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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.

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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Year	Haryana	Himachal Pradesh	Jammu & Kashmir	Jharkhand	Karnataka	Kerala	Madhya Pradesh
2009-10	3008.3	1380.8	1913.8	1546.1	2482.2	2556.8	872.0
2010-11	2788.8	1672.9	1942.5	1541.0	2719.5	2452.0	1105.6
2011-12	3043.7	1704.5	2077.6	2131.0	2793.1	2733.3	1340.1
2012-13	3272.4	1629.1	3126.4	2237.5	2632.2	2576.7	1474.0
2013-14	3255.7	1624.9	2250.0	2238.0	2666.1	2551.0	1474.0

Year	Maharashtra	Manipur	Meghalaya	Mizoram	Nagaland	Odisha	Punjab
2009-10	1485.0	18.9	1910.3	938.8	14.3	1584.7	4010.0
2010-11	1776.0	24.5	1911.6	1160.3	21.0	1615.8	3828.0
2011-12	1841.2	26.4	1988.3	1410.9	21.1	1450.1	3741.0
2012-13	1963.4		2125.4	2087.7		1813.5	3997.9
2013-14	1934.3	1788.4	2493.0	1522.1	2267.5	1821.3	3951.9

Year	Rajasthan	Sikkim	Tamil Nadu	Tripura	Uttar Pradesh	Uttara-khand	West Bengal
2009-10	1515.0	1869.2	3069.7	2606.1	2083.6	2068.0	2547.2
2010-11	2025.1	1727.3	3039.5	2655.3	2119.9	1901.2	2638.7
2011-12	1886.0	1729.9	3917.8	2700.4	2357.8	2121.4	2688.0
2012-13	1771.0	1790.3	2712.4	2799.8	2459.6	2206.4	2759.5
2013-14	2147.0	1815.4	3100.0	2799.7	2446.7	2288.7	2787.7

Year	A. & N. Islands	D.&N. Haveli	Daman & Diu	Delhi	Puducherry
2009-10	3059.0	10.8	1650	2834.4	2503.8
2010-11	2850.5	19.3	1650	2786.7	2596.2
2011-12	2960.5	1739.5	1650	2884.7	2538.0
2012-13	2738.9	1928.1	1712	2935.3	2856.9
2013-14	2029.4	1876.4	1805	4905.6	3147.3

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.

Table 1. Straight line trend equation for the expected yield of rice in India (state-wise).

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	$Y_e = 1578.6680 + 137.6102X$

Goa	2563	2577	100.52286	$Y_e = 2563.1332 + 184.6176X$
Gujarat	2034	2038	100.19396	$Y_e = 2034.1209 + 69.2748X$
Haryana	3074	3078	100.15189	$Y_e = 3073.7814 + 97.8476X$
Himachal Pradesh	1602	1606	100.22453	$Y_e = 1602.4452 + +44.4573X$
Jammu & Kashmir	2262	2306	101.92290	$Y_e = 2262.0378 + 185.6359X$
Jharkhand	1939	1965	101.37006	$Y_e = 1938.7393 + 208.0339X$
Karnataka	2659	2660	100.05710	$Y_e = 2658.6132 + 28.0579X$
Kerala	2574	2575	100.04257	$Y_e = 2573.9678 + 11.2873X$
Madhya Pradesh	1253	1274	101.67938	$Y_e = 1253.1310 + 157.2510X$
Maharashtra	1800	1808	100.42259	$Y_e = 1799.9897 + 108.5870X$
Manipur	372	800	215.19816	$Y_e = 371.6390 + 351.4440X$
Meghalaya	2086	2097	100.52189	$Y_e = 2085.7371 + 137.9273X$
Mizoram	1424	1476	103.62410	$Y_e = 1423.9385 + 209.4009X$
Nagaland	465	1014	218.15653	$Y_e = 464.7678 + 448.5418X$
Odisha	1657	1663	100.33785	$Y_e = 1657.0846 + 67.0878X$
Punjab	3906	3907	100.02305	$Y_e = 3905.7515 + 5.3823X$
Rajasthan	1869	1881	100.64929	$Y_e = 1868.8211 + 100.9854X$
Sikkim	1786	1787	100.01712	$Y_e = 1786.4336 - 4.4716X$
Tamil Nadu	3168	3193	100.77891	$Y_e = 3167.8862 - 26.6588X$
Tripura	2712	2713	100.02230	$Y_e = 2712.2596 + 53.1774X$
Uttar Pradesh	2294	2299	100.22396	$Y_e = 2293.5237 + 106.5908X$
Uttarkand	2117	2121	100.16918	$Y_e = 2117.1476 + 74.6601X$
West Bengal	2684	2685	100.03309	$Y_e = 2684.2123 + 60.2044X$
A. & N. Islands	2728	2751	100.87412	$Y_e = 2727.6417 - 217.0906X$
D. & N. Haveli	1115	1432	128.48953	$Y_e = 1114.8150 + 563.9998X$
Daman & Diu	1693	1694	100.03481	$Y_e = 1693.4000 + 37.2000X$
Delhi	3269	3370	103.08003	$Y_e = 3269.3331 + 429.1156X$
Puducherry	2728	2739	100.37877	$Y_e = 2728..4382 + 154.7642X$

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 Ye**	**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.

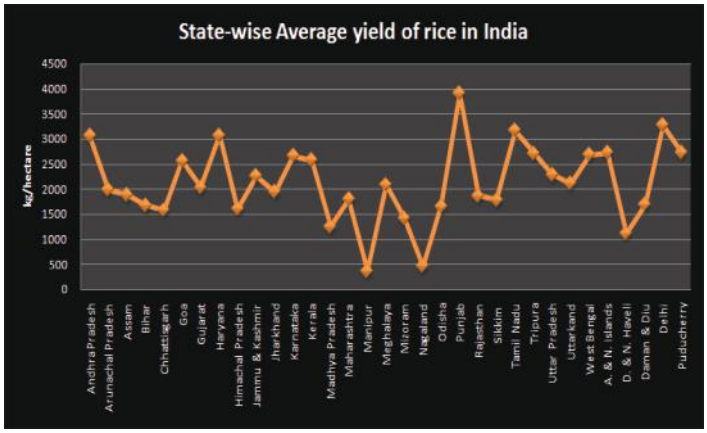

Figure 1. Average yield of rice in India for the past 10 years.

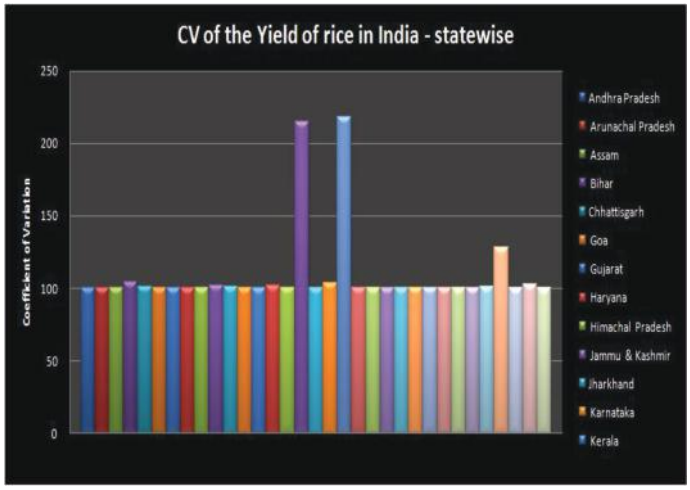

Figure 2. Co-efficient of variation of rice production in India.

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

Jowar	1414.6800	1471.5500	1528.4200	1585.2900	1642.1600	1699.0300
Bajra	2435.0800	2540.5100	2645.9400	2751.3700	2856.8000	2962.2300
Maize	4862.5600	4879.3600	4896.1600	4912.9600	4929.7600	4946.5600
Ragi	3510.1200	3696.0900	3882.0600	4068.0300	4254.0000	4439.9700
Small millets	1212.1600	1237.9500	1263.7400	1289.5300	1315.3200	1341.1100

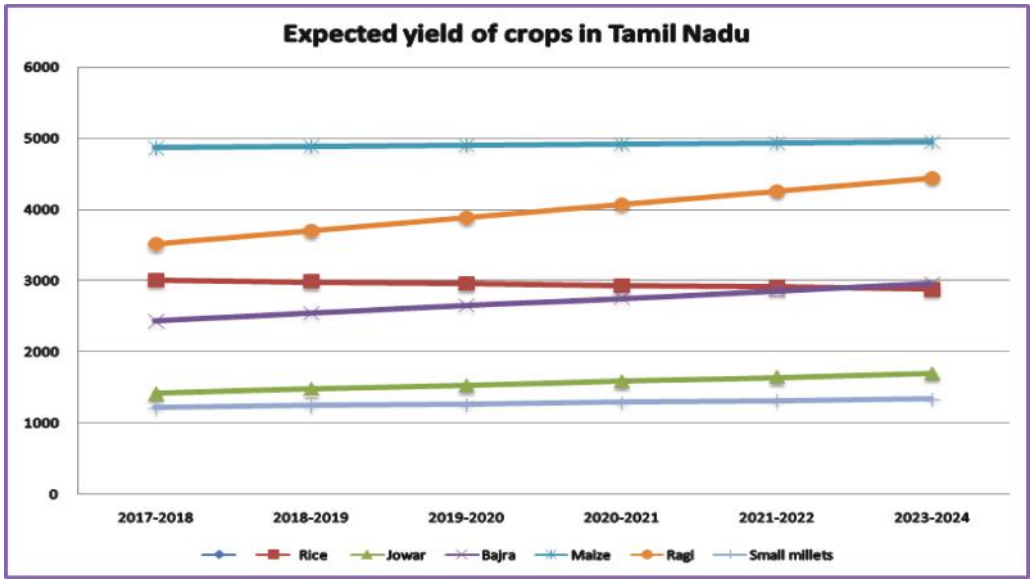

Figure 3. Expected yield of crops in Tamil Nadu for the years 2018-2024.

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

Manipur	2480.3030	2831.7470	3183.1910	3534.6350	3886.0790	4237.5230
Meghalaya	2913.3009	3051.2282	3189.1555	3327.0828	3465.0101	3602.9374
Mizoram	2480.3030	2831.7470	3183.1910	3534.6350	3886.0790	3727.3484
Nagaland	3156.0186	3604.5604	4053.1022	4501.6440	4950.1858	5398.7276
Odisha	2059.6114	2126.6992	2193.7870	2260.8748	2327.9626	2395.0504
Punjab	3938.0453	3943.4276	3948.8099	3954.1922	3959.5745	3964.9568
Rajasthan	2474.7335	2575.7189	2676.7043	2777.6897	2878.6751	2979.6605
Sikkim	1759.6040	1755.1324	1750.6608	1746.1892	1741.7176	1737.2460
Tamil Nadu	3007.9334	2981.2746	2954.6158	2927.9570	2901.2982	2874.6394
Tripura	3031.3240	3084.5014	3137.6788	3190.8562	3244.0336	3297.2110
Uttar Pradesh	2933.0685	3039.6593	3146.2501	3252.8409	3359.4317	3466.0225
Uttarakhand	2565.1082	2639.7683	2714.4284	2789.0885	2863.7486	2938.4087
West Bengal	3045.4387	3105.6431	3165.8475	3226.0519	3286.2563	3346.4607
A. & N. Islands	1425.0981	1208.0075	990.9169	773.8263	556.7357	339.6451
D. & N. Haveli	4498.8138	5062.8136	5626.8134	6190.8132	6754.8130	7318.8128
Daman & Diu	1916.6000	1953.8000	1991.0000	2028.2000	2065.4000	2102.6000
Delhi	5844.0267	6273.1423	6702.2579	7131.3735	7560.4891	7989.6047
Puducherry	3657.0234	3811.7876	3966.5518	4121.3160	4276.0802	4430.8444

Table 6. Expected values of the average yield rice in India using the proposed linear trend lines.

States in India	Expected value of Y_e for the years 2009-2010	Expected value of Y_e for the years 2010-2011	Expected value of Y_e for the years 2011-2012	Expected value of Y_e for the years 2012-2013	Expected value of Y_e 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
Gujarat	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

Nagaland	-432.3158	16.2260	464.7678	913.3096	1361.8514	0.7037
Odisha	1522.9090	1589.9968	1657.0846	1724.1724	1791.2602	0.6668
Punjab	3894.9869	3900.3692	3905.7515	3911.1338	3916.5161	0.0727
Rajasthan	1666.8503	1767.8357	1868.8211	1969.8065	2070.7919	0.6561
Sikkim	1795.3768	1790.9052	1786.4336	1781.9620	1777.4904	0.1179
Tamil Nadu	3221.2038	3194.5450	3167.8862	3141.2274	3114.5686	0.0942
Tripura	2605.9048	2659.0822	2712.2596	2765.4370	2818.6144	0.9714
Uttar Pradesh	2080.3421	2186.9329	2293.5237	2400.1145	2506.7053	0.9370
Uttarakhand	1967.8274	2042.4875	2117.1476	2191.8077	2266.4678	0.8028
West Bengal	2563.8035	2624.0079	2684.2123	2744.4167	2804.6211	0.9862
A. & N. Islands	3161.8229	2944.7323	2727.6417	2510.5511	2293.4605	0.8406
D. & N. Haveli	-13.1846	550.8152	1114.8150	1678.8148	2242.8146	0.8861
Daman & Diu	1619.0000	1656.2000	1693.4000	1730.6000	1767.8000	0.8660
Delhi	2411.1019	2840.2175	3269.3331	3698.4487	4127.5643	0.7403
Puducherry	2418.9098	2573.6740	2728.4382	2883.2024	3037.9666	0.8993

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

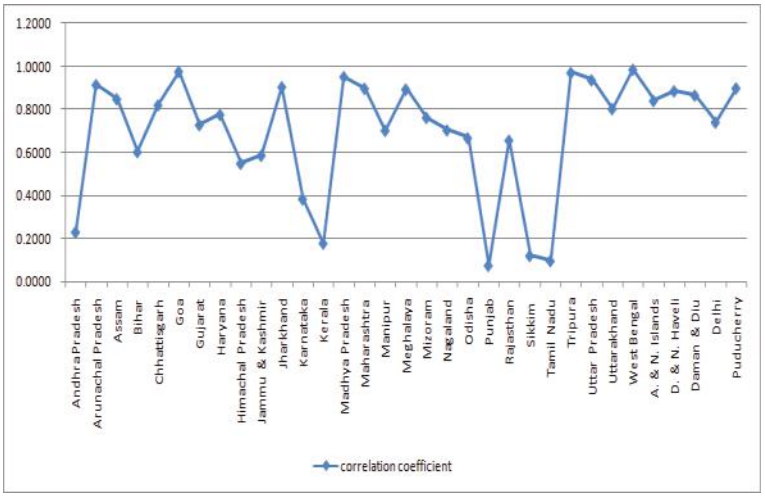

Figure 4. The correlation coefficient between the actual yield and the expected yield.

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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