The Mystery Of The Namibian Fairy Circles

By Rui Wang & Hongshuo Wang

Introduction

In southern Africa, Namib Desert, the so-called “fairy circle” is a barren small circle surrounded by vegetation, ranging from 10 to 65 feet in diameter and stretching for hundreds of miles.

“Footprints of the gods”

---------- By Himba people who live in the region

Corina Tarnita's Research

Fairy circle may be a joint work of hungry termites and thirsty plants

1.plant competition

"The amount of vegetation thins or disappears at the edges of the patch, forming regular distanced gaps", Tarnita explains.

2.Termite nests

The termite burrow a large network of underground tunnels to forage for food, decimating the vegetation above them.

Collaboration

When combined together could the researchers create the entirety of the landscape.

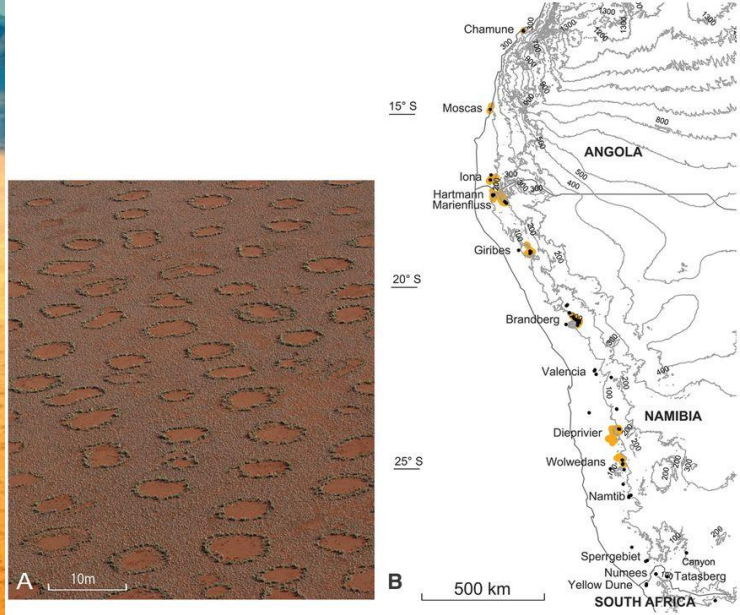
Not everyone is convinced

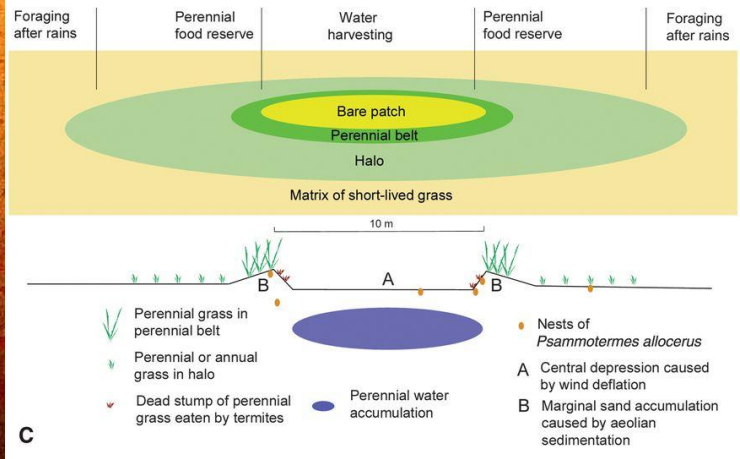
COURTESY NAMIBRAND NATURE RESERVE

"Logically, if there are fairy circles without the presence of termites, the termite theory cannot be considered as a strong explanation for the phenomenon," Stephan Getzin says.

Hyphothesis

The main driving force proposed to promote the growth of fairy circles is the competition among plants for scarce water. In addition, there are many other factors, but as a modeler, it is necessary to ignore all the complexity and just think carefully.

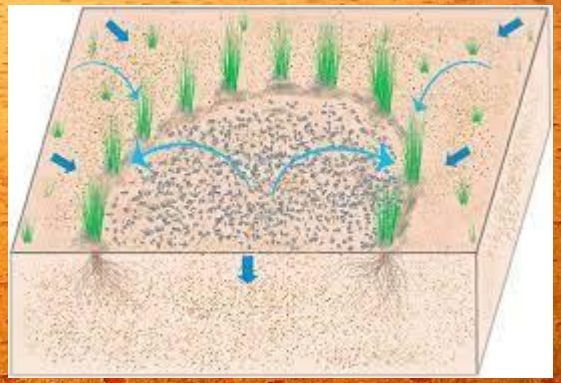




Main factor: Plant Competition

Reason:

1. low level of precipitation in the semi-arid and arid regions
2. low level of biodiversity



Conceptual framework for fairy circle development. This one
The blue straight arrow indicates that the hydrological process (infiltration and interstitial runoff) dominates during the rainy season. The curved blue arrow indicates the wind-sand process (deposition and erosion of fine sand) that dominates during the dry season.

Auxiliary factor: Termite Nests

Reason:

1. Termite Nests have impact on the formation of the fairy circle.
2. No termite nest in the central underground but a fairy circle is still formed

Model Assumption

1. There exists only two kinds of plants in our model:
   a. Strong plants vs weak plants
   b. N(Strong plants) = N(Fairy circles)
   c. N(strong plants) << N(weak plants) such as 10 vs 10000
2. each plant is represented as a dot
   a. blue for strong plants vs red for weak plants
   b. our plants are randomly distributed in some fixed region
3. modeling as proceeding in discrete steps (each step = one iteration)
4. Simulating discrete time steps by using iteration, and each plant will be assign a probability, which denotes the probability of death (the probability of a plant is removed from area after each iteration)
5. During each iteration, we are rolling a imaginary die to decide whether or not plant dies during that iteration, and after each iteration, removing all dead plants.
6. After some iterations, the fiary circles shows up.

P(S): The death probability of a strong plant

1. Assume that strong plants always has a stronger ability of absorbing water than weak plants. (always the winner during resource competition) and it has enough water resource to stay alive.
2. Termite is the only factor that kills our strong plant. We assume that a plant has less neighbour near around will be more likely attack by termite than the plants who has lots of neighbour nearby.

$$p(s) = \alpha(1.0 - \frac{N(current\ neighbours)}{N(init\ neighbours)})$$

P(W): The death probability of a weak plant

1. Neglecting the effects of termite and assume each weak plant will always has lots of neighbours around.
2. Suppose the probability of a small plant dying is inversely proportional to how far it is from the nearest strong plant.
3. Suppose the radius of circle is positive proportional to mean annual precipitation

radius threshold $r = a * 10^{-3}$

$$p(w) = 1.0 - min\,max\,scaler(||p_{strong} - p_{weak}||)$$

Formula

update P(w)

for i in N(iterations):

    for each living weak plant, based on P(w) roll a die (random.uniform(0,1)

        if p(die) <= P(w): remove the weak plant from the area

        else: continue

    update P(s)

    for each living strong plant, based on P(s) roll a die (random.uniform(0,1))

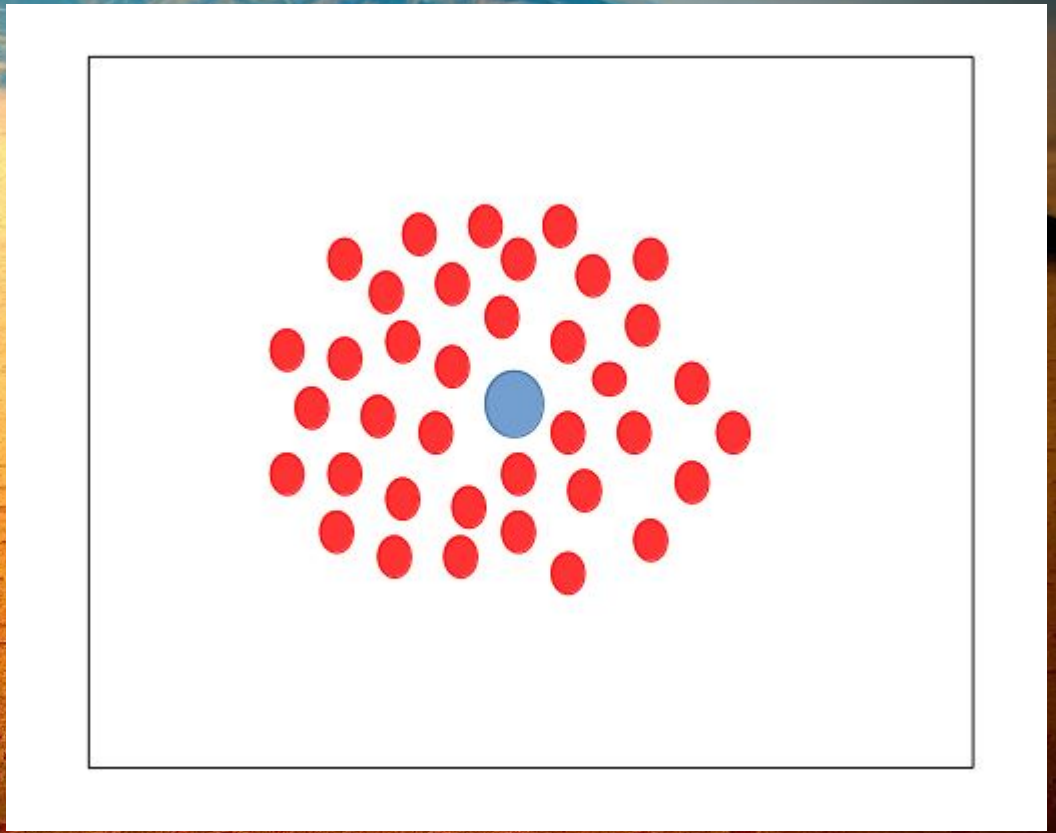
        if p(die) <= P(s): remove the strong plant form the area

        else: continue

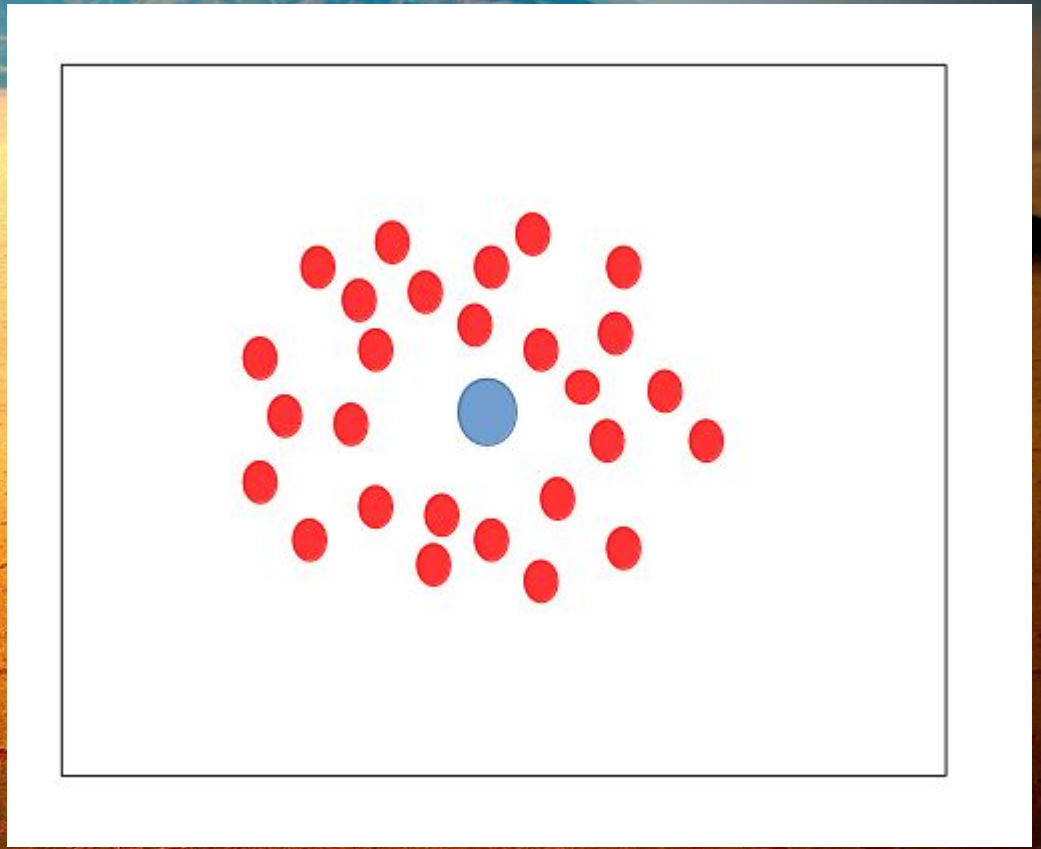
Starting state i = 0

blue: strong plant

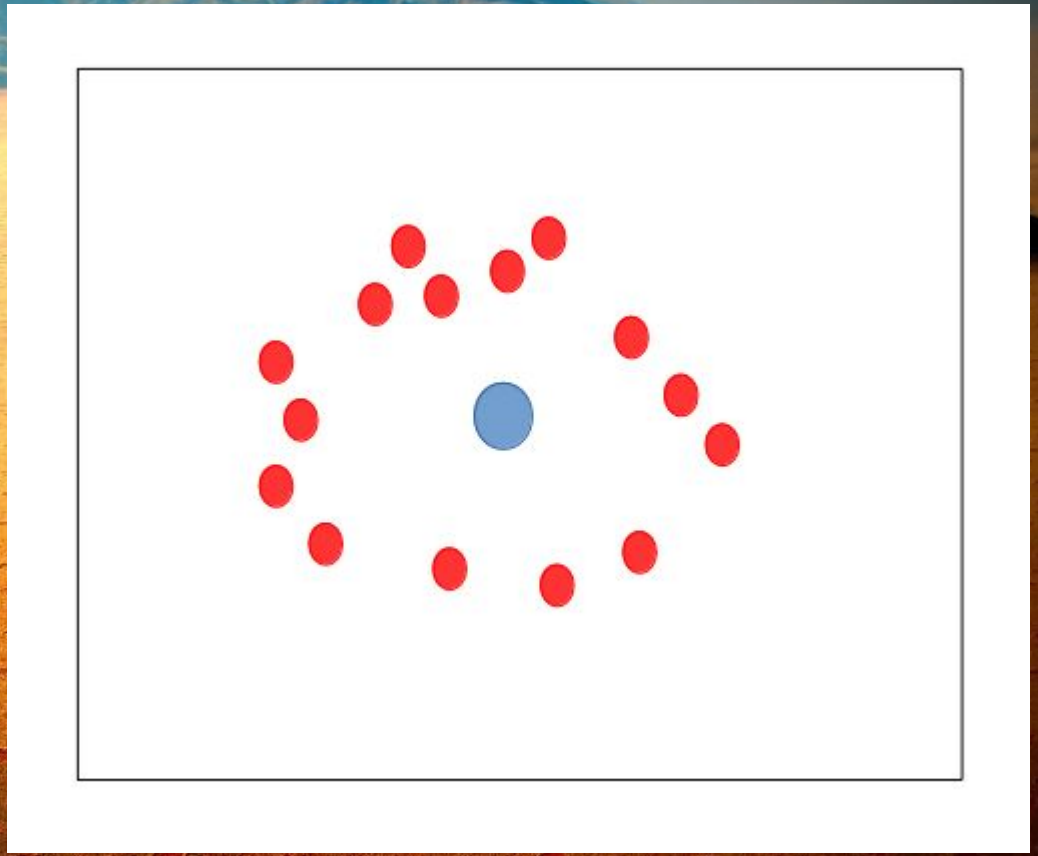
red: weak plant



i = 5

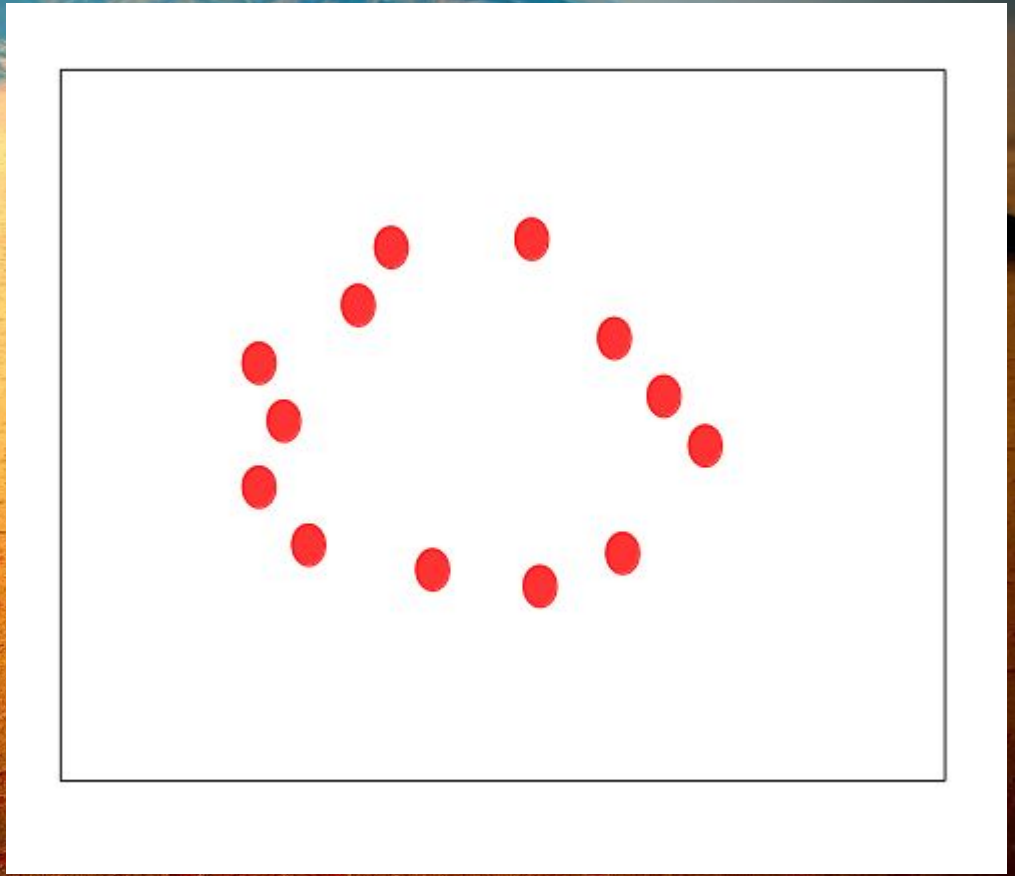


i = 20

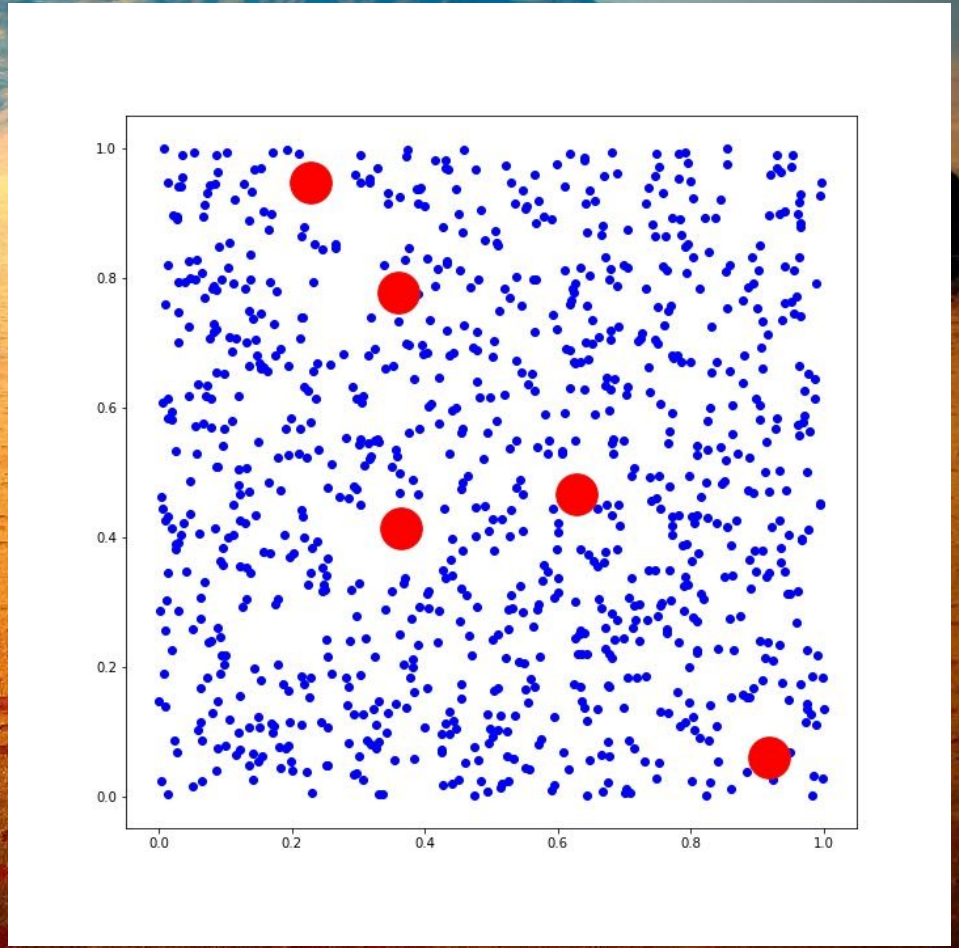


i = 100

Fairy circles



Simulating



Citation:

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Fairy circles and mathematical modeling, Part Two

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