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STOCHASTIC MODELS FOR THE EXPLANATION OF TREND IN PRODUCTION OF RICE IN KERALA FOR THE PERIOD 1957—1958 to 1971—1972

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Production of rice in Kerala State has increased from 925.47 thousand tonnes in 1957-'58 to 1351.74 thousand tonnes in 1971-'72. Various factors have contributed to this increase. Area under rice has increased from 766.8 thousand ha, in 1957-'58 to 875.2 thousand ha. in 1971-'52. Adoption of high yielding varieties of paddy and better management practices also have their own contributions. In this paper an attempt is made to study the trend in the production of rice as a function of area under the crop and also time. It is expected that development in technology will be taken care of by the trend in time.

Materials and Methods

Published data relating to production of rice and area under paddy have been utilised in this study. The data are furnished in Table 1.

Two types of models, viz; the exponential model and the log-normal model have been tried. The exponential model to explain production in terms of one factor (time t or area x) alone is

$$y_t = \text{Const. } e^{b_1 t} \quad \text{or} \quad y_t = \text{const. } e^{b_2 t} \qquad (1)$$

and in the case of two factors,

$$y_t = \text{const. } e^{b_1 t + b_2 t} \qquad (2)$$

The fitting of the exponential model is easy since the logarithm of y is linear in the factors involved.

In the log - normal model the logarithm of production at time t is assumed to be normal with mean equal to log y_T + b(t— T) and variance a(t— T), where y_T is the production during an earlier period T. This implies that,

$$P(\log y_t) = \frac{1}{\sqrt{2\pi a(t-T)}} \exp. \frac{-1}{2a(t-T)} [\log y_t - \log y_T - b(t-T)]^2 \qquad (3)$$

or

$$P(y_t) = \frac{1}{y_t\sqrt{2\pi a(t-T)}} \exp. \frac{-1}{2a(t-T)} [\log y_t - \log y_T - b(t-T)]^2 \qquad (4)$$

Table 1

Yearwise area and production of rice in Kerala and the expected trend in production

Period	t	Area (x) ('00,000 ha)	Production (y) ('000 tonnes)	Estimate of yt by equation number (15)	(16)	(17)	(18)	(19)
1957-58	0	7.668	925.47	946.20	997.70	974 30	925.47	925.47
1958-59	1	7.684	954 43	967.40	1002.00	984.90	952.30	938.70
1959-60	2	7.690	1037.94	989 10	1003.00	993.80	S80.20	952.00
1960-61	3	7.789	1067.53	1011.00	1027.00	1017.00	1009.00	970.20
1961-62	4	7 527	1003.96	1034.00	965.60	984.00	1039.00	978.10
1962-63	5	8.027	1093.21	1057 00	1085.00	1074.00	1069,00	1003.00
1963-64	6	8 051	1128.00	1080 00	1091.00	1086.00	1100.00	1029.00
1964-65	7	8.011	1121.38	1105.00	1031.00	1088 00	1132.00	1055.00
1965-66	8	8 023	997.49	1129.00	1084.00	1100.00	1165.00	1082.00
1966-67	9	7.994	1084.06	1154 00	1076 00	1104.00	1199.00	1109.00
1967-68	10	8.095	1123.90	1180.00	1103.00	1130.00	1234.00	1140.00
1968-69	11	8.739	1251.35	1207.00	1281.00	1262.00	1271.00	1195.00
1969-70	12	8.741	1226.41	1234.00	1288.00	1273.00	1308.00	1254.00
1970-71	13	8.748	1298.01	1261.00	1284.00	1284.00	1346.00	1316.00
1971-72	14	8.752	1351.74	1289.00	1285.00	1295.00	1386.00	1381.00

Source: Fact Book on Agriculture. Issued by the Agricultural Division, State Planning Board, 1969 and Farm Guides. 1971, 1972, 1973 and 1974. Published by the Farm Information Bureau Government of Kerala.

Since the data are at equal intervals of time of unity, and taking the initial period T = 0, the estimates of b and a are obtained by the maximum likelihood method as follows.

$$\hat{b} = (\log y_n - \log y_0)/n \quad (5)$$

$$\hat{a} = (1/n)\, \Sigma\, (\log y_j - \log y_{j-1})^2 - \hat{b}^2 \quad (6)$$

where the data are available from periods 0 to n. Here the expected value and variance of y_t are,

$$\hat{y}_t = y_0\, e^{b_0 t} \quad (7)$$

$$\hat{V}(y_t) = y_0^2 \cdot e^{2b_0 \cdot t} \cdot (e^{at} - 1) \quad (8)$$

where $b_0 = \hat{b} + \hat{a}/2$. (Tintner and Patel - 1965)

Another model is the log-normal process with mean $\log y_T + b_1 \int_T^t dt + b_2 \int_T^t x\,dt$,

and variance $a(t-T)$, such that

$$P(y_t) = \frac{1}{y_t\sqrt{2\pi a(t-T)}} \cdot \exp \frac{-1}{2a(t-T)} \left[\log y_t - \log y_T - b_1(t-T) - b_2(x)_T^t\right]^2$$

where $\int_T^t x\,dt = (x)_T^t$ (9)

Estimating the constants by the method of maximum likelihood, it is found that,

$$\hat{b}_1 = [\log (y_n/y_0) - b_2 \sum_1^n x_i]/n \quad (10)$$

$$\hat{b}_2 = \mathrm{Cov}(x_t, \log y_t/y_{t-1})/V(x_t) \quad (11)$$

$$\hat{a} = (1/n)\left[\sum (\log y_j/y_{j-1})^2 + \hat{b}_2^2 \sum_1^n x_j^2 - 2\hat{b}_2 \sum_1^n x_j \log y_j/y_{j-1}\right] - \hat{b}_1^2 \quad (12)$$

Here the expected production at time t is.

$$\hat{y}_t = y_0\, e^{b_0 t + b_2 \sum_1^t x_i} \quad (13)$$

$$\hat{V}(y_t) = y_0^2 \cdot e^{2(b_0 t + b_2 \sum_1^t x_i) + at} \cdot (e^{at} - 1) \quad (14)$$

(Tintner and Patel - 1965)

Results and Discussion

The exponential functions fitted to the data by taking (1) time alone (2) area alone, and (3) area and time are,

$$\hat{y}_t = 946.2 \times 1.022^t, \quad (15)$$

with $r^2 = 0.80$,

$$\hat{y}_t = 1{,}664 \times 1.263^{x} \quad (16)$$

with $i^2 = 0.84$ and

$$\hat{y}_t = 287{,}9 \times 1.172^{x} \times 1.008^{t} \qquad (17)$$

with $I^2 = 0.84$, where i = index of determination and I = index of multiple determination (Ezekiel and Fox - 1959)

Using the log - normal process, production can be estimated by the expected value. Expected value of y_t by (7) is,

$$\hat{y}_t = 925.47 \cdot e^{0.028829\, t} \qquad (18)$$

with $i^2 = 0.64$, and by (13)

$$\hat{y}_t = 925.47 \cdot e^{0.032018 \sum_{1}^{t} x_j - 0.231688\, t} \qquad (19)$$

with $I^2 = 0.66$.

The estimates of production using the fitted models (15), (16), (17), (18) and (19) are given in Table 1, along with the actual data.

Summary

Five different models were tried to explain the production of rice in terms of area (x), and period (t). The following results were obtained.

$$\hat{y}_t = 946.2 \times 1.022^{t} \qquad \text{with } r^2 = 0.80,$$

$$\hat{y}_t = 166.4 \times 1.263^{x} \qquad \text{with } i^2 = 0.84$$

$$\hat{y}_t = 287.9 \times 1.172^{x} \times 1.008^{t} \qquad \text{with } I^2 = 0.84$$

$$\hat{y}_t = 925.47 \cdot e^{0.028829\, t} \qquad \text{with } r^2 = 0.64 \text{ and}$$

$$\hat{y}_t = 925.47 \cdot e^{0.032018 \sum_{1}^{t} x_j - 0.231688\, t} \qquad \text{with } I^2 = 0.66$$

The values of the coefficients of determination show that these models fit the data satisfactorily.

സംഗ്രഹം

വിസ്തീർണ്ണത്തിന്റേയും കാലത്തിന്റേയും അടിസ്ഥാനത്തിൽ കേരളത്തിലെ അരിയുല്പാദനത്തിന്റെ പ്രവണത വിവരിക്കുവാനായി താഴെ കാണുന്ന അഞ്ചു വ്യത്യസ്ത മാതൃകകൾ പരീക്ഷിച്ചിരിക്കുന്നു.

$$\hat{y}_t = 946.2 \times 1.022^t, \quad i^2 = 0.80$$

$$\hat{y}_t = 166.4 \times 1.263^x, \quad i^2 = 0.84$$

$$\hat{y}_t = 287.9 \times 1.172^x \times 1.008^t, \quad I- = 0.84$$

$$\hat{y}_t = 925.47 \cdot e^{0.028829\, t}, \quad i^2 = 0.64$$

$$\hat{y}_t = 925.47 \cdot e^{0.032018 \sum_{1}^{t} x_i - 0.231688\, t}, \quad P = 0.66$$

ഈ മാതൃകകൾ ദത്തങ്ങളെ തൃപ്തികരമായ രീതിയിൽ ആസംജനം ചെയ്യുന്നവെന്നാണ് നിർധാരണ ഗുണാംക മൂല്യങ്ങൾ കാണിക്കുന്നത്.

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