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Experimentation for Verification of Sine-Product Model

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ABSTRACT

This paper described the verification of the Sine-Product model by a direct experimentation in the field. This model, which acts as the production function of irrigated crops, should be verified before it can be used extensively. This experiment is a limited one which using corn and rice as the model crops. The amount and schedule of water application are controlled and recorded. The initial number of unit of corn and rice crops is 40 respectively. The amount of the water application is varied along the time and among the unit of crops in order to cover the wide range of the model. At the harvest time, the yield of each unit of crop is weighed accurately. Then these measured yields are compared with the computed yields of the Sine-Product model using the recorded water application as the input values. The comparison showed that the Sine-Product model can be used for various ranges of water application.

Keywords: experiment, verification, sine-product model

INTRODUCTION

The Sine-Product model has been constructed for calculating the value of yield at the harvest time based on the series of water application values during the corresponding cropping season [1]. This function is fit to the general shape of relationship between Applied Water and Crop Production as presented by English [2]. The structure of the Sine-Product model is suitable to be used as the objective function of the Dynamic Programming model. Obviously, it can also be used for the Simulation for Optimization model.

The example of application for the Sine-Product model is in the dynamic programming model for the optimization of irrigation reservoir operation [1]. In this case, a reservoir is serving a single planting schedule irrigation block through 3 cropping seasons. Another example of application for the Sine-Product model is also in the dynamic programming model, but in this case is for the optimization of water allocation for 4 sub-irrigation areas [3].

Before it can be used extensively, Sine-Product model need to be verified. It must be stressed that the goal of verification and validation is not the complete and formal proof of the model validity, but the estimation of the model credibility [4]. Moreover, the verification and validation of the model are conducted to assess mainly the accuracy, which is one of many indicators affecting the quality of model [5]. Statistical tests are one way to test the model objectively [6]. Actually, the statistical tests have already been done by using a vast quantity of recorded data from the states in USA. These data include the yield of crops on various locations, and the amount of precipitation on those locations. Using only the precipitation data which fall within the range of crop water requirements, statistical Z_M test has verified the Sine-Product model [7]. If the precipitation data which have zero value or values larger than the crop water requirement are also included, statistical Z_M test has also verified the Sine-Product model [8].

In this article, an experiment which has been conducted for verifying the Sine-Product model is described. The idea undelaying this experiment is to produce a limited number of data of yield and water application which are tightly controlled and carefully measured. These data is then used for verifying the Sine-Product model.

MATERIALS AND METHODS

The Verification of Sine-Product Model by Experiment

The Sine-Product Model as the Production Function

In this experiment, the Irrigation Production Function as the Objective Function is represented by a Sine-Product model. This mathematical form of the production function is proposed in a previous study [9]. In order to fit the function to the general shape of relationship between Applied Water and Crop Production as presented by English [2], an approach has been made to use a model with sine functions for each period of water application as shown Equation (1).

$$Yr_i = \left[Sin\left\{ \left(\left[AWr_i \text{ - a.}Sin\left(AWR_i .2.\pi \right) \right] \times \left[1 - b.Sin\left(Awr_{i.}\pi \right) \right]^c \right)^d .\pi / 2 \right\} \right]^e \qquad (1)$$

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with Yr_i is the representation of Y_r (Crop Production/Yield) at each period/stage, and AWr_i is the applied water at the corresponding period/stage.
If the number of period/stage in a cropping season is 12, then values of the parameters of a = 0.12163, b = 0.29305, c = 1.7806, d = 0.10135, and e = 1.2.

The Crop Production Function for a cropping season is described as Equation (2).

$$\text{Crop Production Function} = Yr = Yr_1 \times Yr_2 \times Yr_3 \times \ ... \ \times Yr_n \qquad (2)$$

with n is the number of period/stage in the cropping season (=12 periods).

The AWr_i, Yr_i, and Yr are all the relative values (between 0 and 1). AWr_i are relative to the standard water requirement which will give the maksimum Yr, whereas Yr is relative to the potentially maksimum Yr.

Experiment for Verification of the Model

The experiment for the verification of the Sine-Product Model has used two kind of crop, corn and rice. These crops were grown in a protected shack. This shack is covered at the top with transparent plastic film as the roof to protect the crops from uncontrolled precipitation but still allowed the sunshine to get through. The shack is covered at the sides with wire mesh to protect the experiment from unwanted interferences. For the purpose of controlling the amount of water application, the crops are differentiated in units. One unit of corn crop consists of a stalk of corn grown on a polybag (plastic bag), and one unit of rice crop consists of a clump of rice grown on a plastic pail. These polybags and pails are filled by soil medium for the crops to grow. For variation of the amount of water application, the original number of units of crops is 40 units for the corn and the rice respectively. But in the as the experiment progressed, the number of rice crop dropped to 25 units due some failure in the crop development. The layout of these remaining units of crops is as the follows .

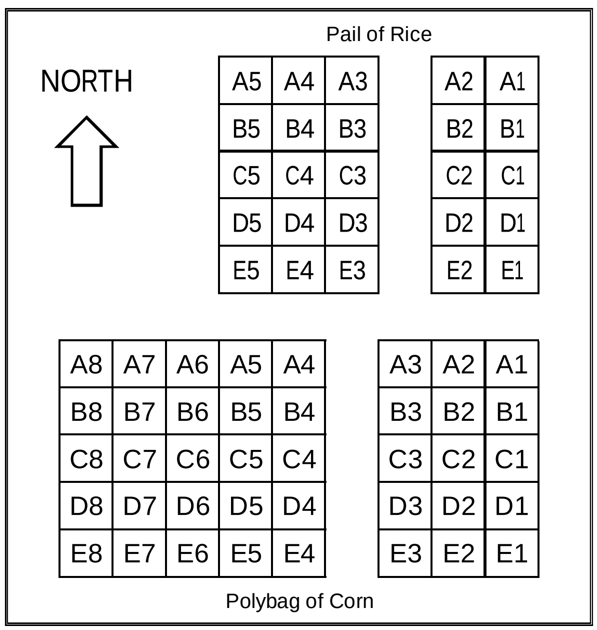

Figure 1 Layout for Units of Corn and Rice in the shack.

The layout was arranged so that the taller corn plant will not obstruct the shorter rice plant from sunshine as the sun is in the northern zone at the time. Beside those varied water application units of crops, there were another 12 units of corn crop and 9 units of rice crop which got full water application. The purpose of these maximum water application units of crops are for obtaining the maksimum Yr, so that the values of measured Yr can be calculated, which is the ratio of the measured yield to the maksimum Yr.

For calculating the values of AWr_i, it needs the standard water requirement which will give the maksimum Yr. For this experiment, the standard water requirement are based on the references for corn [10] and rice [11], which can be presented in graphical form as the following figures.

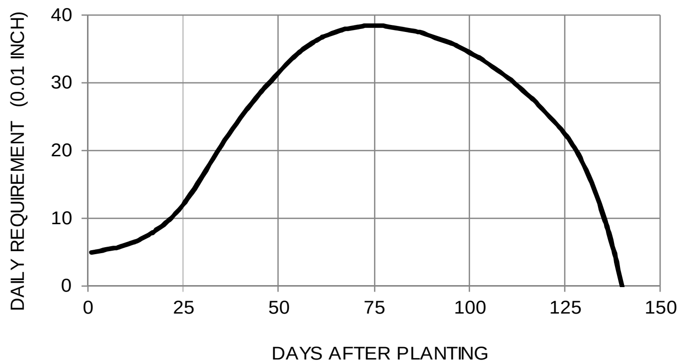

Figure 2 Water Requirements for Corn.

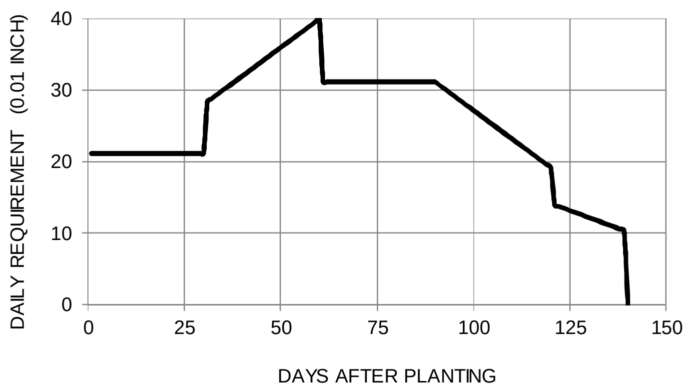

Figure 3 Water Requirements for Rice.

In this experiment, the start of the cropping season (beginning of planting) is 1 June 2011 for rice, and 2 June 2011 for corn. The cropping season is ended when the last yield (of both corn and rice) have been harvested. The real cropping season have length of 145 days for corn and 148 days for rice. In order to conform to the 12-periods Sine-Product model, the divisions of time (days) were done as shown in the following table.

Table 1 Division of 12 periods for Water Application.

No.	**NUMBER OF DAYS**	
Period	Corn	Rice
1	12	12
2	12	12
3	12	12
4	12	12
5	12	12
6	12	12
7	12	12
8	12	12
9	12	12
10	12	12
11	12	12
12	13	16
TOTAL	145	148

Based on these division of 12 periods, then the water requirement of each period for corn and rice are presented in the following table.

Table 2 Water Requirement of each Period.

No.	CROP WATER REQUIREMENT (0,01 INCH)	
Period	Corn	Rice
1	67.6	254.4
2	104.3	254.4
3	200.4	303.6
4	318.5	396.0
5	406.5	453.6
6	452.0	374.4
7	459.2	374.4
8	441.3	366.0
9	403.5	314.4
10	342.9	256.8
11	250.0	154.8
12	59.2	77.0
TOTAL	3505.4	3579.8

The amount of controlled water application divided by the amount of crop water requirement for the period of *i* will produce AWr_i. After conducting the scheduled water application for the entire cropping season, the corn and rice crops were harvested. For the corn, the yield is the weight of kernels per polybag. For the rice, the yield is the weight of grains per pail. The results of the measurement of yields are presented in the following four tables.

Table 3 Yield of Varied Water Application Corn (grams per polybag).

Polybag	A	B	C	D	E
1	0.0	19.3	65.9	79.7	0.0
2	78.1	36.2	15.8	24.5	58.0
3	13.6	4.1	17.5	34.9	65.0
4	109.8	0.0	0.8	0.8	72.0
5	126.0	92.1	81.5	36.0	56.7
6	115.1	3.1	73.0	0.0	92.5
7	161.1	10.1	128.8	10.7	42.3
8	101.0	160.9	137.9	69.6	72.9

Table 4. Yield of Maximum Water Application Corn (grams per polybag).

Polybag	Yield	Polybag	Yield	Polybag	Yield
1	279.6	5	127.4	9	162.3
2	172.3	6	89.9	10	170.2
3	0.0	7	0.0	11	167.1
4	0.0	8	152.4	12	178.0

Table 5. Yield of Varied Water Application Rice (grams per pail).

Pail	A	B	C	D	E
1	39.5	0.1	49.7	12.6	30.3
2	9.5	0.5	6.1	1.2	10.8
3	48.5	20.1	26.0	0.0	12.7
4	1.0	15.1	45.9	0.4	7.1
5	10.8	20.7	63.2	16.5	12.3

Table 6. Yield of Maximum Water Application Rice (grams per pail).

Pail	Yield	Pail	Yield	Pail	Yield
1	151.8	4	22.6	7	85.5
2	49.7	5	44.2	8	27.1
3	105.1	6	81.1	9	83.6

The measured yields of maximum Water Application are used to estimate the maksimum *Yr*, which for corn are in Table 4 and for rice are in Table 6. In this case, the yields on those tables are being averaged (zero values are ignored) and the resulting values are as the follow.

The maksimum Yield of corn = 292.0 grams/polybag.
The maksimum Yield of rice = 72.3 grams/pail.

Dividing the measured yield of varied water application crop by the maximum yield will produce the value of real *Yr*. Meanwhile, by inputting the values of controlled AWr_i for the entire cropping season to the

Sine-Product model will produce the value of model *Yr*. Comparison of these two kind of *Yr* are presented in the two following table.

Table 7 Comparison of the Model and Real *Yr* for Corn Crop.

Polybag	A		B		C		D		E	
	Model	Real	Model	Real	Model	Real	Model	Real	Model	Real
1	0.2261	0.0034	0.1286	0.0695	0.2270	0.2291	0.1754	0.2763	0.2111	0.0034
2	0.2261	0.2708	0.1565	0.1274	0.2270	0.0575	0.1754	0.0875	0.2000	0.2019
3	0.2261	0.0499	0.1761	0.0176	0.2270	0.0633	0.1754	0.1228	0.2092	0.2259
4	0.2261	0.3793	0.1939	0.0034	0.2270	0.0062	0.1754	0.0061	0.1971	0.2499
5	0.2135	0.4350	0.2107	0.3187	0.2270	0.2825	0.1754	0.1267	0.1997	0.1974
6	0.2135	0.3977	0.2252	0.0141	0.2270	0.2534	0.1754	0.0034	0.2110	0.3203
7	0.2135	0.5550	0.2414	0.0381	0.2270	0.4443	0.1754	0.0399	0.2086	0.1484
8	0.2135	0.3493	0.2580	0.5545	0.2270	0.4755	0.1754	0.2418	0.2070	0.2532

Table 8 Comparison of the Model and Real *Yr* for Rice Crop.

Polybag	A		B		C		D		E	
	Model	Real	Model	Real	Model	Real	Model	Real	Model	Real
1	0.2507	0.5599	0.1440	0.0145	0.2904	0.7014	0.2297	0.1874	0.2449	0.4331
2	0.2507	0.1452	0.1958	0.0207	0.2904	0.0985	0.2297	0.0297	0.2652	0.1628
3	0.2748	0.6846	0.3198	0.2924	0.2904	0.3733	0.2297	0.0138	0.2641	0.1892
4	0.2748	0.0279	0.2896	0.2231	0.2904	0.6485	0.2297	0.0194	0.2428	0.1119
5	0.2748	0.1629	0.3293	0.2997	0.2904	0.8874	0.2297	0.2414	0.2071	0.1838

RESULTS AND DISCUSSION

The experiment has produce the comparison of values of the model *Yr* and the real *Yr* as can be seen in Tables 7 and 8. When these two kind of values are plotted in regression graphs, the results are in the two following figures.

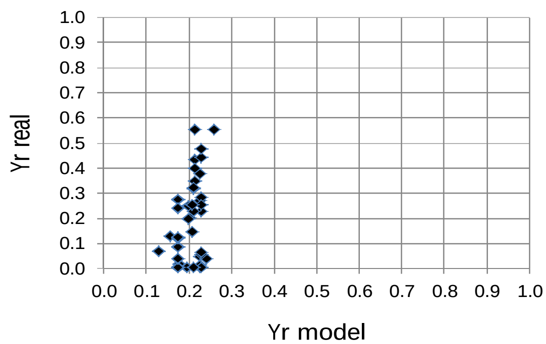

Figure 4 Regression plot for Corn.

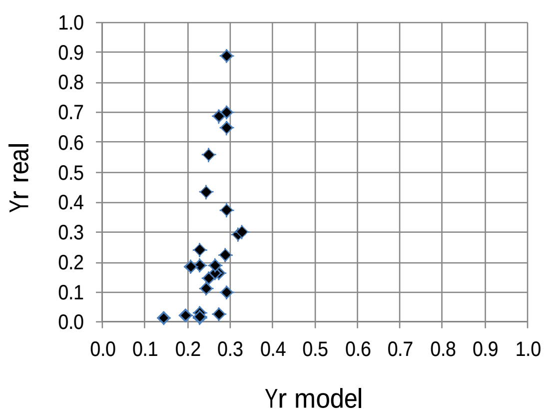

Figure 5 Regression plot for Rice.

A strong relationship between model *Yr* and real *Yr* will produce a diagonal straight line. In the two figures, the relationships are not too apparent, but the tendency is clear enough. If statistical tests are performed, the results are presented in the following table.

Table 9 Statistical Tests.

TEST	Parameter	Values for Corn	Values for Rice
Z_M test	Z_M	0.296	0.225
Linear Correlation	r	0.363	0.483

For corn and rice crops, the Z_M test shows that there is no significant difference between the model and real values of *Yr* (Z critical value = 1.96), while the values of coefficient of correlation *r* indicate a rather weak correlation (under 0.5). About the experiment and the results of model verification, there are some points to be accounted in the follow.

1. The experiment for verifying the Sine-Product model has encountered a number of problems. One of the problems is to obtain a suitable location where every units of crops can receive sunshine uniformly. The rather non-uniform sunshine has the effect of certain variation on the yield.
2. Another problem is to attain the homogenous condition of soil medium. In fact, it will require special and expensive treatments to get a really homogenous soil medium, so it does not affect the variation of yield.
3. In this experiment, the variation of water application is designed to be the only factor which can induce the variation of yield. But in reality, the arrangement of the schedule for water application to each unit of crop is a very complex thing.
4. Even though that every unit of of the same crop were planted simultaneously, in reality each individual unit of crop has different rate of development. There is a tendency for each individual unit of crop to response unpredictably upon a particular water application.
5. The corn plants have grown taller than expectancy where some of them have reached the plastic roof of the covering shack. This trend has made the treatment of the crops become more difficult.
6. The development of the rice plants have gone slower than expectancy. Even in some of the pails, the development of the plants has been stopped altogether.
7. The use of polybag and pail has significantly restricted the development of plants' root, as differ from the condition of plants in the open field.
8. In this experiment, the system of drainage is simple one with some holes in the sides of polybags (for corn) and pail (for rice).
9. The incursion of insect and fungus has caused some problems especially on the corn crops.
10. In this experiment, the number of units of crops (of corn and rice) is not quite adequate due to the restricted fund and resources.

CONCLUSIONS

From these experiments, some conclusions can be drawn as the follow.

1. Specifically, the Sine-Product is valid for various water application schedules during a cropping season. However, a deterministic conclusion cannot be drawn from the experiment of this scale.
2. Generally, it can be said that the Sine-Product model is valid for various kind of crops. However for a particular crop, it may need a special adjustment in estimating the values of AWr_i.
3. The system of water application is closely interrelated to the system of drainage. This is in connection with the estimation of AWr_i values which may not as simple as what has been done in this study.

RECOMMENDATIONS

Also from this experiments, some recommendations can be made as the follow.

1. Further experiments like this one are <u>not</u> recommended, because there are too many influencing factors which can make even a very expensive experiment will not produce a deterministic conclusion. It is better then to implement a system of accurate measurement and recording for water application in a particular irrigation blocks.
2. It is worth to try the application the Sine-Product model in designing water management for irrigation schemes. At least the Sine-Product model can be used as a controlling apparatus for yield values.
3. Further researches for increasing the yield through controlling the water application and drainage have great potential to be conducted.

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REFERENCES

[1] Soetopo, W., 2009, "Application of Sine-Product Model for Operation of Irrigation Reservoir", *World Applied Sciences Journall*, 7(8), 1060-1064.

[2] English, M.J., Solomon, K.H., and Hoffman, G.J., 2002, "A Paradigm Shift in Irrigation Management", *Journal of Irrigation and Drainage Engineering*, 128(5), 267-277.

[3] Soetopo, W. and Limantara, L.M., 2010, "Optimization of Multiplication Sinus Model for Water Irrigation Area of Metro Upstream River, East Java, Indonesia", *Journal of Mathematics and Technology*, No.3 August 2010, 65-67.

[4] Rabe, M, Spieckermann, S., and Wenzel, S., 2008, "A New Procedure Model for Verification and Validation in Production and Logistics Simulation", *Proceeding of the 2008 Winter Simulation Conference*, 1717-1726.

[5] Balci, O., 2004, "Quality Assessment, Verification, and Validation of Modeling and Simulation Applications", *Proceeding of the 2004 Winter Simulation Conference*, 122-129.

[6] Sargent, R.G., 2007, "Verification and Validation of Simulation Models", *Proceeding of the 2007 Winter Simulation Conference*, 124-137.

[7] Soetopo, W., 2010, "Appropriate Data for Verification of Sine-Product Model", *International Journal of Academic Research*, 2(5), 143-145.

[8] Soetopo, W., 2010, "Using Zero and Oversize Data for Sine-Product Model", *Journal of Mathematics and Technology*, No.4 October 2010, 4-7.

[9] Soetopo, W., 2007, "Penerapan Model Sinus-Perkalian Pada Rumusan Fungsi Kinerja Irigasi Untuk Optimasi Dengan Program Dinamik", *Jurnal Teknik – Fakultas Teknik Universitas Brawijaya*, 14(2), 97-103.

[10] Porter, P., Troxclair, N., Schuster, G., Porter, D.O., Cronholm, G., Bynum, E., Jr., Patrick, C., and Davis, S.G., 2005, "Texas Corn Production: Empasizing Pest Management & Irrigation", The Texas A&M University System.

[11] Chapagain, A.K. and Hoekstra, A.Y., 2011, "The Blue, Green and Grey Water Footprint of Rice from Production and Consumption Perspectives", *Ecological Economics*, 70: 749-758.