University Of Calcutta

ROLL NO - 183115-21-0215

REGISTRATION NO- 115-1111-0902-18

NAME OF THE PROJECT- CULTIVATION OF COFFEE AND TEA IN INDIA (A DATA STUDY)

B.Sc. STATISTICS HONS.(SEMESTER – VI)

PROJECT WORK OF -

DISCIPLINE SPECIFIC ELECTIVE COURSE-B2

INDEX

Executive summary:

Tea and coffee are one of the oldest organised industries in India (major commercial crops). Predictive models provide structure and direction in anticipating future needs. Here in our project, we analysed the data of production and area under cultivation of coffee and tea in particular interval of time in India. Here we have four datasets i.e., coffee and tea production and area under cultivation per year from the year 1970-71 to 2019-20. From the data we want to work out several outcomes by using statistical methodology. At first, we plotted the all datasets in Microsoft Excel to find out the curves of the datasets so that we can study the trends of these variables. Then from the trends we studied our data with help of different time series models, methods (moving average, trend curve fitting). After this step we find our best model that suitably fits the data. Then we get our study variable and also the predicting equation which will help us to do forecasting of any year. We also analysed correlation and regression between area under cultivation and production of tea and coffee and also some others descriptive measures. Moreover, from the above study we get several outcomes which helps in anticipating future needs of these industries.

Introduction:

India is one of the largest tea producers in the world, although over 70 per cent of its tea is consumed within India itself. A number of renowned teas, such as Assam and Darjeeling, also grow exclusively in India. The Indian tea industry has grown to own many global tea brands and has evolved into one of the most technologically equipped tea industries in the world. Tea production, certification, exportation, and all other facets of the tea trade in India are controlled by the Tea Board of India.

Indian Tea Giant Goodricke Group parent Camellia Plc becomes the world's largest private tea producer in 2018 producing 103 million kgs. As of 2013 the consumption of green tea in India was growing by over 50% a year.

The major tea-producing states in India are: Assam, West Bengal, Tamil Nadu, Kerala, Tripura, Arunachal Pradesh, Himachal Pradesh, Karnataka, Sikkim, Nagaland, Uttarakhand, Manipur, Mizoram, Meghalaya, Bihar, Orissa.

Coffee growing has a long history that is attributed first to Ethiopia and then to Arabia. In the INDIAN context, Coffee growing started with an Indian Muslim Saint BABA BUDAN. In 1942, the government decided to regulate the export of coffee and protect the small and marginal farmers by passing the Coffee VII Act of 1942, under which the Coffee Board of India got established, operated by the Ministry of Commerce and Industry.

Coffee is grown in three regions of India with Karnataka, Kerala and Tamil Nadu forming the traditional coffee growing region, followed by the new areas developed in the non-traditional areas of Andhra Pradesh and Odisha in the eastern coast of the country and with a third region comprising the states of Assam, Manipur, Meghalaya, Mizoram, Tripura, Nagaland and Arunachal Pradesh of North-eastern India, popularly known as “Seven Sisters of India".

Coffee production in India grew rapidly in the 1970s, increasing from 68,948 tonnes in 1971–72 to 120,000 tonnes in 1979–80 and grew by 4.6 percent in the 1980s. It grew by more than 30 percent in the 1990s, rivalled only by Uganda in the growth of production. By 2007, organic coffee was grown in about 2,600 hectares (6,400 acres) with an estimated production of about 1700 tonnes. According to the 2008 statistics published by the Food and Agriculture Organization (FAO), the area of coffee green harvested in India was 342,000 hectares (850,000 acres), with yield estimates of 7,660 hectogram/ha, forming a total production estimate of 262,000 tonnes.

Over the last 50 years, coffee production in India has grown by over 15 %. From 1991, economic liberalisation took place in India, and the industry took full advantage of this and cheaper labour costs of production. Coffee production in India is dominated in the hill tracts of South Indian states, with Karnataka accounting for 71%, followed by Kerala with 21% and Tamil Nadu (5% of overall production with 8,200 tonnes).

Now coffee bars have gained in popularity with other chains such as Barista; Café Coffee Day is the country's largest coffee bar chain. In the Indian home, coffee consumption is greater in south India than elsewhere.

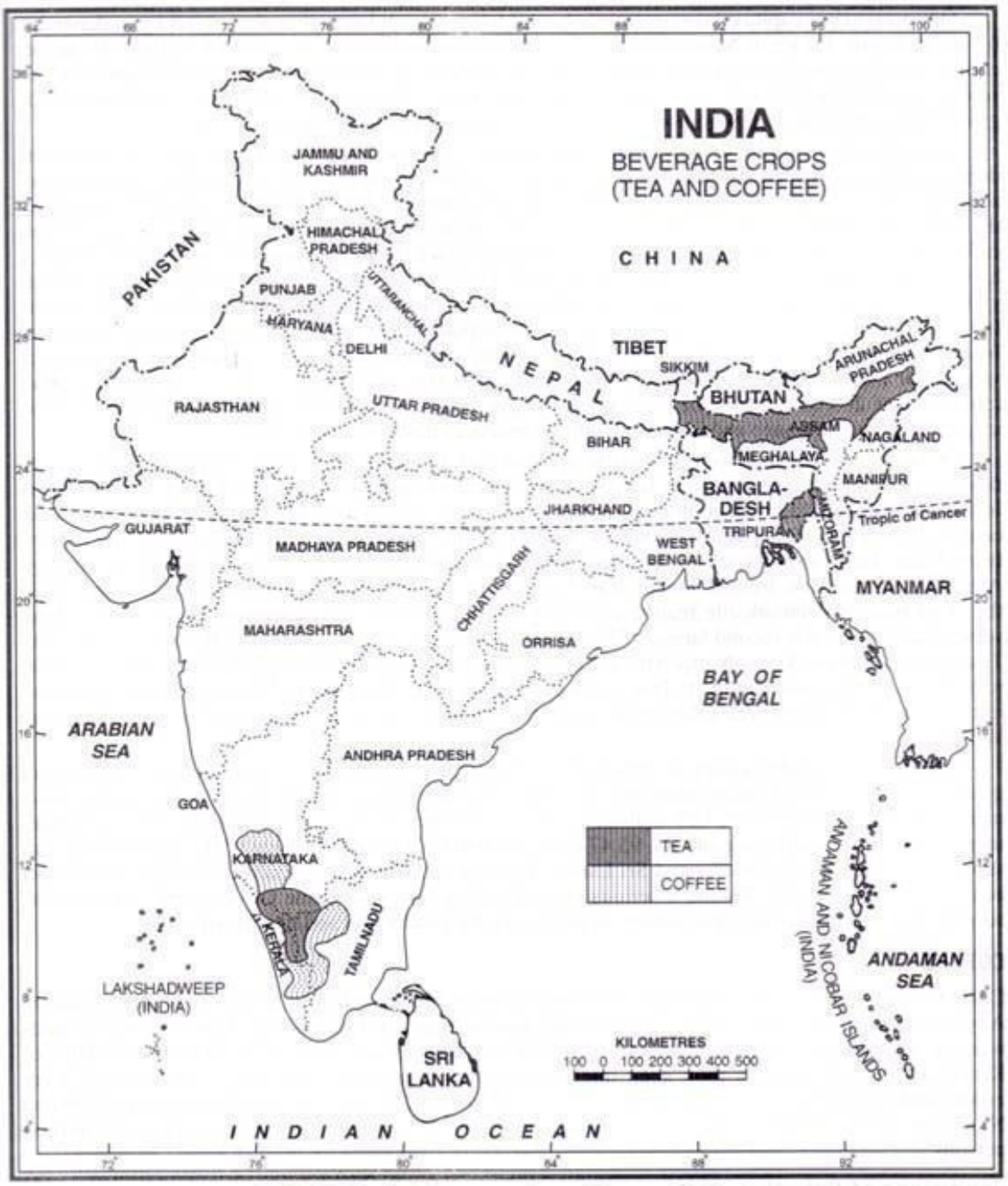


FIG. 24.6. India : Beverage Crops (Tea and Coffee)

METHODOLOGY:

Table 1.1: Showing the data of coffee and tea production and area under cultivation

(Coffee and Tea data measured in lacs kg.)

(Area under cultivation measured in lakh hectares.)

YEAR	T	COFFEE PRODUCTION (Y)	TEA PRODUCTION (Y')	AREA UNDER CULTIVATION OF COFFEE (X)	AREA UNDER CULTIVATION OF TEA (X')
1970-71	1	1102.3	4190	1.4	3.5
1971-72	2	689.5	4350	1.4	3.6
1972-73	3	910.7	4560	1.5	3.6
1973-74	4	863.9	4720	1.6	3.6
1974-75	5	925.1	4890	1.6	3.6
1975-76	6	839.8	4870	1.7	3.6
1776-77	7	1023	5120	1.4	3.6
1977-78	8	1251.4	5560	1.5	3.7
1978-79	9	1104.9	5640	1.6	3.7
1979-80	10	1498.4	5440	1.7	3.7
1980-81	11	1186.5	5696	1.9	3.8
1981-82	12	1521	5604	1.9	3.8
1982-83	13	1299.5	5607	2.1	3.9
1983-84	14	1050.3	5815	2.1	4
1984-85	15	1951.1	6399	2.1	4
1985-86	16	1224.5	6562	2.1	4
1986-87	17	1920.9	6246	2.2	4.1
1987-88	18	1227.1	6743	2.2	4.1
1988-89	19	2147.2	7011	2.2	4.1
1989-90	20	1180.5	6841	2.2	4.1
1990-91	21	1697.3	7203.4	2.2	4.2
1991-92	22	1800	7541.9	2.2	4.2
1992-93	23	1694	7039.3	2.2	4.2
1993-94	24	2120.9	7608.3	2.3	4.2
1994-95	25	1801	7529	2.3	4.3
1995-96	26	2230	7560.2	2.4	4.3
1996-97	27	2050	7801.4	2.5	4.3
1997-98	28	2283	8356.4	2.9	4.3

1998-99	29	2650	8551.6	3	4.7
1999-00	30	2920	8368.6	3.1	4.9
2000-01	31	3012	8484.3	3.1	5
2001-02	32	3006	8514.1	3.2	5.1
2002-03	33	2753	8459.7	3.3	5.2
2003-04	34	2705	8786.5	3.3	5.2
2004-05	35	2755	9068.4	3.3	5.2
2005-06	36	2740	9489.4	3.8	5.6
2006-07	37	2880	9730.7	3.8	5.6
2007-08	38	2620	9870.2	3.9	5.8
2008-09	39	2623	9727.7	3.9	5.8
2009-10	40	2896	9911.8	4	5.8
2010-11	41	3020	9667.3	4	5.6
2011-12	42	3140	10954.6	4.1	5.6
2012-13	43	3182	11350.7	4.1	5.6
2013-14	44	3045	12087.8	4.2	5.7
2014-15	45	3270	11971.8	4.2	5.7
2015-16	46	3480	12331.4	4.3	5.7
2016-17	47	3120	12504.9	4.5	5.8
2017-18	48	3160	13250.5	4.5	5.8
2018-19	49	3195	13500.4	4.6	6.4
2019-20	50	2993	13608.1	4.6	6.4

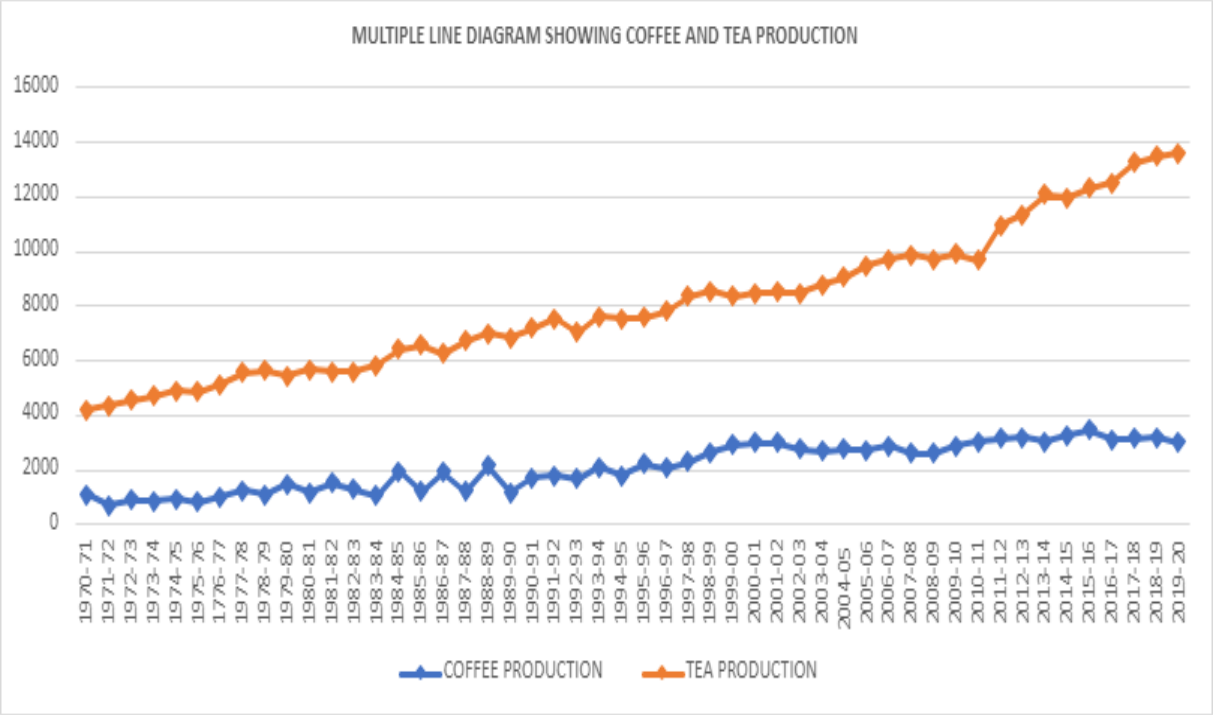


Fig 1.1 : Multiple line diagram showing coffee and tea production during 1970-71 to 2019-20

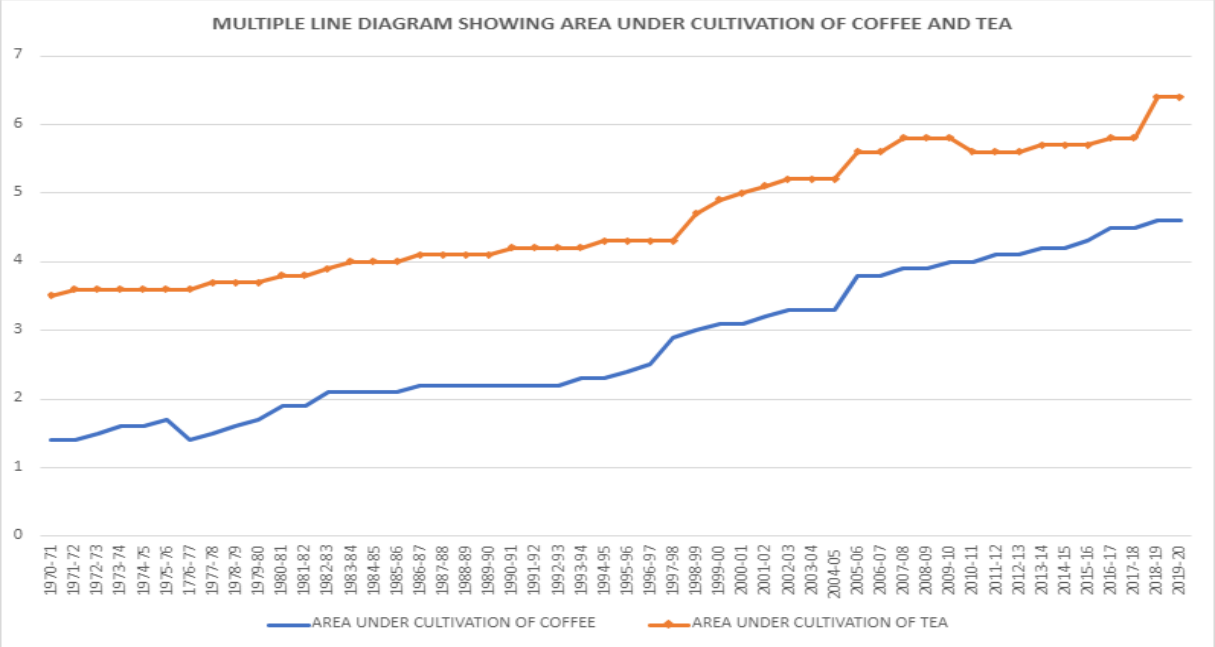


Fig 1.2 : Multiple line diagram showing area under cultivation of coffee and tea

We have taken four datasets:

Y: Production of coffee

Y': Production of tea

X: Area under cultivation of coffee

X': Area under cultivation of tea

T: Time index (1, 2, …, n), where n= number of observations = 50.

Theoretical references:

1. Fundamental of statistics vol – 1 & 2 (A.M Gun, M.K Gupta, B.D Dasgupta)
2. Fundamental of applied statistics (S.C Gupta, V.K Kapoor)
3. Fundamental of mathematical statistics (S.C Gupta, V.K Kapoor)

Analysis:

Correlation and regression analysis:

CORRELATION:

Here we calculate the correlation coefficient (r) between coffee production and the area under cultivation of coffee. By using excel function we can easily calculate the correlation.

The method of calculating correlation is:

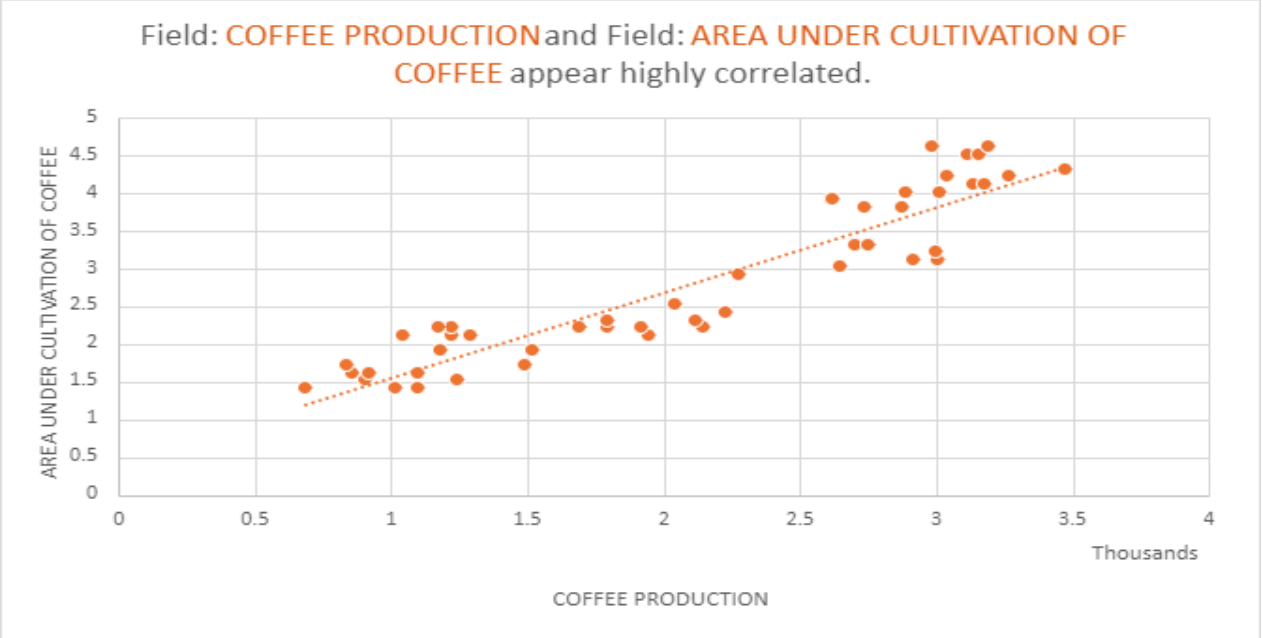
Step 1: Type the function =CORREL(array1,array2).

Step 2: Select the array1 and array2.

Step 3: Press enter.

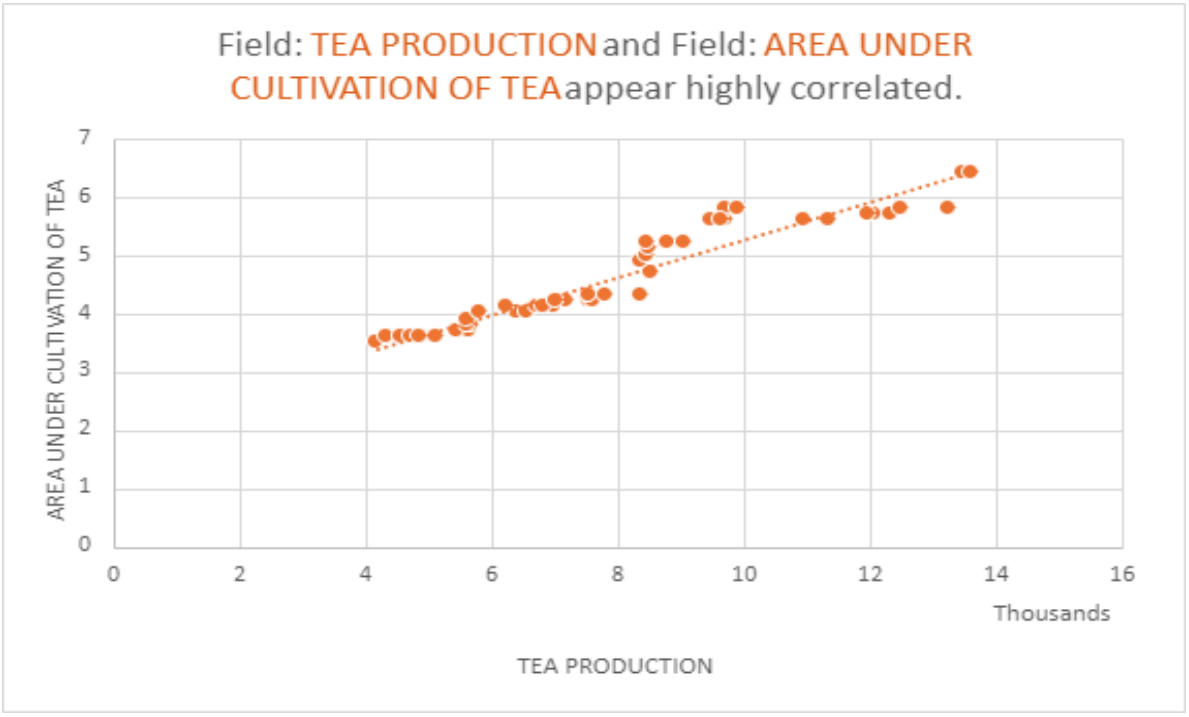
By these steps we find the correlation between Y and X is :

r(Y, X) = 0.931474954



Similarly, we calculate the correlation coefficient between tea production and the area under cultivation of tea i.e., r(Y', X') by using same method.

r(Y', X') = 0.953358263



REGRESSION:

Now we are interested to analyse regression between production and area under cultivation of tea and coffee. Here, we analyse three types of regressions that is Linear regression, Curvilinear regression and exponential regression.

After getting the estimated values of X, X', Y and Y', we have to compare the estimated values with actual values to find the errors and then we calculate the MSE (Mean square Error). The regression curve which will give the least value of MSE, is chosen to be the good fitted.

Regression between production of coffee(Y) and area under cultivation of coffee(X):

Linear Regression:

In this case, we have to find an equation of line of regression by the following process.

Step 1: We have to select the datasets, for which we want to analyse the regression.

Step 2: Click on insert.

Step 3: click on chart.

Step 4: Double click on the diagram and select customise.

Step 5: Click on series and select trend line.

Step 6: Choose the type (hence, Linear).

Step 7: Click on label and select the option 'use equation'.

By this way we find that,

The linear regression line of Y on X is Y = 761.5074201X - 20.09080589

The linear regression line of X on Y is X = 0.001139379Y + 0.39401281

Table 2.1: Showing the Original values and estimated values of X and Y

X	Estimated values of Y	Y	Estimated values of X
1.4	1046.019582	1102.3	1.649950282
1.4	1046.019582	689.5	1.179614631
1.5	1122.170324	910.7	1.431645265
1.6	1198.321066	863.9	1.378322328
1.6	1198.321066	925.1	1.448052323
1.7	1274.471808	839.8	1.350863294
1.4	1046.019582	1023	1.559597527
1.5	1122.170324	1251.4	1.819831691

1.6	1198.321066	1104.9	1.652912667
1.7	1274.471808	1498.4	2.101258304
1.9	1426.773292	1186.5	1.745885994
1.9	1426.773292	1521	2.127008269
2.1	1579.074776	1299.5	1.874635821
2.1	1579.074776	1050.3	1.590702574
2.1	1579.074776	1951.1	2.617055177
2.1	1579.074776	1224.5	1.789182396
2.2	1655.225518	1920.9	2.582645931
2.2	1655.225518	1227.1	1.792144781
2.2	1655.225518	2147.2	2.840487399
2.2	1655.225518	1180.5	1.73904972
2.2	1655.225518	1697.3	2.327880787
2.2	1655.225518	1800	2.44489501
2.2	1655.225518	1694	2.324120836
2.3	1731.37626	2120.9	2.810521731
2.3	1731.37626	1801	2.446034389
2.4	1807.527002	2230	2.93482798
2.5	1883.677744	2050	2.72973976
2.9	2188.280712	2283	2.995215067
3	2264.431454	2650	3.41336716
3.1	2340.582196	2920	3.72099949
3.1	2340.582196	3012	3.825822358
3.2	2416.732938	3006	3.818986084
3.3	2492.88368	2753	3.530723197
3.3	2492.88368	2705	3.476033005
3.3	2492.88368	2755	3.533001955
3.8	2873.63739	2740	3.51591127
3.8	2873.63739	2880	3.67542433
3.9	2949.788133	2620	3.37918579
3.9	2949.788133	2623	3.382603927
4	3025.938875	2896	3.693654394
4	3025.938875	3020	3.83493739
4.1	3102.089617	3140	3.97166287
4.1	3102.089617	3182	4.019516788
4.2	3178.240359	3045	3.863421865
4.2	3178.240359	3270	4.11978214
4.3	3254.391101	3480	4.35905173
4.5	3406.692585	3120	3.94887529
4.5	3406.692585	3160	3.99445045
4.6	3482.843327	3195	4.034328715
4.6	3482.843327	2993	3.804174157

Hence, we calculate the MSE and RMSE by following method.

Step 1: To get the deviation, we have to type =(select the original values)-(select the estimated values)

Step 2: We have to type =(select the deviation values) ^2.

Step 3: To get MSE, we have to type =average(select square of deviation)

Step 4: To get RMSE, we have to type =sqrt(value of MSE).

BY this process we get the MSE (Linear regression of Y on X) = 93942.54194

And the value of RMSE (Linear regression of Y on X) = 306.5004763

MSE (Linear regression of X on Y) = 0.140558266

RMSE (Linear regression of X on Y) = 0.374911011

Exponential Regression:

Similarly, we can find the exponential regression equation of Y on X is Y=780*2.718281828^(0.34X)

And the exponential regression equation of X on Y is X= 1.08*2.718281828^(0.000426*Y).

Table 2.2: Showing the original values and estimated values of X and Y.

X	Estimated Y	Y	Estimated X
1.4	1255.505952	1102.3	1.727267778
1.4	1255.505952	689.5	1.448731058
1.5	1298.927132	910.7	1.591885625
1.6	1343.850016	863.9	1.560462796
1.6	1343.850016	925.1	1.601680901
1.7	1390.32654	839.8	1.544524106
1.4	1255.505952	1023	1.669892146
1.5	1298.927132	1251.4	1.840537118
1.6	1343.850016	1104.9	1.72918196
1.7	1390.32654	1498.4	2.044757992
1.9	1488.157296	1186.5	1.790348048

1.9	1488.157296	1521	2.064539174
2.1	1592.871943	1299.5	1.878639869
2.1	1592.871943	1050.3	1.689426025
2.1	1592.871943	1951.1	2.479680301
2.1	1592.871943	1224.5	1.819566054
2.2	1647.960793	1920.9	2.447983051
2.2	1647.960793	1227.1	1.821582522
2.2	1647.960793	2147.2	2.695727847
2.2	1647.960793	1180.5	1.785777761
2.2	1647.960793	1697.3	2.225565056
2.2	1647.960793	1800	2.325095332
2.2	1647.960793	1694	2.222438555
2.3	1704.954869	2120.9	2.665694012
2.3	1704.954869	1801	2.326086033
2.4	1763.920063	2230	2.792510581
2.5	1824.924544	2050	2.586384724
2.9	2090.783007	2283	2.856277035
3	2163.091916	2650	3.339633402
3.1	2237.901599	2920	3.746720938
3.1	2237.901599	3012	3.896477894
3.2	2315.298545	3006	3.886531214
3.3	2395.372235	2753	3.48943224
3.3	2395.372235	2705	3.418804884
3.3	2395.372235	2755	3.492406503
3.8	2839.246331	2740	3.470161175
3.8	2839.246331	2880	3.683417689
3.9	2937.440549	2620	3.297224457
3.9	2937.440549	2623	3.301441004
4	3039.030775	2896	3.70860962
4	3039.030775	3020	3.909779744
4.1	3144.134459	3140	4.114844484
4.1	3144.134459	3182	4.189129857
4.2	3252.873113	3045	3.951641416
4.2	3252.873113	3270	4.349152684
4.3	3365.37245	3480	4.756162002
4.5	3602.17792	3120	4.079934935
4.5	3602.17792	3160	4.150052733
4.6	3726.757827	3195	4.212393616
4.6	3726.757827	2993	3.865067093

Hence, we calculate the MSE and RMSE by similar method.

MSE (exponential regression of Y on X) = 139401.8111

And the value of RMSE (exponential regression of Y on X) = 373.3655194

MSE (exponential regression of X on Y) = 0.116739706

And the RMSE (exponential regression of X on Y) = 0.341671927

Curvilinear Regression:

Similarly, we get the curvilinear regression of degree 2 and 3.

The curvilinear regression equation of degree 2 of Y on X is Y=-1548 + 1936X + -198X^2

And the curvilinear regression equation of degree 3 of X on Y is

X= 1.96-0.000939Y+0.000000719Y^2-0.0000000000642Y^3

Table 2.3: Showing the original values and estimated values of X and Y

X	Estimated Y	Y	Estimated X
1.4	774.32	1102.3	1.712584916
1.4	774.32	689.5	1.633335007
1.5	910.5	910.7	1.65268197
1.6	1042.72	863.9	1.644011427
1.6	1042.72	925.1	1.655830725
1.7	1170.98	839.8	1.640488221
1.4	774.32	1023	1.683124884
1.5	910.5	1251.4	1.7850784
1.6	1042.72	1104.9	1.713659763
1.7	1170.98	1498.4	1.951320661
1.9	1415.62	1186.5	1.750836518
1.9	1415.62	1521	1.96924173
2.1	1644.42	1299.5	1.813060264
2.1	1644.42	1050.3	1.692535589
2.1	1644.42	1951.1	2.388158953
2.1	1644.42	1224.5	1.770391078
2.2	1752.88	1920.9	2.354242237
2.2	1752.88	1227.1	1.771780264
2.2	1752.88	2147.2	2.623151479

2.2	1752.88	1180.5	1.7478779
2.2	1752.88	1697.3	2.123635994
2.2	1752.88	1800	2.2249456
2.2	1752.88	1694	2.120515595
2.3	1857.38	2120.9	2.590207579
2.3	1857.38	1801	2.225971348
2.4	1957.92	2230	2.729594899
2.5	2054.5	2050	2.503556475
2.9	2401.22	2283	2.799826403
3	2478	2650	3.326089575
3.1	2550.82	2920	3.75020855
3.1	2550.82	3012	3.900319422
3.2	2619.68	3006	3.890454669
3.3	2684.58	2753	3.484706715
3.3	2684.58	2705	3.410264096
3.3	2684.58	2755	3.487827663
3.8	2949.68	2740	3.464457499
3.8	2949.68	2880	3.685752218
3.9	2990.82	2620	3.280704062
3.9	2990.82	2623	3.28522542
4	3028	2896	3.711473035
4	3028	3020	3.913487966
4.1	3061.22	3140	4.113015355
4.1	3061.22	3182	4.183661275
4.2	3090.48	3045	3.95475208
4.2	3090.48	3270	4.332861831
4.3	3115.78	3480	4.694000474
4.5	3154.5	3120	4.079514342
4.5	3154.5	3160	4.146607757
4.6	3167.92	3195	4.205605095
4.6	3167.92	2993	3.869115741

Hence, we calculate the MSE and RMSE by similar method.

MSE (Curvilinear regression of Y on X) = 68395.80714

And the value of RMSE (Curvilinear regression of Y on X) = 261.5259206

MSE (Curvilinear regression of X on Y) = 0.112756531

And the RMSE (Curvilinear regression of X on Y) = 0.335792393

Regression between production of tea(Y') and area under cultivation of tea(X'):

Linear regression:

The linear regression line of Y' on X' is Y' = 2814.223298X'+-5020.993444

The linear regression line of X', on Y' is X' = 0.000322964Y'+2.044886507

Table 3.1: Showing the Original values and estimated values of X' and Y'

X'	Estimated Y'	Y'	Estimated X'
3.5	4828.788099	4190	3.398105667
3.6	5110.210429	4350	3.449779907
3.6	5110.210429	4560	3.517602347
3.6	5110.210429	4720	3.569276587
3.6	5110.210429	4890	3.624180467
3.6	5110.210429	4870	3.617721187
3.6	5110.210429	5120	3.698462187
3.7	5391.632759	5560	3.840566347
3.7	5391.632759	5640	3.866403467
3.7	5391.632759	5440	3.801810667
3.8	5673.055088	5696	3.884489451
3.8	5673.055088	5604	3.854776763
3.9	5954.477418	5607	3.855745655
4	6235.899748	5815	3.922922167
4	6235.899748	6399	4.111533143
4	6235.899748	6562	4.164176275
4.1	6517.322078	6246	4.062119651
4.1	6517.322078	6743	4.222632759
4.1	6517.322078	7011	4.309187111
4.1	6517.322078	6841	4.254283231
4.2	6798.744408	7203.4	4.371325385
4.2	6798.744408	7541.9	4.480648699
4.2	6798.744408	7039.3	4.318326992
4.2	6798.744408	7608.3	4.502093508
4.3	7080.166737	7529	4.476482463
4.3	7080.166737	7560.2	4.48655894
4.3	7080.166737	7801.4	4.564457857
4.3	7080.166737	8356.4	4.743702877
4.7	8205.856057	8551.6	4.806745449

4.9	8768.700716	8368.6	4.747643037
5	9050.123046	8484.3	4.785009972
5.1	9331.545376	8514.1	4.794634299
5.2	9612.967706	8459.7	4.777065058
5.2	9612.967706	8786.5	4.882609693
5.2	9612.967706	9068.4	4.973653245
5.6	10738.65702	9489.4	5.109621089
5.6	10738.65702	9730.7	5.187552302
5.8	11301.50168	9870.2	5.23260578
5.8	11301.50168	9727.7	5.18658341
5.8	11301.50168	9911.8	5.246041082
5.6	10738.65702	9667.3	5.167076384
5.6	10738.65702	10954.6	5.582827941
5.6	10738.65702	11350.7	5.710753982
5.7	11020.07935	12087.8	5.948810746
5.7	11020.07935	11971.8	5.911346922
5.7	11020.07935	12331.4	6.027484777
5.8	11301.50168	12504.9	6.083519031
5.8	11301.50168	13250.5	6.324320989
6.4	12990.03566	13500.4	6.405029693
6.4	12990.03566	13608.1	6.439812915

MSE (Linear regression of Y' on X') = 607870.4459

And the value of RMSE (Linear regression of Y' on X') = 779.6604683

MSE (Linear regression of X' on Y') = 0.069759955

RMSE (Linear regression of X' on Y') = 0.264121099

Exponential regression:

The exponential regression equation of Y' on X' is Y'=1614e^0.337X'

The exponential regression equation of X' on Y' is X'=2.67*2.718281828^(0.000067*Y')

Table 3.2: Showing the Original values and estimated values of X' and Y'

X'	**Estimated Y'**	**Y,**	**Estimated X'**
3.5	5249.934339	4190	3.535336453
3.6	5429.872047	4350	3.573439125

3.6	5429.872047	4560	3.624072786
3.6	5429.872047	4720	3.663131828
3.6	5429.872047	4890	3.705093418
3.6	5429.872047	4870	3.700131917
3.6	5429.872047	5120	3.762631096
3.7	5615.976991	5560	3.875204642
3.7	5615.976991	5640	3.896031505
3.7	5615.976991	5440	3.844172912
3.8	5808.460547	5696	3.910676873
3.8	5808.460547	5604	3.886645601
3.9	6007.541338	5607	3.887426896
4	6213.445479	5815	3.941981329
4	6213.445479	6399	4.099280508
4	6213.445479	6562	4.144294099
4.1	6426.406836	6246	4.057473431
4.1	6426.406836	6743	4.194857928
4.1	6426.406836	7011	4.270861111
4.1	6426.406836	6841	4.222491988
4.2	6646.66729	7203.4	4.326272308
4.2	6646.66729	7541.9	4.42551109
4.2	6646.66729	7039.3	4.278966773
4.2	6646.66729	7608.3	4.445243163
4.3	6874.477011	7529	4.421687773
4.3	6874.477011	7560.2	4.430940537
4.3	6874.477011	7801.4	4.503128027
4.3	6874.477011	8356.4	4.673729085
4.7	7866.518352	8551.6	4.73525544
4.9	8414.997828	8368.6	4.677550953
5	8703.415802	8484.3	4.713951766
5.1	9001.719094	8514.1	4.723373044
5.2	9310.246516	8459.7	4.70618863
5.2	9310.246516	8786.5	4.810369846
5.2	9310.246516	9068.4	4.902088174
5.6	10653.78864	9489.4	5.042329977
5.6	10653.78864	9730.7	5.124512365
5.8	11396.60575	9870.2	5.17263315
5.8	11396.60575	9727.7	5.123482442
5.8	11396.60575	9911.8	5.187070424
5.6	10653.78864	9667.3	5.102790629
5.6	10653.78864	10954.6	5.562438951
5.6	10653.78864	11350.7	5.712035113
5.7	11018.93955	12087.8	6.00120974
5.7	11018.93955	11971.8	5.954749118

5.7	11018.93955	12331.4	6.099960357
5.8	11396.60575	12504.9	6.171283088
5.8	11396.60575	13250.5	6.487400896
6.4	13950.50306	13500.4	6.596935825
6.4	13950.50306	13608.1	6.644710817

MSE (exponential regression of Y' on X') = 665090.7045

And the value of RMSE (exponential regression of Y' on X') = 815.5309341

MSE (exponential regression of X' on Y') = 0.088152685

RMSE (exponential regression of X' on Y') = 0.296905179

Curvilinear Regression:

The curvilinear regression equation of degree 3 of Y' on X' is Y'=-64590 + 40728X' -7896X'^2 + 539X'^3

The curvilinear regression equation of degree 2 of X' on Y' is X'= 1.27 + 0.000518Y' - 0.0000000111Y'^2

Table 3.3: Showing the Original values and estimated values of X' and Y'

X'	Estimated Y'	Y'	Estimated Y'
3.5	4341.625	4190	3.24554729
3.6	4846.224	4350	3.31326025
3.6	4846.224	4560	3.40127104
3.6	4846.224	4720	3.46766976
3.6	4846.224	4890	3.53759569
3.6	4846.224	4870	3.52940241
3.6	4846.224	5120	3.63118016
3.7	5309.327	5560	3.80693904
3.7	5309.327	5640	3.83843344
3.7	5309.327	5440	3.75943104
3.8	5734.168	5696	3.860394982
3.8	5734.168	5604	3.824278542
3.9	6123.981	5607	3.825459216
4	6482	5815	3.906832103
4	6482	6399	4.130168069
4	6482	6562	4.191151732
4.1	6811.459	6246	4.072389072
4.1	6811.459	6743	4.258178656
4.1	6811.459	7011	4.356087257

4.1	6811.459	6841	4.294165981
4.2	7115.592	7203.4	4.425393616
4.2	7115.592	7541.9	4.545333363
4.2	7115.592	7039.3	4.366333036
4.2	7115.592	7608.3	4.568562259
4.3	7397.633	7529	4.540809165
4.3	7397.633	7560.2	4.551745073
4.3	7397.633	7801.4	4.635558754
4.3	7397.633	8356.4	4.823508627
4.7	8369.557	8551.6	4.887987326
4.9	8807.051	8368.6	4.827563328
5	9025	8484.3	4.865852254
5.1	9246.729	8514.1	4.875665923
5.2	9475.472	8459.7	4.857736183
5.2	9475.472	8786.5	4.964458337
5.2	9475.472	9068.4	5.054612948
5.6	10525.264	9489.4	5.185968493
5.6	10525.264	9730.7	5.2594822
5.8	11176.328	9870.2	5.301392187
5.8	11176.328	9727.7	5.258576165
5.8	11176.328	9911.8	5.31380645
5.6	10525.264	9667.3	5.240292149
5.6	10525.264	10954.6	5.612446601
5.6	10525.264	11350.7	5.719556466
5.7	10837.587	12087.8	5.909604912
5.7	10837.587	11971.8	5.880496053
5.7	10837.587	12331.4	5.969761172
5.8	11176.328	12504.9	6.011803183
5.8	11176.328	13250.5	6.184868172
6.4	13944.656	13500.4	6.240112318
6.4	13944.656	13608.1	6.26349352

MSE (Curvilinear regression of Y' on X') = 524038.1607

And the value of RMSE (Curvilinear regression of Y' on X') = 723.9048009

MSE (Curvilinear regression of X' on Y') = 0.063780863

RMSE (Curvilinear regression of X' on Y') = 0.252548734

Method of moving average:

It consists in measurement of trend by smoothing out the fluctuations of the data by means of a moving average. We know that the appropriate period of the moving average is the period of cyclic variations. The given data does not reveal a regular cycle of any fixed period. If we examine the data carefully, we have the peaks at different points for two data sets.

For production of coffee, we have peaks at the following points:

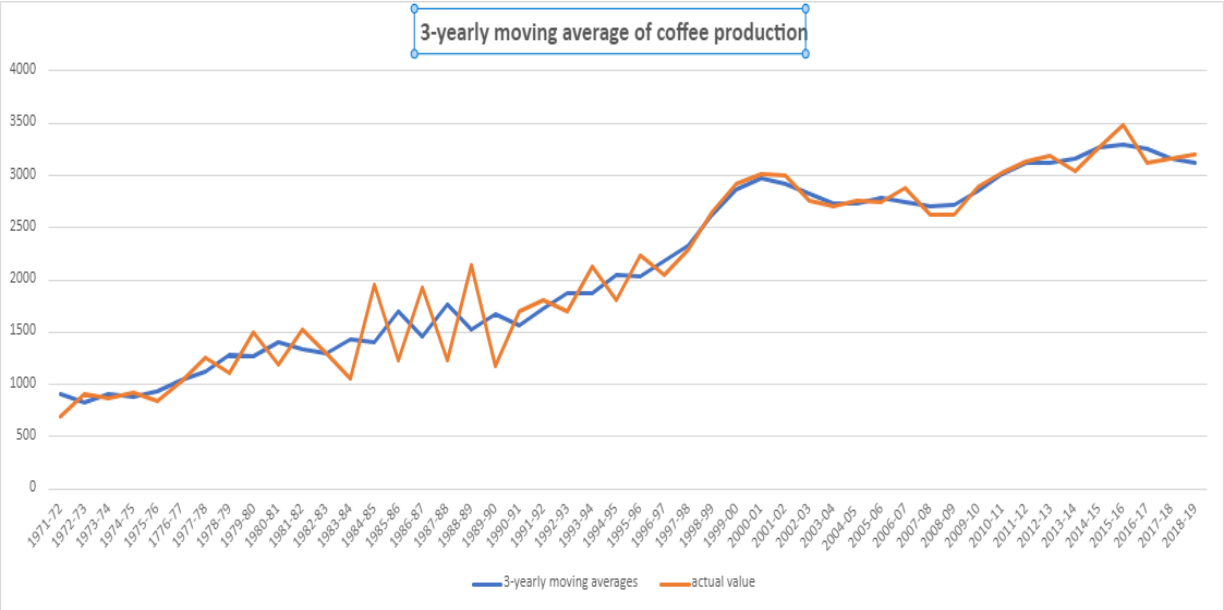
1970-71, 1972-73, 1974-75, 1977-78, 1979-80, 1981-82, 1984-85, 1986-87, 1988-89, 1991-92, 1993-94, 1995-96, 2000-01, 2004-05, 2006-07, 2012-13, 2015-16, 2019-20. Thus, the data exhibits 18 cycles with varying period 2,2,3,2,2,3,2,2,3,2,2,5,4,2,6,3,4 respectively. The appropriate period of moving averages is given by the arithmetic mean of periods of different cycles exhibited by the data. Hence the period of moving average is given by:

$(2+2+3+2+2+3+2+2+3+2+2+5+4+2+6+3+4)/17 = 2.882 \approx 3$

Table 4.1: Computation of 3-yearly moving average

YEAR	COFFEE PRODUCTION	3-yearly moving average
1970-71	1102.3	
1971-72	689.5	900.8333333
1972-73	910.7	821.3666667
1973-74	863.9	899.9
1974-75	925.1	876.2666667
1975-76	839.8	929.3
1776-77	1023	1038.066667
1977-78	1251.4	1126.433333
1978-79	1104.9	1284.9
1979-80	1498.4	1263.266667
1980-81	1186.5	1401.966667
1981-82	1521	1335.666667
1982-83	1299.5	1290.266667
1983-84	1050.3	1433.633333
1984-85	1951.1	1408.633333
1985-86	1224.5	1698.833333
1986-87	1920.9	1457.5
1987-88	1227.1	1765.066667
1988-89	2147.2	1518.266667
1989-90	1180.5	1675
1990-91	1697.3	1559.266667
1991-92	1800	1730.433333
1992-93	1694	1871.633333

1993-94	2120.9	1871.966667
1994-95	1801	2050.633333
1995-96	2230	2027
1996-97	2050	2187.666667
1997-98	2283	2327.666667
1998-99	2650	2617.666667
1999-00	2920	2860.666667
2000-01	3012	2979.333333
2001-02	3006	2923.666667
2002-03	2753	2821.333333
2003-04	2705	2737.666667
2004-05	2755	2733.333333
2005-06	2740	2791.666667
2006-07	2880	2746.666667
2007-08	2620	2707.666667
2008-09	2623	2713
2009-10	2896	2846.333333
2010-11	3020	3018.666667
2011-12	3140	3114
2012-13	3182	3122.333333
2013-14	3045	3165.666667
2014-15	3270	3265
2015-16	3480	3290
2016-17	3120	3253.333333
2017-18	3160	3158.333333
2018-19	3195	3116
2019-20	2993	



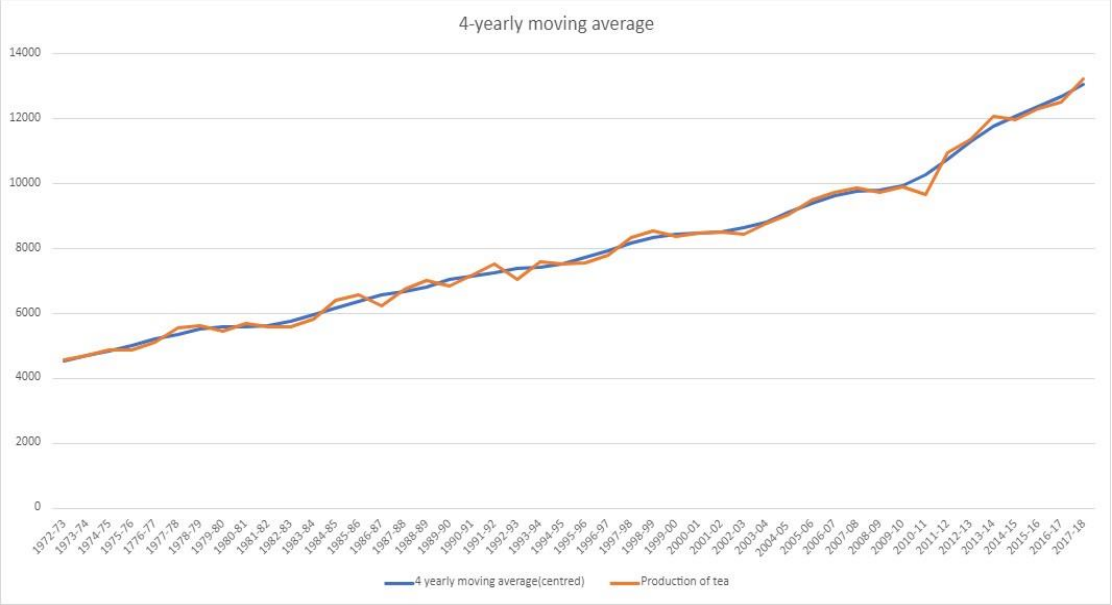
For production of tea, we have peaks at the following points:

1974-75, 1978-79, 1980-81, 1985-86, 1988-89, 1991-92, 1993-94, 1998-99, 2001-02, 2007-08, 2009-10, 2013-14, 2019-20. Thus, the data exhibits 13 cycles with varying period 4,2,5,3,3,2,5,3,6,2,4,6 respectively. The appropriate period of moving averages is given by the arithmetic mean of periods of different cycles exhibited by the data. Hence the period of moving average is given by:(4+2+5+3+3+2+5+3+6+2+4+6)/12 = 3.75 ≈ 4

Table 4.2: Computation of 4-yearly moving average

Year	Production of tea	4 yearly moving average(centred)
1970-71	4190	
1971-72	4350	
1972-73	4560	4542.5
1973-74	4720	4695
1974-75	4890	4830
1975-76	4870	5005
1776-77	5120	5203.75
1977-78	5560	5368.75
1978-79	5640	5512
1979-80	5440	5589.5
1980-81	5696	5590.875
1981-82	5604	5633.625
1982-83	5607	5768.375
1983-84	5815	5976
1984-85	6399	6175.625

1985-86	6562	6371.5
1986-87	6246	6564
1987-88	6743	6675.375
1988-89	7011	6829.925
1989-90	6841	7049.4625
1990-91	7203.4	7152.8625
1991-92	7541.9	7252.3125
1992-93	7039.3	7388.925
1993-94	7608.3	7431.9125
1994-95	7529	7529.4625
1995-96	7560.2	7718.2375
1996-97	7801.4	7939.575
1997-98	8356.4	8168.45
1998-99	8551.6	8354.8625
1999-00	8368.6	8459.9375
2000-01	8484.3	8468.1625
2001-02	8514.1	8508.9125
2002-03	8459.7	8634.1625
2003-04	8786.5	8829.0875
2004-05	9068.4	9109.875
2005-06	9489.4	9404.2125
2006-07	9730.7	9622.0875
2007-08	9870.2	9757.3
2008-09	9727.7	9802.175
2009-10	9911.8	9929.8
2010-11	9667.3	10268.225
2011-12	10954.6	10743.1
2012-13	11350.7	11303.1625
2013-14	12087.8	11763.325
2014-15	11971.8	12079.7
2015-16	12331.4	12369.3125
2016-17	12504.9	12705.725
2017-18	13250.5	13056.3875
2018-19		
2019-20		



Fitting of straight line to find trend values:

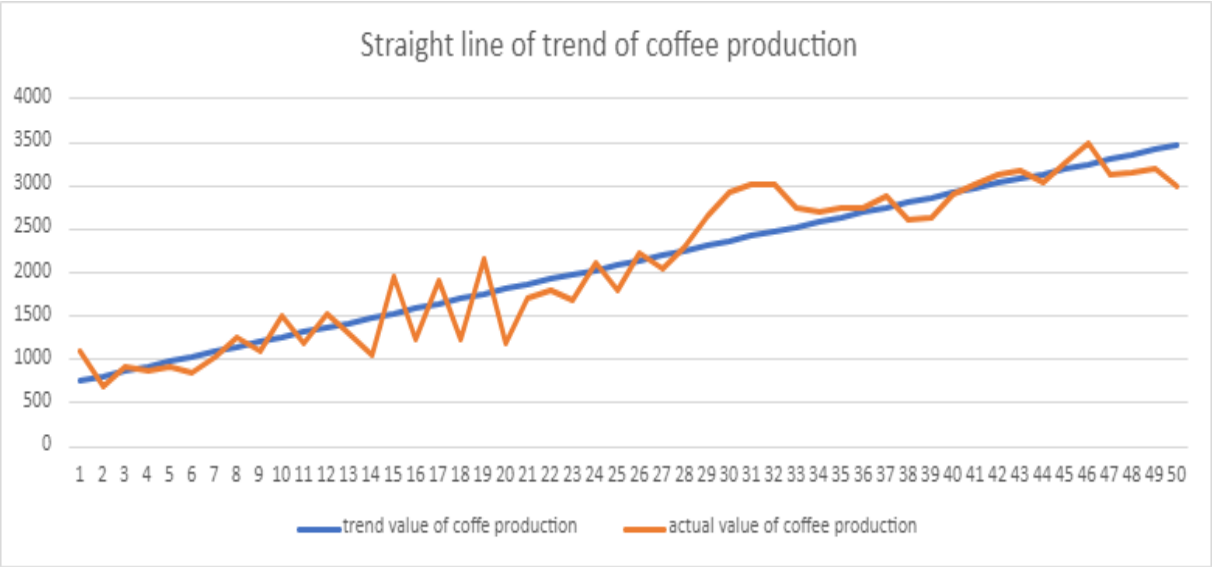
For coffee production:

The straight-line equation is Y_{trend} = 55.34652581T + 703.8395918

Table 5.1: Showing trend values of coffee production

T	Actual value of coffee production(Y)	Trend value of coffee production
1	1102.3	759.1861176
2	689.5	814.5326435
3	910.7	869.8791693
4	863.9	925.2256951
5	925.1	980.5722209
6	839.8	1035.918747
7	1023	1091.265273
8	1251.4	1146.611798
9	1104.9	1201.958324
10	1498.4	1257.30485
11	1186.5	1312.651376
12	1521	1367.997902
13	1299.5	1423.344427
14	1050.3	1478.690953

15	1951.1	1534.037479
16	1224.5	1589.384005
17	1920.9	1644.730531
18	1227.1	1700.077056
19	2147.2	1755.423582
20	1180.5	1810.770108
21	1697.3	1866.116634
22	1800	1921.46316
23	1694	1976.809685
24	2120.9	2032.156211
25	1801	2087.502737
26	2230	2142.849263
27	2050	2198.195789
28	2283	2253.542315
29	2650	2308.88884
30	2920	2364.235366
31	3012	2419.581892
32	3006	2474.928418
33	2753	2530.274944
34	2705	2585.621469
35	2755	2640.967995
36	2740	2696.314521
37	2880	2751.661047
38	2620	2807.007573
39	2623	2862.354098
40	2896	2917.700624
41	3020	2973.04715
42	3140	3028.393676
43	3182	3083.740202
44	3045	3139.086727
45	3270	3194.433253
46	3480	3249.779779
47	3120	3305.126305
48	3160	3360.472831
49	3195	3415.819357
50	2993	3471.165882



MSE (straight line trend ofcoffee production):	71860.91794
RMSE (straight line of coffee production): :	268.0688679

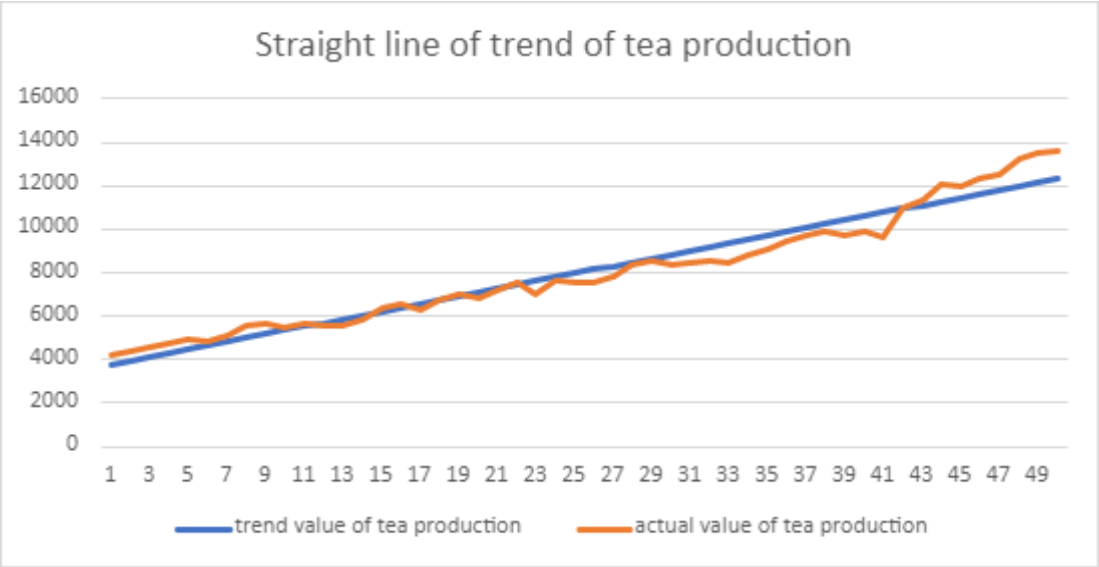
For Tea production:

The straight-line equation is $Y'_{trend} = 174.8102377T + 3596.226939$

Table 5.2: Showing trend values of tea production

T	actual value of tea production (Y')	trend value of tea production
1	4190	3771.037176
2	4350	3945.847414
3	4560	4120.657652
4	4720	4295.46789
5	4890	4470.278127
6	4870	4645.088365
7	5120	4819.898603
8	5560	4994.70884
9	5640	5169.519078
10	5440	5344.329316
11	5696	5519.139553
12	5604	5693.949791
13	5607	5868.760029
14	5815	6043.570267
15	6399	6218.380504
16	6562	6393.190742
17	6246	6568.00098

18	6743	6742.811217
19	7011	6917.621455
20	6841	7092.431693
21	7203.4	7267.24193
22	7541.9	7442.052168
23	7039.3	7616.862406
24	7608.3	7791.672643
25	7529	7966.482881
26	7560.2	8141.293119
27	7801.4	8316.103357
28	8356.4	8490.913594
29	8551.6	8665.723832
30	8368.6	8840.53407
31	8484.3	9015.344307
32	8514.1	9190.154545
33	8459.7	9364.964783
34	8786.5	9539.77502
35	9068.4	9714.585258
36	9489.4	9889.395496
37	9730.7	10064.20573
38	9870.2	10239.01597
39	9727.7	10413.82621
40	9911.8	10588.63645
41	9667.3	10763.44668
42	10954.6	10938.25692
43	11350.7	11113.06716
44	12087.8	11287.8774
45	11971.8	11462.68764
46	12331.4	11637.49787
47	12504.9	11812.30811
48	13250.5	11987.11835
49	13500.4	12161.92859
50	13608.1	12336.73882



MSE (straight line trend oftea production):	308142.5476
RMSE(straight line trend oftea production):	555.1058887

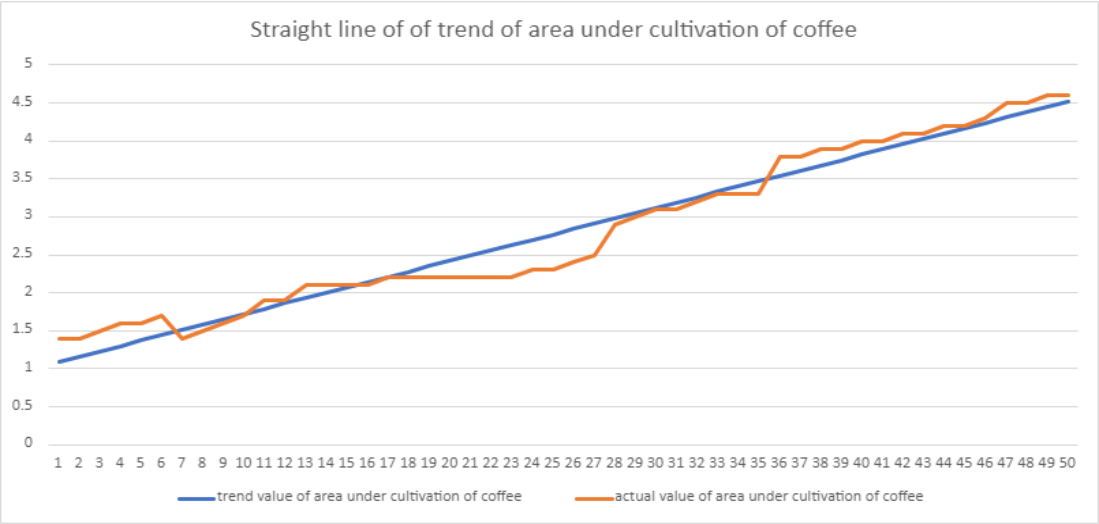
For area under cultivation of coffee:

The straight-line equation is $X_{trend} = 0.069963986T + 1.019918367$

Table 5.3: Showing trend values of area under cultivation of coffee

T	actual value of area under cultivation of coffee(X)	trend value of area under cultivation of coffee
1	1.4	1.089882353
2	1.4	1.159846339
3	1.5	1.229810324
4	1.6	1.29977431
5	1.6	1.369738295
6	1.7	1.439702281
7	1.4	1.509666267
8	1.5	1.579630252
9	1.6	1.649594238
10	1.7	1.719558223
11	1.9	1.789522209
12	1.9	1.859486194
13	2.1	1.92945018
14	2.1	1.999414166
15	2.1	2.069378151

16	2.1	2.139342137
17	2.2	2.209306122
18	2.2	2.279270108
19	2.2	2.349234094
20	2.2	2.419198079
21	2.2	2.489162065
22	2.2	2.55912605
23	2.2	2.629090036
24	2.3	2.699054022
25	2.3	2.769018007
26	2.4	2.838981993
27	2.5	2.908945978
28	2.9	2.978909964
29	3	3.04887395
30	3.1	3.118837935
31	3.1	3.188801921
32	3.2	3.258765906
33	3.3	3.328729892
34	3.3	3.398693878
35	3.3	3.468657863
36	3.8	3.538621849
37	3.8	3.608585834
38	3.9	3.67854982
39	3.9	3.748513806
40	4	3.818477791
41	4	3.888441777
42	4.1	3.958405762
43	4.1	4.028369748
44	4.2	4.098333733
45	4.2	4.168297719
46	4.3	4.238261705
47	4.5	4.30822569
48	4.5	4.378189676
49	4.6	4.448153661
50	4.6	4.518117647



MSE(Straight line trend of area under cultivationof coffee): 0.04260873

RMSE(Straight line trend of area undercultivation of coffee): 0.206418822

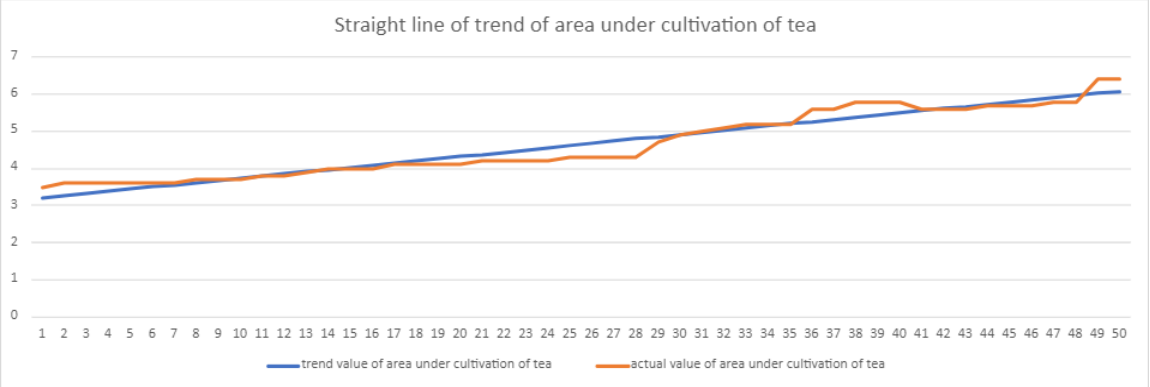
For area under cultivation of tea:

The straight-line equation is $X'_{trend} = 0.058703481T + 3.149061224$

Table 5.3: Showing trend values of area under cultivation of tea

T	Actual value of area under cultivation of tea(X')	Trend value of area under cultivation of tea
1	3.5	3.207764706
2	3.6	3.266468187
3	3.6	3.325171669
4	3.6	3.38387515
5	3.6	3.442578631
6	3.6	3.501282113
7	3.6	3.559985594
8	3.7	3.618689076
9	3.7	3.677392557
10	3.7	3.736096038
11	3.8	3.79479952
12	3.8	3.853503001
13	3.9	3.912206483
14	4	3.970909964
15	4	4.029613445
16	4	4.088316927
17	4.1	4.147020408

18	4.1	4.20572389
19	4.1	4.264427371
20	4.1	4.323130852
21	4.2	4.381834334
22	4.2	4.440537815
23	4.2	4.499241297
24	4.2	4.557944778
25	4.3	4.616648259
26	4.3	4.675351741
27	4.3	4.734055222
28	4.3	4.792758703
29	4.7	4.851462185
30	4.9	4.910165666
31	5	4.968869148
32	5.1	5.027572629
33	5.2	5.08627611
34	5.2	5.144979592
35	5.2	5.203683073
36	5.6	5.262386555
37	5.6	5.321090036
38	5.8	5.379793517
39	5.8	5.438496999
40	5.8	5.49720048
41	5.6	5.555903962
42	5.6	5.614607443
43	5.6	5.673310924
44	5.7	5.732014406
45	5.7	5.790717887
46	5.7	5.849421369
47	5.8	5.90812485
48	5.8	5.966828331
49	6.4	6.025531813
50	6.4	6.084235294



MSE(Straight line of trend of area under cultivationof tea):	0.04803394
RMSE(Straight line of trend of area under cultivationof tea):	0.219166466

Fitting of exponential curve to find trend values:

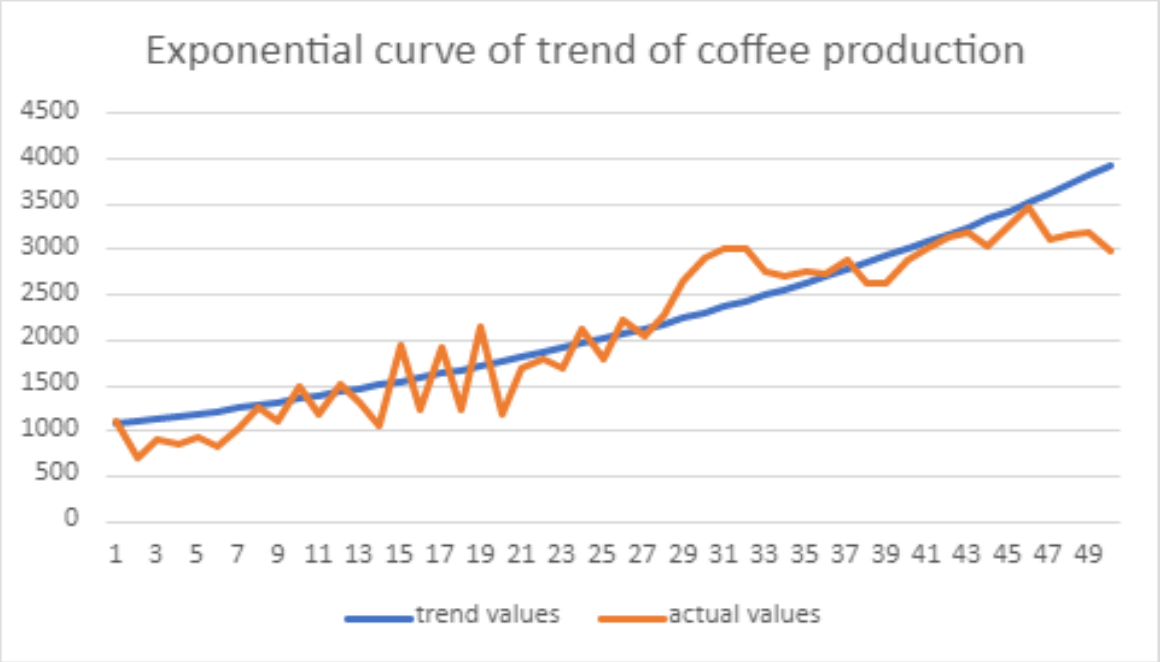
For coffee production:

The exponential curve equation of coffee production is Y_{trend}= 1041*2.718281828^0.0265T

Table 6.1: showing the trend values of coffee production

T	Actual values of production of coffee (Y)	Trend values of production of coffee
1	1102.3	1068.955271
2	689.5	1097.661261
3	910.7	1127.138127
4	863.9	1157.406573
5	925.1	1188.487856
6	839.8	1220.403802
7	1023	1253.176828
8	1251.4	1286.829948
9	1104.9	1321.386798
10	1498.4	1356.871646
11	1186.5	1393.309412
12	1521	1430.725688
13	1299.5	1469.146749

14	1050.3	1508.599579
15	1951.1	1549.111885
16	1224.5	1590.712119
17	1920.9	1633.429496
18	1227.1	1677.294015
19	2147.2	1722.336483
20	1180.5	1768.588533
21	1697.3	1816.082647
22	1800	1864.852179
23	1694	1914.931381
24	2120.9	1966.355422
25	1801	2019.160416
26	2230	2073.383449
27	2050	2129.062601
28	2283	2186.236975
29	2650	2244.946723
30	2920	2305.233077
31	3012	2367.138376
32	3006	2430.706096
33	2753	2495.980878
34	2705	2563.008566
35	2755	2631.836232
36	2740	2702.512212
37	2880	2775.086144
38	2620	2849.608993
39	2623	2926.133098
40	2896	3004.712199
41	3020	3085.401484
42	3140	3168.257618
43	3182	3253.338791
44	3045	3340.704756
45	3270	3430.416867
46	3480	3522.53813
47	3120	3617.13324
48	3160	3714.26863
49	3195	3814.012518
50	2993	3916.434954



MSE(exponential curve of production of coffee): 113727.7199
RMSE(exponential curve of production of coffee): 337.2354073

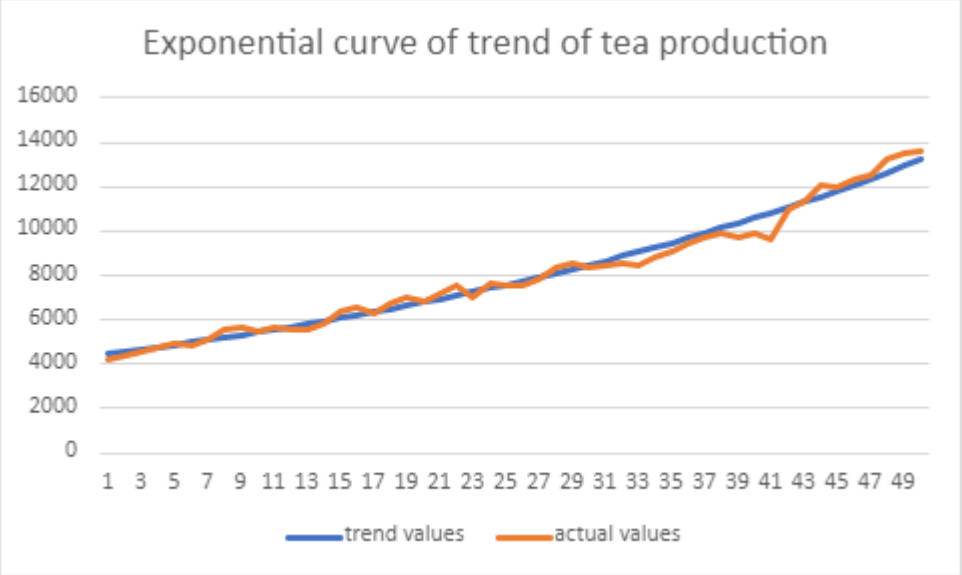
For production of tea:

The exponentialcurve equationofteaproduction is Y'_{trend}= 4356*2.718281828^0.0222T

Table 6.2: showing the trend values of tea production

T	Actual values of tea production(Y')	Trend values of tea production
1	4190	4453.784593
2	4350	4553.764279
3	4560	4655.988335
4	4720	4760.507142
5	4890	4867.372214
6	4870	4976.63622
7	5120	5088.353013
8	5560	5202.577652
9	5640	5319.366435
10	5440	5438.776922
11	5696	5560.867966
12	5604	5685.69974

13	5607	5813.333771
14	5815	5943.832962
15	6399	6077.261632
16	6562	6213.685543
17	6246	6353.171932
18	6743	6495.789547
19	7011	6641.608678
20	6841	6790.701195
21	7203.4	6943.140578
22	7541.9	7099.001959
23	7039.3	7258.362156
24	7608.3	7421.299711
25	7529	7587.894929
26	7560.2	7758.229919
27	7801.4	7932.388632
28	8356.4	8110.456905
29	8551.6	8292.522499
30	8368.6	8478.675147
31	8484.3	8669.006598
32	8514.1	8863.610657
33	8459.7	9062.583237
34	8786.5	9266.022405
35	9068.4	9474.028426
36	9489.4	9686.70382
37	9730.7	9904.153404
38	9870.2	10126.48435
39	9727.7	10353.80624
40	9911.8	10586.23111
41	9667.3	10823.87351
42	10954.6	11066.85057
43	11350.7	11315.28204
44	12087.8	11569.29036
45	11971.8	11829.00073
46	12331.4	12094.54113
47	12504.9	12366.04246
48	13250.5	12643.63852
49	13500.4	12927.46612
50	13608.1	13217.66516



MSE(exponential curve of production of tea): 117864.8499

RMSE(exponential curve of production of tea): 343.3145058

For area under cultivation of coffee:

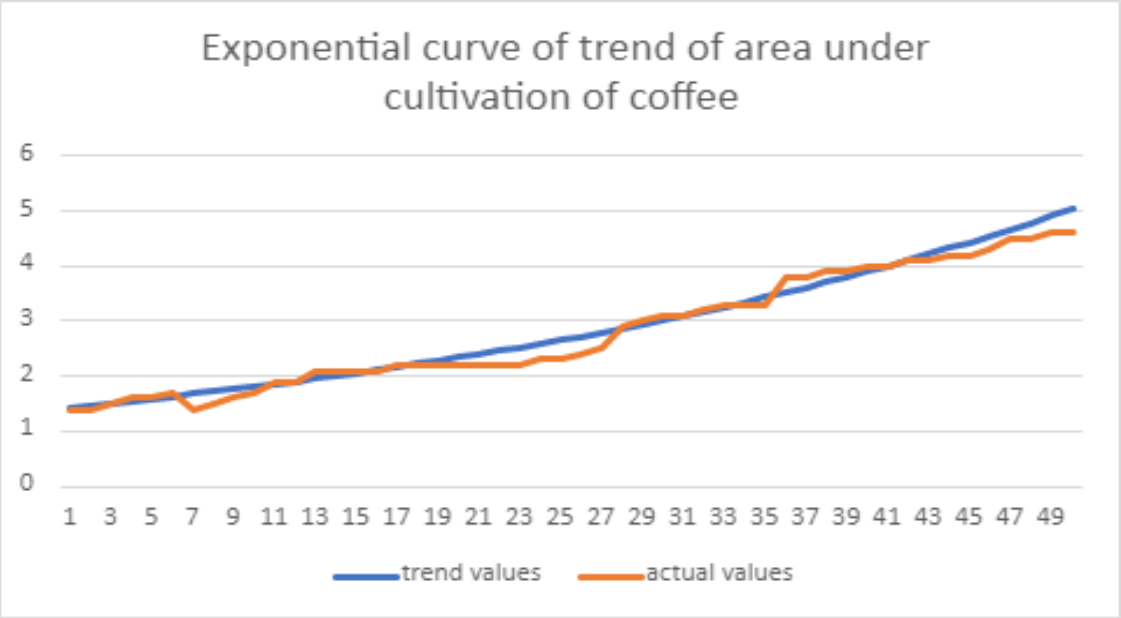
The exponential curve equation of area under cultivation of coffee is

X_{trend}= 1.4*2.718281828^0.0256T

Table 6.3: showing the trend values of area under cultivation of coffee

T	Actual values of area under cultivation of coffee(X)	Trend values of area under cultivation of coffee
1	1.4	1.436302692
2	1.4	1.47354673
3	1.5	1.511756525
4	1.6	1.550957119
5	1.6	1.591174204
6	1.7	1.632434137
7	1.4	1.674763961
8	1.5	1.718191418
9	1.6	1.762744971
10	1.7	1.808453819
11	1.9	1.85534792

12	1.9	1.903458009
13	2.1	1.952815616
14	2.1	2.00345309
15	2.1	2.055403618
16	2.1	2.10870125
17	2.2	2.163380915
18	2.2	2.219478452
19	2.2	2.277030625
20	2.2	2.336075154
21	2.2	2.396650737
22	2.2	2.458797075
23	2.2	2.522554898
24	2.3	2.587965994
25	2.3	2.655073231
26	2.4	2.723920592
27	2.5	2.794553199
28	2.9	2.867017344
29	3	2.941360521
30	3.1	3.017631453
31	3.1	3.095880128
32	3.2	3.176157829
33	3.3	3.258517171
34	3.3	3.343012132
35	3.3	3.429698089
36	3.8	3.518631855
37	3.8	3.609871718
38	3.9	3.703477475
39	3.9	3.799510476
40	4	3.898033661
41	4	3.9991116
42	4.1	4.10281054
43	4.1	4.209198445
44	4.2	4.318345041
45	4.2	4.430321862
46	4.3	4.545202297
47	4.5	4.663061639
48	4.5	4.783977131
49	4.6	4.908028023
50	4.6	5.035295615



MSE(exponential curve of area under cultivation of coffee): 0.0316859
RMSE(exponential curve of area under cultivation of coffee): 0.178005337

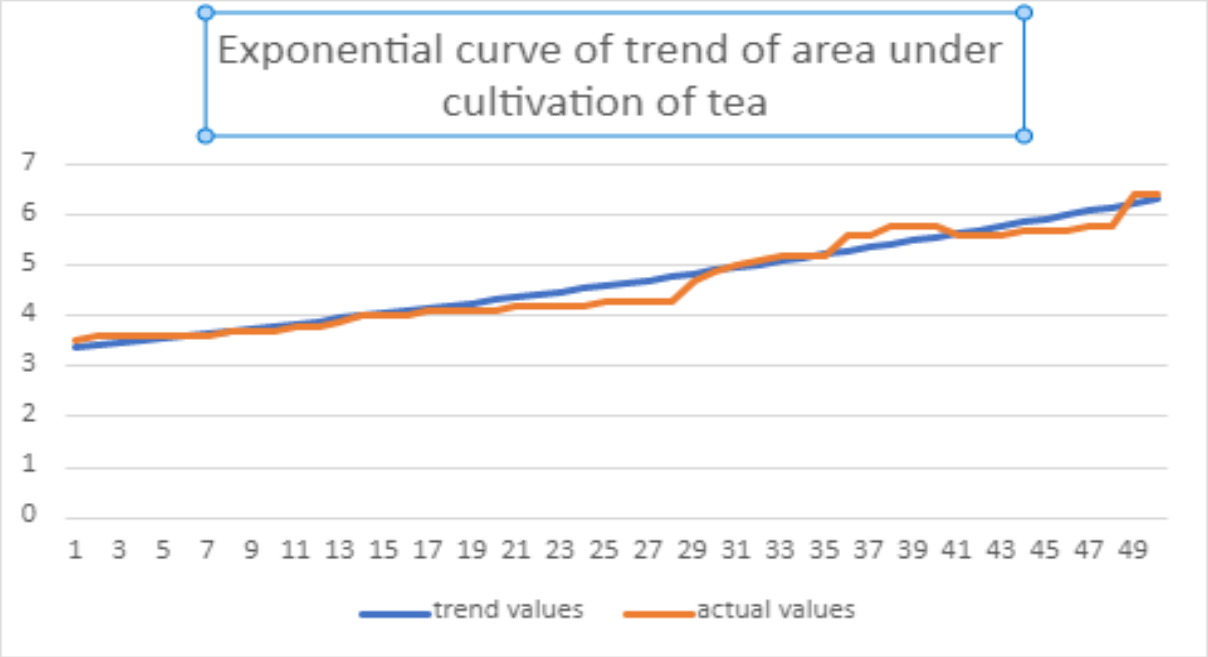
For area under cultivation of tea:

The exponential curve equation of area under cultivation of tea is $X'_{trend} = 3.35*2.718281828^{0.0127T}$

Table 6.4: showing the trend values of area under cultivation of tea

T	Actual values of area under cultivation of tea(X')	Trend values of area under cultivation of tea
1	3.5	3.392816308
2	3.6	3.436179851
3	3.6	3.480097622
4	3.6	3.524576707
5	3.6	3.569624277
6	3.6	3.615247601
7	3.6	3.661454035

8	3.7	3.708251033
9	3.7	3.755646143
10	3.7	3.803647009
11	3.8	3.852261374
12	3.8	3.901497079
13	3.9	3.951362064
14	4	4.001864373
15	4	4.053012152
16	4	4.104813649
17	4.1	4.157277221
18	4.1	4.210411329
19	4.1	4.264224544
20	4.1	4.318725544
21	4.2	4.373923121
22	4.2	4.429826178
23	4.2	4.486443731
24	4.2	4.543784912
25	4.3	4.60185897
26	4.3	4.660675272
27	4.3	4.720243304
28	4.3	4.780572675
29	4.7	4.841673114
30	4.9	4.903554478
31	5	4.966226746
32	5.1	5.029700028
33	5.2	5.093984561
34	5.2	5.159090714
35	5.2	5.225028988
36	5.6	5.291810018
37	5.6	5.359444576
38	5.8	5.42794357
39	5.8	5.497318048
40	5.8	5.567579202
41	5.6	5.638738362
42	5.6	5.710807006
43	5.6	5.783796759
44	5.7	5.857719393
45	5.7	5.932586831
46	5.7	6.008411149
47	5.8	6.085204577
48	5.8	6.1629795
49	6.4	6.241748464
50	6.4	6.321524173



MSE(exponential curve of area undercultivation of tea): 0.041032253
RMSE(exponential curve of area undercultivation of tea): 0.202564196

Fitting of polynomial curve to find trend values:

For coffee production:

The equation of polynomial curve of degree 3 for coffee production is

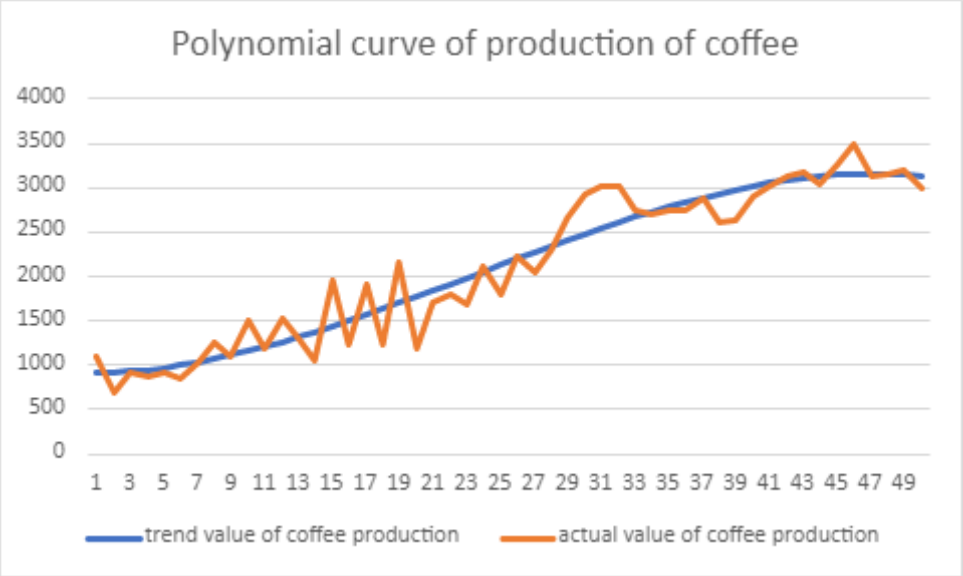
Y_{trend} = -0.0441T^3 + 3.1366T^2 - 2.1663T + 910.1

Table 7.1: Showing the trend values of coffee production

T	Actual value of coffee production(Y)	Trend value of coffee production
1	1102.3	911.0262
2	689.5	917.961
3	910.7	930.6398
4	863.9	948.798

5	925.1	972.171
6	839.8	1000.4942
7	1023	1033.503
8	1251.4	1070.9328
9	1104.9	1112.519
10	1498.4	1157.997
11	1186.5	1207.1022
12	1521	1259.57
13	1299.5	1315.1358
14	1050.3	1373.535
15	1951.1	1434.503
16	1224.5	1497.7752
17	1920.9	1563.087
18	1227.1	1630.1738
19	2147.2	1698.771
20	1180.5	1768.614
21	1697.3	1839.4382
22	1800	1910.979
23	1694	1982.9718
24	2120.9	2055.152
25	1801	2127.255
26	2230	2199.0162
27	2050	2270.171
28	2283	2340.4548
29	2650	2409.603
30	2920	2477.351
31	3012	2543.4342
32	3006	2607.588
33	2753	2669.5478
34	2705	2729.049
35	2755	2785.827
36	2740	2839.6172
37	2880	2890.155
38	2620	2937.1758
39	2623	2980.415
40	2896	3019.608
41	3020	3054.4902
42	3140	3084.797
43	3182	3110.2638
44	3045	3130.626
45	3270	3145.619
46	3480	3154.9782
47	3120	3158.439

48	3160	3155.7368
49	3195	3146.607
50	2993	3130.785



MSE(polynomial curve ofproduction of coffee): 59197.58596
RMSE (polynomial curve of productionof coffee): 243.3055403

For tea production:

The equation of polynomial curve of degree 3 for tea production is

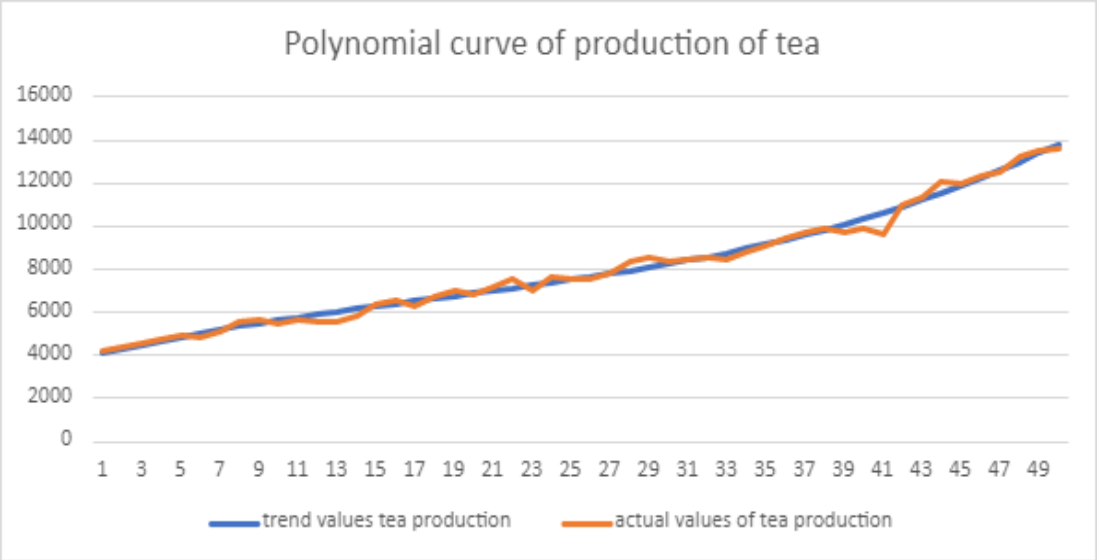
$Y'_{trend} = 0.1058T^3 - 5.8225T^2 + 225.71T + 3856.8$

Table 7.2: Showing the trend values of tea production

T	Actual values of tea production(Y')	Trend values tea production
1	4190	4076.7933
2	4350	4285.7764
3	4560	4484.3841
4	4720	4673.2512
5	4890	4853.0125
6	4870	5024.3028

7	5120	5187.7569
8	5560	5344.0096
9	5640	5493.6957
10	5440	5637.45
11	5696	5775.9073
12	5604	5909.7024
13	5607	6039.4701
14	5815	6165.8452
15	6399	6289.4625
16	6562	6410.9568
17	6246	6530.9629
18	6743	6650.1156
19	7011	6769.0497
20	6841	6888.4
21	7203.4	7008.8013
22	7541.9	7130.8884
23	7039.3	7255.2961
24	7608.3	7382.6592
25	7529	7513.6125
26	7560.2	7648.7908
27	7801.4	7788.8289
28	8356.4	7934.3616
29	8551.6	8086.0237
30	8368.6	8244.45
31	8484.3	8410.2753
32	8514.1	8584.1344
33	8459.7	8766.6621
34	8786.5	8958.4932
35	9068.4	9160.2625
36	9489.4	9372.6048
37	9730.7	9596.1549
38	9870.2	9831.5476
39	9727.7	10079.4177
40	9911.8	10340.4
41	9667.3	10615.1293
42	10954.6	10904.2404
43	11350.7	11208.3681
44	12087.8	11528.1472
45	11971.8	11864.2125
46	12331.4	12217.1988
47	12504.9	12587.7409
48	13250.5	12976.4736
49	13500.4	13384.0317

50	13608.1	13811.05



MSE (Polynomial curve oftea production): 67178.1403
RMSE (Polynomial curve oftea production): 259.1874

For area under cultivation of coffee:

The equation of the polynomial curve of degree 3 for area under cultivation of coffee is

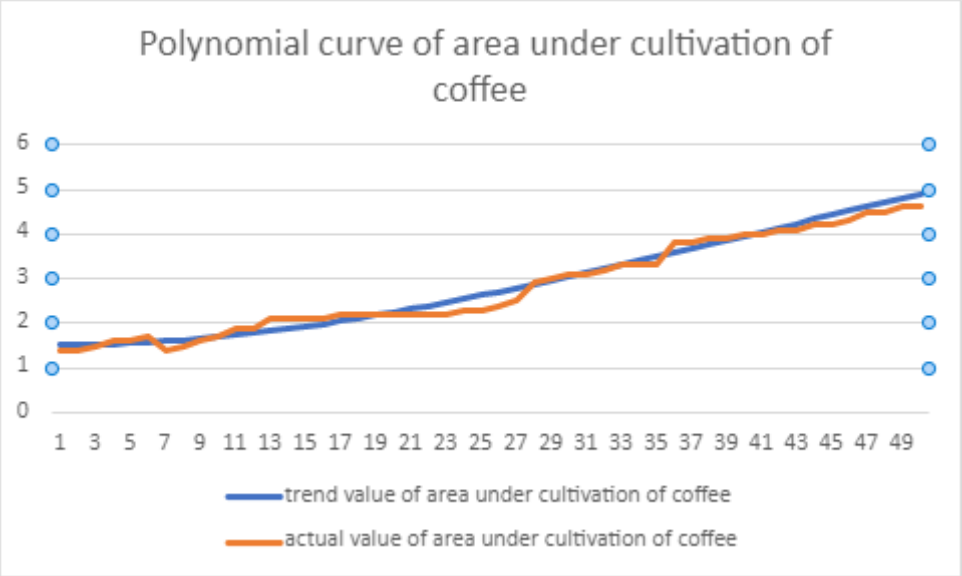
X_{trend} =-0.00002T^3+0.0024T^2-0.0027T+1.5068

Table 7.3: Showing the trend values of area under cultivation of coffee

T	Actual value of area under cultivation of coffee(X)	Trend value of area under cultivation of coffee
1	1.4	1.50648
2	1.4	1.51084
3	1.5	1.51976
4	1.6	1.53312
5	1.6	1.5508

6	1.7	1.57268
7	1.4	1.59864
8	1.5	1.62856
9	1.6	1.66232
10	1.7	1.6998
11	1.9	1.74088
12	1.9	1.78544
13	2.1	1.83336
14	2.1	1.88452
15	2.1	1.9388
16	2.1	1.99608
17	2.2	2.05624
18	2.2	2.11916
19	2.2	2.18472
20	2.2	2.2528
21	2.2	2.32328
22	2.2	2.39604
23	2.2	2.47096
24	2.3	2.54792
25	2.3	2.6268
26	2.4	2.70748
27	2.5	2.78984
28	2.9	2.87376
29	3	2.95912
30	3.1	3.0458
31	3.1	3.13368
32	3.2	3.22264
33	3.3	3.31256
34	3.3	3.40332
35	3.3	3.4948
36	3.8	3.58688
37	3.8	3.67944
38	3.9	3.77236
39	3.9	3.86552
40	4	3.9588
41	4	4.05208
42	4.1	4.14524
43	4.1	4.23816
44	4.2	4.33072
45	4.2	4.4228
46	4.3	4.51428
47	4.5	4.60504
48	4.5	4.69496

49	4.6	4.78392
50	4.6	4.8718



MSE(polynomial curve for area under cultivation of coffee): 0.024638446

RMSE (polynomial curve for area under cultivation of coffee): 0.156966384

For area under cultivation of coffee:

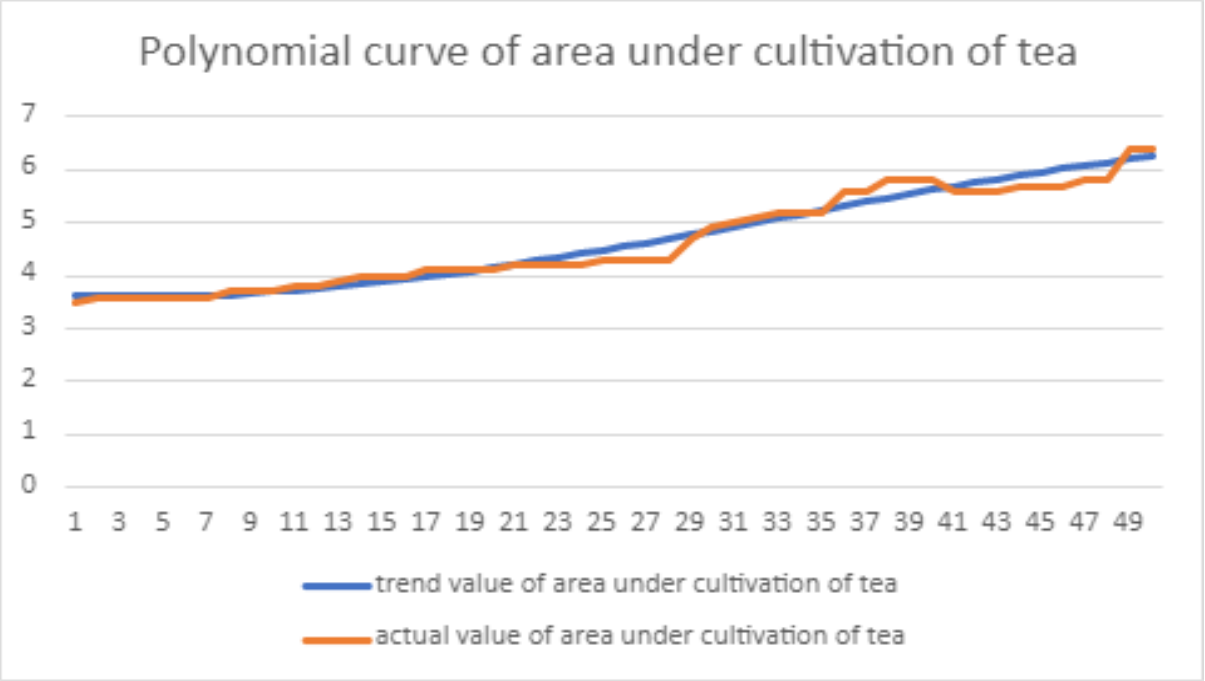
The equation of the polynomial curve of degree 3 for area under cultivation of coffee is

X'_{trend} = -0.00003T^3+0.003T^2-0.0229T+3.6495

Table 7.4: Showing the trend values of area under cultivation of tea

T	actual value of area under cultivation of tea (X')	trend value of area under cultivation of tea
1	3.5	3.62957
2	3.6	3.61546
3	3.6	3.60699
4	3.6	3.60398
5	3.6	3.60625
6	3.6	3.61362
7	3.6	3.62591

8	3.7	3.64294
9	3.7	3.66453
10	3.7	3.6905
11	3.8	3.72067
12	3.8	3.75486
13	3.9	3.79289
14	4	3.83458
15	4	3.87975
16	4	3.92822
17	4.1	3.97981
18	4.1	4.03434
19	4.1	4.09163
20	4.1	4.1515
21	4.2	4.21377
22	4.2	4.27826
23	4.2	4.34479
24	4.2	4.41318
25	4.3	4.48325
26	4.3	4.55482
27	4.3	4.62771
28	4.3	4.70174
29	4.7	4.77673
30	4.9	4.8525
31	5	4.92887
32	5.1	5.00566
33	5.2	5.08269
34	5.2	5.15978
35	5.2	5.23675
36	5.6	5.31342
37	5.6	5.38961
38	5.8	5.46514
39	5.8	5.53983
40	5.8	5.6135
41	5.6	5.68597
42	5.6	5.75706
43	5.6	5.82659
44	5.7	5.89438
45	5.7	5.96025
46	5.7	6.02402
47	5.8	6.08551
48	5.8	6.14454
49	6.4	6.20093
50	6.4	6.2545



MSE(polynomial curve for area under cultivation of tea):	0.029712641
RMSE(polynomial curve for area under cultivation of tea):	0.17237355

Results:

Correlation analysis:

Correlation between	Correlation coefficient (r)
X and Y	0.931474954
X' and Y'	0.953358263

Regression analysis:

Regression analysis of X on Y:

Type	Regression equation	MSE	RMSE
Linear	X = 0.001139379Y + 0.39401281	0.140558266	0.374911011
Exponential	X= 1.08*2.718281828^(0.000426*Y)	0.116739706	0.341671927
Curvilinear	X= 1.96-0.000939Y+0.000000719Y^2-0.0000000000642Y^3	0.112756531	0.335792393

Regression analysis of Y on X:

Type	Regression equation	MSE	RMSE
Linear	Y = 761.5074201X - 20.09080589	93942.54194	306.5004763
Exponential	Y=780*2.718281828^(0.34X)	139401.8111	373.3655194
Curvilinear	Y=-1548 + 1936X + -198X^2	68395.80714	261.5259206

Regression analysis of X' on Y':

Type	Regression equation	MSE	RMSE
Linear	X' = 0.000322964Y'+2.044886507	0.069759955	0.264121099

Exponential	X'=2.67*2.718281828^(0.000067*Y')	0.088152685	0.296905179
Curvilinear	X'= 1.27 + 0.000518Y' - 0.0000000111Y'^2	0.063780863	0.252548734

Regression analysis of Y' on X':

Type	Regression equation	MSE	RMSE
Linear	Y' = 2814.223298X'+-5020.993444	607870.4459	779.6604683
Exponential	Y'=1614e^0.337X'	665090.7045	815.5309341
Curvilinear	Y'=-64590+40728X' -7896X'^2+539X'^3	524038.1607	723.9048009

Trend line fitting:

Trend line fitting of coffee production:

Type	Trend line equation	MSE	RMSE
Straight line	Y_{trend} = 55.34652581T + 703.8395918	71860.91794	268.0688679
Exponential	Y_{trend}= 1041*2.718281828^0.0265T	113727.7199	337.2354073
3rd degree polynomial	Y_{trend}= -0.0441T^3 + 3.1366T^2 - 2.1663T + 910.1	59197.58596	243.3055403

Trend line fitting of tea production:

Type	Trend line equation	MSE	RMSE
Straight line	Y'_{trend} = 174.8102377T + 3596.226939	308142.5476	555.1058887
Exponential	Y'_{trend}= 4356*2.718281828^0.0222T	117864.8499	343.3145058
3rd degree polynomial	Y'_{trend} = 0.1058T^3 - 5.8225T^2+225.71T+3856.8	67178.1403	259.1874

Trend line fitting of area under cultivation of coffee:

Type	Trend line equation	MSE	RMSE
Straight line	X_{trend} = 0.069963986T + 1.019918367	0.04260873	0.206418822
Exponential	X_{trend}= 1.4*2.718281828^0.0256T	0.0316859	0.178005337
3rd degree polynomial	X_{trend}=-0.00002T^3+0.0024T^2-0.0027T+1.5068	0.024638446	0.156966384

Trend line fitting of area under cultivation of tea:

Type	Trend line equation	MSE	RMSE
Straight line	X'_{trend} = 0.058703481T + 3.149061224	0.04803394	0.219166466
Exponential	X'_{trend} = 3.35*2.718281828^0.0127T	0.041032253	0.202564196
3rd degree polynomial	X'_{trend}= -0.00003T^3+0.003T^2-0.0229T+3.6495	0.029712641	0.17237355

Conclusion:

Comment on correlation coefficient:

Hence, we see that the correlation coefficient between Y and X is 0.931474954. Here r > 0 and the value is near to 1 i.e., positively and highly correlated to each other.

In case of Y' and X' the correlation coefficient is 0.953358263. Here r > 0 and the value is near to 1 i.e., positively and highly correlated to each other.

Comment on regression analysis:

Here we study 3 types of regression that is linear regression, exponential regression and curvilinear regression and we find the expected values from the regression curves. We also find the MSE and RMSE for studying the errors.

In case of X on Y the 3rd degree curvilinear regression curve gives the least MSE and RMSE.

The equation of the curve is X= 1.96-0.000939Y+0.000000719Y^2-0.0000000000642Y^3.

Which gives the MSE and RMSE is 0.112756531 and 0.335792393 respectively.

In case of Y on X the 2nd curvilinear regression curve gives the least MSE and RMSE.

The equation of the curve is Y=-1548 + 1936X + -198X^2.

Which gives the MSE and RMSE is 68395.80714 and 261.5259206 respectively.

In case of X' on Y' the 2nd curvilinear regression curve gives the least MSE and RMSE.

The equation of the curve is X'= 1.27 + 0.000518Y' - 0.0000000111Y'^2.

Which gives the MSE and RMSE is 0.063780863 and 0.252548734 respectively.

In case of Y' on X' the 3rd degree curvilinear regression curve gives the least MSE and RMSE.

The equation of the curve is Y'=-64590 + 40728X' -7896X'^2 + 539X'^3.

Which gives the MSE and RMSE is 524038.1607 and 723.9048009 respectively.

Comment on trend line fitting:

Here we study three types of trend line equations that is straight line equation, exponential equation and 3rd degree polynomial equation. We also find the MSE and RMSE for studying the errors. And we compare the MSE and RMSE for all curve and choose one, as the best fitted if the MSE and RMSE is comparatively minimum to others.

In case of coffee production (Y), the 3rd degree polynomial trend curve gives the least MSE and RMSE. The equation of the curve is Y_{trend}= -0.0441T^3 + 3.1366T^2 - 2.1663T + 910.1
Which gives the MSE and RMSE is 59197.58596 and 243.3055403 respectively.

In case of area under cultivation of coffee (X), the 3rd degree polynomial trend curve gives the least MSE and RMSE. The equation of the curve is X_{trend}=-0.00002T^3+0.0024T^2-0.0027T+1.5068.
Which gives the MSE and RMSE is 0.024638446 and 0.156966384 respectively.

In case of tea production (Y'), the 3rd degree polynomial trend curve gives the least MSE and RMSE. The equation of the curve is Y'_{trend} = 0.1058T^3 -5.8225T^2+225.71T+3856.8.
Which gives the MSE and RMSE is 67178.1403 and 259.1874 respectively.

In case of area under cultivation of tea (X'), the 3rd degree polynomial trend curve gives the least MSE and RMSE. The equation of the curve is X'_{trend}= -0.00003T^3+0.003T^2-0.0229T+3.6495
Which gives the MSE and RMSE is 0.029712641 and 0.17237355 respectively.

Forecasting:

We see a growth of production of tea and coffee and the area under cultivation is also increasing day by day. If the growth rate is quite similar for next 10 years, then we can predict the production and area under cultivation of tea and coffee in the year 2030.

We find the best fitted regression curves and trend curves. Now we are going to forecast the productions and area under cultivation of tea and coffee in the year 2030.

The approximated coffee production in the year 2030 is 4024.63114 lacs kg.

The area required for produce this amount of is 5.64181 lacs hectares.

The approximated tea production in the year 2030 is 19291.2 lacs kg.

The area required for produce this amount of tea is 7.1319 lacs hectares.

The approximated area under cultivation of coffee in the year 2030 is 5.6648 lacs hectares.

The approximated production of coffee under this area is 4293.636427 lacs kg.

The approximated area under cultivation of tea in the year 2030 is 7.1775 lacs hectares.

The approximated production of tea under this area is 20261.37768 lacs kg.

References:

1. Fundamental of statistics vol – 1 & 2 (A.M Gun, M.K Gupta, B.D Dasgupta)
2. Fundamental of applied statistics (S.C Gupta, V.K Kapoor)
3. Fundamental of mathematical statistics (S.C Gupta, V.K Kapoor)
4. Ministry of Agriculture & Farmers Welfare, Government of India
5. Coffee Board of India, Tea Board of India

Acknowledgement:

I would like to express my special thanks of gratitude to my teachers, for their able guidance and support in completing my project. This project also helped me in doing a lot of research and I came to know about so many new things.
It helped me to increase my knowledge and skills.

Akash Singh

(Department of Statistics, Surendra Nath College)

Date-26/07/21

Roll no- 183115-21-0215

Regd no- 115-1111-0902-18

Source Of Data –

Ministry of Agriculture & Farmers Welfare, Government of India, Coffee Board of India, Tea Board of India.

The original data set:

TABLE 18 : AGRICULTURAL PRODUCTION - MAJOR COMMERCIAL CROPS

(Lakh Tonnes)

Year	Oilseeds				Coffee	Cotton (Lint)	Raw Jute & Mesta	Sugarcane	Tea	Tobacco
	Groundnut	Rapeseed & Mustard	Soyabean	Total						
1	2	3	4	5	6	7	8	9	10	11
1963-64	53.0	9.2	-	**71.3**	-	57.5	79.8	1042.3	-	3.6
1964-65	60.0	14.7	-	**85.6**	-	60.1	76.6	1219.1	-	3.6
1965-66	42.6	13.0	-	**64.0**	-	48.5	57.8	1239.9	-	2.9
1966-67	44.1	12.3	-	**64.3**	-	52.7	65.8	928.3	-	3.5
1967-68	57.3	15.7	-	**83.0**	-	57.8	75.9	955.0	-	3.7
1968-69	46.3	13.5	-	**68.5**	-	54.5	38.4	1246.8	-	3.6
1969-70	51.3	15.6	-	**77.3**	-	55.6	67.9	1350.2	-	3.4
1970-71	61.1	19.8	0.1	**96.3**	1102.3	47.6	61.9	1263.7	4190.0	3.6
1971-72	61.8	14.3	0.1	**90.8**	689.5	69.5	68.4	1135.7	4350.0	4.2
1972-73	40.9	18.1	0.3	**71.4**	910.7	57.4	60.9	1248.7	4560.0	3.7
1973-74	59.3	17.0	0.4	**93.9**	863.9	63.1	76.8	1408.1	4720.0	4.6
1974-75	51.1	22.5	0.5	**91.5**	925.1	71.6	58.3	1442.9	4890.0	3.6
1975-76	67.6	19.4	0.9	**106.1**	839.8	59.5	59.1	1406.0	4870.0	3.5
1976-77	52.6	15.5	1.2	**84.3**	1023.0	58.4	71.0	1530.1	5120.0	4.2
1977-78	60.9	16.5	1.8	**96.6**	1251.4	72.4	71.5	1769.7	5560.0	4.9
1978-79	62.1	18.6	3.0	**101.0**	1104.9	79.6	83.3	1516.6	5640.0	4.5
1979-80	57.7	14.3	2.8	**87.4**	1498.4	76.5	79.6	1288.3	5440.0	4.4
1980-81	50.1	23.0	4.4	**93.7**	1186.5	70.1	81.6	1542.5	5696.0	4.8
1981-82	72.2	23.8	3.5	**120.8**	1521.0	78.8	83.7	1863.6	5604.0	5.2
1982-83	52.8	22.1	4.9	**100.0**	1299.5	75.3	71.7	1895.1	5607.0	5.8
1983-84	70.9	26.1	6.1	**126.9**	1050.3	63.9	77.2	1740.8	5815.0	4.9
1984-85	64.4	30.7	9.5	**129.5**	1951.1	85.1	77.9	1703.2	6399.0	4.9
1985-86	51.2	26.8	10.2	**108.3**	1224.5	87.3	126.5	1706.5	6562.0	4.4
1986-87	58.8	26.0	8.9	**112.7**	1920.9	69.1	86.2	1860.9	6246.0	4.6
1987-88	58.5	34.5	9.0	**126.5**	1227.1	63.8	67.8	1967.4	6743.0	3.7
1988-89	96.6	43.8	15.5	**180.3**	2147.2	87.4	78.6	2030.4	7011.0	4.9
1989-90	81.0	41.3	18.1	**169.2**	1180.5	114.2	82.9	2255.7	6841.0	5.5
1990-91	75.1	52.3	26.0	**186.1**	1697.3	98.4	92.3	2410.5	7203.4	5.6
1991-92	70.9	58.6	24.9	**186.0**	1800.0	97.1	102.9	2540.0	7541.9	5.8
1992-93	85.6	48.0	33.9	**201.1**	1694.0	114.0	85.9	2280.3	7039.3	6.0
1993-94	78.3	53.3	47.5	**215.0**	2120.9	107.4	84.3	2296.6	7608.3	5.6
1994-95	80.6	57.6	39.3	**213.4**	1801.0	118.9	90.8	2755.4	7529.0	5.7
1995-96	75.8	60.0	51.0	**221.1**	2230.0	128.6	88.1	2811.0	7560.2	5.4
1996-97	86.4	66.6	53.8	**243.8**	2050.0	142.3	111.3	2775.6	7801.4	6.2
1997-98	73.7	47.0	64.6	**213.2**	2283.0	108.5	110.2	2795.4	8356.4	6.4
1998-99	89.8	56.6	71.4	**247.5**	2650.0	122.9	98.1	2887.2	8551.6	7.4
1999-00	52.5	57.9	70.8	**207.1**	2920.0	115.3	105.5	2993.2	8368.6	5.2
2000-01	64.1	41.9	52.8	**184.4**	3012.0	95.2	105.6	2959.6	8484.3	3.4
2001-02	70.3	50.8	59.6	**206.6**	3006.0	100.0	116.8	2972.1	8514.1	5.5
2002-03	41.2	38.8	46.6	**148.4**	2753.0	86.2	112.8	2873.8	8459.7	4.9
2003-04	81.3	62.9	78.2	**251.9**	2705.0	137.3	111.7	2338.6	8786.5	5.5
2004-05	67.7	75.9	68.8	**243.5**	2755.0	164.3	102.7	2370.9	9068.4	5.5
2005-06	79.9	81.3	82.7	**279.8**	2740.0	185.0	108.4	2811.7	9489.4	5.0
2006-07	48.6	74.4	88.5	**242.9**	2880.0	226.3	112.7	3555.2	9730.7	4.7
2007-08	91.8	58.3	109.7	**297.6**	2620.0	258.8	112.1	3481.9	9870.2	4.4
2008-09	71.7	72.0	99.1	**277.2**	2623.0	222.8	103.7	2850.3	9727.7	5.7
2009-10	54.3	66.1	99.6	**248.8**	2896.0	240.2	118.2	2923.0	9911.8	6.9
2010-11	82.7	81.8	127.4	**324.8**	3020.0	330.0	106.2	3423.8	9667.3	8.8
2011-12	69.6	66.0	122.1	**298.0**	3140.0	352.0	114.0	3610.4	10954.6	7.5
2012-13	47.0	80.3	146.7	**309.4**	3182.0	342.2	109.3	3412.0	11350.7	6.6
2013-14	97.1	78.8	118.6	**327.5**	3045.0	359.0	116.9	3521.4	12087.8	7.4
2014-15	74.0	62.8	103.7	**275.1**	3270.0	348.1	111.3	3623.3	11971.8	8.6
2015-16	67.3	67.9	85.7	**220.9**	3480.0	300.0	105.2	3484.4	12331.4	8.0
2016-17	74.6	79.2	131.6	**312.8**	3120.0	325.8	109.6	3060.7	12504.9	8.1
2017-18	92.5	84.3	109.3	**314.6**	3160.0	328.1	100.3	3799.1	13250.5	9.5
2018-19	67.3	92.6	132.7	**315.2**	3195.0	280.4	98.2	4054.2	13500.4	-
2019-20	101.0	91.2	112.2	**334.2**	2993.0	354.9	99.1	3557.0	13608.1	-

Notes : 1. Data for 2019-20 are based on Fourth Advance Estimates.
2. Data for 1960-61 to 1969-70 relate to total five major oilseeds viz., groundnut, castorseed, sesamum, rapeseed and mustard, and linseed.
3. Oilseed data comprises total for nine oilseeds out of the eleven in all.
4. Coffee and Tea data measured in lacs kg.
5. Cotton data measured in lacs bales of 170 kg each.
6. Raw jute and the mesta data measured in lacs bales of 180 kg each.
7. - : Not Available.

Also see Notes on Tables.

Source : Ministry of Agriculture & Farmers Welfare, Government of India, Coffee Board of India, Tea Board of India.