Science Societies

Saline soils and the agricultural failure of a prehistoric population

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Saline Soils and the Agricultural Failure of a Prehistoric Population, CSA News

- The Hohokam, prehistoric farmers in the Salt River Valley of Arizona, used a complex irrigation system to farm in a hostile desert environment.
- Over time, saline irrigation water contributed to soil degradation and the eventual collapse of the Hohokam civilization.
- Present-day farmers in the Salt River Valley overcome desert conditions and soil salinization through modern methods of water management.

A puzzle: You are a farmer with no metal tools. Even if you had a plow, you haven't any animals to pull it. Nearby is a river filled with salty water though that river runs

sporadically throughout the year. You do have an abundance of sunlight, but that sun dries out the soil as quickly as you can water it.

A solution: You dig. You create an elaborate system of ditches carved from the hard, desert soil, and you direct salty water from the river onto your fields as best you can. It works for a while—you and your family can grow food to eat while the river runs.

Soon, some of your fields fail to grow as many crops as they used to.

You expand. You create more canals and fields and let the poorest-performing land lay fallow. It is a constant battle to maintain the same level of production, even with more land growing crops.

Sometimes the rains come down all at once, flooding the river and your carefully dug canals and ditches, occasionally destroying them completely. You start all over, and somehow, the crops grown in the flooded fields yield more than before, until yields fall again. The puzzle continues.

The Hohokam

The Hohokam were prehistoric farmers with incredibly limited resources, working under the conditions described in our puzzle above. From 450 through 1450 CE, they lived in the Salt River Valley in the Sonoran Desert near present-day Phoenix, AZ.

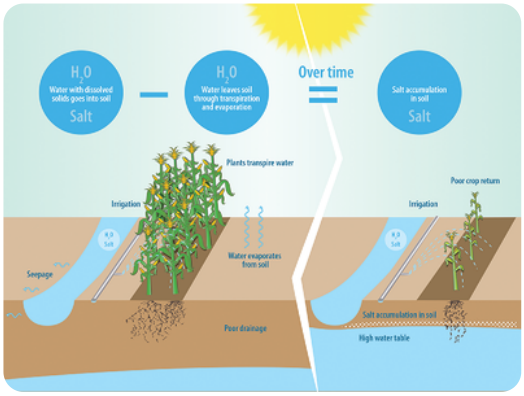
Based on archaeological evidence and population density estimates, Hill et al. (**2004**) posit that the peak Hohokam population was around 40,000 people, spanning about 100,000 km^2 in 1300 CE—a population averaging about one person per square mile.

The exact reason for the disappearance of the Hohokam civilization from the Salt River Valley in 1450 is unknown. Historians have posited that overpopulation, disease, lack of resources, and the disintegration of the social structure that kept the group together might have contributed (Abbott, **2016**).

SSSA member Henry Short, though, thinks there is more to the story. A career ecologist and former employee of the United States Fish and Wildlife Service in Washington, DC, Short took up volunteering at a local museum during his retirement in the Phoenix area. This was where he encountered the Hohokam.

"I was a bit frustrated because I didn't think their story was being told in an ecological manner, and I thought it was an ecological story," Short explains.

In a recent paper published in the *Journal of Environmental Quality* (**https://doi.org/10.2134/jeq2019.01.0015**), Short examines the relationship between the Hohokam and the Salt River and how that tenuous but vital relationship may have led to the civilization's collapse in 1450.



Irrigating with saline water presents many issues, particularly in the desert. If the soil dries out before water flows past crop root zones, salts remain near plant roots and negatively impact growth over time. As soil becomes more sodic, the water table rises, drainage decreases, and water sits near the soil surface, evaporating in the sun and leaving even more salts behind. Source: Karen Brey.

Irrigating with Saline Water

True to its name, the Salt River is salty. Flowing from the mountains of east-central Arizona, the river contains sodium, chloride, calcium, magnesium, calcium carbonates, sulfates, nitrates, and fluorides; it is classified

as “very saline” according to the Bureau of Reclamation (2003).

It is so rife with dissolved solids, in fact, that at the eastern salt springs, the limited water flows are like a solution of table salt. Sodium is typically found at levels between 10 and 13.15 kg m^{-3} water while the chlorine levels are between 15.9 and 20.8 (Bureau of Reclamation, 2003). However, the salt levels are much diluted by the time the river reaches the Phoenix Valley and the water is used in irrigation.

Irrigating with saline water presents many issues, particularly in the desert. If the soil dries out before water flows past crop root zones, salt remains, negatively affecting plant growth as soil becomes more sodic. Any areas with poor drainage accumulate salt even faster as water sits closer to the surface and evaporates before plants can use it.

Panoramic view of the Roosevelt Dam and Reservoir (courtesy of Salt River Project).

Nearly every aspect of plant development is affected by excess salinity. Carillo et al. (2011) list water and oxidative stress, decreased cell division, and ion toxicity as some of the many ways saline conditions impact crops.

Plus, not all salts affect soil the same way. The high sodium content has a peculiar effect on clay in the soil, creating dispersion of clay particles. Over time, these clay particles plug soil pores, decreasing drainage and compounding salinization (Krista et al., **2003**). The cycle of drying and rewetting clay soils containing high sodium ion levels can cause the clay to form a solid, cement-like layer, reducing water availability to crop roots.

It was a balancing act for the Hohokam. Farmers needed to get enough saline irrigation water to the field at the right time while working in a hot-arid desert climate that tended to evaporate that irrigation water before it could reach crop roots, and they needed to drain that water through a deep enough water table to prevent salinization. Failure at any point in the process caused soil salinity increase, plant stress, and crop failure. All of these things increased family and social stresses for the Hohokam, burdening a civilization already working in a hostile environment.

For the Hohokam, the only way to leach the soil was to hope for a flood. “They were dependent on flooding for their efforts at de-salinization of soils. They were dependent on the soil being sufficiently porous and the water table being sufficiently below the root zone so that their saline irrigation water would pass through rather than being evaporated from the surface,” Short says.

Stone Age Innovation

Using a complex system of canals and dependent entirely on the seasonal flow of the Salt River, the Hohokam irrigated crops and supported a civilization in a hostile environment for a millennium.

Excavations of Hohokam canals show that the canal system increased over time, with some canals reaching as far as 16 km away from the river (Hill et al., **2015**). New fields were put into use farther from the Salt River. The Hohokam dug more ditches,

combatting the problem of getting limited water to flow farther to fertile soil while sodic fields lay fallow closer to the river.

“They were conveying their water in dirt ditches that were very imperfect and had great seepage,” Short says. “They were losing extensive amounts of the water they could have used for irrigation. Being dependent on water flow, they had no control over the drought conditions. If water didn’t flow, they didn’t irrigate…then their capability for agriculture and food production was very sorely reduced.”

With the means available to the Hohokam, their only controllable method of combatting soil salinization was to make sure the fields received enough water to leach salts and prevent accumulation. If that failed, they were reliant on floodwaters to leach salt and refresh nutrient-rich topsoil through silt deposition.

Over time, increasing the number of fields in use just to maintain the same level of production was likely the only way the Hohokam could support their population. New development efforts, Short suspects, were not to increase production, but to bypass unproductive agricultural areas to reach new fields.

Salt River Project delivers water to the Salt River Valley through a series of canals with development of the nine canals that make up the system developed over the past 100 years (courtesy of Salt River Project).

Eventually, Short suggests that the degraded soil quality impacted the Hohokam's environment just as surely as deforestation or over-grazing affected other environments. There is no archaeological evidence of the Hohokam inhabiting the Salt River Valley after 1450 CE.

Modern Means

Modern farmers in the Salt River Valley have a very different relationship with the river. Though still used for irrigation, the river is no longer free flowing.

In the 1860s, miners and farmers settled in Arizona, and a modern system of irrigation canals was developed. The settlers, plagued by drought, were searching for a reliable

source of water.

In 1902, President Theodore Roosevelt signed the National Reclamation Act into law, providing government financing for projects like dam and reservoir construction for irrigation.

In 1903, a group of farmers and ranchers came together in the Salt River Valley, pledged their own land as collateral, and obtained a loan through the National Reclamation Act to build a dam, according to the Salt River Project (SRP) website (**https://srp.net/38LMvM3**).

This group formed the SRP, which to this day, still manages the power generated by the dams on the Salt River.

Building dams and reservoirs created a stable source of water for modern farmers, allowing them to increase their growing season and decrease their dependence on the river. Water is now available as its needed, rather than governed by sporadic seasonal flow.

Furthermore, modern farmers are no longer at the mercy of floodwaters to prevent salt accumulation. Soil addendums like calcium and magnesium can replace harmful salt ions that adhere to soil particles, decreasing dispersion. Fields can be built on a slight grade, preventing water from pooling and evaporating before it moves through the root zone. Artificial drainage systems serve as means to prevent water pooling and evaporation, as well.

“The modern farmer is more independent of nature than [the native farmer]—the modern farmer is able to double-crop or multiple-crop, whereas the Hohokam were probably restricted to springtime agriculture,” Short says. “The difference between the

Hohokam and the 21st century farmer is the difference between passive and active management."

Overall, Short emphasizes the respect he has for the Hohokam and their ability to survive in a difficult environment that presents a difficult puzzle to modern farmers, even with 650 years of technological advances.

"It's tough handling water, and it's tough handling water when everything is done by hand," Short says. "The modern farmer should have a tremendous appreciation of how much difficulty, how much effort that entailed and how much success the Hohokam had. It was, I think, one heck of an achievement to stay alive and keep a family or a community fed in the conditions these folks were working under."

Dig Deeper

Check out the related article in the *Journal of Environmental Quality* at **https://doi.org/10.2134/jeq2019.01.0015**.

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