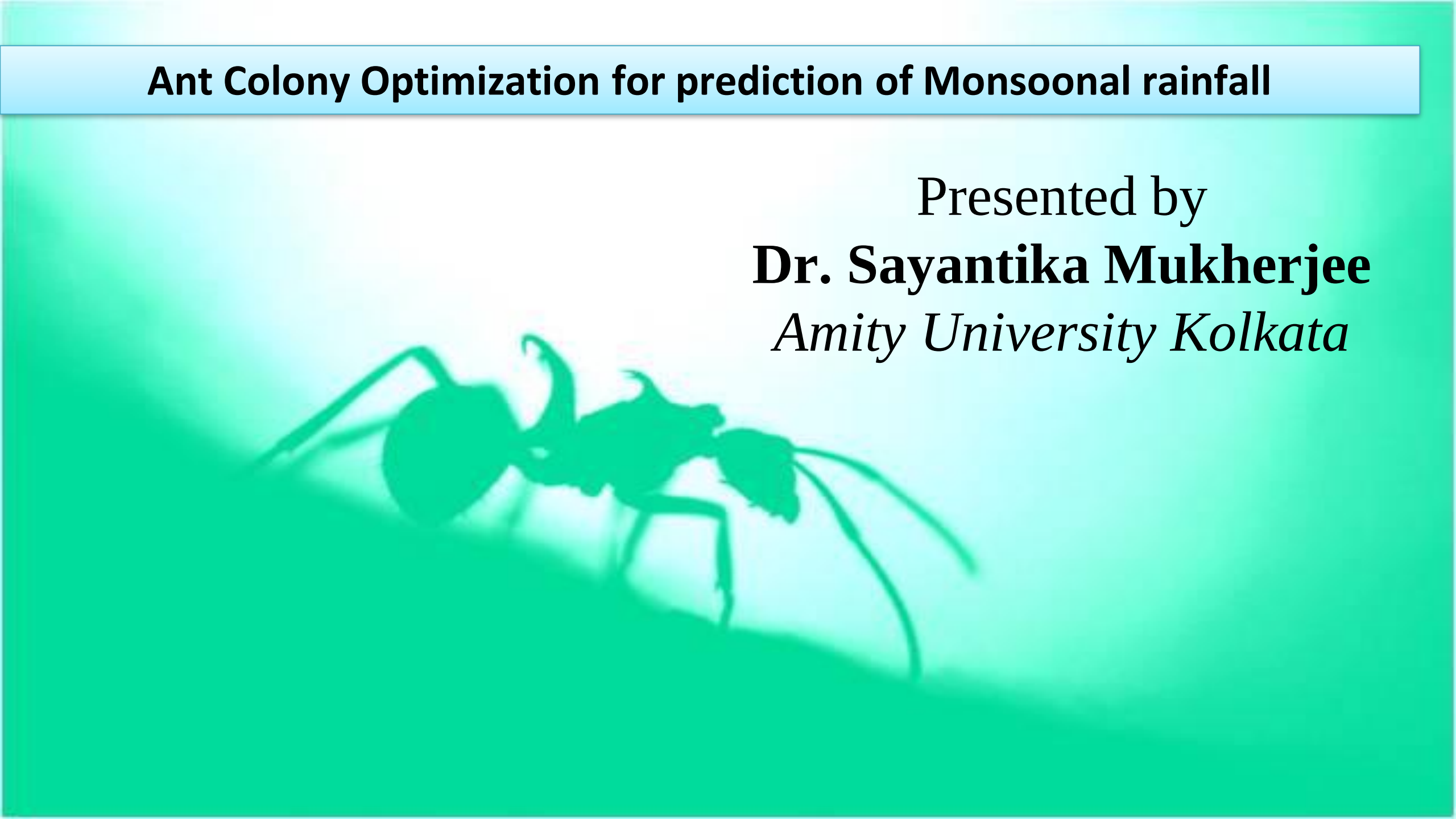
Ant Colony Optimization for prediction of Monsoonal rainfall



Presented by

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Introduction

Indian summer monsoon is a key component of the climate system, both in regards to its strong interaction with other modes of variability and its enormous socioeconomic impacts

Forecasting summer monsoon rainfall with precision becomes crucial for the farmers to plan for harvesting in a country like India where the national economy is mostly based on regional agriculture.

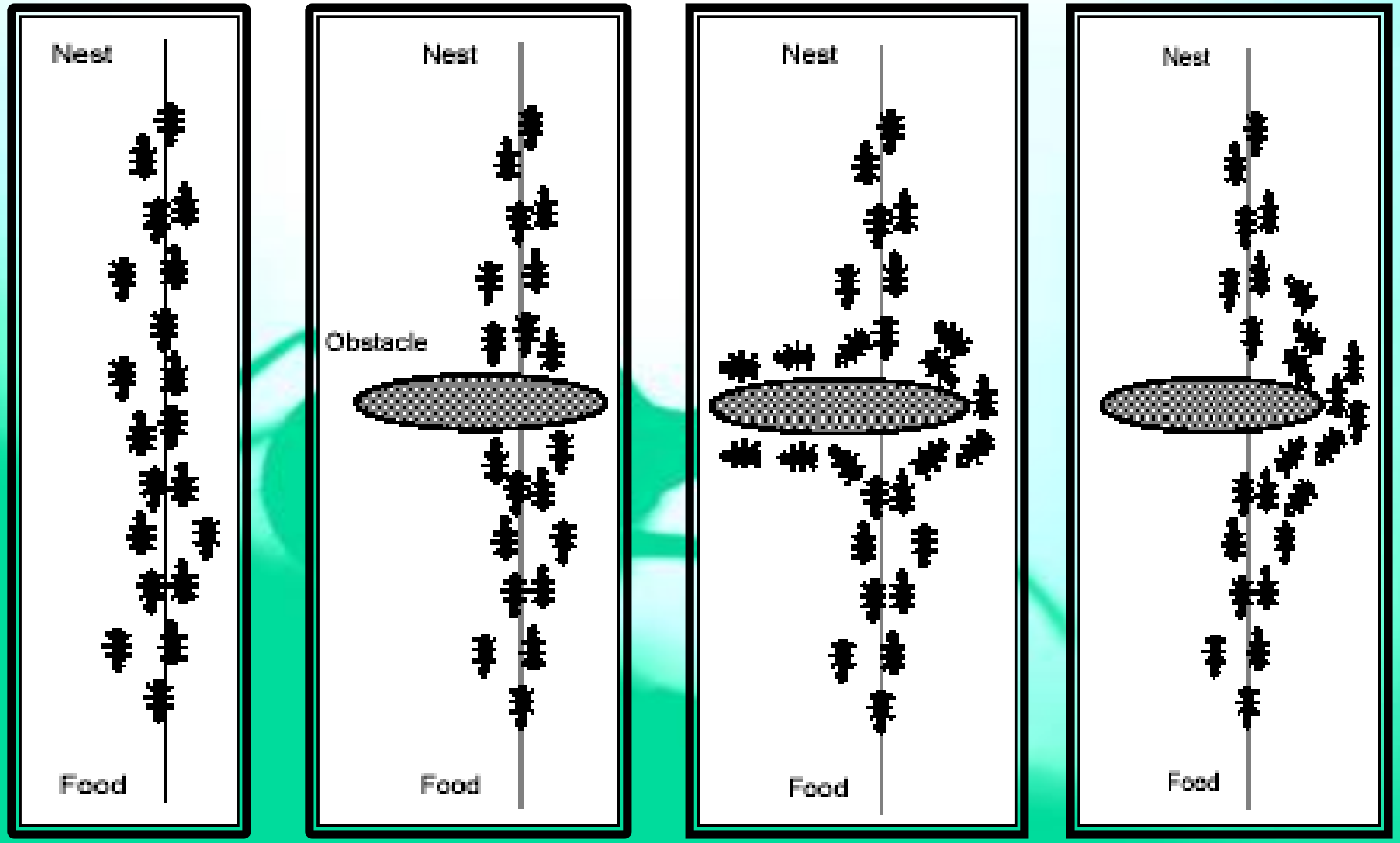
Objectives

In the present study the ACO technique is implemented in forecasting the amount of summer monsoon rainfall over Kolkata, India. The conventional statistical Markov Chain model (MCM) is utilized to assess the skill of the ACO technique.

Data

The record and data of summer monsoon rainfall are collected from regional meteorological centre (RMC), Kolkata, India during the period from 1998 to 2007 on daily temporal scale for the months of June, July, August and September (JJAS) for the present study. The record and data from 2008 to 2015 are utilized for validation of the result.

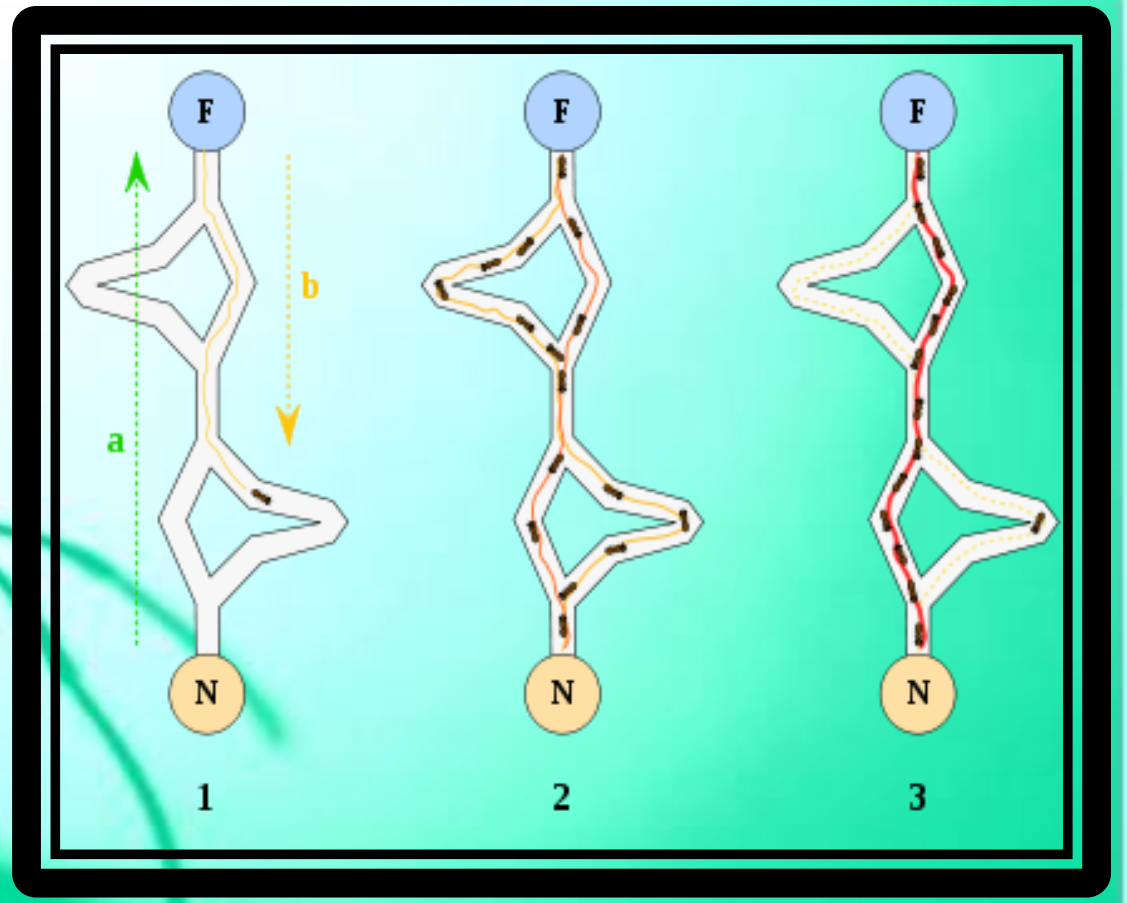
Natural behavior of ant



Ant Colony Optimization

The original idea comes from observing the exploitation of food resources among ants, in which ants' individually limited cognitive abilities have collectively been able to find the shortest path between a food source and the nest.

- **The first ant finds the food source (F), via any way (a), then returns to the nest (N), leaving behind a trail pheromone**
- **Ants indiscriminately follow four possible ways, but the strengthening of the runway makes it more attractive as the shortest route.**
- **Ants take the shortest route, long portions of other ways lose their trail pheromones.**



Methodology -Ant Colony Optimization

The ACO technique belongs to swarm intelligence and simulates the decision-making processes of ant colony similar to other adaptive learning techniques. ACO technique takes inspiration from the foraging behaviour of some ant species. The ants deposit pheromone on the ground in order to mark a favourable path that should be followed by other members of the colony.

It has been established from the double - bridge experiment that the concentration of pheromone deposition is inversely proportional to the path length between the nest and the food-source, which is mathematically represented as:

$$\Delta\tau_{ij}^{k} = \frac{1}{L_k}$$

The amount of pheromone deposition if ant k, travel on edge i, j.
L_k = the path length = (ant hill value - critical value).

Goss et al. (1989) developed a model of the observed behaviour assuming that at a given moment in time m_1 ants have used the first bridge and m_2 the second one, the probability p_1 for an ant to choose the first bridge is:

$$p_1 = \frac{(m_1 + k)h}{(m_1 + k)h + (m_2 + k)h}$$

$$P_2 = 1 - P_1$$

Where parameters k and h are to be fitted to the experimental data.
Monte Carlo simulations showed a very good fit for k ≈20 and h≈ 2

Markov Chain Model

The simplest kind of discrete random variable pertaining to dichotomous (yes / no) forecast is made through the Markov chain model (MCM). A two state MCM is a statistical model for the persistence of binary events. The occurrence or non occurrence of summer monsoon rainfall on a given day is a simple meteorological example of a binary random event.

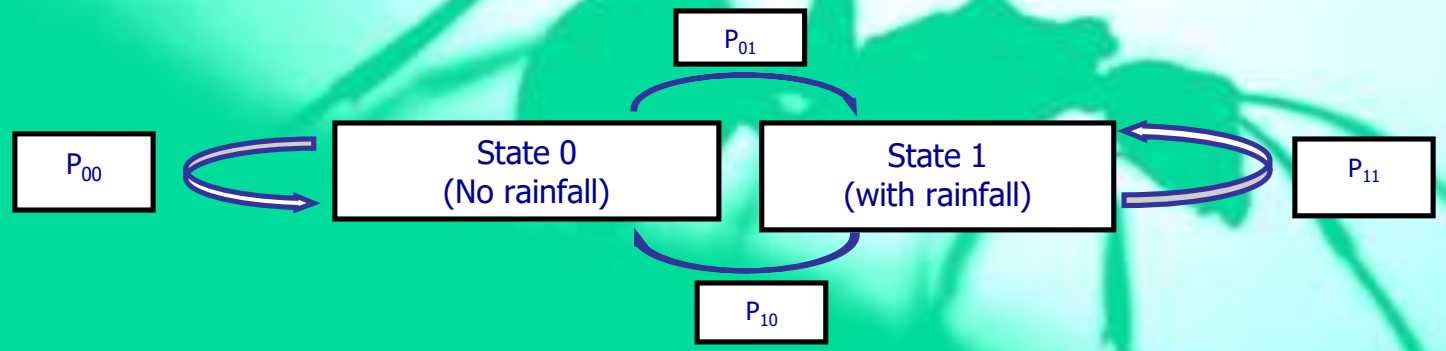


Figure 1 Two states, first order Markov Chain Model

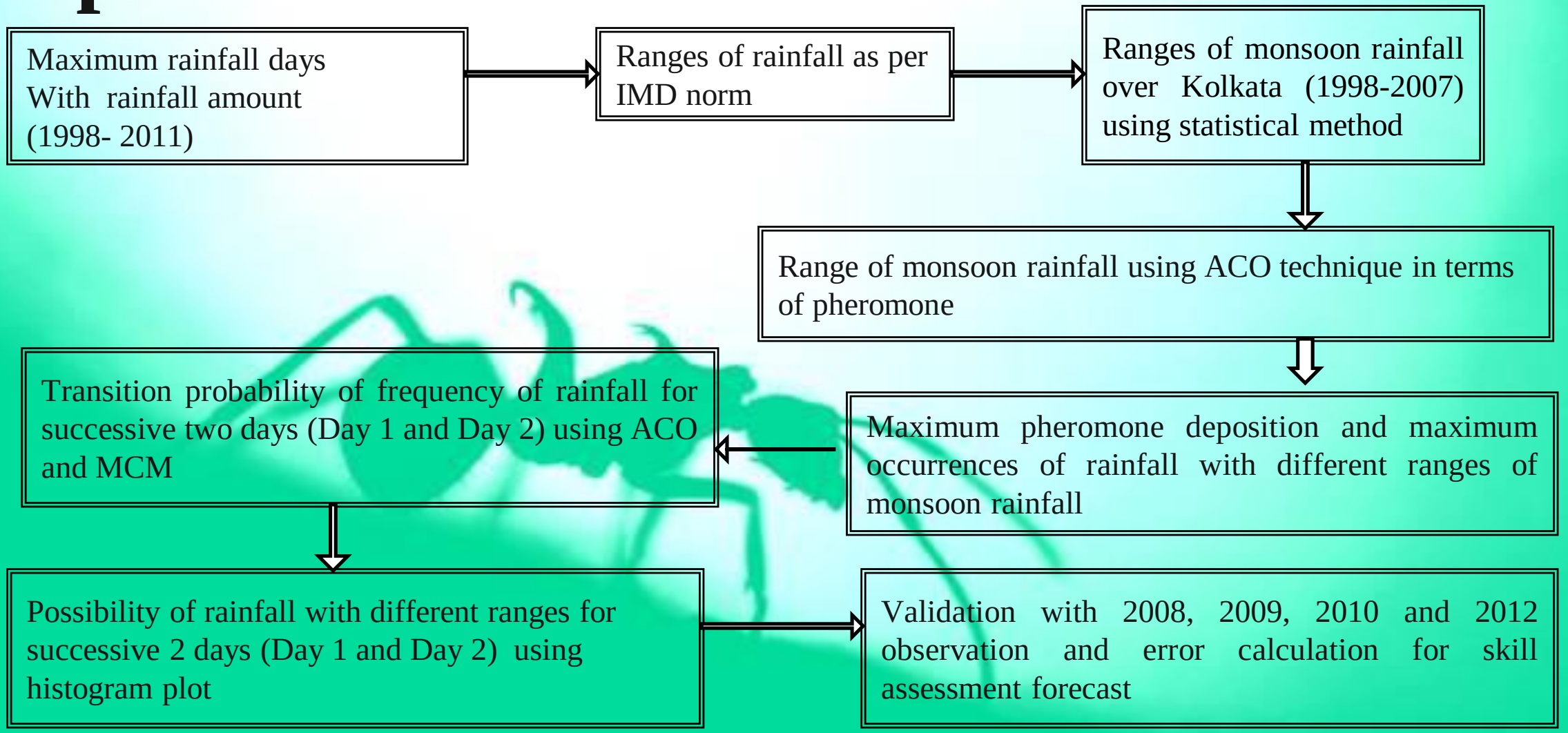
$$P_{00} + P_{01} = 1$$

$$P_{10} + P_{11} = 1$$

$$P_{01} = \frac{n_{01}}{n_{0\cdot}} = \frac{n_{01}}{n_{00} + n_{01}}$$

$$P_{11} = \frac{n_{11}}{n_{1\cdot}} = \frac{n_{11}}{n_{10} + n_{11}}$$

Implementation



Results

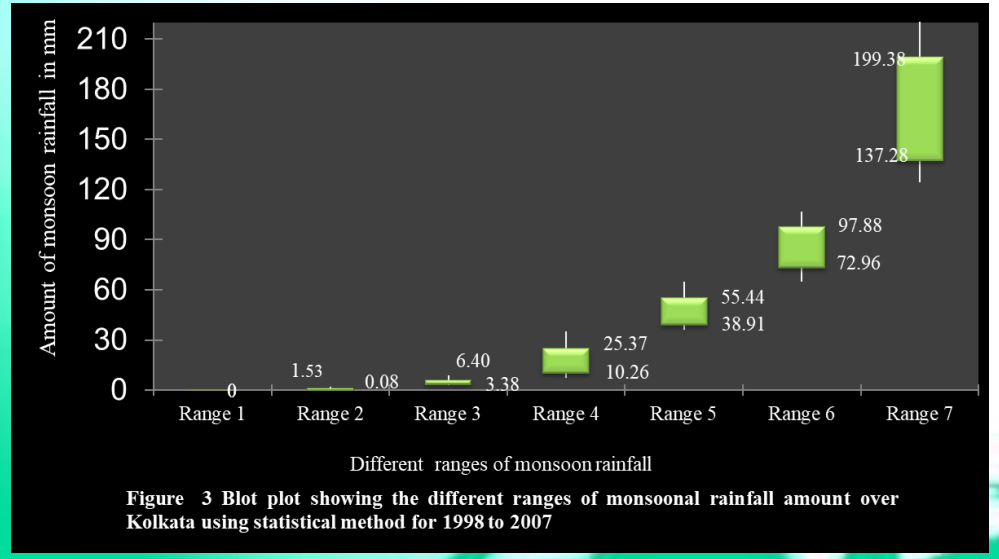


Figure 3 Blot plot showing the different ranges of monsoonal rainfall amount over Kolkata using statistical method for 1998 to 2007

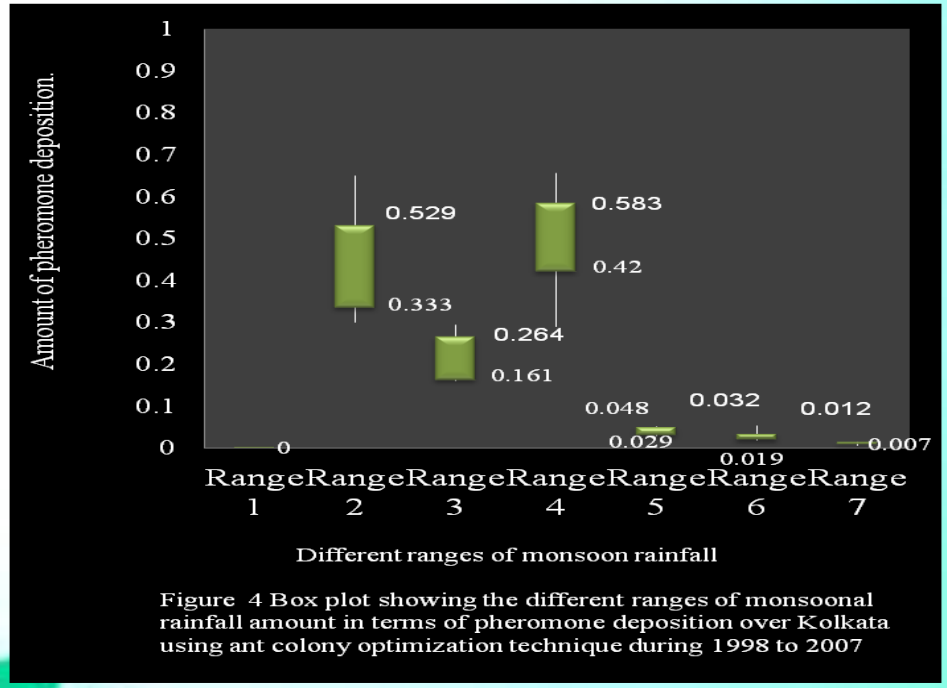


Figure 4 Box plot showing the different ranges of monsoonal rainfall amount in terms of pheromone deposition over Kolkata using ant colony optimization technique during 1998 to 2007

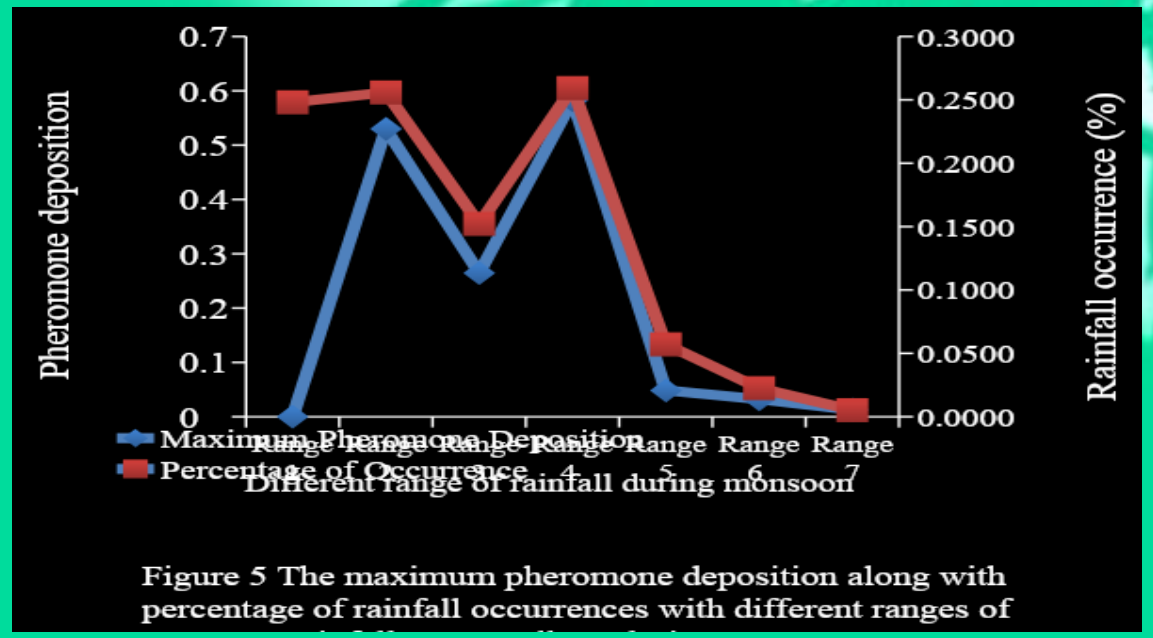


Figure 5 The maximum pheromone deposition along with percentage of rainfall occurrences with different ranges of

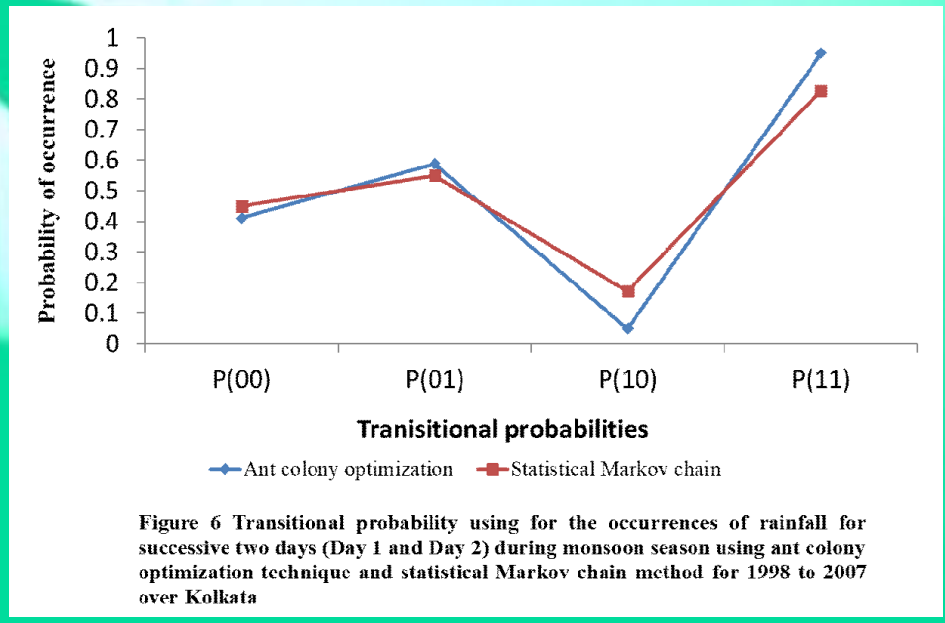
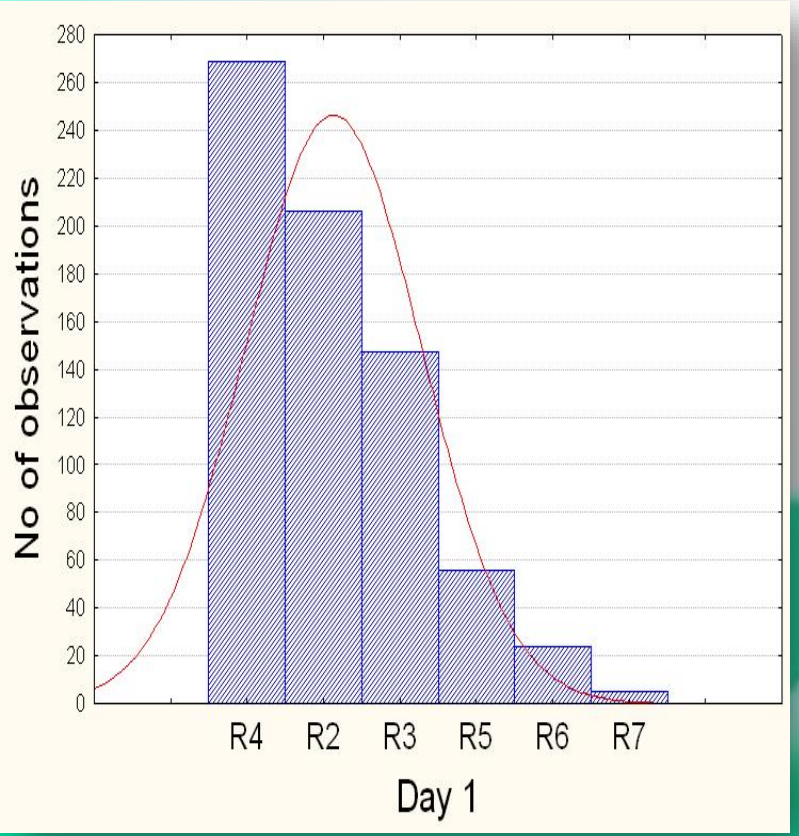
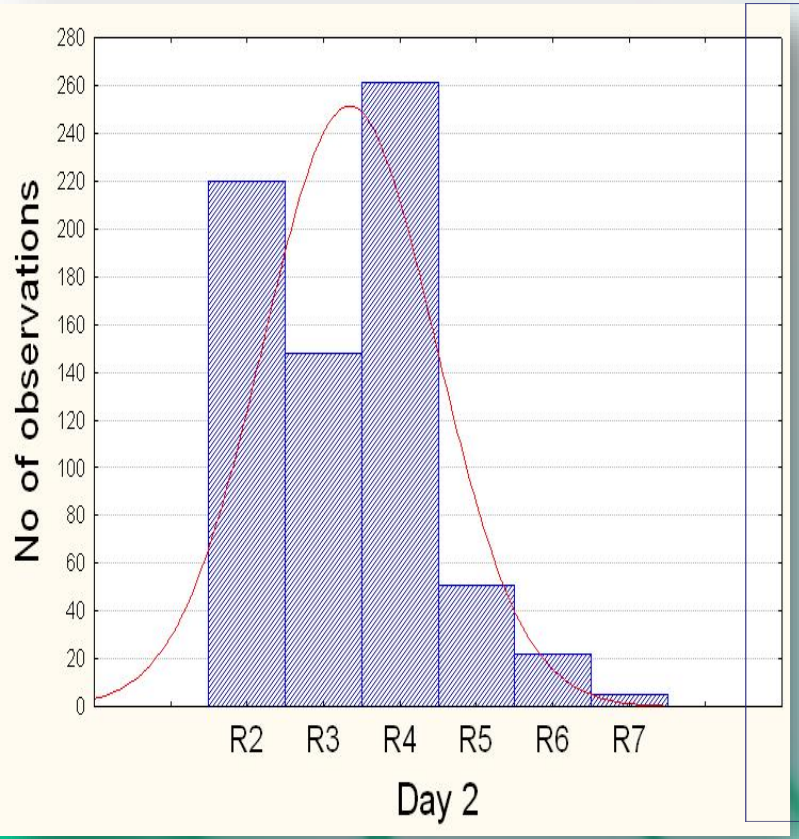
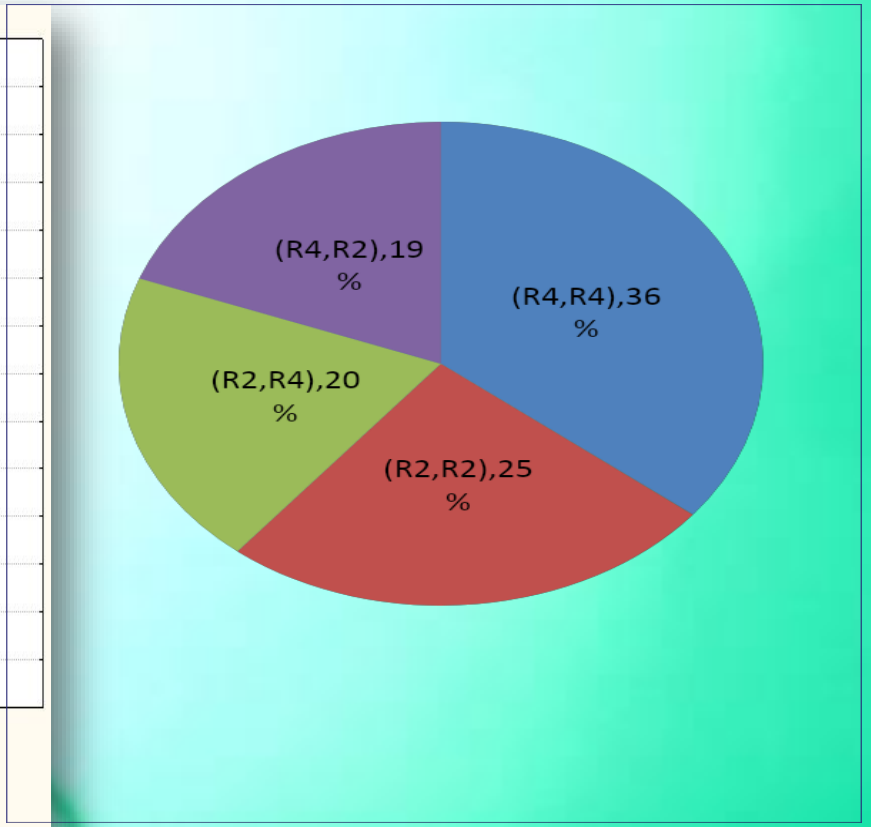


Figure 6 Transitional probability using for the occurrences of rainfall for successive two days (Day 1 and Day 2) during monsoon season using ant colony optimization technique and statistical Markov chain method for 1998 to 2007 over Kolkata

Results

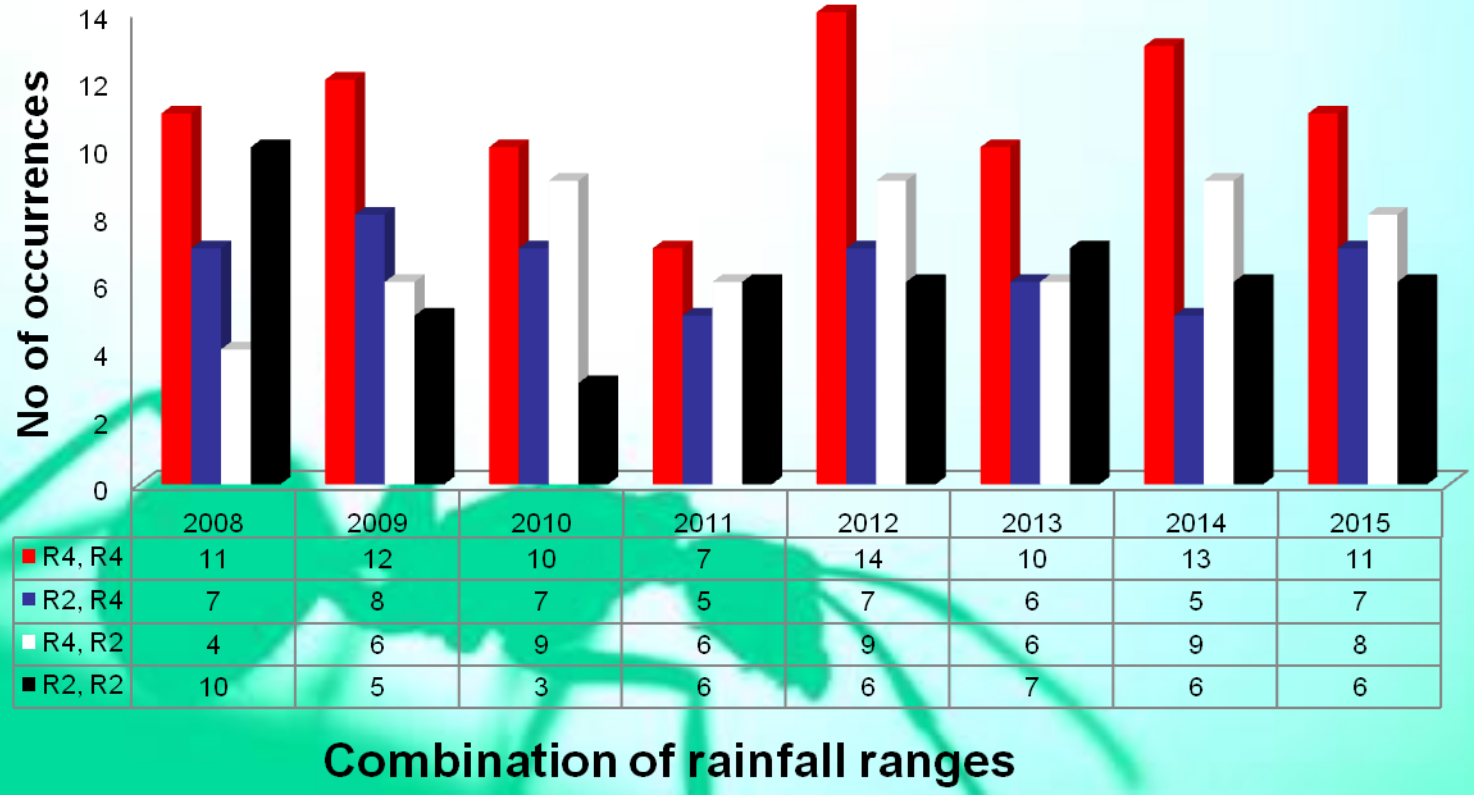






The diagram showing the maximum occurrences of rainfall in (a) Day 1 and (b) Day 2 in histogram plot and (c) maximum occurrences of rainfall with different combinations using range 4 and range 2 throughout the summer monsoon season over Kolkata during 1998 to 2007

Validation



	2008	2009	2010	2011	2012	2013	2014	2015
R4, R4	11	12	10	7	14	10	13	11
R2, R4	7	8	7	5	7	6	5	7
R4, R2	4	6	9	6	9	6	9	8
R2, R2	10	5	3	6	6	7	6	6

The diagram validation the most dominating combination of the amount of rainfall for consecutive two days (Day 1 and Day 2) is (R4,R4) in the year 2008 to 2015 throughout the monsoon season (JJAS) over Kolkata

Validation

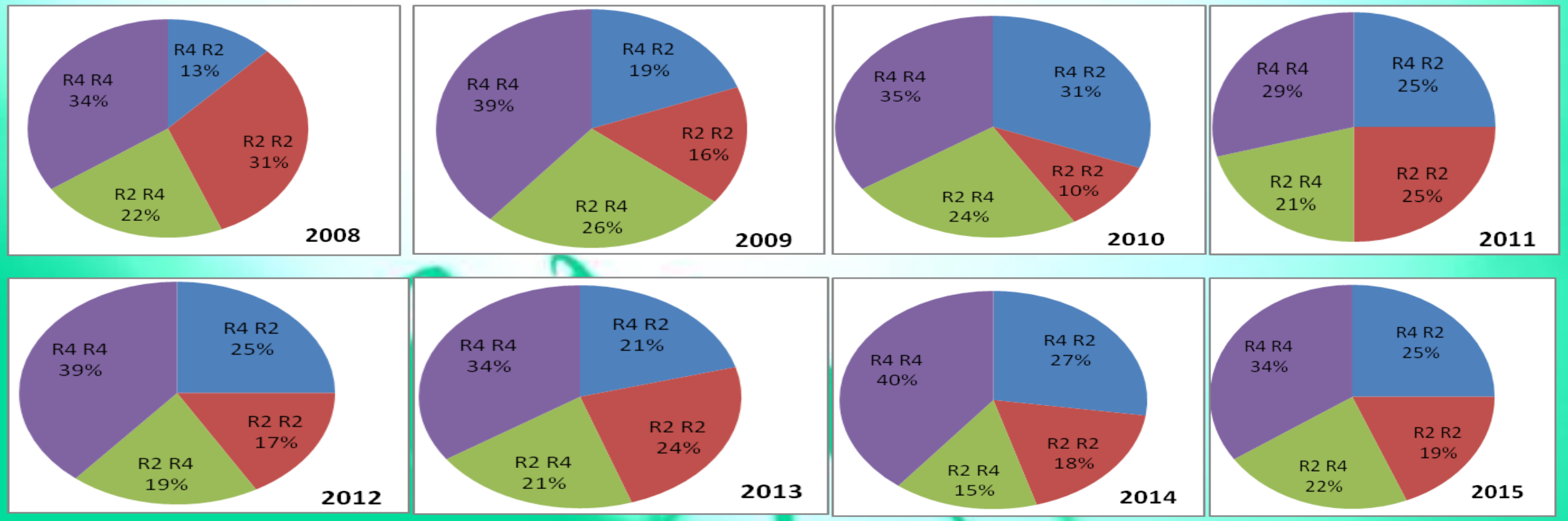
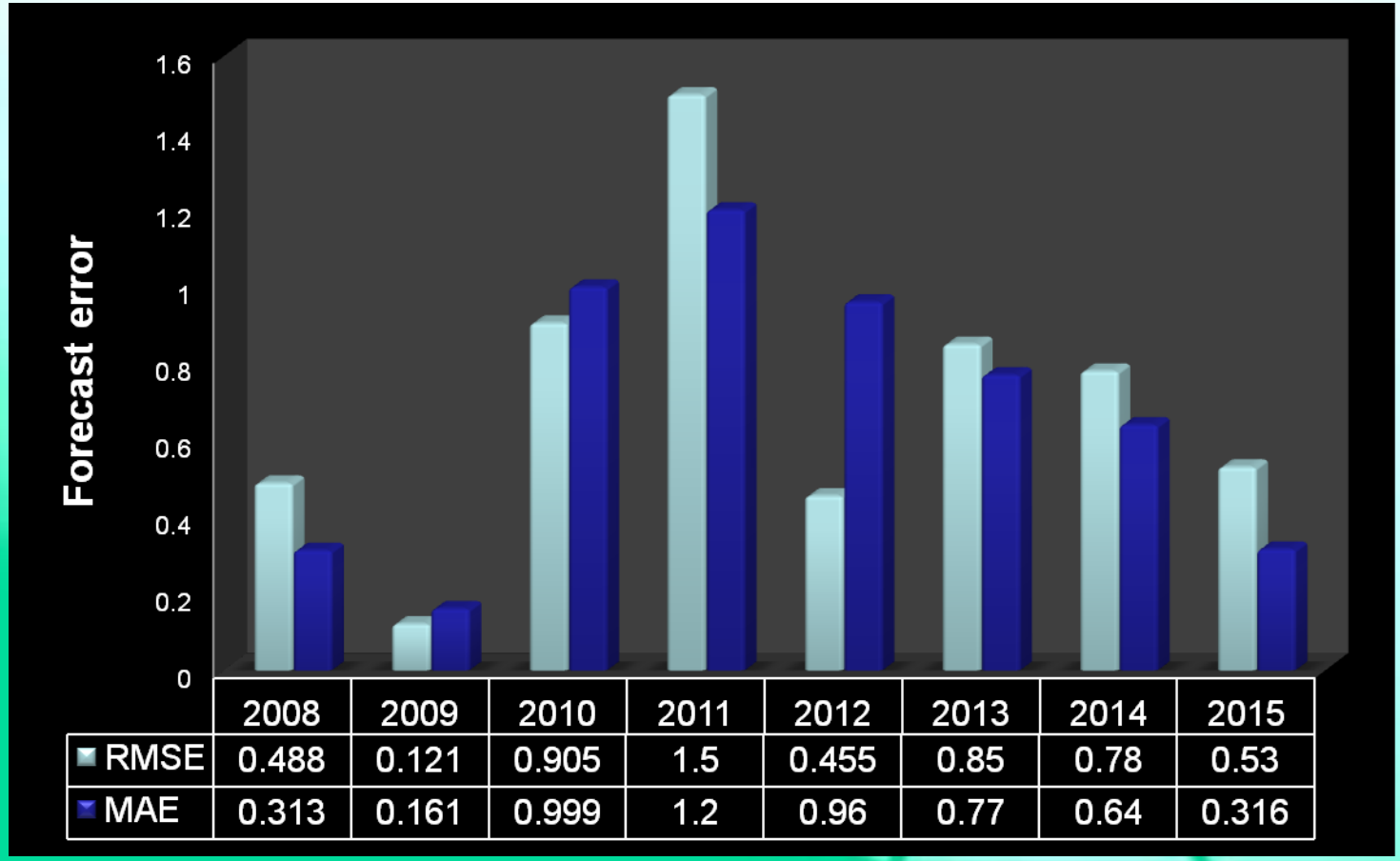


Figure The diagram validating the most dominating combination of amount of rainfall for consecutive two days (R4, R4) from 2008 to 2015 throughout the monsoon season (JJAS) over Kolkata

Validation



	2008	2009	2010	2011	2012	2013	2014	2015
RMSE	0.488	0.121	0.905	1.5	0.455	0.85	0.78	0.53
MAE	0.313	0.161	0.999	1.2	0.96	0.77	0.64	0.316

Different error matrices in predicting the maximum occurrences of the most dominating combination of rainfall amount (R4,R4) of monsoon rainfall over Kolkata during 2008 to 2015

Comparison of present study with other existing models/ methods

	Error
Markov Chain Model (MCM) **Little et al. (2009)**	MAE -1.9
Stochastic model (SM) forecast **(Sanso and Guenni 1999)**	MAD→17.38 to 18.48
Artificial neural network (ANN), a five-neural network architectures Model forecast **(Singh and Borah 2013)**	PE→7.67
Numerical Weather Prediction model (multimodel super ensemble and operational NWP forecast **(Mishra and Krishnamurti 2007)**	RMSE→1.25 to 2.60
Ant colony optimization (ACO) model forecast (**present study**)	RMSE→0.1 to 1.5 MAE→0.16 to 1.2

Conclusions

- The most dominating range of rainfall during ISM is 10.26 to 25.37mm. The pheromone concentration on the other hand remains within the range of 0.42 – 0.58 indicating the maximum amount of pheromone deposition.
- The most dominant combination is P (1, 1).
- The probability, P (1, 1) is 0.95 and 0.83 using ant colony optimization technique and Markov chain model respectively.
- Maximum occurrences of rainfall are found to be within the categories (R4, R4).
- ACO technique, therefore, may be used as an operational model for forecasting the frequency of rainfall as well as its ranges over Kolkata during the summer monsoon season.