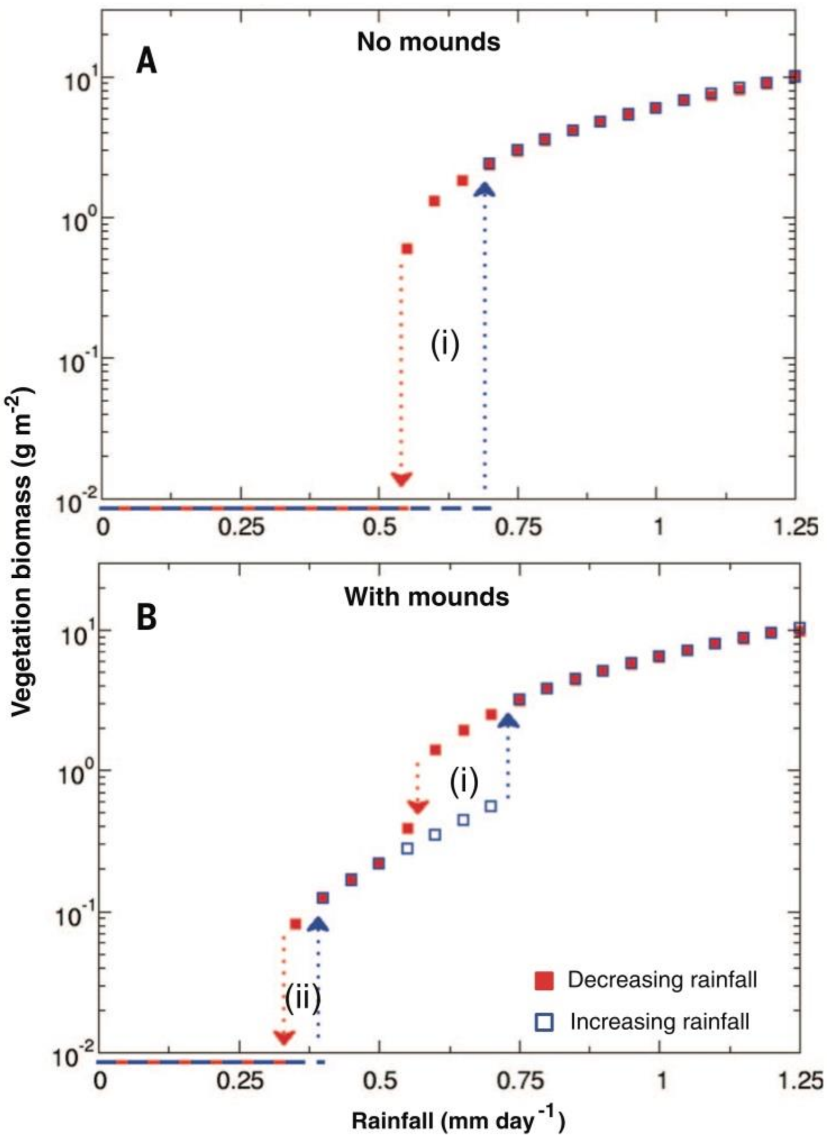
HOW TO USE THIS RESOURCE

Show the figure below to your students along with the caption and background information. The "Interpreting the Graph" and "Discussion Questions" sections provide additional information and suggested questions that you can use to guide a class discussion about the characteristics of the graph and what it shows.



Caption: Diagrams showing how models predict the response of vegetation to increasing (blue squares) and decreasing (red squares) rainfall in ecosystems where termite mounds are not present (A) and are present (B). Each data point indicates the vegetation biomass in an area of land for a particular amount of rainfall. Figure A shows one cycle (i) of desertification (down red arrow) and revegetation (up blue arrow) in the absence of mounds. Figure B shows two cycles representing (i) loss and recovery of vegetation in the landscape between the mounds and (ii) desertification and revegetation of the entire system, including vegetation on the mounds.

BACKGROUND INFORMATION

In arid and semiarid savanna and grassland ecosystems (i.e., dryland ecosystems), a decrease in rainfall typically results in increasingly sparse vegetation, leading to uniformly spaced spots of vegetation (or vegetation patterns), and eventually complete loss of vegetation. The complete loss of vegetation, or desertification, is catastrophic to an ecosystem, and its effects can last for many years. More than 38% of the human population lives in dryland environments, which cover more than 40% of Earth's surface. The risk of desertification is predicted to increase as drought intensity increases in response to global warming. Scientists have proposed using vegetation patterns as an early warning system to predict desertification.

In ecosystems with termites, vegetation tends to be concentrated on termite mounds, which are spread out across the landscape. Dr. Corina Tarnita and colleagues found that the pattern of vegetated termite mounds across a landscape resembles the spotty vegetation that occurs when a system is near desertification. But despite the similarities in these patterns, the fates of these two ecosystems may be very different. The presence of termite mounds in a landscape may actually provide resistance to desertification and a faster recovery of vegetation if desertification does occur. Termite mounds promote vegetation growth because the termites enrich the soil with nutrients found in their waste and they dig tunnels that help to increase water infiltration to plant roots.

The researchers incorporated the positive effects of termite mounds on vegetation growth into an existing mathematical model used to predict how changes in the annual average rainfall alter vegetation patterns in a savanna ecosystem. Panel A in the figure above shows a diagram of the modeled vegetation change as rainfall decreases (red) and increases (blue) in an ecosystem without termite mounds. Panel B shows a model of the vegetation change as rainfall decreases (red) and increases (blue) in an ecosystem with termite mounds. From these models, the researchers were able to predict the system's "robustness," measured by how well the vegetation resisted and then recovered from desertification. They then compared the modeled vegetation patterns against aerial photographs and data collected at their field site in Kenya, confirming that the vegetation patterns predicted by the models closely matched the actual data.

INTERPRETING THE GRAPH

Panel A shows that as rainfall decreases, vegetation decreases (red squares, going from right to left). There is a single sudden catastrophic loss of vegetation, indicated by the symbol (i), at about 0.55 mm/day of rainfall. It is called catastrophic because the loss of vegetation is sudden, not slowly deteriorating. In the other direction, as rainfall increases, vegetation also increases (blue squares, going from left to right). There is a sudden recovery of vegetation biomass at about 0.7 mm/day of rainfall. Once the system is in the desert state, a lot more rainfall is needed to recover the vegetation (blue arrow) than when the vegetation was lost (red arrow). This difference in the rainfall amounts can be explained by the fact that plants play a crucial role in allowing water to infiltrate the soil and, once in the soil, to stay relatively close to the surface, where plant roots can use it. When plants are gone, a lot of rainfall is wasted in two ways: either it cannot efficiently infiltrate the soil and therefore it evaporates, or it can infiltrate but it quickly sinks to depths where it is not accessible to plants. Thus, much more rainfall is needed for vegetation to recover.

Panel B shows that as rainfall decreases, vegetation decreases (red dots, going from right to left). There is a sudden drop in vegetation (i) at the same rainfall level as in Panel A, but this is not a complete loss of vegetation. The vegetation that is lost is located in the areas between the termite mounds. The vegetation that remains is located on the termite mounds and slowly decreases until rainfall rates drop to about 0.3 mm/day, when a complete loss of vegetation occurs. As rainfall increases (blue squares, going from left to right), vegetation on the termite mounds (ii) recovers at about 0.35 mm/day of rainfall and vegetation between the termite mounds (i) recovers at about 0.75 mm/day.

These figures show that termite mounds provide resistance from desertification by allowing vegetation to persist in the system (i.e., on the mounds) at much lower rainfall rates than in ecosystems without mounds, and, if desertification does occur, by enabling recovery at much lower rainfall rates.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:
- Graph Type: Scatter plot (specifically, a phase diagram)
- *X*-Axis: Rainfall (mm/day), linear scale
- *Y*-Axis: Vegetation Biomass (g/m2), logarithmic scale
- Red squares indicate instances of decreasing rainfall (read right to left).
- Blue squares indicate instances of increasing rainfall (read left to right).
- Dashed arrows indicate sudden changes in vegetation biomass.

DISCUSSION QUESTIONS

- For the model without termite mounds (Panel A), describe the change in vegetation biomass as rainfall decreases and as it increases. At what points do sudden shifts occur?
- For the model with termite mounds (Panel B), describe the change in vegetation biomass as rainfall decreases and as it increases. At what points do sudden shifts occur?
- How does the vegetation biomass at 0.5 mm/day of rainfall differ in the two figures? Explain what is contributing to this difference.
- Which of the ecosystems represented by these figures is more vulnerable to desertification? Why?
- Which of the ecosystems represented by these figures is more likely to recover from desertification sooner? Why?
- For each cycle (i) and (ii), why do you think the increases in vegetation biomass (blue arrows) occur at higher rainfall rates than the decreases in biomass (red arrows)? (In other words, why doesn't vegetation recover from drought at the same level of rainfall as when vegetation was lost?)
- Explain how these models could be used by scientists to make predictions about the consequences of climate change in an arid or semiarid area of the world.
- How might these models be used to determine how resources for conservation and land management should be allocated in arid or semiarid areas or to address climate change?
- If termite populations began to collapse in these areas, use the two graphs to predict the effect this might have on arid and semiarid ecosystems.

SOURCE

Figure 4 from:
Bonachela, Juan A., *et al*. Termite mounds can increase the robustness of dryland ecosystems to climatic change. 2015. *Science*. 347(6222): 651-655.
View Paper: http://science.sciencemag.org/content/347/6222/651.full (requires login to AAAS, set up a free AAAS account to view the article via this link: https://pubs.aaas.org/promo/promo_setup_rd.asp?dmc=p0rfb1)

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