



FROM LARGE-SCALE PATTERNS TO PLANT NUTRIENTS: REMOTE SENSING TOOLS AID IN SOLVING ECOLOGICAL PUZZLES

Efrat Sheffer

Hebrew University of Jerusalem

Smith Faculty of Agriculture, Food and Environment

GeoCradle Tel Aviv September 2017

ECOLOGY IN SPACE

- Ecology – study of organisms and interactions
- Local interactions – especially in sessile organisms
- Spatial interactions

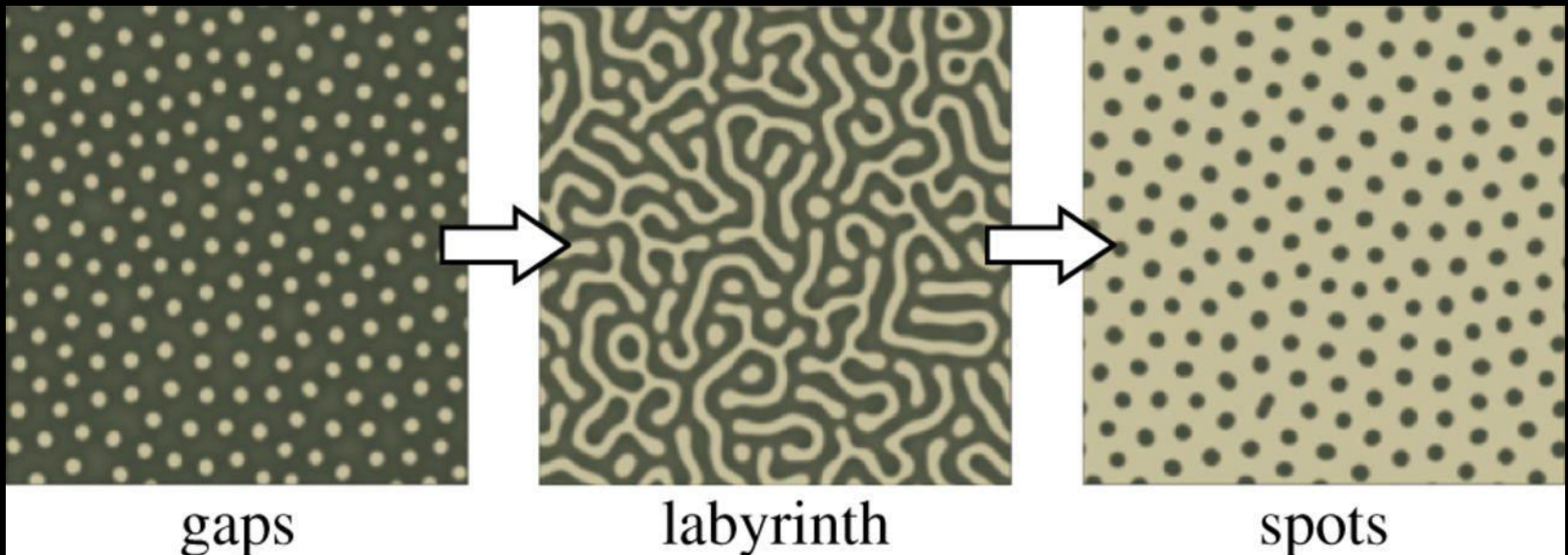
GEOMETRY OF LIFE

- To answer a spatial ecological question
 - Apparatus to capture spatial relationships
 - Analysis of outputs (images)
 - Indices to quantify spatial relationships

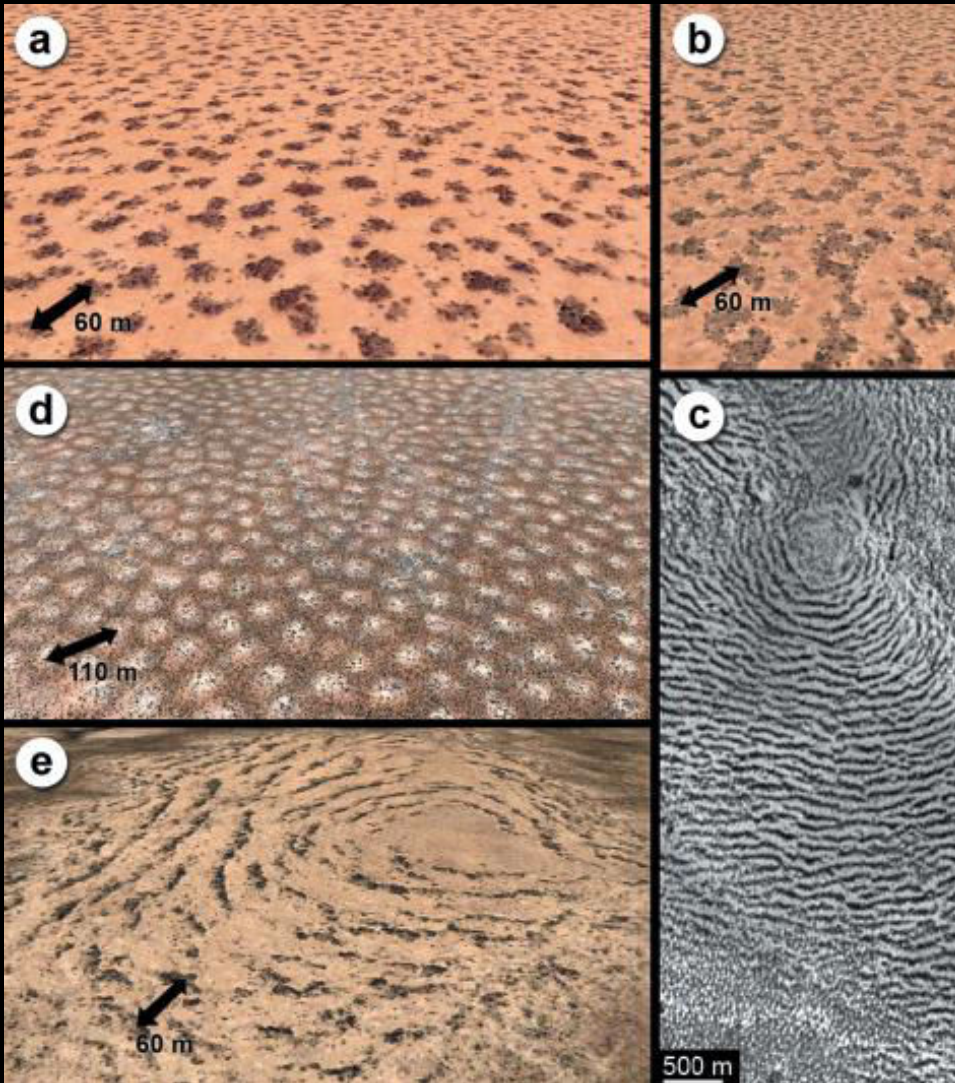
SELF ORGANIZED VEGETATION PATTERNS

- Scale-dependent feedback models predict spatial patterns in water-limited environments
- Two types of feedbacks included:
 - Short-range activation – increased water availability
 - Long-range inhibition – competition for water

Pattern changes with decreasing rainfall



SCALE-DEPENDENT SPATIAL VEGETATION PATTERNS



- Evidences of organized, repetitive spatial patterns of vegetation: spots, stripes, gaps
- Attributed to self-organization due to plant-soil-water (resource) interactions

BUT

- But #1 – in most cases vegetation is not organized – so when should it be?
- But #2 – Does it really indicate plant self-organization?

From Deblauwe et al. 2008

BUT #1 – MOST VEGETATION IS NOT ORGANIZED

Geomorphologic
template (soil-
rock)

Soil patch:Plant
size ratio

- How many
plants interact/
self-organize in
a soil patch

Sarcopoteium shrub

Poa bulbosa grass

Scale is
fundamental

MY FIRST REMOTE SENSING DEVICE

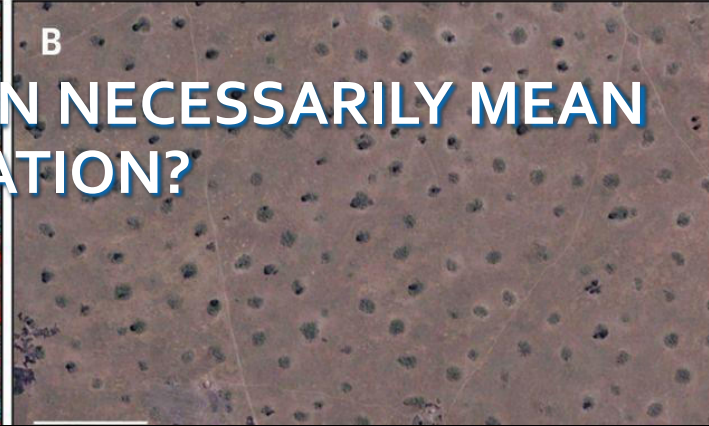
- Capture vegetation pattern at the appropriate scale



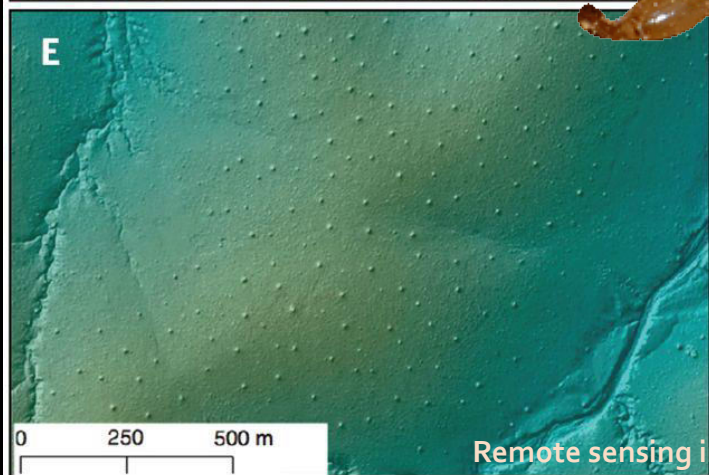
with Moshe Shachak & Ehud Meron



A **BUT #2 – DOES PATTERN NECESSARILY MEAN**
PLANT SELF-ORGANIZATION?



Termite mounds underlie all these vegetation patches



Remote sensing in ecological studies

Bonachela et al.
2015

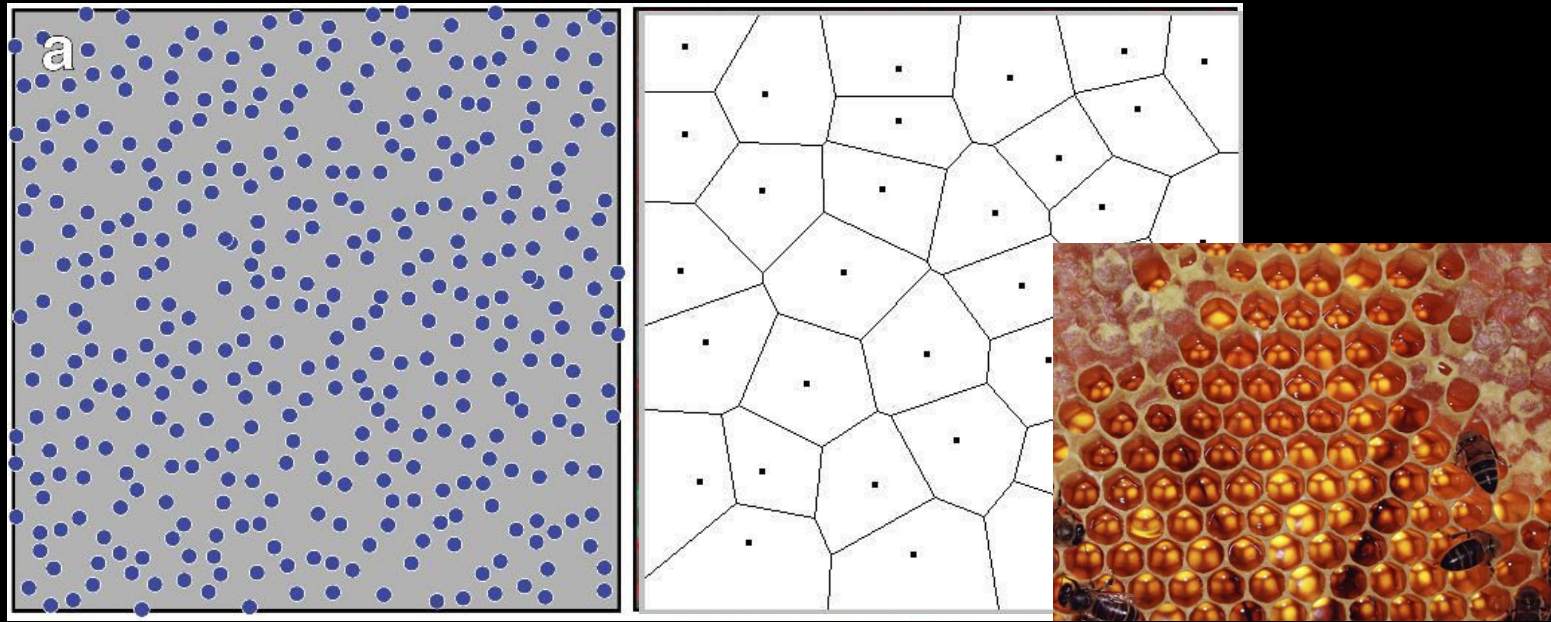
WHY WOULD TERMITE ACTIVITY FORM A PATTERN?

Basic rules of insect colony behavior:

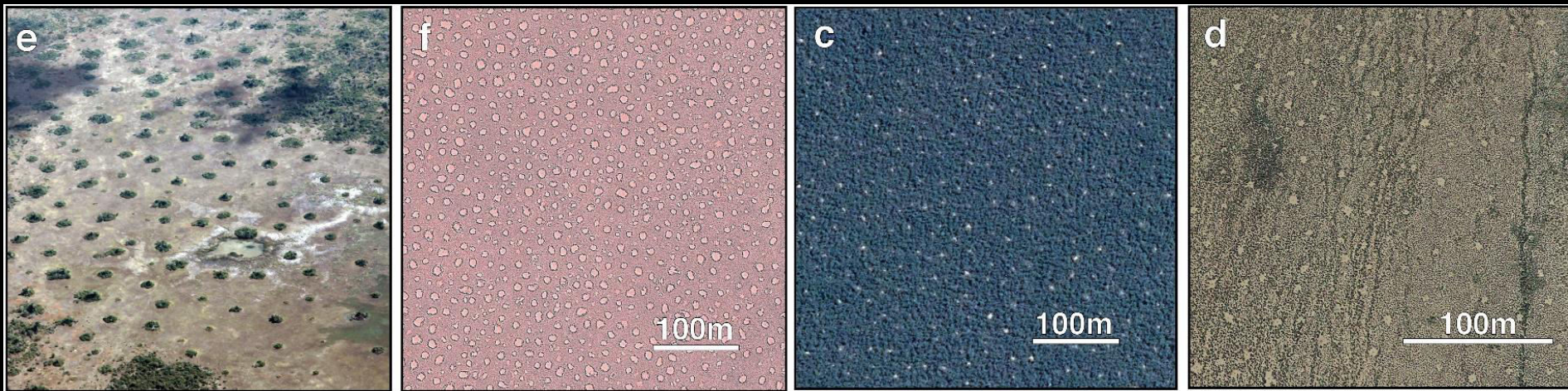
- Alates can form new colonies anywhere
- Colonies grow according to resource availability
- Individuals forage around the nest of the colony
- A conflict arises at the meeting point of two colonies
- In a conflict – a larger colony always wins
- A boundary will form in a conflict between two similar colonies

Tarnita et al. 2017

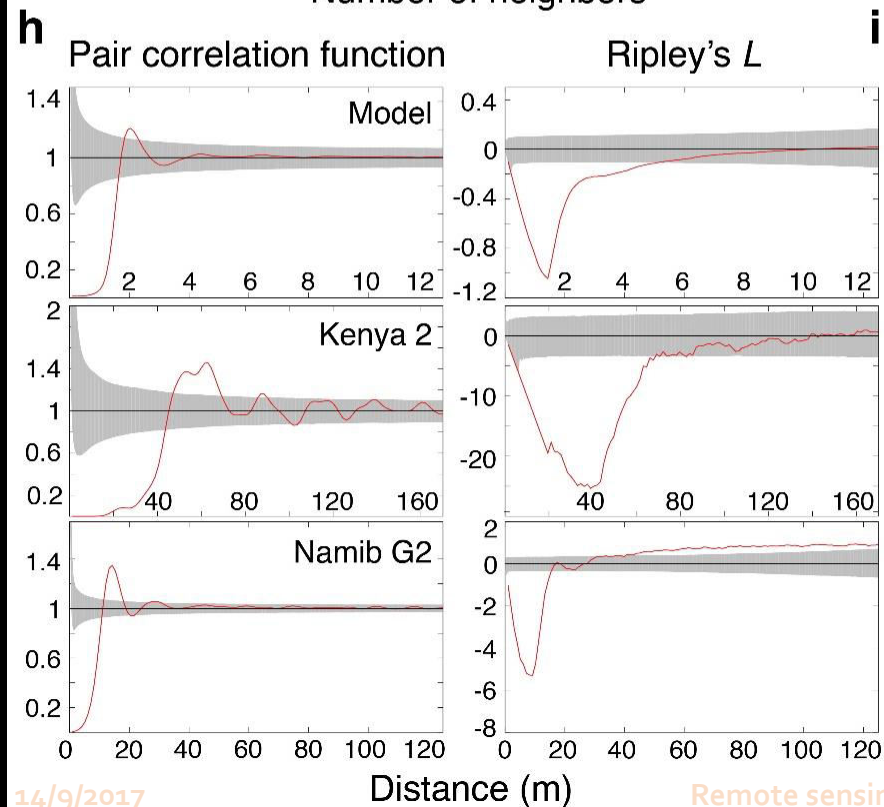
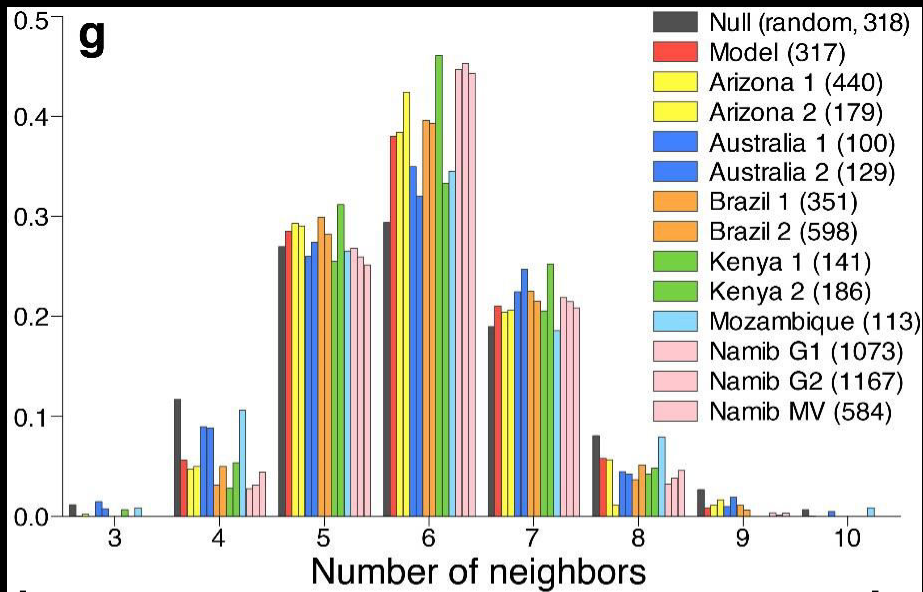
TERMITE MOUNDS FROM A SPOT PATTERN



Tarnita et al. 2017



with Corina Tarnita, Juan Bonachela, Ryan Long, J. Guyton, T. Coverdale & Rob Pringle



- Each colony has 5.99 neighbors
- Colonies are over-dispersed
- The spatial organization of model termites resembles that from field sites
- Spatial organization differs from random

Tarnita et al. 2017

FAIRY CIRCLES



JEN GUYTON/JENGUYTON.COM



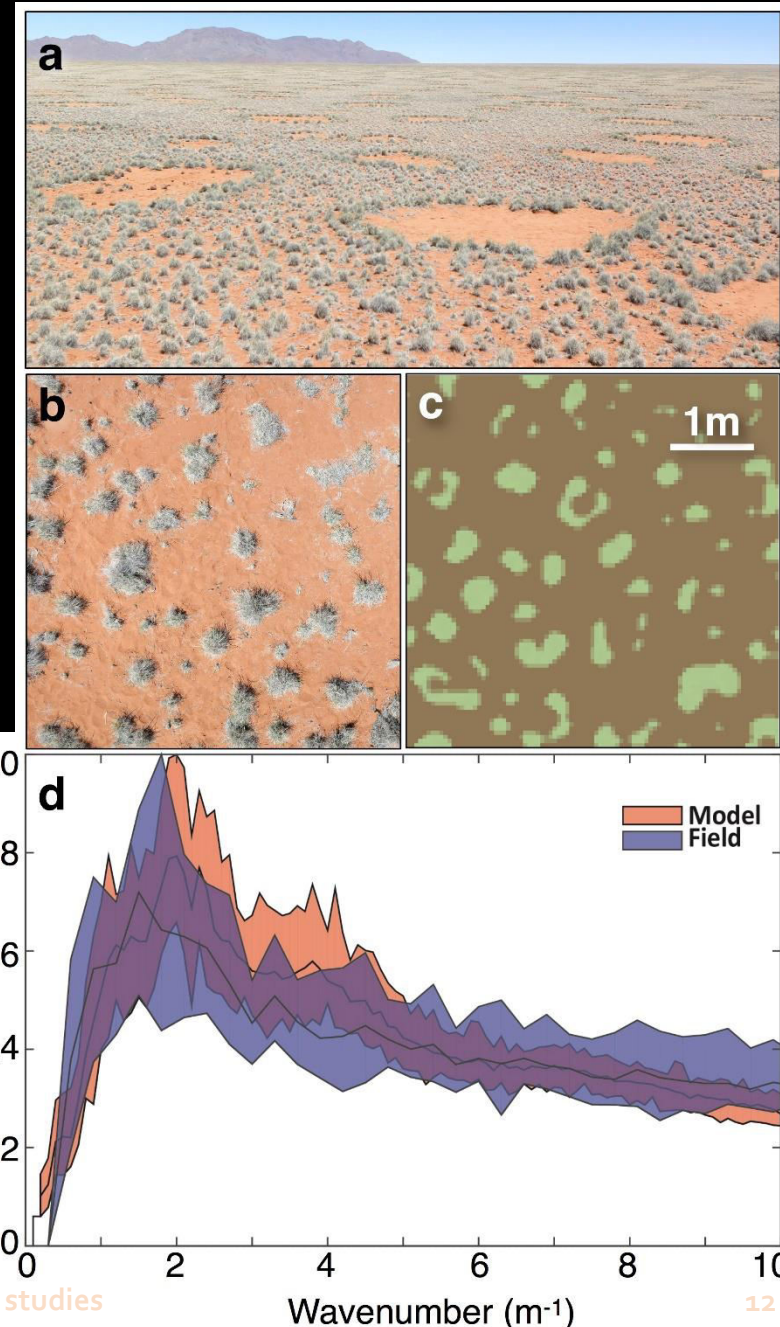
All photos: Jen Guyton



SCALES OF TERMITE VS. PLANT INTERACTIONS AND PATTERNS

In the area between nests:

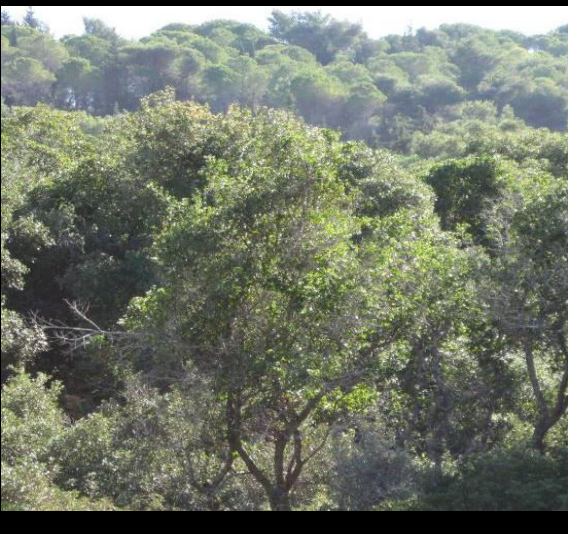
- Plant-plant interaction for limiting water
- Self-organized vegetation patchiness
- Plant patterns in the model resemble field results
- Scale of self-organized plant patches fit the scale of roots



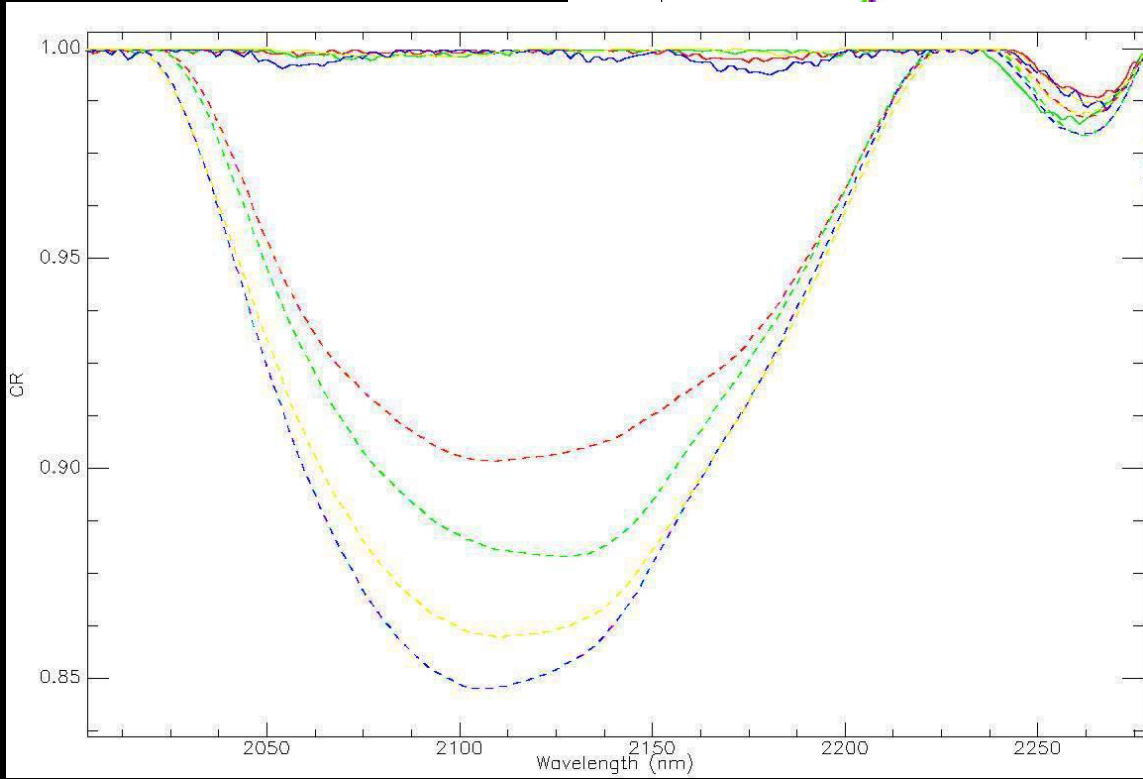
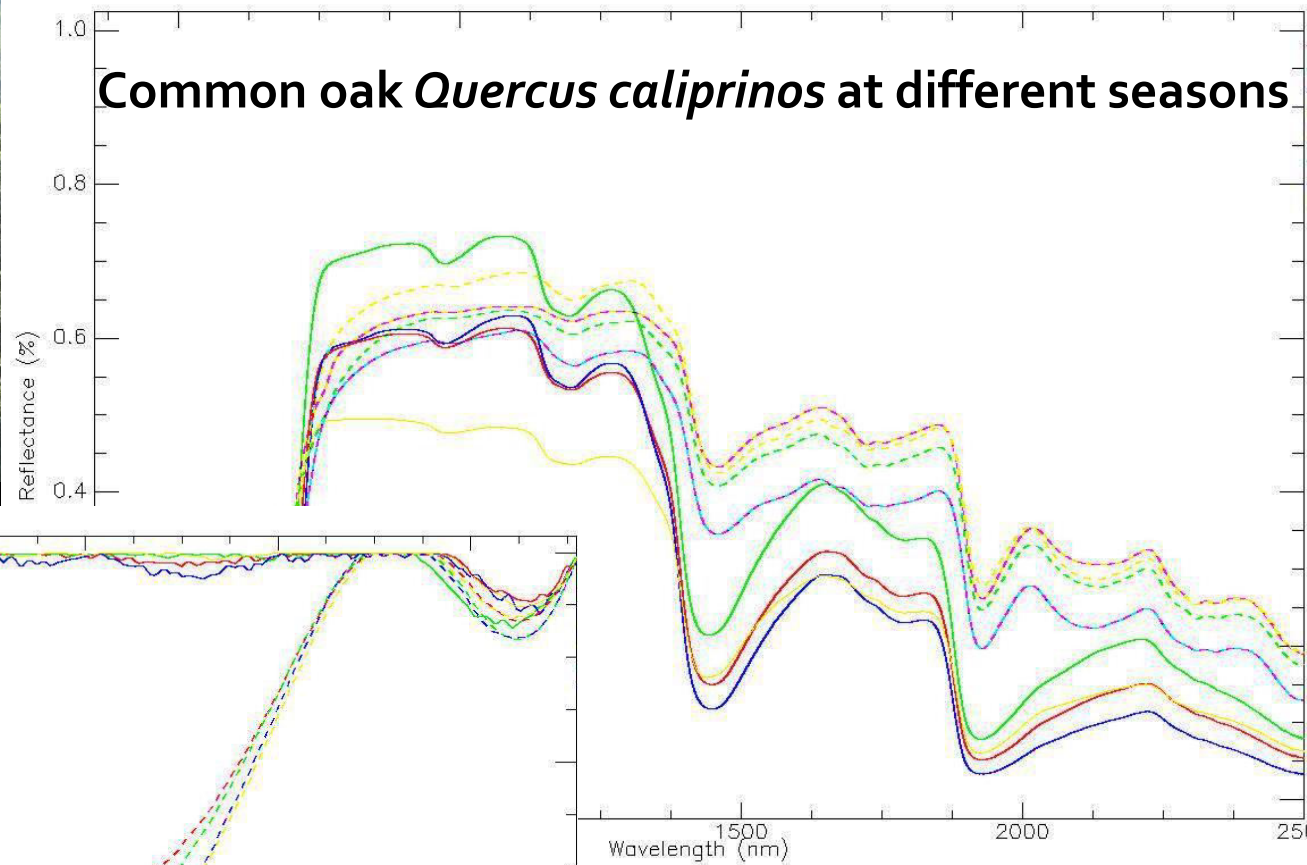
FORESTS & BIOGEOCHEMISTRY

- Spatial structure of plant species
- Spatial pattern of nutrient availability
- How these change - temporal dynamics





Common oak *Quercus caliprinos* at different seasons



with Moshe Mandelmilch & Eyal Ben-Dor

SCALE & RESOLUTION

- Interplay between scales create opportunities for pattern
- Spectral resolution to enable challenging plant analyses, as well as detailed biogeochemistry in space and time

THANK YOU



Juan Bonachela



Rob Pringle



Corina Tarnita



Jen Guyton



Tyler Coverdale

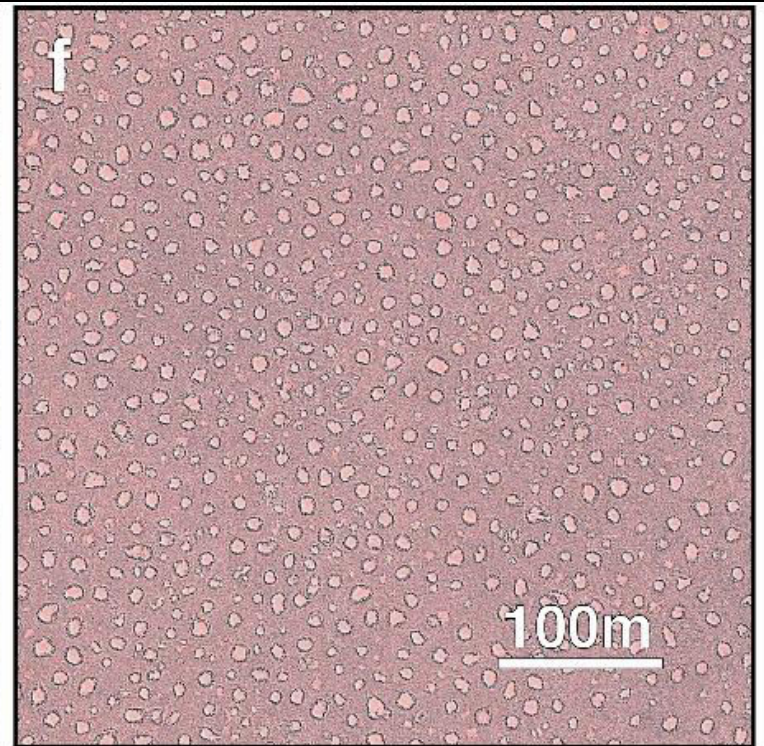
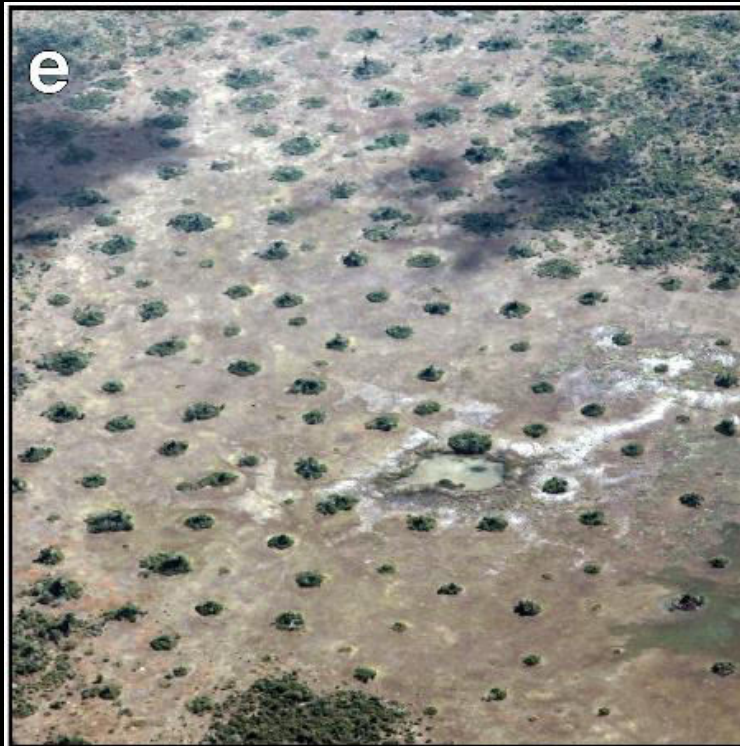


Ryan Long



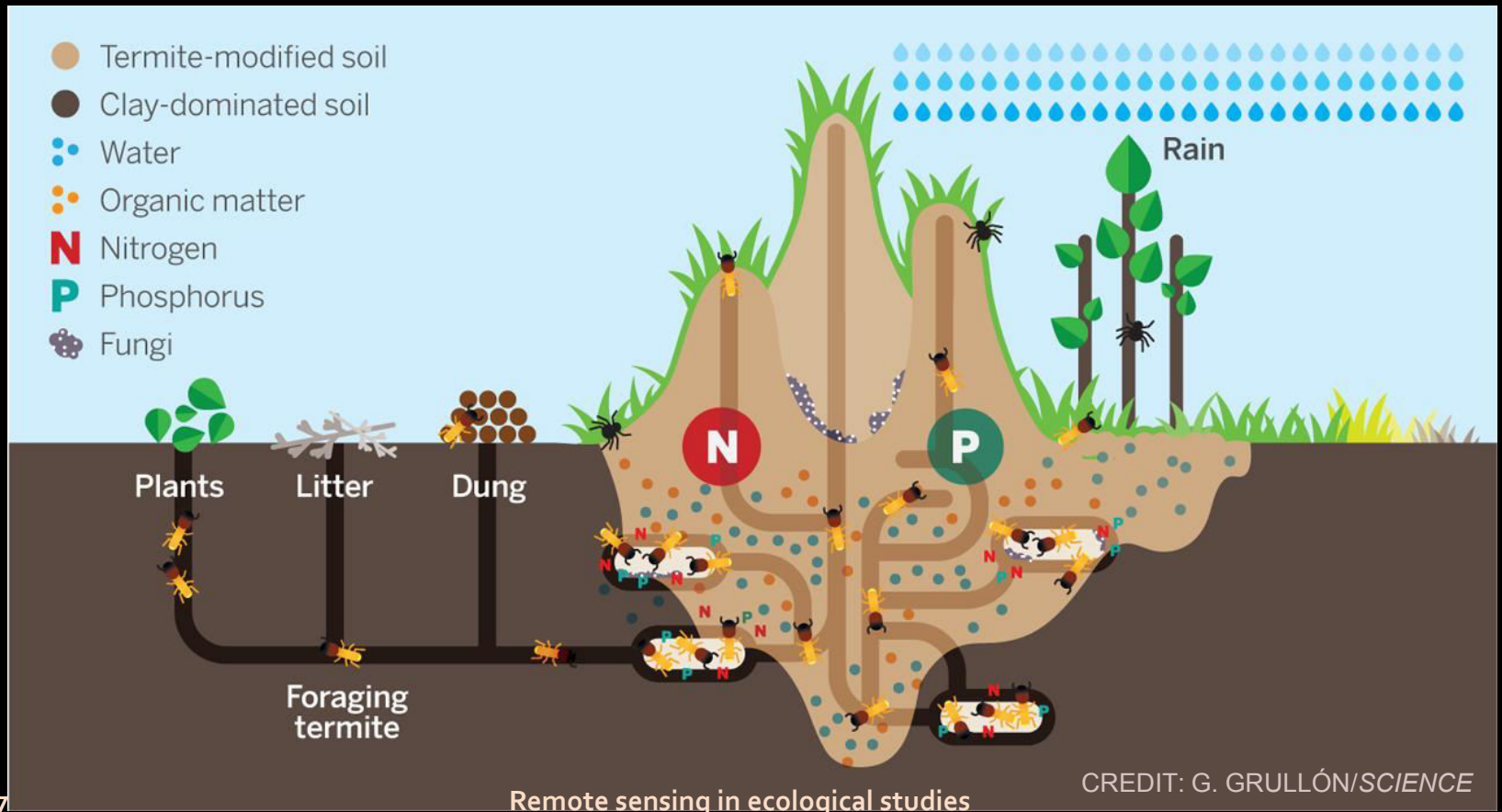
HOW TERMITE MOUNDS CREATE VEGETATION SPOTS OR GAPS?

HOW DOES THE SCALE OF TERMITE PATTERNS RELATE TO PLANT SCALE?



TERMITE NESTS CREATE VEGETATION SPOTS

- Collecting plant material into the colony nest
- Increasing nutrient availability in nest area
- Increasing water infiltration in nest area



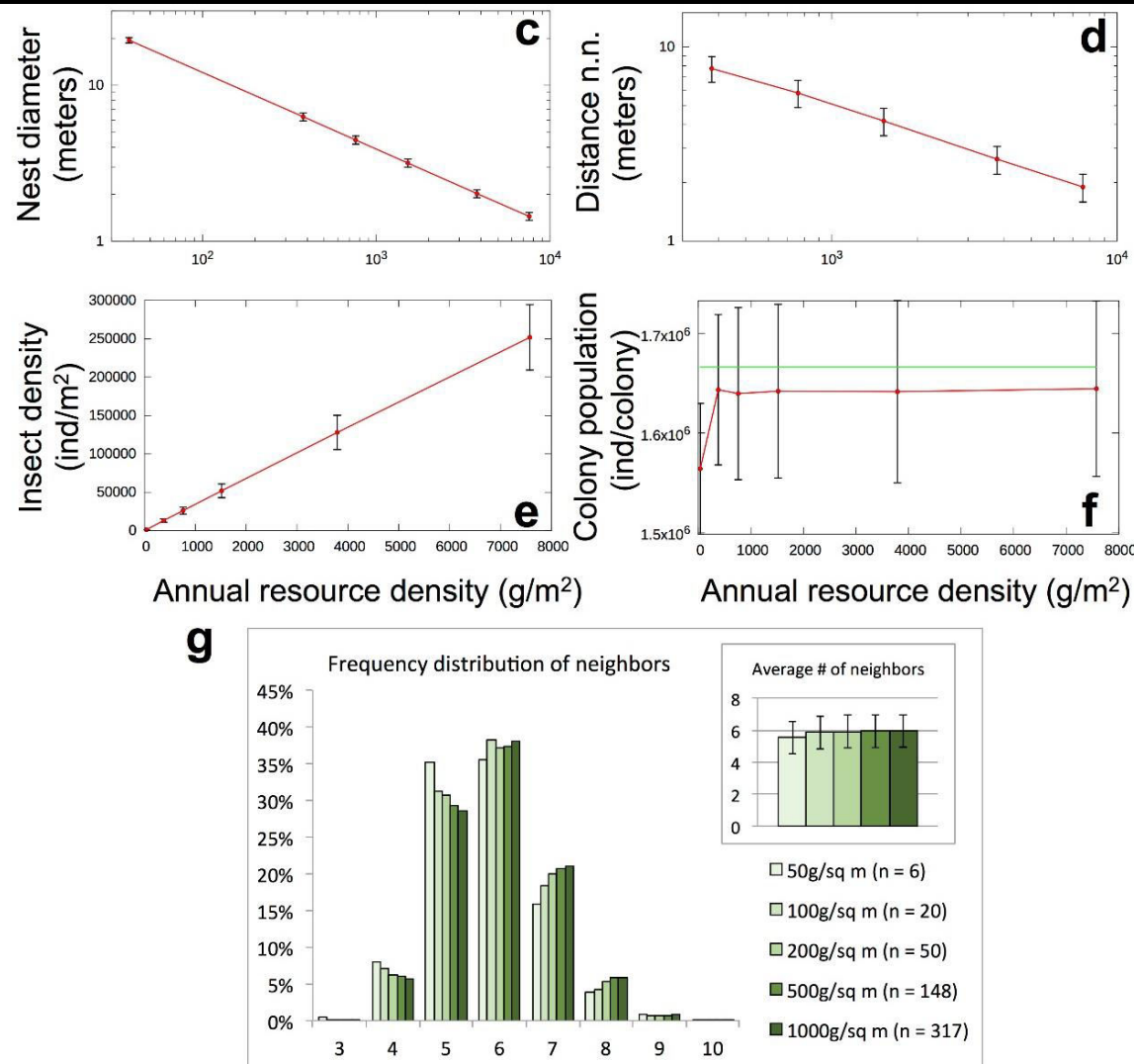
TERMITE NESTS CREATE VEGETATION GAPS

Termites consume all plant material in the nest area

Forming vegetation gaps



RESOURCE SUPPLY AND THE DENSITY OF COLONIES



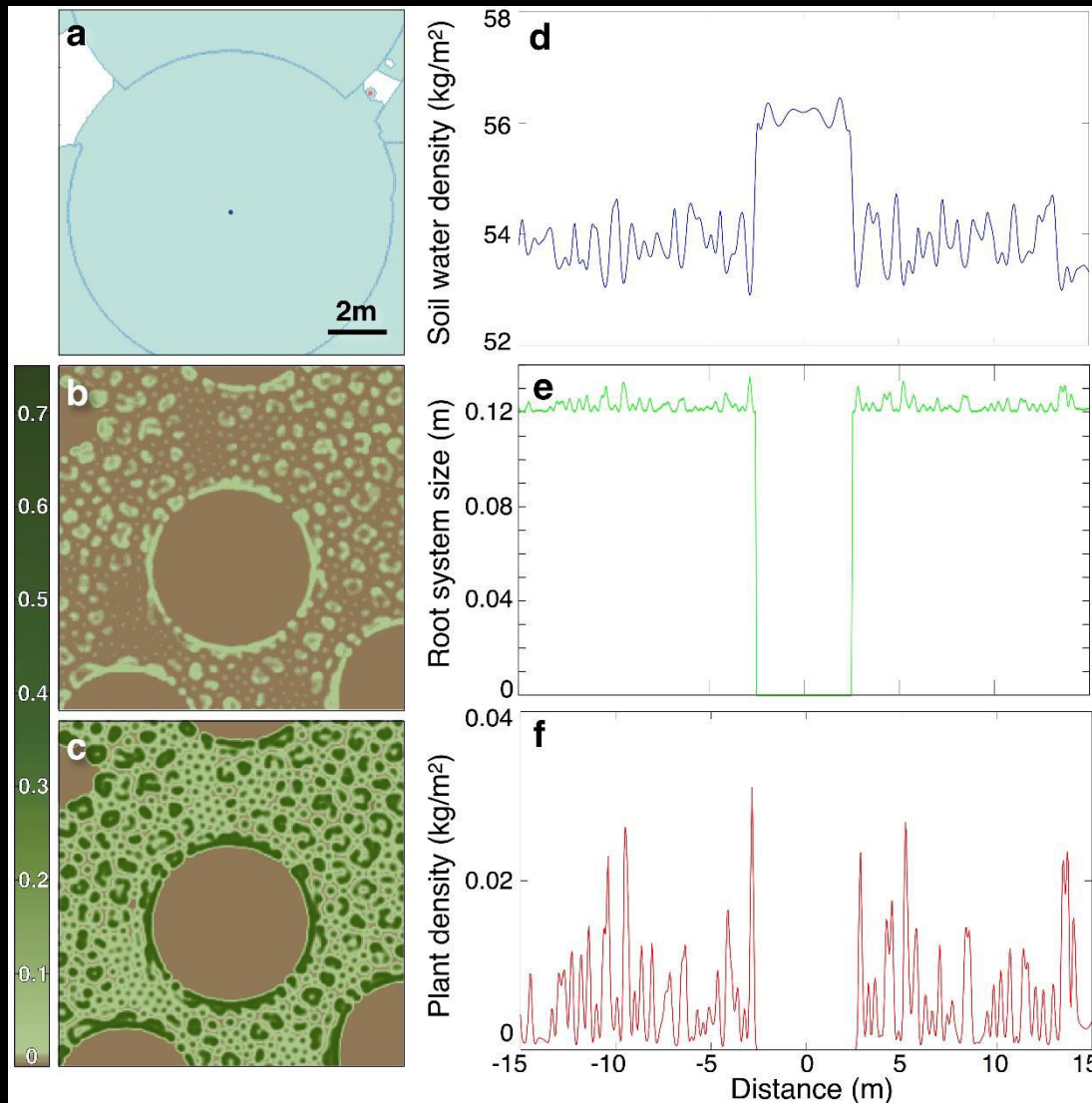
How food supply affect:

- Colony territory?
- Distance between nests?
- Nest density?

Increasing food supply \rightarrow distance between nests decreases and colony density increased

Tarnita et al. 2017

הטרמיטים יוצרים מעגלי פינות



משערים שהפעילות של
מושבת הטרמיטים גורמת
לתמותת הצומח במעגל
כתוצאה מכך תכולת המים
באזור המעגל עולה והצומח
בהיקף גדל

פיזור מים ושורשים במעגל

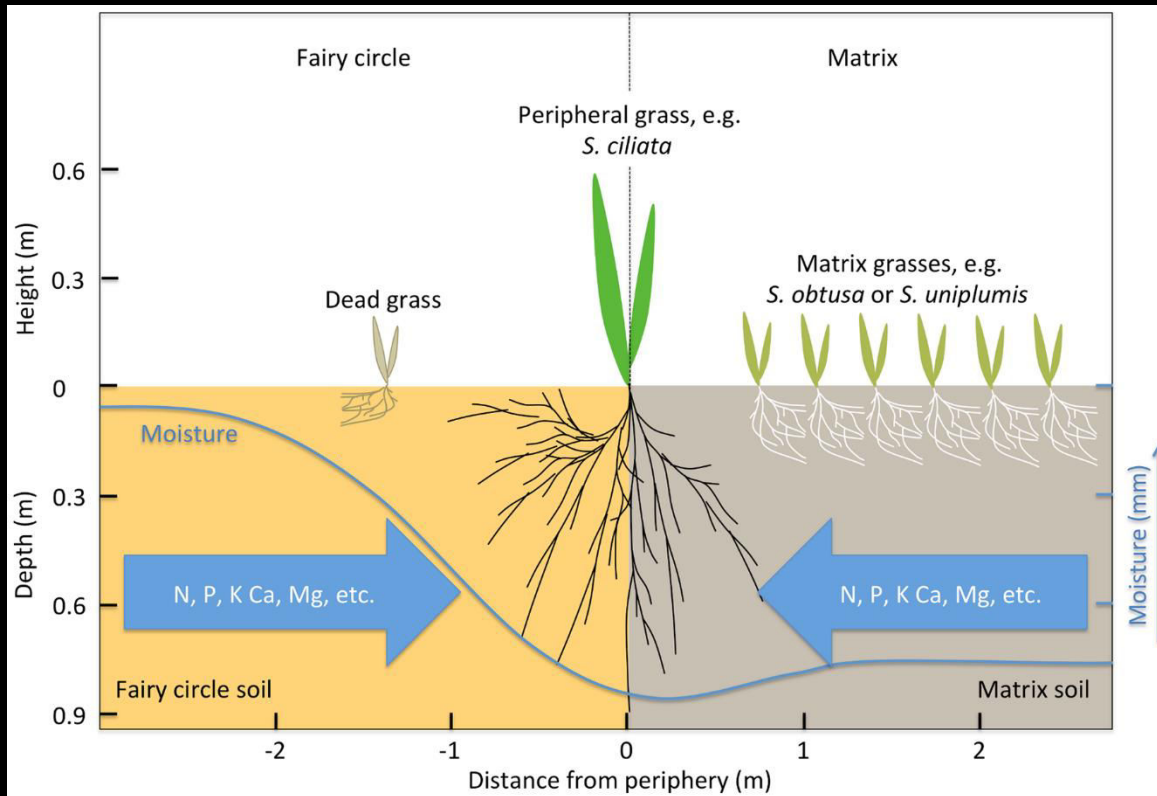
- רטיבות הקרקע גבוהה יותר בתוך המעגל (בשטח ללא צמחים)

- השורשים של הצמחים

בהיקף גדלים אסימטרית
יותר לכיוון פנים המעגל

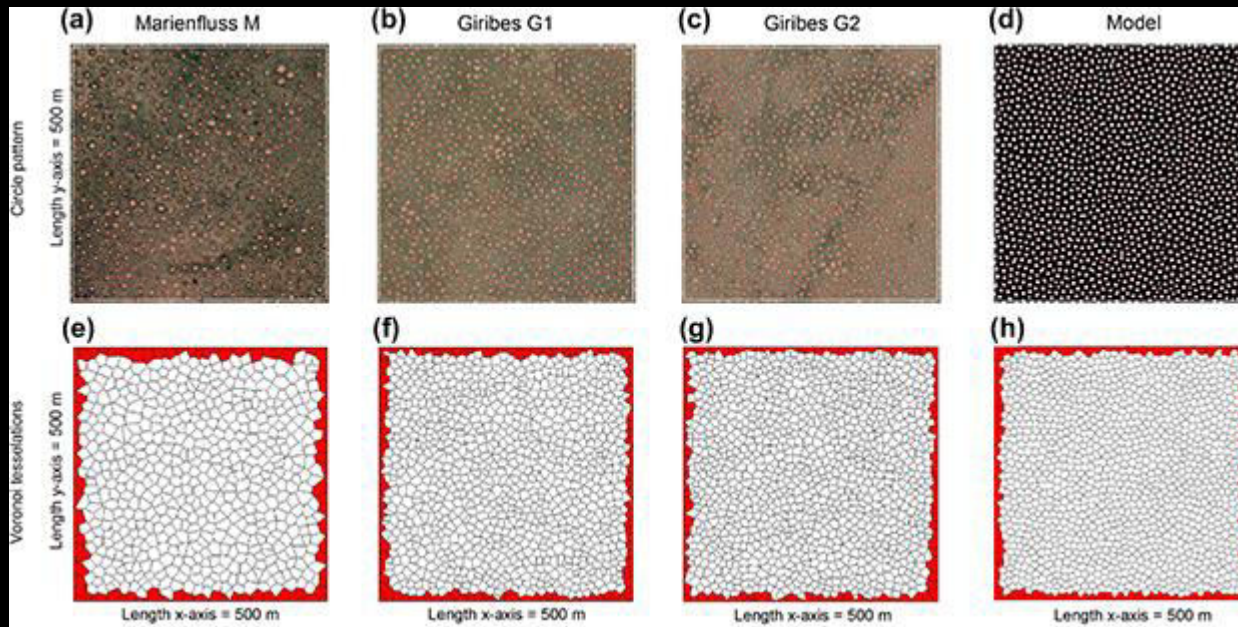
השערה:

יחסי גומלין בין הצמחים
גורמים ליצירתם
ולתארגנות במרחב
של מעגלי הפיות

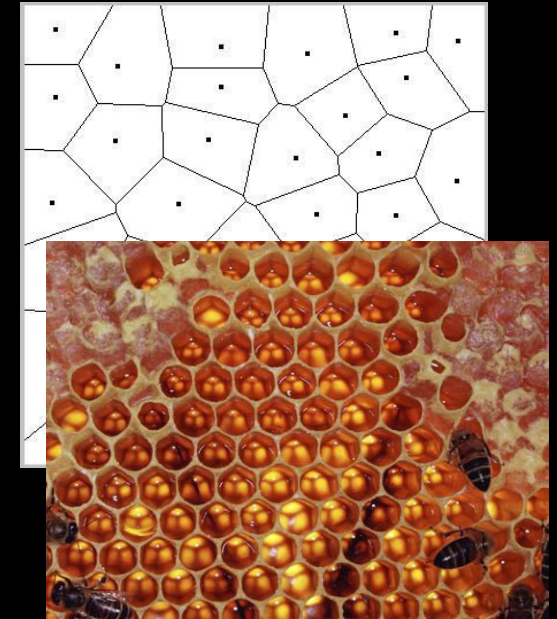


Cramer & Barger 2013. Are Namibian "Fairy Circles" the Consequence of Self-Organizing Spatial Vegetation Patterning?

האם התארגנות עצמית יוצרת מעגלי פיות?



Getzin, Wiegand, Wiegand, Yizhaq, von Hardenberg, & Meron. *Ecography* 2015



מודל של אינטראקציה

- בין צמחים ותחרות על מים יוצר "חורים" (gaps) דומים למעגלי הפיות
- הפיזור של מעגלי הפיות ושל החורים במודל דומה מרחבית
- לכל מעגל ~6 שכנים בממוצע
- גודל המעגל גדול מאורך השורשים של הצמחים בהיקף