Planet Earth's playhouse

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Assistant research professor Sujith Ravi checks on experimental communities of native and invasive grasses. Photo: D. Stolte

At Biosphere 2, scientists can move things around, control the climate, turn off certain parameters and run others full tilt.

Much of the controversy surrounding global climate change stems from the fact that, as of now, there is no clear-cut answer to this question: What will really happen if we continue to burn fossil fuels and keep changing our natural environment?

Scores of scientists across the globe are working to come up with models to better predict the challenges facing humanity in a world of increasing global temperatures, more frequent and severe weather events, encroaching deserts and vanishing natural resources.

The main problem in trying to understand the many factors involved in how global climate affects the environment and vice versa is that it’s incredibly complicated. Everything seems to be somehow connected and influenced by everything else, making efforts to study cause and effect of certain parameters difficult if not impossible.

Computer models make things a bit easier, as they allow scientists to disentangle some of the mess, set certain parameters one way while tuning out others and observe what happens. But the outcomes of those simulations depend on the input they are based on – a chicken and egg problem.

What is needed is a miniature Earth, an ecological playhouse where scientists can move things around, control the climate, turn off certain parameters and run others full tilt.

In a giant greenhouse just 20 miles north of Tucson, an interdisciplinary team of researchers is doing just that.

“Biosphere 2 allows for a level of manipulation that is hard to achieve in a natural environment,” says Biosphere 2 director Travis Huxman, who is also a professor in the UA’s department of ecology and evolutionary biology.

“In the real world, light, temperature and humidity go hand-in hand, they are coupled. Here, we can make it hot at night, we can make it cold during the day, we can do whatever we want.”

“Biosphere 2 offers us the unique setting to tackle complex environmental problems using large scale experimentation and climate control. We can uncouple parameters and see what happens. We feed the results that we get into models, and the models can be used to simulate the real world.”

In addition, Biosphere 2 enables researchers to challenge models and make predictions, according to Huxman. Its controlled environment allows them to play with the models that are used to inform decision makers about critical policy.

Drought threatens the Amazon rainforest

Joost van Haren, a graduate student in the department of soil, water and environmental science in the UA's College of Agriculture and Life Sciences, turns a slightly rusted wheel of an airlock and pushes the steel door open.

"Welcome to the rainforest at Biosphere 2!"

The air is warm and humid. A dense jungle of tropical foliage rises up to the ceiling of the Biosphere's glass-and-steel structure. A narrow wooden boardwalk winds through dark, moist soil toward a tower made from aluminum segments, stacked upon each other and poking through the canopy, one of three so-called profiles.

"This tower measures and records temperature, humidity, wind speed and light at five different heights," van Haren explains. "Down here, the temperature is between 73 and 77 degrees Fahrenheit – just like in the understory of a rainforest."

He points upward. "Under the glass roof, it's around 110. At the top of the canopy of the rainforest in the Amazon basin, we regularly measure 95 to 104 degrees during the dry season, so right now we're not that far off."

During the hot Southern Arizona summers, temperatures just below the glass in the Biosphere 2 rainforest reach up to 140 degrees, to which the trees appear to adapt. In fact, Rafael Rosolem, a graduate student in the department of hydrology and water resources, had to modify an ecosystem model commonly used to describe carbon exchange in real rainforests to account for the high summer temperatures at Biosphere 2.

This profile tower takes measurements at defined heights in Biosphere 2's rainforest. Photo: J. van Haren

Surprisingly, when he applied the model with the modified parameter to “real-world” data from the Amazon basin, he discovered it did a better job in the real world as well.

According to van Haren, several global climate change models have predicted that the Amazon basin will become drier in the near future.

What does this mean for the vast Amazon basin tropical forests? What will happen to tropical rainforests when the amount of rainfall is reduced and how will tropical trees respond to this change? Those are the kinds of questions van Haren and his co-workers are addressing at Biosphere

2.

According to van Haren, dwindling rainfall likely is a much more important fact of climate change that is going to affect tropical ecosystems than rising global temperatures, which often take the center stage in discussions about the issue.

"Even if temperatures are way outside of what trees can handle, they may shed their leaves and their roots may go dormant for a short period of time," he explains. "But once that temperature comes back into a normal range, they can recover."

"Drought is a different case. Drought and increased temperatures likely go hand in hand in tropical forests, because less rainfall means less clouds, therefore more sunlight and higher temperature," van Haren says.

From an experiment conducted by ecology and evolutionary biology graduate student Henry Adams at Biosphere 2, the researchers know that increased temperature kills trees faster when they are under drought stress.

In the rainforest at Biosphere 2, the scientists can simulate droughts at different ambient temperatures and see how the trees react.

"It's just like a Rainforest playhouse," van Haren says. "We can change things here. We can change the precipitation at will; we can change the temperature; we can even change the humidity. It's the only rainforest that I know of where you can really manipulate things."

Field studies complement the experiments conducted under the giant glass dome. van Haren and his team members operate a profile tower just like the ones at Biosphere 2 in the Amazon basin in Brazil, towering above the rainforest at 207 feet.

“The data we gather here at Biosphere 2 inform us about what we need to measure in the real world,” van Haren says.

Going from the tropical rainforest to a dry savannah usually involves many hours on airplanes. At Biosphere 2, the trip can be made by walking through a door, down a corridor, climbing up a spiral staircase and opening another door.

Looking at roots; looking into the future

Sujith Ravi, a hydrologist who recently joined the UA faculty as an assistant research professor, crouches between two rows of potted grass plants. He inserts a tube-like instrument with an attached cable into the sods and looks at a monitor.

“These pots have glass tubes in them, and when I insert this camera, I can look at the roots and take pictures at different depths and quantify the root growth.”

“Our research group has been taking pictures every week for six months,” he says. “This will enable us to track individual root tips and see how fast they grow."

“There aren’t many studies on root growth under different climatic conditions. We know what’s happening above the surface but we don’t really know what happens underneath the soil in response to warming or increased carbon dioxide levels.”

But Ravi and his co-workers are not just looking at roots. In a way, they are looking into the future.

“Here in the lower savannah and the desert, we are trying to mimic the predicted effect of a warmer and drier climate,” the young scientist says.

“We have the same experiment running in two different environments, with the only variable being a difference in temperature – the plant communities growing in the desert biome are exposed to temperatures that are few degrees higher than in the Savannah.”

The research group also plans to monitor the study those plant communities under moisture stress conditions, to simulate a global change-type-drought.

According to Ravi, invasive grasses, which are very adapted to fire, provide what ecologists call connectivity to the landscape. What may sound like a good thing is actually a deadly threat to the native Sonoran desert, whose vegetation is not used to wild fires.

“These grasses were brought here with good intentions for land management, but they escaped from the cultivated areas and spread into the natural landscape. This is a factor of climate change, too, because when it gets warmer, these grasses move up into higher elevations and provide fuel for fires that wasn’t there before.”

“Invasive grasses first gain a foothold under native shrubs like the mesquite, where they find more moisture and more nutrients,” he says. “There they wait for years with high precipitation, and then they spread out.”

“Naturally, in the Sonoran desert there is not enough connectivity in the landscape to allow small fires to grow into big fires and spread, but the invasive grasses, such as buffel grass, provide that connectivity. The fire then kills the native vegetation and wipes out any competition of the invaders.”

“One of the question people often ask is, So why aren’t native grasses doing the same thing? Invasive grasses outcompete the native grasses.

When you apply nutrients or water to a community of natives and invasives, the buffelgrass responds faster."

"That is one of the things we are trying to understand here. In these pots, we grow different assemblies of grasses – native, invasive and mixed."

Ravi and his co-workers grow them at different temperature ranges and measure the physiology such as photosynthesis, water use efficiency, respiration and soil moisture. They also keep track of how much of the nutrients go to the native grass and how much go to the invasive under different climatic conditions.

Modest as the rows of potted grass plants may appear to the uninitiated, the discoveries made here hold implications on a global scale.

"Many dry land systems around the world are predicted to experience hotter and drier climates and recurrent droughts," Ravi says. "Dry lands make up 40 percent of the Earth's land, with about 2 billion people living in those areas, mostly in the developing world. These large-scale changes are happening at a very fast pace, and how they affect people and the fate of water in these landscapes is one of the themes of the Biosphere."

Provided by University of Arizona

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