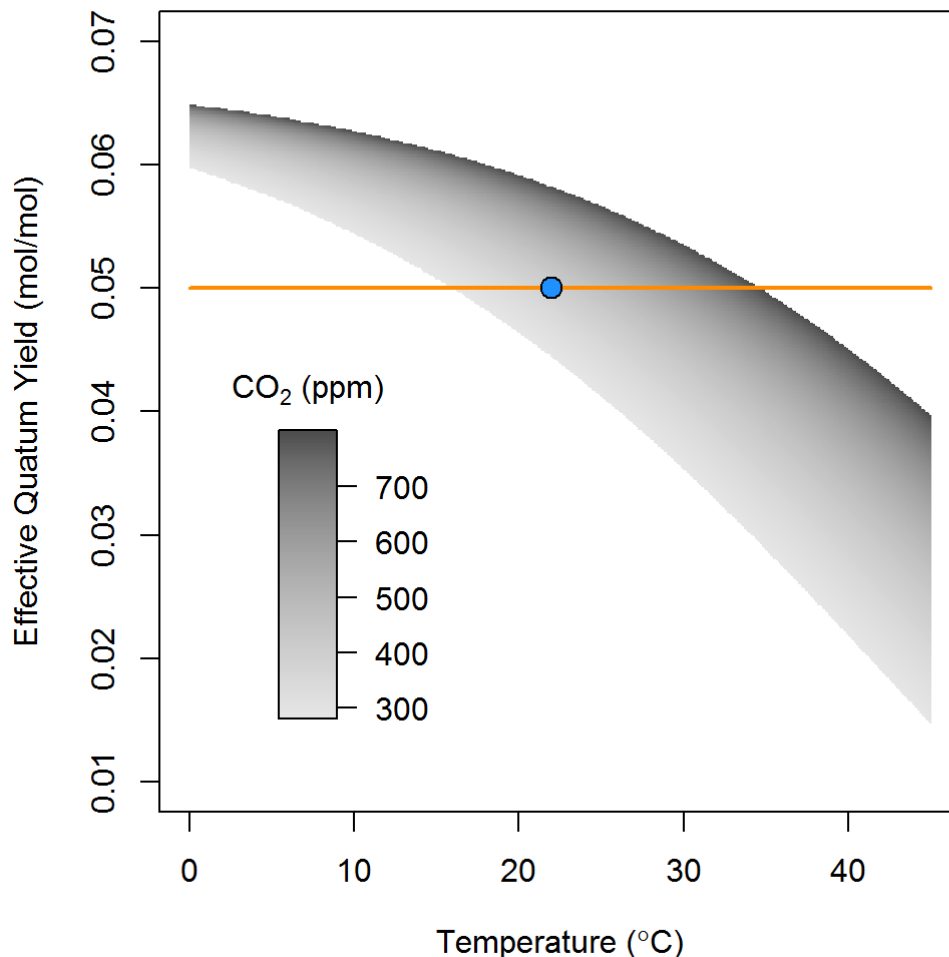


Modeling the terrestrial distribution of plant carbon stable isotopes in R

June 21, 2017

Introduction & Objectives

Our goal is to predict plant tissue $\delta^{13}\text{C}$ variation across a landscape. The primary driver of variation in plant $\delta^{13}\text{C}$ is the greater isotopic fractionation in C_3 plants compared to C_4 plants. The crossover temperature model is a physiologically based model that explains the turnover from C_3 to C_4 plants along gradients of temperature (Ehleringer et al., 1997; Collatz et al., 1998; Still et al., 2003). Note that $\delta^{13}\text{C}$ also varies with photosynthetic subtype in C_4 plants and with rainfall in woody C_3 plants (Cerling & Harris, 1999; Diefendorf et al., 2010; Kohn, 2010). Below, the shaded regions shows the effect of CO_2 and temperature on the light use efficiency of C_3 plants, and illustrates the temperature at which C_3 efficiency drops below that of the average C_4 plant.



We will combine the crossover temperature model with data on land cover and climate to produce map of C₃ and C₄ plants in Colorado. Then, we will apply isotopic end member values to produce a spatially continuous representation of the distribution $\delta^{13}\text{C}$ across Colorado. These layers are useful for understanding grass biogeography and for studies seeking to identify the movement of animals (e.g., Hobson, 1999; Powell et al., 2012)

The code for this workflow is a work in progress, and we are working to produce an R package that will allow all of the pieces to be applied in custom pipelines. This package is called “grassmap” and is installed below.

This workflow also requires learning some basic functionality in the raster R package.

Installation

installation requires GitHub

```
install.packages("devtools", repos = "http://cran.us.r-project.org")
library(devtools)
install_github(repo = "griffithdan/grassmap")
library(grassmap)
```

Load Colorado data

Now we need to load and organize the spatial datasets that we will use.

```
data("COMeanppt")
data("COMeantmp")
data("COC3Crop")
data("COC4Crop")
data("COHerb")
data("COWoody")
```

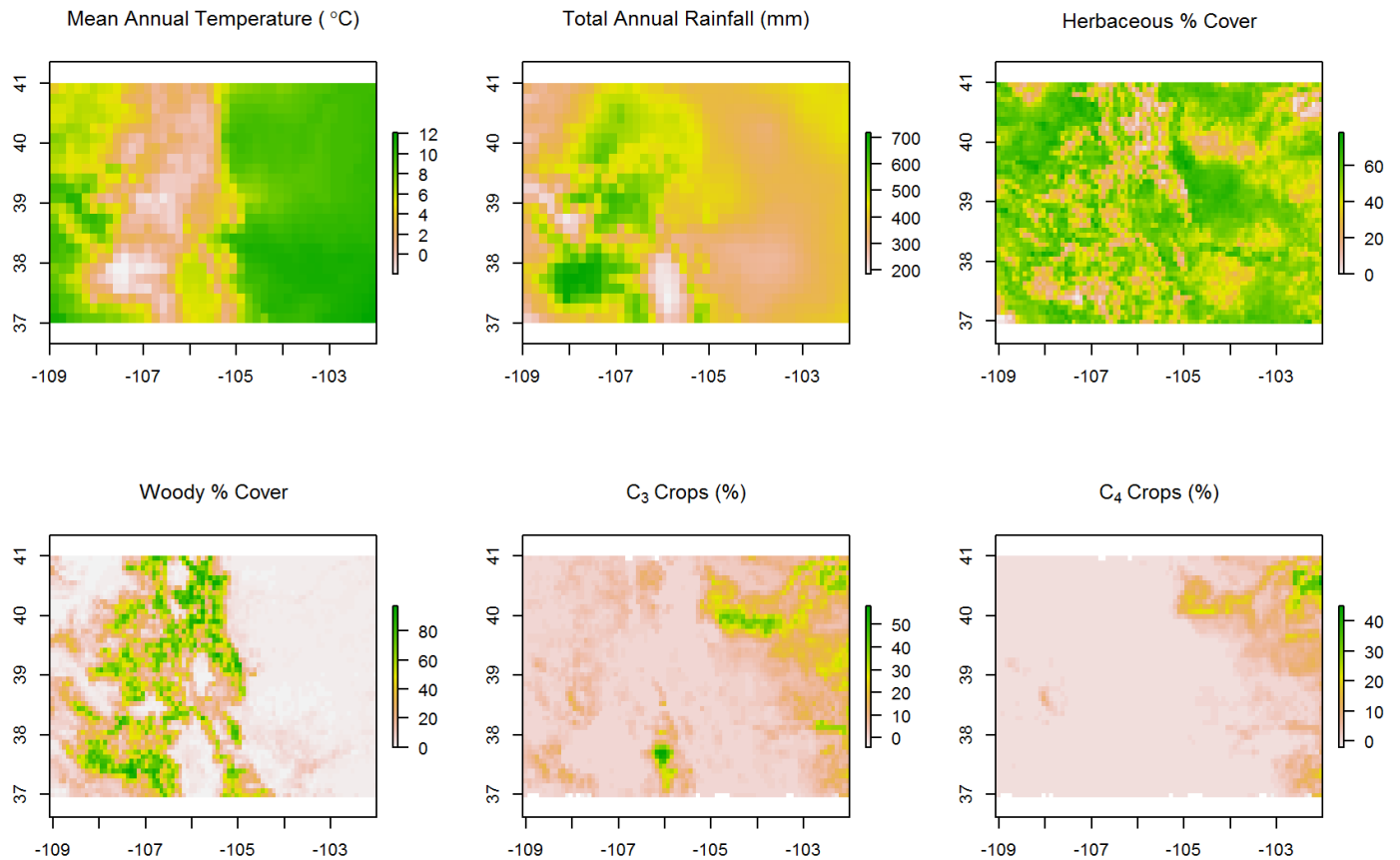
The rainfall and temperature data are monthly climatologies, and so we might want to visualize them here as annual means.

```
annual.tmp <- stackApply(x = COMeantmp, indices = rep(1,12), fun = mean)
annual.ppt <- stackApply(x = COMeanppt, indices = rep(1,12), fun = sum)
```

And, now we should plot the data. Based on the crossover temperature model, where would you expect to find C₄ grasses?

```
par(mfrow = c(2,3))
plot(annual.tmp, main = expression(paste("Mean Annual Temperature (", ~degree, "C)", sep = "")))

plot(annual.ppt, main = expression(paste("Total Annual Rainfall (mm)", sep = "")))
plot(COHerb, main = expression(paste("Herbaceous % Cover", sep = "")))
plot(COWoody, main = expression(paste("Woody % Cover", sep = "")))
plot(COC3Crop, main = expression("C"[3]~"Crops (%)"))
plot(COC4Crop, main = expression("C"[4]~"Crops (%)"))
```



We should ensure that all data have the same spatial extent and resolution.

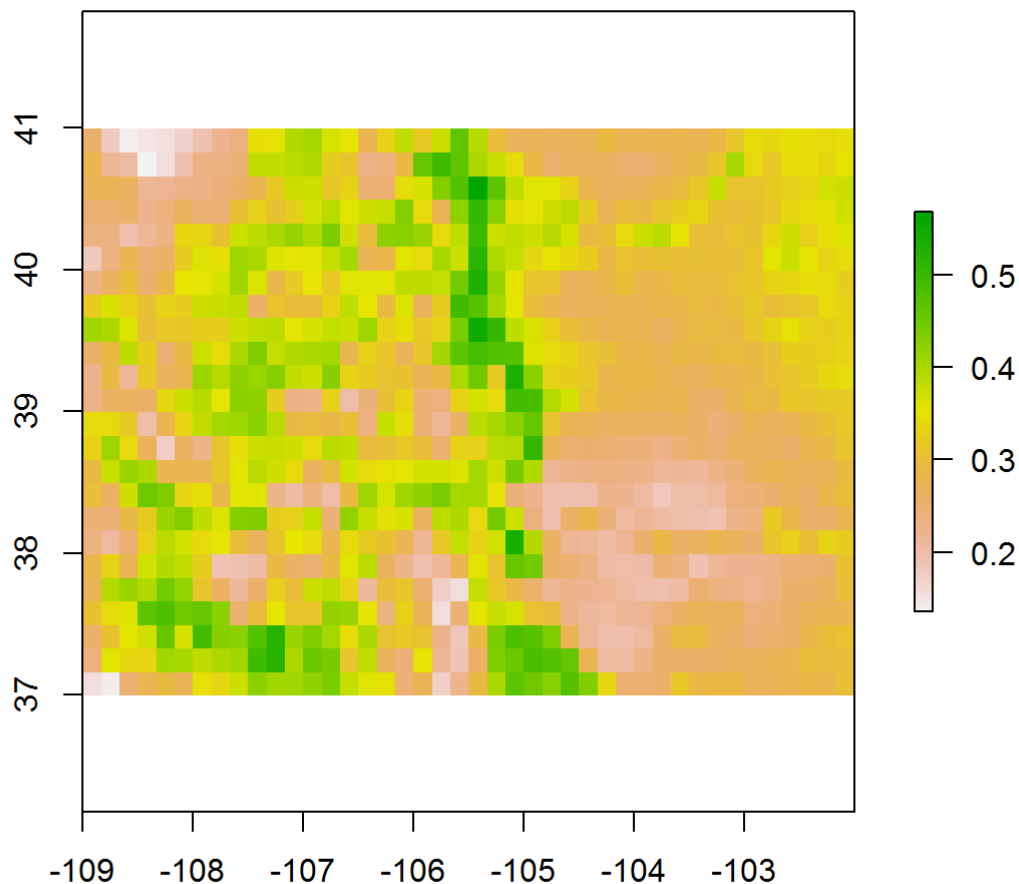
```
COMeanpnt <- resample(x = COMeanpnt, y = COMeantmp, method = "bilinear")
COC3Crop <- resample(x = COC3Crop, y = COMeantmp, method = "bilinear")
COC4Crop <- resample(x = COC4Crop, y = COMeantmp, method = "bilinear")
COHerb <- resample(x = COHerb, y = COMeantmp, method = "bilinear")
COWoody <- resample(x = COWoody, y = COMeantmp, method = "bilinear")
```

We also need a monthly biomass weighting in order to calculate the contribution of growth in each month to the total annual composition of C_3 and C_4 plants, and their isotopic composition.

Oh no! Our NDVI layer is global, and at a different spatial resolution! We can fix that as shown below, and then plot an annual value.

```
data("globalMonthlyNDVI")
COMonthlyNDVI <- resample(x = globalMonthlyNDVI, y = COHerb, method = "bilinear") # resample to CO
annual.ndvi <- stackApply(x = COMonthlyNDVI, indices = rep(1,12), fun = mean)
plot(annual.ndvi, main = "Annual Mean NDVI")
```

Annual Mean NDVI

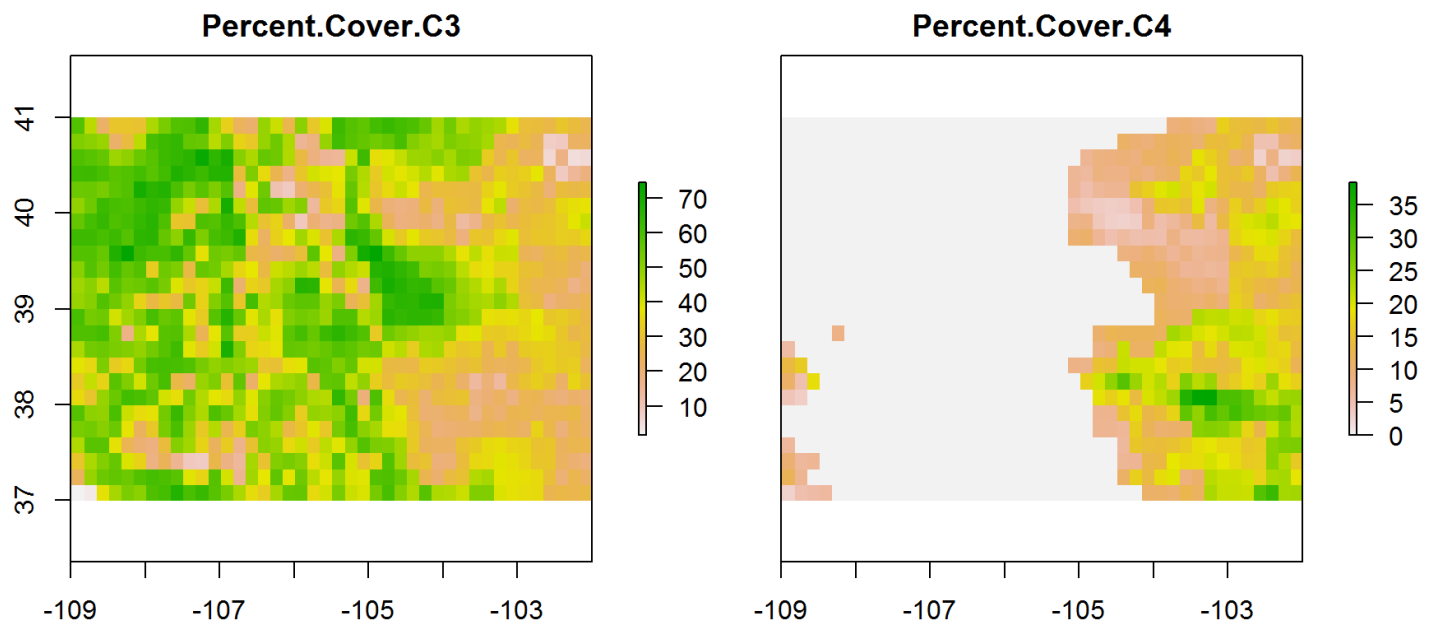


A Workflow to produce a C₃ and C₄ distribution map for Colorado

First, set a temperature threshold based on the crossover temperature model. In addition, set a minimum monthly rainfall threshold, above which grasses will grow - this masks out mediterranean climates. Next, feed data into the model implemented in the `grassbiogeo()` function. This is a wrapper function that applies the crossover model, combines the result with the herbaceous landcover dataset, and then weights the monthly contributions by NDVI.

```
temp.threshold <- 22
precip.threshold <- 25
c3c4Distribution <- grassbiogeo(temperature = COMeantmp,
                                precip = COMeanppt,
                                herb = COHerb,
                                temp.threshold = temp.threshold,
                                precip.threshold = precip.threshold,
                                biomass.weight = COMonthlyNDVI)

plot(c3c4Distribution)
```



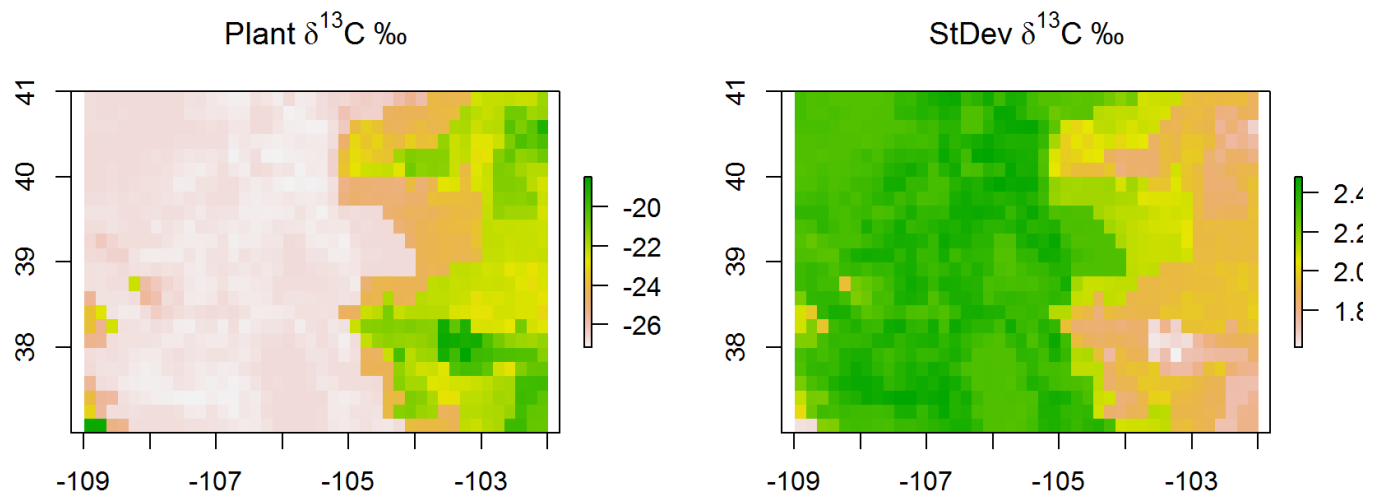
Turning our vegetation map into an isoscape

We now want to combine data from all present vegetation types. First, choose endmembers for these vegetation types. This has been done in the function call below. We will use a second wrapper function, called `isoscape()` that will do all of the heavy lifting for us. Similar to the last step, we will also supply climate data and thresholds in addition to land cover layers.

This function is simply applying the crossover temperature model, as before, and then weighting the contributions of endmembers (C₄ grass, C₃ grass, C₃ woody, and both crop functional types) by their cover abundance. The internal functions for doing this are easily applied to custom cover types, but we are continually working to make the whole process more flexible.

```
COIsoscape <- isoscape(c3.endmember = -26.7,
                      c3.sd = 2.3,
                      c4.endmember = -12.5,
                      c4.sd = 1.1,
                      woody.endmember = -27.2,
                      woody.sd = 2.5,
                      c3.crop = COC3Crop,
                      c4.crop = COC4Crop,
                      woody = COWoody,
                      temperature = COMeantmp,
                      precip = COMeanppt,
                      herb = COHerb,
                      temp.threshold = temp.threshold,
                      precip.threshold = precip.threshold,
                      biomass.weight = COMonthlyNDVI)

par(mfrow = c(1,2))
plot(COIsoscape$layer.1, main = expression(Plant~{\delta}^{13}C~'\211'))
plot(COIsoscape$layer.2, main = expression(StDev~{\delta}^{13}C~'\211'))
```



Thank you for your time, and I hope you enjoyed this test version of grassmap!

Griffith, Powell, Firmin, Cotton, and Still

References

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