Legacy Effects of Prehistoric Farming: Isotopic Analysis of Maize Grown in Sediments from Hohokam Fields

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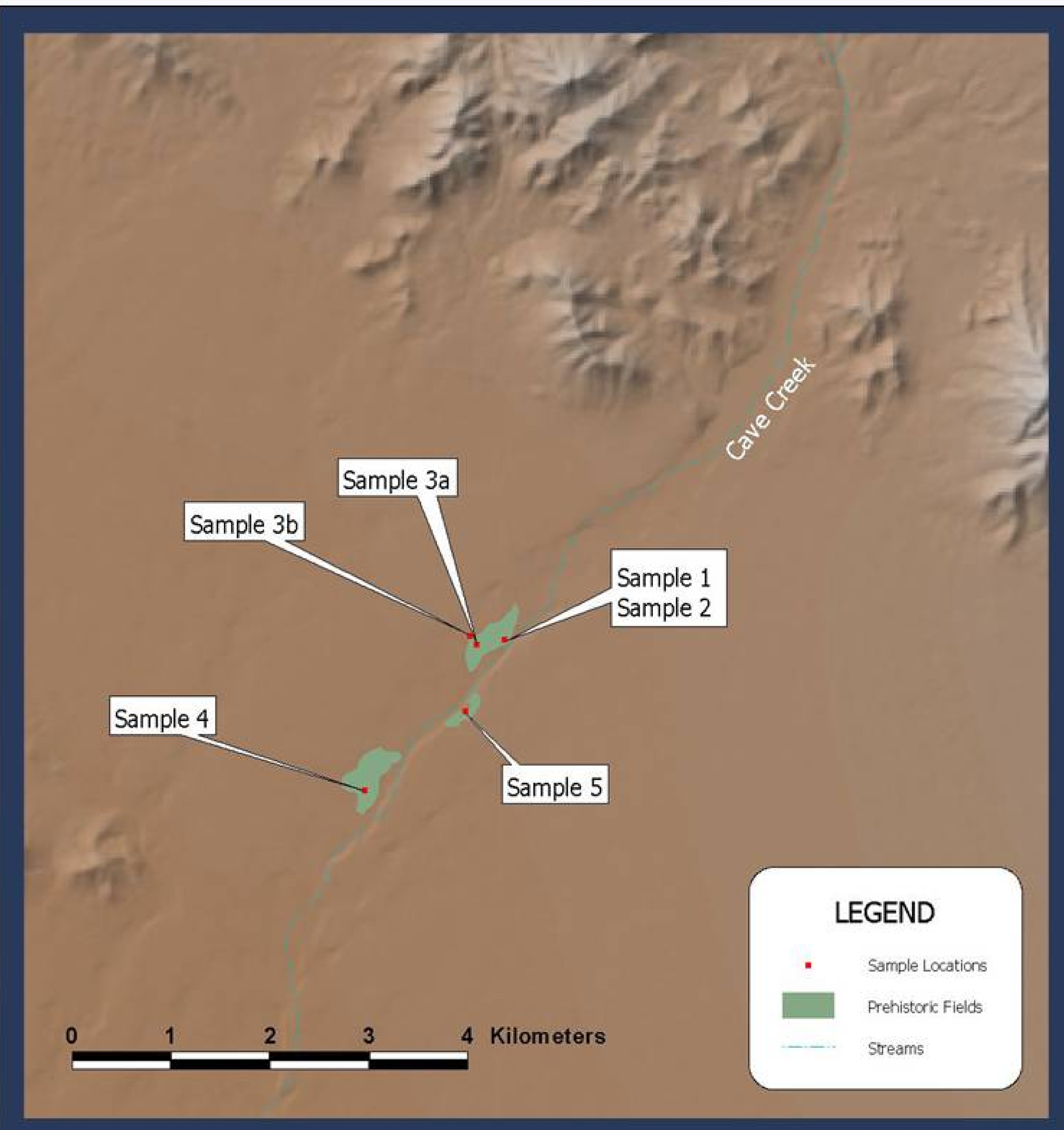
Abstract

Maize was a staple crop in the prehistoric Southwest US. While prehistoric farmers practice diverse agricultural techniques, fertilization was not practiced and over time nutrient depletion in fields may have caused reduced agricultural productivity. Remains of maize are ubiquitous in archaeological contexts, and may retain clues to the fertility of the fields in which they were grown. We conducted two maize grow-outs using sediments collected from four different Hohokam prehistoric agricultural field types along Cave Creek, north of Phoenix, Arizona. This poster reports the results of the grow outs as well as elemental and isotopic analyses of the agricultural sediments and indigenous varieties of maize grown in them.

Study goals

Prehistoric agricultural practices that did not include fertilization or nitrogen fixation techniques would rapidly deplete nitrogen (N) available to plants in repeatedly used crop growing locations. In the prehistoric Southwest, repeated growing of maize over decades and centuries could have had severe impacts on the levels of available N in soil. Other studies have documented severe N depletion in prehistoric agriculture terraces after only decades of use. The goal of this study is to examine the legacy effects of prehistoric agricultural activities on soil nutrients, focusing primarily on N, the most critical soil nutrient for maize growth. Since maize is abundant in archaeological collections, we would like to know whether it has any utility in identifying prehistoric soil N depletion.



Rock alignments at downstream silt field, near sample 4.

Prehistoric field samples

Sample 1: Buried, original terrace before creation of silt field, a "natural" control

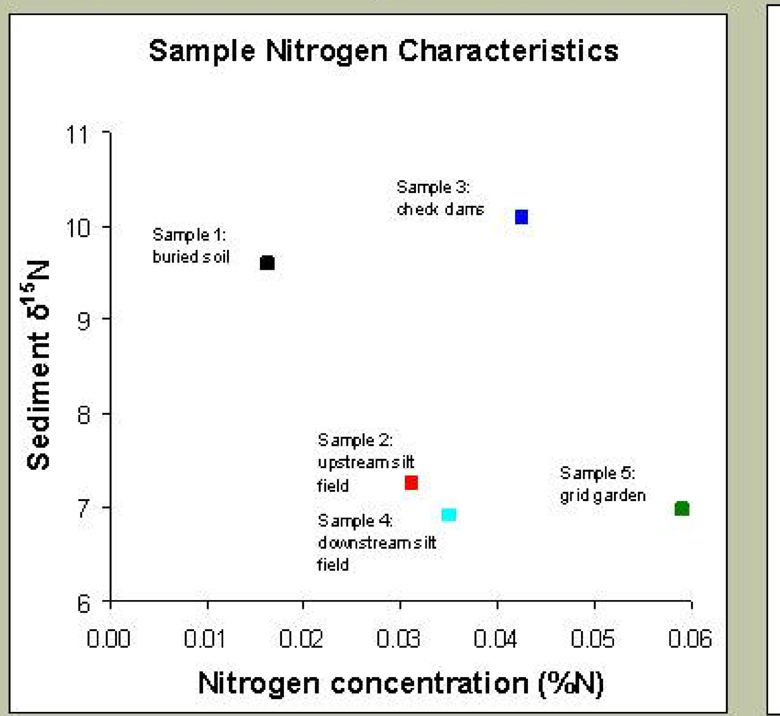
Sample 2: Upstream end of silt field ~1 meter above sample 1, flood/canal irrigated

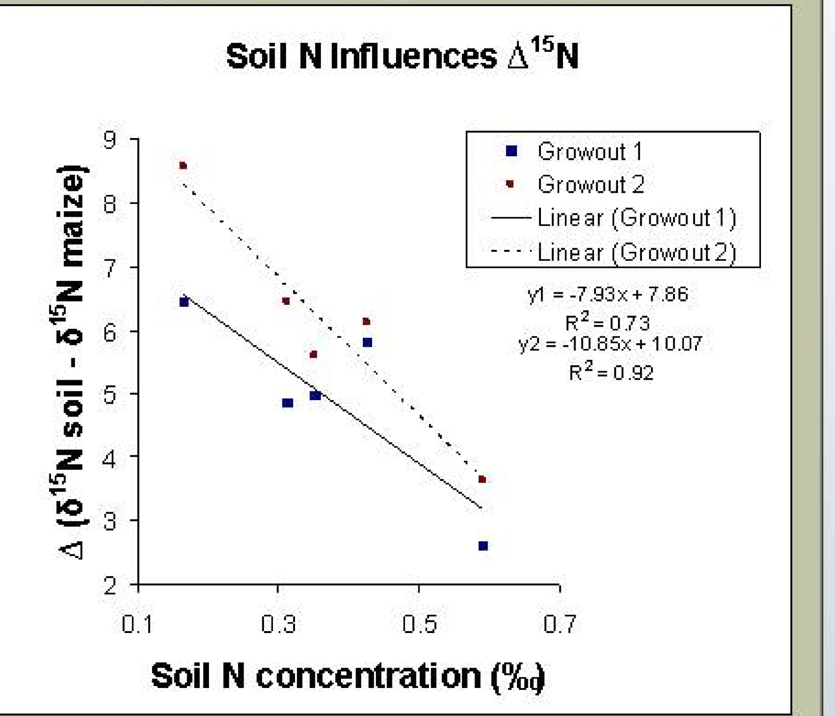
Sample 3: Two locations from check dams at west edge of silt field, dry-farmed

Sample 4: Linear alignment at downstream end of silt field, flood/canal irrigated

Sample 5: Rock grid garden, on east side of stream, dry-farmed

Elemental analysis results: field variety and ^{15}N patterns





As is typical for desert soils, all of the samples had relatively low N concentrations and high $\delta^{15}N$ values. The two samples from the silt fields, though 1km apart, had very similar N concentration and $\delta^{15}N$ values- lower for both variables than the other two field types. The grid garden had higher N concentration than other field types, and the check dams had higher $\delta^{15}N$ values than the other field types.

Interestingly, discrimination against ^{15}N was not constant, but varied according to N levels in the sediments. Also, discrimination increased as N concentration decreased, which we had not expected. We attribute the increased discrimination in the second growout to genetic variation, since we used a different variety of maize than in the first experiment. We found no clear patterns in variability of ^{15}N uptake with different concentrations of soil in our treatments.

Sample collection and experiment design

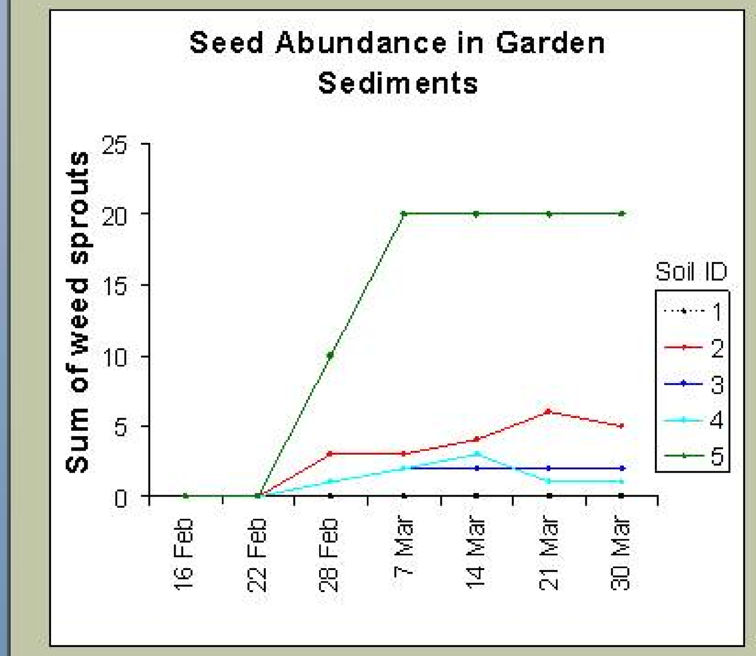
Hoski Schaafsma assisted us in the collection of sediment samples from distinct field types at three archaeological sites along Cave Creek. At each sampling location, we removed the upper 5cm of sediments in two or more small areas, and then collected approximately 15L in buckets. In the lab, sediment was sifted through 8mm mesh to remove large stones, then placed in 4L growing pots. Each sediment was divided into four treatments of 100%, 75%, 50% and 25% concentration by adding perlite. Three maize seeds were placed in each labeled pot, and 1L of reverse osmosis water applied 1-3 times a week. Since the plants were placed outdoors to better replicate natural growth conditions, they received occasional watering from natural precipitation.

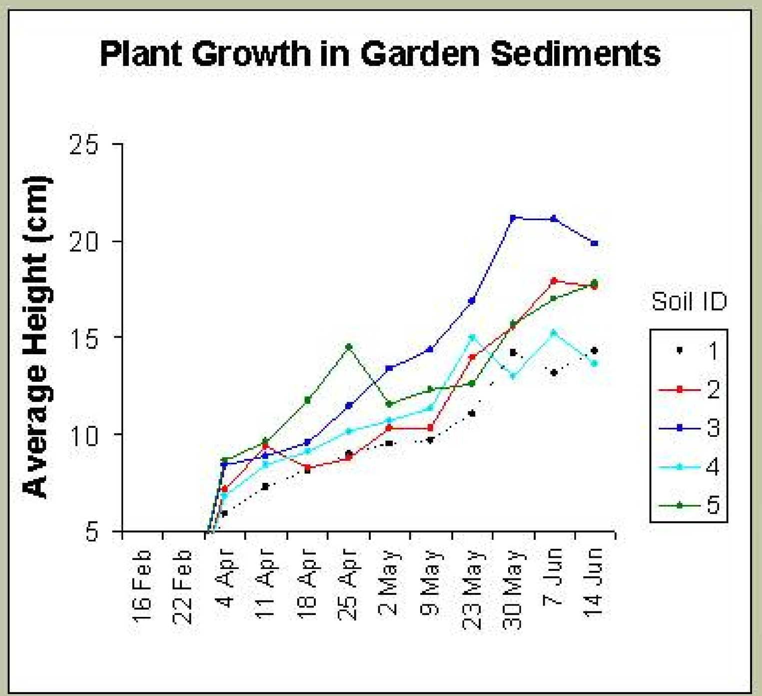
Maize growing experiment, showing drip system and pots used for different treatments.

Sample preparation

Dried maize leaves, cobs, and sediment samples were ground in a ball mill using steel vials to a fine powder. Using a Sartorius Pro-11 micro-balance, samples were weighed and placed into tin capsules to prepare for carbon and nitrogen stable isotope analysis in the ASU Goldwater Environmental Laboratory's Gas-Chromatograph Isotope-Ratio Mass Spectrometer .

Growout result: weed counts and maize performance





During the first grow out, we counted weeds that sprouted in our pots for each sample. The graph on the left shows these results. The sediments buried for several centuries (sample 1) have no seed bank. The grid garden sample has a lot of seeds relative to the other three samples. Perhaps the rock grids facilitate the trapping of seeds. Our plant height data do not show clear differences between the sediments, although the check dam sediments appeared to perform the best, and the buried sediments the worst. We do not believe these to be significant differences, however. Overall, the maize plants greatly underperformed our expectations for growth- they all grew slowly and poorly, were undernourished, and none fruited.

Conclusions

There are interesting differences between field types, reflecting both past and present biochemical and physical processes. The grid garden soils stand out from the other field types, with higher N concentration and more abundant wild seeds. However, maize growth was best, as measured by average height of plants, in the check dam fields. For all fields, maize productivity was very poor. We hoped in this study to determine whether there were clear patterns in maize ^{15}N uptake that could be related to N depletion in soils. These preliminary results suggest that N depletion results in increased discrimination of ^{15}N, although the experiment was not designed to determine the mechanisms responsible for this. There may be some utility in examining ^{15}N abundance in prehistoric maize kernels to detect N depletion, but this would depend on the initial ^{15}N abundance of the prehistoric fields the maize was grown in.

Acknowledgements

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