Should we build a nature reserve on Mars?

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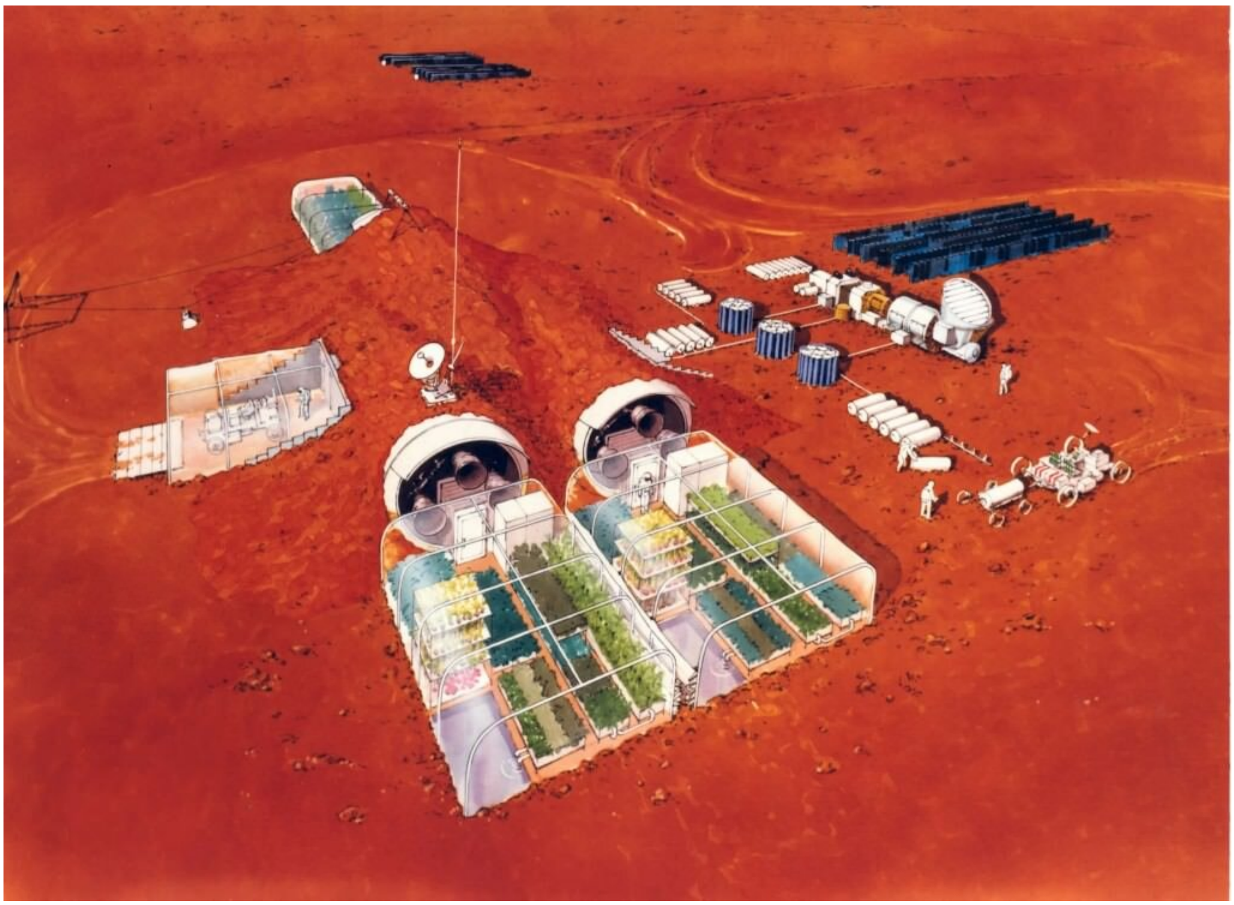


If we ever colonize Mars, nature will have to accompany us. Artist's concept of a habitat for a Mars colony. Credit: NASA

There are 8 billion of us now. The UN says when the population peaks around the year 2100, there'll be 11 billion human souls. Our population growth is colliding with the natural world on a greater scale than ever, and we're losing between 200 and 2,000 species each year, according to the World Wildlife Federation.

An Engineer from the UK says that one way to mitigate the damage from the clash between humanity and nature is to create more habitat. We could do that by building Terran ecosystem preserves on Mars.

Paul L. Smith is a Civil Engineer in the Faculty of Engineering at the University of Bristol, UK. In an article in the *International Journal of Astrobiology*, he explains how we could build a nature preserve on Mars that would act as an extraterrestrial nature reserve (ETNR.) The ETNR would act as both a "psychological refuge and botanical garden," according to Smith.

On the face of it, the idea might seem absurd or preposterous. But Smith is an engineer and has thought this out. He's not saying that an ETNR on Mars is imminent. He takes the long view: that humans will continue to put pressure on Earth and that we will colonize Mars. He says that ETNRs should be part of any colonization effort. Smith isn't the first to think about this idea. He leans on lots of previous research by others.

Before you can evaluate how wise this might be, you have to evaluate how possible it might be. Who better than an engineer to dig into that question?

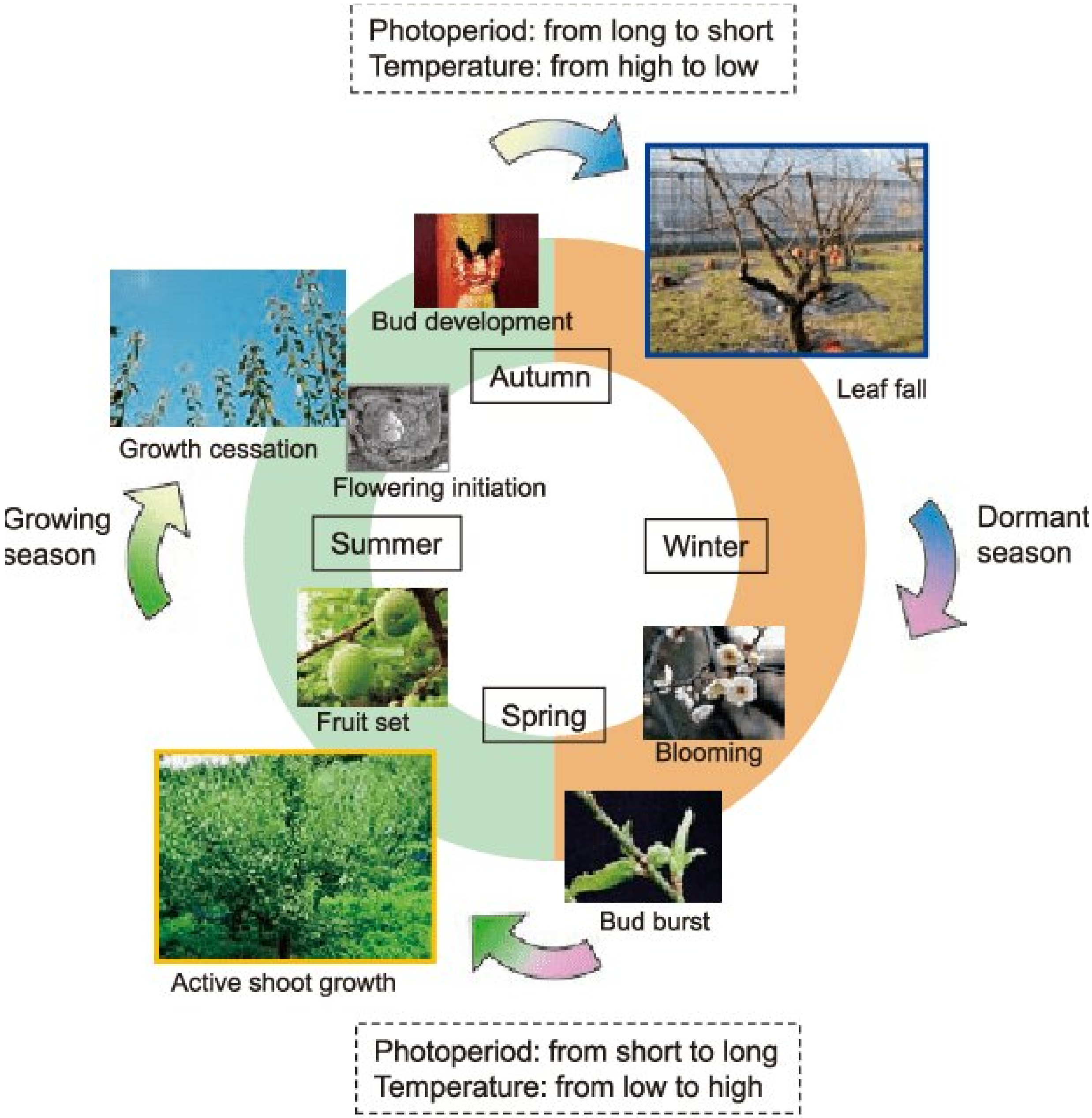
Martian day length is similar to Earth's, so that foundational piece is enough to get started. Mars is much colder, but systems to keep an enclosed spherical preserve already exist, so the temperature can be managed without too much complexity. The Martian surface is dry, but ample frozen water exists underground, so the problem of a water supply isn't insurmountable.

Mars' and Earth's atmospheric makeups are wildly different, but that's one of the easier problems to address. An enclosed environment can be engineered to have whatever atmosphere is desirable. Plant life itself can regulate the environment to some degree. The temperature and pressure are two of the easier factors to regulate.

These are the basics, but much more confounding issues arise when a more detailed analysis is done. And Smith's analysis is detailed.

The Martian radiation environment is where things can begin to get complicated. Without an ozone layer like Earth's, the Martian surface is exposed to dangerous levels of ionizing UV radiation. "Mars' harsh surface UV flux is sterilizing due to thin atmosphere and lack of significant ozone," Smith writes. Some UV radiation is desirable and is part of some creatures' metabolisms. Humans need some UV to stimulate the production of vitamin D. But Earth life forms are not adapted to increased UV and would need adequate protection.

"Fortunately, glass/plastic combinations can exclude harmful wavelengths whilst transmitting beneficial UV and visible light," Smith explains, "so flux in CTTEs (Containted Terran-Type Ecosystem) can be controlled."



The life of plants is intricately connected to seasonality, and so are the lives of other creatures like pollinators. How can this be replicated in an extraterrestrial Terran nature reserve? How much of it will need to be replicated? Credit: H. Yamane 2014

Magnetic fields are a more open question. We know that the magnetic field protects Earth from cosmic rays and that it prevents the solar wind from stripping the ozone layer away. But we don't have a full understanding of the ways that Earth's magnetic fields play a role in life. Some creatures use magnetoreception to migrate and move around. Some call magnetoreception the "greatest mystery in animal biology," and that puzzle needs to be understood better. Could we engineer an artificial magnetic field in a CTTE?

Earth life changes as the seasons change, too. The makeup of the biome changes, and that would have to be managed. Mars' seasonal variability is much different than Earth's, so seasons would have to be engineered. "Temporality determines critical developmental stages, individual physiologies and interspecific relationships, while timing of abiotic events influences global nutrient fluxes," Smith explains.

"Photoperiod and winter chilling are involved in temperate plants' phenology." Phenology includes things like bud set, bud break, and flowering in plants. It also includes more complex animal behavior like migration, breeding, and egg laying. Those behaviors are intimately synchronized in nature, among individuals and among different species. Replicating that will be a massive challenge.

Humans obviously don't breed seasonally, but we're not isolated from the seasons, especially in temperate regions. "Seasons also imbue characteristics critical to psychological restoration, e.g., autumn color, winter silence, spring flowers and summer leafiness," Smith writes, and he's not wrong.

Another difference between Mars and Earth that might be overlooked are lunar cycles. Earth's moon is massive and has a powerful influence. Tiny Phobos and Deimos, Mars's pair of potato-shaped moons, have almost no effect on Mars. Even if Mars were full of life and had oceans, those two small rocks couldn't generate tides. In fact, there may be regions on Mars' surface where the moons are never even visible.

Smith describes Earth's moon as a zeitgeber, "a rhythmically occurring natural phenomenon which acts as a cue in the regulation of the body's circadian rhythms," according to the dictionary definition. Martian day length is similar to Earth's, so diurnal rhythms may not be a challenging issue.

Mars receives only 43% of the sunlight that Earth does. Research shows that it's enough for photosynthesis, but plant growth rates on Mars won't match Earth's without artificial augmentation. This is another obstacle that can be overcome by engineering and technology, but it makes an ETNR more complex.

Smith talks about placing nature preserves in subterranean lava tubes, which would provide UV protection and other benefits. In those instances, artificial light augmentation would be required.

An ETNR would need soil. Mars has a basaltic crust that contains many nutrients necessary for Terran plants. "Basalt-derived soils with volcanic ash are good agricultural soils," Smith writes while referencing other research. "Crushed basalt can increase soil pH, while its dissolution releases beneficial nutrients, including phosphorus." Phosphorus is one of the three primary nutrients plants need to grow: nitrogen, phosphorus, and potassium.

There's probably ample nitrogen in Martian soil for plants to grow, but plants also need 16 other micronutrients. "These are all reported from Mars or Mars meteorites," Smith writes. But other chemicals are involved in soil fertility that aren't directly consumed by plants. It's a complicated puzzle.

Earth soil not only contains all the nutrients plants need. It's also full of microbes and creatures like Earthworms. These creatures are part of the living system in Earth's soil. Will the entire system need to be recreated? If so, that's an extraordinary level of sophistication. Research shows that some of this can be replicated in the Martian regolith, but that research was done on replicated Martian dirt. How confident can we be that we can build an entire soil system on Mars?

Martian regolith also contains greater levels of toxins than Earth soil. There are higher levels of perchlorates on Mars, making the regolith toxic to life forms. There are also far more iron oxides in Martian regolith, and when combined with increased levels of perchlorates and hydrogen peroxide, it's a highly toxic mix. Can remediation deal with that? Possibly. In fact, building soil from scratch is a critical building block for an ETNR and would be one of the most complex tasks.

Then there are Martian dust storms. Some of Mars' regolith is so fine it's sent aloft in storms that are sometimes larger than the continental US. It collects on surfaces and is a problem for solar panels on Martian landers. It also lowers the amount of solar energy reaching the surface, putting further strain on photosynthesis.

Mars' lower gravity has to be accounted for, too. Martian gravity is only 38% of Earth's, and gravity is one of the factors that modulate plant growth. Could a towering evergreen tree grow in Mars' reduced gravity?

"Experiments indicate 0.3 g (

"From such evidence, it is conceivable that some plants will tolerate Mars' gravity," Smith writes. "However, forest function is also influenced."

Gravity affects more than just plant growth. It governs a multitude of other things that have to be accounted for. "Leaf and propagule fall, leaping, flight, deadwood collapse, raindrop impact and drainage of water contribute dynamism," Smith explains. But lower gravity could provide some benefits, too. Mars' lower light could contribute to "leggy" growth in plants, weaker stems, and less vigorous growth overall. Lower gravity might balance some of those negative effects.

Smith points out that trying to recreate a specific Earth forest biome is counterproductive. They're far too complex to replicate. "Earth's forests owe their assemblages to environmental and evolutionary pressures that will differ from those in Martian CTTEs. No single forest food web has been fully mapped, canopies themselves potentially comprise over 100 000 trophic links, challenging duplication." Instead, a terrestrial ecosystem would be a new web of life that would take time to establish itself in Mars' environment. The goal would be to introduce species and see which ones adapted, allowing time for a new hybrid ecosystem to develop.

"ETNR designers should consider species as ecological cogs that might be assembled into functional ecosystems. Replication of Earth forests is currently unfeasible, but development of new ecosystems, functioning in unexpected ways, is conceivable. Mars' forests would not resemble or function exactly like Earth's forests but could still deliver wonder; autumn at 0.38 g offering dreamlike leaf fall," he writes.

There's a lot more detail in Smith's article. This is a huge topic, and we're only beginning to grapple with all the issues. For example, if ETNRs are meant to provide respite for humans on Mars, we need some of the right species. "Woodland without birdsong or butterflies is a poor TTE. Such lack may exacerbate homesickness," he explains. What a haunting feeling to wander through a silent forest. On the other hand, we could all do without mosquitoes.

What about ethical constraints? Not all of our efforts will be successful. Do we have the right to transport other lifeforms to an ETNR, only to watch them suffer and die if they can't withstand conditions? Or would the entire effort be part of sustaining all Earth life in the event of a calamity, so their suffering would be alongside ours?

These are complex questions without simple answers.

Our understanding of how life all works together is far from complete. We're still mystified when groups of whales beach themselves or when there's a massive bird die-off. We can't expect to "freeze" conditions in an ETNR so that there are never die-offs. Those can lead to new niches exploitable by other lifeforms. That's nature, and if we're going to try to recreate it, we have to accept it.

Smith emphasizes another point that sometimes gets lost in these types of discussions. Homo sapiens obviously didn't evolve in a vacuum. We evolved alongside other lifeforms, and we can't survive without them. At a very basic level, our guts are colonized by bacteria—an important part of the human microbiome—and without them, we're screwed. On this basic biological level, we need other lifeforms to survive, and they, in turn, rely on other lifeforms. The web of life is extraordinarily complex.

It's an overwhelming question: Do we have the knowledge to rebuild a contained Earthly ecosystem on Mars? But asking that question leads to another foreboding question:

Are we forcing ourselves into a position where we have to answer the first one before we're ready?

Even if we never get to Mars or build an ETNR, the thought exercise drives home this point: Nature is the overarching structure that governs our lives, and we need it more than it needs us. And we have a responsibility to keep nature alive.

"From a biocentric perspective, world leaders should be concerned about the future of life in the Universe and humanity's role in its protection and promulgation," Smith writes. "On a planet of limited habitability, this is a significant duty. The survival of life, in any form, is the ultimate biocentric priority."

More information: Paul L. Smith, Extraterrestrial nature reserves (ETNRs), *International Journal of Astrobiology* (2022). DOI: 10.1017/S1473550422000398

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