Under the Jungle - Geo Karst challenge - Sunday October 18
Roots in Caves!

ROOTS IN THE CAVES. One of Nat's favorite things is to find tree roots in the caves -- are these trees still alive? How much water are they consuming? Do they actually drain a significant amount of water from the aquifer? Do tree roots actually act as the base for some of the weirder cave formations we see? How do they get down there -- do they bore their own holes, or do the roots find their way through pre-existing holes?

PHREATOPHYTES - is what we call plants that have roots that can reach to the water table. The phreas, is the ground that has standing water, and is defined by the water table. Phytes - means lovers of. Lovers of the water table => phreatophytes!

Are these trees still alive?

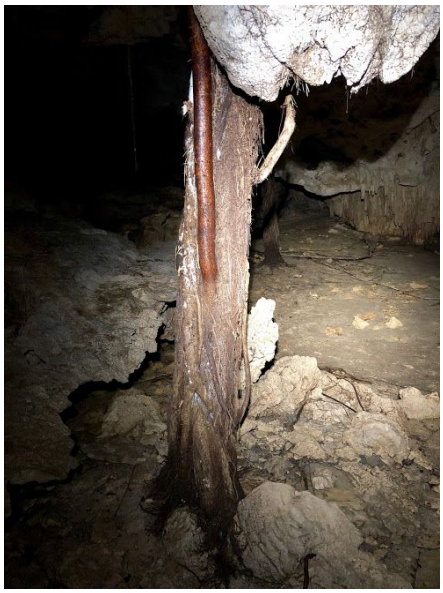
If you see roots that look brown and woody - then yes those trees are undoubtedly alive!
If they look crumbly and/or covered in mold - then they are likely dead and decaying.

In dry caves, you can often see liana roots on the sediment that are in rapid decay. I have seen roots very quickly decompose over just a few weeks.

The super fin roots are called rootlets and if you see these literally blowing in the water flow then yes those are alive.

Are these even trees?

Mostly - yes - but not all!
And there are definitely a number of species that are phreatophytes in the Yucatan.
If you look at the roots closely you can often see many different morph / colors / bark textures all tangled together.
Even in this underwater video from Sara Landau you can see at least 3 different types of rootlets - with the white fine, the tan fine, and then the darker brown thicker ones.



The best recent work in this broad area was done by Rachel Adams on the Yucatan tree roots in the caves, and you can read a recent article here where DNA analysis allows for identifying for who the roots belong to! https://nph.onlinelibrary.wiley.com/doi/full/10.1002/ppp3.10079

This shot from Rachel's webpage neatly shows the inter-twined species

How much water are they consuming? Do they actually drain a significant amount of water from the aquifer?

Trees - in general - consume a surprising amount of ~1 gallon per inch diameter of the trunk. Big trees therefore need gallons of water per day. Overall - more thirsty than humans....

HOWEVER a related question though is how is that water returned to the environment. What is the quality of the discharge water..... Trees release water vapor into the air. Which then comes back down again as clean rain...

Then let's imagine the range of quality of the water that we release as individuals and our industries release back into the environment. Can get pretty nasty sometimes eh!

There was an interesting study in Texas, where it was considered that the trees were taking too much water from the aquifer system. If they cut down all the trees, there would be more groundwater, and therefore more water for things like the cities, agriculture, and such. A controlled field experiment was done, with irrigation over a cave and the infiltrating water measured. Then - they chopped all the trees. Turns out that trees - while cycling alot of water - are actually quite conservative and efficient. The deforested surface suffered much worse water losses from unregulated evaporation, and much harsher run-off of the bare ground. So - while trees use alot of water - they are major regulators of the hydrological cycle!

That was a dryland though - but we have played this experiment many times globally with deforestation and the results are pretty much the same. **Keep the trees to keep the water.**

See - http://agrilifecdn.tamu.edu/wilcox/files/2013/01/2012-Bazan-et-al.-ecohydrology-cave.pdf

ECOHYDROLOGY
Ecohydrol. (2012)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/eco.1277

Removing woody vegetation has little effect on conduit flow recharge

Roberto A. Bazan,[1] Bradford P. Wilcox,[2]* Clyde Munster[3] and Marcus Gary[4]

[1] *Rocky Mountain Research Station, US Forest Service, Fort Collins 80526, CO, USA*
[2] *Ecosystem Science and Management, Texas A&M University, College Station 77803, TX, USA*
[3] *Biological and Agricultural Engineering, Texas A&M University, College Station 77803, TX, USA*
[4] *Edwards Aquifer Authority, San Antonio 78215, TX, USA*

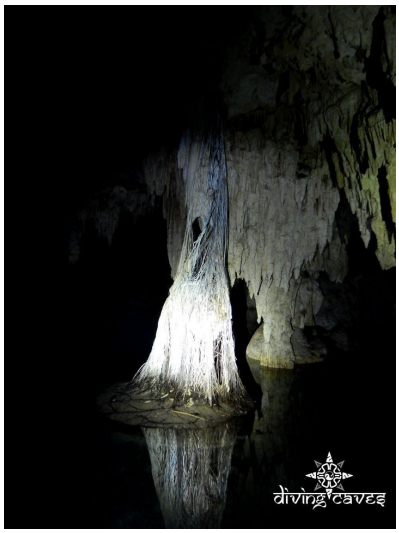
ABSTRACT

In drylands across the globe, grasslands and savannas have succumbed to encroachment by woody plants. There is a concern that, in some cases, these changes may lead to lower groundwater recharge and streamflow. In karst landscapes, the effect of woody plants on recharge is difficult to determine because of the shallow and rocky soils. In our study, we estimated the amount of water entering a shallow cave (3–5 m deep) as a surrogate measurement for groundwater recharge, to evaluate whether the removal of Ashe juniper (*Juniperus ashei*) above the cave would affect recharge. Three sets of large-scale rainfall simulations were conducted in 2005, before removal of the overstory juniper; seven were conducted in 2008, soon after the juniper were removed; and two were conducted in 2009, one year after juniper removal. We found that recharge occurred mainly via conduits or macropores and, as such, was extremely dynamic and responsive to rainfall. The amount of recharge ranged from 3% to 17% of the water applied, the higher percentages being measured when antecedent soil conditions were wet. At least in this case of recharge taking place via conduit flow, removal of the juniper had little if any effect.

KEY WORDS recharge; woody plant encroachment; karst; cave hydrology; juniper

Do tree roots actually act as the base for some of the weirder cave formations we see?

Lexi's sweet photo of rootlets growing out of a soda straw is notable, but not common. Christine's photo of a "root ball" though - that is where the interesting things happen.



If you hang out in caves at and above the water table, it is interesting to watch these white, bulbous, low density, calcite tufa exude water when it rains. It is almost as if the pathways of the roots allows the water to run down them and come out around the root tips.

Roots respire, and all the organic matter in the soil and any rotting roots also add to the CO2 in the space above the caves. That leads to supercharged infiltrating water, and much dissolution above the cave.

The root balls really are lumps of rapidly forming calcite that forms when this infiltrating water hits the cave air, the CO2 leaves the water rapidly since the pressure gradients are so great - and presty you get a massive porous sponge forming around the roots. I think there is great storage in these root balls and may be a reason why the phreatophyte trees are so good are getting through any droughts and such - they build their one storage reservoirs!

Martin asks about weird symbiosis…. How about this one - IRRIGATION!

Glad you asked. In addition to the usal super interesting and rich relationships with fungi, and all sorts of micro-organisms, it also turns out that a lot of trees - especially in the tropics have very leaky roots. It is likely that the phreatophytes in the yucatan are literally leaking water in the shallow group - irrigating the forest floor. It is likely that some key trees keep the whole jungle accessing groundwater - even if all the roots are not getting there directly.

In part to study this question, my backyard this summer has featured instrumenting 4 tree species with 30 loggers….and when I can I will be bringing these new instruments to the Ycuatan to figure out who is taking up how much water, and if they are sharing it around!

How do they get down there -- do they bore their own holes, or do the roots find their way through pre-existing holes?

Yes - without question tree roots occupy available holes. However, trees also are very good at drilling their own holes. Rootlets exude acids, which help them dissolve minerals for adsorption.

However more importantly, the roots respire which releases CO2 and that very much boosts the carbonate acid generation around the roots, which also allow water to run along them. Dissolution therefore happens RIGHT where the root is headed.

A very neat positive feedback. This is a form of **BIOLOGICAL WEATHERING** that leads to targeted **CHEMICAL WEATHERING**.

And - roots are also very effective at **MECHANICAL WEATHERING** busting up rocks, even the hardest ones.

There is also a process called plucking, when trees are knocked over they pull apart the rocks they are rooted in. You can see this with rocks stuck in the roots of tree stumps.

Picture essary from Pawlik et al 2016 - https://www.sciencedirect.com/science/article/abs/pii/S0012825216301143

Martin Pollizotto asks - Can a high density of large trees have roots that actually disrupt the integrity of the cave room resulting in additional windows opening up?

Oh yes - and indeed I think the ficus (alamo?) is particularly good at this. See picture with ficus roots literally opening and weakening small cracks. Ficus is especially common around cenotes, and many of the hanging pendulum roots into open cenotes are ficus - you can tell as they are the common cream/light grey bark trees with buttress roots and notably good spreading roots.

However - the lianas love living around the ficus - so we need to turn to Rachel's work to learn more - and even once species are identified we still need to figure out who is doing what - even once we know they are there.