants can take advantage of high enough radiation without experiencing water stress. In addition to the maturation phase of the seeds required a high enough radiation and water needs are not so great again, and this is also one factor that supports the high production in the normal year.

Studies conducted by Kaimuddn, *et al.*, (2005) "Ref. [3]" in South Sulawesi, show that climate patterns based on land physiography produce three rain regions, namely monsoon, local and equatorial patterns. The predicted rainfall anomaly probability at rain stations in Maros and Gowa shows the same pattern, that is, during the rainy season of La-Nina years, has a longer range of positive values than El-Nino years, on the dry season of El -Nino has an opportunity to get anomaly of rain approaching normal (positive value) is very small. From the simulation result using DSSAT V4.0 it is known that in El-Nino year the production of food plants is lower compared to normal year and La-Nina. Even in the dry year (El-Nino) decline in rice production from normal year to 100% for PCHPB area (west coast rainfall pattern) and PCHPT (east coast rainfall pattern). Furthermore, for PCHPer area (coastal rainfall pattern of transition) there was a decrease of production up to 99.45%. As for the crops of palawija there is a decrease in production is smaller than the rice.

According to Fagi and Manwan (1992) "Ref. [6]", based on rainfall patterns, generally drought-prone agri-cultural areas in the sense of high probability of drought are areas experiencing annual deficit by water availability for plants. The growing season (GS), especially on rainy land, depends on rainfall and its distribution over a period of time. Generally estimates in each region are determined based on monthly rainfall patterns.

## IV. DISCUSSION

Correlation between production processed in Pangkep Regency using simulation production of cropsyst model got result of Efficiency Index test of 0,933. This means that both models are suitable to use to simulate production based on the right planting time for soybean cultivation. The closer the value of EF to one the more valid this model.

The same research was done by Marshal (2012) "Ref. [7]" that simulation using CropSyst can be used as a decision support system that can work independently in potential water measurement (irrigation). Improper planting times can cause failures including:

1. Pest attacks, especially the peanut fly (Agromyze). Especially if the soybean is planted 2-4 weeks after the surrounding planting was planted so it is recommended to plant in unison. However, the results of research by Hong *et al.*, (2012) "Ref. [8]" found that with a delay of 15 days planting time can reduce the attack of diseases caused by bacteria.

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2. Drought due to delay in planting differences in the dry season and the rainy season, among others, are caused by differences in climatic elements (especially solar radiation).

Hu *et al.*, (2012) "Ref. [9]" resulted that delaying of planting time due to unfavorable environmental conditions had a negative effect on growth, development and yield of soybean and affect the quality of soybean seeds.

In China, as results of research conducted by Li *et al.* (2014) "Ref. [10]" found that climate and geographical gave various effects in soybean crops, especially with protein content (29%), crude oil content (20%), weight 100 seeds (17%) and plant height (38%).

Strategies that can be offered in terms of determining the time of planting is the time of planting soybean for rainfed land is at the end of the rainy season where at that time there is still remaining rain water in the soil that can be utilized by the plant primarily in the beginning of the growth phase. As we know that water is needed especially during the early stadia (vegetative phase) of plant growth.

The result of Aminah research (2013) "Ref. [11]" found that the availability of water for soybean plants is very sensitive to affect plant height, leaf number, leaf area, root dry weight, chlorophyll content, and various variables of plant production.

The strategies offered for the use of varieties are Tanggamus varieties that have resistance to shifting cultivation time, evidenced by lower decreasing yield compared to other varieties (Wilis and Anjasmoro).

Talking about the determination of adaptation strategy / scenario with cropsyst usage, the result of research conducted by Samiha *et al.*, (2013) "Ref. [12]" on the influence of adaptation strategy to improve water use efficiency, using Cropsyst Model with two climate change scenario / scenario ie first scenario is A2 (temperature increased 3.1oC and CO2 concentration was 834 ppm) and the second scenario was B2 (temperature increased 2.2 o C and CO2 concentration was 601 ppm), the adaptation strategy for the first scenario was sowing the corn two weeks earlier with two irrigation schedule able to increase efficiency water use compared to the second scenario, the results also show that under conditions of climate change, TWC324 hybrid corn used is more tolerant to heat stress than TWC310 in both climatic conditions.

## V. Conclusion

1. Cropsyst is a tool that significantly potential in giving the right planting time recommendation so that the determination of planting time of soybean based on cropsyst model that has been made valid for use.

2. The best planting time for Pangkep regency in the case of el nino is Tanggamus varieties with the first planting time on April 4 (V1W1) due to it's rate of yield reduction is 36.67%, while in the case of La Nina is Tanggamus varieties with the third planting time (V1W3) due to the rate of yield increasing is the highest one, namely 42.98%.

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