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Tendency of Rainfall by Probabilistic Approach: Application in Indian Scenario

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Abstract

In a recent study, probability has been defined on the basis of outcomes that do happen automatically instead of the outcomes obtained from performing experimentation. The definition has been derived by the application of the philosophy behind the empirical definition (also known as statistical definition) of probability, introduced by von Mises, which is based on performing actual experimentation. This definition of probability has been applied in estimating the probability distribution of occurrence of rainfall (in terms of number of rainy days) in each of the 12 months at 12 places/stations in India. Moreover, expected numbers of rainy days to be occurred in each of the 12 months at the stations have been estimated by the application of the definition of mathematical expectation based on this definition of probability. The study has been done with the objective of obtaining a picture, though not deterministic and appropriate but probabilistic and approximate, of the tendency of rainfall in India.

Key Words: *Probabilistic Approach, Rainy Days, Probability Distribution, Mathematical Expectation, Picture in India*

1. Introduction:

The theory of probability, which has become essentially useful for scientific analysis of data in almost every study of research and investigation type, is a basic statistical tool for understanding and explaining ~~of~~ various phenomena in almost every branch of science [Papoulis (1965]. The theory of probability, the beginning of whose history was lost in the dust of antiquity [Chakrabarty 2014,2023*i* ; Maistrov 1974], has been developed by the six approaches namely

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(1) Subjective Approach [Bernard 1958], (2) Intuitive Approach [Koopman 1940*a*, 1940*b* : Savage 1954 , 1961], (3) Classical Approach [Bernoulli 1713 ; Chakrabarty 2002 , 2003, 2005*a*, 2006, 2008, 2009, 2022*a*], (4) Empirical Approach (also knows as statistical approach [Camp 1962 ; Chakrabarty 2007 , 2022*a*, 2023*i* ; von Mises 1931, 1939, 1941], (5) Axiomatic Approach [Berstein 1927 , 1946 ; Jack & Albert 1978 ; Kolmogorov 1933, 1956] and (6) Theoretical Approach [Chakrabarty 2004 , 2010*a* , 2010*b* , 2010*c* , 2010*d* , 2011*a* , 2022*a* , 2022d]. The first two approaches are subjective while the other approaches are based on scientific logic [Feller 1968]. Probability is determined in the empirical approach by performing the associated experimentation while in the classical approach probability is determined without performing the experimentation. Axiomatic approach is based on some conditions called axioms that are satisfied by probability and it is silent about how to determine the value of probability. In theoretical approach, probability is defined in theoretically ideal situation and is determined in practically ideal situation by performing the associated experimentation. Recently, one definition of probability, that can be interpreted as an extended definition of empirical probability, has been developed on the basis of outcomes that do happen automatically instead of the outcomes obtained from performing experimentation [Chakrabarty 2023*c* , 2023*h* , 2023*i*, 2023*j*].

Central tendency [Chakrabarty 2015*a* , 2015*b*, 2020*b*, 2021*g* ; Weisberg 1992], which is one of the basic characteristics of data, plays a vital role in statistical analysis of data. A number of formulations, though may not be as sufficient as to handle all the real situation, have already been developed for measuring central tendency of data [Chakrabarty 2021*a*, 2021*b*, 2021*e* , 2021*f* , 2022*b* , 2022*c*, 2022*e* , 2022*h* ; Williams 1984] which is basically based on measures of average [Chakrabarty 2016 , 2017, 2018*b*, 2018*c*, 2018*d*, 2018*e*, 2018*g* , 2019*c* , 2019*d* , 2020*a* , 2021*c* , 2021*d*]. There had been several studies on various aspects of rainfall like trend of rainfall [Bisht et al., 2018 ; Goswami et al., 2006 ; Guhathakurta & Rajeevan 2008 ; Jagannathan & Parthasarathi 1973 ; Jain & Kumar 2012 ; Kumar et al., 2010 ; Pandey & Tiwari 2021 ; Paul et al ., 2017 ; Tank et al., 2021 ; Taxak et al., 2014] , tendency of rainfall [Chakrabarty 2022*i* , 2023*a* , 2023*d* , 2023*g* ; Hills 1974 ; Nikumbh et al., 2019] , confidence interval of rainfall [Chakrabarty 2014*b* , 2019*b* , 2021*h*] , significance of change in rainfall [Chakrabarty 2014*a* ,

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2019*b* , 2021*h*] , forecasting of rainfall [Chakrabarty 2005*b*] etc. which are mostly based on non-probabilistic approach. Study of rainfall by probabilistic approach has been initiated recently [Chakrabarty 2023*b* , 2023*c* , 2023*e* , 2023*e* , 2023*h* , 2023*i* , 2023*j*].

In a recent study, the concept of extended definition of empirical probability has been applied in defining the probability of occurrence of rainfall in terms of rainy days together with the definition of mathematical expectation of number of rainy days on the basis of the data on automatically happened outcomes [Chakrabarty 2023*b* , 2023*d* , 2023*e* , 2023*f*]. This definition of probability has been applied in estimating the probability distribution of occurrence of rainfall (in terms of number of rainy days) in each of the 12 months at 12 places/stations in India. Moreover, expected numbers of rainy days corresponding to the 12 months at the stations have been estimated by the application of the definition of mathematical expectation based on this definition of probability. The study has been done with the objective of obtaining a picture, though not deterministic and appropriate but probabilistic and approximate, of the tendency of rainfall in India.

2. Rainy Days – Probability & Mathematical Expectation:

Probability: Empirical Definition

The following fact is a consequence of the statistical definition of probability:

If the random performing of a trial is repeated N times under identical homogenous conditions and if out of the N repetitions of the trail, an event E occurs n times, then the probability of occurrence of the event E, denoted by $P(E)$, is a number towards which the ratio $\frac{n}{N}$ approaches a number, i.e. $P(E)$, as N becomes large

i.e. $\frac{n}{N} \to P(E)$ as $N \to \infty$

i.e. $P(E)$ is the limiting value of $\frac{n}{N}$ as N becomes large.

Conversely,

if the random performing of a trial is repeated N times under identical homogenous condition then the probability of occurrence of the event E, denoted by $P(E)$, is a number such that

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the number of occurrences of the event E out of the N repetitions of the trial approaches $N.P(E)$ as N becomes large

i.e. $n \rightarrow N.P(E)$ as $N \rightarrow \infty$

This definition states that the number of occurrences of the event E out of N repetitions of the trial can be approximated by $N.P(E)$ provided N is large.

Automatically Happened Outcomes: Definition of Probability

Let us use the standard notation $P(E)$ to denote the probability of occurrence or happening of event E .

Probability has recently been defined on the basis of automatically happened outcomes of a natural phenomenon as follows [Chakrabarty 2023*c*]:

Definition (1):

If in a set of N repetitions of a natural phenomenon already happened, an event E has occurred n times then the probability of occurrence of E is

the limiting value of the ratio $\frac{n}{N}$ as $N \rightarrow \infty$

i.e. $P(E)$ can be approximated by the ratio provided N is large

Definition (2):

In a set of N repetitions of a natural phenomenon automatically happened, the number of occurrence n of an event E with probability of occurrence $P(E)$ is

the limiting value of the ratio $N.P(E)$ as $N \rightarrow \infty$

i.e. n can be approximated by $N.P(E)$ provided N is large.

Note:

(1) The value of $P(E)$ lies within 0 & 1.

(2) Definition (1) is just the converse of Definition (2).

(3) Definition (1) provides a way of approximating/estimating the probability of occurrence of an event while Definition (2) provides a way of approximating/estimating the number of occurrence of the event.

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(4) The happening of an event E is certain if $P(E) = 1$ and vice versa while the non-happening of E is certain if $P(E) = 0$ and vice versa.

(5) Happening or non-happening of an event E is uncertain if $0 < P(E) < 1$ and vice versa. The uncertainty of happening or non-happening increases as $P(E)$ increases from 0 or decreases from 1. The uncertainty is maximum when $P(E) = 0.5$ and vice versa.

Probability of Number of Rainy Days

Suppose that E is an event that denotes the occurrence of r rainy days in a month.

Consider the observations on happenings of rainfall in the month on a number of years (say N years) i.e. on N repetitions of the happenings.

Since the phenomenon has happened naturally, it is free from error that occurs due to performing of experiment.

Moreover, the natural happening of the phenomenon can be thought of as the performing of experiment on rainfall not by human but by nature.

If out of N repetitions the event E occurs $N(E)$ times then the probability of occurrence of the event E, denoted by $P(E)$, can be defined by the number towards which the ratio $\frac{n}{N}$ approaches as N becomes larger i.e.

$$\frac{n}{N} \rightarrow P(E) \quad \text{as} \quad N \rightarrow \infty$$

i.e. $P(E)$ is the limiting value of $\frac{n}{N}$ as N becomes larger and larger.

Accordingly, the value of this ratio can be regarded as an estimator of $P(E)$.

Mathematical Expectation of Number of Rainy Days

In probability theory, the expected value (also called expectation) of a random variable X is defined as the arithmetic mean the possible values assumed by the variable i.e. if a random variable X assumes the values

$$X_1, X_2, \ldots\ldots\ldots, X_n$$

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with respective probabilities

$$p_1, p_2, \ldots\ldots\ldots, p_n$$

then the mathematical expectation of a random variable X is defined by

$$E(X) = \sum_{i-1}^{n} X_i P(X = X_i) = \sum_{i-1}^{n} p_i X_i$$

[Papoulis 1965; Feller 1968]. Accordingly, if

$$r_1, r_2, \ldots\ldots\ldots, r_n$$

are the possible values of number of rainy days R occurring in a period with respective probabilities

$$p_1, p_2, \ldots\ldots\ldots, p_n$$

then the mathematical expectation of the number of rainy days R in the period is defined by

$$E(R) = \sum_{i=1}^{n} r_i P(R = r_i) = \sum_{i=1}^{n} p_i r_i$$

Since

$$p_1, p_2, \ldots\ldots\ldots, p_n$$

are not exact but approximate value, due to the limitation of number of observed data and since the variable R is non-negative integral valued,

therefore, the nearest non-negative integral value of $\sum_{i=1}^{n} p_i r_i$ will be the estimated value of $E(R)$ (i.e. of the expected number of rainy days).

Note:

In the case of interval values of a number of rainy days, the midpoints of the intervals are to be used in this formula. In this case, the interval which contains the value of $\sum_{i=1}^{n} p_i r_i$ will be estimated interval value of $E(R)$.

3. Probability Distribution and Expectation of Rainy Days at 12 Stations in India:

The definition of probability based on the data on already happened outcomes has been applied in estimating probability of occurrence of number of rainy days in different months at the 12

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stations i.e., Ahmadabad , Allahabad , Amritsar , Bangalore , Bhopal , Chennai , Guwahati , Hydarabad , Kolkata , Mumbai , New Delhi & Trivandrum in India. For this purpose, data on number of rainy days (month-wise) at the 12 stations [Chakrabarty 2005*b* , 2014*b* , 2019*b*] have been collected from the year 1969 onwards from Meteorological Department of Government of India and then the above formulation of probability has been applied in computing the desired values of probabilities. The number of rainy days considered here are the point values

$$0 , 1 , 2 , 3 , 4 , 5$$

and the interval values

$$6 – 10 , 11 – 15 , 16 – 20 , 21 – 25 , 26 – 30$$

Estimated values of probabilities corresponding to these point/interval values of number of rainy days in different months, obtained by the formulation of probability defined above, have been shown in **Table – 5.1**. Estimated values of number of rainy days in different months, obtained by the formulation of mathematical expectation mentioned above, have been shown in **Table – 5.2**. It is to be mentioned that computed values of expected number of rainy days have been found to be non-integral values. Since number of rainy days is an integral value, the integers nearest to the computed values have been retained as the estimated values of the same. Moreover, the fractional parts of the computed values do also carry significance in terms of a day. The fractional part of a computed value is a part of a whole day, the rainfall occurring in a part of a day cannot be ignored. Therefore corresponding to each of the computed values, the interval bounded by the integer just less the computed value and the integer just greater the computed value has been retained as the estimated interval value of the number of rainy days. Estimated interval values of number of rainy days in different months, obtained by the formulation of the mathematical expectation mentioned above, have been shown in **Table – 5.2**.

4. Discussion and Conclusion:

If the probability of occurrence of zero rainy day at a place during a period is 1 then the period can be regarded as a certain non-rainy one. In reality, there may be rainfall during a non-rainy period due to some random cause that occurs accidently but not regularly and not always so that 1 rainy day can occur during a non-rainy month with very small (near to 0) probability. Thus, if

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the probability of occurrence of zero rainy day during a period is not 1 but near to 1 and the probability of occurrence of 1 rainy day during the period is very small such that the probability of occurrence of either 0 rainy day or 1 rainy day is 1 (i.e. there are only 2 possible outcomes namely 0 and 1) then the period can be regarded as almost certain non-rainy period. Similarly, if the probability of occurrence of 2 or more rainy days (i.e. at least 2 rainy days) is 1 then the period can be regarded as a certain rainy one. Similarly, if the probability of occurrence of 2 or more rainy days is very near to 1 and the probability of occurrence of at least 1 rainy day is 1 then the period can be regarded as an almost certain rainy one. In similar manner, the period can be regarded as more likely rainy period, equally likely rainy period or less likely rainy period depending upon the probability of occurrence of rainy days.

It is to be noted that at the stations under study, no month has been found to have 100% rainy days. On the other hand, no month is certain to be completely free from influence of rainfall. The maximum number of rainy days in a month has been found to be 28. This finding possibly carries some significance in terms of the maximum duration of continuous rainfall. Possibly, continuous rainfall at a place cannot last more than 28 days. This can be a hypothesis to be established or disestablished by further research study.

Finally, one can conclude that the logical derivation of the definition of probability based on data on already happened outcomes can be a useful statistical tool of analysis of data obtained from automatically happened or naturally happened events. Therefore, as per the meaning of research [Chakrabarty 2011*b* , 2012 , 2013*a* , 2013*b* , 2013*c* , 2014*a* , 2018*a* , 2018*f* , 2019*a* , 2022*f*], this extended definition of probability can be regarded as a fundamental research carrying significant potentiality of application in analysis of data. The concept of probability defined for already happened outcomes, introduced here logically, can be applied, in a similar manner, in estimating probability distribution and mathematical expectation of number of rainy days at other places of the globe also.

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5. Tables of Findings – Values obtained from Computation:

Table – 5.1-1

Estimated Probability Distribution of Number of Rainy Days at **Ahmadabad**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.78125	0	0.90625	0	0.96875
1	0.21875	1	0.0625	1	0.03125
> 1	0	2	0.03125	> 1	0
		> 2	0		
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.84375	0	0.65625	0	0.03125
1	0.125	1	0.1875	1	0.09375
2	0.03125	2	0.0625	2	0.15625
> 2	0	3	0.09375	3 – 7	0.65625
		> 3	0	8 – 10	0.0625
				> 10	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 4	0	< 2	0	0	0.09375
4 – 8	0.28125	2	0.03125	1	0.1875
9 – 13	0.5	3 – 7	0.25	2	0.125
14 – 18	0.09375	8 – 12	0.5	3 – 7	0.375
19 – 23	0.125	13 – 17	0.125	8 – 12	0.1875
> 23	0	18 – 20	0.09375	9 – 17	0
		> 20	0	18	0.03125
				> 18	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.625	0	0.75	0	0.8125
1	0.21875	1	0.09375	1	0.15625
2	0.0625	2	0.03125	2	0.03125
3	0.03125	3 – 5	0.125	> 2	
4 – 6	0.0625	> 5	0		
> 6	0				

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Table – 5.1-2

Estimated Probability Distribution of Number of Rainy Days at **Allahabad**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.1875	0	0.40625	0	0.625
1	0.34375	1	0.25	1	0.21875
2	0.25	2	0.15625	2	0.03125
3	0.09375	3	0.15625	3	0.09375
4	0.125	4	0.03125	6	0.03125
> 4	0	> 4	0	> 6	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.5	0	0.46875	0	0.09375
1	0.34375	1	0.25	1	0.03125
2	0.15625	2	0.125	2	0.125
> 2	0	3	0.125	3 – 7	0.65625
		5	0.03125	8 – 10	0.09375
		> 5	0	> 10	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0	< 4	0	< 2	0
1	0.03125	4 – 8	0.19355	2	0.03226
2	0	9 – 13	0.48387	3	0.03226
3 – 7	0.125	14 – 18	0.32258	4 – 8	0.51613
8 – 12	0.375	> 18	0	9 – 13	0.32258
13 – 17	0.3125			14 – 18	0.09677
18 – 20	0.15625			> 18	0
> 20	0				
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.29032	0	0.71875	0	0.65625
1	0.22581	1	0.15625	1	0.3125
2	0.19355	2	0.0625	2	0
3	0.12903	3	0.03125	3	0.03125
4 – 8	0.16129	4	0.03125	> 3	0
> 8	0	> 4	0		

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Table – 5.1-3

Estimated Probability Distribution of Number of Rainy Days at **Amritsar**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.24242	0	0.06061	1	0.18182
1	0.18182	1	0.09091	2	0.15151
2	0.15152	2	0.21212	3	0.27273
3 – 7	0.42424	3 – 7	0.63637	4 – 8	0.39394
> 7	0	> 7	0	> 8	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.12121	0	0.18182	0	0.03030
1	0.36364	1	0.21212	1	0.09091
2	0.21212	2	0.30303	2	0.24243
3 – 7	0.30303	3	0.15152	3 – 7	0.60606
> 7	0	4 – 8	0.15151	8 – 10	0.03030
		> 8		> 10	
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 2	0	< 1	0	0	0.0625
2	0.0303	1	0.0303	1	0.125
3 – 7	0.24243	2	0.60606	2	0.15625
8 – 12	0.60606	3 – 7	0.36364	3 – 7	0.65625
13 – 15	0.12121	8 – 12	0.54545	> 7	0
> 15	0	> 12	0		
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.40625	0	0.6875	0	0.4375
1	0.28125	1	0.21875	1	0.25
2	0.15625	2	0.09375	2	0.1875
3	0.125	> 2	0	3	0.125
4	0.03125			> 3	0
> 4	0				

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Table – 5.1-4

Estimated Probability Distribution of Number of Rainy Days at **Bangalore**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.875	0	0.71875	0	0.6875
1	0.09375	1	0.15625	1	0.09375
2	0	2	0.0625	2	0.09375
3	0.03125	3	0.0625	3	0.09375
> 3	0	> 3	0	4	0.03125
				> 4	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.0625	< 3	0	< 2	0
1	0.21875	3	0.0625	2	0.09375
2	0.125	4 – 8	0.71875	3	0.0625
3 – 7	0.59375	9 – 11	0.21875	4 – 8	0.59375
> 7	0	> 11	0	9 – 11	0.25
				> 11	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 3	0	< 5	0	< 4	0
3 – 5	0.3125	6 – 10	0.59375	4 – 8	0.34375
6 – 8	0.40625	11 – 15	0.375	9 – 13	0.46875
9 – 11	0.15625	16 – 17	0	14 – 16	0.15625
12 – 14	0.125	18	0.03125	17	0.03125
> 14	0	> 18	0	> 17	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 2	0	0	0.0625	0	0.3125
2	0.03125	1	0.0625	1	0.25
3 – 5	0.15625	2	0.15625	2	0.125
6 – 8	0.3125	3 – 7	0.625	3	0.125
9 – 11	0.40625	8 – 10	0.09375	4 – 6	0.1875
12 – 14	0.09375	> 10	0	> 6	0
> 14	0				

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Table – 5.1-5

Estimated Probability Distribution of Number of Rainy Days at **Bhopal**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.43333	0	0.5	0	0.63334
1	0.23333	1	0.2	1	0.26667
2	0.16667	2	0.13333	2	0.03333
3 – 7	0.16667	3 – 5	0.16667	3	0.03333
> 7	0	> 5	0	4	0.03333
				> 4	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.68965	0	0.39286	< 3	0
1	0.20689	1	0.42857	3 – 7	0.67858
2	0.06898	2	0.07143	8 – 12	0.28571
3	0.03448	3	0.07143	13	0.03571
> 3	0	4	0.03571	> 13	0
		> 4	0		
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 6	0	< 8	0	0	0.03448
6 – 10	0.14286	8 – 12	0.31034	1	0.03448
11 – 15	0.46429	13 – 17	0.48276	2 – 6	0.44828
16 – 18	0.28571	18 – 20	0.2069	7 – 11	0.31035
19	0.10714	> 20	0	12 – 16	0.10344
> 19	0			17 – 19	0.06897
				> 19	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.28571	0	0.6	0	0.64286
1	0.32143	1	0.13333	1	0.14286
2	0.14286	2	0.1	2	0.14286
3 – 7	0.25	3 – 7	0.16667	3	0.07142
> 7	0	> 3	0	> 3	0

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Table – 5.1-6

Estimated Probability Distribution of Number of Rainy Days at **Chennai**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.53333	0	0.8	0	0.76667
1	0.13333	1	0.066667	1	0.16667
2	0.1	2	0.1	2	0
3	0.13333	3 – 7	0	3	0.06667
4	0.066667	8	0.033333	> 3	0
7	0.033333	> 8	0		
> 7	0				
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.6	0	0.3	1	0.1
1	0.13333	1	0.36667	2	0.13333
2	0.16667	2	0.06667	3	0.13333
3	0.066667	3 – 5	0.26667	4 – 6	0.4
4	0.03333	> 5	0	7 – 9	0.23333
> 4	0			> 9	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
1	0.06667	1	0.03333	< 2	0
2	0.03333	2	0.066667	2	0.06452
3 – 7	0.43333	3 – 7	0.366667	3	0.03226
8 – 12	0.46667	8 – 12	0.366667	4 – 8	0.51613
> 12	0	13 – 15	0.16667	9 – 13	0.38709
		> 15	0	> 13	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 2	0	< 4	0	0	0.1
2 – 6	0.23333	4 – 8	0.33333	1	0.06667
7 – 11	0.36667	9 – 13	0.533333	2	0.1
12 – 16	0.36667	14 – 18	0.1	3	0.13333
17 – 20	0	19 – 20	0	4 – 8	0.43333
21	0.03333	21	0.03333	9 – 13	0.1
> 21	0	> 21	0	14	0.03333
				18	0.03333
				> 18	0

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Table – 5.1-7

Estimated Probability Distribution of Number of Rainy Days at **Guwahati**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.32143	0	0.25	1	0.17857
1	0.25	1	0.07143	2	0.17857
2	0.25	2	0.35714	3 – 7	0.5
3	0.17857	3 – 7	0.32143	8 – 10	0.14286
> 3	0	> 7	0	> 10	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 3	0	< 7	0	< 10	0
3 – 7	0.35714	8 – 12	0.24138	10 – 14	0.48276
8 – 12	0.57143	13 – 17	0.58621	15 – 17	0.34483
13 – 15	0.07143	18 – 20	0.10345	18 – 20	0.10345
> 15	0	21	0.06896	21	0.06896
		> 21	0	> 21	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 9	0	< 6	0	< 4	0
9 – 14	0.25	6 – 10	0.25	4 – 8	0.25
15 – 19	0.5	11 – 15	0.57143	9 – 13	0.71429
20 – 22	0.14286	16 – 18	0.14286	14	0
23	0.10714	19	0.03571	15	0.03571
> 23	0	> 19	0	> 15	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
1	0.10714	0	0.32	0	0.52
2	0.03571	1	0.28	1	0.28
3 – 5	0.39286	2	0.2	2	0.16
6 – 8	0.39286	3 – 5	0.2	3	0.04
9 – 11	0.07143	> 5	0	> 3	0
> 11	0				

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Table – 5.1-8

Estimated Probability Distribution of Number of Rainy Days at **Hydarabad**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.63333	0	0.73333	0	0.6
1	0.26667	1	0.16667	1	0.23333
2	0.06667	2	0.06667	2	0.16667
3	0	3	0	> 3	0
4	0.033333	4	0.03333		
> 4	0	> 4	0		
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.23333	0	0.2	1	0.03333
1	0.36667	1	0.2	2 – 3	0
2	0.2	2	0.13333	4 – 8	0.66667
3	0.13333	3 – 7	0.43333	9 – 13	0.26667
4	0.06667	8	0.03333	14	0.03333
> 4	0	> 8	0	> 14	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 3	0	< 3	0	1	0.03333
3 – 7	0.31034	3 – 7	0.16667	2	0
8 – 12	0.44828	8 – 12	0.53333	3 – 7	0.43333
13 – 17	0.24138	13 – 17	0.26667	8 – 12	0.46667
> 17	0	18	0.03333	13 – 15	0.06667
		> 18	0	> 15	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
1	0.1	0	0.33333	0	0.7
2	0.13333	1	0.13333	1	0.23333
3 – 7	0.5	2	0.13333	2	0.06667
8 – 12	0.2	3	0.23333	> 2	0
13 – 15	0.06667	4 – 6	0.16667		
> 15	0	> 6	0		

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Table – 5.1-9

Estimated Probability Distribution of Number of Rainy Days at **Kolkata**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.42857	0	0.142857	0	0.35714
1	0.28572	1	0.39286	1	0.07143
2	0.17857	2	0.17857	2	0.21429
3 – 7	0.10714	3 – 7	0.28571	3 – 7	0.35714
> 7	0	> 7	0	> 7	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.07143	1	0.03571	< 5	0
1	0.21429	2	0.07143	5 – 9	0.21428
2	0.17857	3	0.07143	10 – 14	0.46429
3 – 7	0.5	4 – 8	0.53572	15 – 19	0.25
8	0	9 – 11	0.25	20 – 22	0.07143
9	0.03571	12 – 15	0	> 22	0
> 9	0	16	0.03571		
		> 16	0		
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 11	0	< 10	0	< 7	0
11 – 15	0.178571	10 – 14	0.21429	7 – 11	0.28571
16 – 20	0.75	15 – 19	0.57142	12 – 16	0.57143
21	0	20 – 22	0.21429	17 – 19	0.14286
22	0.071429	> 22	0	> 19	0
> 22	0				
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.03571	0	0.39286	0	0.71429
1	0.03571	1	0.21429	1	0.07143
2	0.03572	2	0.21429	2	0.10714
3 – 7	0.5	3	0.14285	3	0.03571
8 – 12	0.39286	4	0.03571	4	0.07143
> 12	0	> 4	0	> 4	0

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Table – 5.1-10

Estimated Probability Distribution of Number of Rainy Days at **Mumbai**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.9375	0	0.90625	0	0.96875
1	0.0625	1	0.09375	1	0.03125
≥ 2	0	≥ 2	0	≥ 2	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.90625	0	0.75	< 16	0
1	0.09375	1	0.09375	16 – 20	0.3125
≥ 2	0	2	0.03125	21 – 25	0.375
		3 – 7	0.125	26 – 28	0.3125
		> 7	0	> 28	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 16	0	< 12	0	< 5	0
16 – 20	0.3125	12 – 16	0.125	5 – 9	0.21875
21 – 25	0.375	17 – 21	0.34375	10 – 14	0.3125
26 – 28	0.3125	22 – 26	0.4375	15 – 19	0.3125
> 28	0	27	0.09375	20 – 24	0.09375
		> 27	0	25	0.0625
				> 25	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.1875	0	0.625	0	0.78125
1	0.0625	1	0.0625	1	0.125
2	0.15625	2	0.1875	2	0.09375
3 – 7	0.5	3 – 7	0.125	> 2	0
8 – 12	0.09375	> 7	0		
> 12	0				

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Table – 5.1-11

Estimated Probability Distribution of Number of Rainy Days at **New Delhi**

January		**February**		**March**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.30303	0	0.15625	0	0.28125
1	0.21212	1	0.34375	1	0.21875
2	0.30303	2	0.3125	2	0.25
3	0.12121	3 – 5	0.1875	3 – 5	0.25
4	0.06061	> 5	0	> 5	0
> 4	0				
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.375	0	0.3125	1	0.0625
1	0.375	1	0.125	2	0.09375
2	0.125	2	0.25	3 – 5	0.5625
3	0.03125	3	0.1875	6 – 8	0.25
4 – 6	0.09375	4 – 6	0.125	9	0.03125
> 6	0	> 6	0	> 9	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 4	0	< 3	0	0	0.0625
4 – 8	0.36364	3	0.03125	1	0.03125
9 – 13	0.42424	4 – 8	0.375	2	0.125
14 – 18	0.18182	9 – 13	0.4375	3 – 7	0.5625
19 – 20	0	14 – 18	0.15625	8 – 10	0.15625
21	0.0303	> 18	0	11	0.0625
> 21	0			> 11	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.4375	0	0.75	0	0.5
1	0.25	1	0.125	1	0.25
2	0.125	2	0.09375	2	0.15625
3 – 5	0.1875	3 – 5	0.03125	3 – 5	0.0625
> 5	0	> 5	0	6	0.03125
				> 6	0

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Table – 5.1-12

Estimated Probability Distribution of Number of Rainy Days at **Trivandrum**

January		February		March	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
0	0.46667	0	0.43333	0	0.2
1	0.33333	1	0.16667	1	0.2
2	0.1	2	0.23333	2	0.23333
3	0.03333	3	0.06667	3	0.166667
4 – 6	0.066667	4	0.03333	4 – 6	0.166667
> 6	0	7	0.06667	10	0.03333
		> 7	0	> 10	0
April		**May**		**June**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
1	0.03333	< 3	0	< 4	0
2	0.06667	3 – 7	0.3	4 – 8	0.06667
3	0	8 – 12	0.5	9 – 13	0.16667
4 – 8	0.66667	13 – 17	0.13333	14 – 18	0.36667
9 – 13	0.23333	18 – 20	0.06667	19 – 23	0.33333
> 13	0	> 20	0	24 – 27	0.06667
				> 27	0
July		**August**		**September**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 6	0	< 2	0	< 1	0
6	0.03333	2	0.03333	1	0.03333
9 – 13	0.5	3 – 7	0.2	2 – 6	0.3
14 – 18	0.4	8 – 12	0.53333	7 – 11	0.43333
19	0.03333	13 – 17	0.23333	12 – 16	0.16667
22	0.03333	> 17	0	17 – 19	0.06667
> 22	0			> 19	0
October		**November**		**December**	
Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence	Number of Rainy Days	Probability of occurrence
< 1	0	< 2	0	0	0.06667
1	0.03333	2	0.03333	1	0.03333
4 – 8	0.23333	5 – 9	0.5	2	0.33333
9 – 11	0.16667	10 – 12	0.3	3 – 7	0.43333
12 – 14	0.3	13 – 15	0.1	8 – 12	0.13333
15 – 17	0.2	16 – 18	0.06667	> 12	0
18 – 20	0.06667	> 18	0		
> 20	0				

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Table – 5.2-1
Estimated Expected Number of Rainy Days

Month	Number of Rainy Days			
	Ahmadabad	Allahabad	Amritsar	Bangalore
January	0	2	1	0
February	0	1	4	0
March	0	1	4	1
April	0	1	2	3
May	1	1	2	7
June	4	4	4	6
July	11	12	9	7
August	10	12	9	10
September	5	8	4	10
October	1	2	1	8
November	0	1	0	4
December	0	0	1	1

Table – 5.2-2
Estimated Expected Number of Rainy Days

Month	Number of Rainy Days			
	Bhopal	Chennai	Guwahati	Hydarabad
January	1	1	1	1
February	1	1	2	1
March	0	0	4	1
April	0	1	9	1
May	1	2	15	3
June	7	5	15	7
July	14	7	17	10
August	14	8	10	11
September	7	8	10	8
October	2	10	5	6
November	1	10	1	2
December	1	5	1	0

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Table – 5.2-3
Estimated Expected Number of Rainy Days

Month	Number of Rainy Days			
	Kolkata	Mumbai	New Delhi	Trivandrum
January	1	0	1	1
February	2	0	2	1
March	2	0	2	2
April	3	0	1	7
May	7	1	2	10
June	13	23	5	10
July	17	23	10	13
August	18	21	10	10
September	13	14	5	9
October	7	4	1	11
November	1	1	0	9
December	1	0	1	4

Table – 5.2-4
Estimated Expected Interval of Number of Rainy Days

Month	Interval of Number of Rainy Days			
	Ahmadabad	Allahabad	Amritsar	Bangalore
January	0 – 1	1 – 2	0 – 1	0 – 1
February	0 – 1	1 – 2	3 – 4	0 – 1
March	0 – 1	0 – 1	3 – 4	0 – 1
April	0 – 1	0 – 1	2 – 3	3 – 4
May	0 – 1	1 – 2	2 – 3	6 – 7
June	0 – 1	4 – 5	3 – 4	6 – 7
July	11 – 12	12 – 13	9 – 10	7 – 8
August	9 – 10	11 – 12	8 – 9	10 – 11
September	4 – 5	8 – 9	3 – 4	9 – 10
October	0 – 1	1 – 2	1 – 2	8 – 9
November	0 – 1	0 – 1	0 – 1	4 – 5
December	0 – 1	0 – 1	1	1 – 2

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Table – 5.2-5
Estimated Expected Number of Rainy Days

Month	Interval of Number of Rainy Days			
	Bhopal	Chennai	Guwahati	Hydarabad
January	1 – 2	1 – 2	1 – 2	0 – 1
February	1 – 2	0 – 1	2 – 3	0 – 1
March	0 – 1	0 – 1	4 – 5	0 – 1
April	0 – 1	0 – 1	8 – 9	1 – 2
May	0 – 1	1 – 2	14 – 15	2 – 3
June	6 – 7	4 – 5	14 – 15	7 – 8
July	14 – 15	6 – 7	16 – 17	9 – 10
August	14 – 15	8 – 9	10 – 11	10 – 11
September	7 – 8	7 – 8	9 – 10	7 – 8
October	1 – 2	10 – 11	5 – 6	5 – 6
November	1 – 2	10 – 11	1 – 2	1 – 2
December	0 – 1	4 – 5	0 – 1	0 – 1

Table – 5.2-6
Estimated Expected Number of Rainy Days

Month	Interval of Number of Rainy Days			
	Kolkata	Mumbai	New Delhi	Trivandrum
January	0 – 1	0 – 1	1 – 2	0 – 1
February	2 – 3	0 – 1	1 – 2	1 – 2
March	1 – 2	0 – 1	1 – 2	2 – 3
April	3 – 4	0 – 1	1 – 2	6 – 7
May	6 – 7	0 – 1	1 – 2	9 – 10
June	12 – 13	22 – 23	4 – 5	9 – 10
July	17 – 18	22 – 23	9 – 10	12 – 13
August	17 – 18	21 – 22	9 – 10	9 – 10
September	13 – 14	14 – 15	5 – 6	8 – 9
October	6 – 7	3 – 4	1 – 2	11 – 12
November	1 – 2	1 – 2	0 – 1	9 – 10
December	0 – 1	0 – 1	0 – 1	4 - 5

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