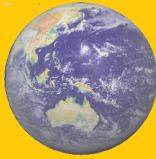


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NCC RESEARCH REPORT

Mapping of Drought Areas over India

*P.G. Gore
Thakur Prasad
H.R. Hatwar*

NATIONAL CLIMATE CENTRE
OFFICE OF THE
ADDITIONAL DIRECTOR GENERAL OF METEOROLOGY (RESEARCH)
INDIA METEOROLOGICAL DEPARTMENT
PUNE - 411 005



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P.G. Gore, Thakur Prasad and H.R. Hatwar
India Meteorological Department, Pune

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Abstract

Mapping of the extreme events is one of the adaptation strategies to consequences of increasing climatic variability and climate changes. Drought is one of the short-term extreme event. There is no operational practice to forecast the drought. One of the suggestions is to update mapping of drought prone areas for developmental planning. In the present study, authors have tried to compute districtwise drought probabilities all over India for 319 districts having long data series of rainfall. Mapping for moderate and severe drought probabilities for India for various districts has been done and regions belonging to different class intervals of probabilities of drought have been demarcated. Such type of information would be a good tool for planning purposes and for input in modelling.

1. Introduction

While considering challenges to coping strategies with Climatological or Agrometeorological risks and uncertainties in different regions one has to see large spatial and temporal variability of disasters. There are 4 coping strategies viz. preparedness, mitigation, contingency planning and disaster risk management. Adaptation strategies to consequences of increasing climatic variability and climatic changes are policy framework, mapping, monitoring and early warning.

Drought is one of the short term extreme events. There is no operational practice to forecast the drought. One of the suggestions is to update mapping of drought prone areas for developmental planning. Statistical analysis is very important in such mapping.

Many scientists have worked on different statistical analysis in drought and other climatological hazards. In discussion of contingency planning and responses the first step suggested is "Identifying disaster and probabilities". It is suggested more focused and urgent effort, be made world wide to provide enhanced and targeted climate trend and scenario information, i.e. of direct relevance and value to contingency planning. In risk management, drought preparedness and drought contingency planning require many information sources to be effective. Historical knowledge of extremes and climatic variability is very much important in risk management.

Many workers have studied droughts individually for different sub-divisions or for India. Bhalme and Mooley (1980) studied large scale droughts and floods over India and related monsoon circulation. Chowdhury and Abhyankar (1984), Rama Krishna et.al (1984), Narain et.al. (1984) etc. have worked on probabilistic analysis of drought. Chowdhury and Abhyankar (1984) have also studied climatological aspects of drought. Mooley et al (1984) worked for drought over peninsular India. Gregory and Parthasarthy (1986) studied extreme monsoon rainfall deficits in India. Parthasarthy et.al. (1987) have worked on 'Drought/floods in summer monsoon season over different meteorological sub-divisions of India for the period 1871-1984.' Chowdhury et.al. (1989) have worked on drought incidences over India as a statistical approach. Recently Sinha Ray and Shewale (2001) worked on probabilities of occurrence of drought in various sub-divisions of India. Gore and Sinha Ray studied droughts over Maharashtra (2002) and Gujarat (2002, 2004) over

smaller spatial scale. Guhathakurta (2003) studied droughts in India during recent all India normal monsoon years and its probability of occurrence.

Very few workers have studied districtwise probabilities over large scale. In the present study, authors have tried to compute districtwise drought probabilities all over India for 319 districts having long data series of rainfall. Mapping for moderate and severe drought probabilities for India for various districts has been done and regions belonging different class intervals of probabilities of drought have been demarcated. Such type of information would be a good tool for planning purposes and for input in modelling.

2. Data and Methodology

2.1 The daily rainfall data of different stations for the period 1901 to 2000 for selected districts with long rainfall data series have been considered. The data are collected from National Data Centre, Office of Additional Director General of Meteorology (Research); Pune.

2.2 Drought criteria :- A meteorological drought over an area is defined as a situation when rainfall over that area is less than 75% of the climatological normal. Further, when deficit of rainfall is in between 26 to 50%, moderate drought is defined. When deficit of rainfall is more than 50%, severe drought is defined.

Using above criteria, probabilities of drought have been estimated for different districts in various subdivisions considering the rainfall data for the period 1901-2000 as above. The probabilities of drought have been presented for different subdivisions in five homogenous regions (Parthasarthy, 1995) and hilly region of India.

3. Results

3.1 Probabilities of Drought

The probabilities of drought are presented in tabular form for different subdivisions in 6 regions as given below in Table A. The 5 subdivisions are homogenous and the 6th is the hilly region of India.

TABLE: A

	Region	Sub-divisions
1.	Northwest India	Haryana, Chandigarh and Delhi, East Rajasthan, West Rajasthan, Gujarat Region, Saurashtra & Kutch and Punjab.
2.	West Central India	East Madhya Pradesh, West Madhya Pradesh, Konkan and Goa, Madhya Maharashtra, Marathwada, Vidarbha, Telangana and North Interior Karnataka.
3.	Peninsular India	Coastal Andhra Pradesh, Rayalaseema, Tamilnadu and Puducherry, Kerala, Coastal Karnataka, South Interior Karnataka.
4.	Central Northeast India	Jharkhand, Bihar, Orissa, East Uttar Pradesh, West Uttar Pradesh.
5.	Northeast India	Assam and Meghalaya, Nagaland, Manipur, Mizoram and Tripura, Sub-Himalayan West Bengal and Sikkim and Gangetic West Bengal.
6.	Hilly region	Jammu and Kashmir, Himachal Pradesh, Uttarakhand.

Table 1 (a,b,c,d,e,f) represents the probabilities for the subdivisions as in the Northwest region. In the Northwest region, in the subdivisions Haryana, Chandigarh & Delhi, East Rajasthan, West Rajasthan, Gujarat Region, Saurashtra & Kutch and Punjab, the probabilities of moderate drought vary from 17 to 24%, 14 to 28%, 17 to 25%, 14 to 25%, 16 to 25% and 12 to 30% respectively. Whereas the probabilities of severe drought for the above said subdivisions vary from 2 –14%, 1-13%, 7-17%, 2-15%, 10-30% and 1-17% respectively.

Table 2 (a,b,c,d,e,f,g,h) represents the probabilities for the West Central region. In West Central India, in the subdivisions, East Madhya Pradesh, West Madhya Pradesh, Konkan and Goa, Madhya Maharashtra, Marathwada, Vidarbha, Telangana and North Interior Karnataka, the probabilities of moderate drought vary from 06-22%, 12-25%, 8-16%, 5-19%, 15-26%, 11-20%, 10-24% and 9-28% respectively. The probabilities of severe drought for the same subdivisions as above vary from 1-4%, 1-8%, 1-4%, 1-6%, 2-6%, 1-2%, 1-3% and 1-6% respectively.

Table 3 (a,b,c,d,e,f) represents the probabilities for the Peninsular region. In Peninsular region, in the sub-divisions Coastal Andhra Pradesh, Rayalaseema, Tamilnadu and Puducherry, Coastal Karnataka, South Interior Karnataka and Kerala, the probabilities of moderate drought vary from 6-22%, 9-24%, 8-27%, 3-4%, 7-27%, 5-25% respectively. The probabilities of severe drought for the above sub-divisions vary from 1-3%, 1-4%, 1-18%, 0-1%, 1-3% and 1-3% respectively.

Table 4(a,b,c,d,e) represents the probabilities in the Central Northeast region. In Central Northeast region, in the subdivisions Orissa, Jharkhand, Bihar, East Uttar Pradesh and West Uttar Pradesh the probabilities of moderate drought vary from 6-21%, 6-13%, 6-19%, 10-37%, 7-29% respectively. The probabilities of severe drought for the above sub-divisions except Jharkhand vary from 1-3%, 1-2%, 1-5%, 1-10% respectively. Jharkhand has experienced no severe drought.

Table 5(a,b,c,d) represents the probabilities in North-east region. In the North-east region, in the sub-divisions Assam and Meghalaya, Nagaland, Manipur, Mizoram and Tripura, Sub-Himalayan West Bengal & Sikkim and Gangetic West Bengal the probabilities of moderate drought vary from 1-14%, 7-14%, 6-16%, 8-26% respectively. The probabilities of severe drought for the above said sub-divisions vary from 1-3%, 1-2%, 1-3%, 0-3% respectively.

Table 6 (a,b,c) represents the probabilities in the hilly regions of India. In the hilly region, the sub-divisions Jammu-Kashmir, Himachal Pradesh and Uttarakhand, the probabilities of moderate drought vary from 10-29%, 9-31%, 14-27%, respectively. The probabilities of severe drought for the above sub-divisions vary from 1-9% except Ladakh, 2-12% and 1-5% respectively. The probability of severe drought for Leh (Ladakh) in Jammu and Kashmir is 21% and that for Lahaul & Spiti is 25%.

3.2 Spatial variation of probabilities of drought

The probabilities of moderate drought and severe drought for various districts are shown in diagrams 1 and 2 respectively. These diagrams show demarcation of the probabilities in different class intervals. It is seen in fig.1 that moderate drought probabilities more than 21% are noticed in Northwest region of India and some parts of West Central India and Peninsular region. In some parts of the Northwest, Peninsular, West Central India and Hilly region of India, the probabilities of moderate drought in the range 16 to 20% are mostly noticed. In some parts of Northeast, Central Northeast, West Central and Peninsular India, the probabilities of moderate drought are in the range of 11 to 15% in major parts. In coastal region near Arabian sea of West Central and Peninsular region, some parts of Central Northeast region, West Central Region and extreme Northeast region, the probabilities of moderate drought are less than 10%. In most parts of India, the probabilities of moderate drought are in the range 11 to 20%.

It is seen in fig.2 that major parts of India show probability of severe drought in the range 1 to 5%. In some parts of Northwest region, northern Hilly region and Peninsular region, probability of severe drought is in the range of 6 to 10%. Further ahead in parts of Northwest region and in small Hilly region, the probability of severe drought is greater than 10%. In extreme Northwest region, especially in the region of Saurashtra and Kutch, it is greater than 20% also. In Northeast India, some parts of West Central India and Central Northeast India, no severe drought is experienced.

4. Conclusions

- 1) In the Northwest region of India, the probability of moderate drought varies from 12 to 30% and that for severe drought varies from 1 to 20% in most of the parts and about 20-30% in the extreme northwestern parts.
- 2) In West Central India, the probability of moderate drought varies from 5 to 26% and that for severe drought varies from 1 to 8%.
- 3) In the Peninsular region, the probability of moderate drought varies from 3 to 27%, and that for severe drought varies from 1 to 9% in major parts.
- 4) In the Central Northeast region, the probability of moderate drought varies from 6 to 37% and that for severe drought varies from 1 to 10%.
- 5) In the Northeast region, the probability of moderate drought varies from 1 to 26% and that for severe drought varies from 1 to 3%.

- 6) In the hilly region, the probability of moderate drought varies from 9 to 31% and that for severe drought varies from 1 to 12% except in Leh and Lahul & Spiti.

In general it can be concluded that in most parts of India, probabilities of moderate drought are in the range 11 to 20%. Major parts of India show probabilities of severe drought in the range 1 to 5%. In some West Central, Central Northeast and Northeast region of India, no severe drought is experienced.

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**Probabilities of moderate and severe drought during 1901-2000
North West India**

Sr.No.	District	Probability (%) of drought	
		Moderate	Severe
1(a) Haryana, Chandigarh & Delhi			
1.	Ambala	17	02
2.	Delhi	17	13
3.	Gurgaon	18	05
4.	Hissar	18	14
5.	Jind	24	12
6.	Karnal	21	06
7.	Mahendragarh	20	08
8.	Rohtak	18	09
1(b) East Rajasthan			
1.	Ajmer	17	08
2.	Alwar	20	08
3.	Banswara	21	06
4.	Bharatpur	12	08
5.	Bhilwara	20	05
6.	Bundi	21	08
7.	Chittorgarh	21	04
8.	Dungarpur	25	05
9.	Jaipur	17	08
10.	Jhalawar	27	01
11.	Jhunjhunu	14	08
12.	Kota	21	04
13.	Sawai Madhopur	23	05
14.	Sikar	21	08
15.	Tonk	17	08
16.	Udaipur	20	05
17.	Sirohi	28	13
1(c) West Rajasthan			
1.	Barmer	24	14
2.	Bikaner	21	11
3.	Churu	17	07
4.	Ganganagar	24	08
5.	Jaisalmer	17	17
6.	Jalore	23	14
7.	Jodhpur	22	15
8.	Nagour	22	10
9.	Pali	25	12

**Probabilities of moderate and severe drought during 1901-2000
North West India (contd...)**

Sr.No.	District	Probability (%) of drought	
		Moderate	Severe
1(d) Gujarat Region			
1.	Ahmedabad	18	10
2.	Amreli	25	09
3.	Banaskantha	22	15
4.	Baroda	18	09
5.	Broach	14	10
6.	Dangs	18	02
7.	Kaira	17	11
8.	Mehsana	24	08
9.	Panch-Mahals	24	07
10.	Sabarkantha	19	12
11.	Surat	19	05
12.	Valsad	14	03
1(e) Saurashtra & Kutch			
1.	Bhaunagar	21	12
2.	Jamnagar	21	23
3.	Junagarh	19	18
4.	Kutch	16	30
5.	Rajkot	25	10
6.	Surendranagar	20	13
1(f) Punjab			
1.	Amritsar	25	05
2.	Bhatinda	25	13
3.	Ferozepore	16	13
4.	Gurdaspur	14	13
5.	Hoshiarpur	30	01
6.	Jullundar	18	06
7.	Ludhiana	23	04
8.	Patiala	25	04
9.	Rupar	12	04
10.	Sangrur	26	17

**Probabilities of moderate and severe drought during 1901-2000
West Central India**

Sr.No.	District	Probability (%) of drought	
		Moderate	Severe
2(a) East Madhya Pradesh			
1.	Balaghat	14	00
2.	Bastar	14	00
3.	Bilaspur	06	00
4.	Durg	11	00
5.	Jabalpur	14	00
6.	Mandla	11	01
7.	Panna	16	04
8.	Raigarh	06	00
9.	Rewa	17	02
10.	Satna	15	01
11.	Shahdol	15	00
12.	Sidhi	22	03
13.	Surguja	09	01
2(b) West Madhya Pradesh			
1.	Bhind	16	08
2.	Bhilsa/Vidisha	19	00
3.	Chhatrapur	16	05
4.	Chindwara	18	00
5.	Damoh	15	01
6.	Dhar	23	02
7.	Datia	24	03
8.	Dewas	25	02
9.	Guna	17	01
10.	Gwalior	13	06
11.	Hoshangabad	22	00
12.	Indore	19	02
13.	Jhabua	20	03
14.	Mandsaur	15	03
15.	Morena	18	05
16.	Narsinghpur	14	00
17.	Nimar/Khargone	15	00
18.	Raesen	12	01
19.	Ratlam	24	03
20.	Sagar	12	00
21.	Sehpore	22	02
22.	Shajapur	20	02
23.	Seoni	21	01
24.	Shivpuri	17	02
25.	Tikamgarh	19	03
26.	Ujjain	23	03

**Probabilities of moderate and severe drought during 1901-2000
West Central India (contd...)**

		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
2(c) Konkan & Goa			
1.	Mumbai	12	04
2.	Kolaba	08	01
3.	Ratnagiri	09	00
4.	Sindhudurg	10	00
5.	Thane	15	00
6.	Goa	16	00
2(d) Madhya Maharashtra			
1.	Ahmednagar	19	03
2.	Dhulia	15	02
3.	Jalgaon	17	01
4.	Kolhapur	05	01
5.	Nashik	11	01
6.	Pune	19	03
7.	Sangamner	16	01
8.	Satara	06	01
9.	Solapur	15	06
2(e) Marathwada			
1.	Aurangabad	15	04
2.	Beed	22	06
3.	Jalna	14	02
4.	Latur	08	02
5.	Nanded	14	02
6.	Osmanabad	26	04
7.	Parbhani	17	02
2(f) Vidarbha			
1.	Akola	12	02
2.	Amravati	11	01
3.	Bhandara	13	00
4.	Buldana	17	02
5.	Chandrapur	14	00
6.	Gadchiroli	16	00
7.	Nagpur	13	00
8.	Wardha	20	00
9.	Yeotmal	17	01

**Probabilities of moderate and severe drought during 1901-2000
West Central India (contd...)**

		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
2(g) Telangana			
1.	Adilabad	10	03
2.	Hyderabad	20	00
3.	Karimnagar	12	02
4.	Khammam	14	00
5.	Mahbubnagar	24	03
6.	Medak	19	03
7.	Nalgonda	21	01
8.	Nizamabad	21	01
9.	Warangal	18	03
2(h) North Interior Karnataka			
1.	Bidar	28	02
2.	Bijapur	21	01
3.	Belgaum	09	01
4.	Gulbarga	22	06
5.	Raichur	17	04

**Probabilities of moderate and severe drought during 1901-2000
Peninsular India**

		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
3(a) Coastal Andhra Pradesh			
1.	East Godavari	15	00
2.	Guntur	13	00
3.	Krishna	18	00
4.	Nellore	22	01
5.	Prakasam	13	03
6.	Srikakulam	06	01
7.	Visakhapatnam	14	00
8.	West Godavari	15	01
3(b) Rayalaseema			
1.	Anantpur	20	04
2.	Chittoor	15	00
3.	Cuddapah	24	01
4.	Kurnool	09	04
3(c) Tamilnadu & Puducherry			
1.	Arcot North	23	01
2.	Arcot South	19	01
3.	Chennai	20	04
4.	Chingleput	20	01
5.	Coimbatore	15	18
6.	Dharmapuri	19	01
7.	Kanyakumari	27	06
8.	Madurai	17	04
9.	Nilgiris	08	03
10.	Ramanathapur	18	09
11.	Sambuvarayar	16	01
12.	Tiruchirapalli	16	03
13.	Tanjavur	22	05
14.	Tirunelveli	25	07

**Probabilities of moderate and severe drought during 1901-2000
Peninsular India (contd...)**

		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
3(d) Coastal Karnataka			
1.	Kanara North	03	01
2.	Kanara South	04	00
3(e) South Interior Karnataka			
1.	Bangalore	17	02
2.	Bellary	15	03
3.	Chickmanglur	07	03
4.	Chitradurga	21	01
5.	Hassan	18	01
6.	Kolar	18	03
7.	Coorg/Kudagu	07	00
8.	Mandya	27	03
9.	Mysore	20	03
10.	Shimoga	34	02
11.	Tumkur	19	02
3(f) Kerala			
1.	Alleppey	09	00
2.	Cannanore	08	00
3.	Ernakulam	09	00
4.	Idukki	13	01
5.	Kasargode	05	00
6.	Kottayam	11	00
7.	Kozhikode	11	01
8.	Malapuram	06	01
9.	Palghat	12	01
10.	Pathanamthitta	11	00
11.	Quillon	13	00
12.	Trichur	12	00
13.	Tiruanantpuram	25	03
14.	Wynad	19	03

**Probabilities of moderate and severe drought during 1901-2000
Central Northeast India**

		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
4(a) Orissa			
1.	Balasore	08	00
2.	Bolangir	19	00
3.	Cuttack	10	00
4.	Dhenkanal	09	00
5.	Ganjam	09	00
6.	Kalahandi	10	03
7.	Keonjhar	21	00
8.	Koraput	07	00
9.	Mayurbhanj	06	00
10.	Puri	08	00
11.	Sambalpur	16	01
12.	Sundergarh	16	00
4(b) Jharkhand			
1.	Dhanbad	10	00
2.	Hazaribagh	06	00
3.	Palamau	13	00
4.	Ranchi	07	00
5.	Singhbhum	08	00
6.	Santhal Parganas	07	00.
4(c) Bihar			
1.	Bhagalpur	12	00
2.	Champanan	15	01
3.	Darbhanga	17	02
4.	Gaya	13	00
5.	Monghyr	15	00
6.	Muzaffarpur	16	00
7.	Patna	17	00
8.	Purnea	12	01
9.	Shahabad	06	01
10.	Saharsa	12	00
11.	Saran	19	00
4(d) East Uttar Pradesh			
1.	Allahabad	10	02
2.	Azamgarh	14	01
3.	Bahraich	13	04
4.	Ballia	17	02
5.	Basti	13	02

**Probabilities of moderate and severe drought during 1901-2000
Central Northeast India (contd..)**

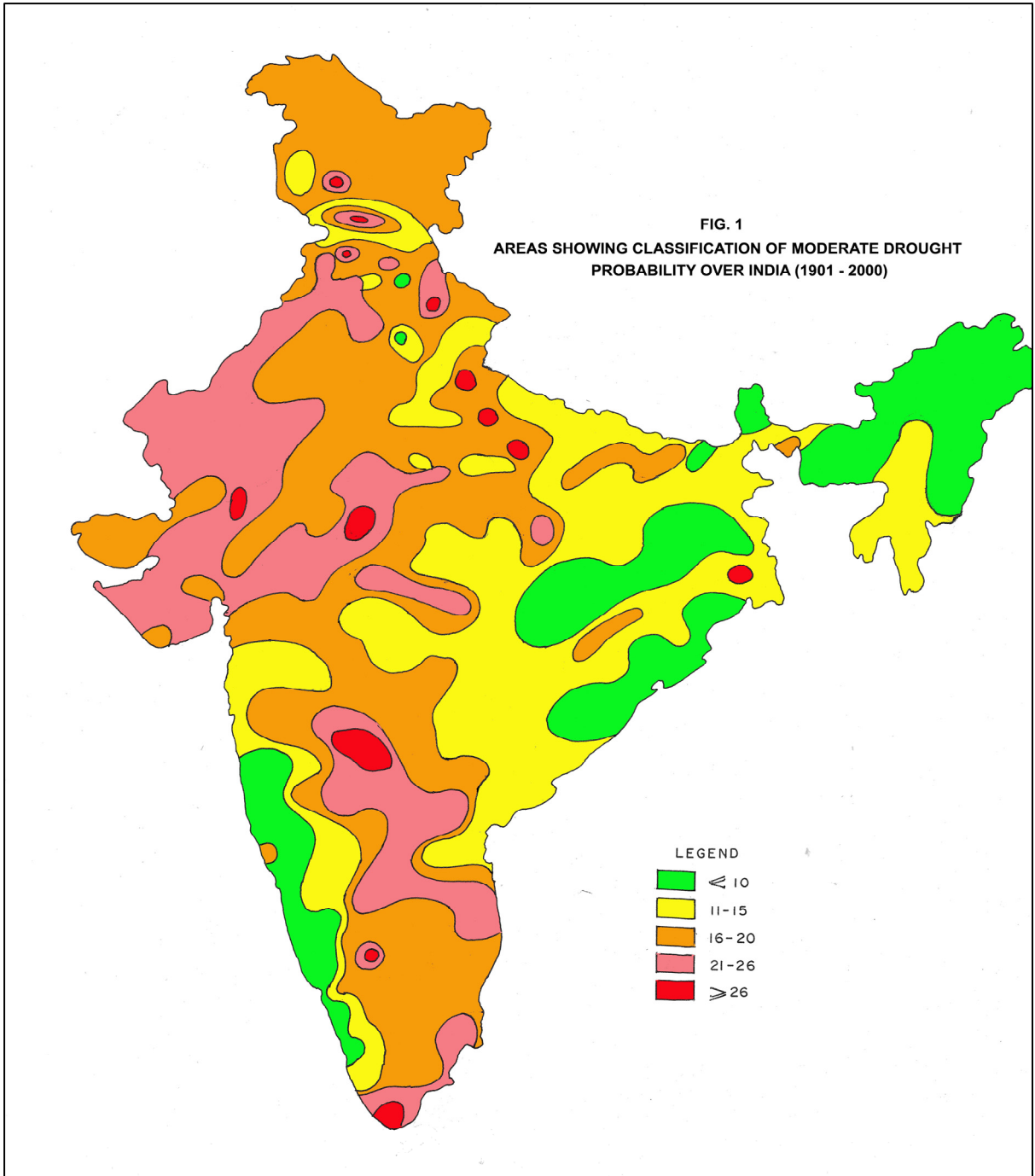
		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
4(d) East Uttar Pradesh (contd...)			
6.	Faizabad	20	04
7.	Fatehpur	14	03
8.	Gazipur	15	02
9.	Gonda	12	01
10.	Gorakhpur	14	00
11.	Hardoi	26	04
12.	Jaunpur	13	00
13.	Kanpur	16	05
14.	Kheri Lakhimpur	15	03
15.	Lucknow	20	04
16.	Mirzapur	11	03
17.	Pratapgarh	21	01
18.	Raebareli	37	01
19.	Sultanpur	15	02
20.	Varanasi	22	01
21.	Unnao	16	00
4(e) West Uttar Pradesh			
1.	Agra	15	07
2.	Aligarh	15	05
3.	Banda	17	01
4.	Badaun	16	07
5.	Bareilly	29	01
6.	Bijnor	18	01
7.	Bulandshahr	19	07
8.	Etawah	17	05
9.	Hamirpur	15	04
10.	Jalaun	21	05
11.	Jhansi	12	04
12.	Mainpuri	13	04
13.	Mathura	12	07
14.	Meerut	13	06
15.	Moradabad	13	03
16.	Muzaffarnagar	07	08
17.	Pilibhit	18	10
18.	Saharanpur	18	06

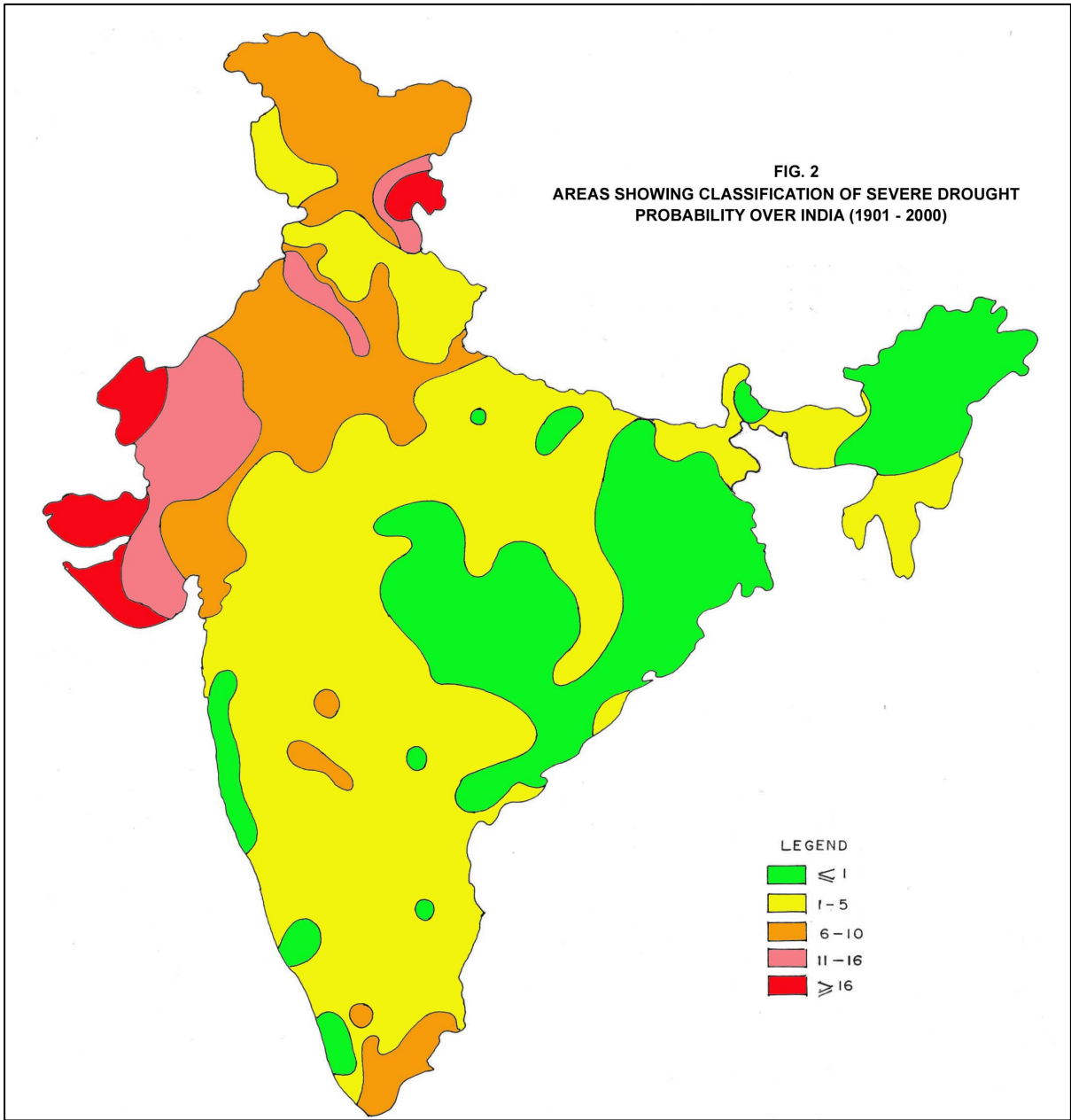
**Probabilities of moderate and severe drought during 1901-2000
Northeast India**

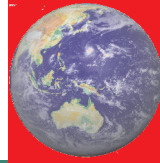
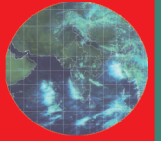
		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
5(a) Assam & Meghalaya			
1.	Cachar	04	00
2.	Darrang	06	01
3.	Goalpara	05	03
4.	Garohills	14	00
5.	Kamrup	06	01
6.	Lakhimpur	03	00
7.	Nowgong	14	00
8.	Sibsagar	01	00
5(b) Nagaland, Manipur, Mizoram & Tripura			
1.	Nagaland	09	00
2.	Mizoram	14	02
3.	Tripura	07	01
5(c) Sub-Himalayan West Bengal & Sikkim			
1.	Cooch Behar	16	01
2.	Darjeeling	06	00
3.	Jalpaiguri	10	00
4.	Malda	15	03
5.	West Dinajpur	15	00
5(d) Gangetic West Bengal			
1.	Bankura	13	00
2.	Birbhum	09	00
3.	Burdwan	08	00
4.	Hooghly	16	00
5.	Howrah	26	00
6.	Murshidabad	13	00
7.	Nadia	11	03
8.	Parganas 24	13	00
9.	Purulia	09	00

**Probabilities of moderate and severe drought during 1901-2000
Hilly Region of India**

		Probability (%) of drought	
Sr.No.	District	Moderate	Severe
6(a) Jammu & Kashmir			
1.	Anantnag	29	09
2.	Baramulla	20	07
3.	Doda	15	04
4.	Jammu	16	02
5.	Kathua	16	04
6.	Ladakh	23	21
7.	Mirpur	15	02
8.	Muzaffarbad	13	00
9.	Poonch	10	01
6(b) Himachal Pradesh			
1.	Bilaspur	18	02
2.	Chamba	31	07
3.	Kangra	13	03
4.	Kinnaur	23	12
5.	Kullu	11	09
6.	Lahaul & Spiti	12	25
7.	Mahasu	11	00
8.	Mandi	22	04
9.	Shimla	09	02
10.	Sirmaur	29	07
6(c) Sub-division: Uttarakhand			
1.	Almora	14	00
2.	Chamoli	12	03
3.	Dehradun	18	01
4.	Garhwal	12	01
5.	Nainital	15	04
6.	Pithorgarh	15	05
7.	Sharjahanpur	25	00
8.	Tehri-Garhwal	27	05







NCC

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