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Contents

Abstract

Time series analysis is an important part of statistical analysis. Here in our project we are wising to analyse the production of Yield-Per Hector – Food grain from the year 1963-64 to 2019-20. Here we have four types of dataset as follows rice, wheat, Coarse Cereals, pulses. From the data we have worked out several outcomes by using statistical methodology. At first we have plotted the all datasets in Microsoft Excel to find out the curves of the datasets so that we can study the trends of them. Then from the trends we have studied our data with help of different time series methods, models (polynomial trend, moving average, exponential smoothing). After doing these steps we have found our best forecasted models for every dataset, those suitably our datasets. Then we get our study variable and also the predicting equation which help us to do forecast of upcoming time periods. Our main objectives for forecasting the crop production to derive a reliable estimate on the production of major agricultural commodities (Rice, Wheat, Coarse cereals and Pulse).

As there is no seasonality or cyclic variation in our datasets, we do not need to verify the methods that are used for seasonal or cyclic variation.

1. Introduction:

Agriculture sector in India has always been the backbone of the economy. As roughly 70-75% of the population depends directly or indirectly on agricultural sector (RBI source). Different studies have found that in 1950-51, India's agricultural sector contributes almost 57% share of total National Income (NI) and 54.66% share of county's total Gross Domestic product (GDP) (Dutt & Sundaram)[1]. In present time, though the share of NI and the share of GDP decline to 17% and 20% respectively of total NI and GDP of India, but still 1/6th of NI income of India come from agricultural sector (V.K.Puri and S.K. Misra)[2]. As time went on agriculture continued to grow. A vast increase in agricultural output that has been brought about in India since 1960 by 'Green Revolution'. By using high-Yielding seeds, modern fertilizers in 1960-61 the food-grain production increased from 82.0 million tonnes to 272.0 million tonnes (Ajoy Kumar Nandi)[3].

This food grain production can be projected by time series analysis.

In this context, in our work, we have worked on the data of "Production of Yield per Hector Food-grain", from the year 1963-64 to 2019-20. We have done our forecasting by different models of time series analysis. Our main objective for forecasting the crop production to derive a reliable estimate on the production of major agricultural commodities (Rice, Wheat, Coarse cereals and Pulse).

Here, point 2 derives the methodology; point 3 describes the results and the next point concludes the project.

[1] See Dutt & Sundaram, Indian Economy, 72nd Edition, S Chand and Company Pvt. In this context.

[2] See V.K.Puri and S.K.Misra, Indian Economy, 35th Revised Edition, Himalayan Publishing House. In this context.

[3] See Ajoy Kumar Nandi, An Outline of Micro Economics & Indian Economy, B.B. Kundu Grandsons. In this context.

2. Methodology:

(i) Study of the data Set: We are working on the secondary data. After observing the above data, we have found there are four types of datasets; Rice, Wheat, Coarse Cereals, Pulse. As we have taken year wise data, there are no seasonal or cyclic variation among these four datasets .So we need not use the measurements (ratio to trend, harmonic analysis etc.) related to seasonal variation and cyclic variations. Here we have tried to analysis all the fours datasets by time series analysis and other statistical measurements.

(ii) Identification of the variables: Here, in this data we have taken all the four datasets. Here we denote four datasets by four variables. They are as follows,

A: Rice production per hector

B: Wheat production per hector

C: Coarse Cereals production per hector

D: Pulse production per hector

(iii) Theoretical reference of analysis:

1. Gun, A.M, Gupta, M.K & Dasgupta, B.D (2019) Fundamental of Statistics VOL- 2, Analysis of time series. The World Press Private Limited. Pp.404-412

2. Gupta, S.C & Kapoor, V.K (2020) Fundamental of Applied Statistics, Analysis of time series. Sultan Chand & Sons. Pp.2.26-2.33

3. Das, N.G (2010) Statistical Methods (Volume I & II), Time series. Tata McGraw Hill education private limited, Pp.632-674

4. Dutt & Sundaram, Indian Economy, 72nd Edition, S Chand and Company Pvt.

5. V.K.Puri and S.K.Misra, Indian Economy, 35th Revised Edition, Himalayan Publishing House.

6. Ajoy Kumar Nandi, An Outline of Micro Economics & Indian Economy, B.B. Kundu Grandsons.

7. https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

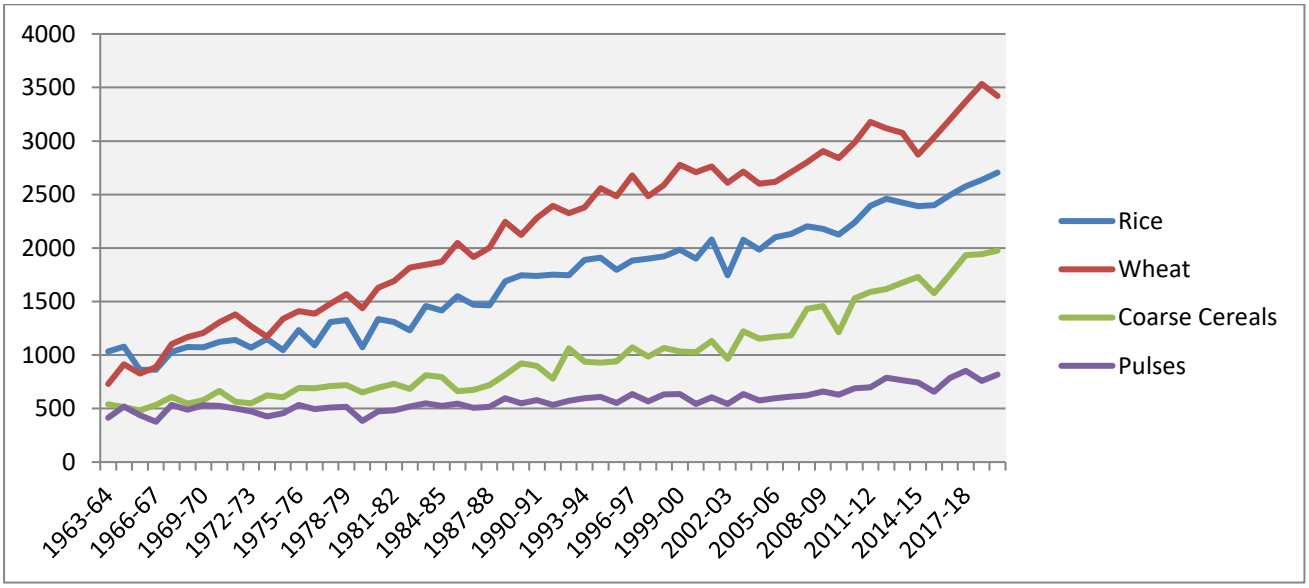
Analysis of the data:

For analysis of our dataset we have done following steps.

Plotting the graphs of all four data sets:

At first we have plotted the graphs of all four datasets (Rice, Wheat, Coarse Cereals and Pulses) by using Excel software. Here we use the line diagram to understand the production fluctuations of different years and also it is easy to everyone for understanding how the data is changing.

Figure: 1 Multiple line diagram showing the production of Rice, Wheat, Coarse Cereals, Pulses from 1963-64 to 2019-20



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Finding trend lines:

Straight line:

Here we are interested about the trend of the data, so that we can forecast or give a prediction about production of four types of yields for upcoming years.

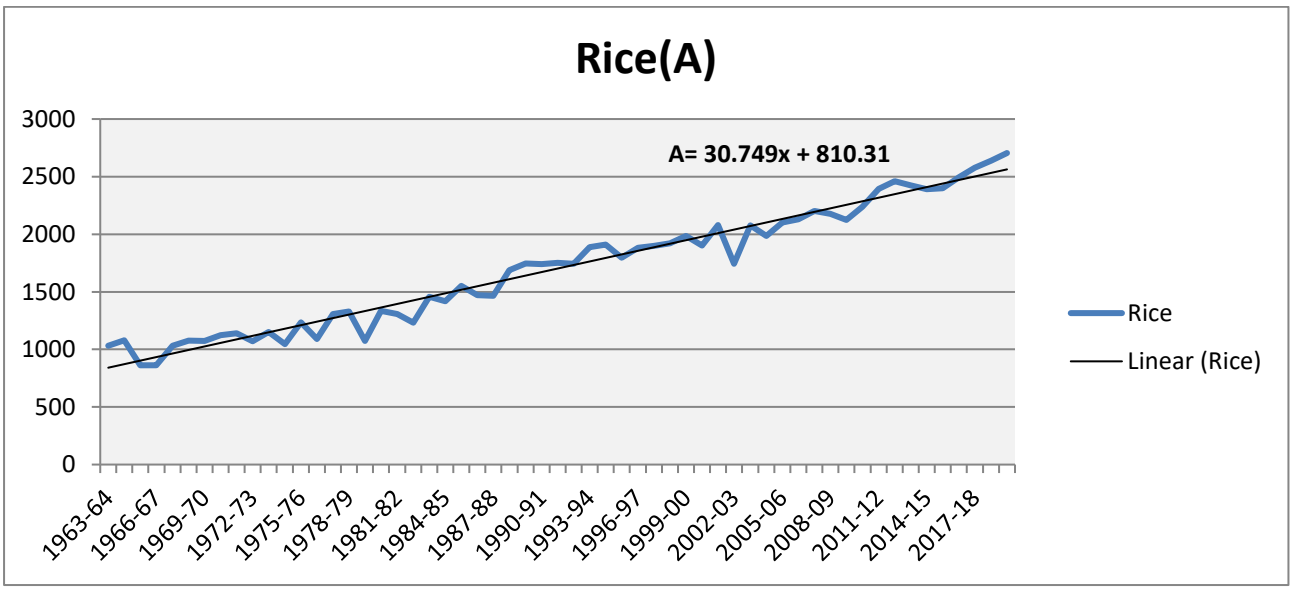
For finding the best trend line for each of the yield production, we use least square method (straight line and polynomial) and method of moving average.

For trend line equation of straight line we put each of the four dataset in Excel and draw the trend line also it gives the trend equation. Now we put a new column 'value of x 'where we give each year a number from 1 up to 57, as we have 57 observation in each data set. Now by putting the 'values of x' column on trend equation. Then the equation gives us trend values for different years.

We can also compute the trend values manually or using calculator. In case of straight line trend we assume an equation of a straight line $= a + bx$, say and then we find out 'a' and 'b' such that for given values of 'y' corresponding the 57 different values of 'x'. For details theoretical derivation one may see the reference. After finding 'a' and 'b' we put them in our straight line equation and we get our predicting equation. As our data is in year interval form so we take the middle point of every year interval (If the interval is 1963-64, we take 1963.5). Here the origin changes[4] and it goes to 6 months (if we consider July-1963 to July-1964). Now we find out a new value by origin shifting. For details of this theoretical derivation part, one may see the reference.

Straight line trend for Rice production:

Figure: 2 Graph Showing Linear Trend for Rice Production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 1 Table for calculation of linear trend

Year	mid value	Rice(A)	x	A= 30.749x + 810.31
1963-64	1963.5	1033	1	841.059
1964-65	1964.5	1078	2	871.808
1965-66	1965.5	862	3	902.557
1966-67	1966.5	863	4	933.306
1967-68	1967.5	1032	5	964.055
1968-69	1968.5	1076	6	994.804

[4] For details of this theoretical derivation part, one can refer Das, N.G (2010) Statistical Methods (Volume-i & ii), and Time Series. Tata McGraw Hill Education Private Limited, Pp.632-674

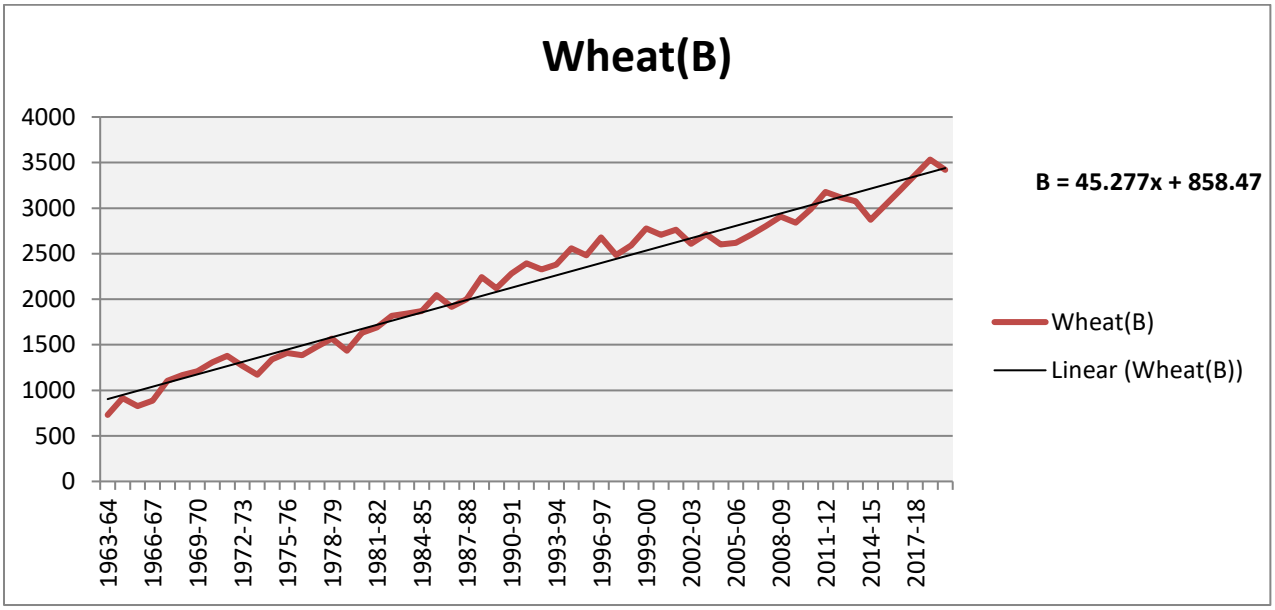
1969-70	1969.5	1073	7	1025.553
1970-71	1970.5	1123	8	1056.302
1971-72	1971.5	1141	9	1087.051
1972-73	1972.5	1070	10	1117.8
1973-74	1973.5	1151	11	1148.549
1974-75	1974.5	1045	12	1179.298
1975-76	1975.5	1235	13	1210.047
1976-77	1976.5	1089	14	1240.796
1977-78	1977.5	1308	15	1271.545
1978-79	1978.5	1328	16	1302.294
1979-80	1979.5	1074	17	1333.043
1980-81	1980.5	1336	18	1363.792
1981-82	1981.5	1308	19	1394.541
1982-83	1982.5	1231	20	1425.29
1983-84	1983.5	1457	21	1456.039
1984-85	1984.5	1417	22	1486.788
1985-86	1985.5	1552	23	1517.537
1986-87	1986.5	1471	24	1548.286
1987-88	1987.5	1465	25	1579.035
1988-89	1988.5	1689	26	1609.784
1989-90	1989.5	1745	27	1640.533
1990-91	1990.5	1740	28	1671.282
1991-92	1991.5	1751	29	1702.031
1992-93	1992.5	1744	30	1732.78
1993-94	1993.5	1888	31	1763.529
1994-95	1994.5	1911	32	1794.278
1995-96	1995.5	1797	33	1825.027
1996-97	1996.5	1882	34	1855.776
1997-98	1997.5	1900	35	1886.525
1998-99	1998.5	1921	36	1917.274
1999-00	1999.5	1986	37	1948.023
2000-01	2000.5	1901	38	1978.772
2001-02	2001.5	2079	39	2009.521
2002-03	2002.5	1744	40	2040.27
2003-04	2003.5	2077	41	2071.019
2004-05	2004.5	1984	42	2101.768
2005-06	2005.5	2102	43	2132.517
2006-07	2006.5	2131	44	2163.266
2007-08	2007.5	2202	45	2194.015
2008-09	2008.5	2178	46	2224.764
2009-10	2009.5	2125	47	2255.513
2010-11	2010.5	2239	48	2286.262
2011-12	2011.5	2393	49	2317.011
2012-13	2012.5	2461	50	2347.76

2013-14	2013.5	2424	51	2378.509
2014-15	2014.5	2390	52	2409.258
2015-16	2015.5	2400	53	2440.007
2016-17	2016.5	2494	54	2470.756
2017-18	2017.5	2576	55	2501.505
2018-19	2018.5	2638	56	2532.254
2019-20	2019.5	2705	57	2563.003

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Straight line trend for Wheat production:-

Figure: 3 Graph showing linear trend for Wheat production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 2Table for calculation of linear trend

Year	Wheat(B)	x	B = 45.277x + 858.47
1963-64	730	1	903.747
1964-65	913	2	949.024
1965-66	827	3	994.301
1966-67	887	4	1039.578
1967-68	1103	5	1084.855
1968-69	1169	6	1130.132
1969-70	1208	7	1175.409
1970-71	1307	8	1220.686
1971-72	1380	9	1265.963
1972-73	1271	10	1311.24
1973-74	1172	11	1356.517
1974-75	1338	12	1401.794

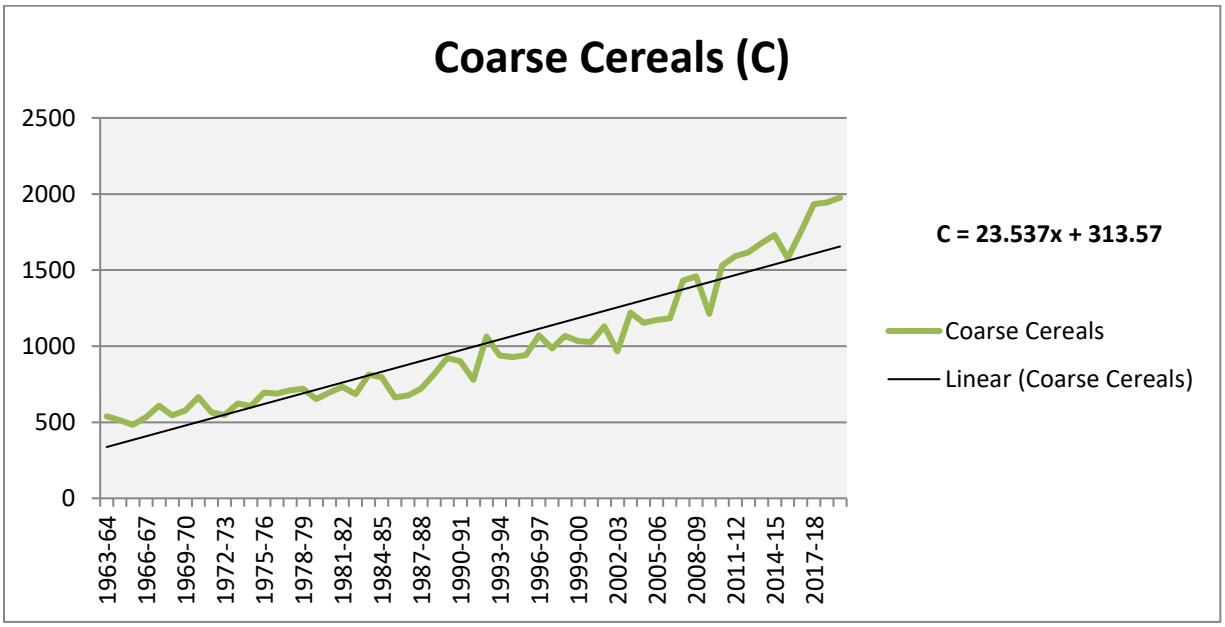
1975-76	1410	13	1447.071
1976-77	1387	14	1492.348
1977-78	1480	15	1537.625
1978-79	1568	16	1582.902
1979-80	1436	17	1628.179
1980-81	1630	18	1673.456
1981-82	1691	19	1718.733
1982-83	1816	20	1764.01
1983-84	1843	21	1809.287
1984-85	1870	22	1854.564
1985-86	2046	23	1899.841
1986-87	1916	24	1945.118
1987-88	2002	25	1990.395
1988-89	2244	26	2035.672
1989-90	2121	27	2080.949
1990-91	2281	28	2126.226
1991-92	2394	29	2171.503
1992-93	2327	30	2216.78
1993-94	2380	31	2262.057
1994-95	2559	32	2307.334
1995-96	2483	33	2352.611
1996-97	2679	34	2397.888
1997-98	2485	35	2443.165
1998-99	2590	36	2488.442
1999-00	2778	37	2533.719
2000-01	2708	38	2578.996
2001-02	2762	39	2624.273
2002-03	2610	40	2669.55
2003-04	2713	41	2714.827
2004-05	2602	42	2760.104
2005-06	2619	43	2805.381
2006-07	2708	44	2850.658
2007-08	2802	45	2895.935
2008-09	2907	46	2941.212
2009-10	2839	47	2986.489
2010-11	2988	48	3031.766
2011-12	3177	49	3077.043
2012-13	3117	50	3122.32
2013-14	3075	51	3167.597
2014-15	2872	52	3212.874
2015-16	3034	53	3258.151
2016-17	3200	54	3303.428
2017-18	3368	55	3348.705
2018-19	3533	56	3393.982

2019-20	3421	57	3439.259

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Straight line trend for Coarse Cereals production:-

Figure: 4 Graph showing linear trend for Coarse Cereals production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 3 Table for calculation of linear Trend

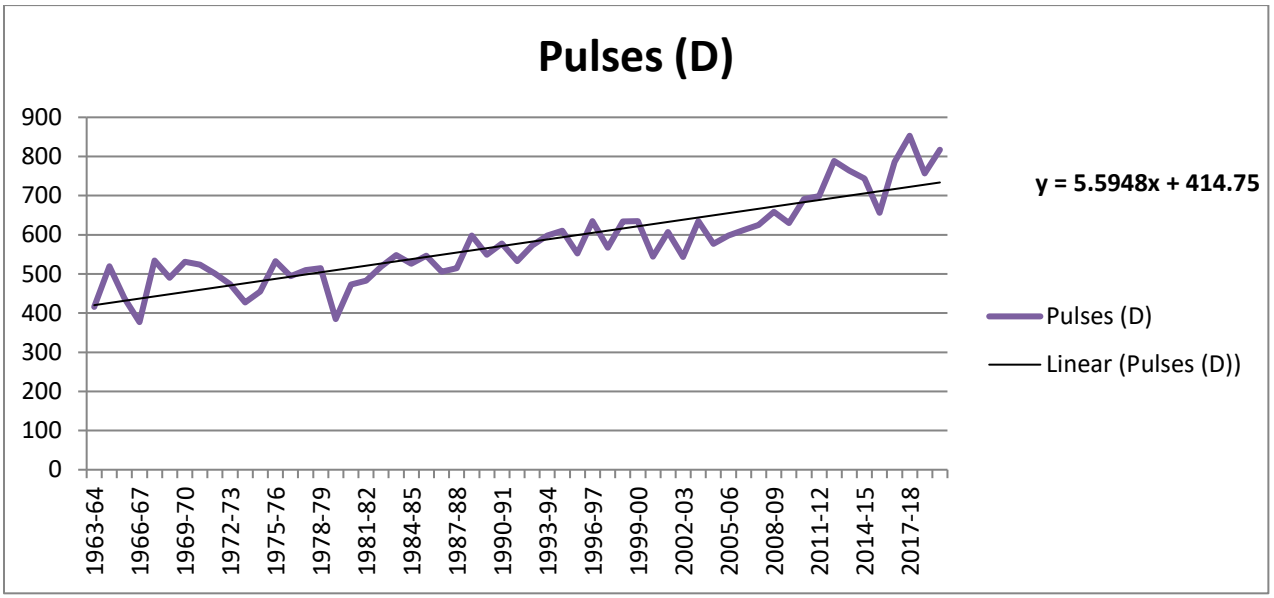
Year	Coarse Cereals	x	C = 23.537x + 313.57
1963-64	540	1	337.107
1964-65	514	2	360.644
1965-66	483	3	384.181
1966-67	533	4	407.718
1967-68	608	5	431.255
1968-69	545	6	454.792
1969-70	578	7	478.329
1970-71	665	8	501.866
1971-72	564	9	525.403
1972-73	548	10	548.94
1973-74	623	11	572.477
1974-75	606	12	596.014
1975-76	694	13	619.551
1976-77	689	14	643.088
1977-78	710	15	666.625
1978-79	721	16	690.162
1979-80	652	17	713.699

1980-81	695	18	737.236
1981-82	733	19	760.773
1982-83	685	20	784.31
1983-84	813	21	807.847
1984-85	795	22	831.384
1985-86	664	23	854.921
1986-87	675	24	878.458
1987-88	721	25	901.995
1988-89	814	26	925.532
1989-90	922	27	949.069
1990-91	900	28	972.606
1991-92	778	29	996.143
1992-93	1063	30	1019.68
1993-94	939	31	1043.217
1994-95	929	32	1066.754
1995-96	940	33	1090.291
1996-97	1072	34	1113.828
1997-98	986	35	1137.365
1998-99	1068	36	1160.902
1999-00	1034	37	1184.439
2000-01	1027	38	1207.976
2001-02	1131	39	1231.513
2002-03	966	40	1255.05
2003-04	1221	41	1278.587
2004-05	1153	42	1302.124
2005-06	1172	43	1325.661
2006-07	1182	44	1349.198
2007-08	1431	45	1372.735
2008-09	1459	46	1396.272
2009-10	1212	47	1419.809
2010-11	1531	48	1443.346
2011-12	1590	49	1466.883
2012-13	1617	50	1490.42
2013-14	1677	51	1513.957
2014-15	1729	52	1537.494
2015-16	1579	53	1561.031
2016-17	1750	54	1584.568
2017-18	1934	55	1608.105
2018-19	1944	56	1631.642
2019-20	1976	57	1655.179

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Straight line trend for Pulses production:-

Figure: 5 Graph showing linear Trend for Pulse production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 4 Table for calculation of liner trend of Pulse production (per hector)

Year	Pulses (D)	x	y = 5.5948x + 414.75
1963-64	416	1	420.3448
1964-65	520	2	425.9396
1965-66	438	3	431.5344
1966-67	377	4	437.1292
1967-68	534	5	442.724
1968-69	490	6	448.3188
1969-70	531	7	453.9136
1970-71	524	8	459.5084
1971-72	501	9	465.1032
1972-73	474	10	470.698
1973-74	427	11	476.2928
1974-75	455	12	481.8876
1975-76	533	13	487.4824
1976-77	494	14	493.0772
1977-78	510	15	498.672
1978-79	515	16	504.2668
1979-80	385	17	509.8616
1980-81	473	18	515.4564
1981-82	483	19	521.0512
1982-83	519	20	526.646
1983-84	548	21	532.2408
1984-85	526	22	537.8356

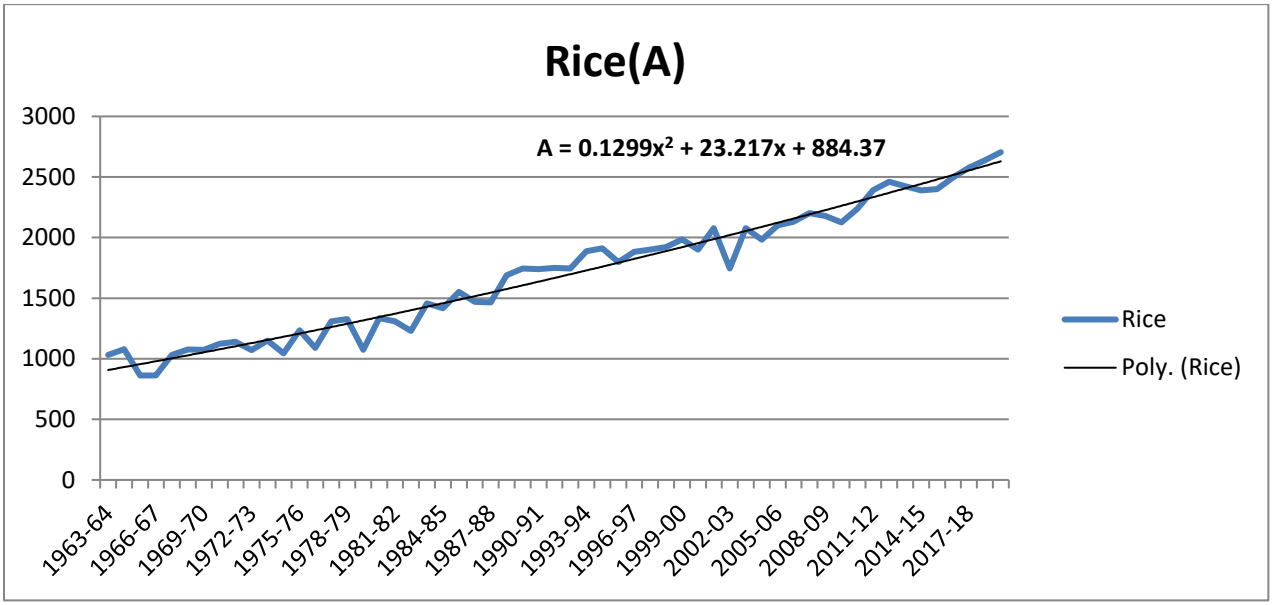
1985-86	547	23	543.4304
1986-87	506	24	549.0252
1987-88	515	25	554.62
1988-89	598	26	560.2148
1989-90	549	27	565.8096
1990-91	578	28	571.4044
1991-92	533	29	576.9992
1992-93	573	30	582.594
1993-94	598	31	588.1888
1994-95	610	32	593.7836
1995-96	552	33	599.3784
1996-97	635	34	604.9732
1997-98	567	35	610.568
1998-99	634	36	616.1628
1999-00	635	37	621.7576
2000-01	544	38	627.3524
2001-02	607	39	632.9472
2002-03	543	40	638.542
2003-04	635	41	644.1368
2004-05	577	42	649.7316
2005-06	598	43	655.3264
2006-07	612	44	660.9212
2007-08	625	45	666.516
2008-09	659	46	672.1108
2009-10	630	47	677.7056
2010-11	691	48	683.3004
2011-12	699	49	688.8952
2012-13	789	50	694.49
2013-14	764	51	700.0848
2014-15	744	52	705.6796
2015-16	656	53	711.2744
2016-17	786	54	716.8692
2017-18	853	55	722.464
2018-19	757	56	728.0588
2019-20	817	57	733.6536

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial Trend for the datasets: - For polynomial trend we use 1st, 2nd and 3rd degree polynomial for best outcome. Here we follow the same method to find out polynomial trend equations that we have done to find out straight-line trend equation.

Polynomial trend (2nd degree) for Wheat production:-

Figure: 6 Graph showing second degree polynomial trend for Rice production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 5 Table for calculation of second degree polynomial trend for Rice production

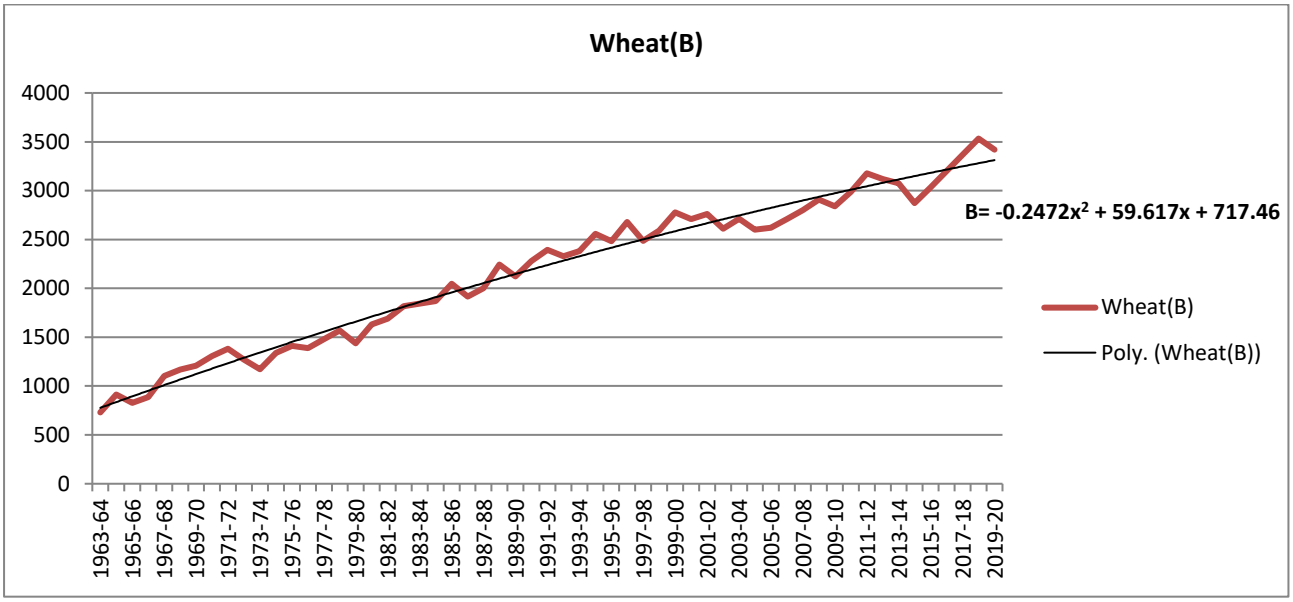
Year	Rice(A)	x	A = 0.1299x² + 23.217x + 884.37
1963-64	1033	1	907.7169
1964-65	1078	2	931.3236
1965-66	862	3	955.1901
1966-67	863	4	979.3164
1967-68	1032	5	1003.7025
1968-69	1076	6	1028.3484
1969-70	1073	7	1053.2541
1970-71	1123	8	1078.4196
1971-72	1141	9	1103.8449
1972-73	1070	10	1129.53
1973-74	1151	11	1155.4749
1974-75	1045	12	1181.6796
1975-76	1235	13	1208.1441
1976-77	1089	14	1234.8684
1977-78	1308	15	1261.8525
1978-79	1328	16	1289.0964

1979-80	1074	17	1316.6001
1980-81	1336	18	1344.3636
1981-82	1308	19	1372.3869
1982-83	1231	20	1400.67
1983-84	1457	21	1429.2129
1984-85	1417	22	1458.0156
1985-86	1552	23	1487.0781
1986-87	1471	24	1516.4004
1987-88	1465	25	1545.9825
1988-89	1689	26	1575.8244
1989-90	1745	27	1605.9261
1990-91	1740	28	1636.2876
1991-92	1751	29	1666.9089
1992-93	1744	30	1697.79
1993-94	1888	31	1728.9309
1994-95	1911	32	1760.3316
1995-96	1797	33	1791.9921
1996-97	1882	34	1823.9124
1997-98	1900	35	1856.0925
1998-99	1921	36	1888.5324
1999-00	1986	37	1921.2321
2000-01	1901	38	1954.1916
2001-02	2079	39	1987.4109
2002-03	1744	40	2020.89
2003-04	2077	41	2054.6289
2004-05	1984	42	2088.6276
2005-06	2102	43	2122.8861
2006-07	2131	44	2157.4044
2007-08	2202	45	2192.1825
2008-09	2178	46	2227.2204
2009-10	2125	47	2262.5181
2010-11	2239	48	2298.0756
2011-12	2393	49	2333.8929
2012-13	2461	50	2369.97
2013-14	2424	51	2406.3069
2014-15	2390	52	2442.9036
2015-16	2400	53	2479.7601
2016-17	2494	54	2516.8764
2017-18	2576	55	2554.2525
2018-19	2638	56	2591.8884
2019-20	2705	57	2629.7841

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (2nd degree) Trend for Wheat:-

Figure: 7 Graph Showing 2nd degree polynomial trend for Wheat Production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 6 Table for calculation of second degree polynomial trend for Wheat production

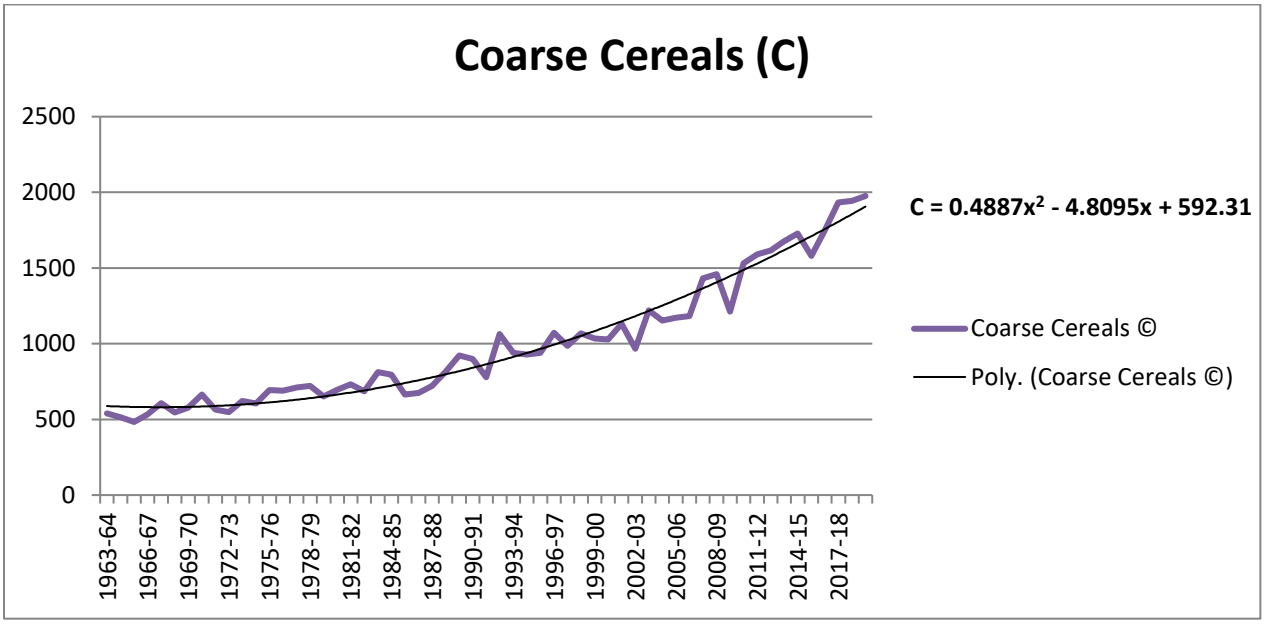
Year	Wheat(B)	x	B= -0.2472x² + 59.617x + 717.46
1963-64	730	1	773.8298
1964-65	913	2	832.7052
1965-66	827	3	891.0862
1966-67	887	4	948.9728
1967-68	1103	5	1006.365
1968-69	1169	6	1063.2628
1969-70	1208	7	1119.6662
1970-71	1307	8	1175.5752
1971-72	1380	9	1230.9898
1972-73	1271	10	1285.91
1973-74	1172	11	1340.3358
1974-75	1338	12	1394.2672
1975-76	1410	13	1447.7042
1976-77	1387	14	1500.6468
1977-78	1480	15	1553.095
1978-79	1568	16	1605.0488
1979-80	1436	17	1656.5082
1980-81	1630	18	1707.4732
1981-82	1691	19	1757.9438
1982-83	1816	20	1807.92

1983-84	1843	21	1857.4018
1984-85	1870	22	1906.3892
1985-86	2046	23	1954.8822
1986-87	1916	24	2002.8808
1987-88	2002	25	2050.385
1988-89	2244	26	2097.3948
1989-90	2121	27	2143.9102
1990-91	2281	28	2189.9312
1991-92	2394	29	2235.4578
1992-93	2327	30	2280.49
1993-94	2380	31	2325.0278
1994-95	2559	32	2369.0712
1995-96	2483	33	2412.6202
1996-97	2679	34	2455.6748
1997-98	2485	35	2498.235
1998-99	2590	36	2540.3008
1999-00	2778	37	2581.8722
2000-01	2708	38	2622.9492
2001-02	2762	39	2663.5318
2002-03	2610	40	2703.62
2003-04	2713	41	2743.2138
2004-05	2602	42	2782.3132
2005-06	2619	43	2820.9182
2006-07	2708	44	2859.0288
2007-08	2802	45	2896.645
2008-09	2907	46	2933.7668
2009-10	2839	47	2970.3942
2010-11	2988	48	3006.5272
2011-12	3177	49	3042.1658
2012-13	3117	50	3077.31
2013-14	3075	51	3111.9598
2014-15	2872	52	3146.1152
2015-16	3034	53	3179.7762
2016-17	3200	54	3212.9428
2017-18	3368	55	3245.615
2018-19	3533	56	3277.7928
2019-20	3421	57	3309.4762

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (2nd degree) Trend for Coarse Cereals:-

Figure: 8 Graph showing 2nd degree polynomial trend for Coarse Cereals production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 7 Table for calculation of second degree polynomial trend for Coarse Cereals production

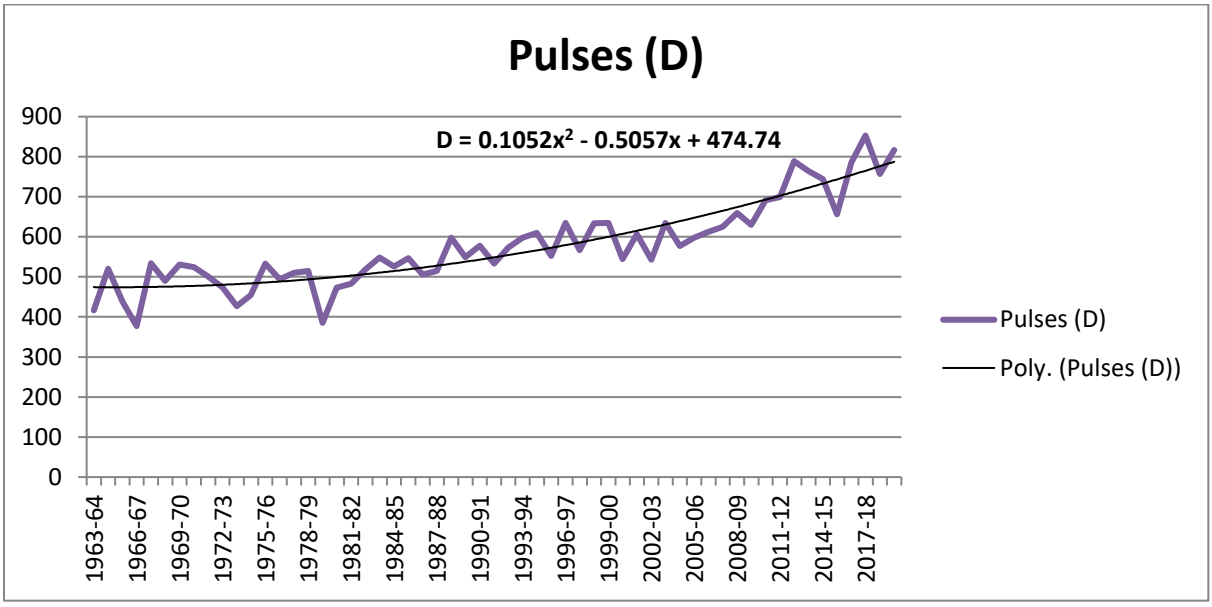
Year	Coarse Cereals (C)	x	$C = 0.4887x^2 - 4.8095x + 592.31$
1963-64	540	1	587.9892
1964-65	514	2	584.6458
1965-66	483	3	582.2798
1966-67	533	4	580.8912
1967-68	608	5	580.48
1968-69	545	6	581.0462
1969-70	578	7	582.5898
1970-71	665	8	585.1108
1971-72	564	9	588.6092
1972-73	548	10	593.085
1973-74	623	11	598.5382
1974-75	606	12	604.9688
1975-76	694	13	612.3768
1976-77	689	14	620.7622
1977-78	710	15	630.125
1978-79	721	16	640.4652
1979-80	652	17	651.7828
1980-81	695	18	664.0778

1981-82	733	19	677.3502
1982-83	685	20	691.6
1983-84	813	21	706.8272
1984-85	795	22	723.0318
1985-86	664	23	740.2138
1986-87	675	24	758.3732
1987-88	721	25	777.51
1988-89	814	26	797.6242
1989-90	922	27	818.7158
1990-91	900	28	840.7848
1991-92	778	29	863.8312
1992-93	1063	30	887.855
1993-94	939	31	912.8562
1994-95	929	32	938.8348
1995-96	940	33	965.7908
1996-97	1072	34	993.7242
1997-98	986	35	1022.635
1998-99	1068	36	1052.5232
1999-00	1034	37	1083.3888
2000-01	1027	38	1115.2318
2001-02	1131	39	1148.0522
2002-03	966	40	1181.85
2003-04	1221	41	1216.6252
2004-05	1153	42	1252.3778
2005-06	1172	43	1289.1078
2006-07	1182	44	1326.8152
2007-08	1431	45	1365.5
2008-09	1459	46	1405.1622
2009-10	1212	47	1445.8018
2010-11	1531	48	1487.4188
2011-12	1590	49	1530.0132
2012-13	1617	50	1573.585
2013-14	1677	51	1618.1342
2014-15	1729	52	1663.6608
2015-16	1579	53	1710.1648
2016-17	1750	54	1757.6462
2017-18	1934	55	1806.105
2018-19	1944	56	1855.5412
2019-20	1976	57	1905.9548

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (2nd degree) Trend for Pulses:

Figure: 9 Graph showing 2nd degree polynomial trend for Pulses production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 8 Table for calculation of second degree polynomial trend for Pulse production:-

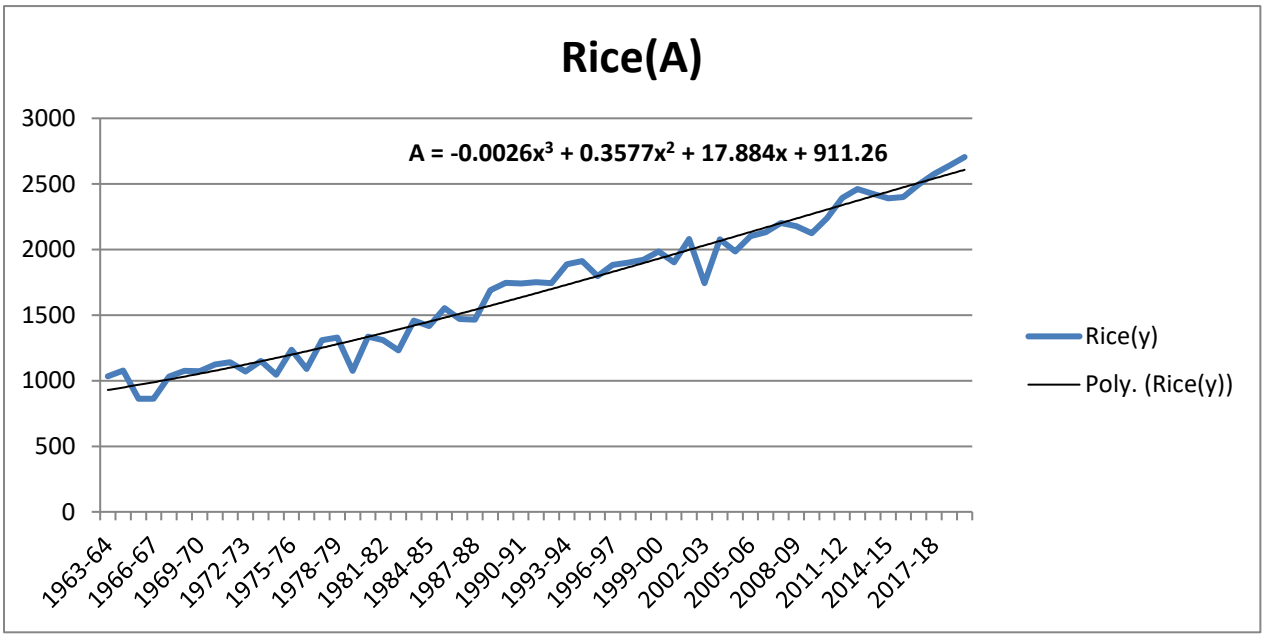
Year	Pulses (D)	x	D = 0.1052x² - 0.5057x + 474.74
1963-64	416	1	474.3395
1964-65	520	2	474.1494
1965-66	438	3	474.1697
1966-67	377	4	474.4004
1967-68	534	5	474.8415
1968-69	490	6	475.493
1969-70	531	7	476.3549
1970-71	524	8	477.4272
1971-72	501	9	478.7099
1972-73	474	10	480.203
1973-74	427	11	481.9065
1974-75	455	12	483.8204
1975-76	533	13	485.9447
1976-77	494	14	488.2794
1977-78	510	15	490.8245
1978-79	515	16	493.58
1979-80	385	17	496.5459
1980-81	473	18	499.7222
1981-82	483	19	503.1089
1982-83	519	20	506.706

1983-84	548	21	510.5135
1984-85	526	22	514.5314
1985-86	547	23	518.7597
1986-87	506	24	523.1984
1987-88	515	25	527.8475
1988-89	598	26	532.707
1989-90	549	27	537.7769
1990-91	578	28	543.0572
1991-92	533	29	548.5479
1992-93	573	30	554.249
1993-94	598	31	560.1605
1994-95	610	32	566.2824
1995-96	552	33	572.6147
1996-97	635	34	579.1574
1997-98	567	35	585.9105
1998-99	634	36	592.874
1999-00	635	37	600.0479
2000-01	544	38	607.4322
2001-02	607	39	615.0269
2002-03	543	40	622.832
2003-04	635	41	630.8475
2004-05	577	42	639.0734
2005-06	598	43	647.5097
2006-07	612	44	656.1564
2007-08	625	45	665.0135
2008-09	659	46	674.081
2009-10	630	47	683.3589
2010-11	691	48	692.8472
2011-12	699	49	702.5459
2012-13	789	50	712.455
2013-14	764	51	722.5745
2014-15	744	52	732.9044
2015-16	656	53	743.4447
2016-17	786	54	754.1954
2017-18	853	55	765.1565
2018-19	757	56	776.328
2019-20	817	57	787.7099

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (3rd degree) Trend for Rice :-

Figure: 10 Graph showing 3rd degree polynomial trend for Rice production (per hector) -



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 9 Table showing 3rd degree polynomial trend for Rice production (per hector)

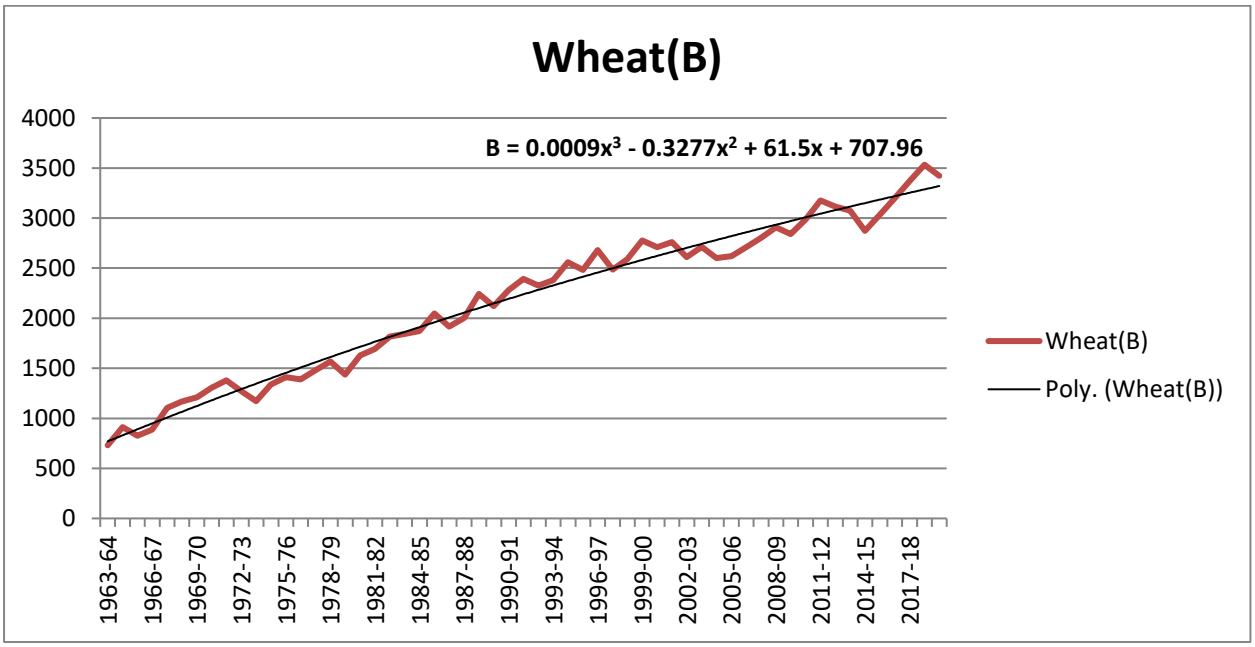
Year	Rice(A)	x	A = -0.0026x³ + 0.3577x² + 17.884x + 911.26
1963-64	1033	1	929.4991
1964-65	1078	2	948.438
1965-66	862	3	968.0611
1966-67	863	4	988.3528
1967-68	1032	5	1009.2975
1968-69	1076	6	1030.8796
1969-70	1073	7	1053.0835
1970-71	1123	8	1075.8936
1971-72	1141	9	1099.2943
1972-73	1070	10	1123.27
1973-74	1151	11	1147.8051
1974-75	1045	12	1172.884
1975-76	1235	13	1198.4911
1976-77	1089	14	1224.6108
1977-78	1308	15	1251.2275
1978-79	1328	16	1278.3256
1979-80	1074	17	1305.8895
1980-81	1336	18	1333.9036

1981-82	1308	19	1362.3523
1982-83	1231	20	1391.22
1983-84	1457	21	1420.4911
1984-85	1417	22	1450.15
1985-86	1552	23	1480.1811
1986-87	1471	24	1510.5688
1987-88	1465	25	1541.2975
1988-89	1689	26	1572.3516
1989-90	1745	27	1603.7155
1990-91	1740	28	1635.3736
1991-92	1751	29	1667.3103
1992-93	1744	30	1699.51
1993-94	1888	31	1731.9571
1994-95	1911	32	1764.636
1995-96	1797	33	1797.5311
1996-97	1882	34	1830.6268
1997-98	1900	35	1863.9075
1998-99	1921	36	1897.3576
1999-00	1986	37	1930.9615
2000-01	1901	38	1964.7036
2001-02	2079	39	1998.5683
2002-03	1744	40	2032.54
2003-04	2077	41	2066.6031
2004-05	1984	42	2100.742
2005-06	2102	43	2134.9411
2006-07	2131	44	2169.1848
2007-08	2202	45	2203.4575
2008-09	2178	46	2237.7436
2009-10	2125	47	2272.0275
2010-11	2239	48	2306.2936
2011-12	2393	49	2340.5263
2012-13	2461	50	2374.71
2013-14	2424	51	2408.8291
2014-15	2390	52	2442.868
2015-16	2400	53	2476.8111
2016-17	2494	54	2510.6428
2017-18	2576	55	2544.3475
2018-19	2638	56	2577.9096
2019-20	2705	57	2611.3135

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (3rd degree) Trend for Wheat:-

Figure: 11 Graph Showing 3rd degree polynomial trend for Wheat production (per hector) -



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 10 Table showing 3rd degree polynomial trend for Wheat production (per hector)

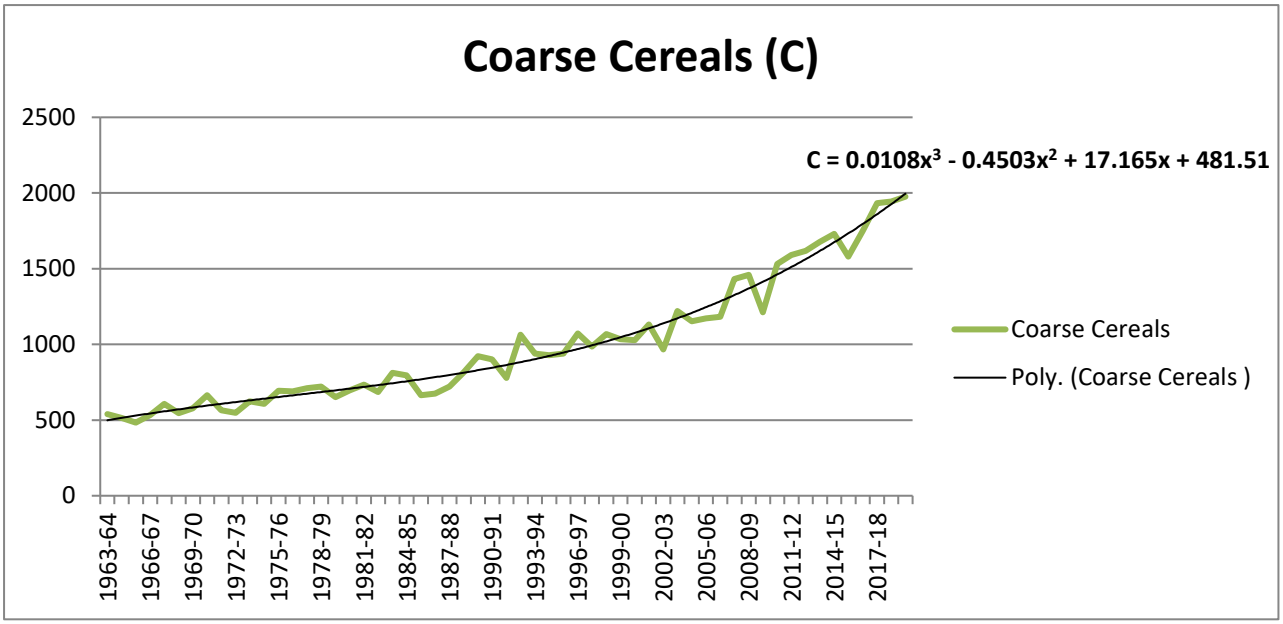
Year	Wheat(B)	x	$B = 0.0009x^3 - 0.3277x^2 + 61.5x + 707.96$
1963-64	730	1	769.1332
1964-65	913	2	829.6564
1965-66	827	3	889.535
1966-67	887	4	948.7744
1967-68	1103	5	1007.38
1968-69	1169	6	1065.3572
1969-70	1208	7	1122.7114
1970-71	1307	8	1179.448
1971-72	1380	9	1235.5724
1972-73	1271	10	1291.09
1973-74	1172	11	1346.0062
1974-75	1338	12	1400.3264
1975-76	1410	13	1454.056
1976-77	1387	14	1507.2004
1977-78	1480	15	1559.765

1978-79	1568	16	1611.7552
1979-80	1436	17	1663.1764
1980-81	1630	18	1714.034
1981-82	1691	19	1764.3334
1982-83	1816	20	1814.08
1983-84	1843	21	1863.2792
1984-85	1870	22	1911.9364
1985-86	2046	23	1960.057
1986-87	1916	24	2007.6464
1987-88	2002	25	2054.71
1988-89	2244	26	2101.2532
1989-90	2121	27	2147.2814
1990-91	2281	28	2192.8
1991-92	2394	29	2237.8144
1992-93	2327	30	2282.33
1993-94	2380	31	2326.3522
1994-95	2559	32	2369.8864
1995-96	2483	33	2412.938
1996-97	2679	34	2455.5124
1997-98	2485	35	2497.615
1998-99	2590	36	2539.2512
1999-00	2778	37	2580.4264
2000-01	2708	38	2621.146
2001-02	2762	39	2661.4154
2002-03	2610	40	2701.24
2003-04	2713	41	2740.6252
2004-05	2602	42	2779.5764
2005-06	2619	43	2818.099
2006-07	2708	44	2856.1984
2007-08	2802	45	2893.88
2008-09	2907	46	2931.1492
2009-10	2839	47	2968.0114
2010-11	2988	48	3004.472
2011-12	3177	49	3040.5364
2012-13	3117	50	3076.21
2013-14	3075	51	3111.4982
2014-15	2872	52	3146.4064
2015-16	3034	53	3180.94
2016-17	3200	54	3215.1044
2017-18	3368	55	3248.905
2018-19	3533	56	3282.3472
2019-20	3421	57	3315.4364

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (3rd degree) Trend for Coarse Cereals:-

Figure: 12 Graph Showing 3rd degree polynomial trend for Coarse Cereals (per hector) -



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 11 Table showing 3rd degree polynomial trend for Coarse Cereals production (per-hector)

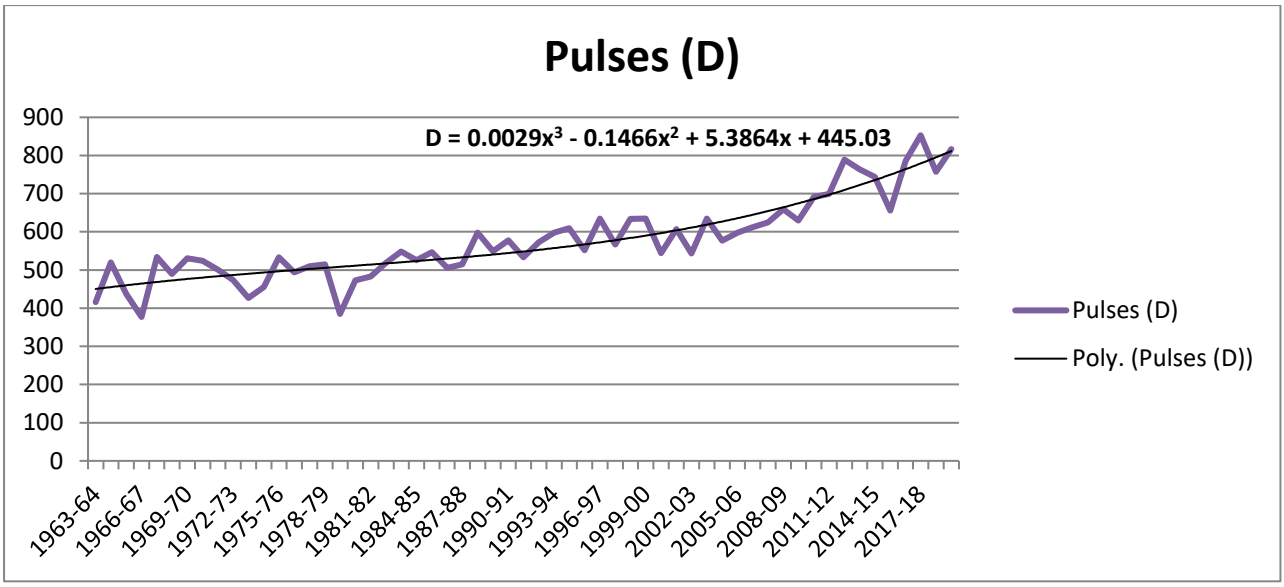
Year	Coarse Cereals (C)	x	C = 0.0108x³ - 0.4503x² + 17.165x + 481.51
1963-64	540	1	498.2355
1964-65	514	2	514.1252
1965-66	483	3	529.2439
1966-67	533	4	543.6564
1967-68	608	5	557.4275
1968-69	545	6	570.622
1969-70	578	7	583.3047
1970-71	665	8	595.5404
1971-72	564	9	607.3939
1972-73	548	10	618.93
1973-74	623	11	630.2135
1974-75	606	12	641.3092
1975-76	694	13	652.2819
1976-77	689	14	663.1964
1977-78	710	15	674.1175
1978-79	721	16	685.11
1979-80	652	17	696.2387

1980-81	695	18	707.5684
1981-82	733	19	719.1639
1982-83	685	20	731.09
1983-84	813	21	743.4115
1984-85	795	22	756.1932
1985-86	664	23	769.4999
1986-87	675	24	783.3964
1987-88	721	25	797.9475
1988-89	814	26	813.218
1989-90	922	27	829.2727
1990-91	900	28	846.1764
1991-92	778	29	863.9939
1992-93	1063	30	882.79
1993-94	939	31	902.6295
1994-95	929	32	923.5772
1995-96	940	33	945.6979
1996-97	1072	34	969.0564
1997-98	986	35	993.7175
1998-99	1068	36	1019.746
1999-00	1034	37	1047.2067
2000-01	1027	38	1076.1644
2001-02	1131	39	1106.6839
2002-03	966	40	1138.83
2003-04	1221	41	1172.6675
2004-05	1153	42	1208.2612
2005-06	1172	43	1245.6759
2006-07	1182	44	1284.9764
2007-08	1431	45	1326.2275
2008-09	1459	46	1369.494
2009-10	1212	47	1414.8407
2010-11	1531	48	1462.3324
2011-12	1590	49	1512.0339
2012-13	1617	50	1564.01
2013-14	1677	51	1618.3255
2014-15	1729	52	1675.0452
2015-16	1579	53	1734.2339
2016-17	1750	54	1795.9564
2017-18	1934	55	1860.2775
2018-19	1944	56	1927.262
2019-20	1976	57	1996.9747

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Polynomial (3rd degree) Trend for Pulses:-

Figure: 13 Graph Showing 3rd degree polynomial trend of Pulses (per hector) -



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Table: 12 Table showing 3rd degree polynomial trend for pulses production (per hector)

Year	Pulses (D)	x	D = 0.0029x³ - 0.1466x² + 5.3864x + 445.03
1963-64	416	1	450.2723
1964-65	520	2	455.2388
1965-66	438	3	459.9469
1966-67	377	4	464.414
1967-68	534	5	468.6575
1968-69	490	6	472.6948
1969-70	531	7	476.5433
1970-71	524	8	480.2204
1971-72	501	9	483.7435
1972-73	474	10	487.13
1973-74	427	11	490.3973
1974-75	455	12	493.5628
1975-76	533	13	496.6439
1976-77	494	14	499.658
1977-78	510	15	502.6225
1978-79	515	16	505.5548
1979-80	385	17	508.4723
1980-81	473	18	511.3924
1981-82	483	19	514.3325
1982-83	519	20	517.31
1983-84	548	21	520.3423

1984-85	526	22	523.4468
1985-86	547	23	526.6409
1986-87	506	24	529.942
1987-88	515	25	533.3675
1988-89	598	26	536.9348
1989-90	549	27	540.6613
1990-91	578	28	544.5644
1991-92	533	29	548.6615
1992-93	573	30	552.97
1993-94	598	31	557.5073
1994-95	610	32	562.2908
1995-96	552	33	567.3379
1996-97	635	34	572.666
1997-98	567	35	578.2925
1998-99	634	36	584.2348
1999-00	635	37	590.5103
2000-01	544	38	597.1364
2001-02	607	39	604.1305
2002-03	543	40	611.51
2003-04	635	41	619.2923
2004-05	577	42	627.4948
2005-06	598	43	636.1349
2006-07	612	44	645.23
2007-08	625	45	654.7975
2008-09	659	46	664.8548
2009-10	630	47	675.4193
2010-11	691	48	686.5084
2011-12	699	49	698.1395
2012-13	789	50	710.33
2013-14	764	51	723.0973
2014-15	744	52	736.4588
2015-16	656	53	750.4319
2016-17	786	54	765.034
2017-18	853	55	780.2825
2018-19	757	56	796.1948
2019-20	817	57	812.7883

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Root Mean Square Error:-

Here we introduce a concept **Root Mean Square Error** (**RMSE**). Root Mean Square Error is the standard deviation of the residuals (prediction errors). Residuals are a measure of how far from the regression line data points are; **RMSE** is a measure of how spread out these residuals are. In other words, it tells us how concentrated the data is around the line of best fit.

To calculate the RMSE, the following equation is used

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(f_i - o_i)^2}$$

Where:

- n: number of samples
- f: forecasts
- o: observed values

For production of Rice:-

Table: 13; Table showing the compression of the value of Root Mean Square Error (RMSE) between Straight line, Polynomial of 2nd degree and polynomial of 3rd degree of Rice production:

Year	Rice (A)	Straight Line A=30.749x + 810.31	RMSE	2nd degree polynomial A=0.1299x² + 23.217x + 884.37	RMSE	3rd degree polynomial A = -0.0026x³+ 0.3577x² + 17.884x + 911.26	RMSE
1963-64	1033	841.059	97.66378202	907.7169	92.47103707	929.4991	92.02721
1964-65	1078	871.808		931.3236		948.438	
1965-66	862	902.557		955.1901		968.0611	
1966-67	863	933.306		979.3164		988.3528	
1967-68	1032	964.055		1003.7025		1009.2975	
1968-69	1076	994.804		1028.3484		1030.8796	
1969-70	1073	1025.553		1053.2541		1053.0835	
1970-71	1123	1056.302		1078.4196		1075.8936	
1971-72	1141	1087.051		1103.8449		1099.2943	
1972-73	1070	1117.8		1129.53		1123.27	
1973-74	1151	1148.549		1155.4749		1147.8051	
1974-75	1045	1179.298		1181.6796		1172.884	

1975-76	1235	1210.047		1208.1441		1198.4911	
1976-77	1089	1240.796		1234.8684		1224.6108	
1977-78	1308	1271.545		1261.8525		1251.2275	
1978-79	1328	1302.294		1289.0964		1278.3256	
1979-80	1074	1333.043		1316.6001		1305.8895	
1980-81	1336	1363.792		1344.3636		1333.9036	
1981-82	1308	1394.541		1372.3869		1362.3523	
1982-83	1231	1425.29		1400.67		1391.22	
1983-84	1457	1456.039		1429.2129		1420.4911	
1984-85	1417	1486.788		1458.0156		1450.15	
1985-86	1552	1517.537		1487.0781		1480.1811	
1986-87	1471	1548.286		1516.4004		1510.5688	
1987-88	1465	1579.035		1545.9825		1541.2975	
1988-89	1689	1609.784		1575.8244		1572.3516	
1989-90	1745	1640.533		1605.9261		1603.7155	
1990-91	1740	1671.282		1636.2876		1635.3736	
1991-92	1751	1702.031		1666.9089		1667.3103	
1992-93	1744	1732.78		1697.79		1699.51	
1993-94	1888	1763.529		1728.9309		1731.9571	
1994-95	1911	1794.278		1760.3316		1764.636	
1995-96	1797	1825.027		1791.9921		1797.5311	
1996-97	1882	1855.776		1823.9124		1830.6268	
1997-98	1900	1886.525		1856.0925		1863.9075	
1998-99	1921	1917.274		1888.5324		1897.3576	
1999-00	1986	1948.023		1921.2321		1930.9615	
2001-02	2079	2009.521		1987.4109		1998.5683	
2002-03	1744	2040.27		2020.89		2032.54	
2003-04	2077	2071.019		2054.6289		2066.6031	
2004-05	1984	2101.768		2088.6276		2100.742	
2005-06	2102	2132.517		2122.8861		2134.9411	
2006-07	2131	2163.266		2157.4044		2169.1848	
2007-08	2202	2194.015		2192.1825		2203.4575	
2008-09	2178	2224.764		2227.2204		2237.7436	
2009-10	2125	2255.513		2262.5181		2272.0275	
2010-11	2239	2286.262		2298.0756		2306.2936	
2011-12	2393	2317.011		2333.8929		2340.5263	
2012-13	2461	2347.76		2369.97		2374.71	
2013-14	2424	2378.509		2406.3069		2408.8291	
2014-15	2390	2409.258		2442.9036		2442.868	
2015-16	2400	2440.007		2479.7601		2476.8111	
2016-17	2494	2470.756		2516.8764		2510.6428	
2017-18	2576	2501.505		2554.2525		2544.3475	
2018-19	2638	2532.254		2591.8884		2577.9096	
2019-20	2705	2563.003		2629.7841		2611.3135	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

For Wheat production:-

Table: 14; Table showing the compression of the value of Root Mean Square Error (RMSE) between Straight line, Polynomial of 2nd degree and polynomial of 3rd degree of Wheat production:

Year	Wheat(B)	B = 45.277x + 858.47	RMSE	B= -0.2472x^2 + 59.617x + 717.46	RMSE	B = 0.0009x^3 - 0.3277x^2 + 61.5x + 707.96	RMSE
1963-64	730	903.747	130.597	773.8298	116.1245	769.1332	**116.0558**
1964-65	913	949.024		832.7052		829.6564	
1965-66	827	994.301		891.0862		889.535	
1966-67	887	1039.578		948.9728		948.7744	
1967-68	1103	1084.855		1006.365		1007.38	
1968-69	1169	1130.132		1063.2628		1065.3572	
1969-70	1208	1175.409		1119.6662		1122.7114	
1970-71	1307	1220.686		1175.5752		1179.448	
1971-72	1380	1265.963		1230.9898		1235.5724	
1972-73	1271	1311.24		1285.91		1291.09	
1973-74	1172	1356.517		1340.3358		1346.0062	
1974-75	1338	1401.794		1394.2672		1400.3264	
1975-76	1410	1447.071		1447.7042		1454.056	
1976-77	1387	1492.348		1500.6468		1507.2004	
1977-78	1480	1537.625		1553.095		1559.765	
1978-79	1568	1582.902		1605.0488		1611.7552	
1979-80	1436	1628.179		1656.5082		1663.1764	
1980-81	1630	1673.456		1707.4732		1714.034	
1981-82	1691	1718.733		1757.9438		1764.3334	
1982-83	1816	1764.01		1807.92		1814.08	
1983-84	1843	1809.287		1857.4018		1863.2792	
1984-85	1870	1854.564		1906.3892		1911.9364	
1985-86	2046	1899.841		1954.8822		1960.057	
1986-87	1916	1945.118		2002.8808		2007.6464	
1987-88	2002	1990.395		2050.385		2054.71	
1988-89	2244	2035.672		2097.3948		2101.2532	
1989-90	2121	2080.949		2143.9102		2147.2814	
1990-91	2281	2126.226		2189.9312		2192.8	
1991-92	2394	2171.503		2235.4578		2237.8144	
1992-93	2327	2216.78		2280.49		2282.33	
1993-94	2380	2262.057		2325.0278		2326.3522	
1994-95	2559	2307.334		2369.0712		2369.8864	
1995-96	2483	2352.611		2412.6202		2412.938	
1996-97	2679	2397.888		2455.6748		2455.5124	

1997-98	2485	2443.165		2498.235		2497.615	
1998-99	2590	2488.442		2540.3008		2539.2512	
1999-00	2778	2533.719		2581.8722		2580.4264	
2000-01	2708	2578.996		2622.9492		2621.146	
2001-02	2762	2624.273		2663.5318		2661.4154	
2002-03	2610	2669.55		2703.62		2701.24	
2003-04	2713	2714.827		2743.2138		2740.6252	
2004-05	2602	2760.104		2782.3132		2779.5764	
2005-06	2619	2805.381		2820.9182		2818.099	
2006-07	2708	2850.658		2859.0288		2856.1984	
2007-08	2802	2895.935		2896.645		2893.88	
2008-09	2907	2941.212		2933.7668		2931.1492	
2009-10	2839	2986.489		2970.3942		2968.0114	
2010-11	2988	3031.766		3006.5272		3004.472	
2011-12	3177	3077.043		3042.1658		3040.5364	
2012-13	3117	3122.32		3077.31		3076.21	
2013-14	3075	3167.597		3111.9598		3111.4982	
2014-15	2872	3212.874		3146.1152		3146.4064	
2015-16	3034	3258.151		3179.7762		3180.94	
2016-17	3200	3303.428		3212.9428		3215.1044	
2017-18	3368	3348.705		3245.615		3248.905	
2018-19	3533	3393.982		3277.7928		3282.3472	
2019-20	3421	3439.259		3309.4762		3315.4364	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

For production of Coarse Cereals:-

Table: 15; Table showing the compression of the value of Root Mean Square Error (RMSE) between Straight line, Polynomial of 2nd degree and polynomial of 3rd degree of Coarse Cereals production:

Year	Coarse Cereals (C)	C = 23.537x + 313.57	RMSE	C = 0.4887x^2 - 4.8095x + 592.31	RMSE	C = 0.0108x^3 - 0.4503x^2 + 17.165x + 481.51	RMSE
1963-64	540	337.107	143.6175	587.9892	81.48556	498.2355	72.2451
1964-65	514	360.644		584.6458		514.1252	
1965-66	483	384.181		582.2798		529.2439	
1966-67	533	407.718		580.8912		543.6564	
1967-68	608	431.255		580.48		557.4275	
1968-69	545	454.792		581.0462		570.622	
1969-70	578	478.329		582.5898		583.3047	
1970-71	665	501.866		585.1108		595.5404	
1971-72	564	525.403		588.6092		607.3939	
1972-73	548	548.94		593.085		618.93	

1973-74	623	572.477		598.5382		630.2135	
1974-75	606	596.014		604.9688		641.3092	
1975-76	694	619.551		612.3768		652.2819	
1976-77	689	643.088		620.7622		663.1964	
1977-78	710	666.625		630.125		674.1175	
1978-79	721	690.162		640.4652		685.11	
1979-80	652	713.699		651.7828		696.2387	
1980-81	695	737.236		664.0778		707.5684	
1981-82	733	760.773		677.3502		719.1639	
1982-83	685	784.31		691.6		731.09	
1983-84	813	807.847		706.8272		743.4115	
1984-85	795	831.384		723.0318		756.1932	
1985-86	664	854.921		740.2138		769.4999	
1986-87	675	878.458		758.3732		783.3964	
1987-88	721	901.995		777.51		797.9475	
1988-89	814	925.532		797.6242		813.218	
1989-90	922	949.069		818.7158		829.2727	
1990-91	900	972.606		840.7848		846.1764	
1991-92	778	996.143		863.8312		863.9939	
1992-93	1063	1019.68		887.855		882.79	
1993-94	939	1043.217		912.8562		902.6295	
1994-95	929	1066.754		938.8348		923.5772	
1995-96	940	1090.291		965.7908		945.6979	
1996-97	1072	1113.828		993.7242		969.0564	
1997-98	986	1137.365		1022.635		993.7175	
1998-99	1068	1160.902		1052.5232		1019.746	
1999-00	1034	1184.439		1083.3888		1047.2067	
2000-01	1027	1207.976		1115.2318		1076.1644	
2001-02	1131	1231.513		1148.0522		1106.6839	
2002-03	966	1255.05		1181.85		1138.83	
2003-04	1221	1278.587		1216.6252		1172.6675	
2004-05	1153	1302.124		1252.3778		1208.2612	
2005-06	1172	1325.661		1289.1078		1245.6759	
2006-07	1182	1349.198		1326.8152		1284.9764	
2007-08	1431	1372.735		1365.5		1326.2275	
2008-09	1459	1396.272		1405.1622		1369.494	
2009-10	1212	1419.809		1445.8018		1414.8407	
2010-11	1531	1443.346		1487.4188		1462.3324	
2011-12	1590	1466.883		1530.0132		1512.0339	
2012-13	1617	1490.42		1573.585		1564.01	
2013-14	1677	1513.957		1618.1342		1618.3255	
2014-15	1729	1537.494		1663.6608		1675.0452	
2015-16	1579	1561.031		1710.1648		1734.2339	
2016-17	1750	1584.568		1757.6462		1795.9564	

2017-18	1934	1608.105		1806.105		1860.2775	
2018-19	1944	1631.642		1855.5412		1927.262	
2019-20	1976	1655.179		1905.9548		1996.9747	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

For production of Pulses:-

Table: 16; Table showing the compression of the value of Root Mean Square Error (RMSE) between Straight line, Polynomial of 2nd degree and polynomial of 3rd degree of Pulse production:

Year	Pulses (D)	D = 5.5948x + 414.75	RMSE	D = 0.1052x² - 0.5057x + 474.74	RMSE	D = 0.0029x³ - 0.1466x² + 5.3864x + 445.03	RMSE
1963-64	416	420.3448	51.4937	474.3395	44.76382	450.2723	43.60993
1964-65	520	425.9396		474.1494		455.2388	
1965-66	438	431.5344		474.1697		459.9469	
1966-67	377	437.1292		474.4004		464.414	
1967-68	534	442.724		474.8415		468.6575	
1968-69	490	448.3188		475.493		472.6948	
1969-70	531	453.9136		476.3549		476.5433	
1970-71	524	459.5084		477.4272		480.2204	
1971-72	501	465.1032		478.7099		483.7435	
1972-73	474	470.698		480.203		487.13	
1973-74	427	476.2928		481.9065		490.3973	
1974-75	455	481.8876		483.8204		493.5628	
1975-76	533	487.4824		485.9447		496.6439	
1976-77	494	493.0772		488.2794		499.658	
1977-78	510	498.672		490.8245		502.6225	
1978-79	515	504.2668		493.58		505.5548	
1979-80	385	509.8616		496.5459		508.4723	
1980-81	473	515.4564		499.7222		511.3924	
1981-82	483	521.0512		503.1089		514.3325	
1982-83	519	526.646		506.706		517.31	
1983-84	548	532.2408		510.5135		520.3423	
1984-85	526	537.8356		514.5314		523.4468	
1985-86	547	543.4304		518.7597		526.6409	
1986-87	506	549.0252		523.1984		529.942	
1987-88	515	554.62		527.8475		533.3675	
1988-89	598	560.2148		532.707		536.9348	
1989-90	549	565.8096		537.7769		540.6613	
1990-91	578	571.4044		543.0572		544.5644	
1991-92	533	576.9992		548.5479		548.6615	
1992-93	573	582.594		554.249		552.97	

1993-94	598	588.1888		560.1605		557.5073	
1994-95	610	593.7836		566.2824		562.2908	
1995-96	552	599.3784		572.6147		567.3379	
1996-97	635	604.9732		579.1574		572.666	
1997-98	567	610.568		585.9105		578.2925	
1998-99	634	616.1628		592.874		584.2348	
1999-00	635	621.7576		600.0479		590.5103	
2000-01	544	627.3524		607.4322		597.1364	
2001-02	607	632.9472		615.0269		604.1305	
2002-03	543	638.542		622.832		611.51	
2003-04	635	644.1368		630.8475		619.2923	
2004-05	577	649.7316		639.0734		627.4948	
2005-06	598	655.3264		647.5097		636.1349	
2006-07	612	660.9212		656.1564		645.23	
2007-08	625	666.516		665.0135		654.7975	
2008-09	659	672.1108		674.081		664.8548	
2009-10	630	677.7056		683.3589		675.4193	
2010-11	691	683.3004		692.8472		686.5084	
2011-12	699	688.8952		702.5459		698.1395	
2012-13	789	694.49		712.455		710.33	
2013-14	764	700.0848		722.5745		723.0973	
2014-15	744	705.6796		732.9044		736.4588	
2015-16	656	711.2744		743.4447		750.4319	
2016-17	786	716.8692		754.1954		765.034	
2017-18	853	722.464		765.1565		780.2825	
2018-19	757	728.0588		776.328		796.1948	
2019-20	817	733.6536		787.7099		812.7883	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Moving Average Method:

In this method we have tried to smooth our production graphs of 4 datasets so that we can easily understand what should be the value of upcoming some years. From the given data we cannot realise about what time period of moving average should be taken. Here we use a method of moving average that can give best result. For this method we have to observe how many peak points are there in a graph. Then we count the distance between every peak point and sum up them. The appropriate period of the moving average is given by the arithmetic mean of distance of periods. This method applies for each of four dataset.

4 years moving average of rice production:

Here for rice, we have taken the peaks of the data. The followings are-

1964-65, 1971-72, 1973-74, 1975-76, 1978-79, 1980-81, 1983-84,1985-86,1989-90,1994-95,1990 -00,2001-02,2007-08,2012-13,2019-20.

The appropriate year of moving average $\frac{7+2+2+3+2+3+2+4+5+5+2+6+5+7}{14} = 3.9 \approx 4$

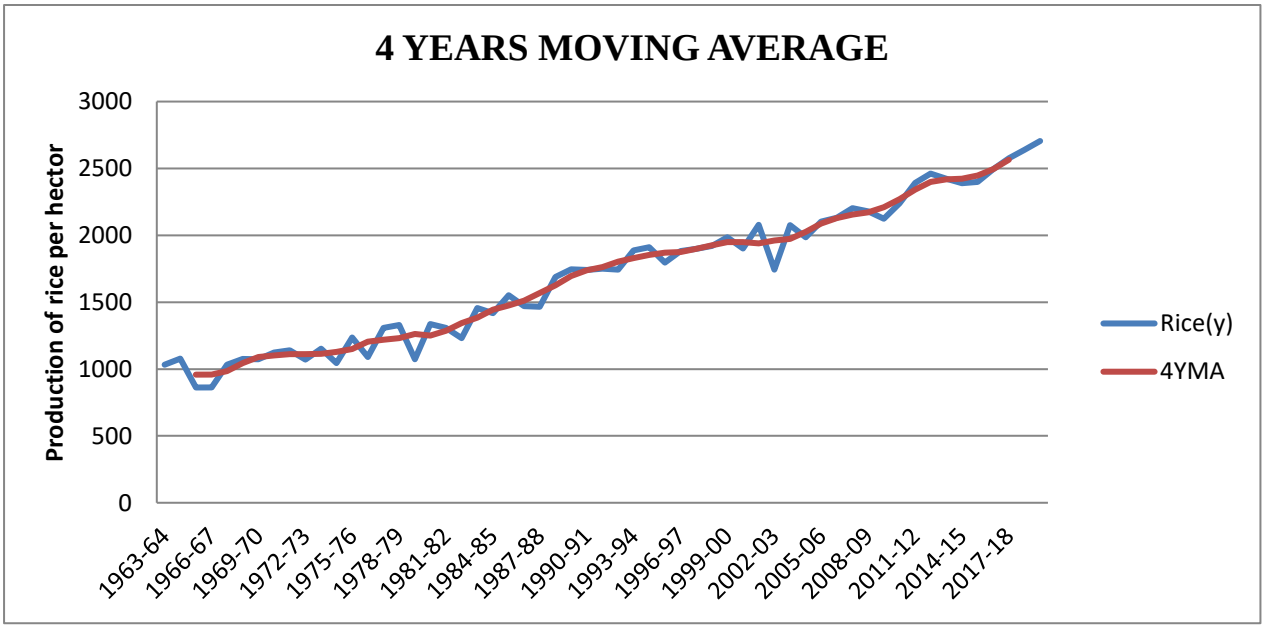
Table: 17; Table for calculation of 4 years moving average of rice production

Year	Rice(A)	4YMA
1963-64	1033	
1964-65	1078	
1965-66	862	958.875
1966-67	863	958.5
1967-68	1032	984.625
1968-69	1076	1043.5
1969-70	1073	1089.625
1970-71	1123	1102.5
1971-72	1141	1111.5
1972-73	1070	1111.5
1973-74	1151	1113.5
1974-75	1045	1127.625
1975-76	1235	1149.625
1976-77	1089	1204.625
1977-78	1308	1219.875
1978-79	1328	1230.625
1979-80	1074	1261.5
1980-81	1336	1249.375
1981-82	1308	1285.125
1982-83	1231	1343.125
1983-84	1457	1383.75
1984-85	1417	1444.25
1985-86	1552	1475.25
1986-87	1471	1510.25
1987-88	1465	1568.375
1988-89	1689	1626.125
1989-90	1745	1695.5
1990-91	1740	1738.125
1991-92	1751	1762.875
1992-93	1744	1802.125
1993-94	1888	1829.25
1994-95	1911	1852.25
1995-96	1797	1871
1996-97	1882	1873.75
1997-98	1900	1898.625
1998-99	1921	1924.625

1999-00	1986	1949.375
2000-01	1901	1949.625
2001-02	2079	1938.875
2002-03	1744	1960.625
2003-04	2077	1973.875
2004-05	1984	2025.125
2005-06	2102	2089.125
2006-07	2131	2129
2007-08	2202	2156.125
2008-09	2178	2172.5
2009-10	2125	2209.875
2010-11	2239	2269.125
2011-12	2393	2341.875
2012-13	2461	2398.125
2013-14	2424	2417.875
2014-15	2390	2422.875
2015-16	2400	2446
2016-17	2494	2496
2017-18	2576	2565.125
2018-19	2638	
2019-20	2705	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 14 Graph showing 4 years moving average of Rice production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

5 years moving average of Wheat production:-

Here for wheat, we have taken the peaks of the data. The followings are-
1964-65 , 1971-72 , 1978-79 , 1985-86 , 1988-99 , 1991-92 , 1994-95 , 1996-97 , 1999-00 , 2008-09 , 2011-12 , 2018-19

The appropriate year of moving average $= \frac{7+7+7+3+3+3+2+3+9+3+7}{11} = 4.9 \approx 5$

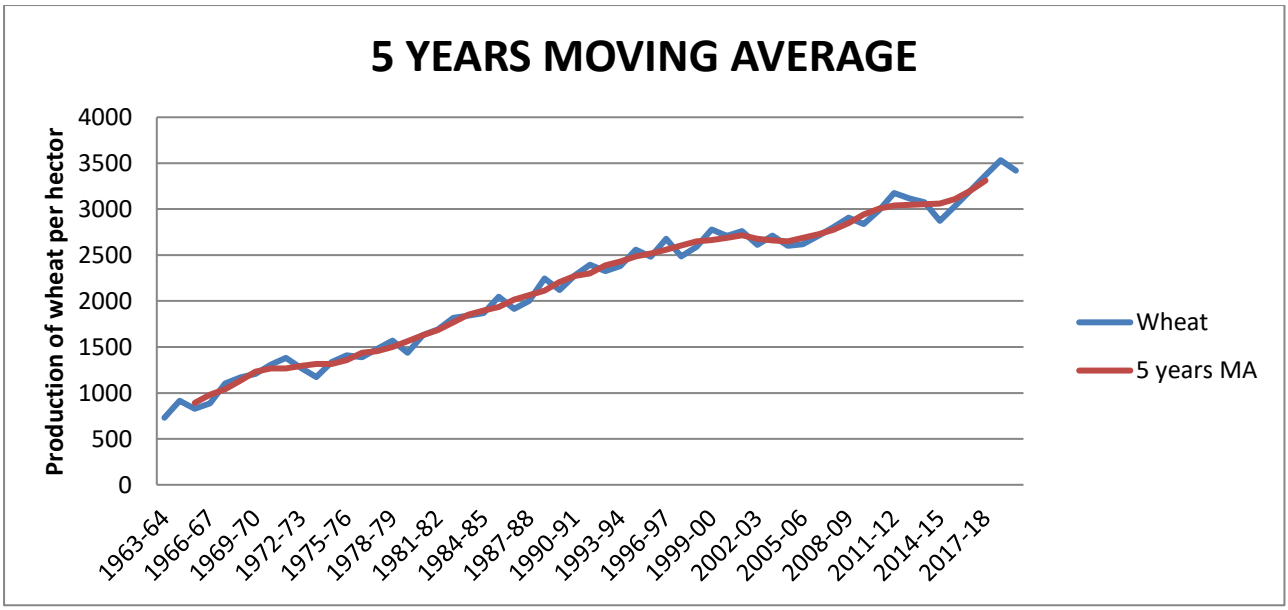
Table: 18; Table for calculation of 5 years moving average of Wheat production (per hector)

Year	Wheat	5 years MA
1963-64	730	-
1964-65	913	-
1965-66	827	892
1966-67	887	979.8
1967-68	1103	1038.8
1968-69	1169	1134.8
1969-70	1208	1233.4
1970-71	1307	1267
1971-72	1380	1267.6
1972-73	1271	1293.6
1973-74	1172	1314.2
1974-75	1338	1315.6
1975-76	1410	1357.4
1976-77	1387	1436.6
1977-78	1480	1456.2
1978-79	1568	1500.2
1979-80	1436	1561
1980-81	1630	1628.2
1981-82	1691	1683.2
1982-83	1816	1770
1983-84	1843	1853.2
1984-85	1870	1898.2
1985-86	2046	1935.4
1986-87	1916	2015.6
1987-88	2002	2065.8
1988-89	2244	2112.8
1989-90	2121	2208.4
1990-91	2281	2273.4
1991-92	2394	2300.6
1992-93	2327	2388.2
1993-94	2380	2428.6
1994-95	2559	2485.6
1995-96	2483	2517.2

1996-97	2679	2559.2
1997-98	2485	2603
1998-99	2590	2648
1999-00	2778	2664.6
2000-01	2708	2689.6
2001-02	2762	2714.2
2002-03	2610	2679
2003-04	2713	2661.2
2004-05	2602	2650.4
2005-06	2619	2688.8
2006-07	2708	2727.6
2007-08	2802	2775
2008-09	2907	2848.8
2009-10	2839	2942.6
2010-11	2988	3005.6
2011-12	3177	3039.2
2012-13	3117	3045.8
2013-14	3075	3055
2014-15	2872	3059.6
2015-16	3034	3109.8
2016-17	3200	3201.4
2017-18	3368	3311.2
2018-19	3533	-
2019-20	3421	-

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 15 Graph showing 5 years moving average of Wheat production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

3 years moving average of coarse cereal production:-

Here for Coarse Cereals, we have taken the peaks of the data. The followings are-
1963-64 , 1967-68 ,1970-71 , 1973-74 , 1975-76 , 1978-79 , 1981-82 , 1983-84 , 1989-90 , 1992-93 , 1996-97 , 1998-99, 2001-02, 2003-04, 2008-09, 2014-15
The appropriate year of moving average $= \frac{4+3+3+2+3+3+2+6+3+4+2+3+2+5+6}{15} = 3.4 \approx 3$

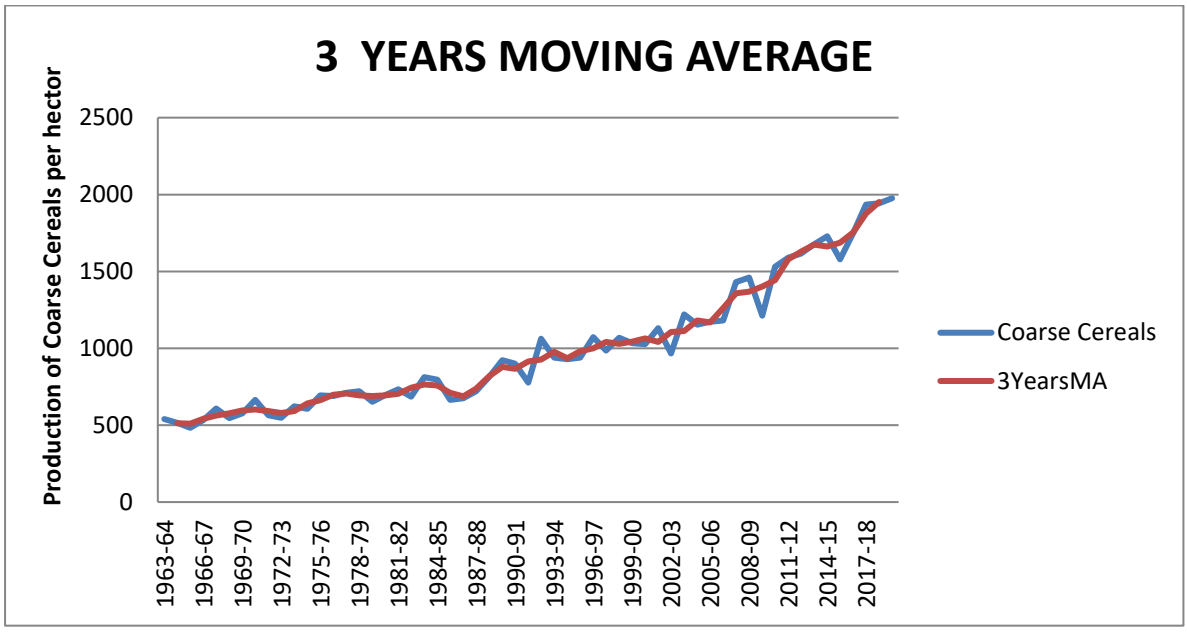
Table: 19; Table for calculation of 3 years moving average of Coarse Cereals production (per-hector)

Year	Coarse Cereals	3YearsMA
1963-64	540	-
1964-65	514	512.3333
1965-66	483	510
1966-67	533	541.3333
1967-68	608	562
1968-69	545	577
1969-70	578	596
1970-71	665	602.3333
1971-72	564	592.3333
1972-73	548	578.3333
1973-74	623	592.3333
1974-75	606	641
1975-76	694	663
1976-77	689	697.6667
1977-78	710	706.6667
1978-79	721	694.3333
1979-80	652	689.3333
1980-81	695	693.3333
1981-82	733	704.3333
1982-83	685	743.6667
1983-84	813	764.3333
1984-85	795	757.3333
1985-86	664	711.3333
1986-87	675	686.6667
1987-88	721	736.6667
1988-89	814	819
1989-90	922	878.6667
1990-91	900	866.6667
1991-92	778	913.6667
1992-93	1063	926.6667

1993-94	939	977
1994-95	929	936
1995-96	940	980.3333
1996-97	1072	999.3333
1997-98	986	1042
1998-99	1068	1029.333
1999-00	1034	1043
2000-01	1027	1064
2001-02	1131	1041.333
2002-03	966	1106
2003-04	1221	1113.333
2004-05	1153	1182
2005-06	1172	1169
2006-07	1182	1261.667
2007-08	1431	1357.333
2008-09	1459	1367.333
2009-10	1212	1400.667
2010-11	1531	1444.333
2011-12	1590	1579.333
2012-13	1617	1628
2013-14	1677	1674.333
2014-15	1729	1661.667
2015-16	1579	1686
2016-17	1750	1754.333
2017-18	1934	1876
2018-19	1944	1951.333
2019-20	1976	-

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 16 Graph showing 3 years moving average of Coarse Cereals production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

4 years moving average of Pulses production:-

Here for Coarse Cereals, we have taken the peaks of the data. The followings are- 1964-65, 1967-68, 1975-76, 1983-84, 1988-89, 1990-91, 1994-95, 1996-97, 2001-02, 2003-04, 2008-09, 2010-11, 2012-13, 2017-18.

The appropriate year of moving average $= \frac{3+8+8+5+2+4+2+5+2+5+2+2+5}{13} = 3.78 \approx 4$

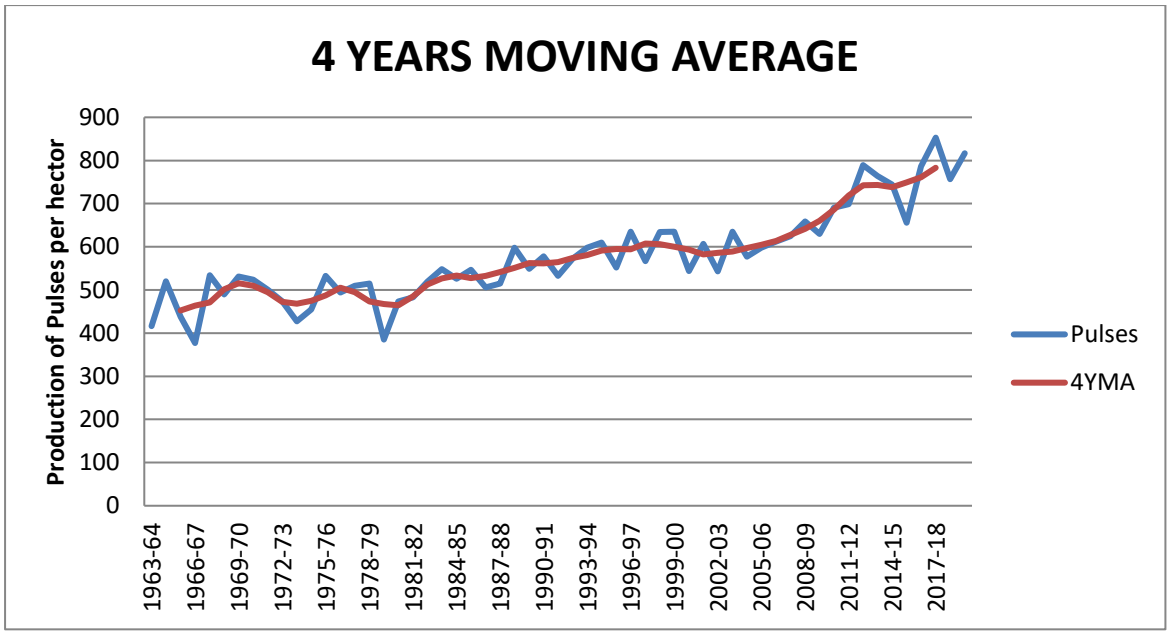
Table: 20; Table for calculation of 4 years moving average of Pulses production (per hector)

Year	Pulses	4YMA
1963-64	416	-
1964-65	520	-
1965-66	438	452.5
1966-67	377	463.5
1967-68	534	471.375
1968-69	490	501.375
1969-70	531	515.625
1970-71	524	509.5
1971-72	501	494.5
1972-73	474	472.875
1973-74	427	468.25
1974-75	455	474.75
1975-76	533	487.625
1976-77	494	505.5

1977-78	510	494.5
1978-79	515	473.375
1979-80	385	467.375
1980-81	473	464.5
1981-82	483	485.375
1982-83	519	512.375
1983-84	548	527
1984-85	526	533.375
1985-86	547	527.625
1986-87	506	532.5
1987-88	515	541.75
1988-89	598	551
1989-90	549	562.25
1990-91	578	561.375
1991-92	533	564.375
1992-93	573	574.5
1993-94	598	580.875
1994-95	610	591
1995-96	552	594.875
1996-97	635	594
1997-98	567	607.375
1998-99	634	606.375
1999-00	635	600
2000-01	544	593.625
2001-02	607	582.25
2002-03	543	586.375
2003-04	635	589.375
2004-05	577	596.875
2005-06	598	604.25
2006-07	612	613.25
2007-08	625	627.5
2008-09	659	641.375
2009-10	630	660.5
2010-11	691	686
2011-12	699	719
2012-13	789	742.375
2013-14	764	743.625
2014-15	744	738.25
2015-16	656	749
2016-17	786	761.375
2017-18	853	783.125
2018-19	757	-
2019-20	817	-

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 17 Graph showing 4 years moving average of Pulses production (per hector)



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Exponential Smoothing Technique:

Exponential smoothing is a time series forecasting method for univariate data. We have using this method for more accurate furcating of our data. Usually exponential smoothing method is of three types. They are (i) Simple exponential smoothing (ii) Double exponential smoothing and (iii) Triple exponential smoothing. As there is no seasonal or cyclic variation in our datasets, we need not use double or triple exponential smoothing method.

If we manually calculate the simple smoothing method, we can consider our model

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$$

Where F_t be the forecasted value of the current period and t be the time period.

F_{t-1} be the forecasted value of previous period.

α be the smoothing constant, a value from 0 to 1. When α is close to zero, smoothing happens more slowly. Following this, the best value for α is the one that results in the smallest mean squared error (MSE).

A_{t-1} be the actual value of the previous period.

In this way form the above formula we can calculate the forecasted values of upcoming years. But as we are using Excel software, we have used its data analysis tool-pack to analyse the datasets to get better forecasting result. Here, in our analysis, a term dumping factor is used. Damping factors are used to smooth out the graph and take on a value between 0 and 1. Technically, the damping factor is 1 minus the alpha level i.e $(1 - \alpha)$.

Here we are deriving our steps to analysis the data using data analysis tool-pack.

Step 1: Click the "Data" tab and then click "Data Analysis."
Step 2: Select "Exponential Smoothing" and then click "OK."
Step 3: Click the Input Range box and then type the location for our forecast data. For example, if we typed our data into cells E1 to E10, type "E1:E10" into that box.
Step 4: Type a damping factor into the damping factor box. A valid value is 0 to 1.
Step 5: Type a cell location into the Output range box. We generally want this in the next column. For example, if we typed our data into cells E1 to E10, type "F1" into that box.
Step 6: Click "OK."

The following graph shows the original data set (first column of data), and what happens when a damping factor is applied:

Exponential smoothing for Rice production from 1963-64 to 2019-20 (in hector) :-

For the dataset of Rice production we analysis the data and we can see that for $\alpha = 0.9$ the RMSE is minimum rather than others value of α (0.3, 0.6 etc). As shown in the following table below when damping factor is applied:

Table: 21

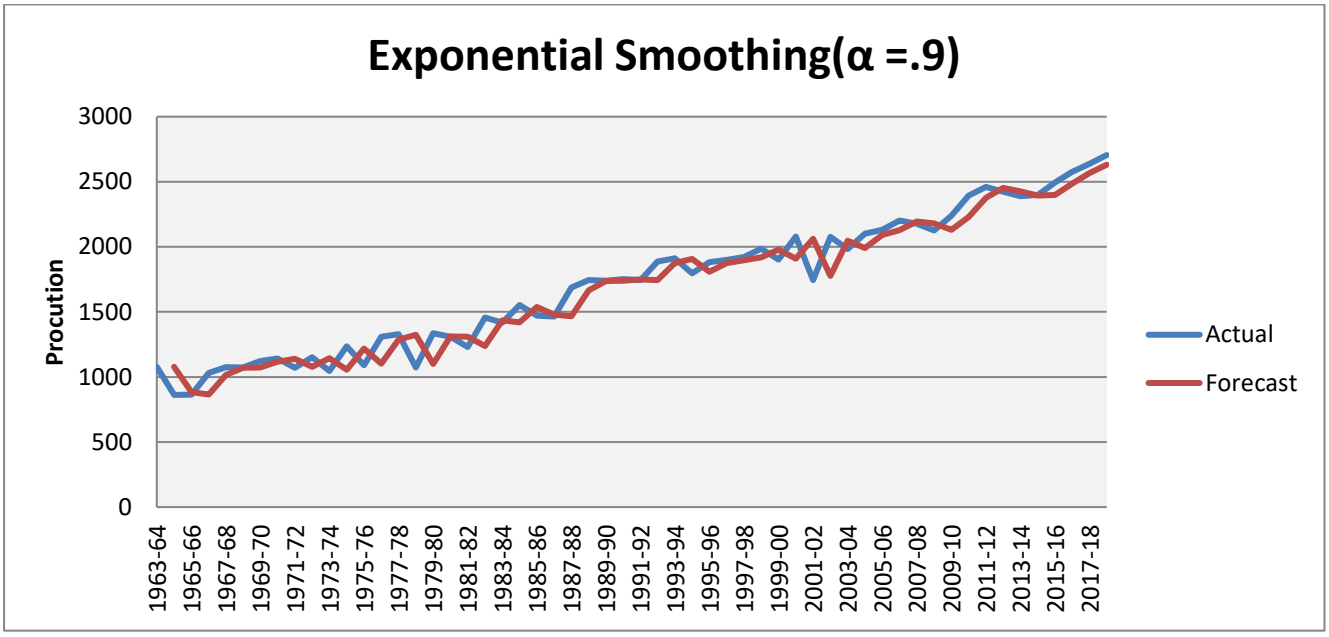
Year	Rice(y)	Dumping factor=0.1	MSE
1963-64	1033	1033	146.6084
1964-65	1078	1078	**RMSE**
1965-66	862	883.6	12.10819
1966-67	863	865.06	
1967-68	1032	1015.306	
1968-69	1076	1069.9306	
1969-70	1073	1072.69306	

1970-71	1123	1117.969306
1971-72	1141	1138.696931
1972-73	1070	1076.869693
1973-74	1151	1143.586969
1974-75	1045	1054.858697
1975-76	1235	1216.98587
1976-77	1089	1101.798587
1977-78	1308	1287.379859
1978-79	1328	1323.937986
1979-80	1074	1098.993799
1980-81	1336	1312.29938
1981-82	1308	1308.429938
1982-83	1231	1238.742994
1983-84	1457	1435.174299
1984-85	1417	1418.81743
1985-86	1552	1538.681743
1986-87	1471	1477.768174
1987-88	1465	1466.276817
1988-89	1689	1666.727682
1989-90	1745	1737.172768
1990-91	1740	1739.717277
1991-92	1751	1749.871728
1992-93	1744	1744.587173
1993-94	1888	1873.658717
1994-95	1911	1907.265872
1995-96	1797	1808.026587
1996-97	1882	1874.602659

1997-98	1900	1897.460266
1998-99	1921	1918.646027
1999-00	1986	1979.264603
2000-01	1901	1908.82646
2001-02	2079	2061.982646
2002-03	1744	1775.798265
2003-04	2077	2046.879826
2004-05	1984	1990.287983
2005-06	2102	2090.828798
2006-07	2131	2126.98288
2007-08	2202	2194.498288
2008-09	2178	2179.649829
2009-10	2125	2130.464983
2010-11	2239	2228.146498
2011-12	2393	2376.51465
2012-13	2461	2452.551465
2013-14	2424	2426.855146
2014-15	2390	2393.685515
2015-16	2400	2399.368551
2016-17	2494	2484.536855
2017-18	2576	2566.853686
2018-19	2638	2630.885369
2019-20	2705	2697.588537

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 18 The graph showing the smoothness of forecasted values for Rice production (per hector):-



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Exponential smoothing for Wheat production from 1963-64 to 2019-20 (in hector)

For the dataset of Wheat production we analysis the data and we can see that for α =0.9 the RMSE is minimum rather than others value of α (0.3,0.6 etc). As shown in the following table below when damping factor is applied:

Table: 22

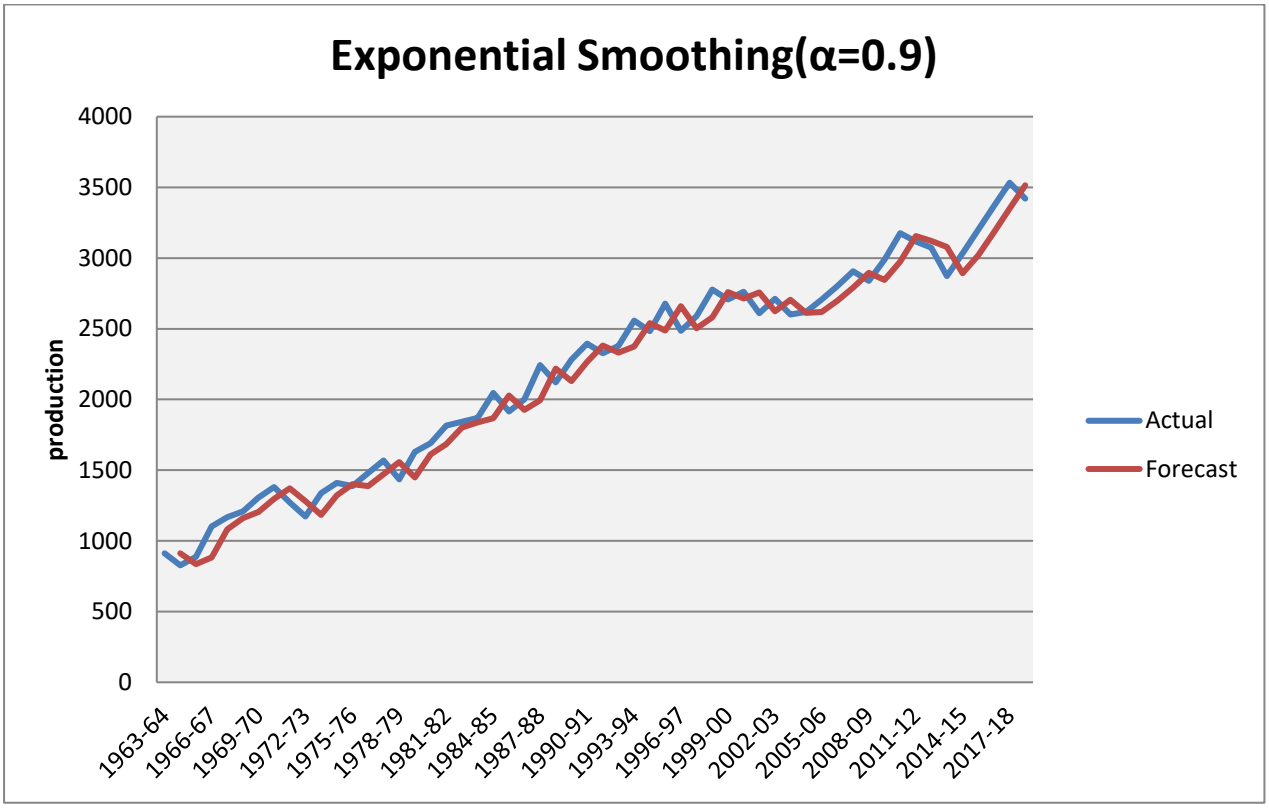
Year	Wheat(B)	Dumping factor =0.1	MSE
1963-64	730	730	154.9332
1964-65	913	913	**RMSE**
1965-66	827	835.6	12.44722
1966-67	887	881.86	
1967-68	1103	1080.886	
1968-69	1169	1160.189	
1969-70	1208	1203.219	
1970-71	1307	1296.622	

1971-72	1380	1371.662
1972-73	1271	1281.066
1973-74	1172	1182.907
1974-75	1338	1322.491
1975-76	1410	1401.249
1976-77	1387	1388.425
1977-78	1480	1470.842
1978-79	1568	1558.284
1979-80	1436	1448.228
1980-81	1630	1611.823
1981-82	1691	1683.082
1982-83	1816	1802.708
1983-84	1843	1838.971
1984-85	1870	1866.897
1985-86	2046	2028.09
1986-87	1916	1927.209
1987-88	2002	1994.521
1988-89	2244	2219.052
1989-90	2121	2130.805
1990-91	2281	2265.981
1991-92	2394	2381.198
1992-93	2327	2332.42
1993-94	2380	2375.242
1994-95	2559	2540.624
1995-96	2483	2488.762
1996-97	2679	2659.976
1997-98	2485	2502.498

1998-99	2590	2581.25
1999-00	2778	2758.325
2000-01	2708	2713.032
2001-02	2762	2757.103
2002-03	2610	2624.71
2003-04	2713	2704.171
2004-05	2602	2612.217
2005-06	2619	2618.322
2006-07	2708	2699.032
2007-08	2802	2791.703
2008-09	2907	2895.47
2009-10	2839	2844.647
2010-11	2988	2973.665
2011-12	3177	3156.666
2012-13	3117	3120.967
2013-14	3075	3079.597
2014-15	2872	2892.76
2015-16	3034	3019.876
2016-17	3200	3181.988
2017-18	3368	3349.399
2018-19	3533	3514.64
2019-20	3421	3430.364

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 19 The graph showing smoothness of forecasted values for Wheat production (in hector):-



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Exponential smoothing for Coarse Cereals production from 1963-64 to 2019-20 (in hector)

For the dataset of Coarse cereals production we analysis the data and we can see that for α =0.9 the RMSE is minimum rather than others value of α (0.3,0.6 etc) . As shown in the following table below when damping factor is applied:

Table: 23

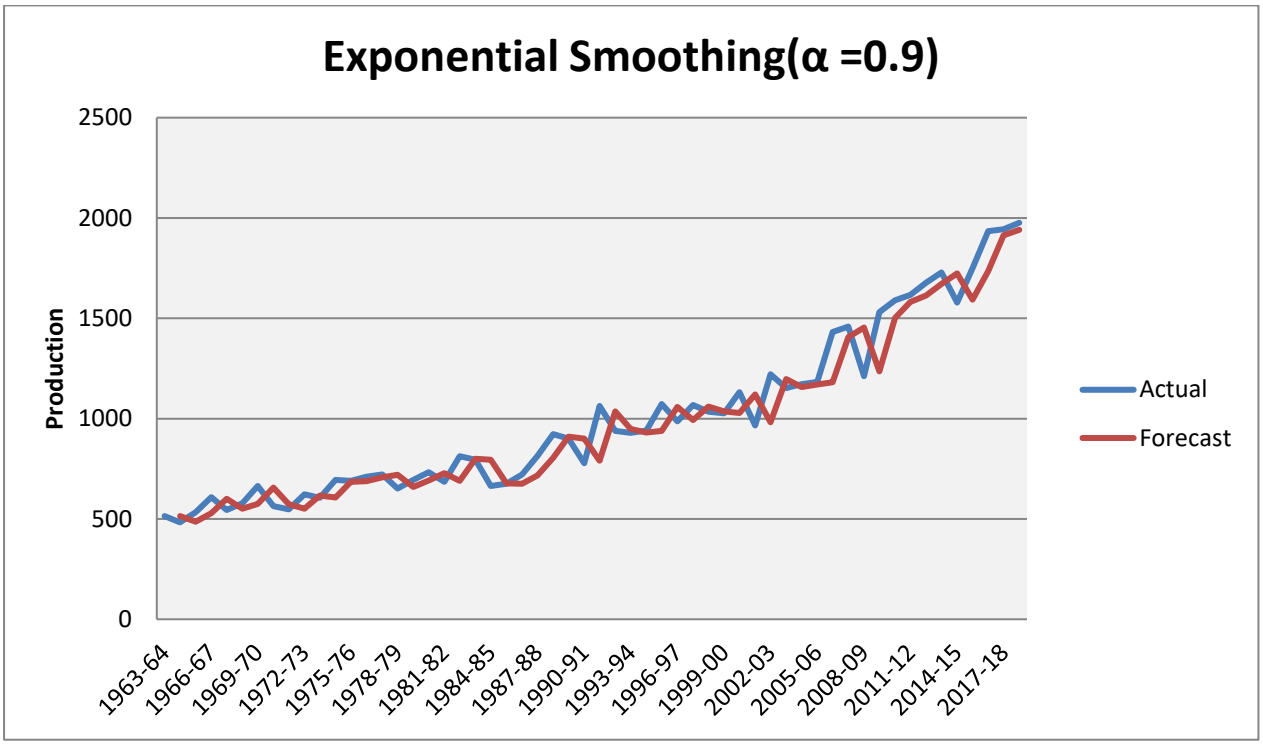
Year	Coarse Cereals	Dumping Factor=0.1	MSE
1963-64	540	540	1001.392
1964-65	514	514	**RMSE**
1965-66	483	486.1	31.64478
1966-67	533	528.31	
1967-68	608	600.031	
1968-69	545	550.5031	

1969-70	578	575.25031	
1970-71	665	656.025031	
1971-72	564	573.2025031	
1972-73	548	550.5202503	
1973-74	623	615.752025	
1974-75	606	606.9752025	
1975-76	694	685.2975203	
1976-77	689	688.629752	
1977-78	710	707.8629752	
1978-79	721	719.6862975	
1979-80	652	658.7686298	
1980-81	695	691.376863	
1981-82	733	728.8376863	
1982-83	685	689.3837686	
1983-84	813	800.6383769	
1984-85	795	795.5638377	
1985-86	664	677.1563838	
1986-87	675	675.2156384	
1987-88	721	716.4215638	
1988-89	814	804.2421564	
1989-90	922	910.2242156	
1990-91	900	901.0224216	
1991-92	778	790.3022422	
1992-93	1063	1035.730224	
1993-94	939	948.6730224	
1994-95	929	930.9673022	
1995-96	940	939.0967302	

1996-97	1072	1058.709673	
1997-98	986	993.2709673	
1998-99	1068	1060.527097	
1999-00	1034	1036.65271	
2000-01	1027	1027.965271	
2001-02	1131	1120.696527	
2002-03	966	981.4696527	
2003-04	1221	1197.046965	
2004-05	1153	1157.404697	
2005-06	1172	1170.54047	
2006-07	1182	1180.854047	
2007-08	1431	1405.985405	
2008-09	1459	1453.69854	
2009-10	1212	1236.169854	
2010-11	1531	1501.516985	
2011-12	1590	1581.151699	
2012-13	1617	1613.41517	
2013-14	1677	1670.641517	
2014-15	1729	1723.164152	
2015-16	1579	1593.416415	
2016-17	1750	1734.341642	
2017-18	1934	1914.034164	
2018-19	1944	1941.003416	
2019-20	1976	1972.500342	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 20 The graph showing smoothness of forecasted values for Coarse Cereals production (per hector):-



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Exponential smoothing for Pulse production from 1963-64 to 2019-20 (in hector):-

For the dataset of Pulse production we analysis the data and we can see that for α =0.8 the RMSE is minimum rather than others value of α (0.3,0.6 etc) . As shown in the following table below when damping factor is applied:

Table: 24

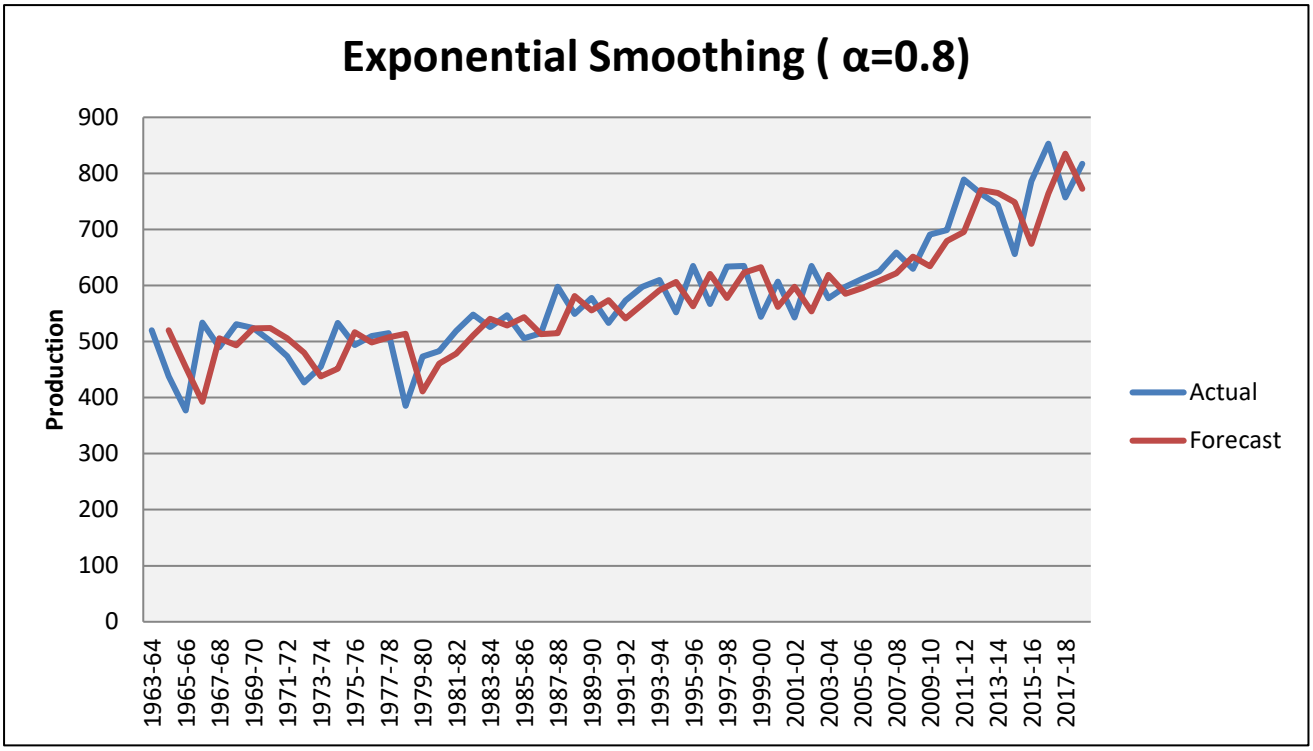
Year	Pulses (D)	Dumping Factor =0.2	MSE
1963-64	416	416	123.4042
1964-65	520	520	**RMSE**
1965-66	438	454.4	11.10874
1966-67	377	392.48	
1967-68	534	505.696	
1968-69	490	493.1392	
1969-70	531	523.42784	
1970-71	524	523.885568	

1971-72	501	505.5771136	
1972-73	474	480.3154227	
1973-74	427	437.6630845	
1974-75	455	451.5326169	
1975-76	533	516.7065234	
1976-77	494	498.5413047	
1977-78	510	507.7082609	
1978-79	515	513.5416522	
1979-80	385	410.7083304	
1980-81	473	460.5416661	
1981-82	483	478.5083332	
1982-83	519	510.9016666	
1983-84	548	540.5803333	
1984-85	526	528.9160667	
1985-86	547	543.3832133	
1986-87	506	513.4766427	
1987-88	515	514.6953285	
1988-89	598	581.3390657	
1989-90	549	555.4678131	
1990-91	578	573.4935626	
1991-92	533	541.0987125	
1992-93	573	566.6197425	
1993-94	598	591.7239485	
1994-95	610	606.3447897	
1995-96	552	562.8689579	
1996-97	635	620.5737916	
1997-98	567	577.7147583	

1998-99	634	622.7429517	
1999-00	635	632.5485903	
2000-01	544	561.7097181	
2001-02	607	597.9419436	
2002-03	543	553.9883887	
2003-04	635	618.7976777	
2004-05	577	585.3595355	
2005-06	598	595.4719071	
2006-07	612	608.6943814	
2007-08	625	621.7388763	
2008-09	659	651.5477753	
2009-10	630	634.3095551	
2010-11	691	679.661911	
2011-12	699	695.1323822	
2012-13	789	770.2264764	
2013-14	764	765.2452953	
2014-15	744	748.2490591	
2015-16	656	674.4498118	
2016-17	786	763.6899624	
2017-18	853	835.1379925	
2018-19	757	772.6275985	
2019-20	817	808.1255197	

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Figure: 21 The graph showing smoothness of forecasted values for Pulse production (per hector):-



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Forecasting:

From the forecasted models, we have forecasted the datasets in the following table. **(Table: 25)**

Year	X	Rice production $A = -0.0026x^3 + 0.3577x^2 + 17.884x + 911.26$	Wheat Production $B = 0.0009x^3 - 0.3277x^2 + 61.5x + 707.96$	Coarse cereal $C = 0.0108x^3 - 0.4503x^2 + 17.165x + 481.51$	Pulse Production $D = 0.0029x^3 - 0.1466x^2 + 5.3864x + 445.03$
1963-64	1	929.4991	769.1332	498.2355	450.2723
1964-65	2	948.438	829.6564	514.1252	455.2388
1965-66	3	968.0611	889.535	529.2439	459.9469
1966-67	4	988.3528	948.7744	543.6564	464.414
1967-68	5	1009.2975	1007.38	557.4275	468.6575
1968-69	6	1030.8796	1065.3572	570.622	472.6948
1969-70	7	1053.0835	1122.7114	583.3047	476.5433
1970-71	8	1075.8936	1179.448	595.5404	480.2204

1971-72	9	1099.2943	1235.5724	607.3939	483.7435
1972-73	10	1123.27	1291.09	618.93	487.13
1973-74	11	1147.8051	1346.0062	630.2135	490.3973
1974-75	12	1172.884	1400.3264	641.3092	493.5628
1975-76	13	1198.4911	1454.056	652.2819	496.6439
1976-77	14	1224.6108	1507.2004	663.1964	499.658
1977-78	15	1251.2275	1559.765	674.1175	502.6225
1978-79	16	1278.3256	1611.7552	685.11	505.5548
1979-80	17	1305.8895	1663.1764	696.2387	508.4723
1980-81	18	1333.9036	1714.034	707.5684	511.3924
1981-82	19	1362.3523	1764.3334	719.1639	514.3325
1982-83	20	1391.22	1814.08	731.09	517.31
1983-84	21	1420.4911	1863.2792	743.4115	520.3423
1984-85	22	1450.15	1911.9364	756.1932	523.4468
1985-86	23	1480.1811	1960.057	769.4999	526.6409
1986-87	24	1510.5688	2007.6464	783.3964	529.942
1987-88	25	1541.2975	2054.71	797.9475	533.3675
1988-89	26	1572.3516	2101.2532	813.218	536.9348
1989-90	27	1603.7155	2147.2814	829.2727	540.6613
1990-91	28	1635.3736	2192.8	846.1764	544.5644
1991-92	29	1667.3103	2237.8144	863.9939	548.6615
1992-93	30	1699.51	2282.33	882.79	552.97
1993-94	31	1731.9571	2326.3522	902.6295	557.5073
1994-95	32	1764.636	2369.8864	923.5772	562.2908
1995-96	33	1797.5311	2412.938	945.6979	567.3379
1996-97	34	1830.6268	2455.5124	969.0564	572.666
1997-98	35	1863.9075	2497.615	993.7175	578.2925

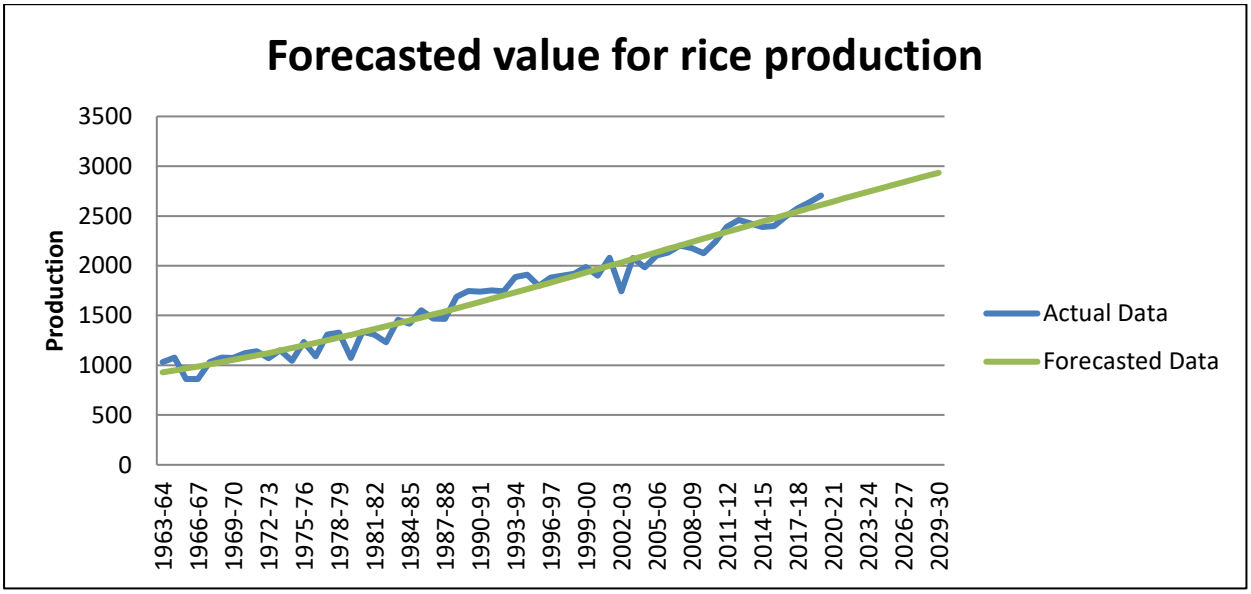
1998-99	36	1897.3576	2539.2512	1019.746	584.2348
1999-00	37	1930.9615	2580.4264	1047.2067	590.5103
2000-01	38	1964.7036	2621.146	1076.1644	597.1364
2001-02	39	1998.5683	2661.4154	1106.6839	604.1305
2002-03	40	2032.54	2701.24	1138.83	611.51
2003-04	41	2066.6031	2740.6252	1172.6675	619.2923
2004-05	42	2100.742	2779.5764	1208.2612	627.4948
2005-06	43	2134.9411	2818.099	1245.6759	636.1349
2006-07	44	2169.1848	2856.1984	1284.9764	645.23
2007-08	45	2203.4575	2893.88	1326.2275	654.7975
2008-09	46	2237.7436	2931.1492	1369.494	664.8548
2009-10	47	2272.0275	2968.0114	1414.8407	675.4193
2010-11	48	2306.2936	3004.472	1462.3324	686.5084
2011-12	49	2340.5263	3040.5364	1512.0339	698.1395
2012-13	50	2374.71	3076.21	1564.01	710.33
2013-14	51	2408.8291	3111.4982	1618.3255	723.0973
2014-15	52	2442.868	3146.4064	1675.0452	736.4588
2015-16	53	2476.8111	3180.94	1734.2339	750.4319
2016-17	54	2510.6428	3215.1044	1795.9564	765.034
2017-18	55	2544.3475	3248.905	1860.2775	780.2825
2018-19	56	2577.9096	3282.3472	1927.262	796.1948
2019-20	57	2611.3135	3315.4364	1996.9747	812.7883
2020-21	58	2644.5436	3348.178	2069.4804	830.0804
2021-22	59	2677.5843	3380.5774	2144.8439	848.0885
2022-23	60	2710.42	3412.64	2223.13	866.83
2023-24	61	2743.0351	3444.3712	2304.4035	886.3223
2024-25	62	2775.414	3475.7764	2388.7292	906.5828

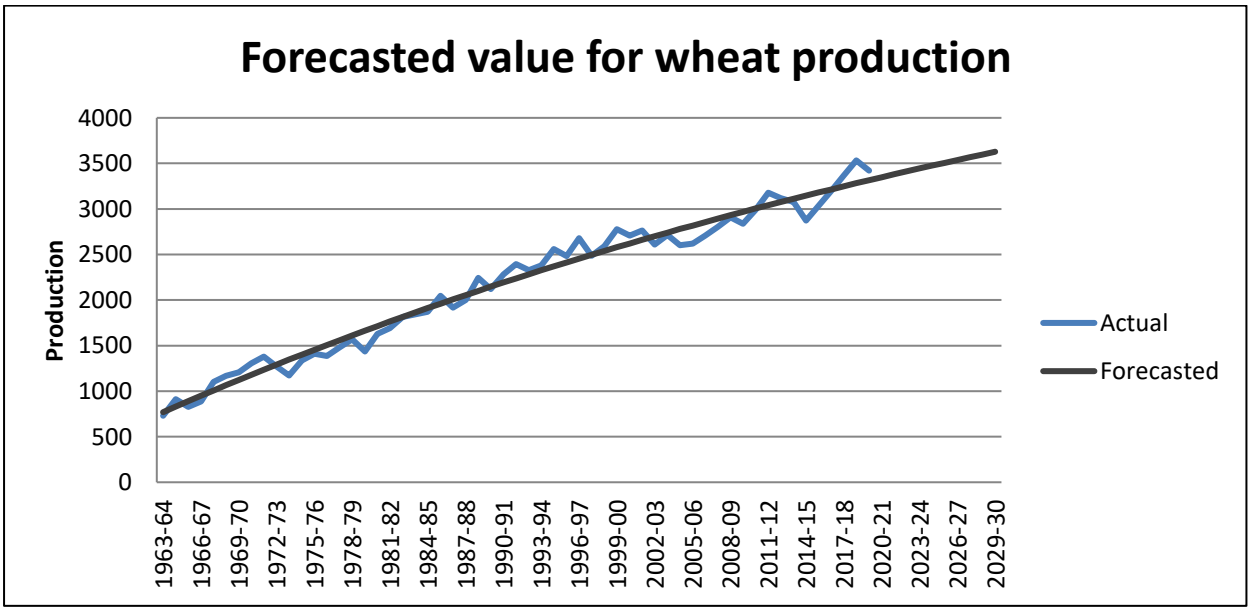
2025-26	63	2807.5411	3506.861	2476.1719	927.6289
2026-27	64	2839.4008	3537.6304	2566.7964	949.478
2027-28	65	2870.9775	3568.09	2660.6675	972.1475
2028-29	66	2902.2556	3598.2452	2757.85	995.6548
2029-30	67	2933.2195	3628.1014	2858.4087	1020.0173

Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

In the above table the coloured boxes form **2020-21 to 2029-30** are the forecasted values for the four datasets; Rice, Wheat, Coarse cereals and Pulse. We have forecasted by using the best fitted models for different data sets.

The forecasted values have shown below by graphical representation for 4 datasets.





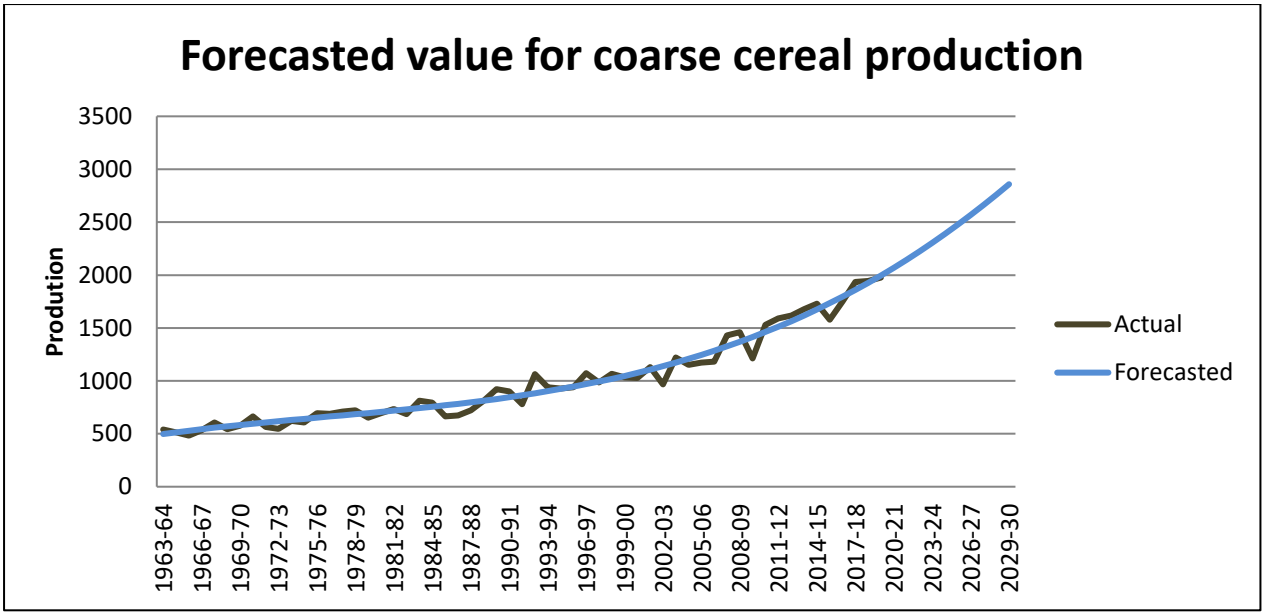
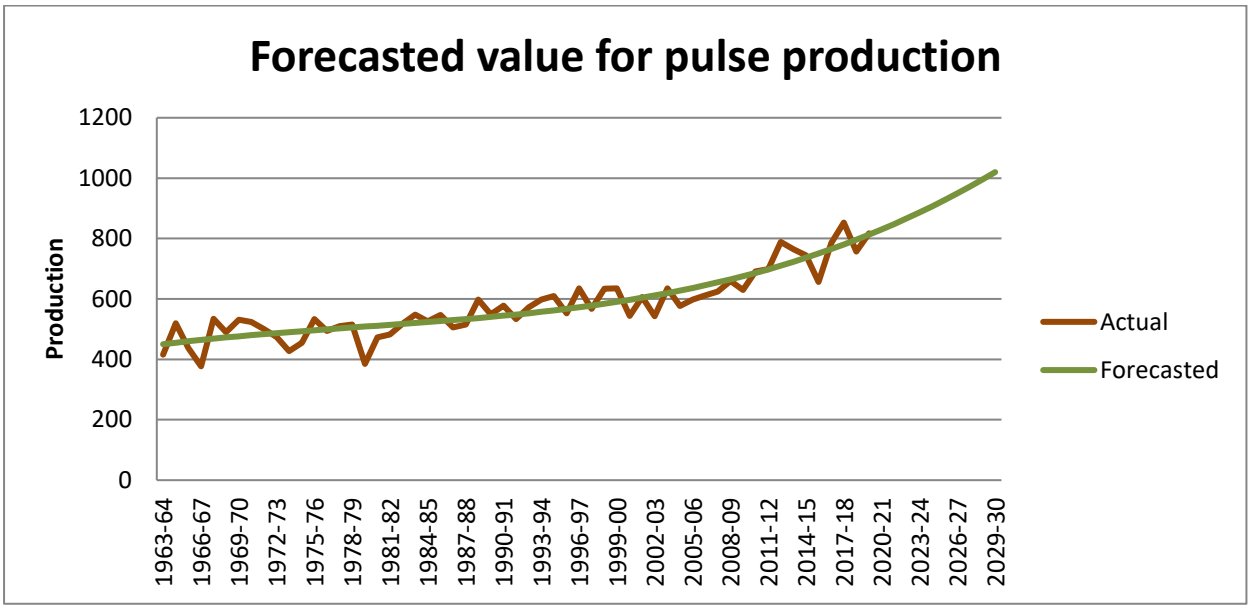


Figure: 22, 23, 24 are drawn above.

Figure: 25



Data source: https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19754

Software used for analysing the data:-

For analysis of the datasets we are using **Microsoft Office Excel_2007**. In the time of analysing the datasets we used several formula and code in Excel.

- **FORMULA USED :-**

ADDITION : " =sum(number1, number2, ……,numbern)"

EXAMPLE : =SUM(N2:N58) ⟶ PRESS ENTER

SUBSTRACTION : " =sum(number1, -number2)"
EXAMPLE : =SUM(D2,-B2) —› PRESS ENTER

RMSE :
"=SQRT(SUM(power(number1,2),power(number2,2),……,power(numbern,2))/n)"
EXAMPLE : =SQRT(sum(power(F2,2),power(F3,2),……..,power(F57,2))/57) —› PRESS ENTER

MULTIPLICATION: =M2*M2 —› PRESS ENTER
EXAMPLE : = C1*C2—› PRESS ENTER

FUNCTION USED : "=Power(number, power)"

Now, we are trying to explain that functions and steps below-

- **Steps for drawing multiple line diagram**

SELECT THE DATASET —› INSERT —› LINE

- **Steps for drawing liner trend**

SELECT THE DATASET —› INSERT —›LINE.

RIGHT CLICK ON THE GRAPH —› ADD TREND LINE —› SELECT LINEAR & SHOW THE EQUATION IN THE GRAPH

FUNCTION USED:
"=Power (number, power)"

- **Steps for drawing 2ND degree polynomial trend**

SELECT THE DATASET —› INSERT —› LINE

RIGHT CLICK ON THE GRAPH —› ADD TREND LINE —› SELECT POLYNOMIAL OF ORDER 2 & SHOW THE EQUATION IN THE GRAPH

FUNCTION USED: "=Power(number, power)"

- **Steps for drawing 3rd degree polynomial trend-**

SELECT THE DATASET —› INSERT —› LINE—› RIGHT CLICK ON THE GRAPH —› ADD TREND LINE —› SELECT POLYNOMIAL OF ORDER 3 & SHOW THE EQUATION IN THE GRAPH

FUNCTION USED: "=Power(number, power)"

- **Excel Steps for Moving Average:-**

SELECT THE DATASET —› INSERT —› LINE—› RIGHT CLICK ON THE GRAPH —› ADD TREND LINE —› SELECT MOVING AVARAGE WITH PERIOD

3. Results:

By analysing our entire data sets we have found several outcomes. They are-

Form the data of Rice production:-

Trend	Trend Equations	Value of RMSE
Straight Line	**$A = 30.749x + 810.31$**	**97.66378202**
2nd degree polynomial	**$A = 0.1299x^2 + 23.217x + 884.37$**	**92.47103707**
3rd degree polynomial	**$A = -0.0026x^3 + 0.3577x^2 + 17.884x + 911.26$**	**92.02721**

As we know smaller the RMSE better the model we get. From the above table we can see 3rd degree polynomial has the smaller RMSE, 3rd degree polynomial model **$A = -0.0026x^3 + 0.3577x^2 + 17.884x + 911.26$** is the best model.

From our analysis, we can see that **4-years moving average** is best for the dataset of rice production.

Exponential Smoothing	Value of RMSE
Exponential Smoothing (α=0.3)	**95.65356**
Exponential Smoothing (α=0.5)	**23.6302**
Exponential Smoothing (α=0.9)	**12.10819**

Form the data of Wheat production:-

Trend	Trend Equation	Value of RMSE
Straight line	**$B = 45.277x + 858.47$**	**130.597**
2nd degree polynomial	**$B = -0.2472x^2 + 59.617x + 717.46$**	**116.1245**
3rd degree polynomial	**$B = 0.0009x^3 - 0.3277x^2 + 61.5x + 707.96$**	**116.0558**

As we know smaller the RMSE better the model we get. From the above table we can see 3rd degree polynomial has the smaller RMSE, 3rd degree polynomial model **$B = 0.0009x^3 - 0.3277x^2 + 61.5x + 707.96$** is the best model.

From our analysis, we can see that **5-years moving average** is best for the dataset of wheat production.

Exponential Smoothing	Value of RMSE
Exponential Smoothing (α=0.2)	**192.957**
Exponential Smoothing (α=0.5)	**71.81587**
Exponential Smoothing (α=0.8)	**25.49028**

Form the data of Coarse cereal production:-

Trend	Trend Equation	Value of RMSE
Straight line	**C = 23.537x + 313.57**	**143.6175**
2nd degree polynomial	**$C = 0.4887x^2 - 4.8095x + 592.31$**	**81.48556**
3rd degree polynomial	**$C = 0.0108x^3 - 0.4503x^2 + 17.165x + 481.51$**	**72.2451**

As we know smaller the RMSE better the model we get. From the above table we can see 3rd degree polynomial has the smaller RMSE, 3rd degree polynomial model **$C = 0.0108x^3 - 0.4503x^2 + 17.165x + 481.51$** is the best model.

From our analysis, we can see that **3-years moving average** is best for the dataset of coarse cereal production.

Exponential Smoothing	Value of RMSE
Exponential Smoothing (α=0.3)	**87.24416**
Exponential Smoothing (α=0.6)	**41.79599**
Exponential Smoothing (α=0.9)	**31.64478**

Form the data of Pulse production:-

Trend	Trend Equation	Value of RMSE
Straight line	**D = 5.5948x + 414.75**	**51.4937**
2nd degree polynomial	**$D = 0.1052x^2 - 0.5057x + 474.74$**	**44.76382**
3rd degree polynomial	**$D = 0.0029x^3 - 0.1466x^2 + 5.3864x + 445.03$**	**43.60993**

As we know smaller the RMSE better the model we get. From the above table we can see 3rd degree polynomial has the smaller RMSE, 3rd degree polynomial model

$D = 0.0029x^3 - 0.1466x^2 + 5.3864x + 445.03$ is the best model.

From our analysis, we can see that **4-years moving average** is best for the dataset of pulse production.

Exponential Smoothing	Value of RMSE
Exponential Smoothing (α=0.3)	**53.13894**
Exponential Smoothing (α=0.5)	**21.2279**
Exponential Smoothing (α=0.8)	**11.10874**

Conclusion

Time series analysis and modelling is a very popular technique in mathematics and statistics used to explore the hidden details in time dependent data. In this project we have forecasted our four datasets through different time series models and have given the best forecasted model for each dataset. From our analysis we can see that for all four datasets, 3^{rd} degree polynomial gives us the best forecasted model than 2^{nd} degree polynomial or straight line for the all four datasets as the RMSE of 3^{rd} degree polynomial is minimum than 2^{nd} degree polynomial or straight line.

Though we have used moving average to understand the trend of the datasets, but it assumes no law of change so we cannot use this method for forecasting further trend.

Here, by using exponential smoothing technique we have founded that it gives the smallest RMSE than other models but in Exponential smoothing**,** the forecast will constantly require updating to respond new information. So we exclude the exponential smoothing form our forecasting technique.

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I am extremely thankful to my brother, my seniors Deboleena Di, Debolina ma'am, Tanmoy Da, and friends Arkaprabha, Sagnik, Sujith and others for their sincere co-operation and support during this period.

Appendix:

Year	Cereals				Pulses	Total Foodgrains
	Rice	Wheat	Coarse Cereals	Total		
1	2	3	4	5	6	7
1963-64	1033	730	540	757	416	687
1964-65	1078	913	514	817	520	757
1965-66	862	827	483	676	438	629
1966-67	863	887	533	707	377	644
1967-68	1032	1103	608	840	534	783
1968-69	1076	1169	545	843	490	781
1969-70	1073	1208	578	865	531	805
1970-71	1123	1307	665	949	524	872
1971-72	1141	1380	564	936	501	858
1972-73	1070	1271	548	886	474	813
1973-74	1151	1172	623	918	427	827
1974-75	1045	1338	606	907	455	824
1975-76	1235	1410	694	1041	533	944
1976-77	1089	1387	689	985	494	894
1977-78	1308	1480	710	1100	510	991
1978-79	1328	1568	721	1136	515	1022
1979-80	1074	1436	652	982	385	876
1980-81	1336	1630	695	1142	473	1023
1981-82	1308	1691	733	1157	483	1032
1982-83	1231	1816	685	1151	519	1035
1983-84	1457	1843	813	1296	548	1162
1984-85	1417	1870	795	1285	526	1149
1985-86	1552	2046	664	1323	547	1175
1986-87	1471	1916	675	1266	506	1128
1987-88	1465	2002	721	1315	515	1173
1988-89	1689	2244	814	1493	598	1331
1989-90	1745	2121	922	1530	549	1349
1990-91	1740	2281	900	1571	578	1380
1991-92	1751	2394	778	1574	533	1382
1992-93	1744	2327	1063	1654	573	1457
1993-94	1888	2380	939	1701	598	1501
1994-95	1911	2559	929	1763	610	1546
1995-96	1797	2483	940	1703	552	1491
1996-97	1882	2679	1072	1831	635	1614
1997-98	1900	2485	986	1775	567	1552
1998-99	1921	2590	1068	1856	634	1627
1999-00	1986	2778	1034	1925	635	1704
2000-01	1901	2708	1027	1844	544	1626
2001-02	2079	2762	1131	1980	607	1734
2002-03	1744	2610	966	1753	543	1535
2003-04	2077	2713	1221	1983	635	1727
2004-05	1984	2602	1153	1903	577	1652
2005-06	2102	2619	1172	1968	598	1715
2006-07	2131	2708	1182	2021	612	1756
2007-08	2202	2802	1431	2151	625	1860
2008-09	2178	2907	1459	2183	659	1909
2009-10	2125	2839	1212	2075	630	1798
2010-11	2239	2988	1531	2256	691	1930
2011-12	2393	3177	1590	2415	699	2078
2012-13	2461	3117	1617	2449	789	2129
2013-14	2424	3075	1677	2438	764	2101
2014-15	2390	2872	1729	2373	744	2070
2015-16	2400	3034	1579	2392	656	2056
2016-17	2494	3200	1750	2525	786	2129
2017-18	2576	3368	1934	2657	853	2235
2018-19	2638	3533	1944	2752	757	2286
2019-20	2705	3421	1976	2756	817	2325

Source : Ministry of Agriculture & Farmers Welfare, Government of India.
https://www.rbi.org.in/Scripts/PublicationsView.aspx?id=19754