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# Trends in irrigated area under cereal crops in India

**D Srinivasa Chary, K Supriya, A Meena and M Ramesh**

**Abstract**
Linear and nonlinear growth models were fitted to identify the best fitted model for the 70 years data of the irrigated area under cereal crops from 1950-51 to 2019-20 and linear & compound growth rates of the data pertaining to the irrigated area under cereal crops were computed. The irrigated area under the rice, jowar, maize, ragi, wheat, barley and other cereal crops was best fitted with the cubic model, where as for bajra the quadratic model was best fitted. Forecasts of irrigated area under different cereal crops for next four years were made. The irrigated area under the wheat crop has recorded with highest significant positive linear and compound growth rates of 2.696% and 3.505% respectively at 1% level. The rice, bajra and maize crops have also recorded with significant positive linear and compound growth rates at 1% level. The ragi, barley and other cereal crops have recorded the significant negative linear and compound growth rates at 1% level.

**Keywords:** Irrigated area, growth model, $R^2$, *Adj.* $R^2$, trends, linear growth rate, compound growth rate

## 1. Introduction

Agriculture sector provides food and livelihood activities to much of the Indian population. Many factors are influencing the farming sector such as rainfall, soil nutrient status, weather parameters etc. Some of them can be managed by the human being, which are like providing irrigation facilities, and application of fertilizers to the crops in need etc. Indian agriculture was purely dependent on the rainfall and thereby the agriculture sector was most uncertain sector. Providing irrigation to the crops at critical stages will save the crop and enhances the crop productivity. Increasing the irrigation facilities will change the cropping pattern and shows impact of the food habits.

In India the Irrigated area comprises a network of major and minor canals from rivers, well based ground water systems, tanks, and other rainwater harvesting projects for agricultural activities. The groundwater system is the largest among these (Siebert *et at.* 2010) [11]. The share of effective utilization of available water resources is critical for a country like, India, since it has 17% of the global population, only 2.4% of land and 4% of the water resources (Rajni *et at.*, 2019) [7]. The per capita availability of utilizable water was reduced from 5247 $m^3$ in 1951 to 1486 $m^3$ in the years 2021, it was expected to further come down to 1367 $m^3$ by 2031 (CWC, 2021). Annual per-capita water availability of less than 1700 $m^3$ is considered as water stressed condition. Hence we are in water stressed condition in India. Now the effective utilization of available water is the component. Alone the agricultural consumes 80% of the ground water (Harsha, 2017) [2]. The groundwater level is showing a declining trend in all parts of the country, which will shows that the assured good quality supply of water will become a concern. (Manivannan *et al*., 2017) [3].

## 2. Materials and Methods

The present study was based on the data for 70 years from 1950-51 to 2019-20 pertaining to the irrigated area under cereal crops in India, the data was collected from the Ministry of Agriculture & Farmers Welfare, Govt. of India in indiastat.com website. The cereal crops studied are rice, jowar, bajra, maize, ragi, wheat, barley and other cereals. The data was analyzed by using the software SPSS 20.0

### 2.1 Growth Rates

The linear growth rate (LGR) and compound growth rates (CGR) were calculated by fitting the functions given below.

**2.1.1 Linear Function**
The function given below is called the linear function

$$y = a + bt \quad (1)$$

where, $y$ = irrigated area, the dependent variable; $t$ = time in years, independent variable;
$a$ and $b$ are the parameters, estimated using the ordinary least square (OLS) method.
The linear growth rate is calculated by using the formula:

$$\text{Linear Growth Rate (LGR)} = \frac{b}{y}.100 \quad (2)$$

**2.1.2 Compound Function**
The exponential function given below is called the compound function

$$y = a.b^t \quad (3)$$

Where $y$ = irrigated area, the dependent variable; $t$ = time in years, independent variable;
$a$ and $b$ are parameters and these parameters are estimated by the method of Ordinary Least Squares (OLS).

Representing the equation (3) in logarithmic form,

$$\log y = \log a + t \log b \quad (4)$$

The Compound Growth Rate (CGR) is calculated by the formula (Sharma 2013):

$$\text{Compound Growth Rate (CGR)} = (b - 1).100 \quad (5)$$

The significance of these growth rates can be tested using a student t-test

$$t = \frac{r}{SE(r)} \text{ with } (N-2) \text{ degrees of freedom,} \quad (6)$$

Where $r$ is the growth rate; $N$ is the total no of years taken under study and
$SE(r)$ is the standard error of the growth rate.

**2.2 Trend Analysis**
The present study analyzes the trends of irrigated areas under Cereal Crops in India from 1950-51 to 2019-2020. To identify the best fitted model, the following trend models were fitted for the data using the method of Ordinary Least Square (OLS):

The linear growth rate (LGR) and compound growth rates (CGR) were calculated by fitting the functions given below

| S. No. | Function | Equation |
|---|---|---|
| 1 | Linear | $Y_t = a + bt$ |
| 2 | Exponential | $Y_t = a + e^{bt}$ |
| 3 | Logarithmic | $Y_t = a + b\ln(t)$ |
| 4 | Quadratic | $Y_t = a + bt + ct^2$ |
| 5 | Cubic | $Y_t = a + bt + ct^2 + dt^3$ |
| 6 | Compound | $Y_t = a.b^t$ |
| 7 | Inverse | $Y_t = a + \frac{b}{t}$ |
| 8 | Power | $Y_t = a.t^b$ |
| 9 | Square root | $Y_t = a + b\sqrt{t}$ |
| 10 | Growth | $Y_t = e^{a+bt}$ |

Where, $y$ = irrigated area, the dependent variable; $t$ = time in years, independent variable;
$a$ and $b$ are parameters to be estimated.
It was observe that $R^2$ is not enough to examine goodness of fit of a model. So, in addition to $R^2$, the Residual Mean Square Error (*RMSE*), Mean Absolute Percentage Error (*MAPE*) and Theil's U-Statistics were calculated and these are used to choose a model from among the alternatives methods (Murthy 2018).

$$Adj.R^2\left(or\ \overline{R}^2\right) = 1 - (1 - R^2)\frac{n-1}{n-p-1}, \quad (7)$$

Where, $n$ is the number of observations and $p$ is the number of parameters in the model.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\left|\frac{A_i - F_i}{A_i}\right|\right).100, \quad (8)$$

Where, $A_i$ is the actual value at time $i$ and $F_i$ is the forecasted value at time $i$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(A_i - F_i)^2}{n}} \quad (9)$$

**Theil's U-Statistic**

This statistic allows a relative comparison of normal forecasting methods with naive approaches and also squares the errors involved so that large errors are given much more weight than small errors. The positive characteristic that is given up in moving to Theil's U-Statistic as a measure of accuracy is that of intuitive interpretation. It is given by

$$U = \sqrt{\frac{\sum_{t=1}^{n-1}\left(\frac{F_{t+1} - A_{t+1}}{A_i}\right)^2}{\sum_{t=1}^{n-1}\left(\frac{A_{t+1} - A_t}{A_t}\right)^2}}, \qquad (10)$$

where, $F_{t+1}$ is the predicted value at time period $t+1$; $A_{t+1}$ is the actual value at time period $t+1$; $A_t$ is the actual value of a point for a given time period $t$; and $n$ is the number of observations.

If $U = 1$, there is no difference between a naive forecast and the technique used.

If $U < 1$, the technique is better than a naive forecast and if $U > 1$, then the technique is no better than a naive forecast.

The model will be considered for which the $U$ value is smallest. The model which showed relatively the least *MAPE*, *RMSE* and *Theil's U- Statistic*, highest Adj.$R^2$ and significant is chosen for the purpose of trend fitting.

## 3. Results and Discussion

The linear and nonlinear growth models were fitted and identified the best fitted model the trends and growth rates of the irrigated under cereal crops from 1950-51 to 2019-20 were found. The results are as give below:

### 3.1 Growth models and trends in the irrigated area

Different linear and non-linear growth models *viz*. Linear, Logarithmic, Inverse, Quadratic, Cubic, Compound, Power, S curve, Growth, Exponential and Logistic were fitted to the irrigated under cereal crops and found the best fitted model based on the relatively highest *Adj.$R^2$* value, least *MAPE*, *RMSE* and *Theil's U- Statistic* for the specific crop and found the trends.

Rice is the food crop for majority of Indian population. The irrigated area under the rice was subjected to linear and non-linear growth models mentioned. The results in table-1 reveal that the cubic model was found to be the best fitted for the irrigated area under the rice crop as the highest *Adj.$R^2$* (0.973) value, least *MAPE*(3.44), *RMSE* (919.43) and *Theil's U-Statistic* (22.12) were found to the cubic model, which is significant at 1% level. It was observed from the Fig. 1 that the irrigated area under rice crops is gradually increasing, which will influence in increasing rice yields and there by production is increased. The fitted cubic model for rice crop is given by

$$y_t = 10010.15 + 149.39t + 2.927t^2 - 0.018t^3 \qquad (11)$$

**Table 1:** Model Summary for Rice

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 2124.8 | .000 | 8813.00 | 275.99 | | | .969 | .969 | 4.23 | 997.57 | 22.15 |
| Logarithmic | 203.3 | .000 | 739.16 | 5428.73 | | | .749 | .746 | 14.28 | 2836.10 | 22.94 |
| Inverse | 21.9 | .000 | 20027.51 | -20524.69 | | | .243 | .232 | 25.75 | 4927.95 | 24.72 |
| Quadratic | 1218.1 | .000 | 9674.46 | 204.20 | 1.011 | | .973 | .972 | 3.45 | 926.78 | 22.15 |
| Cubic | 813.2 | .000 | 10010.15 | 149.39 | 2.927 | -.018 | .976 | .973 | 3.44 | 919.43 | 22.12 |
| Compound | 2714.5 | .000 | 10271.75 | 1.02 | | | .976 | .972 | 3.95 | 1030.04 | 22.12 |
| Power | 375.5 | .000 | 6173.46 | .32 | | | .847 | .844 | 10.06 | 2233.89 | 22.50 |
| S | 32.2 | .000 | 9.87 | -1.31 | | | .321 | .311 | 23.13 | 4769.75 | 23.66 |
| Growth | 2714.5 | .000 | 9.24 | .02 | | | .976 | .973 | 3.95 | 1030.04 | 22.12 |
| Exponential | 2714.5 | .000 | 10271.75 | .02 | | | .976 | .973 | 3.95 | 1030.04 | 22.12 |
| Logistic | 2714.5 | .000 | .00 | .98 | | | .976 | .973 | 3.95 | 1030.04 | 22.12 |

The irrigated area under jowar crop was used to fit the linear and non-linear growth models. The results in table-2 are showing that the highest *Adj.$R^2$* value (0.769), least *MAPE* (4.89), *RMSE* (46.38) and *Theil's U- Statistic* (12.08) were found for the cubic model, which is significant at 1% level. Hence the cubic model is the best fitted for the irrigated area under the jowar crop. Further it was observed from the Fig. 2 that the irrigated area under the jowar crop has shown increasing trend with positive linear and compound growth rates of 0.97% and 1.00% respectively from 2050-51 to 1989-90 and there from it has shown decreasing trend with the negative linear and compound growth rates of -1.55% linear and -1.60% respectively. The fitted cubic model is given by

$$y_t = 531.94 + 8.57t + 0.063t^2 - 0.003t^3 \qquad (12)$$

**Table 2:** Model Summary for Jowar

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | .95 | .334 | 677.32 | .57 | | | .014 | -.001 | 12.17 | 97.93 | 12.37 |
| Logarithmic | 12.69 | .001 | 555.13 | 43.29 | | | .157 | .145 | 10.75 | 90.53 | 12.34 |
| Inverse | 18.51 | .000 | 720.77 | -335.12 | | | .214 | .202 | 10.59 | 87.42 | 12.37 |
| Quadratic | 98.35 | .000 | 480.38 | 16.98 | -.231 | | .746 | .738 | 5.08 | 49.71 | 12.11 |
| Cubic | 77.46 | .000 | 531.94 | 8.57 | .063 | -.003 | .779 | .769 | 4.89 | 46.38 | 12.08 |
| Compound | .77 | .383 | 671.32 | 1.00 | | | .011 | -.003 | 12.18 | 98.27 | 12.24 |
| Power | 12.75 | .001 | 556.13 | .07 | | | .158 | .146 | 10.84 | 91.45 | 12.23 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 21.36 | .000 | 6.57 | -.54 | | | .239 | .228 | 10.35 | 86.99 | 12.26 |
| Growth | .77 | .383 | 6.51 | .00 | | | .011 | -.003 | 12.18 | 98.27 | 12.24 |
| Exponential | .77 | .383 | 671.32 | .00 | | | .011 | -.003 | 12.18 | 98.27 | 12.24 |
| Logistic | .77 | .383 | .00 | 1.00 | | | .011 | -.003 | 12.18 | 98.27 | 12.24 |

The quadratic model was best fitted for the bajra crop irrigated area during the study period, as it has recorded with the highest *Adj* $R^2$ value (0.847) and lowest *MAPE* (1.05), *RMSE* (83.02) and *Theil's U-Statistic* (7.98) and are significant at 1% level. The Fig. 3 reveals that the irrigated area under the bajra crop has small amount of fluctuations with increasing trend in the study period. The fitted cubic model is given by

$$y_t = 315.34 + 5.77t + 0.057t^2 \qquad (13)$$

**Table 3:** Model Summary for Bajra

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 362.85 | .000 | 266.94 | 9.80 | | | .842 | .840 | 13.86 | 85.73 | 8.08 |
| Logarithmic | 107.87 | .000 | -1.03 | 187.09 | | | .613 | .608 | 21.67 | 134.18 | 8.54 |
| Inverse | 13.94 | .000 | 660.02 | -653.89 | | | .170 | .158 | 31.33 | 196.57 | 9.35 |
| Quadratic | 191.95 | .000 | 315.34 | 5.77 | .057 | | .851 | .847 | 13.05 | 83.02 | 7.98 |
| Cubic | 126.62 | .000 | 300.57 | 8.18 | -.028 | .001 | .850 | .845 | 13.41 | 83.02 | 8.08 |
| Compound | 316.20 | .000 | 317.27 | 1.02 | | | .823 | .820 | 13.05 | 83.84 | 7.98 |
| Power | 125.85 | .000 | 192.14 | .33 | | | .649 | .644 | 17.95 | 117.91 | 8.21 |
| S | 16.13 | .000 | 6.44 | -1.20 | | | .192 | .180 | 28.28 | 194.84 | 8.78 |
| Growth | 316.20 | .000 | 5.76 | .02 | | | .823 | .820 | 13.05 | 83.84 | 7.98 |
| Exponential | 316.20 | .000 | 317.27 | .02 | | | .823 | .820 | 13.05 | 83.84 | 7.98 |
| Logistic | 316.20 | .000 | .00 | .98 | | | .823 | .820 | 13.05 | 83.84 | 7.98 |

The irrigated area under the maize crop was drastically increased. It was 3,69,000 ha in the year 1950-51 and it has increased to 28,51,000 ha in the year 2019-20. The maize irrigated are under the study period was best fitted with the cubic model among all the other growth models studied with highest *Adj* $R^2$ value (0.950) and lowest *MAPE* (11.64), *RMSE* (133.92) and *Theil's U-Statistic* (5.91), significant at 1% level. It is concluded from Fig. 4 that the irrigated area under the maize crop is gradually increasing. The best fitted cubic model for maize in the study period is given below:

$$y_t = 232.42 + 51.18t - 1.275t^2 + 0.015t^3 \qquad (14)$$

**Table 4:** Model Summary for Maize

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 544.87 | .000 | 233.24 | 28.66 | | | .889 | .887 | 15.01 | 204.56 | 5.93 |
| Logarithmic | 119.82 | .000 | -536.95 | 543.00 | | | .638 | .633 | 30.19 | 369.51 | 6.58 |
| Inverse | 15.99 | .000 | 1386.50 | -1968.62 | | | .190 | .179 | 46.69 | 552.55 | 7.94 |
| Quadratic | 427.00 | .000 | 513.40 | 5.31 | .329 | | .927 | .925 | 12.45 | 165.63 | 5.99 |
| Cubic | 440.64 | .000 | 232.42 | 51.18 | -1.275 | .015 | .952 | .950 | 11.64 | 133.92 | 5.91 |
| Compound | 713.44 | .000 | 457.64 | 1.03 | | | .913 | .912 | 11.64 | 155.84 | 5.91 |
| Power | 264.38 | .000 | 201.33 | .52 | | | .795 | .792 | 18.52 | 300.54 | 6.12 |
| S | 29.33 | .000 | 7.15 | -2.11 | | | .301 | .291 | 36.55 | 545.10 | 7.02 |
| Growth | 713.44 | .000 | 6.13 | .02 | | | .913 | .912 | 11.64 | 155.84 | 5.91 |
| Exponential | 713.44 | .000 | 457.64 | .02 | | | .913 | .912 | 11.64 | 155.84 | 5.91 |
| Logistic | 713.44 | .000 | .00 | .98 | | | .913 | .912 | 11.64 | 155.84 | 5.91 |

The irrigated area under the ragi crop has shown decreasing trend (Fig. 5) in the study period. It was best fitted with cubic model, which is significant at 1% level, having highest *Adj* $R^2$ value (0.957) and lowest *MAPE* (8.62), *RMSE* (24.43) and *Theil's U-Statistic* (7.88).

**Table 5:** Model Summary for Ragi

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 690.66 | .000 | 451.79 | -5.68 | | | .910 | .909 | 15.00 | 36.04 | 8.08 |
| Logarithmic | 117.55 | .000 | 599.17 | -106.07 | | | .634 | .628 | 33.54 | 72.87 | 9.58 |
| Inverse | 10.96 | .001 | 227.25 | 329.51 | | | .139 | .126 | 61.96 | 111.70 | 12.14 |
| Quadratic | 363.43 | .000 | 431.46 | -3.99 | -.024 | | .916 | .913 | 15.93 | 34.97 | 8.02 |
| Cubic | 512.09 | .000 | 359.34 | 7.78 | -.436 | .004 | .959 | .957 | 8.62 | 24.43 | 7.88 |
| Compound | 477.02 | .000 | 562.25 | .97 | | | .875 | .873 | 17.26 | 56.68 | 8.02 |
| Power | 86.17 | .000 | 1056.81 | -.48 | | | .559 | .552 | 35.71 | 126.35 | 8.85 |
| S | 9.16 | .003 | 5.27 | 1.48 | | | .119 | .106 | 55.73 | 130.34 | 10.43 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Growth | 477.02 | .000 | 6.33 | -.03 | | | .875 | .873 | 17.26 | 56.68 | 8.02 |
| Exponential | 477.02 | .000 | 562.25 | -.03 | | | .875 | .873 | 17.26 | 56.68 | 8.02 |
| Logistic | 477.02 | .000 | .00 | 1.03 | | | .875 | .873 | 17.26 | 56.68 | 8.02 |

The decrease in the irrigated area under the ragi crop might be due to the fact that, it is the rainfed crop. The best fitted model for the ragi crop is given below:

$$y_t = 359.34 + 7.78t - 0.436t^2 + .004t^3 \quad (15)$$

The second major food crop for the Indian population after the rice is the wheat. From Fig 6 it can be concluded that the irrigated under the wheat crop is showing positive trend. The cubic model was found to be the best fitted for the irrigated area under wheat crop during the period under study with highest *Adj* $R^2$ value (0.984) and lowest *MAPE* (9.70), *RMSE* (11.04.86) and *Theil's U-Statistic* (18.09), significant at 1% level. The best fitted model for the wheat crop is given below:

$$y_t = 1771.74 + 251.27t + 7.147t^2 - 0.07t^3 \quad (16)$$

**Table 6:** Model Summary for Wheat

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 3815.36 | .000 | 706.12 | 443.99 | | | .982 | .982 | 12.13 | 1197.63 | 18.30 |
| Logarithmic | 231.81 | .000 | -12535.04 | 8810.13 | | | .773 | .770 | 43.97 | 4310.28 | 22.57 |
| Inverse | 20.79 | .000 | 18688.81 | -32169.70 | | | .234 | .223 | 80.80 | 7920.57 | 32.33 |
| Quadratic | 1893.21 | .000 | 471.40 | 463.55 | -.275 | | .983 | .982 | 12.31 | 1193.40 | 18.27 |
| Cubic | 1454.22 | .000 | 1771.74 | 251.27 | 7.147 | -.070 | .985 | .984 | 9.70 | 1104.86 | 18.09 |
| Compound | 700.44 | .000 | 3898.85 | 1.04 | | | .912 | .910 | 20.03 | 3975.38 | 18.35 |
| Power | 463.89 | .000 | 1107.72 | .75 | | | .872 | .870 | 18.63 | 2296.41 | 19.04 |
| S | 33.75 | .000 | 9.70 | -3.08 | | | .332 | .322 | 59.07 | 7834.35 | 25.70 |
| Growth | 700.44 | .000 | 8.27 | .03 | | | .912 | .910 | 20.03 | 3975.38 | 18.35 |
| Exponential | 700.44 | .000 | 3898.85 | .03 | | | .912 | .910 | 20.03 | 3975.38 | 18.35 |
| Logistic | 700.44 | .000 | .00 | .97 | | | .912 | .910 | 20.03 | 3975.38 | 18.35 |

The best fitted model for irrigated area under the barley crop was found to be the cubic model, as it has highest *Adj* $R^2$ value (0.900) and lowest *MAPE* (13.26), *RMSE* (134.13) and *Theil's U-Statistic* (10.07), significant at 1% level. The increase in the irrigation facilities in the country during study period forced the farmers to go for irrigated crops like rice, rather than rainfed crops. Hence the irrigated area under the barley has shown negative trend in the period under study and this can be found from Fig. 7. The best fitted model for the barley is given below:

$$y_t = 1446.89 + 14.26t - 1.445t^2 + 0.015t^3 \quad (17)$$

The irrigated area under the other cereal crops was meager compared to the cereal crops studied above. It is clear from Fig. 8 that the irrigated area under the other cereal crops has shown a decreasing trend. It was 2,48,000 ha in the year 1950-51 and it has decreased to 7,000 ha in the year 2019-20.

**Table 7:** Model Summary for Barley

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 332.03 | .000 | 1579.87 | -19.54 | | | .830 | .828 | 21.02 | 178.62 | 10.37 |
| Logarithmic | 151.48 | .000 | 2198.09 | -398.46 | | | .690 | .686 | 21.87 | 241.15 | 10.82 |
| Inverse | 17.58 | .000 | 786.78 | 1442.52 | | | .205 | .194 | 47.54 | 386.19 | 12.87 |
| Quadratic | 193.42 | .000 | 1731.07 | -32.14 | .177 | | .852 | .849 | 15.62 | 166.46 | 10.23 |
| Cubic | 207.53 | .000 | 1446.89 | 14.26 | -1.445 | .015 | .904 | .900 | 13.26 | 134.13 | 10.07 |
| Compound | 420.98 | .000 | 1768.50 | .98 | | | .861 | .859 | 14.98 | 174.62 | 10.06 |
| Power | 139.14 | .000 | 3482.79 | -.45 | | | .672 | .667 | 22.83 | 381.12 | 10.32 |
| S | 15.71 | .000 | 6.55 | 1.59 | | | .188 | .176 | 42.34 | 462.85 | 11.46 |
| Growth | 420.98 | .000 | 7.48 | -.02 | | | .861 | .859 | 14.98 | 174.62 | 10.06 |
| Exponential | 420.98 | .000 | 1768.50 | -.02 | | | .861 | .859 | 14.98 | 174.62 | 10.06 |
| Logistic | 420.98 | .000 | .00 | 1.02 | | | .861 | .859 | 14.98 | 174.62 | 10.06 |

The cubic model was found to be the best fitted for irrigated area under the other cereal crops with highest *Adj* $R^2$ value (0.738) and lowest *MAPE* (31.74), *RMSE* (22.51) and *Theil's U-Statistic* (3.38), significant at 1% level. The best fitted model for the irrigated area under the other cereal crops is given below:

$$y_t = 161.47 - 2.37t - 0.056t^2 + 0.001t^3 \quad (17)$$

**Table 8:** Model Summary for Other Cereals

| Equation | Model | | Parameter Estimates | | | | $R^2$ | Adj. $R^2$ | MAPE | RMSE | Theil's U-Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | Constant | b1 | b2 | b3 | | | | | |
| Linear | 73.82 | .000 | 133.49 | -1.61 | | | .521 | .513 | 55.65 | 31.14 | 4.05 |
| Logarithmic | 137.96 | .000 | 210.63 | -40.75 | | | .670 | .665 | 50.35 | 25.84 | 3.98 |
| Inverse | 59.41 | .000 | 60.91 | 225.61 | | | .466 | .458 | 69.22 | 32.86 | 4.92 |
| Quadratic | 88.96 | .000 | 181.13 | -5.58 | .056 | | .726 | .718 | 39.58 | 23.52 | 3.69 |
| Cubic | 65.81 | .000 | 161.47 | -2.37 | -.056 | .001 | .749 | .738 | 31.74 | 22.51 | 3.38 |
| Compound | 51.45 | .000 | 138.07 | .98 | | | .431 | .422 | 44.13 | 28.90 | 3.54 |
| Power | 58.68 | .000 | 344.52 | -.52 | | | .463 | .455 | 46.25 | 32.44 | 3.56 |
| S | 18.75 | .000 | 3.97 | 2.35 | | | .216 | .205 | 62.73 | 51.96 | 4.17 |
| Growth | 51.45 | .000 | 4.93 | -.02 | | | .431 | .422 | 44.13 | 28.90 | 3.54 |
| Exponential | 51.45 | .000 | 138.07 | -.02 | | | .431 | .422 | 44.13 | 28.90 | 3.54 |
| Logistic | 51.45 | .000 | .01 | 1.02 | | | .431 | .422 | 44.13 | 28.90 | 3.54 |

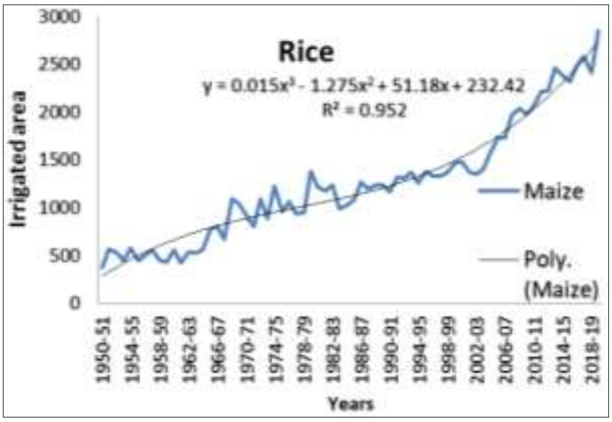


**Fig 1:** Observed and predicted values of the irrigated area under the Rice crop (in '000 ha)

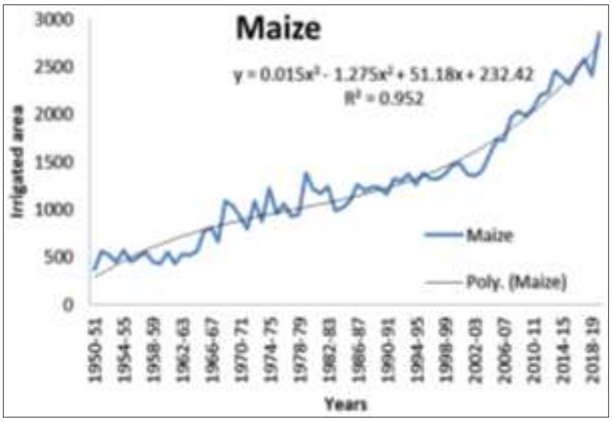


**Fig 4:** Observed and predicted values of the irrigated area under the Maize crop (in '000 ha)

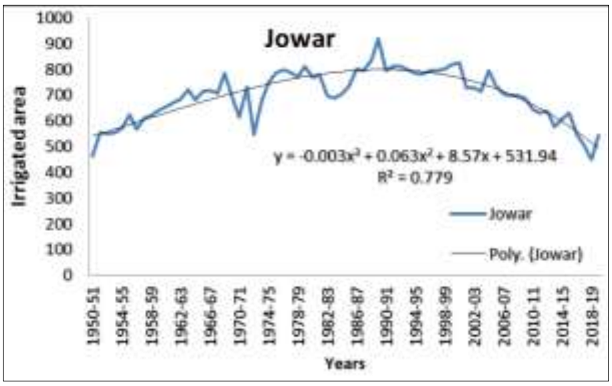


**Fig 2:** Observed and predicted values of the irrigated area under the Jowar crop (in '000 ha)


**Fig 5:** Observed and predicted values of the irrigated area under the Ragi crop (in '000 ha)

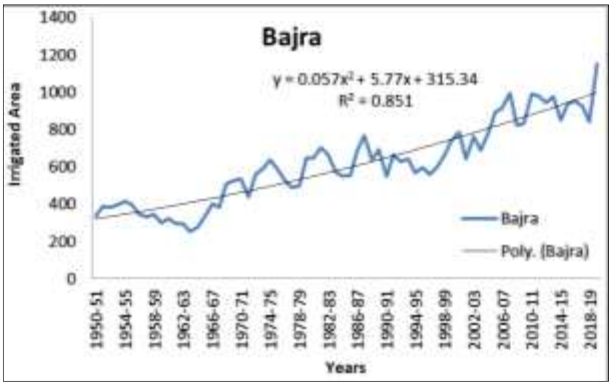


**Fig 3:** Observed and predicted values of the irrigated area under the Bajra crop (in '000 ha)

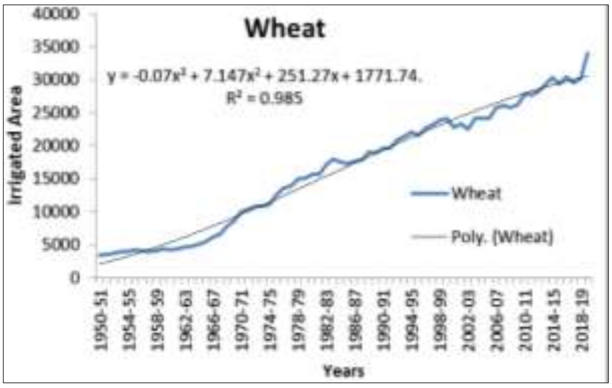


**Fig 6:** Observed and predicted values of the irrigated area under the Wheat crop (in '000 ha)

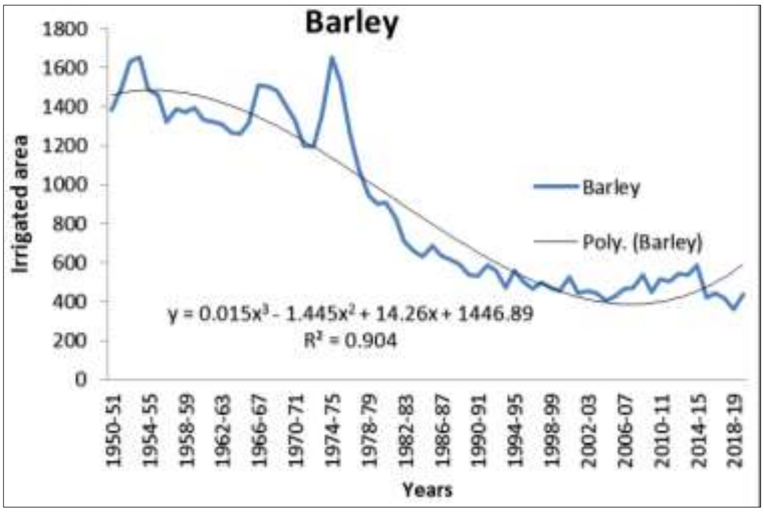


**Fig 7:** Observed and predicted values of the irrigated area under the Barley crop (in '000 ha)

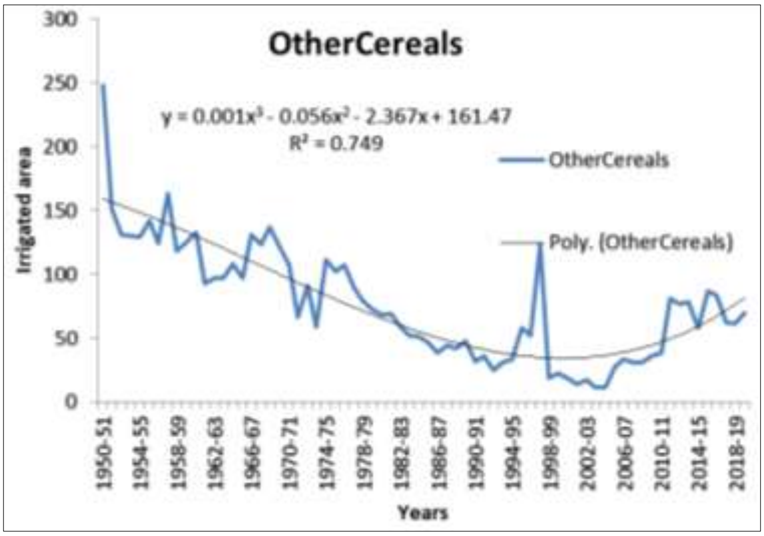


**Fig 8:** Observed and predicted values of the irrigated area under the Other Cereals (in '000 ha)

### 3.2 Forecast for the irrigated area

Forecast for next four years were made for the irrigated are under cereal crops based on the best fitted model obtained above.

**Table 9:** Forecasted values of the irrigated area under the cereal crops

| Year | Rice | Jowar | Bajra | Maize | Ragi | Wheat | Barley | Other Cereals |
|---|---|---|---|---|---|---|---|---|
| 2020-21 | 28929.45 | 384.26 | 1012.347 | 2807.59 | 145.488 | 30586.17 | 543.77 | 68.815 |
| 2021-22 | 29221.33 | 355.828 | 1026.268 | 2906.5 | 152.268 | 30785.87 | 581.45 | 73.774 |
| 2022-23 | 29511.3 | 326.226 | 1040.303 | 3009.34 | 159.904 | 30969.62 | 622.72 | 79.053 |
| 2023-24 | 29799.23 | 295.436 | 1054.452 | 3116.2 | 168.42 | 31137.01 | 667.67 | 84.658 |

### 3.3 Growth rates in the irrigated area

The linear and compound growth rates for the irrigated area under the Cereal crops from 1950-51 to 2019-20 were calculated.

The irrigated area under the wheat crop has recorded highest significant positive linear and compound growth rates of 2.696% and 3.505% respectively at 1% level of significance among the cereal crops. The irrigated area under the maize crop has recorded second highest positive linear and compound growth rates of 2.292% and 2.502% respectively at 1% level of significance. The rice and bajra crops were also recorded positive growth rates in the irrigated area during the study period. The irrigated area under the ragi, barley and other Cereal crops was recorded with significant negative growth rates at 1% level of significance. However the area under these crops is less, compared to the rice, jowar, maize and wheat.

**Table 10:** Linear and compound Growth Rates of the crops

| Crop | LGR (%) | CGR (%) |
|---|---|---|
| Rice | 1.483** | 1.600** |
| Jowar | 0.082 | 0.078 |
| Bajra | 1.594** | 1.691** |
| Maize | 2.292** | 2.502** |
| Ragi | -2.272** | -2.667** |
| Wheat | 2.696** | 3.505** |
| Barley | -2.204** | -2.268** |
| Other Cereals | -2.100** | -2.213** |

**4. Conclusion**

The rice and wheat are staple food crops for most of the Indian population and irrigation facilities are constantly increasing for both the crops. The irrigated area under the bajra crop was best fitted with the quadratic model, where as for the rice, jowar, maize, ragi, wheat, barley and other cereal crops was best fitted with the cubic model. The irrigated area under rice crop has recorded significant positive linear and compound growth rates of 1.483% and 1.600% respectively, whereas the wheat crop has recorded significant positive linear and compound growth rates of 2.696% and 3.505% respectively. The increasing in the irrigation facilities for these crops influenced in increasing the area under these crops and productivity. The similar results were also found by Sharma (2013) [1]. The irrigation requirement for the crops like bajra and ragi are less, however the irrigated area under the bajra crop has recorded significant positive linear and compound growth rates of 1.594% and 1.691% respectively at 1% level of significance, and ragi crop irrigated area was recorded -2.272% and -2.667% negative linear and compound growth rates at 1% level of significance.

**5. References**

1. Amod Sharma. Trends in Area, Production and Productivity of Food Grain Crops: An Overview, Economic Affairs. 2013;58(1):1-12.
2. Harsha J. Micro-irrigation in India: An assessment of bottlenecks and realities; c2017. [http://www.globalwaterforum.org/2017/06/13/micro-irrigation-in-india-an-assessment-of-bottlenecks-and-realities] [Visited on 06 March, 2023]
3. Manivannan S, Thilagam VK, Khola OPS. Soil and water conservation in India: Strategies and research challenges. Journal of Soil and Water Conservation. 2017;16(4):312-319.
4. Naomi K, FUkaGaWa, Lewis H ZISka. Rice: Importance for Global Nutrition, Journal of Nutritional Science and Vitaminology. 2019;65:52-53.
5. Pangayar Selvi R, Muraligopal S, Vasanthi R, Swaminathan B. Statistical Analysis of Trends in the Maize Area, Production and Productivity in India, Annals of Plant and Soil Research. 2015;17:233-237.
6. Parimalarangan R. Trends in Area, Production and Productivity in Onion in Tamil Nadu, International Journal of Environment and Climate Change. 2020;10(11):95-99
7. Rajni Jain, Prabhat Kishore, Dhirendra Kumar Singh. Irrigation in India: Status, challenges and options, Journal of Soil and Water Conservation. 2019;18(4):1-11.
8. Ramana Murthy B, Hari Babu O. A Statistical Trend Analysis of Mango Area, Production and Productivity in Andhra Pradesh, International Journal of Agricultural and Statistical Sciences. 2018;14(1):337-342.
9. Sathish Kumar M, Lad YA, Ashish B Mahera. Trend Analysis of Area, Production and Productivity of Minor Millets in India, Biological Forum – An International Journal. 2022;14(2):14-18.
10. Shyam Prakash Singh, Ajay Kumar Srivastava, Shalini Sinh. Growth Trend and Instability in Area, Production and Productivity of Sugarcane in Uttar Pradesh: An Overview, Economic Affairs. 2022;67(05):739-744.
11. Siebert S, Burke J, Faures JM, Frenken K, Hoogeveen J, Doll P, *et al*. Groundwater use for irrigation – a global inventory, Hydrology and Earth System Sciences. 2010;14:1863-1880.
12. Unjia YB, Lad YA, Sathish Kumar M, Mahera AB. Trend Analysis of Area, Production and Productivity of Maize in India, International Journal of Agriculture Sciences. 2021;13(9):10880-10882.