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Droughts and famines in India — A historical perspective*

P. K. DAS

Meteorological Office, Lodi Road, New Delhi, India

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सार — उन्नीसवीं सदी के अन्तिम चतुर्थ में अकाल और वर्षा की कमी की बारम्बारता प्रस्तुत की गई है । ऐतिहासिक अभिलेखों से पता चलता है कि ग्यारहवीं से सत्रहवीं शताब्दी के बीच में दस बार अकाल पड़ा और अन्य 12 अकाल 1769 से 1958 की अवधि के नब्बे वर्षों में पड़े । उधर 1860 से 1908 के मध्य इनकी संख्या में तेजी से वृद्धि हुई । परन्तु अकाल और अनावृष्टि हमेशा एक ही वर्ष में साथ-साथ नहीं आए । पिछले प्रमाणों से पता चलता है कि अनेक बार अकाल उपयुक्त संचार सुविधाओं की कमी के कारण पड़े हैं ।

हाल के वर्षों में अनावृष्टि सूचकांकों के विकास की दिशा में अनुसंधान हुए हैं । भाल्में एवं मुले (1981) ने सूचकांक का उपयोग करके 1951, 1965-66, 1972 एवं 1974 में हुई अनावृष्टि का पता लगाया। 1965 और 1966 के दो क्रमागत वर्षों की अनावृष्टि एक विरली घटना थी ।

शोधपत्र के दूसरे भाग में मानसूनी वर्षा के लिए स्वासमाश्रयण पर आधारित प्रसंभाव्य प्रागुक्ति तकनीक का उल्लेख किया गया है । यह 'अरिमा' का एक रूपांतरण है । जिसका अर्थमिति में उपयोग किया जाता रहा है । मौसम विज्ञान में भी इसका अनुप्रयोग बड़ा रोचक है ।

ABSTRACT. The frequency of famines and rainfall deficiency is described for the last quarter of the nineteenth century. Historical records suggest that there were 14 famines between the 11th and 17th centuries and another 12 famines in 90-year period 1769 and 1958, with a sharp increase in number between 1860 and 1908. But, famines did not always coincide with years of drought. Past evidence suggests that many famines were caused by lack of adequate communications.

In recent years research has been directed towards development of drought indices. Using an index Bhalme and Mooley (1981) found droughts in 1951, 1965-66, 1972 and 1974. Two years of consecutive drought in 1965 and 1966 was a rare event.

In the second part of this paper we describe a stochastic prediction technique based on autoregression for monsoon rainfall. This is a variation of ARIMA, which has been used in econometrics but has an interesting application in Meteorology.

1. Introduction

Droughts and famines are associated with periods of decline in food production. Mc Alpin (1979) states, for example, that the frequency of famines was highest over western India in the last quarter of the 19th century. This was also a period of rainfall deficit. The impact of inadequate rain on the economics of an agrarian system is relevant today because of an increasing demand for food and better nutrition.

Many parts of India have been confronted with failure of crops in the past. It has been customary to link this with inadequate rainfall. But, it is by no means clear that a drought was always a precursor of famine, because the latter — a situation of distress — might have been caused by lack of communications and other economic factors.

The purpose of the present paper is to examine the history of Indian rainfall to see how far they were associated with famines. We also consider the outlook for long range prediction of rainfall by regarding it as a stochastic process.

2. Classification of droughts

The absence of a clear link between droughts and famines is best reflected by the current divergence of opinion on what constitutes a drought. Sarker (1979), for example, mentions three facets of droughts :

(*i*) Meteorology : A situation when the rainfall is substantially below its climatological expectation.

(*ii*) Hydrology : Rapid depletion of surface water and a fall in the level of reservoirs, lakes and rivers.

(*iii*) Agriculture : Inadequate soil moisture to support the growth of plants and crops to maturity.

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TABLE 1

Indices of rail shipments of grain and pulses and exports of wheat and rice (*McAlpin* **1979**)

Year	Rail shipment of grain and pulses	Export of Wheat	Export of Rice and Paddy
1881-1885	100 a	100 b	100 b
1886-1890	112	127	98
1891-1895	155	100	114
1896-1900	196	56	118
1901-1905	220	110	152
1906-1910	260	100	139
1911-1915	337	158	173
1916-1920	365	110	132

a — **Index base** : 1883-85 average equals 100.
Absolute value : 3550 thousand tons.
b — **Index base** : 1881-85 avearage equals 100.
Absolute values : Wheat, 783.9 thousand tons; **Rice and** paddy, 1365 thousand tons.

TABLE 2

Famine casualties (*After* **Majumdar 1970**)

Years	Casualties (in millions)
1800-25	1.0
1825-50	0.4
1859-75	5.0
1875-1900	15.0

These aspects of a drought are closely linked, but one need not necessarily lead to another. A meteorological drought, for example, need not generate a hydrological drought if the level of reservoirs was sufficiently high before a drought set in. The duration of a lean spell of rain and conditions preceding a lean spell need consideration.

3. Famines of the nineteenth century

There are few authentic rainfall records in prehistoric times. Variations in rainfall have been inferred from pollen data by Singh (1971). He suggests that the climate of Rajasthan, which is now semi-arid, was not always so. Bryson and Murray (1977) suggests that the change from a hospitable to a hostile climate was brought about by human activity.

Historical records suggest that between the eleventh and seventeenth centuries there were at least 14 famines over India. Another 12 famines and periods of scarcity were observed in the ninety-year period between 1769 and 1858. But, in the next 49 years between 1860 and 1908 there was a famine or scarcity in some parts of the country in 20 out of 49 years. A list of major famines between 1801 and 1943 is provided in Appendix II. This is reproduced from a compilation by Bhatia (1967). But, as pointed out by Sarker (1979), the years of scarcity did not always coincide with years of inadequate rain. Sarker tabulated areas which received less than 75 per cent of the normal rain during the monsoon season. The area of inadequate rainfall (less than 75 per cent of the normal) was expressed as a percentage of the total area of the country. The years when the affected area exceeded 25 per cent of the arable land were termed as drought years. Droughts defined in this manner are shown in Appendix I. The worst drought years, in terms of rainfall, were in 1877, 1899, 1904 and 1918. In these years more than 50 per cent of India had less than 75 per cent of normal rainfall. 1918 was worst year in which 70 per cent of the country was affected. But, it is to be noted from Appendix I that between 1877 and 1901, Bombay and the west coast of India had only two spells of inadequate rains, namely in 1877 and 1899. It is difficult to assert that the rainfall over western India was unusually deficient in the years between 1898 and 1906.

It was not merely the lack of rainfall which caused famines in the past. Lack of adequate communications prevented rapid movement of foodgrains from one part of the country to another. There is evidence to suggest that despite scarcities, wheat and rice were exported. This is indicated in Table 1 reproduced from McAlpin (1979). Despite exports, a progressive increase in communications was significant between 1881 and 1920.

Interestingly, Sir George Campbell, then Lieutenant Governor of Bengal, resisted an export of rice out of Bengal but his objections were turned down by Lord Northbrook, the Governor General from 1872 to 1876. Bengal, it may be noted, was under the grip of famines in 1873 and in 1876. Sir George remarked : "Lord Northbrook, bred in the strictest sect of free traders, looked on my proposal as a sort of abominable heresy — was as shocked as a bishop might be with a clergyman who denied all the thirty-nine articles" (Majumdar 1970). Ultimately, the Government decided to overcome the emergency by purchasing and importing food rather than stopping export — a decision that must have perplexed Sir George further.

As stated earlier, famines were more numerious in the last quarter of the nineteenth century. Approximate figures of casualties (Majumdar 1970) are shown in Table 2.

Unfortunately, rainfall figures for earlier years are not available, but from Sarker's data (Appendix I) we see that between 1875 and 1900 there were four periods of rainfall deficit, of which only two were really widespread. The large increase in casualties between 1875 and 1900 could be hardly attributed to rainfall deficits alone.

TABLE 3

Frequency of droughts (*Sarker* 1979)

Period of recurrence (years)	Sub-divisions
4-5	Rajasthan, Punjab, Gujarat, Telengana.
6-8	Haryana, Jammu & Kashmir, Uttar Pradesh (East), Sub-Himalayan West Bengal, Vidarbha, South Interior Karnataka, Coastal Andhra Pradesh.
10	Himachal Pradesh, West Uttar Pradesh, Madhya Pradesh, Bihar Plains, Marathwada, Konkan, Rayalaseema, Kerala.
15-20	Madhya Maharashtra, South Assam, Tamil Nadu, Interior Karnataka (North), Orissa.
Very rare	Coastal Karnataka, Bihar Plateau, North Assam and Gangetic West Bengal.

4. Human response to droughts of the nineteenth century

The large casualty figures (Table 2) for the last quarter of the nineteenth century seem surprising, because the density of population was not as great as it is today. High casualties were probably caused by uneven distribution of foodgrains resulting from lack of storage facilities and communication links between one part of the country and another.

The response of the people to a famine or drought was generally positive.

McAlpin (1979) has drawn our attention to the fact that attempts to select weather-resistant crops began as early as 1840. A cotton plant was found that had a long taproot and was commonly grown on deep black soil. The soil would tend to retain its moisture for sometime during a break in rains ; this provided sustenance to any crop whose roots were long enough to use the moisture. The tendency of farmers in western India to mix crops was also prevalent around 1884. This reduced the dependence on a single crop.

Migration from drought affected parts was widely practised. It appears this was inversely proportional to the size of the area affected by drought. When large areas were affected, even this was not successful because of meagre communications.

Large scale "relief" by way of alternative jobs and financial assistance appear to have been started after the famine of 1877. To-day, this is widely accepted as a relief measure for drought affected people.

Such steps were progressively increased until, by the end of the first quarter of this century, deaths on account of famine had considerably diminished.

5. Droughts in recent years

We have considered droughts and famines of the nineteenth century. Coming to recent times, the difficulty in finding an acceptable definition of drought has been recognised in most research publications.

The earlier method of identifying a drought and its areal extent by Sarker (1979) did not consider variability of rainfall. To overcome this difficulty Bhalme and Mooley (1981) compute drought indices from the equation :

$$I_k = 0.5\, I_{k-1} + M_k/48.55 \qquad (4.1)$$

where I_k, I_{k-1} are drought indices for the k and $k-1$ month, and M_k is a standardized measure of the rainfall deficiency. If R is the mean rainfall, with mean $\bar{R}$ and standard deviation σ_R then:

$$M_k = 100 \times (R - \bar{R}) / \sigma_R$$

To begin the computations for the monsoon months of June to September, Bhalme and Mooley start by assuming $I_0 = 0$ for May.

By computing the mean monthly monsoon index $\bar{I}$, which is a weighted average of all indices from June to September, a Drought Area Index is defined as the percentage of area having $\bar{I} \leqslant -2$.

Although the reasons for setting $I_0 = 0$ are not very clear, the procedure has the advantage of taking into consideration the variance of rainfall. With this index of drought, Mooley and Bhalme (1981) find five years with large droughts in the fifty-year period between 1920 and 1975. They were : 1951, 1965-66, 1972 and 1974. A sequence of two consecutive droughts occurred in 1965 and 1966. This is a rare event in the history of droughts.

6. Frequency of droughts

A power spectrum analysis by Bhalme and Mooley of their drought area indices suggests a periodicity of 2.7 to 2.9 years at 90 per cent significant level. This gives some indication of the frequency of droughts, but we cannot specify which parts of the country are likely to be affected. Sarker (1979) on the other hand, finds frequencies shown in Table 3 for the meteorological sub-divisions of India (Fig. 1).

Not unexpectedly, droughts are most frequent in areas of high rainfall variability. It is to be noted that, purely on account of rainfall, droughts are rare in West Bengal. This suggests, again, that the Bengal and Maharashtra famines of the nineteenth century were not entirely because of deficient rain (Fig. 1).

7. Long range prediction of rainfall

Two points of view emerge on future prospects of long range prediction. On the one hand, we have a deterministic approach based on General Circulation Models (GCM) of the atmosphere.

These models are useful for the study of climate and climate variability, but they have not been used so far for studying interannual variability of monsoon rain. But, the models have drawn attention to meteorological features which have a feed-back on monsoon rain. Shukla (1975) finds, for example, anomalies in sea surface temperature are associated with variations in monsoon rain. An earlier study by Das (1962) had indicated subsiding motion over the semi-arid regions of northwest India. Observations by weather satellites indicate that these semi-arid regions experience a radiation deficit, that is, more radiation is emitted back to space than is received by way of incoming solar energy. A deficit in the radiation budget should lead to atmospheric cooling; but this is off-set by subsiding motion which warms the atmosphere by adiabatic compression. It is not yet clear whether the radiation deficit is caused by the high reflectivity of the soil (albedo) or by the high dust load of the atmosphere over semi-arid zones. In any event, modelling experiments suggest soil reflectivity and dust content as being important for rainfall variability. As the albedo is closely linked with soil moisture, the latter is yet another element which needs monitoring for a possible impact on rainfall variation.

Numerical models help us to identify the physical processes that lead to rainfall variations, they have not been used for long range prediction. A stochastic or probabilistic approach is being tried in India along with deterministic models. A technique, which has been used in econometrics but does not appear to have been much used in meteorology, is based on autoregression. This is an improvement on earlier multiple regression techniques that relate monsoon rain with antecedent features, because the strength and sign of a correlation coefficient changes with time. A correlation coefficient, which appears significant at a certain point of time, does not retain its original value of sign as the length of a time-series increases.

We consider as input and output to a physical system by a sequence of observations $\{x_t\}$, $\{y_t\}$ at discrete times. Let them be related by:

$$y_t = \sum_{0}^{\infty} h_k \, x_{t-k} + N_t \qquad (7.1)$$

where the coefficients $\{h_k\}$ represent the response of the system at each value of k and $\{N_t\}$ is a sequence of random noise imposed on the time series. Values of $\{h_k\}$ could be estimated by multiplying (7.1) by x_{t-m} and taking estimations. We have

$$\gamma_{xy}(m) = h_0 \, \gamma_{xx}(m) + h_1 \, \gamma_{xx}(m-1) + \ldots \qquad (7.2)$$

where $\gamma_{xy}(m)$, $\gamma_{xx}(m)$ represent covariances.

Fig. 1. Meteorological sub-divisions (1-35) of India and coefficient of variation of rainfall (June-September)

1 Bay Islands
2 Arunachal Pradesh
3 Assam & Meghalaya
4 Nagaland, Manipur, Mizoram & Tripura
5 Sub-Himalayan West Bengal & Sikkim
6 Gangetic West Bengal
7 Orissa
8 Bihar Plateau
9 Bihar Plains
10 Uttar Pradesh East
11 Plains of West Uttar Pradesh
12 Hills of West Uttar Pradesh
13 Haryana, Chandigarh & Delhi
14 Punjab
15 Himachal Pradesh
16 Jammu & Kashmir
17 Rajasthan West
18 Rajasthan East
19 Madhya Pradesh West
20 Madhya Pradesh East
21 Gujarat Region, Daman, Dadra & Nagar Haveli
22 Saurashtra & Kutch and Diu
23 Konkan & Goa
24 Madhya Maharashtra
25 Marathwada
26 Vidarbha
27 Coastal Andhra Pradesh
28 Telengana
29 Rayalaseema
30 Tamil Nadu & Pondicherry
31 Coastal Karnataka
32 Interior Karnataka North
33 Interior Karnataka South
34 Kerala
35 Lakshadweep

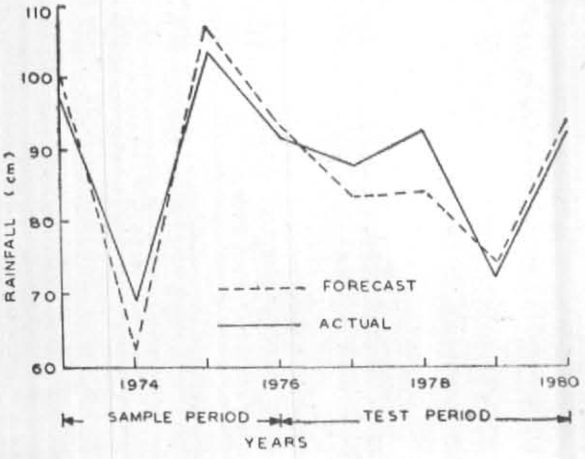

Fig. 2. Performance of ARIMA during 1973-1980

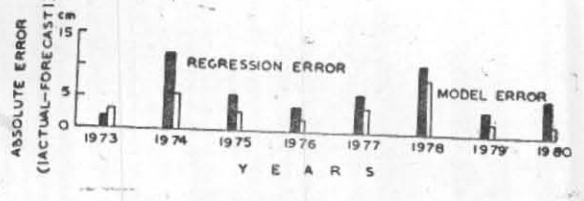

Fig. 3. Comparison of ARIMA with multiple regression techniques. Shaded portion shows error by multiple regression techniques

It is difficult to know where to terminate the series (7.2), nor is it justified to assume $\{N_t\}$ is independent of $\{x_t\}$. These difficulties are minimised if $\{x_t\}$, $\{y_t\}$ are made stationary.

Trends are first removed from the original data by differencing. Generally first order differencing is adequate for first order stationarity. A new sequence $\{x_t\}$ is obtained from the original series by :

$$X_t = x_{t+1} - x_t = \nabla x_t \tag{7.3}$$

Conversion to white noise is achieved if, following Box and Jenkins (1970), the input is put in the form :

$$\phi(B) X_t = \theta(B)\, \alpha_t \tag{7.4}$$

where α_t is a random series. If a similar conversion is made to the output, we have from (7.4) :

$$\alpha_t = \phi(B)\, \theta^{-1}(B)\, X_t$$

$$\beta_t = \phi(B)\, \theta^{-1}(B)\, Y_t \tag{7.5}$$

B stands for the backward shift operator, and $\phi(B)$, $\theta(B)$ are polynominals in B. We have

$$\phi(B) = 1 - \phi_1(B) \ldots \quad - \phi_p B^p$$

$$\theta(B) = 1 + \theta_1(B) + \ldots + \theta_q B^q \tag{7.6}$$

The coefficients ϕ_i, θ_i are constants and the indices p, q are referred to as the order of the system. For achieving stationarity, the roots of

$$\phi(B) = 0 \ ; \ \theta(B) = 0$$

must lie outside the unit circle (Box and Jenkins 1970).

It is easier to compute cross covariances of $\{\alpha_t\}$ and $\{\beta_t\}$ because if we put (7.1) as

$$Y_t = h(B)\, X_t + N_t \tag{7.7}$$

We have

$$\begin{aligned} \beta_t &= \phi(B)\, \theta^{-1}(B)\, Y_t \\ &= \phi(B)\, \theta^{-1}(B)\, [h(B)\, X_t + N_t] \\ &= h(B)\, \alpha_t + \phi(B)\, \theta^{-1}(B)\, N_t \end{aligned} \tag{7.8}$$

and

$$\gamma_{\alpha\beta}(m) = h_m\, \sigma_\alpha \tag{7.9}$$

because $\{\alpha_t\}$ is a random process and N_t is not correlated with $\{\alpha_t\}$. σ_α is the variance of α_t whence

$$h(m) = \gamma_{\alpha\beta}(m) \div \sigma_\alpha \tag{7.10}$$

Further refinement of $\{h_m\}$ is made if (7.1) is expressed in the form

$$Y_t = \frac{\omega(B)}{\delta(B)} X_{t-b} + N_t \tag{7.11}$$

where,

$$\delta(B) = 1 - \delta_1 B - \ldots - \delta_r B^r$$

$$\omega(B) = \omega_0 - \omega_1 B - \ldots - \omega_s B^s$$

and b is a "lag" or delay in response. Box and Jenkins (1970) have shown how a preliminary estimate of h_m could be used to derive the appropriate values of r, b and s in (7.11). Given specified values of r, b and s it is possible to obtain least square estimates of δ_1, $\delta_2 \ldots$ and ω_0, $\omega_1, \ldots$

Thapliyal (1982) used this technique to forecast several features of monsoon rain in India. As an example, he regarded the total quantum of monsoon rainfall over the Indian Peninsula as the output Y_t and the mean position at 500 mb along 75° E in April as the input X_t. He decided on this choice because during the last 40 years the mean April ridge position had shown the most stable relation with rainfall over the Peninsula. During this period, the value of the correlation coefficient between the position of the ridge and rainfall remained steady and never fell below a value of 0.5. From the days of Sir Gilbert Walker (1924), Indian meteorologists have tried a large number of tests to discover an association between monsoon rain and antecedent features. The stablest association in recent years appears to be the April position of the sub-tropical ridge. Consequently, Thapliyal (1982) used this as an input to predict the output, namely, monsoon rainfall over the Peninsula. In Figs. 2 and 3 we show the performance of this model for the

TABLE 4

Final estimates (*Thapliyal* 1982)

i	0	1	2	3	4
δ	—	—.8986	—.5319	—.3459	—.2007
ω	.0554	—.0520	—.0385	—.0197	—.0056

The values become vanishingly small after $i=4$

period 1973-1980. Thapliyal (1982) reports that the root mean square prediction error of rainfall for an eight-year period (1973-1980) was 4.4 cm by this method. If multiple regression equations were used, the error was nearly twice as large 8 cm for the same period.

As the model is based on autoregression, and as it uses integrated moving averages by way of differencing it is often known by its acronym ARIMA (autoregressive integrated moving averages). Thapliyal's model shows that for operational use the lag '*b*' in 7.11 is exceedingly small. The final estimates of δ_i and ω_i in (7.11) are shown in Table 4.

An advantage of AIRMA is that it could be used in future to provide a mix between deterministic and stochastic models. We could, for example, use an output from a General Circulation Model, such as, sea surface temperature and use it as an input for ARIMA. Experiments along these lines are now in progress.

8. Summary and conclusion

The main results from the present study are :

(*i*) Famines in the last quarter of the nineteenth century were not always related to rainfall deficiency.

(*ii*) The definition of a drought is sensitive to the factors that are considered. The meteorological, hydrological and agricultural aspects of a drought are closely linked, but one need not necessarily lead to another.

(*iii*) A stochastic model (ARIMA) provides the possibility of using outputs from General Circulation Models for long range prediction of rainfall.

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APPENDIX I

Areas affected by droughts in the past

Year	Areas affected	Percentage of total area of the country
1877	Sub-Himalayan West Bengal, Bihar Plains, East Uttar Pradesh, West Uttar Pradesh, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Konkan, Marathwada, Vidarbha, Coastal Andhra Pradesh, Telengana, Jammu & Kashmir	63.9
1883	West Uttar Pradesh, Haryana, Himachal Pradesh, Rajasthan	20.0
1891	North Assam, Sub-Himalayan West Bengal, Bihar plains, Rajasthan, Andhra Pradesh, Tamilnadu	33.6
1899	Haryana, Punjab, Himachal Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Saurashtra & Kutch, Maharashtra, Andhra Pradesh, Tamilnadu, Coastal Karnataka, Kerala	64.5
1901	Sub-Himalayan West Bengal, Orissa, Punjab, Rajasthan, Gujarat, Telengana, Saurashtra & Kutch, South Interior Karnataka	29.6
1904	Sub-Himalayan West Bengal, East Uttar Pradesh, Punjab, Gujarat, Vidarbha, Andhra Pradesh, West Rajasthan and Saurashtra & Kutch and South Interior Karnataka	52.6
1905	West Uttar Pradesh, Haryana, Punjab, East Rajasthan, Konkan, Madhya Maharashtra, Marathwada, North Interior Karnataka and South Interior Karnataka	29.8
1907	East Uttar Pradesh, West Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, East Rajasthan, West Madhya Pradesh	25.2
1911	Punjab, Rajasthan, Gujarat, Madhya Maharashtra, Telengana, Saurashtra & Kutch	24.7
1918	East Uttar Pradesh, West Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Rajasthan, West Madhya Pradesh, Saurashtra & Kutch, Gujarat, Maharashtra, Telengana, Rayalaseema, Jammu & Kashmir, Karnataka, Tamilnadu, Kerala	70.7
1920	Punjab, West Madhya Pradesh, Gujarat, Konkan, Marathwada, Vidarabha, Coastal Andhra Pradesh, Gujarat, Telengana, West Rajasthan, Jammu & Kashmir	36.4
1939	Haryana, Punjab, Rajasthan, Gujarat, Telangana, Saurashtra & Kutch	22.9
1941	West Uttar Pradesh, Haryana, East Madhya Pradesh, Konkan, Telengana, West Rajasthan	23.1
1951	Bihar Plains, Haryana, Punjab, Rajasthan, West Madhya Pradesh, Gujarat, Kerala, Saurashtra & Kutch, Jammu & Kashmir	37.2
1965	East Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, East Rajasthan, Madhya Pradesh, Gujarat, Vidarbha, Kerala, Jammu & Kashmir	40.8
1966	Gangetic West Bengal, Bihar, East Uttar Pradesh, East Rajasthan, Madhya Pradesh	30.2
1971	South Assam, Madhya Maharashtra, Vidarbha, Telengana, West Rajasthan South Interior Karnataka, Jammu & Kashmir	29.6
1972	South Assam, Sub-Himalayan West Bengal, Bihar Plains, Punjab, East Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Kerala, Saurashtra, Kutch, South Interior Karnataka, Jammu & Kashmir	47.8
1974	Orissa, Punjab, East Madhya Pradesh, Gujarat, Madhya Maharashtra, Marathwada, Vidarba, West Rajasthan, Saurashtra & Kutch, South Interior Karnataka, Jammu & Kashmir	42.8

APPENDIX II

Famines and scarcities in India (1801-1943)

Year	Parts of the country affected	Year	Parts of the country affected
1799-1801 to 1802-04	N.W. Provinces, Bombay, Central India and Rajputana.	1876-78	Madras, Bombay, Mysore and Hyderabad.
1806-07	Widespread, especially Karnataka.	1877-78	N.W.P., Kashmir and Punjab.
1812	Bombay, Madras and Agra.	1879-80	Deccan.
1819-20	N.W. Provinces, Rajputana, Deccan and Broach.	1880	N.W.P.
1824-25	Bombay (Deccan). Also in Deccan districts of Madras.	1884-85	Bengal.
1832-33	Sholapur (Bombay) and Northern Madras.	1886-87	Central Provinces.
1833-34	Gujarat, Khandesh, N. Deccan and parts of N.W.F.	1888-89	Ganjam (Madras), Orissa.
1837-38	N.W.P., Punjab and Rajputana	1890-92	Local scarcities in Garhwal, Almorah, Bengal and Bihar, Madras and Ajmer Marwara.
1853-55	Madras, Bombay and Rajputana.	1894	Central Provinces.
1860-61	N.W.P., Punjab, Rajputana and Kutch.	1896-97	N.W.P., Oudh, Bengal, Madras, Central Provinces, Bombay, Punjab and several Indian States.
1862	Deccan.	1899-1900	Central Provinces, Berar, Bombay, Punjab and Ajmer.
1866-67	Orissa, Bengal and Bihar.	1905-06	Bombay.
1868-69	N.W.P., Punjab and Rajputana.	1906-07	North Bihar.
1873-74	Bengal, Bihar and Bundelkhand.	1907-08	Severe in United Provinces, Central Provinces, Madras, Bengal and Bombay slightly affected.
1876	Bengal.	1943	Bengal.

(*After* Bhatia 1967)