Linear Modelling of The State-Wise Yield of Principal Crops in India

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ABSTRACT

Modelling techniques are applied in agriculture field. Yield of rice is modelled using the method of least squares in Time Series Analysis and linear equations are fitted for the state-wise average yield of crops in kg per hectare in India and also for the average yield of various principal crops in Tamil Nadu.

Keywords:
Crop Modelling, Time Series Analysis, Average Yield of Crops in India.

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1. Introduction

The statistical data from the agricultural department from the online sources for the past ten years are considered. The mathematical modelling techniques are applied to the observations obtained from the agriculture field. Yield of rice is modelled for the data taken. The method of least squares in Time Series Analysis (John 1984), (Meena, Subramanian and Gayathri 2014), (Gayathri and Subramanian 2016), (Somu 2015), (Yudo et. al. 2018) is considered. The linear equations are fitted for the state-wise average yield of crops in kg per hectare in India and also for the average yield of various principal crops in Tamil Nadu. The average yields of rice in India and also the variation of mean production of rice given in kg/hectare for the past ten years are computed. For the data taken in to consideration the co-efficient of variation of average yield of rice in India are evaluated. The mean yield of crops in Tamil Nadu for Rice, Jowar, Bajra, Maize, Ragi and Small Millets are calculated for the years from 2009 to 2014. The correlation coefficient (Efstathios 2018), (Siegfried, Piotr and Gilles 2018), (Hongyuan, Weidong, Zhou and Bernoulli 2018) between the actual yield and the expected yield of rice is graphically shown and it shows that the time series trend really depict the production of rice in India. Trend lines for the average yield of important crops in Tamil Nadu are obtained from the records of the agricultural survey. The expected yield of crops in Tamil Nadu for the years 2018-2024 are computed from the linear equations obtained from the linear Regression analysis. The obtained linear equations of the yield of rice in different states in India are useful to predict the growth and yield in upcoming years. The important crops yields are compared and the growths of crops in various states are compared. The modelling will be very much useful for the agricultural society to develop their production and profit.

2. Input / State-Wise Rice Average Yield In Kg/Hectare In India

| Year       | Andhra Pradesh | Arunachal Pradesh | Assam | Bihar | Chhattisgarh | Goa    | Gujarat |
|------------|----------------|-------------------|-------|-------|--------------|--------|---------|
| 2009-10    | 3062.5         | 1776.6            | 1737.2| 1120.0| 1119.8       | 2137.5 | 1902.8  |
| 2010-11    | 3034.7         | 1924.8            | 1842.8| 1095.2| 1663.5       | 2467.0 | 1852.2  |
| 2011-12    | 3148.2         | 2064.8            | 1780.2| 2154.9| 1597.4       | 2577.3 | 2141.1  |
| 2012-13    | 3172.5         | 2085.9            | 2061.1| 2282.4| 1746.2       | 2679.4 | 2198.3  |
| 2013-14    | 2921.2         | 2092.4            | 2011.8| 1758.6| 1766.5       | 2954.5 | 2076.1  |

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### 3. Statistical Analysis - Output

From the statistically observed data the mean of rice production in every States are obtained. Correspondingly the standard deviation, the co-efficient of variation is calculated for the respective yields of each state. The well known statistical Regression technique is used to find the straight line trend equations for the production of rice in different states in India and tabulated as shown below.

| States in India | Mean yield | Standard deviation | Co-efficient of variance | Straight line Trend |
|----------------|------------|--------------------|--------------------------|---------------------|
| Andhra Pradesh | 3068       | 3069               | 100.02625                | $Y_e = 3067.8284 - 14.4765X$ |
| Arunachal Pradesh | 1989  | 1992               | 100.16447                | $Y_e = 1988.8756 + 79.2655X$ |
| Assam          | 1887       | 1890               | 100.20275                | $Y_e = 1886.6273 + 76.7381X$ |
| Bihar          | 1682       | 1754               | 104.29565                | $Y_e = 1682.2018 + 246.4412X$ |
| Chhattisgarh   | 1579       | 1596               | 101.09168                | $Y_e = 1578.6680 + 137.6102X$ |
| State               | Latitude | Longitude | Mean Rainfall (mm) | Equation           |
|--------------------|----------|-----------|--------------------|--------------------|
| Goa                | 2563     | 2577      | 100.52286          | \( Y_c = 2563.1332 + 184.6176X \) |
| Gujarat            | 2034     | 2038      | 100.19396          | \( Y_c = 2034.1209 + 69.2748X \) |
| Haryana            | 3074     | 3078      | 100.15189          | \( Y_c = 3073.7814 + 97.8476X \) |
| Himachal Pradesh   | 1602     | 1606      | 100.22453          | \( Y_c = 1602.4452 + 44.4573X \) |
| Jammu & Kashmir    | 2262     | 2306      | 101.92290          | \( Y_c = 2262.0378 + 185.6359X \) |
| Jharkhand          | 1939     | 1965      | 101.37006          | \( Y_c = 1938.7393 + 208.0339X \) |
| Karnataka          | 2659     | 2660      | 100.05710          | \( Y_c = 2658.6132 + 28.0579X \) |
| Kerala             | 2574     | 2575      | 100.04257          | \( Y_c = 2573.9678 + 11.2873X \) |
| Madhya Pradesh     | 1253     | 1274      | 101.67938          | \( Y_c = 1253.1310 + 157.2510X \) |
| Maharashtra        | 1800     | 1808      | 100.42259          | \( Y_c = 1799.9897 + 108.5870X \) |
| Manipur            | 372      | 800       | 215.19816          | \( Y_c = 371.6390 + 351.4440X \) |
| Meghalaya          | 2086     | 2097      | 100.52189          | \( Y_c = 2085.7371 + 137.9273X \) |
| Mizoram            | 1424     | 1476      | 103.62410          | \( Y_c = 1423.9385 + 209.4009X \) |
| Nagaland           | 465      | 1014      | 218.15653          | \( Y_c = 464.7678 + 448.5418X \) |
| Odisha             | 1657     | 1663      | 100.33785          | \( Y_c = 1657.0846 + 67.0878X \) |
| Punjab             | 3906     | 3907      | 100.02305          | \( Y_c = 3905.7515 + 5.3823X \) |
| Rajasthan          | 1869     | 1881      | 100.64929          | \( Y_c = 1868.8211 + 100.9854X \) |
| Sikkim             | 1786     | 1787      | 100.01712          | \( Y_c = 1786.4336 - 4.4716X \) |
| Tamil Nadu         | 3168     | 3193      | 100.77891          | \( Y_c = 3167.8862 - 26.6588X \) |
| Tripura            | 2712     | 2713      | 100.02230          | \( Y_c = 2712.2596 + 53.1774X \) |
| Uttar Pradesh      | 2294     | 2299      | 100.22396          | \( Y_c = 2293.5237 + 106.5908X \) |
| Uttarkhand         | 2117     | 2121      | 100.16918          | \( Y_c = 2117.1476 + 74.6601X \) |
| West Bengal        | 2684     | 2685      | 100.03309          | \( Y_c = 2684.2123 + 60.2044X \) |
| A. & N. Islands    | 2728     | 2751      | 100.87412          | \( Y_c = 2727.6417 - 217.0906X \) |
| D. & N. Haveli     | 1115     | 1432      | 128.48953          | \( Y_c = 1114.8150 + 563.9998X \) |
| Daman & Diu        | 1693     | 1694      | 100.03481          | \( Y_c = 1693.4000 + 37.2000X \) |
| Delhi              | 3269     | 3370      | 103.08003          | \( Y_c = 3269.3331 + 429.1156X \) |
| Puducherry         | 2728     | 2739      | 100.37877          | \( Y_c = 2728.4382 + 154.7642X \) |
The mean yield of crops in Tamil Nadu for Rice, Jowar, Bajra, Maize, Ragi and Small Millets are calculated for the years from 2009 to 2014. Trend lines for the average yield of important crops in Tamil Nadu are obtained from the records of the agricultural survey. The trend lines for the average yield of important crops in Tamil Nadu are obtained using time series analysis of regression technique and tabulated and shown in the table 3. For the years 2009 to 2014 the mean yield of crops like rice, jowar, bajra, maize, ragi and small millets are computed and listed as below.

Table 2. Yield of mean production of crops in India.

| Year  | Rice  | Jowar | Bajra | Maize | Ragi  | Small millets |
|-------|-------|-------|-------|-------|-------|---------------|
| 2009-10 | 3069.7 | 929.1 | 1512.3 | 4685.3 | 1976.2 | 939.6 |
| 2010-11 | 3039.5 | 1014.5 | 1563.6 | 4457.7 | 2260.2 | 1042.6 |
| 2011-12 | 3917.8 | 1277.4 | 2452.3 | 6041.7 | 2715.4 | 1210.3 |
| 2012-13 | 2712.4 | 851.2 | 1326.1 | 3251.9 | 1967.1 | 1009.5 |
| 2013-14 | 3100.0 | 1295.1 | 2158.2 | 5372.2 | 3052.6 | 1085.1 |
| Mean   | 3168  | 1073  | 1803  | 4762  | 2394  | 1057 |

Table 3. Trend lines for the average yield of important crops in Tamil Nadu

| Crops     | Trend line $Y_e$       | Mean value $\bar{Y}$ |
|-----------|------------------------|----------------------|
| Rice      | $Y_e = 3167.8862 - 26.6588X$ | 3168                 |
| Jowar     | $Y_e = 1073.4600 + 56.8700X$ | 1073                 |
| Bajra     | $Y_e = 1802.5000 + 105.4300X$ | 1803                 |
| Maize     | $Y_e = 4761.7600 + 16.8000X$ | 4762                 |
| Ragi      | $Y_e = 2394.3000 + 185.9700X$ | 2394                 |
| Small millets | $Y_e = 1057.4200 + 25.7900X$ | 1057                 |

The figure(1) shows that the average yields of rice in India and also the variation of mean production of rice given in kg/hectare for the past ten years. The figure(2) shows that the co-efficient of variation of average yield of rice in India for the data taken in to consideration. The figure (3) shows that the expected yield of crops in Tamil Nadu for the years 2018-2024. The figure (4) gives the correlation coefficient ‘r’ between the actual yield and the expected yield of the various states in India.

Figure 1. Average yield of rice in India for the past 10 years.

Figure 2. Co-efficient of variation of rice production in India.

5. Results Of The Mathematical Technique

The expected values of the average yield of important crops in Tamil Nadu are obtained and shown graphically for the better understanding. The values are computed from the linear regression model as per the time series analysis.

Table 4. Expected values of the average yield of important crops in Tamil Nadu

| Crops     | Expected value of $Y_e$ for the years 2018-2019 | Expected value of $Y_e$ for the years 2019-2020 | Expected value of $Y_e$ for the years 2020-2021 | Expected value of $Y_e$ for the years 2021-2022 | Expected value of $Y_e$ for the years 2022-2023 | Expected value of $Y_e$ for the years 2023-2024 |
|-----------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Rice      | 3007.9334                                      | 2981.2746                                     | 2954.6158                                     | 2927.9570                                     | 2901.2982                                     | 2874.6394                                     |
Figure 3. Expected yield of crops in Tamil Nadu for the years 2018-2024.

Table 5. Expected values of the average yield rice in India using the linear trend lines.

| States in India       | Expected value of $Y_e$ for the years 2017-2018 | Expected value of $Y_e$ for the years 2018-2019 | Expected value of $Y_e$ for the years 2019-2020 | Expected value of $Y_e$ for the years 2020-2021 | Expected value of $Y_e$ for the years 2022-2023 | Expected value of $Y_e$ for the years 2023-2024 |
|-----------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Andhra Pradesh        | 2980.9694                                       | 2966.4929                                       | 2952.0164                                       | 2937.5399                                       | 2923.0634                                       | 2908.5869                                       |
| Arunachal Pradesh     | 2464.4686                                       | 2543.7341                                       | 2622.9996                                       | 2702.2651                                       | 2781.5306                                       | 2860.7961                                       |
| Assam                 | 2347.0556                                       | 2423.7936                                       | 2500.5317                                       | 2577.2697                                       | 2654.0078                                       | 2730.7458                                       |
| Bihar                 | 3160.8490                                       | 3407.2902                                       | 3653.7314                                       | 3900.1726                                       | 4146.6138                                       | 4393.0550                                       |
| Chhattisgarh          | 2404.6941                                       | 2542.3651                                       | 2680.0362                                       | 2817.7072                                       | 2955.3782                                       | 3093.0492                                       |
| Goa                   | 3670.8388                                       | 3855.4564                                       | 4040.0740                                       | 4224.6916                                       | 4409.3092                                       | 4593.9268                                       |
| Gujarat               | 2449.7697                                       | 2519.0445                                       | 2588.3193                                       | 2657.5941                                       | 2726.8689                                       | 2796.1437                                       |
| Haryana               | 3660.8670                                       | 3758.7146                                       | 3856.5622                                       | 3954.4098                                       | 4052.2574                                       | 4150.1050                                       |
| Himachal Pradesh      | 1869.1890                                       | 1913.6463                                       | 1958.1036                                       | 2002.5609                                       | 2047.0182                                       | 2091.4755                                       |
| Jammu & Kashmir       | 3375.8532                                       | 3561.4891                                       | 3747.1250                                       | 3932.7609                                       | 4118.3968                                       | 4304.0327                                       |
| Jharkhand             | 3186.9427                                       | 3394.9766                                       | 3603.0105                                       | 3811.0444                                       | 4019.0783                                       | 4227.1122                                       |
| Karnataka             | 2826.9606                                       | 2855.0185                                       | 2883.0764                                       | 2911.1343                                       | 2939.1922                                       | 2967.2501                                       |
| Kerala                | 2641.6916                                       | 2652.9789                                       | 2664.2662                                       | 2675.5535                                       | 2686.8408                                       | 2698.1281                                       |
| Madhya Pradesh        | 2196.6370                                       | 2353.8880                                       | 2511.1390                                       | 2668.3900                                       | 2825.6410                                       | 2982.8920                                       |
| Maharashtra           | 2451.5117                                       | 2560.0987                                       | 2668.6857                                       | 2777.2727                                       | 2885.8597                                       | 2994.4467                                       |
Table 6. Expected values of the average yield rice in India using the proposed linear trend lines.

| States in India | Expected value of Y for the years 2009-2010 | Expected value of Y for the years 2010-2011 | Expected value of Y for the years 2011-2012 | Expected value of Y for the years 2012-2013 | Expected value of Y for the years 2013-2014 | Correlation between actual yield and expected yield |
|-----------------|-------------------------------------------|-------------------------------------------|-------------------------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------------|
| Andhra Pradesh | 3096.7815                                 | 3082.3050                                 | 3067.8284                                 | 3053.3519                                 | 3038.8754                                 | 0.2287                                         |
| Arunachal Pradesh | 1830.3446                              | 1909.6101                                 | 1988.8756                                 | 2068.1411                                 | 2147.4066                                 | 0.9149                                         |
| Assam           | 1733.1512                                 | 1809.8892                                 | 1886.6273                                 | 1963.3653                                 | 2040.1034                                 | 0.8491                                         |
| Bihar           | 1189.3194                                 | 1435.7606                                 | 1682.2018                                 | 1928.6430                                 | 2175.0842                                 | 0.6020                                         |
| Chhattisgarh    | 1303.3260                                 | 1440.9970                                 | 1578.6680                                 | 1716.3390                                 | 1854.0100                                 | 0.8202                                         |
| Goa             | 2193.8980                                 | 2378.5156                                 | 2563.1332                                 | 2747.7508                                 | 2932.3684                                 | 0.9768                                         |
| Gujrat          | 1895.5713                                 | 1964.8461                                 | 2034.1209                                 | 2103.3957                                 | 2172.6705                                 | 0.7282                                         |
| Haryana         | 2878.0862                                 | 2975.9338                                 | 3073.7814                                 | 3171.6290                                 | 3269.4766                                 | 0.7760                                         |
| Himachal Pradesh| 1513.5306                                 | 1557.9879                                 | 1602.4452                                 | 1646.9025                                 | 1691.3598                                 | 0.5483                                         |
| Jammu & Kashmir | 1890.7660                                 | 2076.4019                                 | 2262.0378                                 | 2447.6737                                 | 2633.3096                                 | 0.5856                                         |
| Jharkhand       | 1522.6715                                 | 1730.7054                                 | 1938.7393                                 | 2146.7732                                 | 2354.8071                                 | 0.9051                                         |
| Karnataka       | 2602.4974                                 | 2630.5553                                 | 2658.6132                                 | 2686.6711                                 | 2714.7290                                 | 0.3830                                         |
| Kerala          | 2551.3932                                 | 2562.6805                                 | 2573.9678                                 | 2585.2551                                 | 2596.5424                                 | 0.1761                                         |
| Madhya Pradesh  | 938.6290                                  | 1095.8800                                 | 1253.1310                                 | 1410.3820                                 | 1567.6330                                 | 0.9531                                         |
| Maharashtra     | 1582.8157                                 | 1691.4027                                 | 1799.9897                                 | 1908.5767                                 | 2017.1637                                 | 0.8980                                         |
| Manipur         | -331.2490                                 | 20.1950                                  | 371.6390                                  | 723.0830                                  | 1074.5270                                 | 0.7016                                         |
| Meghalaya       | 1809.8825                                 | 1947.8098                                 | 2085.7371                                 | 2223.6644                                 | 2361.5917                                 | 0.8939                                         |
| Mizoram         | 2480.3030                                 | 2831.7470                                 | 3183.1910                                 | 3534.6350                                 | 3886.0790                                 | 0.7620                                         |
Table 7. Expected values of the average yield of important crops in Tamil Nadu using proposed trend lines.

| Crops       | Expected value of $Y_e$ for the years 2017-2018 | Expected value of $Y_e$ for the years 2018-2019 | Expected value of $Y_e$ for the years 2019-2020 | Expected value of $Y_e$ for the years 2020-2021 | Expected value of $Y_e$ for the years 2021-2022 | Expected value of $Y_e$ for the years 2023-2024 |
|-------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Rice        | 3221.2038                                        | 3194.5450                                        | 3167.8862                                        | 3141.2274                                        | 3114.5686                                        | 0.0942                                          |
| Jowar       | 959.7200                                         | 1016.5900                                        | 1073.4600                                        | 1130.3300                                        | 1187.2000                                        | 0.4435                                          |
| Bajra       | 1591.6400                                        | 1697.0700                                        | 1802.5000                                        | 1907.9300                                        | 2013.3600                                        | 0.3482                                          |
| Maize       | 4728.1600                                        | 4744.9600                                        | 4761.7600                                        | 4778.5600                                        | 4795.3600                                        | 0.0254                                          |
| Ragi        | 2022.3600                                        | 2208.3300                                        | 2394.3000                                        | 2580.2700                                        | 2766.2400                                        | 0.6159                                          |
| Small millets | 1005.8400                                          | 1031.6300                                        | 1057.4200                                        | 1083.2100                                        | 1109.0000                                        | 0.4051                                          |

Figure 4. The correlation coefficient between the actual yield and the expected yield.
Conclusion and Future Study

The obtained linear equations of the yield of rice in different states in India are useful to predict the growth and yield in upcoming years. The important crops yields are compared and the growths of crops in various states are compared. The modelling will be very much useful for the agricultural society to develop their production and profit. The results and observations obtained from the least square modelling technique we can say that the statistical Time series analysis plays a vital role in the agricultural field. The correlation coefficient shows that the above said statement is true. This study can be extended to find the most affecting factor of the yield of rice using multi linear regression analysis.

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