Evaluation of CropSyst model in simulating the growth and production of Katokkon chili (Capsicum chinense Jacq)

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Abstract. This study aims to evaluate the CropSyst model in simulating the growth and production of Katokkon. The research was carried out from December 2018 to May 2019 in two stages: the first stage was in To’pao Village in Tana Toraja Regency and Tallang Sura Village in North Toraja Regency, and the second stage was in the Agro-climatology and Biostatistics Laboratory of the Department of Agronomy, Faculty of Agriculture, Hasanuddin University. The method used in this research was survey method and simulation method with CropSyst. The survey method was used to obtain information regarding some phenology and production of three Katokkon plant sources ie. Leatung 1, Leatung 2 and Limbong Sapolo. While the simulation method with CropSyst was carried out by incorporating all information obtained in the first stage to run the model. The results of this study indicate that the productivity of the Katokkon chili at the two study sites are similar to the output of the CropSyst model. Katokkon chili productivity in To’pao Village simulated by the model was 6.87 ton/ha while observed yield was 6.60 ton/ha. The productivity of the Katokkon chili in Tallang Sura Village were 6.74 and 6.63 ton/ha for the simulated and observed, respectively. Index of Agreement (d) at the two research locations shows that the CropSyst model can accurately predict the productivity of the Katokkon chili from Leatung 2 (d = 0.54) compared to the Katokkon chili from Limbong Sampolo (d = 0.51) and Leatung 1 (d = 0.48).

1. Introduction
Chili is a plant that comes from the eggplant family (Solanaceae) and the genus Capsicum. Chili is one of the horticultural commodities of the vegetable group that is quite well known in the community. This is because chili has an important role in everyday life. Chili is usually used as a spice in food and ingredients in the processing industry for food and beverage. In addition, chili can also be used as a raw material in the manufacture of medicines and cosmetics.

The national demand for chili increases from year to year. In 2017 the number of chilli consumption reached 488,872 tons while the population was 261,891 [1]. So far, there are is about 30% lack of the needs for chili, especially when there is no harvest due to climate factor such as high rainfall. The demand for chili cannot be fulfilled by the market at certain times causing a fairly high price increase [2].
Based on the Central Statistics Agency [3], South Sulawesi is ranked as the seventh largest producer of chili after other provinces such as West Nusa Tenggara, West Java, Aceh, West Sumatra, North Sumatra, and Bali. South Sulawesi in 2017 has a large chili plantation area reaching 3,633 ha. Large chili production was recorded respectively at 27,059 tons (2013), 28,006 tons (2014), 23,781 tons (2015), 27,638 tons (2016), and 32,289 tons (2017). While the productivity of large chili in the planting area is 7.46 tons / ha (2013), 7.87 tons / ha (2014), 8.32 tons / ha (2015), 8.04 tons / ha (2016) and 8.89 tons / ha (2017). Some obstacles that can affect the low production are caused by the level of knowledge and technological mastery at the level of farmers who are still lacking, limited capital and pest attacks.

The selection of varieties to be cultivated is one of the important steps in improving cultivation techniques. Variety is a type or species of plant that has certain genotypic plant growth characteristics such as fruit shapes, leaves, flowers and seeds that can be distinguished with other types or species of plants and do not changes when propagated. There are three groupings of chili varieties, namely hybrid varieties, superior varieties and local varieties.

Katokkon chili is a local variety that is typical of the Tana Toraja and North Toraja regions. Katokkon chili which is classified as large chili has good potential to be developed because it has a distinctive taste and aroma (spicy, sweet and pungent) and has a unique shape because it is similar to paprika but smaller in size [4]. This plant is known as a flavoring and a complement to various dishes, especially traditional Toraja cuisine.

Katokkon chili in the study sites has an oval leaf shape (Ovalis) with tapered leaf tips (Acuminatus), blunt leaf base (Obtusus), pinnate leaf bones (Penninervis), flat edge edges (Serratus), and dark green color (figure 1). This type of Katokkon chili has a round fruit shape, short fat with a flat fruit base, with a fruit length of 2.2 - 5.8 cm and a diameter of 1.18 - 4.08 cm similar to paprika peppers only smaller size, average fruit per plant is 30.64 g and fruit weight is 234.36 grams. Has a distinctive aroma and a specific taste because the taste is very spicy. Young fruit is light green with a base of purple fruit while ripe fruit is bright red [5].

**Figure 1.** Katokkon Chili varieties from Limbong Sampolo (A); Leatung 1 (B); and Leatung 2 (C)

Katokkon chili can grow well at an altitude of 1000 - 1500 m asl, with podsolic soil types, with soil pH ranging from 3.5 - 5.0. Optimum average temperature range are from 16 ºC (59 ºF) at night and 24 ºC (76 ºF) during the day with a minimum humidity of 82% and a maximum of 86%, while an average rainfall of 1500 mm to 3500 mm per year.

Katokko chili can be cultivated throughout the year, with fluctuating production, depending on the season especially rainfall and sunlight. Consequently, the price on the market is not stable, following the law of demand [6]. The large chili group in North Toraja Regency is dominated by 80% by the Katokkon chili variety. The production of this commodity have not met the target of the North Toraja Regency. In 2013, the production target was 107.3 tons, but the realization only reached 94 tons. Likewise in 2014, the production target was 110.2 tons but the realization could only reach 102 tons [7].
Utilization of a simulation model can be used as a tool for analysis and decision making of various problems in agriculture. This tool can be used to explain the relationship between environmental factors and plant growth and development. Crop yield technology and its relationship to climate and soil are widely used. The usefulness of the relationship between weather and plants will be more meaningful in agricultural planning and operations [8].

The CropSyst (Cropping Systems) Simulation Model is one of the prediction models to study the effects of crop management on crop productivity and the environment. Plant simulation models based on crop, soil and weather factors are effective tools in research in the agricultural sector. This model can be used to plan alternative strategies for planting, land use and water management [9], to evaluate plants, varieties and cultivation technology, to analyze the level of climate risk to plant growth, so that expansion can be used the area of planting and the selection of a suitable farming system location to formulate hypotheses and experimental designs of studies, to predict crop yields [10].

CropSyst is used to simulate growth of selected plants for selected soil. CropSyst produces a model that allows estimating plant potential under specific soil and climate conditions [11]. The CropSyst model is used as an applied research tool, analysis of productivity scenarios and environmental impacts of cropping systems and crop management in this case determining planting time and cropping patterns as well as the impact of climate change on cropping systems and planting management strategies for efficient water use and water productivity. Before a plant model is applied as a management tool, the model must be evaluated both in terms of performance and the accuracy of the outcomes produced in the form of parameterization, verification and validation.

Previous study has shown that the use of CropSyst on various plants is quite reliable. A study conducted by Kaimuddin [12], showed that the model can simulate soybean phenology and productivity in response to water stress and high radiation intensity. Other study by Zare [12] based on CropSyst simulation results show that irrigation once every 5 days with the application of 45 kg N / ha is the best for rice plants. Razaa [14] research results show that CropSyst is accurate in predicting groundwater in water-scarce soils. Similarly, a validation research by Aminah et al. [15] showed that the model accurately predict the production in Maros Regency compared to the other three regencies (Pangkep, Soppeng, Wajo) with the efficiency index value of 0.784. Therefore, the recent was conducted to evaluate the accuracy of the model to simulate the growth and production of three local Katokkon varieties against the local growing condition in Toraja regencies.

2. Methodology
This research was carried out in two stages with the first stage was a field survey and the second was desktop study. The survey was carried out in in To’pao Village of the Tana Toraja Regency and Tallang Sura Village of the North Toraja Regency. The second stage was conducted at the Agro-climatology and Biostatistics Laboratory of the Department of Agronomy, Faculty of Agriculture, Hasanuddin University. The study was carried out from December 2018 to May 2019.

The first stage of the study was conducted by survey and observation. The survey and observation were made in the Katokkon production center villages to obtain plant data. Farmers were selectively determined (purposive sampling) by looking at the Katokkon chili planting. While the second stage was the simulation of CropSyst to determine and compare the production of chili plants from measurements in the field with the results of the CropSyst model output.

2.1. Input data
The input data for CropSyst Model were as follows:

2.1.1. Daily climate data. Daily climate data collection included rainfall (mm), maximum temperature (°C), minimum temperature (°C), maximum humidity (%), minimum humidity (%) was carried out by measuring the data directly at two research sites using thermometer and rainfall measuring instruments. While the collection of wind speed data (km / day) and day length (hours) was carried out by taking secondary data from the nearest station at the study site.
2.1.2. Soil data. Soil sample from the two research sites were collected and analysed for soil texture, cation exchange capacity, and soil pH. The soil analysis conducted at the Maros Agricultural Research and Development Laboratory.

2.1.3. Crop data. Plant data including plant types / varieties, planting time, length of growth phase / plant phenology (days), and production of Katokkon chili were obtained by direct observation at the research location. Crop productivity data collection for CropSyst model calibration purposes was done through research in the field. Data collection on the Katokkon chilli crop covered the phenology (table 1) and productivity.

Table 1. Growth and development phases of Chili [15].

| Phase | Development phases description |
|-------|--------------------------------|
| FV1   | Germination                    |
| FV2   | First Leaves Appear           |
| FG1   | New buds appear: the petals have not yet bloomed, but are still covered by flower petals |
| FG2   | Crown of flowers began to appear |
| FG3   | The flower crown is growing and almost blooming |
| FG4   | The flower crown is in full bloom |
| FG5   | The flower crown closes again withered and finally falls off the stem |
| FG6   | Fruit begins to form: light green, very soft fruit skin and fruit length of approximately 2cm. |
| FG7   | The fruit has grown into a bigger, 5-6 cm long, light green and still soft |
| FG8   | The fruit is still light green in color, but the skin of the fruit and the fruit stalk are rather tough |
| FG9   | Fruit skin color begins to redden at a quarter edge |
| FG10  | The skin is red at half the tip. |
| FG11  | Red fruit evenly distributed with stalk clay |
| FG12  | Fruit skin begins to wrinkle, fruit stalks dry and easily separated from the stem (harvested fruit) |

2.1.4. Plant management. Plant management data collected for three local varieties used (Katokkon from Limbong Sampo, Leatung 1, and Leatung 2 villages). Data collected, specifically on fertilization management, was obtained by observing directly the cultivation activities at the two study sites. Fertilization conducted were the application of Tithonia compost concentration with three dosage, 25%, 50%, and 75%.

2.2. Model calibration
Calibration was performed to improve plant parameters (heat accumulation, phenology, canopy growth, roots, and harvest).

2.3. Model validation
Validation was conducted to adjust the calibration results with the results in the field, both in To’Pao Village, Tana Toraja Regency and Tallang Sura Village, North Toraja Regency. Validation was carried out by comparing the results of observations with the simulations using deviation, index of agreement and t-test independent analysis.

Deviation was used to determine the deviation in Katokkon chili production between simulated and observed. The equations used for this validation are:
Deviation = (Simulated – Observed) x 100/Observed ........ (1)

Index of Agreement (d) shows the level of suitability of the model accurately predicting the results of observations [16]. The value of d is in the range of $0 \leq d \leq 1$. The higher the value of d (close to 1), the more accurate the prediction of the model.

$$d = 1 \left( \frac{\sum (S-O)^2}{\sum |S-O| + |O-O|)^2} \right)$$ .................. (2)

$S =$ Simulation
$O =$ Observation
$\bar{O} =$ Average observation

Independent analysis of the sample t test used to compare two averages to determine the difference in the average.

3. Results
3.1. Phenology of Katokkon chili

The growth phases of the Katokkon chilli plants grown in Tana Toraja and North Toraja districts are presented in table 2. The duration of the growth phases are shown in the accumulation of degree days. Variation in the phenology duration were found between the seed sources or varieties especially in the time of canopy growth end, flowering, senescence, maturity, and the time of full senescence. Katokkon chili from Limbong Sampolo village seems to mature and senesce earlier compared to the varieties from Leatung villages. Difference in the use of Titonia compost, with dosages of 25%, 50%, and 75%, did not necessary affect the accumulation of degree days for the phenology of the Katokkon chili. All varieties showed a same time to emergence.

| Phenology                  | Day degree accumulation |
|----------------------------|-------------------------|
|                            | Var. Limbong Sampolo    | Var. Leatung 1 | Var. Leatung 2 |
|                            | 25%  | 50%  | 75%  | 25%  | 50%  | 75%  | 25%  | 50%  | 75%  |
| Emergence ($^\circ$C-days) | 88   | 88   | 88   | 88   | 88   | 88   | 88   | 88   | 88   |
| End Canopy Growth ($^\circ$C-days) | 1243 | 1228 | 1243 | 1288 | 1273 | 1199 | 1228 | 1228 | 1199 |
| Begin Flowering ($^\circ$C-days) | 1243 | 1228 | 1243 | 1288 | 1273 | 1199 | 1228 | 1228 | 1199 |
| Begin Filling ($^\circ$C-days) | 1590 | 1590 | 1590 | 1703 | 1649 | 1649 | 1590 | 1576 | 1590 |
| Begin Senescence ($^\circ$C-days) | 1745 | 1759 | 1745 | 1820 | 1820 | 1820 | 1880 | 1850 | 1865 |
| Maturity ($^\circ$C-days) | 1775 | 1805 | 1775 | 1865 | 1865 | 1865 | 1910 | 1894 | 1910 |
| Full Senescence ($^\circ$C-days) | 1805 | 1835 | 1805 | 1894 | 1894 | 1894 | 1940 | 1925 | 1940 |

Percentage represent fertilization management ei. dosage of Titonia compost.
3.2. Total production

The observed production of three types of Katokkon chili in two regencies are shown in tables 3 and 4. Total productivity of the Katokkon chili varied between varieties and Titonia compost dosages. The use of a higher dose of Titonia compost seem to increase the productivity of the Katokkon chili from Leatung compared to the variety of Limbong Sampolo. Table 3 shows that Leatung 2 Katokkon chili was observed to be more responsive to the Titonia compost than the Leatung 1 chili. However, observation in the other regency show a decrease when the compost dose was increased to 75% in table 4. In general, productivity of the Leatung varieties were higher than the Limbong Sampolo variety that range from 3.5 to 4.97 ton per hectare.

Table 3. Katokkon Chili production in Tana Toraja Regency

| Variety            | Titonia Compost | 1st Harvest | 2nd Harvest | 3rd Harvest | 4th Harvest | Total |
|--------------------|-----------------|-------------|-------------|-------------|-------------|-------|
|                    |                 | 1st Harvest | 2nd Harvest | 3rd Harvest | 4th Harvest |       |
| Limbong Sampolo    | 25%             | 0.07        | 0.89        | 1.52        | 2.49        | 4.97  |
|                    | 50%             | 0.02        | 0.33        | 1.29        | 2.35        | 3.99  |
|                    | 75%             | 0.09        | 1.12        | 0.99        | 1.32        | 3.52  |
| Leatung 1          | 25%             | 0.63        | 0.88        | 1.96        | 3.11        | 6.58  |
|                    | 50%             | 0.75        | 1.26        | 2.30        | 2.21        | 6.52  |
|                    | 75%             | 0.29        | 1.04        | 2.80        | 2.80        | 6.93  |
| Leatung 2          | 25%             | 0.27        | 1.31        | 7.54        | 0.52        | 9.64  |
|                    | 50%             | 0.00        | 2.96        | 2.67        | 3.68        | 9.31  |
|                    | 75%             | 0.34        | 2.00        | 5.07        | 2.98        | 10.38 |

Table 4. Katokkon Chili production in North Toraja Regency

| Variety            | Titonia Compost | 1st Harvest | 2nd Harvest | 3rd Harvest | 4th Harvest | Total |
|--------------------|-----------------|-------------|-------------|-------------|-------------|-------|
|                    |                 | 1st Harvest | 2nd Harvest | 3rd Harvest | 4th Harvest |       |
| Limbong Sampolo    | 25%             | 1.32        | 0.35        | 1.82        | 0.75        | 4.24  |
|                    | 50%             | 0.70        | 1.48        | 1.89        | 0.73        | 4.79  |
|                    | 75%             | 0.00        | 0.32        | 0.94        | 2.67        | 3.92  |
| Leatung 1          | 25%             | 0.72        | 1.83        | 2.34        | 1.07        | 5.95  |
|                    | 50%             | 1.12        | 2.16        | 1.40        | 0.72        | 5.40  |
|                    | 75%             | 1.76        | 1.19        | 1.95        | 0.83        | 5.73  |
| Leatung 2          | 25%             | 2.06        | 2.45        | 4.00        | 1.36        | 9.87  |
|                    | 50%             | 0.88        | 1.53        | 5.37        | 1.83        | 9.61  |
|                    | 75%             | 1.16        | 2.50        | 4.70        | 1.76        | 10.12 |

3.3. CropSyst model plant parameter input

Plant parameters input were obtained from the observation activities. The parameters used to calibrate or adjust the productivity of the Katokkon chili plants simulated by CropSyst are shown in table 2 and
5. Some parameters were obtained from the literature study to ensure the simulation of the Katokkon chili by the model.

### Table 5. Crop Parameters of Katokkon chili plants for CropSyst Model Calibration

| Parameter                                      | V1 P1 | V1 P2 | V1 P3 | V2 P1 | V2 P2 | V2 P3 | V3 P1 | V3 P2 | V3 P3 | Sources |
|------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|
| **Heat accumulation**                           |       |       |       |       |       |       |       |       |       |         |
| Base temperature (°C)                           | 10    | 10    | 10    | 10    | 10    | 10    | 10    | 10    | 10    | L       |
| Maximum temperature (°C)                       | 30    | 30    | 30    | 30    | 30    | 30    | 30    | 30    | 30    | L       |
| **Transpiration**                               |       |       |       |       |       |       |       |       |       |         |
| Canopy coefficient for total radiation          | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | L       |
| Plant Evapotranspiration on full canopy         | 1.35  | 1.35  | 1.35  | 1.35  | 1.35  | 1.35  | 1.35  | 1.35  | 1.35  | L       |
| Leaf water potential at stomatal closure (J Kg⁻¹) | -1000 | -1000 | -1000 | -1000 | -1000 | -1000 | -1000 | -1000 | -1000 | D       |
| Leaf water potential at wilting point (J Kg⁻¹)  | -1500 | -1500 | -1500 | -1500 | -1500 | -1500 | -1500 | -1500 | -1500 | D       |
| Maximum water absorption (mm d⁻¹)               | 10    | 10    | 10    | 10    | 10    | 10    | 10    | 10    | 10    | L       |
| **Roots**                                       |       |       |       |       |       |       |       |       |       |         |
| Maximum root depth (m)                          | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | 0.5   | O       |
| **Harvest**                                     |       |       |       |       |       |       |       |       |       |         |
| Harvest index free of stress                    | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | L       |
| **Maturity**                                    |       |       |       |       |       |       |       |       |       |         |
| Duration of fully expanded leaf (°C-days)       | 900   | 900   | 900   | 900   | 900   | 900   | 1200  | 1200  | 1200  | D       |

P1: cv. Limbong sampolo; P2: cv. Leatung 1; P3: cv. Leatung 2; V1: Titonia compost 25%; V2: Titonia compost 50%; and Titonia compost 75%. D= Default, L=Literature (Fernandes et al., 2012), O=Observation.

3.4. Calibration

Calibration was carried out in the study area in To'Pao Village and Tallangsura Village, by conducting a "trial and error" in order to obtain results in accordance with the study area. The magnitude of the presentation of the productivity deviation of the Katokkon chili on the comparison of observations and simulations in the To’Pao village of Tana toraja Regency area is presented in table 6. While table 7 shows the deviation percentage between simulated and observed productivity of Katokkon chili in Tallangsura Villages of North Toraja Regency.

The percentage of deviation shown in the calibration of the CropSyst model in simulating the productivity of the local Katokkon chili varieties range from 0.31% for Leatung 1 variety with 25%
Titonia compost at Tallangsura’ village to 31.99% for Limbong Sampolo variety with 75% Titonia compost at To’Pao village. Higher deviation percentage between observed and simulated values is shown in the data at To’Pao village compared to the deviation percentage in the Tallangsura’ village.

### Table 6. Percentage of deviation between observed and simulated productivity of three varieties of Katokkon chili in To’Pao Village of Tana Toraja Regency.

| Variety         | Titonia Compost | Productivity (ton/ha) | Percentage of deviation (%) |
|-----------------|-----------------|-----------------------|----------------------------|
|                 | Observed        | Simulated             |                            |
| Limbong Sampolo| 25%             | 4.97                  | 6.70                       |
|                 | 50%             | 3.99                  | 17.19                      |
|                 | 75%             | 3.52                  | 31.99                      |
| Leatung 1       | 25%             | 6.58                  | 11.40                      |
|                 | 50%             | 6.52                  | 10.60                      |
|                 | 75%             | 6.93                  | 16.10                      |
| Leatung 2       | 25%             | 9.64                  | 2.01                       |
|                 | 50%             | 9.31                  | 0.69                       |
|                 | 75%             | 10.38                 | 10.44                      |

### Table 7. Percentage of deviation between observed and simulated productivity of three varieties of Katokkon chili in Tallangsura’ Village of North Toraja Regency.

| Variety         | Titonia Compost | Productivity (ton/ha) | Percentage of deviation (%) |
|-----------------|-----------------|-----------------------|----------------------------|
|                 | Observed        | Simulated             |                            |
| Limbong Sampolo| 25%             | 4.24                  | 8.21                       |
|                 | 50%             | 4.79                  | 3.16                       |
|                 | 75%             | 3.92                  | 17.09                      |
| Leatung 1       | 25%             | 5.95                  | 0.31                       |
|                 | 50%             | 5.40                  | 10.36                      |
|                 | 75%             | 5.73                  | 2.93                       |
| Leatung 2       | 25%             | 9.87                  | 0.45                       |
|                 | 50%             | 9.61                  | 0.91                       |
|                 | 75%             | 10.12                 | 5.35                       |

### 3.5. Validation

A t-test results between the observed and simulated productivity of the Katokkon chili both in the study location are shown in table 8.

### Table 8. Validation of Katokkon Chili Productivity

| Village         | Observed (ton/ha) | Simulated (ton/ha) | p-value | t-table |
|-----------------|-------------------|--------------------|---------|---------|
| To’Pao          | 6.63              | 6.74               | t= 0.248| t= 1.746|
|                 |                   |                    | P-value = 0.404 | P-value (t) = 0.05 |
| Tallang Sura’   | 6.87              | 6.60               | t= 0.224| t= 1.746|
|                 |                   |                    | P-value = 0.413 | P-value (t) = 0.050 |

### 3.6. Evaluation

Evaluation is carried out to obtain the accuracy level of the model to predict the results of observations. Evaluation was carried out with a statistical equation in the form of an Index of Agreement (d). Evaluations of the CropSyst model are presented in tables 9 and 10.
### Table 9. Evaluation of the CropSyst model in the productivity of three types of Katokkon chili in Tana Toraja Regency

| Variety          | Average of productivity (ton/ha) |  |
|------------------|----------------------------------|--|
|                  | Observed | Simulated | D    |
| Limbong Sampolo  | 4.16     | 4.65      | 0.46 |
| Leatung 1        | 6.68     | 5.82      | 0.27 |
| Leatung 2        | 9.78     | 9.33      | 0.49 |

### Table 10. Evaluation of the CropSyst model in the productivity of three types of Katokkon chili in North Toraja Regency

| Variety          | Average of productivity (ton/ha) |  |
|------------------|----------------------------------|--|
|                  | Observed | Simulated | D    |
| Limbong Sampolo  | 4.32     | 4.61      | 0.51 |
| Leatung 1        | 5.69     | 5.94      | 0.48 |
| Leatung 2        | 9.87     | 9.67      | 0.54 |

### 4. Discussion

The type of Katokkon chillies planted by farmers in the two research locations were Limbong Sampolo, Leatung 1, and Leatung 2. Of the three types of Katokkon, they had morphological differences. The basic difference can be seen from the shape of the fruit such as Limbong Sampolo has a round fruit shape, short fat with a flat fruit base, Leatung 1 has an oval fruit shape and uneven fruit base (bumpy), and Leatung 2 has a round fruit shape at the base of the tapered fruit at fruit base. One of the causes of the emergence of various types of Katokkon chili are chili seeds originating from different regions with different heights.

Air temperature is one of the climate factors that can be used as an indication of the amount of heat energy in a system. Air temperature can determine various levels of growth in terms of physiological, vegetative and generative development. Air temperature directly affects the process of photosynthesis, respiration, cell wall permeability, absorbing water and nutrients, transpiration, enzyme activity and protein coagulation [18]. The concept of plant development (phenology) during its life cycle can be suspected using the concept of heat accumulation or heat units (HU). The concept of heat units only applies to plants that are not responsive to day length. This concept uses the daily average air temperature and plant base temperature as a variable to determine the stage of development and age of the plant. The value of the rate of plant development (s) is directly proportional to the daily average air temperature (T) above the base temperature (Tb) [16].

Table 2 shows the value of heat accumulation and a description of the development phases (phenology) of the Katokkon chili plants from each treatment. The accumulation of heat needed for the Katokkon chilli plants to full maturity (ready for harvest) in each treatment were varied between treatments. This is in accordance with the opinion of Adipati [16] stating that there are several factors that influence the value of heat accumulation and phenology of red chili plants, namely air temperature, solar radiation, and other factors. Basically, these factors also affect each other.

The selection of an agricultural commodity that is biophysically appropriate, economically viable for cultivation, and alternative land management technologies for each region must be based on the characteristics of the land and its environment. Regional selection based on soil and environmental characteristics (land unit zones) will be significant to determine technology packages to be applied in certain environmental physical conditions [19].

CropSyst, a friendly plant simulation model, was developed by Washington State University, to study the influence of climate, soil, and crop management systems on crop productivity and the
environment. CropSyst simulates groundwater, nitrogen, plant growth and development, crop yields, residual production, soil erosion by water, and salinity. Current developments which are mostly caused by the development of changes rather than climate will be a challenge for plant modelling to always be able to update the model [20].

Some plant parameters were calibrated to obtain the simulation value that is close to observation. To adjust the simulation value with observation, a statistical tool is used, the percentage deviation. The presentation of the deviation will be a measure of the success of the calibration. The deviation percentage values between simulated and observed productivity both in To'Pao Village of Tana Toraja Regency shows that the average percentage deviation for productivity was 11.90%. While the values for Tallangsura’ Village North Toraja Regency shows an average percentage deviation of 5.42%.

Validation in this model simulation is done by comparing yield data from model output with yield data in the field (observation). Validation is also carried out to see whether the model can be applied on a broader scale (outside of the field research area) in this case South Sulawesi. The first validation was carried out in the To’Pao Village of Tana Toraja Regency using the t-test analysis. The results of the average test analysis of two samples of Katokkon chili productivity showed that the t-test was 0.101 <t-table 1.746. Then H0 is accepted and H1 is rejected, meaning there is no difference in productivity from the model output to observation. The second validation was conducted in Tallangsura Village, North Toraja Regency. The results of the average test analysis of two samples of Katokkon chili productivity also showed the same results that the t-test was 0.248 <t-table 1.746. Then H0 is accepted and H1 is rejected, meaning there is no difference between the productivity of the model output with observation.

The results of evaluations carried out by the statistical equation of Index of Agreement (d). The values indicate that simulation and prediction of the productivity of Leatung 2 variety (0.49) and Limbong Sampolo (0.46) were more accurate than Leatung 1 (0.27). While the validation of three types of Katokkon chili in Tallangsura village, North Toraja District shows that the value of the Leatung 2 (0.54) and Limbong Sampolo (0.51) were also more accurate than Leatung 1 (0.48). This is in accordance with the opinion of Umair et al. [21] states that the index of agreement values can show the level of suitability of the model to accurately predict the results of observations. The results of the value of d = 1.0 or show a very good level of agreement between observation and simulation.

5. Conclusions
• Validation of the two study sites shows that the output of the CropSyst model is not different from the observation. The simulated productivity of Katokkon chili in To’pao Village was 6.87 ton/ha compared to observed productivity of 6.60 ton/ha. Katokkon chili productivity at Tallangsura Village simulated by the CropSyst was 6.74 ton/ha compared to observed productivity of 6.63 ton/ha.
• The accuracy of the CropSyst model seen from the Index of Agreement (d) at the two research locations shows that the CropSyst model can accurately predict the productivity of Katokkon chili from Leatung Village 2 (d = 0.54) compared to the Katokkon chili from Limbong Sampolo Village (d = 0.51) and Leatung Village 1 (d = 0.48).

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