

Science Studio Vol 010 (Guest Sharon Hall)

Habitats - Past and Future

Assistant professor Sharon Hall takes us on a journey from past to future as she discusses how she got into her research: how human habitation changes landscapes, and for how long. The Hohokam are still influencing our environment 600 years later, how can we determine what our urban legacy will be?

Transcript

Peggy Coulombe: Hi, this is Peggy Coulombe and welcome to School of Life Sciences Science Studio. Arizona State University recently had a visitor, Al Gore, come through to talk about global warming. Whether you agree with his summation of facts or not, I think we can all come together and agree that landscapes that have had humans on them or near them are changed, just as you might expect if there had been a herd of elephants tramping about in profusion.

But unlike elephants or packs of wild dogs, humans have the tools and the sheer numbers to impact landscapes and resources much more widely. In fact, whilst the two creatures that I mentioned are struggling to maintain their numbers, the human population is expected to increase from 6.5 billion to 10 billion by mid-century.

With numbers like these, you have to wonder how we care for our growing population and still maintain our planetary life support systems. This question is at the heart of the research that's being conducted by our guest today, Sharon Hall. Sharon is an assistant professor in the School of Life Sciences and is studying how human activity affects natural processes that occur in our soils, our atmosphere and our urban and natural communities. Welcome Sharon.

Sharon Hall: Thank you.

Peggy: First let's talk generally about how humans change landscapes.

Sharon: Well, if you take a broader look at that, humans are just one species on the planet and all organisms and all species change landscapes depending on your perspective. You can be a microbe and change your microenvironment. Or you can be, like we were talking earlier, an elephant and change something on a really macro scale.

The thing about humans is that we have the ability to use tools. And historically and pre-historically, especially our use of fire has been a really important mediator of landscape change. In fact, since the beginning of humans on the planet, especially with human use of fire, humans have been changing landscapes quite intensely.

For example, the prehistoric humans in North America are known to have used wildfire to clear large areas of land and in Australia the same. So the idea that human landscape change or human change of the environment is a modern issue alone is really not true. If you take a look at how we've changed things it has been quite prevalent throughout history.

Now, again, the rate of change is quite different. Now we have so many more people on the planet and our tools are bigger. We can do many more things, not just direct changes on the landscape, but indirect changes as well. So definitely, humans have been a part of our environment. In fact, they have evolved with the earth. We have been a major modulator of the environment for many, many years.

Peggy: Has this type of change happened in Phoenix?

Sharon: Yes, in fact, Phoenix is one of the best places to look at the long-term impact of human activity, because we have in this area a history of long-term prehistoric population. The Hohokam lived here for many years prior to the Spanish invasion. They were some of the best engineers. They moved water around from the rivers that we have in this southwestern area.

In fact, Phoenix grew up around the remnants of this ancient population, rising from the ashes of the old population. In fact, these Hohokam moved water around with canals. They diverted rivers into big silt fields on which they grew their agricultural crops. Many of our canals now that are moving water essentially from the Colorado River are using some of the old canals that were built by these prehistoric people.

In addition, if you take a look at the historic occupation, there were the prehistoric communities that lived here and then after that, because these canals were built and because there was ample water from the confluences of the Gila and Salt and Verde rivers, this was a great place for modern humans to occupy this land. So we build our landscape and our agricultural fields right on the same area.

Peggy: How long does a human population need to live in an area to have an impact?

Sharon: That's a really good question. So, the question of how much human activity causes a long-term impact on the landscape really depends on what we call impact. For example, the chemical changes in our atmosphere, if we put molecules of chlorofluorocarbons, those can last tens of thousands of years. It could be just the few molecules in parts per trillion.

Or, if we have an agricultural field let's say in a really humid, mesic environment where plants are really growing, let's say the northeastern United States, maybe that field there will be covered very quickly by successional plants that will be moving into the area quite naturally.

So that's an interesting question because maybe it depends on the climate. Maybe impacts here are more visible because the plant growth is generally slow.

Or is it that the type of human impact matters? If humans are just on the landscape and living in a certain area, does that make a long-term impact or do we need to have an agricultural field if it is subsistence distance farming? Maybe is that important? Or do we have to have plows and tractors? So these are questions that we are trying to explore in our search, because we are interested in what causes a long term, perhaps millennial human impact. Is it just the type of impact, or is it where the impact is occurring?

Peggy: So, in your studies of the Hohokam, you were looking up in Agua Fria, is that correct?

Sharon: Yes, well that was a different group of people that lived on the Agua Fria plateau, but yes, we have a study that's going to be exploring the long-term impact of these prehistoric agricultural communities. One group is up on the Agua Fria plateau. It's a national monument now. These people lived in this area for several hundred years up until about 1200 A.D., 1300 A.D.

It's not exactly clear what time they left. But we think it was a fairly large group of people for several hundred years. Their ruins of their communities are still there. The ruined blocks are still there. We have a group of students from ASU that are surveying these landscapes right now. It's amazing. We are finding more fields and more ruined blocks that have never been mapped nor excavated before.

What we are also finding is lots of agricultural terraces. And what Hoski Schaafsma and John Briggs, and I and Kate Spielman and some archaeologists and ecologists have noticed is that some of the plant communities on these agricultural terraces even now are quite different than the landscapes around them.

So we asked the question, are these plant communities and perhaps animal communities a result of the agricultural terrace? Is that something that is a persistent legacy of agriculture that lasts even into the modern time? If that's true, people lived all over the Southwest, how much of the landscape that we see now that we think is natural and pristine is in fact changed by prehistoric humans? We don't know this question, so we are very excited to explore this over the next several years.

Peggy: Yeah, that's kind of a fantastic thought that people who were around in 1200 to 1400 A.D. have altered the landscape in ways that affect us presently.

Sharon: Yes, and it's even more interesting, because we think of the arid Southwest as this place where things don't change. We look at how slowly these plants grow. In fact, we might think that perhaps these legacies of humans might be most visible here, because the plants grow so slowly that if we change them, maybe it takes a hundred years to be able to see some sort of impact.

Whereas, again, if you were in the southeast where plants are growing like crazy, maybe those changes just disappear within 10 years or decades.

Peggy: I was going to ask you, how long a human impact lasts on a landscape, but it sounds like maybe it lasts forever.

Sharon: Well, yeah. You think about what humans are doing, and maybe you think about subsistence farming, where they would plant their seeds just by poking the seeds down with a stick into the soil. Maybe that changes that one little area. But if there hasn't been a major shift in the soil structure or nutrient input, maybe it was all organic essentially, maybe that's making a natural clearing from a hurricane or a disturbance or a tree fall.

Remember that change in forests and on landscapes is natural. In fact, we know now that if we stop change from occurring on a landscape we can have disastrous consequences like fire suppression. Smokey the bear for many, many years now, has told us not to light fires and now many of our Ponderosa pine forests are devastated because of how densely packed these trees are and the seeds can't germinate. So we know now that change is natural, and in fact quite healthy for an ecosystem.

So, in fact, if humans modify an environment similar to how nature does it, maybe that type of change has less of an impact in the long run than plowing an entire field or clear cutting an entire forest, which is something that doesn't necessarily happen on that scale, naturally.

Peggy: If humans that existed several centuries ago can have such a lasting effect on present ecosystems and biodiversity, what effects are our growing urban systems having on the Sonoran desert ecosystems surrounding us?

Sharon: Well, that's a really great question because what we are doing now is just on an exponential scale with our sheer numbers. We can remember a time when we used to see vast expanses of empty space. And now we see large tracts of houses. So, the types of things that humans are doing to the landscape in terms of the direct effects are very visible. And they are disturbing to many of us, but at the same time it is providing opportunities that we didn't have before.

We have people coming to the Valley, who lived in other places and maybe this is an opportunity for new residents to start to appreciate the desert ecosystem that we have here. Some of the most important changes, however, aren't necessarily the direct ones on the landscape. They might be indirect. For example, but all the people coming to the Valley, we are bringing our cars and we have lots of pollution in the Valley. We know this because we have the bad air days where people can't go outside.

All of that is adding to change in the atmosphere and in the climate. We know that on a local scale from the urban heat island. We know that it's several degrees warmer in the city than outside the city. That obviously changes many ecological processes that are dependent on temperature.

But also inside the city, we have removed many of our predators. So what we are finding is that we have a completely different suite of birds and herbivores on our plants that are living there as we can call them 'weedy species'. There are weedy because they come with us.

Now we aren't really expecting to have a decline and extinction of all species. That's not ever going to happen. We are just going to be eliminating the species that can live with us. So, in fact, the types of changes we are seeing in the Phoenix ecosystem now are really interesting, because we have brought some plants and animals with us and we are excluding some others.

We are studying now the impact of that on the larger Sonora desert ecosystem around Phoenix. We are not sure how big the footprint is essentially is of Phoenix.

Peggy: With all the influx of humans into urban environments I understand that there is an increase in things like nitrogen. We usually think of nitrogen as being a good thing. Tell me why people are concerned about it.

Sharon: Well nitrogen is an interesting element. Nitrogen is an essential element in all of our DNA, in our proteins. We wouldn't be here without that particular element. But when we are using fossil fuels, we are taking a lot of the nitrogen that was buried for millennia and burning it very quickly and releasing it to the atmosphere.

Now the tricky thing about nitrogen is that we are bathed in it actually. In our atmosphere right now we have about 78% nitrogen. Then you hear scientists say, 'Well, nitrogen is a problem'. Why is that? It's because the form of nitrogen that is in the atmosphere is really unusable. It is nitrogen bonded with another triple bond to another nitrogen. We can't use that even though we are bathed in it.

What we need first are microorganisms to take that nitrogen and make it into an available form for us. And then we can incorporate that into our proteins or our DNA. So what we are essentially doing with fossil fuel combustion is taking an unavailable nitrogen compound, which is in an organic form, and we are burning it and making it available.

Then that changes everything, because we all love it, we all need it, plants need it. It's fertilizer. So we are adding it to the desert ecosystem. We are adding it to ecosystems around the world. And as a result, plants are growing. So you might ask why that is bad.

Peggy: Yeah, usually plants growing are considered a good thing.

Sharon: Right, right. So we generally think that plants growing are a good thing. But if you have an ecosystem, let's say, a stream, that is naturally, let's say, prehuman - a very nutrient poor stream, very clear and if you add a lot of plant growth to that you will cause a lot of algae to bloom in that stream.

This will cause it to change quite radically. Maybe the oxygen concentrations will go down in the bottom of the stream or lake. It will become quite eutrophic; maybe similar to the duck ponds that you saw when you were a kid, throwing all that bread in those really algae covered ponds.

Peggy: Into the greenness.

Sharon: That's right. So that's not necessarily bad on its own. We just have to think, what do we want our ecosystems to be like. Do we want them to be like they were before modern humans? And in fact, if that is the case, we need to make sure that the chemical balance is the same as well.

Peggy: So what happens when nitrogen held in the soils is released during the monsoons for example?

Sharon: Well, that is really interesting. The desert ecosystems, we have around here have lots of nitrogen compounds on the surfaces of the soils naturally and also from human pollution taken up by the soils essentially. Now when it's dry, for most of the year, the microbes in the soil are essentially dormant. They are just sitting there waiting for something to happen. Like my dogs. They're sitting there waiting for something to happen.

Peggy: [laughs]

Sharon: Then what happens is when you get a rainstorm everything in the desert comes to life. The microbes suddenly turn on, and they use this nitrogen and grow like crazy. They take the nitrogen and build up a population of microorganisms. The plants are also competing for that nitrogen.

But essentially what happens is because of this rapid pulse of microbial activity a lot of the nitrogen that is being mobilized by these microbes is actually re-released to the atmosphere as NO_x, the very same gas that cars are putting out of their tailpipes.

So we think of nitric oxide or NO_x. It's one of the criteria pollutants in the Clean Air Act. It's highly regulated. But essentially soils also produce NO_x. It's from the rapid flush of microbial activity.

So when you accumulate, let's say, nitrogen from the atmosphere, again natural and anthropogenic or human caused, for four months prior to the monsoon and then you get the first monsoon rain, a lot of the nitrogen is just re-mobilized back out as NO_x. In fact, some of our calculations are showing that the amount of nitric oxide produced by the soils is equivalent to the amount produced by cars in that very same day after a monsoon rain.

Peggy: So, the soils are almost like a storage site for noxious NO_x?

Sharon: It is. Now remember, nitric oxide is a natural compound produced by many soils across the world. It's only noxious in high concentrations. The amount produced by soils in one day is not high enough to cause any health problems at all.

But when you add it to all the pollution that comes from cars, and remember cars are running 365 days a year, and this is happening potentially once, it certainly does add a piece of the puzzle to the air quality issue there. If we are going to try and control ozone - just to back up a bit, ozone is really the chemical that the EPA is really trying to control. It is a strong oxidant. It can cause all sorts of problems with plants and smog.

NO_x is a precursor to that. And that combined with some other chemicals in the atmosphere can cause ozone. So if we are trying to control ozone, we need to control some of the precursors. If we are thinking only that people are producing these precursors, we are really missing an important part of the equation.

Peggy: Now I'm going to step aside and ask you a more primary question. How did you choose to go into science?

Sharon: That's a great question. Hmm.

Peggy: Now you mentioned that her father had been in computers.

Sharon: That's right. That's right. So I think from the beginning we always had pets. Now I know this sounds silly, but I became very close to the animals in my household. I became close enough to them, as many children do, that I had a real emotional connection to them.

I also happen to grow up during the Jacques Cousteau era. We had a television, and I remember sitting and being mesmerized by what I was seeing on the television. It was through those shows like Nova and other nature shows that I realized, wow, there is a lot to this world.

It became quite a justice issue for me. I personally have values that other species have equal rights as humans on this planet. It's amazing that all this life is here in the first place. We can all debate about why that is. But it's really quite an amazing and personal thing for me. So as I got into science I really was interested in trying to understand how we could make more of a connection between humans and the other species.

So I became interested in neuroscience actually. I wanted to understand how other animals communicate with one another. Luckily, I grew up in an area, in the Bay area of San Francisco and you might know Coco, the gorilla is in the Bay area.

I had a professor at Stanford in my undergraduate days, who worked with Coco. He was an older, white haired professor, your typical scientist that you might think of. He was very quantitative. And yet when he spoke of Coco, the nature of his speech changed quite dramatically because it was a transformative experience for him and apparently every other person who has worked with this gorilla.

So at that time, I thought that I needed to understand this work. So I went into neuroscience and try to understand a bit about the biochemistry of emotion. And as I learned more I realize that most of my work was going to be done in a lab on brains. Lots of the professors that I was working with were using primates. I didn't feel like I could do that, although it was such a fascinating area. We definitely know nothing about the brain. And we need to know more. And as we know more we feel like we know so little essentially.

[laughter]

Sharon: So after that I decided that I needed to transfer my energies into something where I can feel more passionate about what I am doing on a day-to-day basis. So I turned my attention to the environment. I went to a course at the Hopkins Marine Station, and I had the opportunity to do a lot of diving in Monterey Bay. Again, it was a really spiritual experience being down there with all the kelp forests and looking at all the animals all around me. I said to myself, 'You know I think I have found my life's work.'

Peggy: You had your experience at the Hopkins Marine Station. But what took you onto the land and looking at issues with ancient peoples and urban environments?

Sharon: That was time point; it was an exact time point, when I decided if I was going to study the oceans, which is actually the place where I had my first discoveries of science.

Sylvia Earle was another famous marine biologist, marine ecologist, who was a great influence on me. She happened to live in Oakland. I heard a talk by her when I was a young girl. My dad took me to a talk. And I thought, 'Wow, an amazing woman in science. I want to be her!'

[laughter]

Sharon: In fact, I had the opportunity to invite her to Colorado College where I used to work and introduced her and had the opportunity to spend an evening with her, which was one of the highlights of my career I have to say.

As I graduated from college, I wanted to go into education and spread the word a bit. Then I got to the point where I felt like I needed to know more before I could be a good teacher. So I decided to go to graduate school. And I thought I would like to study something in the environment.

I recognized that studying the ocean was quite difficult. I did a lot of diving and much of our work was very challenging because you set up a transect, let's say, on the ocean floor. When you come back the currents had washed it all away. The forces in the ocean were so severe that it was hard to do anything in person. So the kinds of questions I wanted to ask were more about the system, the ocean system and how humans were changing it but to do that we had to do most of our work from a boat.

I needed to be in it more. I needed to be up close and personal with the ecosystems that I was studying. So I applied to Scripps, and I got in there. I thought I could be an oceanographer studying most of my work from a boat, maybe from computers. Or I could study the ecosystem from a more personal point of view.

So I decided to go to Stanford and work with Pamela Matson, who then, that first summer took me to Hawaii.

[laughter]

Sharon: There I was, in the rain forests of Hawaii, definitely up close and personal and touching the organisms that I was studying and feeling the rain on my face. It was just a much better place for me to get in touch with some very difficult concepts that are about nitrogen and carbon and things that I can't see.

I knew that I wanted to study these things because they are essentially, in my opinion, some of the most important changes in that our humans are making to the environment. It also allowed me to be a human being and feel that closeness to the environment that I was studying.

Peggy: We have mainly been talking about how human systems have directly impacted the environment. What about something like introduced or invasive species? You mentioned Hawaii. That's why I'm bringing this one up.

Sharon: Well, it's interesting. I think that if you look at all the ways that humans as a species are changing Earth systems, I think the indirect ways are more important than the direct ways. We always think about CO₂, which is good. I'm glad we are thinking about that.

But what Al Gore pointed out, in his talk also is that the earth and the biosphere actually has a breathing pattern of its own. The inter-annual variation of CO₂ is much larger than the CO₂ that humans are putting into the atmosphere annually.

So it's the same thing with invasive species. As humans are moving species around - now remember, other plant and animal species arrive in places naturally. That's in fact how Hawaii became populated with species. We are very fortunate that they dispersed, and they can move. The issue now is that humans are moving them at rates that they haven't been moved before, and introducing them into places that haven't seen those types of organisms before.

Essentially, in Hawaii, it is an interesting issue. Many island ecosystems are the same in that the species that arrived there are special. And there weren't very many of them. As a result, they evolved in a time where they didn't have certain selection pressures.

So now we introduce, for example, the brown tree snake into Guam. It's a good example to introduce a snake into an ecosystem that did not have snakes. Pretty soon all of the ground dwelling birds were no longer because the snake was able to eat at will, essentially.

Peggy: Eat at will.

Sharon: So good for the snake. It's a survival of the fittest. That's true. So, is that a bad thing? No. It's a really great thing for the snake and its snake babies essentially.

Peggy: [laughs]

Sharon: But if we want an ecosystem to be preserved at a certain time point this is something we have to define. If we have decided that Guam's native flora was important to us, then we need to make sure that we no longer have the brown tree snake there or in other island ecosystems. But if we decide it's survival of the fittest, and that's just what happens.

But it's about us and our values because the ecosystems aren't going to care so much. It's us who really cares. So if we put our minds to it we can certainly change it if we want to and stop the trajectory of animals and plants moving around the planet if we need to.

Peggy: A lot of people are designing xeric gardens in their homes to be more conscious about water issues and invasive plant species issues and things like that. Is what we are

creating in our residential gardens that has the look of a desert community actually like a natural desert community?

Sharon: You think about what people gain from ecosystems and we call these ecosystem services. They provide us lots of things including aesthetics. It certainly allows us to participate with the land in a way that we never used to. If you lived in a high-rise in New York and you didn't have a garden, you wouldn't be necessarily interacting with your land, or the land on a daily basis.

So the landscapes that we have in single home families, for example, are a really important way for people to get in touch with the land. So what we are doing with these xeric gardens, you're right, on average the water use in these xeriscaped areas is much lower. We have drip irrigation, rather than sprinkler irrigation. We irrigate much less frequently. All these things are really great for water conservation.

One thing that we have discovered, however, is that instead of changing our irrigation schedules according to the climate, we basically with these drip irrigation systems - and Chris Martin over at the ASU Polytech campus has really explored this - essentially turn our irrigation systems on. We let them go according to their schedule. We don't change them. So essentially, these plants are getting way more water than they even need.

But in comparison to lawns, yes, they are using less water. In terms of the plants, we like them to look like a desert landscape. But in fact, the types of plants that we are putting in these yards aren't necessarily native. In fact, the herbivore communities, let's say the insect communities on these plants and these ecosystems may be different because the bird predators are different. That's because maybe the raptor species are different in the city.

So, unless we bring back all of the different pieces of the ecosystem, including different parts of the food chain and maybe the same soil texture, maybe the same microbial communities, I don't know how close we are going to get to the desert.

At the same time, however, compared to a lawn, these ecosystems are functioning very closely to deserts. They release gases at the same rates as the desert, as it turns out. They respond to water additions in the same way as deserts. And maybe they look enough like deserts that that's good enough for us.

Peggy: So what kinds of things, can we do to change our nitrogen footprint?

Sharon: Well, I think in terms of changing the nitrogen footprint, if we know more about it I think people will make the right decision. I am a firm believer that you give people the scientific tools and information, and maybe the economic will to do so and they will make the right decisions.

So one thing for all of us to know is that the impact that we have with our cars has a nitrogen consequence especially if we have some lawns, which may be great for families, and it certainly cools the environment. I know that on a hot day I want to sit in the middle of a lawn. I do not want to sit in someone's xeric garden.

Peggy: [laughs]

Sharon: It's certainly cooling and there are all sorts of ecosystem benefits to lawns, I have to say, for humans. But what we need to be aware of is the nitrogen fertilizers that we put on, on average in agricultural systems, which is essentially what lawns are, they are little urban agricultural systems, about 50% of the nitrogen that we put onto an ecosystem doesn't stay there. Most of it goes down into the groundwater or into streams or lakes. Some of it goes off, as we talked earlier, into the atmosphere.

So if we understand that we might not over fertilize. We might change our fertilization practice. Or we might think about planting species that don't require so much nitrogen.

It's like when we talk about waste. There is no throwing away. There is no away. It goes somewhere. The nitrogen goes somewhere. As it turns out, most of the nitrogen in the Phoenix ecosystem goes into the groundwater or into our streams. If we are dependent on groundwater for drinking, which we are, we need to think about maybe thinking systematically and looking downstream if we have a roadmap of where nitrogen goes, which we do. Let's look a little downstream and think about reducing some of that problem a little earlier, which might occur in our homes.

Peggy: Well Sharon, I want to thank you today for sharing your thoughts with us. Good luck with your research.

Sharon: Thank you.

Peggy: You have been listening to Science Studio. Science Studio is produced in the School of Life Sciences in the College of Liberal Arts and Sciences on the Tempe campus of Arizona State University.