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Constraint Factors and Mathematical Models for Forecasting Rice Production in Thailand

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ABSTRACT

The constraint factors in rice cultivation were analyzed with the producing variables such as planted area, quantity of product and actual farm yield. Constraint factors of water resources development, fertilizer usage, the previous season farm price, annual rainfall and the replacement of high yielding rice varieties were closely related to such variables. The mathematical models of the above variables were established respect to relationship of these factors.

INTRODUCTION

Thailand is an agricultural country located in Southeast Asia. Most people are famers. Rice is a crop which Thai farmers have acquainted to grow since the ancient time. Rice is not only the main staple food for Thai people, but still be the important exporting goods for Thailand also. Thailand becomes the most famous country in exporting rice. This success is associated by improvement of rice production factors such as irrigation and drainage facilities, fertilizer and chemical application, high yield rice varieties replacement. However, the actual farm yield is still low and differs from the potential yield. The factors which constrain the yield are investigated in this study.

MATERIALS AND METHODS

This study is based on secondary data. Various sources of data may include errors themselves. In order to eliminate the effects from data errors between the different sources, data of interested factors from the same sources is analyzed together. The accuracy is limited by data available and the picked up procedures. The recorded data of planted area (A_t), rice production (P_t) and actual farm yield (Y_t) are analyzed with the important factors such as developed area for water resources (WR) or completed area of irrigation project, fertilizer used for rice cultivation (F), farm price (FP) which is the average value of paddy per ton in the former year or crop season and annual rainfall (AR). Three main groups of data are classified, namely major rice within irrigated area, major rice within non-irrigated area and second rice.

RESULTS AND DISCUSSION

From Table 1, for major rice within irrigated area, all of factors mentioned above except annual rainfall are strongly related with planted area, rice production, actual farm yield and planted area of major rice within non-irrigated area while the actual farm yield in this area is strongly related with annual rainfall but not related to the

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survived factors. For this case, rice production is related with WR and F but strongly related with FP and AR. For second rice, A_t, P_t and Y_t are strongly related with annual rainfall but not related with F while FP is related with planted area and rice production but not related with actual farm yield and WR is related with Y_t but not related with A_t and P_t.

Table 1 Summary of relationship between constraint factors and rice production .

Items of constraint factors	Major rice						Second rice		
	Irrigated area			Non Irrigated area					
	At	Pt	Yt	At	Pt	Yt	At	Pt	Yt
Water resources development (WR)	SR	SR	SR	SR	R	NR	NR	NR	R
Fertilizer used for rice (F)	SR	SR	SR	SR	R	NR	NR	NR	NR
Farm price (FP)	SR	SR	SR	SR	NR	NR	R	R	NR
Annual rainfall (AR)	NR	NR	NR	NR	SR	SR	SR	SR	SR

Remark:
SR = Strongly related (Significant at 5% level) At = Planted area
R = Related (Significant at 10% level) area Pt = Rice production
NR = Not related (Insignificant at 10% level) Yt = Actual farm yield

Mathematical models for forecasting rice production

Model I

From Table 1, equations for prediction planted area, rice production and actual farm yield could be formed by means of multiple regression of concerning factors. Therefore, mathematical models could be expressed in form of double-log linear function as following.

$$LnYY_t = a+b_1LnWR_t+b_2LnF_t+b_3LnFP_{t-1}+b_4LnAR_t \quad (1)$$

Where

YY_t = dependent variables of subcategories, planted area A_t, actual farm yield Y_t and production P_t.

WR_t = the factor of water resources development in year t by given the average value from year 1970−1972 as base year.

F_t = the factor of quantity of fertilizer usage in year t by given the average value from year 1970−1972 as base year.

FP_{t-1} = the factor of farm price in year t−1 by given the average value from year 1970−1972 as base year.

AR_t = the average value of annual rainfall of Thailand (computed from year 1973−1986).

Table 2 Records of major rice production and important concerning factors.

Year	At (mil. ha)**		Pt (mil. ton)**		Yt (ton. ha)**		WRt*	Ft*	FPt-1*
	Irr. area	Non-irr area	Irr. area	Non-irr area	Irr. area	Non-irr area	(ha)	(ton)	(฿/ton)
1970	1.84	5.96	4.45	8.95	2.42	1.50	2118720	168415	860
1971	1.87	6.13	5.02	9.18	2.68	1.50	2128054	164696	629
1972	1.81	5.33	4.61	7.06	2.55	1.32	2297072	228038	800
1973	1.82	5.79	5.02	8.91	2.75	1.54	2325690	192940	1311
1974	1.86	5.47	4.66	7.94	2.51	1.45	2377719	132597	1955
1975	1.88	6.53	4.74	11.02	2.52	1.69	2420709	172462	2105
1976	1.91	6.53	5.32	11.22	2.78	1.72	2419109	240802	1948
1977	1.94	6.46	5.49	6.79	2.83	1.05	2575733	265662	1844
1978	2.04	7.24	5.62	10.22	2.76	1.41	2667407	291365	2397
1979	2.06	7.17	5.90	9.49	2.87	1.32	2835931	300000	2266
1980	2.06	7.74	6.12	11.02	2.97	1.42	2990459	320000	2676
1981	2.12	7.40	6.26	10.45	2.95	1.41	3171450	340055	3133
1982	2.19	7.02	6.71	8.98	3.06	1.28	3320366	373851	2909
1983	2.25	8.42	6.20	13.61	2.76	1.62	3464980	466454	2942
1984	2.31	6.95	7.13	10.14	3.08	1.46	3658580	443808	2757
1985	2.38	7.13	7.40	10.53	3.11	1.48	3822264	413929	2299
1986	2.39	6.88	7.31	9.52	3.06	1.38	3911532	447857	2320

Source * derived from Center for Agricultural Statistics (1980-1988) and Division of Agricultural Economics (1964-1978)

** derived from Committee of Dry Season Crop Planting and Extension (1989) and Section of Agro-irrigation (1988)

According to data shown in Table 2 and the assumption of the effects of other factors are constant, mathematical models for forecasting the possible trends of the variables of subcategories could be expressed as the following.

Major rice within irrigated area

$$LnA_t = -6.3255+0.4754LnWR_t+0.0113LnF_t-0.0216LnFP_{t-1} \quad \text{(2a)}$$
$$(R^2 = 0.9671)^{**}$$
$$F\text{-ratio} = 127.38 \{3.41\}$$

$$LnP_t = -8.9262+0.6507LnWr_t+0.0923LnF_t-0.0198LnFP_{t-1} \quad \text{(2b)}$$
$$(R^2 = 0.9303)^{**}$$
$$F\text{-ratio} = 57.84 \{3.41\}$$

$$LnY_t = -2.6007+0.1752LnWR_t+0.0810LnF_t+0.0018LnFP_{t-1} \quad \text{(2c)}$$
$$(R^2 = 0.7388)^{**}$$
$$F\text{-ratio} = 12.26 \{3.41\}$$

Major rice within non-irrigated area

$$LnA_t = 2.1520 - 0.3262LnWR_t + 0.2842LnF_t + 0.1367LnFP_{t-1} \quad \text{(3a)}$$
$$(R^2 = 0.7366)^{**} \qquad F\text{-ratio} = 11.93 \ \{3.41\}$$

$$LnP_t = -12.5017 - 0.3538LnWR_t + 0.3547LnF_t + 0.0679LnFP_{t-1} + 2.0357LnAR_t \quad \text{(3b)}$$
$$(R^2 = 0.7386)^{**} \qquad F\text{-ratio} = 6.36 \ \{3.63\}$$

$$LnY_t = -10.9312 + 1.525LnAR_t \quad \text{(3c)}$$
$$(R^2 = 0.5730)^{**}$$

Remark : $(R^2)^{**}$ = significant at 5% level
(R^2) = insignificant at 5% level
{ } = F-ratio required at 5% significatn level

For major rice within irrigated area, (Eq.2a to Eq.2c), may be concluded that 1% increasing of water resources development, A_t, P_t and Y_t will increase 0.4754, 0.6507 and 0.1752 percent respectively while 1% increasing rate of fertilizer usage will increase 0.0113, 0.0923 and 0.0810 percent for A_t, P_t and Y_t respectively. Unreasonable, there are converse relationships between farm price with planted area and production (Eq.2a and Eq.2b), but still reasonable with actual farm yield (Eq.2c).

The statistical values of R^2 means that all variables (WR_t, F_t, FP_{t-1}) are related to each parameter, (A_t, P_t and Y_t), at 96.71, 93.03 and 73.88% respectively.

In similarity the other equation may be interpreted by the similar way. For forecasting of Y_t (Eq.3c), there is no variable related to Y_t except annual rainfall (AR_t). Unfortunately, AR_t is different from other variables because of inability to control or forecast. However, Y_t may be predicted by using the average value of the records of annual rainfall.

According to the given data in Table 2, the annual increasing rate of water resources developed area, fertilizer usage and farm price is 4, 8 and 8 percent respectively. In addition with taking the average of the first three year data of such variables as the base year, the predicted values of A_t, P_t and Y_t could be obtained and those are shown in Table 3.

Table 3 Estimation of planted area (mil ha), rice production (mil ton) and actual farm yield (ton/ha) of major rice within irrigated and nonirrigated area.

Year	Planted Area (At)	Rice production (Pt)	Actual farm yield (Yt)	Zone of area
1995	2.80	10.04	3.56	Irrigated
2000	3.08	11.73	3.80	area
1995	9.19	13.58	1.43	Non
2000	10.14	14.91	1.43	irr. area

Table 4 Records of second rice production and important concerning factors.

Year	** At (ha)	** Pt (ton)	** Yt (ton/ha)	* WRt (ha)	* Ft (ton)	* FPt (฿/ton)
1977	490206	1664388	3.39	2575733	104338	1967
1978	644886	2133402	3.31	2667407	128635	1898
1979	407598	1308345	3.21	2835931	178500	2144
1980	645914	2453722	3.79	2990459	100940	2164
1981	741615	2606459	3.54	3171450	154092	3119
1982	685740	2307847	3.43	3320366	169453	3416
1983	728223	2648831	3.65	3464980	202490	2617
1984	706350	2630008	3.73	3658580	204125	2903
1985	637647	2334114	3.66	3822264	196071	2970
1986	580474	2042164	3.52	3911532	212143	2499

Source : * derived from Center for Agricultural Statistics (1980-1988) and Division of Agricultural Economics (1964-1978)
** derived from Committee of Dry Season Crop Planting and Extension (1989) and Section of Agro-irrigation (1988)

In similarity, data given in Table 4 are introduced to form the mathematical models to forecast A_t, P_t and Y_t for second rice. These equations are shown as the following.

$$\begin{aligned} LnA_t &= -6.9641+0.4393LnFP_{t-1}+2.2817LnAR_t \\ (R^2 &= 0.8905)^{**} \end{aligned} \qquad \text{(4a)}$$

F-ratio = 28.46 {4.74}

$$\begin{aligned} LnP_t &= -10.0426+0.4975LnFP_{t-1}+2.8065LnAR_t \\ (R^2 &= 0.8949)^{**} \end{aligned} \qquad \text{(4b)}$$

F-ratio = 29.80 {4.74}

$$\begin{aligned} LnY_t &= -4.5183+0.1624LnWR_t+0.4526LnAR_t \\ (R^2 &= 0.5844)^{**} \end{aligned} \qquad \text{(4c)}$$

F-ratio = 5.00 {4.74}

The relationship between FP_{t-1} and AR_t to A_t and P_t (Eq.4a and Eq.4b) are 89.05 and 89.49% respectively. Each 1% increasing (decreasing) of FP_{t-1} will increase (decrease) 0.4393 and 0.4975 % for A_t and P_t respectively. At the same time 1% increasing (decreasing) of AR_t will increase (decrease) 2.8065) percent of P_t. In equation 4c, 1% increasing rate of WR_t will increase 0.1624 percent to Y_t while 1% increasing rate of AR_t will increase 0.4526 percent to Y_t also.

By the assumption of the annual increasing rate of WR_t and FP_{t-1} at 4%. In addition with the annual rainfall is assumed constant (in this study the average value from year 1973 to 1986 is used). The approximate values of A_t, P_t and Y_t could be forecast by using the above models and using the average values of the first three year data as base year data. The predicted values mentioned above are presented in Table 5.

Table 5 Estimation of planted area (ha), rice production (ton) and actual farm yield (ton/ha) of second rice.

Year	Planted Area (At)	Rice production (Pt)	Actual farm yield (Yt)
1995	774481	2807488	3.84
2000	844130	3095074	3.96

Model II

Generally, combined rice, which composed of major rice in wet season and second rice in dry season, are deeply interested by the observers. The factors affecting to production and actual farm yield are list namely the ratio of water resources developed area to total planted area, rate of fertilizer application and ratio of high yield varieties growing area to the total planted area. The relationship analysis of these factors to actual farm yield (Y_o) and total production (P_o) are presented in Table 6.

Table 6 Analysis of important factors to actual farm yield and production of combined rice.

Items	Ratio of WRt to At (RWRt)	Rate of fertilizer used (RFt)	Ratio of HYVs area (RHYt)
Yo	SR	R	SR
Po	SR	SR	SR

From this analysis, the mathematical models in from of multiple regression can be formulated as the following.

$$Y_o = a_1 + b_1 RWR_t + b_2 RF_t + b_3 RHY_t \quad \text{(5a)}$$

$$P_o = a_1 + b_1 RWR_t + b_2 RF_t + b_3 RHY_t \quad \text{(5b)}$$

where

Y_o = actual farm yield of combined rice (ton/ha)
P_o = production of combined rice (mil.ton)
RF_t = rate of fertilizer used to the total planted area in combined rice in a particular year (kg/ha)
RHY_t = ratio of high yield varieties growing area (HYV_s) to total planted area of combined rice (A_T) in a particular year
RWR_t = ratio of water resources developed are (WR_t) to total planted area of combined rice (A_T) in a particular year

Table 7 Records of combined rice (major and second rice) and concerning factors.

Year	P_o mil. ton $	Y_o ton/ha $	Ratio of WRt to At	Rate of fertilizer used (kg/ha)	Ratio of HYVs area to At @
1970	13.85	2.013	0.31	26.63	0.4
1971	13.74	1.938	0.30	25.41	1.4
1972	12.41	1.831	0.34	37.32	4.1
1973	14.90	1.940	0.30	30.24	5.0
1974	13.39	1.782	0.32	25.79	5.5
1975	15.30	1.831	0.29	29.05	7.1
1976	15.07	1.845	0.30	39.59	11.3
1977	13.92	1.591	0.29	42.29	11.2
1978	17.47	1.955	0.30	47.01	11.8
1979	15.76	1.821	0.33	55.29	8.5
1980	17.37	1.888	0.33	45.75	-
1981	17.77	1.952	0.35	54.27	-
1982	16.88	1.888	0.37	60.77	-
1983	19.55	2.035	0.36	69.64	-
1984	19.91	2.067	0.38	67.28	-
1985	20.26	2.061	0.39	62.04	-
1986	18.87	2.052	0.43	71.79	-

Source : $ derived from ASEAN Agricultural Development Planning (1985 , 1989)
@ referred by Delane and Tonqpan (1973)

In addition with, given data in Table 7, the specific models for determining Y_o and P_o are constructed. The analysis of Y_o and P_o with three variables is unable to be accepted because its F-ratio is smaller than that required level. However, the mathematical models could be accepted by two variables analysis, RWR_t and RF_t. These models are illustrated in the following.

$$Y_o = 1.2395+2.1285RWR_t+0.0008RF_t \quad (R^2 = 0.3581)^{**} \qquad \text{F-ratio} = 3.91 \{3.74\} \quad (6a)$$

$$P_o = 10.6353+2.0189RWR_t+0.1355RF_t \quad (R^2 = 0.7402)^{**} \qquad \text{F-ratio} = 19.94 \{3.74\} \quad (6b)$$

The trends of Y_o and P_o (Eq.6a and Eq.6b) depend upon the variation of RWR_t and RF_t directly. The statistical values of R^2 show the compound relationship of these two variables to Y_o and P_o at 35.81 and 74.02% respectively. The prediction of Y_o and P_o may be proceeding on assumption of the annual increasing rate of RWR_t at 0.0063 per year and 3.0277 kg/ha per year of RF_t. The results of these models are expressed in Table 8.

Table 8 Prediction of actual farm yield and production of combined rice .

Year	Actual farm yield (ton/ha)	Production (mil. ton)
1995	2.27	24.81
2000	2.33	26.92

CONCLUSION

From the consideration of constraint factors analysis, it is concluded that rice production is closely accompanied with planted area, therefore expansion of planted area will make rice production increased. However, in future the paddy potential area is the limitation for increasing planted area, therefore increasing in yield will be the solution to expand production. To develop rice yield, expansion in command area of irrigation project is necessary as well as improvement in fertilizer application and replacement of high yielding variety to the local variety.

Various sources of data available, which lacking of precision, may provide unreasonable results. In this study it is found that there are the converse relationships between the farm price (FP) and planted area, production of major rice within irrigated area (Eq.2a and Eq.2b). According to this reason, trends of planted area and production in irrigated area may be not expected.

LITERATURE CITED

Asean Agricultural Development Planning Centre. 1985. Asean Statistical Yearbook on Food, Agriculture and Forestry 1970-1983. Bangkok

Asean Agricultural Development Planning Centre. 1989. Asean Statistical Yearbook on Food, Agriculture and Forestry 1978-1987. Bangkok.

Center for Agricultural Statistics. 1980-1988. Agricultural Statistics of Thailand Crop Year 1979/80-1987/88. Office of Agricultural Economics, Ministry of Agriculture & Co-operatives, Bangkok.

Committee of Dry Season Crop Planning and Extension. 1989. A Report of Dry Season Crop Planting for Crop Year 1988-1989. The Royal Irrigation Department, Ministry of Agriculture & Co-operatives, Bangkok.

Delane, E.W., and S. Tongpan. 1973. Background to the Introduction of High Yielding Varieties of Rice in Thailand. Department of Agricultural Economics, Faculty of Economics and Business Administration, Kasetsart University, Reprint series No. 3, 141 p.

Division of Agricultural Economics. 1964-1978. Agricultural Statistics of Thailand 1962-1977. Office of the Under-Secretary of State, Ministry of Agriculture & Co-operatives, Bangkok.

Section of Agro-irrigation. 1988. A Report of Acreage and Production of Major Rice within Irrigation Project Area 1987/1988. The Royal Irrigation Department, Ministry of Agriculture & Co-operatives, Bangkok.