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Extension of Statistical Definition of Probability: Expected Number of Rainy Days in Indian Context

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ABSTRACT: A study has been carried out on determining expected number of rainy days, with a view of obtaining a picture of tendency of rainfall in India, on the basis of the extension of the statistical definition of probability extended to the situation where outcomes of the associated trials happen automatically. This article presents the estimated values of the expected number of rainy days in each of the 12 months at the 30 stations in India obtained by the application of this extended definition.

KEYWORDS*:* Automatic Trial, Probability, Extended Statistical Definition, Expectation of Rainy Days

I. INTRODUCTION

Probability has become the basis of statistical methods as well as of statistical tools of analysis of data on phenomena not deterministic in nature. Probability, which has become essentially useful for scientific analysis of data in almost every study of research and investigation type, is a basic statistical concept/tool for understanding and explaining of various phenomena in almost every branch of science [88]. The theory of probability, the beginning of whose history was lost in the dust of antiquity [6 , 85 , 88], has been developed by the six approaches namely (1) Subjective Approach [2], (2) Intuitive Approach [6 , 82 , 83 , 90 , 91], (3) Classical Approach [3 , 7 , 8 , 11 , 12 , 14 , 15 , 53], (4) Empirical Approach (also knows as statistical approach [10 , 13 , 53 , 94 , 95 , 96], (5) Axiomatic Approach [4 , 5 , 76 , 80 , 81] and (6) Theoretical Approach [9 , 13 – 20 , 53 , 56]. The first two approaches are subjective while the other approaches are based on scientific logic [Feller (1968)]. Probability is determined in empirical approach by performing the associated experimentation while in 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 [64 , 69].

Central tendency [28 , 29 , 44 , 51 , 61 , 97] is one of the basic characteristics of data which 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 [45 , 46 , 49 , 50 , 54 , 55 , 57 , 61 , 98] which is basically based on measures of average [30 , 31 , 33 – 37 , 41 – 43 , 47 , 48]. There had already been several studies on various aspects like measures of characteristics of rainfall, trend of rainfall, forecasting on rainfall etc. [1 , 11 , 26 , 27 , 40 , 52 , 60 – 71 , 73 – 75 , 77 – 79 , 84 , 86 , 87 , 89 , 92 , 93]. The studies on rainfall done so far are mostly based on non-probabilistic approach. Study on rainfall has hardly been done so far by probabilistic approach which has been applied in the current study on the same. 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 estimating the probability distribution of number of rainy days at some places/stations in India [63 – 71]. In the present study, this definition of probability has been applied in estimating the expected number of rainy days in each of the 12 months at 30 stations in India. The study has been done with an objective of obtaining a picture, though not deterministic and appropriate but probabilistic and approximate, of tendency of rainfall in India.

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II. RAINY DAY IN A PERIOD – MATHEMATICAL EXPECTATION

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

Probability of Number of Rainy Days

Suppose that E is an event that denotes 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.

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

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

If a random variable X assumes the values

$$X_1, X_2, \dots\dots\dots, X_n$$

with respective probabilities

$$p_1, p_2, \dots\dots\dots, p_n$$

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

$$r_1, r_2, \dots\dots\dots, r_n$$

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

$$p_1, p_2, \dots\dots\dots, p_n$$

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

$$p_1, p_2, \dots\dots\dots, p_n$$

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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 estimated value of $E(R)$ (i.e. of expected number of rainy days).

Note:

In the case of interval values of number of rainy days, the mid points 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 $E(R)$.

III. EXPECTED RAINY DAYS IN INDIA

The definition of probability based on the data on already happened outcomes has been applied in estimating expected number of rainy days in each of the 12 months at the following 30 stations
Agartala , Ahmadabad , Allahabad , Amritsar , Bangalore , Bhopal , Bhubaneswar , Bhunter , Chennai , Guwahati , Hisar , Hyderabad , Imphal , Jaipur , Kolkata , Lucknow , Mumbai , Nagpur , New Delhi , Palam , Panjim , Patna , Pondicherry , Port Blair , Pune , Shillong , Tezpur , Trivandrum , Udaipur , Varanasi
in India.
For this purpose, data on number of rainy days (month-wise) at the 30 stations [11 , 27 , 52] 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

At the first step, estimated values of probabilities corresponding to these point/interval values of number of rainy days in each of the 12 months at the 30 stations had been computed by the formulation of probability defined above.
At the next step, estimated values of expected number of rainy days in each of the 12 months at the 30 stations were computed by the formulation of mathematical expectation as mentioned above.
The estimated values of expected number of rainy days obtained have been shown in **Table – 5.1**.

IV. RESULT AND DISCUSSION

Since mathematical expectation of a variable is its theoretical central tendency, the estimated values obtained can be regarded as the estimates of central tendency of the respective number of rainy days.

If the number of occurrence of rainy day at a place during a period is 0 then the period can be regarded as a period having perfect non-rainfall tendency. In reality, there may be rainfall during a period having non-rainfall tendency due to some random cause that occurs accidently but not regularly and not always so that the probability of occurrence of a rainy day in that period is very small (near to 0). Thus, if the number of occurrence of rainy day in a period is not 0 but very small (near to 0 i.e very less than 1) then the period can be regarded as a period having significant non-rainfall tendency. The periods having non-rainfall tendency can be identified from the estimated values presented in **Table – 5.1**.

It is to be mentioned that the findings obtained in this study are based on the assumption that data used in the analysis satisfy the condition(s) under which the definition of probability is valid. Thus the accuracy of findings is subject to the validity of this assumption.

It is to be mentioned that in this study attempt has been made on estimating/approximating expected number of rainy days at a place in a period. This has been done by the extension of its empirical definition extended to the situation where outcomes of the associated trials happen automatically. Similar study can be made for the other places in the globe.

Finally, one can conclude that the extended definition of empirical probability extended to the situation where outcomes of the associated trials happen automatically can be a useful statistical tool of analysis of data obtained from

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automatically happened or naturally happened phenomena. Therefore, as per the meaning of research [21 – 25 , 32 , 37 , 39 , 58], the innovation of this extended definition of empirical probability can be regarded as a fundamental research carrying significant potentiality of application in analysis of data.

V. TABLES OF FINDINGS

Table – 5.1
Expected Number of Rainy Days

Month	Estimated Value				
	Agartala	**Ahmadabad**	**Allahabad**	**Amritsar**	**Bangalore**
January	0.64	0.21875	1.625	2.0303	0.1875
February	2.2	0.125	1.15625	3.21212	0.46875
March	3.24	0.03125	0.75	3.42424	0.6875
April	8.64	0.1875	0.65625	2.0303	2.875
May	13.04	0.59375	1.06452	2.15152	6.90625
June	15.12	4.125	4.53125	3.57576	6.15625
July	15.8	11.3125	11.9688	9.09091	7.15625
August	15.48	10.6875	11.7097	7.39394	10.0625
September	11.72	4.9375	8.45161	3.375	9.96875
October	6.64	0.75	1.80645	1.09375	8.03125
November	1.96	0.59375	0.51613	0.51515	3.9375
December	0.68	0.21875	0.41935	1.15152	1.78125

Table – 5.1: Continuation (1)
Expected Number of Rainy Days

Month	Estimated Value				
	Bhopal	**Bhubaneswar**	**Bhunter**	**Chennai**	**Guwahati**
January	1.26667	0.40741	5.80645	1.23333	1.28571
February	1.1	1.77778	6.29032	0.53333	2.03571
March	0.56667	1.66667	8.09677	0.36667	4
April	0.44828	2	5.6129	0.8	9.17241
May	0.92857	3.96429	6.29032	1.46667	12.8966
June	7.03448	10	4.43333	4.56667	14.7931
July	14.2069	15.0714	8.93333	6.73333	17.0345
August	14.5517	15.5357	8.76667	8	12.8966
September	7.66667	11.8929	4.86667	7.19355	10.0345
October	1.93103	7.39286	1.90323	10.0667	4.96552
November	1.10345	1.85185	1.53333	10.3	1.53846
December	0.64286	0.44444	2.55172	5.4	0.72

Table – 5.1: Continuation (2)
Expected Number of Rainy Days

Month	Estimated Value				
	Hisar	**Hyderabad**	**Imphal**	**Jaipur**	**Kolkata**
January	1.24242	0.53333	1.22222	0.53125	1.03571
February	1.54545	0.44828	3.32143	1.03125	1.85714
March	1.48485	0.58621	6.10714	0.4375	2.32143
April	1.15152	1.43333	9.89655	0.71875	2.96429
May	1.81818	2.56667	10.4138	1.46875	6.82143
June	3.5625	7.33333	15.4483	3.77419	12.6429
July	7.42424	9.65517	15.7931	10.1935	17.6071

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August	6.5	10.9	12.8966	9.41935	16.7857
September	3	7.66667	9.41379	3.54839	13.2857
October	0.75758	5.73333	6.51724	1.12903	6.53571
November	0.3125	1.93333	3.25	0.48387	1.21429
December	0.65625	0.36667	1.125	0.32258	0.67857

Table – 5.1: Continuation (3)
Expected Number of Rainy Days

Month	Estimated Value				
	Lucknow	**Mumbai**	**Nagpur**	**New Delhi**	**Palam**
January	1.29032	0.0625	1.24138	1.16568	1.5
February	1.58065	0.09375	1.48276	1.25928	1.63636
March	0.90323	0.03125	1.33333	1.21809	1.33333
April	0.58065	0.09375	1	1.06794	1.27273
May	1.74194	0.75	1.67857	1.29572	1.80645
June	4.96774	13.0938	8.5	1.95305	3.63636
July	11.8065	22.6129	13.8621	2.62849	9.81818
August	11.0323	21.5625	13.4483	2.5941	9.12121
September	8.41935	13.8438	8.13333	2.01536	4.53125
October	1.45161	3.65625	3	1.06865	1.15152
November	0.48387	1.03125	1.03448	0.6566	0.4375
December	0.64516	0.3125	0.78571	0.96875	0.75

Table – 5.1: Continuation (4)
Expected Number of Rainy Days

Month	Estimated Value				
	Panjim	**Patna**	**Pondicherry**	**Port Blair**	**Pune**
January	0.1	1.4	1.06667	1.66667	0.12121
February	0.03333	1.2069	0.6	1	0.15152
March	0.03333	0.93103	0.6	1.03226	0.24242
April	0.46667	1	0.33333	4.22581	0.87879
May	3.13333	2.93333	1.62069	15.9355	2.30303
June	21.3333	6.33333	2.7	18.3871	9
July	26.2	14.3793	4.86667	18.871	12.2121
August	24.0667	12.6897	6.36667	18.3226	9.39394
September	12.3667	10	6.16667	17.9677	7.36364
October	5.8	3.24138	9.73333	14.7742	4.45455
November	2.33333	0.33333	11.1	12.4194	1.48485
December	0.2	0.51724	6.36667	4.32258	0.39394

Table – 5.1: Continuation (5)
Expected Number of Rainy Days

Month	Estimated Value				
	Shillong	**Tezpur**	**Trivandrum**	**Udaipur**	**Varanasi**
January	1.5	1.48148	1	0.3	1.19475
February	2.10714	1.92857	1.43333	0.35484	1.23886
March	3.96429	3.96429	2.33333	0.12903	0.7274
April	8.60714	10.5862	6.56667	0.56667	0.66171
May	15.8214	12.5517	9.73333	1.3	1.11916
June	18.8214	15.1379	16.3333	4.76667	1.92783
July	18.3214	16.4138	13.4333	8.17241	2.74743
August	15.4643	13.1379	10.2333	9.89655	2.74106
September	16.4286	11.8621	8.9	5.07143	2.5451

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October	8.32143	5.65517	11.5333	1.53571	1.4157
November	2.61538	1.60714	9.23333	0.68966	0.75222
December	1.26923	1.18519	4.33333	0.24138	0.78256

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Dr. Dhritikesh Chakrabarty passed B.Sc. (with Honours in Statistics) Examination from Darrang College, Gauhati University, in 1981 securing 1st class &1st position. He passed M.Sc. Examination (in Statistics) from the same university in the year 1983 securing 1st class & 1st position and successively passed M.Sc. Examination (in Mathematics) from the same university in 1987 securing 1st class (5th position). He obtained the degree of Ph.D. (in Statistics) in the year 1993 from Gauhati University. Later on, he obtained the degree of Sangeet Visharad (inVocal Music) in the year 2000 from Bhatkhande Sangeet vidyapith securing 1st class, the degree of Sangeet Visharad (in Tabla) from Pracheen Kala Kendra in 2010 securing 2nd class, the degree of Sangeet Pravakar (in Tabla) from Prayag Sangeet Samiti in 2012 securing 1st class, the degree of Sangeet Bhaskar (in Tabla) from Pracheen Kala Kendra in 2014 securing 1st class and Sangeet Pravakar (in Guitar) from Prayag Sangeet Samiti in 2021 securing 1st class. He obtained Jawaharlal Nehru Award for securing 1st position in Degree Examination in the year 1981. He also obtained Academic Gold Medal of Gauhati University and Prof. V. D. Thawani Academic Award for securing 1st position in Post Graduate Examination in the year 1983.
Dr. Dhritikesh Chakrabarty also did post doctoral research under the Post Doctoral Research Award by the University Grants Commission for the period 2002 – 05.

(Dr. Dhritikesh Chakrabarty, 2nd from the left, (with from the left Scientist (F) Sri Sunit Das, Dr. Dhritikesh Chakrabarty, Scienticic Assistant Ms Anamika Sarma, Professor Minakshi Devi, Scientist (G) Sri K. N. Mohan & Scientist (F) Dr. Sanjay O'Neill Shaw respectively) in the campus of Regional Meteorological Centre at Guwahati on October 17, 2023.)

He attended five of orientation/refresher course held in Gauhati University, Indian Statistical Institute, University of Calicut and Cochin University of Science & Technology sponsored/organized by University Grants Commission/Indian Academy of Science. He also attended/participated eleven workshops/training programmes of different fields at various institutes.

Dr. Dhritikesh Chakrabarty, currently an independent researcher, served Handique Girls' College, Gauhati University, during the period of 34 years from December 09, 1987 to December 31, 2021, as Professor (first Assistant and then Associate) in the Department of Statistics along with Head of the Department for 9 years and also as Vice Principal of

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the college. He also served the National Institute of Pharmaceutical Education & Research (NIPER) Guwahati, as guest faculty (teacher cum research guide), during the period from May, 2010 to December, 2016. Moreover, he is a Research Guide (Ph.D. Guide) in the Department of Statistics of Gauhati University and also a Research Guide (Ph.D. Guide) in the Department of Statistics of Assam Down Town University. He has been guiding a number of Ph.D. students in the two universities. He acted as Guest Faculty in the Department of Statistics and also in the Department of Physics of Gauhati University. He also acted as Guest Faculty cum Resource Person in the Ph.D. Course work Programme in the Department of Computer Science and also in the Department of Biotechnology of the same University for the last six years. Dr. Chakrabarty has been working as an independent researcher for the last more than thirty years. He has already been an author of 260 published research items namely research papers, chapter in books / conference proceedings, books etc. He visited U.S.A. in 2007, Canada in 2011, U.K. in 2014 and Taiwan in 2017. He has already completed one post doctoral research project (2002 – 05) and one minor research project (2010 – 11). He is an active life member of the academic cum research organizations namely (1) Assam Science Society (ASS), (2) Assam Statistical Review (ASR), (3) Indian Statistical Association (ISA), (4) Indian Society for Probability & Statistics (ISPS), (5) Forum for Interdisciplinary Mathematics (FIM), (6) Electronics Scientists & Engineers Society (ESES) and (7) International Association of Engineers (IAENG). Moreover, he is a Reviewer/Referee of (1) Journal of Assam Science Society (JASS) & (2) Biometrics & Biostatistics International Journal (BBIJ); a member of the executive committee of Electronic Scientists and Engineers Society (ESES); and a Member of the Editorial Board of (1) Journal of Environmental Science, Computer Science and Engineering & Technology (JECET), (2) Journal of Mathematics and System Science (JMSS) & (3) Partners Universal International Research Journal (PUIRJ). Dr. Chakrabarty acted as members (at various capacities) of the organizing committees of a number of conferences/seminars already held.

Dr. Chakrabarty was awarded with the prestigious SAS Eminent Fellow Membership (SEFM) with membership ID No. SAS/SEFM/132/2022 by Scholars Academic and Scientific Society (SAS Society) on March 27, 2022.

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