Changing Perspectives California Grassland Restoration: What was the prehistoric distribution of Native grasses, what the current distribution, and how do they compare?

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Introduction

It has been traditionally assumed that prior to European colonization, California grasslands were dominated by native, perennial bunch-grasses (clements). As a result, most ecological restoration in these areas, which are now dominated by annual exotic grasses and forbs, has focused on (re)introducing a native perennial grass component to these communities. New evidence from soil phytoliths records (silcate deposits generated over millenia by grasses) and re-evaluations of historical accounts have called this fundamental assumption into question. It has been hypothesized that perrenial bunchgrasses composed a minor component of pre-columbian communities, if at all.

Species distribution models make use of relationships between recorded observations of species (or species density) and environmental covariates related to each record location to make predictions about the likelihood of species occupation at unsampled locations. Previous maps of prehistoric native grass distributions in California have identified large swaths of the central valley as likely dominated by native grasses (Kuchler 1977). Given recent suspcions about the true extent of perennial grass dominance in what is now California annual grasslands, new visualizations of native grass distributions based on phytolith-derived distribution models may be helpful for evaluating restoration decisions.

Previous analyses of phytolith data have revealed a coarse decline in average phytolith density between coastal and interior California (Evett and Bartolome 2013). This pattern is thought to be related to differences in climate such as warm-season temperatures and precipitation, as has been observed in analyses of modern distributions of native perennial grasses in California (Clary 2012). However the the relationships between phytolith assemblages and environmental parameters were not explicitly tested in this analysis. Clary (2012) identified four variables significantly correlated with current densities of native perennial grasses in California : 1) the number degree-days over 18 C (negatively correlated), 2) slope (negative correlated) 3) Proximity to the pacific coast (positively correlated), and 4) average warm season precipitation (positively correlated). The growing phytolith datasets provide a means to test these environment-distribution relationships in a pre-historic context.

The following analysis is based on three guiding questions:

1. What was the pre-historic distribution of Native Perennial Grasses, based on phytolith-derived species distribution models.
2. How does the distribution predicted from phytoliths compare to estimates based on durrent distributions of Native Perennial Grasses?
3. What are the important environmental factors which most strongly correlate with grass presence, both currently and pre-historically?

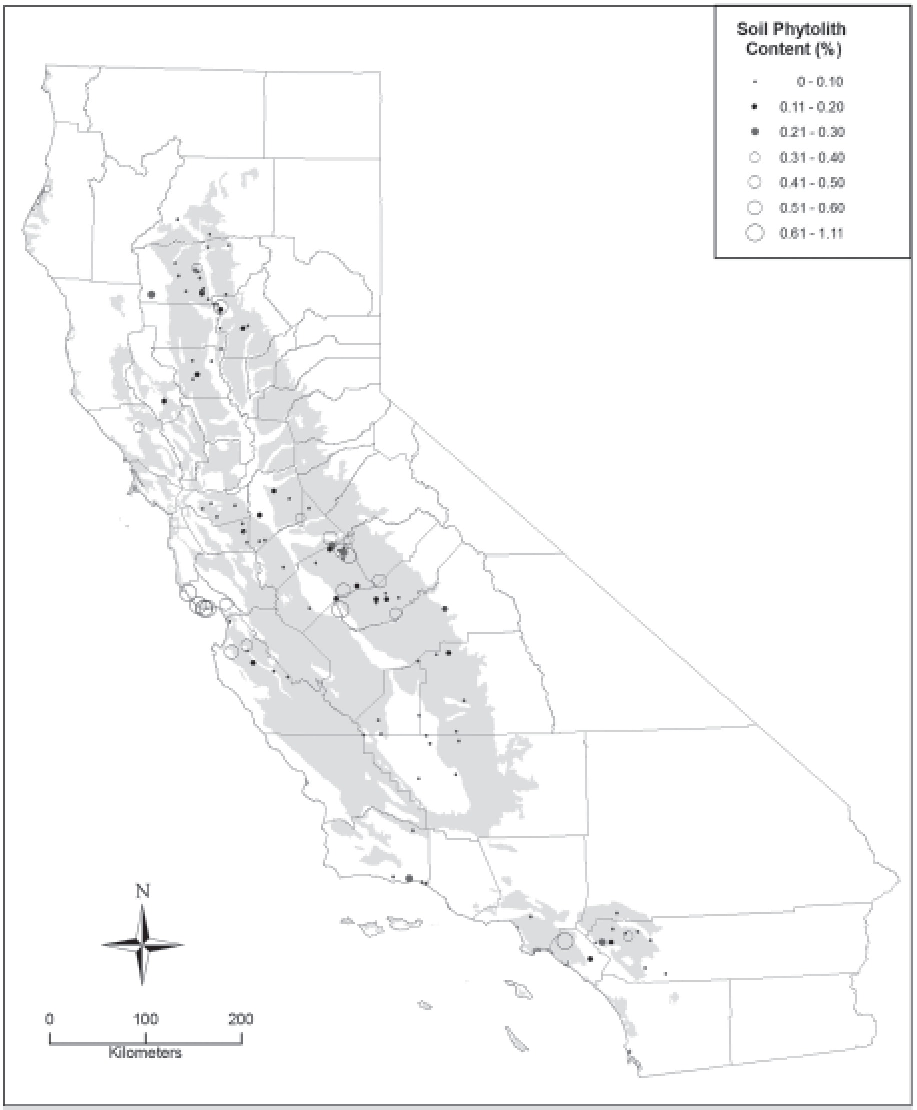


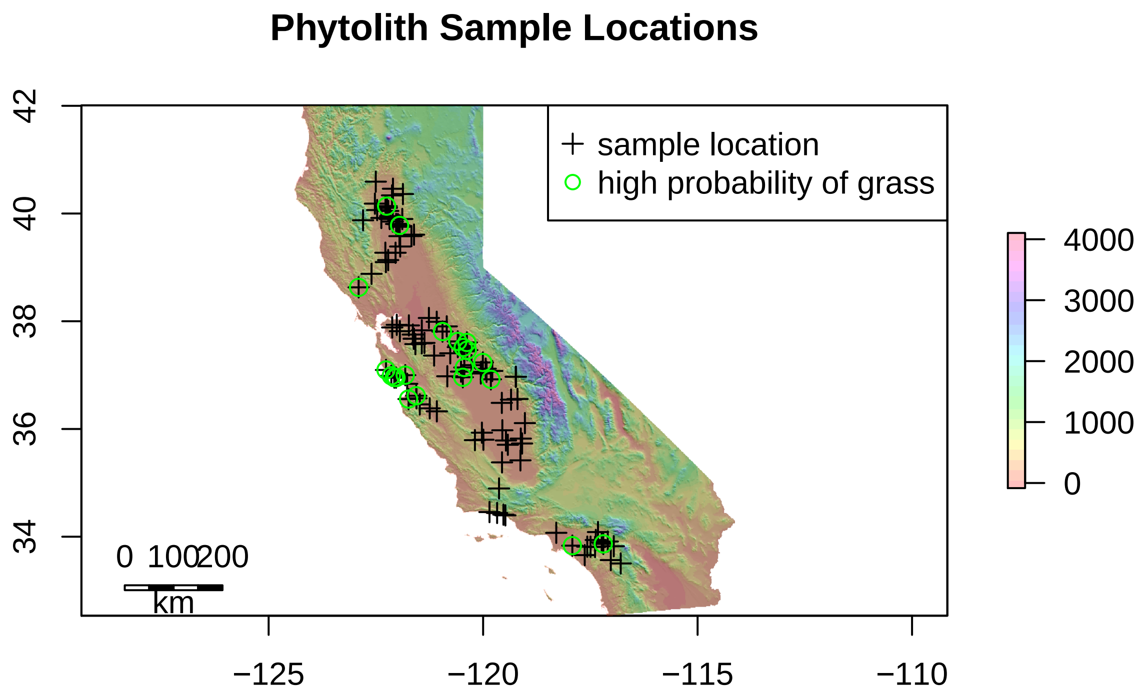
Fig 1. (from Evett and Bartolome (2013)) Shaded area indicates supposed pre-historic extent of native perennial grasses

```
library(maps)
library(fields)
library(raster)
library(dismo)
library(xtable)
library(arm)
```

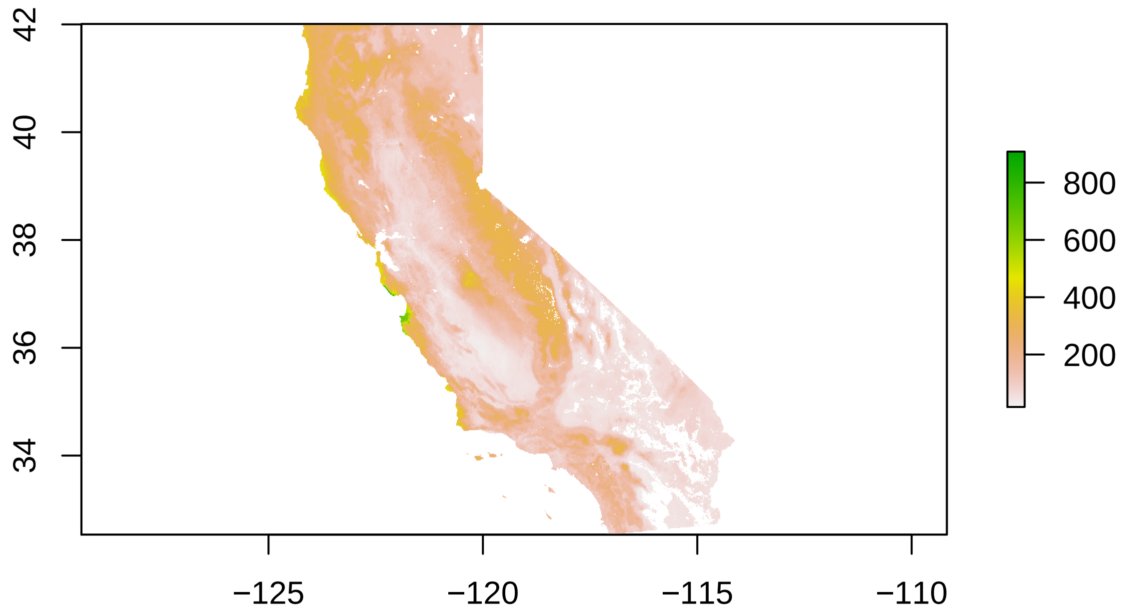
```r
setwd('C:/projects/phytolith/')

p <- read.csv('data/dat.csv', stringsAsFactors = F)

# remove records with missing spatial information
p <- p[-which(is.na(p$lon)),]

# reverse longitude
p$lon <- -1*p$lon

# Grass threshold according to Evett and Bartolome
p$grass <- as.factor(p$phyto_content >= .3)

# Had bilobate cells (only produced by PNG)
p$PNG <- as.numeric(p$bilobate_cells > 0)

# Choose the variable to be modeled. Here, I'm choosing phytolith content
p$y <- p$phyto_content

# fix bilob_ratio
p$bilob_ratio <- gsub('*','', p$bilob_ratio)
p$bilob_ratio <- as.numeric(p$bilob_ratio)

sp <- p
coordinates(sp) <- ~ lon + lat

# create a distance matrix between points to consider spatial autocorrelation in models
dd <- as.matrix(as.dist(pointDistance(sp, lonlat = TRUE, allpairs=TRUE)))
dd.inv <- 1/dd
diag(dd.inv) <- 0
```

```r
# Covariates
b <- brick('C:/projects/phytolith/data/predictors.grd')
mb <- brick('C:/projects/phytolith/data/mpredictors.grd')
ca <- shapefile('C:/Users/steve/Downloads/GEO2015/13/counties_2000.shp')

# Extract from location
X <- as.data.frame(extract(b, sp))
i <- which(is.na(X$slope))
X$aspect[i] <- X$slope[i] <- 0
```

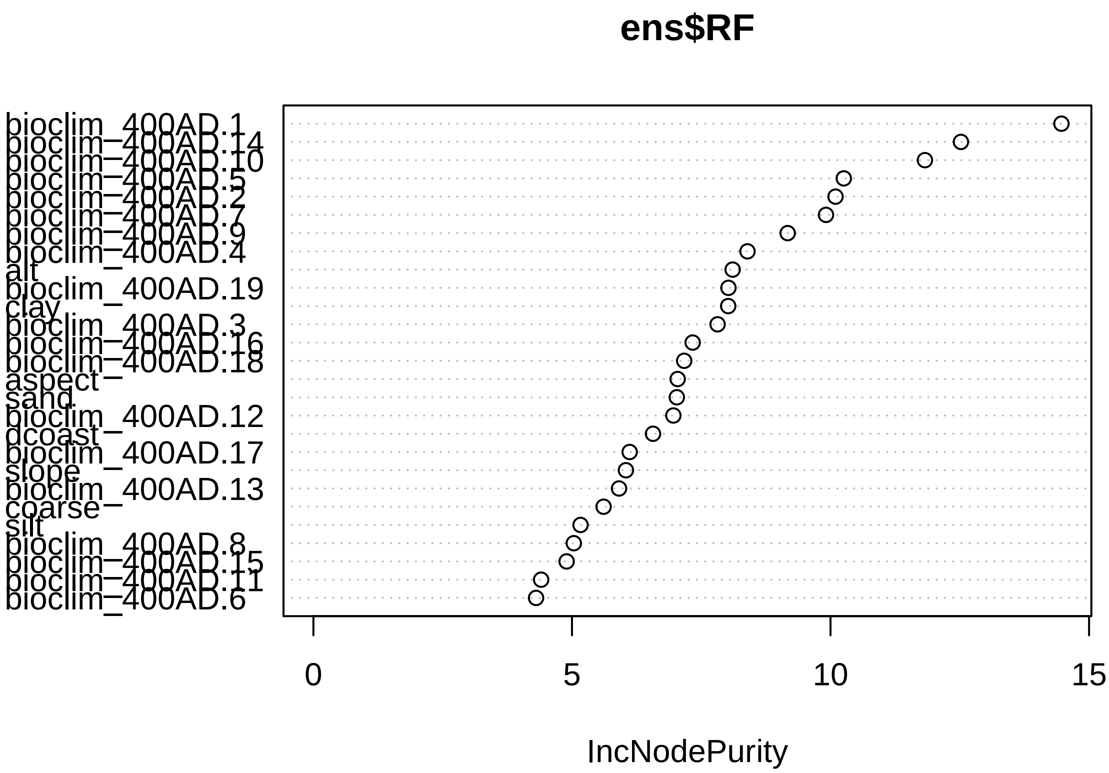
```r
  # Plot of sites
  plot(mb$hillshade, col=grey(0:100/100),legend = FALSE, main = 'Phytolith Sample Locations')
  plot(mb$alt, col = rainbow(25, alpha = .25), add=TRUE)
  scalebar(200, divs = 4, below = 'km', type = 'bar')
  points (sp, pch =3); points(sp[which(as.logical(p$grass)),], col = 'green', cex = 1.2)
  legend('topright', col = c(1,'green'), pch =c(3,1), legend = c('sample location', 'high probability o
```



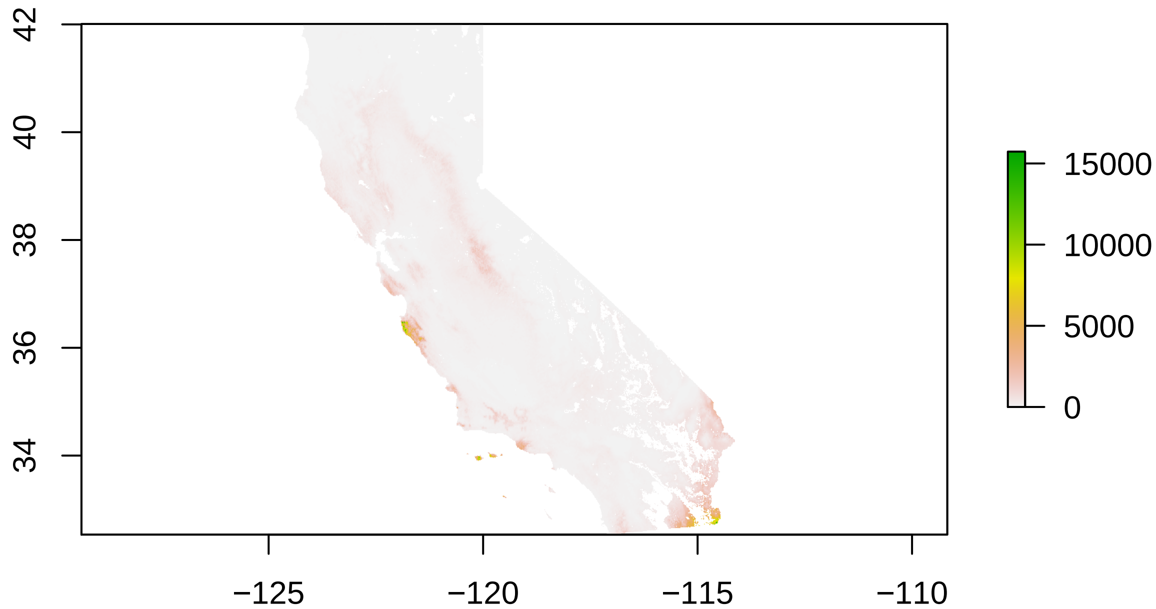

```r
# predictions

#random forest prediction
p.rf <- predict(mb, ens$RF)
plot(exp(p.rf))
```



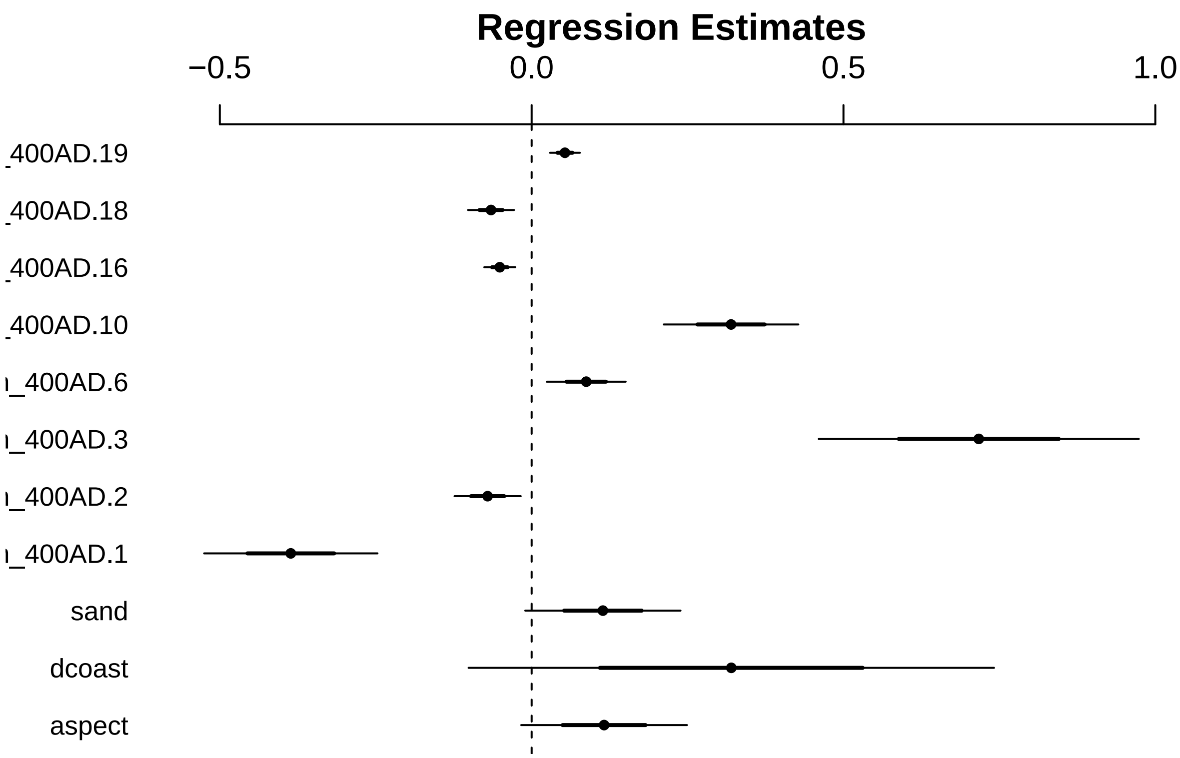

```
#random forest important variables
varImpPlot(ens$RF)
```



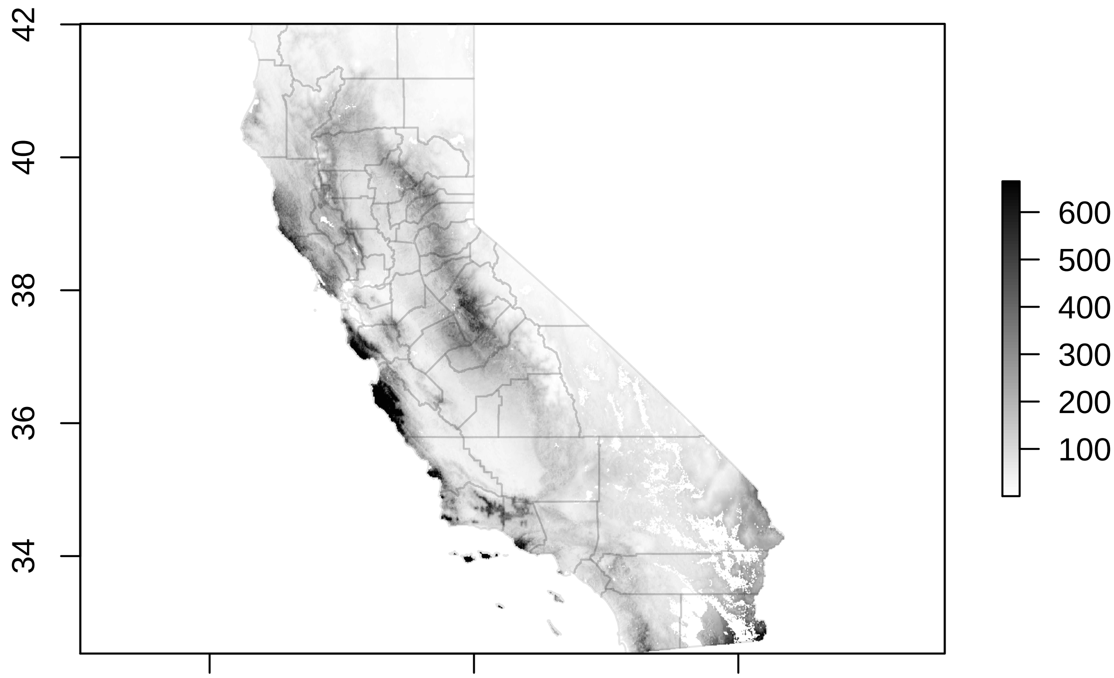

```r
#OLS prediction
p.ols <- predict(mb, ens$OLS)
plot(exp(p.ols))
```




```r
#OLS important variables
coefplot(ens$OLS)
```




```
m <- mean(p.ols,p.rf)
m[m > 6.5] <- 6.5

plot(exp(m), col = gray(100:1/100)); plot(ca, add=TRUE, border = rgb(0,0,0,.1), main = 'Predicted total
```




```
#plot(exp(m)); plot(ca, add=TRUE, border = rgb(0,0,0,.1))
#map('state' , 'california', add=TRUE, lwd = 2)
#points(sp,pch=3, col = rgb(0,0,0,.4))
```

Methods

1. Data

phytolith data

Phytolith data was taken from (Evett and Bartolome 2013).

Climate data

Paleoclimate Modelling Intercomparison Project Phase II (http://pmip2.lsce.ipsl.fr/)

Phytolith assemblage data

references

Clary, Jeffrey. 2012. "Determinants of Perennial and Annual Grass Distribution in Mediterranean-Climate California." *Plant Ecology* 213 (7): 1203–8. doi:10.1007/s11258-012-0076-7.

Evett, Rand R., and James W. Bartolome. 2013. "Phytolith Evidence for the Extent and Nature of Prehistoric Californian Grasslands." *The Holocene* 23 (11): 1644–49. http://hol.sagepub.com/content/23/11/1644.short.