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A study of development of irrigation potential under five year plans in India

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Abstract
Agriculture plays a major role in India's economy and irrigation is the catalyst for the agriculture development. Now a day's dependency on irrigation has been increased due to uncertainty of rainfall in India. This paper discusses the development of the irrigation system in India by using the secondary information, which is helpful to provide a background for the objective, based analysis of the irrigation development. In this paper the study focuses on plan wise irrigation potential created and utilized and the gap created between both the irrigation potential which is analysed through statistical methods. Descriptive statistics and parametric regression models and correlation analysis have been employed out to study the relationship. This study is accomplished in SPSS Software. It is observed from the results that the plan wise development of irrigation potential and utilized during the plan periods, we observed that gradually a gap has been created between Irrigation potential created (IPC) and Irrigation potential utilized (IPU) over the plan periods. The results of this study will be used for utilized for coming up with an acceptance policy for groundwater use and its appropriate regulation to avoid future crisis.

Keywords: Irrigation potential created (IPC), irrigation potential utilized (IPU), gap between IPC and IPU, parametric regression model, correlation analysis

Introduction

Agriculture is the most important sector of Indian economy, where more than 58 per cent of population depends on agriculture. It is the backbone of Indian economy. According to India economic survey 2018, agriculture sector employs more than 50 per cent of the total workforce in India and contributes around 17-18 percent to the country's GDP. Irrigated agriculture has made a major contribution to food production and food security throughout the world: without irrigation much of the impressive growth in agricultural productivity over the last 50 years could not have been achieved. Recent studies show that the irrigation needs to play a bigger role towards a goal of achieving a better agricultural productivity and also the national food security (Persaud and Stacey, 2003; Kumar 1998, GOI 1999; Bhaduri *et al.*, 2012) [8, 5, 1]. Water is a necessary element for successful agriculture. Therefore, any water management policy must incorporate the varied aspects associated with irrigation, including the irrigation potential of the country and the type of irrigation facilities to be put in place. (Source: Envystats India, 2018, www.mospi.in). Irrigation Potential Created (IPC) is the aggregate gross area that can be irrigated annually by the quantity of water that could be made available by all the connected and completed works up to the end of the water courses or the last purpose within the water delivery system. Irrigation Potential Utilized (IPU): It is the total gross area actually irrigated by a project/scheme during the agricultural year under consideration. Ultimate Irrigation Potential (UIP): It is the total area that can be irrigated from a project in pre-planned year for the projected cropping pattern and assumed water allowance on its full development. Efforts have been made in the different Five-Year Plans to attain this potential through irrigation projects, which are generally classified as under: 1. Major project: It consists of huge surface water, storage reservoirs and flow diversion structures and covers area under irrigation is 10000 hectares. 2. Medium project: It coves area under irrigation between 10000 hectares and 2000 hectares. 3. Minor project: It is below 2000Ha and the source of water is either ground water or from wells or tube wells or surface water lifted by pumps or by gravity flow from tanks. The foremost vital increase has been created in potential because of ground (well) water irrigation development & additionally due to minor surface potential (GOI, 1999:477) [5]. Development of Irrigation under Plan in India: In the First Five Year Plan (1951- 56), the country embarked on a major irrigation programme. During the periods of the Second Five Year Plan (1956- 61), the Third Five Year Plan (1961- 66) and the three annual plans (1966- 69), new irrigation programmes were implemented. During the fourth Five Year Plan (1969- 74), the stress was shifted to the completion of ongoing projects, integrated use of surface and ground water, adoption of efficient management techniques and modernization of existing schemes. During the annual plans of 1978- 80 and the Sixth Five Year Plan (1980- 85), ‘new starts’ continued and at the end of the Seventh Plan, there were as many as 182 major and 312 medium continuing projects. This was continued during 1990- 91 & 1991- 92 annual plans, the VIII Plan (1992- 97) and the IX Plan (1997- 2002).

Materials and Methods

Materials

All the data are used in the study relies on secondary data compiled from various published sources. Data with respect to plan-wise irrigation potential created and utilised in India are collected from, Ministry of Agriculture & Farmers Welfare, Govt. of India and also through the website www.indiastat.com. From a period of 1st plan (1951-56) up to 11th plan (2007-2012).

Methodology

This present paper is attempting to analyse the plan-wise irrigation potential created and utilised in India through various linear and non-linear parametric model. For the study of plan wise irrigation potential created and utilised in India from first plan to eleventh plan has been taken for the best trend fit. Also, to examine the nature of each series which has been subjected to get various descriptive statistical measures.

Descriptive Statistics

Descriptive statistics offer simple summaries about the data and the measures. The descriptive statistics study that used for study are maximum, minimum, mean, median, skewness, kurtosis etc. to describe the pattern of the series and draw a consensus under consideration.

Mean: Arithmetic mean or simple mean of a set of observation is their sum divided by the number of observation, *e.g.*, the arithmetic mean x of n observation x_1, x_2, x_3,...,x_n.is given by

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{i} x_i.$$

Median: Median of a distribution is the value of the variable which divides the distribution it into two equal parts. It is a positional average. In case of continuous frequency distribution, the class corresponding to the cumulative frequency just greater than N/2 is called median class and the value of median is obtained by the following formula:

$$\text{Median} = 1 + \frac{h}{f}\left(\frac{N}{2} - C\right)$$

Where, l = lower limit of the median class, f = frequency of median class, h = width of the median class, C = cumulative frequency of the class preceding the median class and $N = \sum f$.

Mode: It is that value which happens most frequently in a set of observations and around which the other items of the set cluster densely.

In case of continuous frequency distributions, mode is given by the formula:

$$\text{Mode} = L + \frac{h(f_1 - f_0)}{2f_1 - f_0 - f_1}$$

Where, L = lower limit, h = magnitude and f_1 = frequency of modal class, f_0 and f_2 are frequencies of the classes preceding and succeeding the modal class respectively.

Range: The range is the difference between two extreme observations of the distribution. If A and B are the greatest and smallest values respectively in a distribution, then its range is given by

Range = Xmax-Xmin = A-B

Standard deviation: It is more accurate and detailed estimate of dispersion because an outlier can greatly exaggerate the range. It is expressed by: $\sigma = {}^{+}\sqrt{\sum_{i=1}^{n} \frac{1}{n-1}(x_i - \bar{x})^2}$

Where, x_i = value of the variable for the i^{th} observations, x = the mean or average, N = the number of values

Standard Error: The standard deviation of the sampling distribution of a statistic is known as its standard error, abbreviated as S.E. The standard error of mean is given by the formula:

$$\text{S.E. } (\bar{x}) = \frac{\sigma}{\sqrt{n}}$$

Skewness: Skewness means “lack of symmetry”. We study skewness to have an idea about the shape of the curve which we can draw with the help of given data. Based upon moments, coefficient of skewness is

$$S_k = \frac{\sqrt{\beta_1}(\beta_2+3)}{2(5\beta_2 - 6\beta_1 - 9)}, \text{ where } \beta_1 = \frac{m_3^2}{m_2^3},\ \beta_2 = \frac{m_4}{m_2^2}$$

Where m_2, m_3 and m_4 are the 2^{nd}, 3^{rd} and 4^{th} central moments respectively.

Kurtosis: It means “flatness or peakness” of the frequency curve. It is measured by the coefficient β_2 and its deviation given by γ_2 given by

$$\beta_2 = \frac{\mu_4}{\mu_2^2},\ \gamma_2 = \beta_2 - 3$$

Simple growth rate per annum (SGAR): It has been calculated by using the following formula:

$$\text{SGAR } (\%) = \frac{X_t - X_0}{X_o \times n} \times 100;$$

Where X_t = value of the series for the last period and X_o is the value of the series for first period and n is the total number of periods

Jarque Bera (JB) test: The Jarque-Bera Test, a type of Lagrange multiplier test, is a test for normality. This test is a goodness-of-fit test of whether sample data have the skewness and kurtosis matching a normal distribution. The JB test is always non negative. The JB test is defined as:

$$JB = \frac{n-k+1}{6}\left(S^2 + \frac{(C-3)^2}{4}\right)$$

Parametric Trend models

Parametric modelling is an important statistical technique which used as a basis for manual and also automatic planning in many kinds of application domains (Gooijer and Hyndman, 2006) [6]. In this study, we have tried different parametric models to describe the series under consideration, which are briefly given here under:

- Linear model: It is one in which all the parameters appear linearly and it is formulated as $X_t = a + bt + e_t$.
- Quadratic model: It can be used to model a series which "takes off" or a series which "dampens". It expressed as $X_t = a + bt + ct^2 + e_t$.
- Cubic model: The equation of cubic model is a 3rd order of polynomial regression equation and it is represented as $X_t = a + bt + ct^2 + dt^3 + e_t$.
- Exponential model: The equation of exponential model is Xt = a [Exp (bt)] + et.
- Logarithmic model: The equation of logarithmic model is given by $X_t = a + b\ln(t) + e_t$.
- Growth Model: The equation of growth model is given by $(X_t) = \exp(b_0 + b_1 t) + e_t$

Parameters selection criterion

R-squared. It is an estimate of the proportion of the total variation in the series that is explained by the model. It is most useful when the series is stationary. $R^2 = \frac{\sum_{i=1}^{n}(\hat{X}_i - \bar{X})^2}{\sum_{i=1}^{n}(X_i - \bar{X})^2}$

Adjusted R-squared. It is a modified version of R-squared that has been adjusted for the number of predictors in the model. The only difference between R^2 and Adjusted R^2 equation is degree of freedom.

$R^2_{adjusted} = 1 - \frac{(1-R^2)(N-1)}{N-p-1}$, where, p = Number of predictors N = Total sample size

Root Mean Square Error. (**RMSE).** It is the square root of mean square error. It is a measure of how much a dependent series varies from its model-predicted level, expressed in the same units as the dependent series.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \hat{X}_i)^2}{n}}$$

Mean Absolute Percentage Error. (**MAPE).** It is a measure of how much a dependent series varies from its model-predicted level. It is independent of the units. MAPE = $\frac{\sum_{i=1}^{n}\left|\frac{X_i - \hat{X}_i}{X_i}\right|}{n} \times 100$

Correlation analysis: Correlation is a bivariate analysis that measures the strength of association between two variables and the direction of the relationship. It is known as Pearson product moment correlation coefficient. Its correlation coefficient is denoted as r. It ranges between-1 and +1.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Results and discussion

Table-1 explains that the irrigation potential created and irrigation potential utilized is presented through various plan periods. In all Five Year Plans, maximum potential creation is estimated through major and medium projects. But it has been noticed that the trend has been declining over time since Seventh Five Year Plan. In pre-Plan period, the irrigation potential which is created was fully utilized, i.e. utilized is almost equal of created, but since First Five Years Plan, a gap is started to appear between irrigation potential created and utilized

Table 1: Plan- Wise Cumulative Potential Created and Utilization through major and medium projects (in Mha.)

Plan	Potential Created		Potential Utilized	
	Major and Medium	Total	Major and Medium	Total
Up to 1951(Pre- plan)	9.7	22.62	9.7	22.60
First plan (1951-56)	12.2	26.08	10.98	25.04
Second plan (1956-61)	14.33	33.57	13.05	27.80
Third plan (1961-66)	16.57	37.10	15.17	32.17
Annual plan (1966-1969)	18.1	44.20	16.75	35.75
Forth plan (1969-74)	20.7	52.02	18.39	41.89
Fifth plan (1974-78)	24.72	56.61	21.16	48.46
Annual plan (1978-1980)	26.61	65.22	22.64	58.82
Sixth plan (1980-85)	27.7	11.31	23.57	58.82
Seventh plan(1985-90)	29.92	76.44	25.47	68.59
Annual plan (1990-92)	30.74	81.09	26.31	72.85
Eighth plan (1997-02)	32.95	86.26	28.44	77.21
Ninth plan (1997-02)	37.05	93.95	31.01	81.00
Tenth plan (2002-07)	42.35	102.77	34.42	87.23
Eleventh plan (2007-12)	45.34	108.91	34.66	87.39

Source: Eleventh Five Year Plan 2007-12; Planning Commission, Government of India

To rule out the impact of such long term changes on the potential of an irrigation system realized, we concentrated on the gaps between incremental values of irrigation potential created (IPC) and irrigation potential utilized (IPU) across different plan periods through plotting. To elaborate, each plan period has witnessed changes in IPC and IPU. We look into the gap between the increment in IPC and that in IPU observed during a particular plan period. The observed information is plotted in fig.1 shows a trend graph. There is a clear cumulative gap between IPC and IPU for different categories of irrigation.

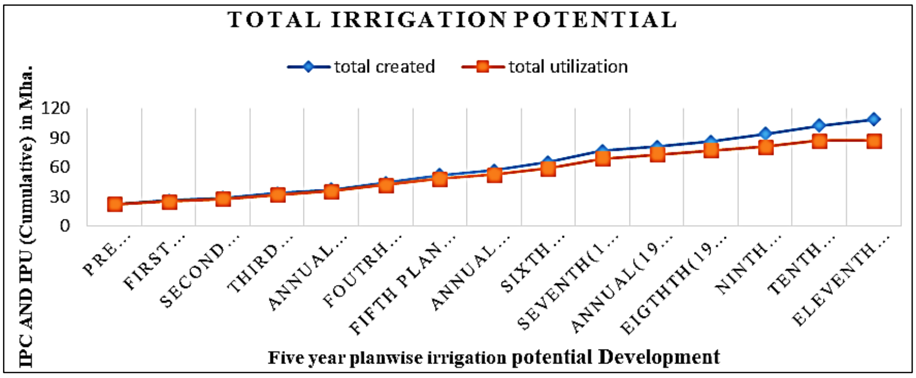

Fig 1: Inter-temporal gap between IPC and IPU in India (Surface and Ground Water)

Initially univariate data of irrigation created and utilized potential from 1977-2012 (plan wise pre-plan up to eleventh plan) are investigated. To examine the basic behaviour of each series, descriptive statistics is also computed as shown in table-2. It is observed that the irrigation potential created is varied from 22.6 to 108.91 million hectares with an average of 61.07 million hectares. Irrigation potential created has registered a simple growth rate (SAGR) of almost 0.12 per cent per annum. Similarly, utilized potential is varied from 22.6 to 87.39 million hectares with an average of 54.63 million hectares with SGR of 0.10 per cent. It is noticed that simple growth rate of irrigation potential created is comparatively higher than irrigation potential utilized with a gap of 0.2 per cent which revealed that there is a gap created between IPC and IPU, which should not be good for irrigation indicating that in 12th plan there has been increase in IPC but due to improper maintenance of irrigation plan, decreasing SGAR percent has been observed. In case of both IPC and IPU, indicate positive skewness and negative kurtosis, which means that there has been increasing order during early half of the study period and its remain steady for a long time. It is also observed that all he datasets are normally distributed, which are tested from Jarque-Bera test. The standard deviation (29.07) of IPC is greater than standard deviation (23.23) of IPU, it showed a start of variation between IPU and IPC.

Table 2: Descriptive statistics of Irrigation potential created (IPC) and Irrigation potential utilized (IPU) in India

Descriptive Statistics	Irrigation Potential Created (IPC)	Irrigation Potential Utilization (IPU)
No. of observations(N)	15	15
Range	86.31	64.79
Maximum	108.91	87.39
Minimum	22.60	22.60
Sum	916.17	819.58
Mean	61.07	54.63
Standard deviation	29.07	23.23
Variance	845.17	539.70
Skewness	0.24	0.06
Kurtosis	-1.35	-1.54
Jarque-bera test	0.583	0.55
SGR%	0.12	0.10

Irrigation Potential Created

As per the study, various linear and nonlinear regressions models are applied to all dataset for path of movement of the series from knowing the above per se performance. All estimated parameter and goodness of fit by those models are presented in table-3. For testing parametric models, cubic model is best fitted trend model among all other models for IPC on the basis of R^2 value, adjusted R^2, minimum value of RMSE and MAPE. In IPC, it is found that for cubic model, the value of R^2 (0.998), adjusted R^2 (0.997), RMSE (1.50) and major MAPE (1.78). The coefficients of cubic time factor are negative in nature and thereby indicating the tendencies of the series to decline in recent past.

Table 3: Fitting of linear and nonlinear regression models for IPC in India

Model	Parameters Estimates				Goodness of Fit			
	a	b_1	b_2	b_3	RMSE	MAPE	R^2	Adjusted R^2
Linear	9.41	6.46			3.46	6.62	0.987	0.986
Quadratic	16.50	3.96	0.15		2.14	3.15	0.995	0.994
Cubic	22.14	0.30	0.71	-0.02	1.50	1.78	0.998	0.997
Inverse	78.92	-80.66			22.05	40.25	0.465	0.424
Logarithmic	-1.04	33.40			13.24	23.94	0.807	0.792
Exponential	21.42	0.12			1.60	5.08	0.986	0.985
Logistic	0.05	0.890			1.60	5.08	0.986	0.985
Power	16.45	0.64			1.85	12.19	0.920	0.913
Growth	3.06	0.12			1.60	5.08	0.986	0.985
Compound	21.41	1.12			1.60	5.08	0.986	0.985

*Significant at 5%

Irrigation Potential Utilized

Similarly, in IPU various linear and nonlinear regressions models are applied to all dataset for path of movement of the series from knowing the above per se performance. All estimated parameter and goodness of fit by those models are presented in table-4. For testing parametric models, cubic model is best fitted trend model among all other models for IPU on the basis of R^2 value, adjusted R^2, minimum value of RMSE and MAPE. It is found that for cubic model, the value of R^2 (0.998), adjusted R^2 (0.997), RMSE (1.18) and major MAPE (1.45). Here also, the coefficients of cubic time factor are negative in nature and thereby indicating the tendencies of the series to decline in recent past. This is clearly a major concern towards irrigation potential showing increasing gap between potential created and potential utilized.

Table 4: Fitting of linear and nonlinear egression models for IPU in India

Model	Parameters estimates				Goodness of Fit			
	a	b_1	b_2	b_3	RMSE	MAPE	R^2	Adjusted R^2
Linear	13.31	5.16			2.54	4.58	0.989	0.988
Quadratic	14.70	4.67	0.31		2.60	3.97	0.989	0.988
Cubic	22.90	-0.64	0.83	-0.03	1.18	1.45	0.998	0.997
Inverse	69.40	-66.71			17.07	32.38	0.499	0.460
Logarithmic	4.03	27.21			9.67	18.36	0.839	0.826
Exponential	21.61	0.10			1.27	5.62	0.975	0.973
Power	16.90	0.58			1.33	9.66	0.926	0.920
Growth	3.07	0.10			1.27	5.62	0.975	0.973
Compound	21.61	1.11			1.27	5.62	0.975	0.973

*Significant at 5% level

From the fig.2 and fig.3. It is noticed that the IPC and IPU have been increased continuously, this is more visible during the XIth plan. It shows over all increasing trend with short term fluctuations with proper sigmoid curve.

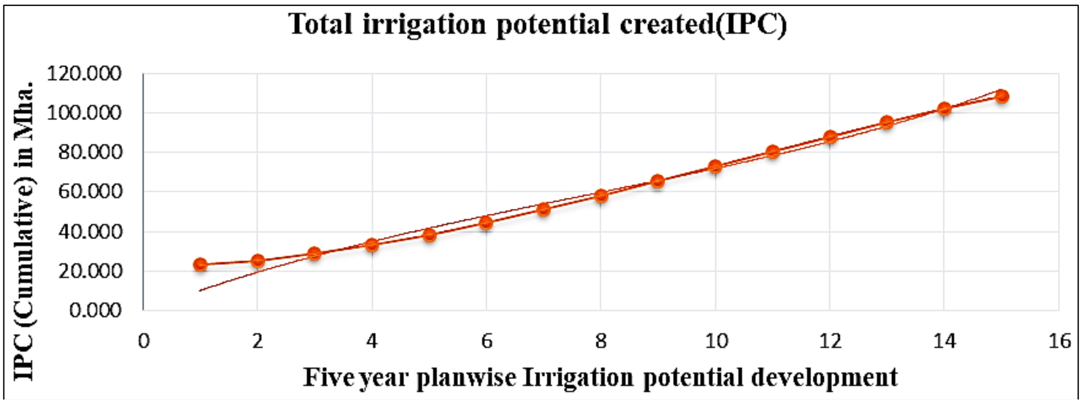

Fig 2: Best trend fit (Cubic model) for IPC in India

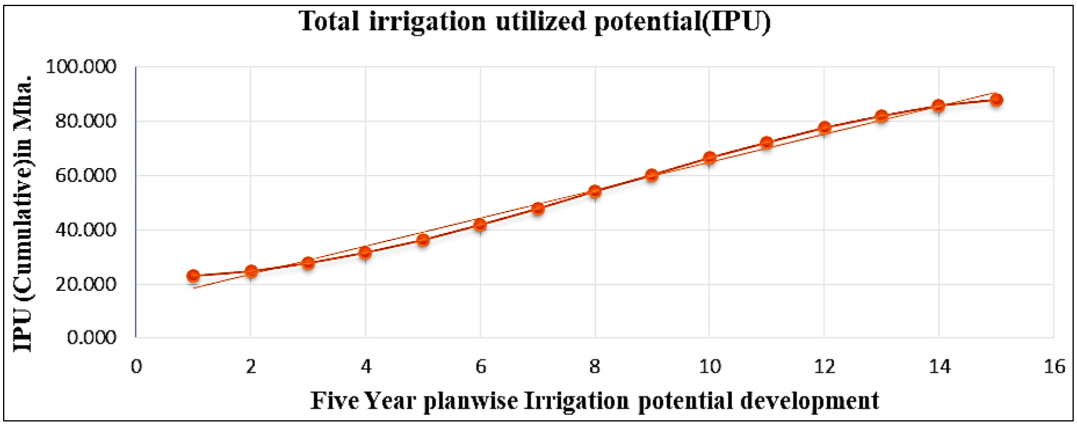

Fig 3: Best trend fit (Cubic model) for IPU in India

Correlation coefficient between IPC and IPU

Table-5 showed that, the both IPC and IPU were significantly strong positively correlated. The correlation coefficient of IPC and IPU was 0.996 at 0.01% indicated a perfect positive fit. Positive values indicated that a relationship between IPC and IPU such that one increases with the other.

Table 5: Correlation coefficient between IPC and IPU in India

Correlation			
		IPC	IPU
IPC	Pearson Correlation	1	0.996**
	Sig. (2-tailed)		0.000
	N	15	15
IPU	Pearson Correlation	0.996**	1
	Sig. (2-tailed)	0.000	
	N	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

Conclusion

After analysing the data on potential created and utilized over different plan periods, it is observed that irrigation potential has increased from 22.6 Mha in pre-plan era to 108.91 Mha by the end of XIth plan in table 4. In respect of irrigation potential utilized it is observed that the utilization of total potential created was 22.60 Mha in pre-plan period which increased to 87.39 Mha by the end of XIth plan. It is also observed that the percentage IPC was equal to IPC in the pre-plan and in the first plan also. But now there is a gap between IPC and IPU in the XIth plan. This is clearly a major concern over reducing the gap between IPC and IPU. The gap should be tried to be bridged through micro level infrastructure development and efficient farm-level water management practices. The gap between irrigation potential created and utilised has been increasing steadily over the last few decades. Poor budgetary provisions for operating and maintaining irrigation projects, incomplete distribution systems, non-completion of the command area development works, changes from the initially designed cropping pattern, etc. are some of the major reasons responsible for the sub-optimal utilisation of irrigation potential. Given the heavy dependence on groundwater sources for irrigation, groundwater depletion has emerged as a serious concern. Inter-state water disputes are another major cause of concern for irrigation projects.

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