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Comparative study: A crop yield in India using distributions

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Abstract
The present study discusses the trends and pattern in Agricultural growth at the national and sub-national levels in India. Data on important variables like area, production, input use and value of output are compiled for the period 1967-68 to 2007-08 from various published sources. The analysis of data reveals that cropping pattern in India has undergone significant changes over time. There is a marked shift from the cultivation of food grains to commercial crops. Among food grains, the area under coarse cereals declined by 13.3 percent between 1970-71 and 2007-08. Similarly, the performance of pulses in terms of area and output was not impressive during the study period. The use of technological inventions in the cultivation of other crops was also not so conspicuous in pulses. Nevertheless, the increase in crop yield has been a major factor for accelerating production in the country since the late 1960's. The use of modern varieties, irrigation and fertilizers are important factors that ensured higher growth in crop production. However, technological and institutional support for a few crops like rice and wheat brought significant changes in crop area and output composition in some regions. The results of crop output growth model indicate that the enhanced capital formation, better irrigation facilities, normal rainfall and improved fertilizer consumption fertilizer consumption helped to improve crop output in the country. We will discuss Eight Distributions in data. Exponential Distribution, 2 parameter Exponential distribution, log logistic Distribution, Three parameter log normal distribution, Weibull distribution, 3 parameter Weibull distribution and the goodness of fit studies using Kolmogorov-Smirnov, Anderson darling and χ^2 distribution.

Keywords: Log logistic distribution, weibull distribution, lognormal distribution, χ^2 distribution, K-S test, Anderson darling test

1. Introduction
Agriculture is the major occupation in India. Apart from Agriculture, fruits like banana, mango, guava, papaya, lemon and vegetables like okra and chickpea, major spices like chilly, pepper, ginger, fibrous crops such as jute, staples such as millets and castor oil seeds. India is the second largest producers of wheat and rice.
After independence, India has seen great progress towards food security. Indian population has tripled and food grain production has more than quadrupled. There has been a substantial increase in available food-grain per capita.
Agricultural Scientist M.S. Swaminathan has played a vital role in the green revolution. Indian irrigation is mainly depends on major and minor canals from rivers, ground water well-based systems, tanks and other rain water harvesting projects for agricultural activities. Of these, the ground water system is largest free power and attractive minimum support price for water intensive crops such as sugarcane and rice have encouraged groundwater mining leading to groundwater depletion and poor water quality. Among 37 million hectare calculated by ground water wells, irrigation canals, 22 million hectares are by ground water and remaining.

2. Methodology
We are fitted 8 distributions for the agricultural statistics data

2.1 Exponential Distribution: The probability density function of the exponential distribution with one parameter "λ" is as follows.

$f(x) = \lambda e^{-\lambda x}$, λ>0
0<x<∞
= 0 otherwise

2.2 Exponential (2 parameters) Distribution: The 2-paramter exponential probability density function is given by

$$f(t) = \lambda e^{-\lambda(t-\Upsilon)}$$

f(t)≥0
λ>0
t≥ϒ
=0 else

Where ϒ is the location parameter

2.3 Log Logistic Distribution: The Probability Density Function of Log logistic Distribution with parameters α, β is as follows

$$f(x) = \beta/_{\alpha}\,(x \mid \alpha)^{\beta-1}$$

2.4 Log Logistic (3p) Distribution: The probability Density Function of Log logistic Distribution with parameters α, β, ϒ is as follows

$$f(x) = \begin{cases} \dfrac{\left(\frac{\beta}{\alpha}\right)\left[\left(\frac{x-\gamma}{\alpha}\right)\right]^{\beta-1}}{\left(1+\left[\left(\frac{x-\gamma}{\alpha}\right)\right]^{\beta}\right)^{2}}, & \alpha, x>1,\ \beta \geq 1 \\ 0 \qquad\qquad\qquad\qquad , & else \end{cases}$$

2.5 Log Normal Distribution: The positive random variable 'X' is said to have a log normal distribution if loge X is normally distributed as

$$f_x(u) = \begin{cases} \dfrac{1}{x\sigma\sqrt{2\Pi}} e^{-\left(\frac{\ln x-\mu}{2\sigma^2}\right)^2}, & U>0 \\ 0 \qquad\qquad\qquad , & U \leq 0 \end{cases}$$

2.6 Log Normal (3p) Distribution: The probability density function of three-parameter lognormal distribution is

$$f(x;\mu,\sigma,\gamma) = \frac{1}{(x-\gamma)\sigma\sqrt{2\Pi}} e^{-\left(\frac{\ln(x-\gamma)-\mu}{2\sigma^2}\right)}$$

$$x > \gamma \geq 0$$

Where $-\infty < \mu < \infty$

$$\sigma > 0$$

2.7 Weibull Distribution (3p): A Continuous Random variable 'x' has a Weibull Distribution with parameters α, β, ϒ if its probability density function is

$$f(x;\alpha,\beta,\gamma) = \frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1} e^{-\left(\frac{x-\gamma}{\beta}\right)},\ x>\gamma,\ \alpha>0$$

2.8 Weibull Distribution: A Continuous Random variable 'x' has a Weibull Distribution with parameters α, β if its probability density function is

$$f(x) = \frac{\alpha}{\beta}\left(\frac{x}{\beta}\right)^{\alpha-1} e^{-\left(\frac{x}{\beta}\right)},\ x \geq 0$$

3. Empirical investigations

For the crop yield data, we are fitted Eight Distributions i.e Exponential Distribution, Exponential (2 parameters) Distribution, Log Logistic Distribution, log logistic (3p) distribution, three parameters of Weibull Distribution, Weibull Distribution(3p), Lognormal distribution, χ^2 distribution.

Fitted Results

#	Distribution	Parameters
1	Exponential	λ=2.0380E-4
2	Exponential (2P)	λ=2.0914E-4 γ=125.2
3	Log-Logistic	α=1.1342 β=2664.5
4	Log-Logistic (3P)	α=2.2689 β=4901.1 γ=-1082.6
5	Lognormal	σ=1.2602 μ=7.969
6	Lognormal (3P)	σ=0.67592 μ=8.5495 γ=-1460.2
7	Weibull	α=0.83683 β=4981.2
8	Weibull (3P)	α=0.92893 β=4716.0 γ=125.2

For the Eight fitted Distributions goodness of fit is tested using Anderson darling and χ^2 value and they are Ranked least value of Statistics to highest

Goodness of Fit- Summary

	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Exponential	0.1657	4	0.47732	2	0.802	5
2	Exponential (2P)	0.15993	3	2.2482	7	1.0001	6
3	Log-Logistic	0.24273	8	1.1072	6	0.51671	3
4	Log-Logistic (3P)	0.15649	2	0.48805	3	0.07152	1
5	Lognormal	0.22035	7	1.0095	5	1.0095	7
6	Lognormal (3P)	0.15069	1	0.46705	1	0.09575	2
7	Weibull	0.18928	6	0.60463	4	0.799	4
8	Weibull (3P)	0.17655	5	4.3009	8		

4. Conclusions

Exponential Distribution, Exponential (2 parameters) Distribution, Log Logistic Distribution, log logistic(3p) distribution, three parameters of Weibull Distribution, Weibull Distribution (3p), Lognormal distribution are fitted for crop yield data. χ^2 test, Kolmogorov Smirnov test, Anderson Darling are used for Goodness of fit ranking for the models.

5. References

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