# Reassessing Agricultural Potential in Chaco Canyon: Exploring the Link Between Soil Salinity and Maize Agriculture


Archaeology Southwest

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## Introduction

The agricultural potential of Chaco Canyon has been a topic of archaeological debate for several decades. Some researchers argue that the soil quality in the area would have prohibited inhabitants from growing their own food, forcing residents to rely on outlier settlements. Many of these arguments focus on soil salinity and the availability of water in the area, although factors like water management strategies that may have mitigated these conditions are often ignored (Scarborough et al. 2018; Vivian 1990). The recent contradictory publications from Tankersley et al. (2016) and Benson (2016) focusing on these variables highlight the divergent interpretations that have been made based on these data. Recently, McCool et al. (2018) have focused on exploring the methodological incompatibilities of soil salinity measures within the canyon and the high spatial variability of the results. In this poster, we compare data from Chaco Canyon with studies of the Middle Gila River Valley to highlight the different ways this soil methodology has impacted archaeological interpretations of these two regions. Particularly, we focus on a comparison of salinity variability and recommend caution in applying this measure to the archaeological record.

## What is Salinity?

Salinity is the amount of salt dissolved in a solution, and is a key factor in determining soil quality. If too much salt is dissolved into a solution (saturation), dissolution will cease and subsequent precipitation of salt, or salinization, may begin. This process can occur naturally—rock weathering, tidal exchange, evaporative processes—or anthropogenically with irrigation practices. High dissolved salt levels restrict plant growth by inhibiting water flow into the root system, which causes the plant to wilt, regardless of water availability. Salt tolerance among plants varies depending on heartiness, growth cycle, and root systems. Maize, the primary Southwest crop, has a relatively low salt tolerance.

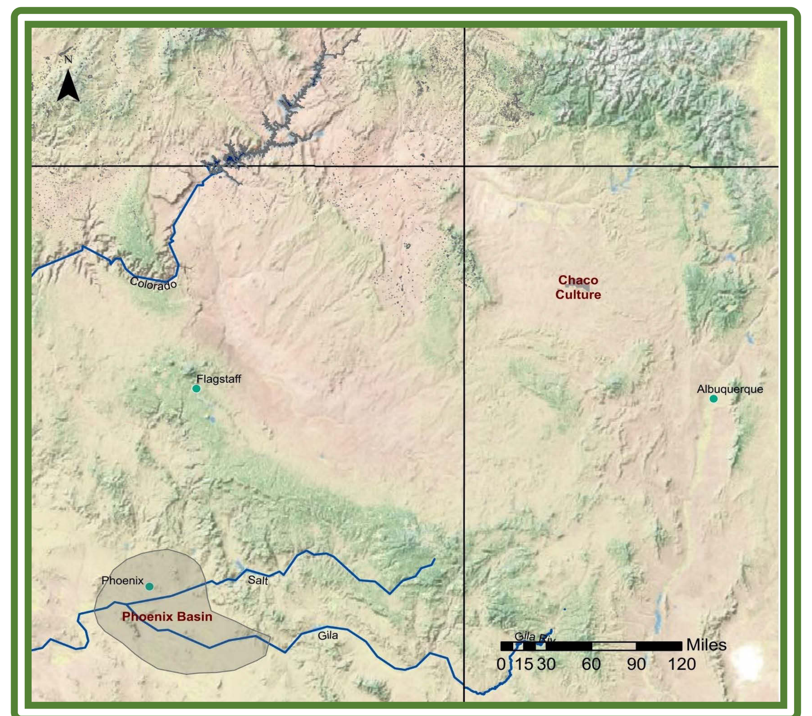
**Above: Electrical Conductivity (EC) meter**

## Measuring Salinity

The primary method of determining soil salinity levels is by measuring the electrical conductivity (EC) of a soil mixed with pure water. The EC level, measured in deciSiemens per meter (dS/m), increases with the amount of ions in solution, introduced from the soil sample, which carry (i.e. conduct) a charge through the water. The process for measuring EC consists of:

- Collection of field samples
- Creation of a specific mass:volume mixture of the soil sample and deionized water
- Allowing adequate time for salts to dissolve (equilibrate)
- Use of an EC meter to measure conductivity on the mixture or a filtered extract

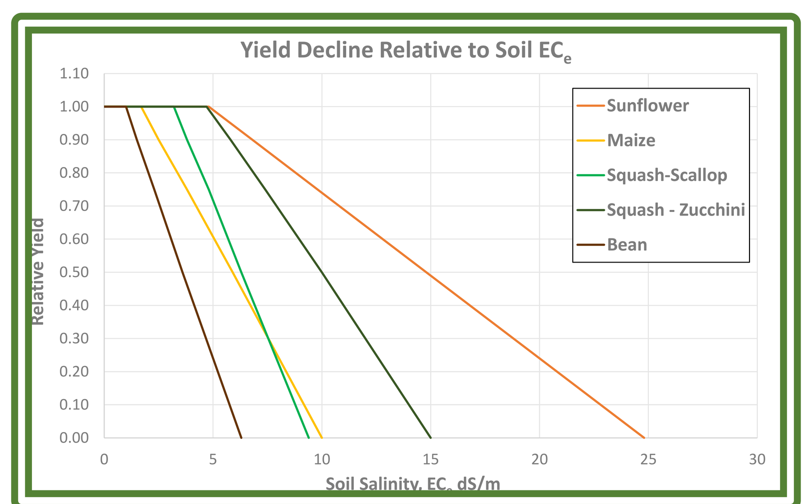
There is considerable variation in the measurement of salinity, such as different soil-to-water ratios or equilibration times, which can produce differing and incomparable results (McCool et al. 2018). When different methodologies are employed, conversion factors must be used to estimate values at a consistent soil to moisture ratio to allow comparison of data.



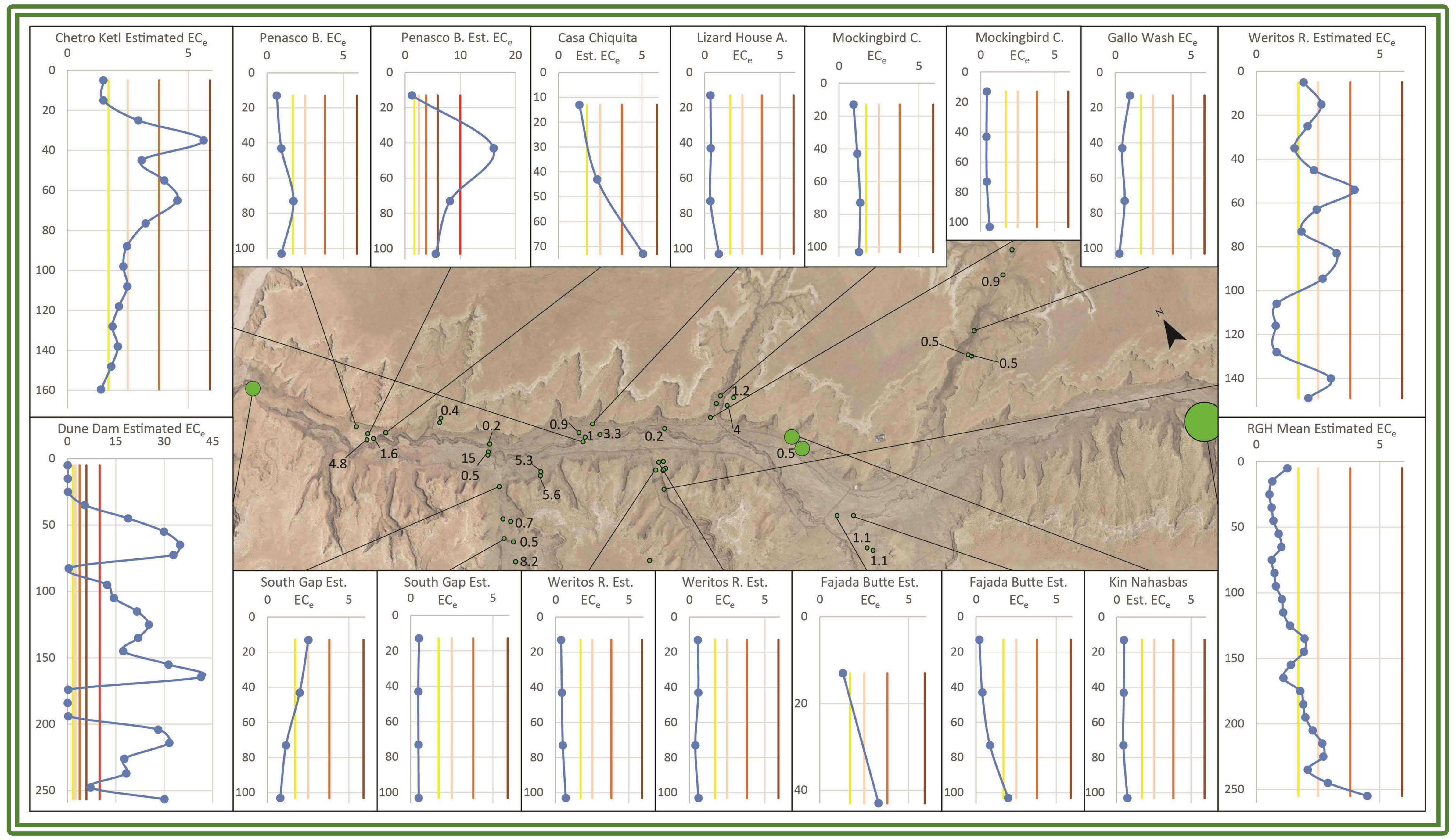

**Above: Map of the location of Chaco Canyon and the Phoenix Basin.**

## Maize Productivity

Salt tolerance varies greatly amongst plants. Maize has one of the lowest tolerances of the staple crops in the Southwest at 1.7 dS/m. However, salinity has a *gradual* affect on its yield, *not* causing a 100% decline until soil $EC_e$ reaches10 dS/m.




**Above: Piece-wise linear response functions of common crop types to increasing soil salinity (Ayers & Wescott 1985, Grieve et al. 2012).**

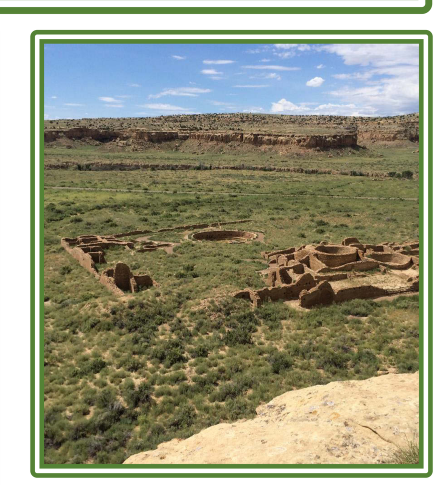



**Left: Shows the location for all known soil salinity samples in the main area of Chaco Canyon. Larger circles are to avoid providing precise locational information for non-public archaeological areas. Selected profiles are presented with values for single depth samples shown next to their location. Estimated $EC_e$ values in profiles are represented by blue circles, connected by a simple smoothed line to assist visual interpretation. For sources that specify a depth range for specific samples, point depth is the range midpoint. For each salinity graph the Y-Axis is Depth (cm), and X-Axis is Estimated $EC_e$. Vertical lines represent varying yield decrease thresholds for maize (moving left to right): Yellow = 0%, Peach = 10%, Orange = 25%, Brown = 50%, and (when shown) Red = 100%.**

## Chaco Canyon

Located in the San Juan Basin of New Mexico, Chaco Canyon acted as a social and political center of Pueblo society from AD 800 to 1130 (Lekson 2006; Vivian 1990). The 17-km canyon is contains a concentration of distinctive multistoried great houses. Dozens to hundreds of Chaco small sites were occupied simultaneously. Residents of the canyon employed a variety of water management systems to support agricultural production, including *akchin* farming and canal irrigation (Scarborough et al. 2018, Vivian 1990, Vivian & Watson 2015).

Salinity testing of Chaco Canyon soils has consistently demonstrated high variability, but discussions of this variability have differed widely. Some interpret these results as signifying maize agriculture was impossible in the central canyon except for in small side drainages (e.g., Benson 2016), while others suggest maize agriculture was negligibly affected by soil salinity (e.g., Tankersley et al. 2016). These divergent opinions have led to continual debate and misunderstandings about the implications of the salinity results.

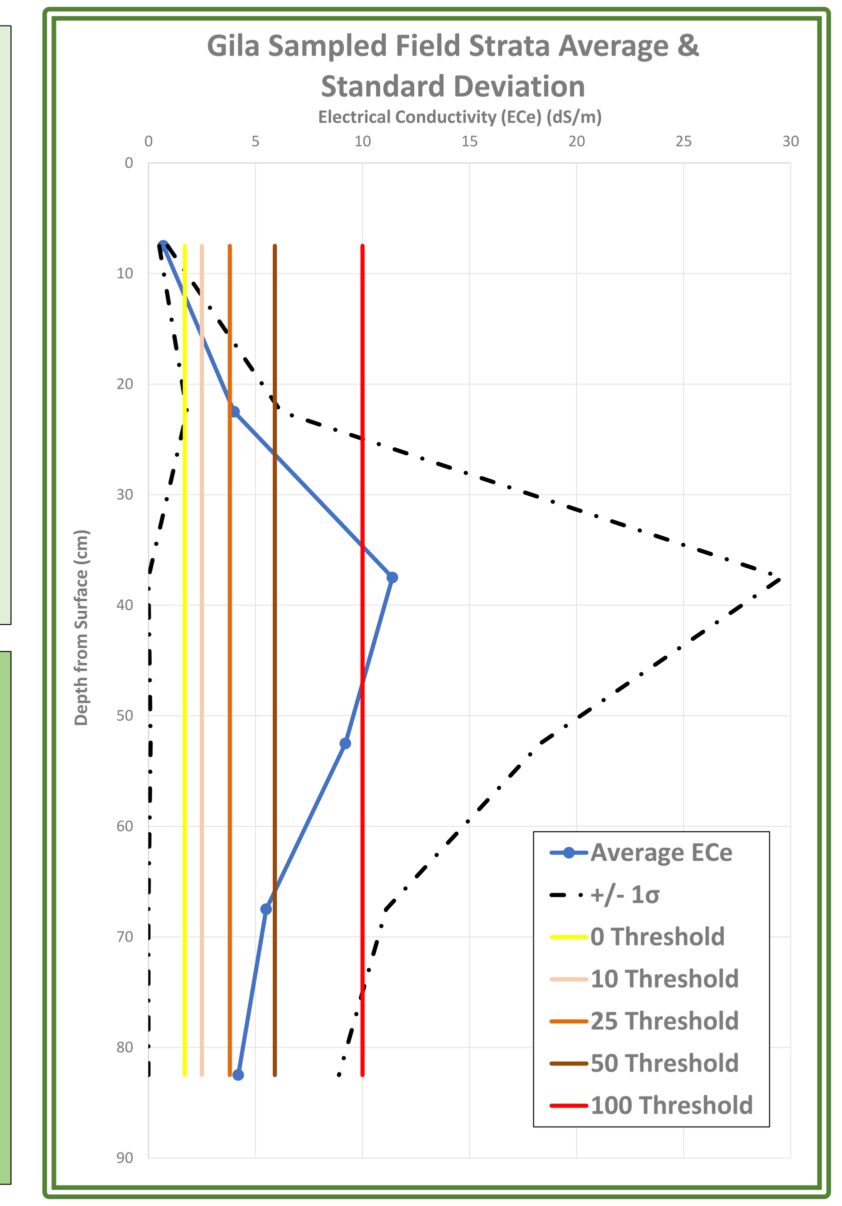


**Above: Chetro Ketl**

## Middle Gila River

The Hohokam Culture is centered around the Middle Gila and Lower Salt Rivers in what is now the Phoenix Basin (Woodson et al. 2015). The Hohokam people lived in rancheria settlements composed of large, rectilinear houses organized around courtyards (Cordell & McBrinn 2012). Their agricultural system was based around an 800-km-long irrigation canal network made up of roughly 24 separate canal systems and capable of irrigating about 28,000 ha (Fish & Fish 2007, Cordell & McBrinn 2012).

Salinity testing from the Gila River Indian Community has demonstrated highly variable soil quality (Strawhacker 2013, Woodson et al. 2015). Salts in the soils may have limited agricultural productivity but would not have prohibited its practice throughout the region. Despite this variability and the potential limitation of maize growth in some areas, the presence of extensive canal systems and substantial evidence for settlement are taken as evidence of successful maize agriculture.




**Right: Shows the location for salinity data collected from the Phoenix Basin by Colleen Strawhacker (2013). The graph depicts the provided means and standard deviations for $EC_e$ of the samples, connected by a simple smooth line to assist visual interpretation. The Y-Axis is Depth (cm), and X-Axis is Estimated $EC_e$. Vertical lines represent varying yield decrease thresholds for maize (moving left to right): Yellow = 0%, Peach = 10%, Orange = 25%, Brown = 50%, Red = 100%.**

## Discussion

As shown by the electrical conductivity graphs from both Chaco Canyon and the Middle Gila, salinity values vary *drastically* in both regions. This variability is evident both *spatially* across the region and with *depth* below the surface—although the Gila graph shows the averaged salinity rates for the spatially discrete sites. While some samples in both regions cross the 10 dS/m threshold indicative of 100% yield decrease, many others fall between 0 and 50% yield declines. Given these datasets, neither Chaco Canyon nor the Middle Gila exhibit clearly preferable soils for maize agriculture based on soil salinity. Despite this overarching similarity, archaeological extrapolations from salinity measures have differed greatly in the two regions.

## Conclusion

Ultimately, the soil salinity from Chaco Canyon and the Middle Gila River Valley do not exhibit significant differences from one another. Spatial variability, both horizontally and vertically, is to be *expected* and has been *observed* in modern productive corn fields (McCool et al. 2018). Additionally, a number of mitigating factors may affect salinity measures over time, making it difficult to associate modern readings with past soil conditions. As a whole, this study suggests salinity should be treated with caution when applied to archaeological contexts.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