Timescales of C turnover in soils with mixed crystalline mineralogies, Kruger National Park, South Africa

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Supplementary Material.

Supplemental Table 1 can be found as an Excel file at the following web location:

https://www.dropbox.com/s/6gahekzzcgvm6vi/Supplementary_Table_1_submit.xlsx?dl=0

(It is too large to print easily for submission as a pdf file). This contains all data from the soil profiles measured in this project. On publication it will be available from either pandora or another archive site.
The data are organized so that each row indicates all analyses for a given depth interval from a soil profile.
The columns are organized as follows:

1) **Identifier:** For each profile, a number and letter combination summarizing lithology, annual rainfall and
2) LAB ID: Identificaiton number for Chadwick laboratory
3) PIT: Pit name (field notes)
4) Geology: lithology of the parent rock
5) Rainfall: mean annual precipitation in mm a^{-1}
6) DATE: Year of soil sampling (important for radiocarbon modeling)
7) EASTING: Latitude
8) NORTHING: Longitude
9) DEPTH 1 (cm): Top depth of horizon sampled (cm)
10) DEPTH 2 (cm): Bottom depth of horizon sampled (cm)
11) Midpoint (cm): Midpoint of horizon sampled (for plotting) (cm)
12) THICKNESS (cm): thickness of horizon (in cm)
13) COLOR: Munsell color (field moisture)
14) TEXTURE: standard classification; sl = silt loam
15) STRUCTURE: standard classification
16) HORIZON: standard classification
17) ROOTS: standard classification
18) GRAVEL (%): per cent of total soil volume estimated to consist of gravel sized rock

19) Fraction fines: fraction of total soil volume estimated to be less than gravel sized
20) mass fines: fraction of fines * bulk density (g cm^{-3}) * horizon thickness (cm) * 10^4 cm^2 m^{-2}* 1000kg/g, final units are kg m^{-2}
21) est. BD: bulk density (g cm^{-3}) estimated using paraffin-clod method.
22) Fe(d): Fe in dithionite citrate bicarbonate (DCB) extract), expressed as % (g Fe per 100 gram dry soil)
23) Fe(o): Fe in acid ammonium oxalate (AAO) extract, expressed as % (g Fe per 100 gram dry soil)
24) Al(d): Al in dithionite citrate bicarbonate (DCB) extract, expressed as % (g Al per 100 gram dry soil)
25) Al(o): Al in acid ammonium oxalate (AAO) extract (expressed as % (g Al per 100 gram dry soil)
26) pH:
27) CEC: Cation Exchange capacity (milli-equivalents of charge per gram dry soil), determined by extracting the ammonium saturated samples with a 1 M potassium chloride solution and determining ammonium by Lachat autoanalyzer
28) carbon-less CEC: CEC corrected for the contribution of organic matter by assuming a contribution of 200 cmol(+) per kg organic C (milli-equivalents of charge per gram dry soil)
29) % Base Saturation
30) oven dry %C: Total C , reported as % (grams C per 100 gram soil).
31) %C organic: Organic C, reported as % (grams C per 100 gram soil). These are analyzed on samples acidified to remove carbonates,
32) LOI inorg C: Determined as the difference between total C and organic C. Reported as % (g inorganic C/100 g soil) .
33) oven dry %N: %N as measured with elemental analayzer, includes organic and inorganic N (g N per 100 gsoil).
34) Horizon Corg inventory: kgCorganic m^{-2} in horizon (mass fines (kg m-2) * org. C (g/100g soil)*1000gsoil/kg soil)
35) C:N Organic C/LOI N
36) $\delta^{13}CaCO_3$: $\delta^{13}C$ of CO2 released from acification of soil (in ‰ PDB)
37) $\Delta^{14}CaCO_3$: $\Delta^{14}C$ of CO2 released from acification of soil (‰), year of measurement should be assumed to be 2011 for conversion to fraction Modern
38) d13C bulk: $\delta^{13}C$ of bulk organic C (in ‰ PDB)
39) D14 bulk : $\Delta^{14}C$ of bulk organic C (‰), year of measurement should be assumed to be 2011 for conversion to fraction Modern
40) bulkTT: Turnover time (years) that yields the radiocarbon signature in the year the soil was collected. We used SoilR (Sierra et al. 2014 and the Hua and Barbetti 2013 curve for the Southern Hemisphere.
41) Fraction HF in soil: grams of HF fraction per gram of bulk soil extracted
42) %C HF: grams C in 100 g HF fraction soil
43) %totalC in HF: calculated as ([100*fraction HF (gHF/gsoil)] x [%C in HF])/(%C in bulk soil)
44) $\delta^{13}C$ HF: 13C in heavy fraction (in ‰, PDB)
45) $\Delta^{14}C$ HF: 14C in heavy fraction (in ‰)

46) HF TT: Turnover time (in years; determined using SoilR; Sierra et al. 2014) and the Intcal 2013 southern hemisphere zone 1,2 atmospheric ^{14}C record.
47) grav fraction LF: grams of LF fraction per gram of bulk soil extracted
48) %C LF: grams C in 100 g HF fraction soil
49) %totalC in LF: calculated as ([100*fraction LF (gLF/gsoil)] x [%C in HF])/(%C in bulk soil)
50) %C roots: visible roots were picked from the LF fraction, this is the gC/100g roots
51) δ^{13}C roots
52) Δ^{14}C roots
53) %C LF: gC/100g combusted of the LF fraction after removal of roots
54) δ^{13}C LF (in ‰)
55) Δ^{14}C LF (in ‰, using 2010 as the date of measurement)
56) LFTT short: For Δ^{14}C where two solutions are possible, the shorter of the two (in years)
57) LFTT long: For Δ^{14}C where two solutions are possible, the longer of the two (in years)
58) %C clay: gC in 100g of isolated clay fraction
59) %total C in clay: calculated as ([100*gravimentric fraction clay (g clay/g soil)] x [%C in clay])/(%C in bulk soil)
60) δ^{13}C clay (in ‰)
61) Δ^{14}C C clay, using 2010 as the date of measurement)
62) TT clay: (turnover time in years)
63) %C nonclay (calculated using mass balance, see equations in text_
64) δ^{13}C C nonclay (calculated using mass balance, see equations in text_
65) Δ^{14}C nonclay (calculated using mass balance, see equations in text_
66) TT nonclay
67) sand: Particle size % of total mass in sand size particles
68) silt: Particle size % of total mass in silt size particles
69) clay: Particle size % of total mass in clay size particles
70) clay*smectite/100: %clay*%smectite/100
71) Quartz
72) Feldspars
73) Calcite
74) Oxides
75) Kaolins
76) Smectites
77) Chlorites
78) Micas

Supplemental Table 2. Correlation matrices (using Hmisc package in R; Harrell et al. 2016). Number of observations =15; Table 5 was the basis for the correlation matrix. Geology was assigned numeric values from felsic to mafic lithologies (1=rhyolite, 2=granite, 2.5= mixed granite, 3=gabbro, 4 = nephelenite, 5=basalt). Depth = maximum soil depth used in the study. CEC = cation exchange capacity corrected for organic C contribution (see text).Clay = mass fraction of soil that is in the clay-sized fraction; Smec = % of clay that is smectite; clay.smec = Clay*smectite (i.e. the average amount (in %) of smectite clay in the profile). Fed and Feo are the citrate-dithionite and oxalate extractable Fe fractions expressed as per cent. (In general extractable Al was much lower and not considered). 13C is the profile-averaged $\delta^{13}C$ (‰) and 14C the profile-averaged $\Delta^{14}C$ (‰). TT is estimated turnover time (in years) and was derived from the C-weighed averages as were the isotopic values.

Significance is indicated as * p<.05, **p<.01, ***p <.001

	geology	rain	pH	CEC	Clay	Smec	Fed	Corg	X13C	X14C	TT
geology	1.00										
rain	-0.23	1.00									
pH	0.50	-0.18	1.00								
CEC	0.84***	-0.15	0.59	1.00							
Clay	0.77**	-0.21	0.41	0.83***	1.00						
Smec	0.87***	-0.31	0.58	0.71**	0.60	1.00					
Fed	0.48	-0.18	0.47	0.72**	0.35	0.36	1.00				
Corg	0.64	-0.24	0.50	0.84***	0.50	0.48	0.91	1.00			
X13C	0.59	0.05	0.65	0.58	0.65	0.49	0.38	0.32	1.00		
X14C	-0.79**	0.38	-0.57	-0.55	-0.59	-0.87***	-0.27	-0.31	-0.73**	1.00	
TT	0.82***	-0.17	0.50	0.52	0.59	0.82***	0.20	0.22	0.75**	-0.94***	1.00

P-Value

	geology	rain	pH	CEC	Clay	Smec	Fed	Corg	X13C	X14C	TT
geology											
rain	0.4519										
pH	0.0836	0.5616									
CEC	0.0004	0.6232	0.0328								
Clay	0.0022	0.4955	0.1664	0.0004							
Smec	0.0001	0.3044	0.0375	0.0071	0.0311						
Fed	0.0995	0.5513	0.1037	0.0053	0.2384	0.2316					
Corg	0.018	0.4335	0.0846	0.0003	0.0794	0.0943	<0.0001				
X13C	0.0329	0.8749	0.0157	0.0393	0.0171	0.0923	0.2063	0.2941			
X14C	0.0012	0.2042	0.0401	0.0524	0.0342	<0.0001	0.3736	0.3072	0.005		
TT	0.0006	0.578	0.0849	0.0675	0.0342	0.0006	0.5156	0.4786	0.0034	<0.0001	

Supplemental Material Part 3. Code for generating radiocarbon for a given TT.
For additional information on SoilR please see Sierra et al. 2014 (in main text references).
S O I L R version 1.1 can be downloaded from the Comprehensive R Archive Network (CRAN) or RForge. Source code and test framework can be obtained from these two repositories. To install, use the function install.packages("SoilR",repo), specifying either a CRAN mirror or RForge in the repo argument.

```
#### R Code for determining the 14C of a steady state homogeneous, one-pool model
##### uses the SoilR package and the Hua and Barbetti 2013 Curve for the Southern
Hemispehre (1,2)
### First, install the SoilR package.

install.packages("SoilR", repo)   ## repo is the repository (CRAN mirror or RForge, as needed)

##### Load the SoilR library

library(SoilR)

#Bind the IntCal13 dataset and Hua2013 for the Southern Hemisphere Zones 1,2
# This produces the atmospheric 14C record from 50,000 BP to 2010 in Years AD

ad=bind.C14curves(prebomb=IntCal13,postbomb=Hua2013$SHZone12,time.scale="AD")

## Plot the atmospheric record
plot(ad[,1:2],type="l")
plot(ad[,1:2],type="l",xlim=c(0,2010))
abline(v=1950,lty=2)

####### To estimate the Value of 14C as a function of time for a given Turnover time (TT)
## Example given is for 50 year TT (you can change the value as needed)
TT=50  ###  Put in the value of the TT in years you wish to use (in years)

### Other factors will be calculated to make sure model is at steady state
k1=1/TT   ### k1 is the decomposition rate (1/TT) in 1/yr
la = 1/8267 ### la is the radio-decay constant for radiocarbon 1/mean life
Fz = k1/(k1+la)     ### Steady state pre-bomb estimate of the Absolute Fraction Modern (see
Sierra et al. 2014)
DFz = 1000*(Fz-1)   ### Expressed as Delta 14C

##### Other model inputs are calculated so as to have the model remain at steady state
LitterInput=10   # arbitrary inputs
Cinit=LitterInput*TT  #  Inventory at steady state = initial Cinventory (arbitrary units)
####  Next step is to run the model
## In SoilR the one pool model is a function that can be called
years=seq(1901,2010,by=0.5)   # time scale for running the model (expressed in years AD)
```

```
Ex=OnepModel14(t=years,k=k1,C0=Cinit,F0=DFz,In=LitterInput, inputFc=ad)   #Soil R model
function
C14t=getF14(Ex)   # Extracts 14C for each year
Ct=getC(Ex)    # Extracts C inventory for each year (check for steady state)
DEL = C14t[217,]   # This extracts the 14C signature in the year 2010
## Next steps make a plot of 14C versus year
plot(C14Atm_NH,type="l",xlab="Year",ylab="Delta 14C (per mil)",xlim=c(1940,2010))
lines(years, C14t[,1], col=4)
points(2010, DEL,  cex=1.5)
legend(
  "topright",
  c("Delta 14C Atmosphere", "Delta 14C in SOM"),
  lty=c(1,1),
  col=c(1,4),
  lwd=c(1,1),
  bty="n"
)

#####
C14t[217,]  #This line will return only the Del14C for the year 2010 (to be compared with the
measured value)
#########
#########

### This code generates a table and a plot of the 14C signature
#### expected in 2010 for the one-pool, homogeneous, steady state model
### assimung a range of TTs (1 to 2000 years).
## This generates a "lookup" table for comparing with the data

sol1=2000   ### This is the end TT, starts with 1 year
sols= data.frame(1:sol1, 1:sol1) ## makes a data frame of the right size
for(i in 1:sol1) ## number of calculations
{
TT=i
k1=1/TT
la = 1/8267
Fz = k1/(k1+la)
DFz = 1000*(Fz-1)
LitterInput=10
Cinit=LitterInput*TT
Cinit
years=seq(1901,2010,by=0.5)
Ex=OnepModel14(t=years,k=k1,C0=Cinit,F0=DFz,In=LitterInput, inputFc=ad)
C14t=getF14(Ex)
DEL = C14t[206,]
sols[i,1] = i
```

```
sols[i,2] = DEL
i=i+1
}
## Write the whole file
write.csv(sols, file = "Solutions.csv")
## make a plot of the 14C expected in 2010 for each TT.
plot(sols[,1],sols[,2],xlab="TT",ylab="Delta 14C (per mil)"
```

References:

Harrell, F.E., Jr, with contributions from Charles Dupont and many others.: Hmisc: Harrell Miscellaneous. R package version 3.17-2. https://CRAN.R-project.org/package=Hmisc, 2016.

Hua, Q., Barbetti, M., and Rakowski, A.: Atmospheric radiocarbon for the period 1950–2010, Radiocarbon, 55, 2059–2072, 2013.

Sierra, C., Müller, M.M., Trumbore, S.E.: Modeling radiocarbon dynamics in soils: SoilR version 1.1, Geoscientific Model Development 7 (5), 1919-1931, 2014.