SAFARI 2000 Plant and Soil C and N Isotopes, Southern Africa, 1995-2000

Abstract

This data set contains measurements of the concentration and stable carbon (^{13}C / ^{12}C) and nitrogen (^{15}N / ^{14}N) isotope ratios of plant (leaves, roots and fungi) and soil samples from southern Africa. The study sites include locations in Zambia, Botswana, Namibia, and South Africa. Some of the sites were relatively undisturbed and located along the Kalahari Transect precipitation gradient, while others had different intensities of cultivation, domestic grazing, and fires. The data were collected to detect patterns of N cycling along precipitation and grazing gradients, including N_2 fixation by legumes. The stable isotope ratios are expressed using standard delta notation in units per mil, relative to the international standard PDB (Pee Dee Belemnite) for carbon and atmospheric N_2 for nitrogen. Data from multiple projects, and sites with variable precipitation and disturbance regimes are included. The plants and soils were sampled mainly in the wet season of years 1995, 1999, and 2000. Some grass samples were collected in the dry season of year 2000 (from a Mongu-dambo and from a Sua Pan grassland site). A large part of the data provided here were collected during the SAFARI 2000 Kalahari Wet Season Field Campaign in February and March of 2000.

Background Information

Investigators:
Julieta N. Aranibar (aranibar@catalase.stanford.edu)
Stephen A. Macko (sam8f@virginia.edu)

Project: SAFARI 2000
Southern Africa Validation of EOS (SAVE)

Data Set Title: SAFARI 2000 Plant and Soil C and N Isotopes, Southern Africa, 1995-2000

Site: Southern Africa

Westernmost Longitude: 19.17° E
Easternmost Longitude: 31.77° E
Northernmost Latitude: -14.42° S
Southernmost Latitude: -27.75° S

Data Set Citation:

Aranibar, J. N. and S. A. Macko. 2005. SAFARI 2000 Plant and Soil C and N Isotopes, Southern Africa, 1995-2000. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Data File Information

The data files contain numerical and character fields of varying length separated by commas. There are no spaces between the fields. The value 999 is a missing value code for this data set.

Plants: Description of the file "**plants_C_N_iso.csv**"

Columns	Column Description	Units
SITE*	Site name	numeric
COUNTRY	Country name	none
LAT	Latitude	decimal degrees
LONG	Longitude	decimal degrees
DATE	Sampling month and year (days are not included unless otherwise available or relevant)	mon-yy

DISTURBANCE*	The letters C, G and F indicate cultivation, grazing and fires respectively. Increasing numbers indicate increasing disturbance intensity for each land-use gradient. Additional information on disturbance code.	none
TAXONOMY	Taxonomic classification of the samples. Identified to the species and subspecies level if possible, otherwise to genus or plant family. Fungi were only identified to division or order.	none
PLANT PART	Part of the plant that was analyzed: L=leaves; LI=soil litter; R=roots; F=fruit; S=sporocarp; W=whole plant	none
NOTES*	Any other characteristic observed in the field	none
C	Percent Carbon. Organic carbon content in the soils, expressed as percent weight of the dry sample.	%
N	Bulk nitrogen content in the soils, expressed as percent weight of the dry sample.	%
d13C	Carbon isotope composition of the soil organic matter, expressed in the 'delta' notation, relative to the standard Pee Dee Belemnite (PDB).	per mil
d15N	Nitrogen isotope composition of soil bulk nitrogen, expressed in the 'delta' notation, relative to the standard atmospheric N_2.	per mil

Soils: Description of the file "**soils_C_N_iso.csv**"

Columns	Column Description	Units
SITE*	Site name	units
COUNTRY	Country name	none
LAT	Latitude	decimal degrees
LONG	Longitude	decimal degrees
DATE	Usually only sampling months, days were not always recorded because they were not considered relevant. For some samples when day is available, it is expressed as dd-mon-yy.	mon-yy
DISTURBANCE*	The letters C, G and F indicate cultivation, grazing and fires respectively. Increasing numbers indicate increasing disturbance intensity for each land-use gradient.	none
START DEPTH	starting depth of the soil sample	cm
END DEPTH	ending depth of the soil sample	cm
CHARACTERISTICS*	characteristics of the surface cover or vegetation type where the soil was collected	none
C	Percent carbon. Organic carbon content in the soils, expressed as percent weight of the dry sample. Organic carbon content of the soil sample	%
N	Percent Nitrogen. Bulk nitrogen content of the soil sample	%

d13C	carbon isotope composition of the soil organic matter, expressed in the 'delta' notation, relative to the standard Pee Dee Belemnite	per mil
d15N	nitrogen isotope composition of soil bulk nitrogen, expressed in the 'delta' notation, relative to the standard atmospheric N_2.	per mil

Note: Additional details and descriptions are available for columns indicated with a '*' in the associated files **soils_CNiso_1995-2000_def.txt** and **plants_CNiso_1995-2000_def.txt** for soil and plant data, respectively.

Study Area

The study sites were located in southern Africa. Some sites (Mongu, Maun, Okwa, Tshane, Lukulu, Senanga, Maziba, Sandveld, and Vastrap) were located along a precipitation gradient, underlain by the same soil substrate: the Kalahari sands. These sites were relatively undisturbed, located at least 5 km from significant human settlements and major roads. Additional sites were selected near some of these main research sites, with different intensities of domestic grazing and cultivation (a cultivation gradient in Mongu, grazing gradients in Maun, Okwa, and Tshane). Fire gradients were sampled in the Kruger National Park, South Africa. Two sites were sampled in the dry season of 2000: Mongu-D (dambos near Mongu) and Sua Pan. Additionally, other soil samples were collected in several sites of Botswana, and in Kruger National Park during 1998 and 1999 for preliminary analyses, and they were included in this data set.

Site	Alternate Site Name	Country	Lat	Long	Mean Annual Precip (mm)
Lukulu	Lishuwa Communal Forest	Zambia	-14.42	23.52	970

Mongu[1]	Kataba Forest Reserve	Zambia	-15.44	23.52	879
Senanga	Liangati Forest Reserve	Zambia	-15.86	23.34	810
Maziba	Maziba Bay Forest or Sioma	Zambia	-16.75	23.61	740
Maun[1]	Harry Oppenheimer Okavango Research Center	Botswana	-19.93	23.59	460
Sua Pan[2]	Makgadigadi	Botswana	-20.5214	26.0346	425
Sandveld	Sandveld Research Station or Gobabis	Namibia	-22.02	19.17	410
Okwa[1]	Okwa River Crossing	Botswana	-22.41	21.71	407
Tshane[1]		Botswana	-24.17	21.89	365
Pandamatenga		Botswana	-18.66	25.5	698
Vastrap		South Africa	-27.75	21.42	210
Skukuza		South Africa	-25.1	31.47	
Satara		South Africa	-24.4	31.75	
Nwaswitshaka		South Africa	-25.1	31.38	
USGS 1-35	Collected during 1999 field campaign funded by USGS to collect soil samples across Botswana	Botswana			

Notes: [1]Additional measurements were taken near these sites at locations for which there are no coordinates. These sites are named similar to those in the table but are distinguished in the data files by an additional number or letter.

Qualitative descriptions of the nature and/or location of these sites relative to the primary site can be found in the text below and in the file **soils_CNiso_1995-2000_def.txt**

[2]Sua Pan coordinates estimated to be the center of the Sua Grassland site described by Buermann and Helmlinger (2004).

Temporal Coverage

Some of the samples presented here were collected during previous Kalahari Transect projects as far back as 1995. Most of the data, however, were collected during the SAFARI 2000 Kalahari Wet Season Field Campaign between February 29 and March 16, 2000. Note that 2000 was a year with unusually high precipitation. Additional samples were also collected in Botswana for the USGS during the dry season of 1999.

Precipitation gradient in the Kalahari sands

Most of the sampling sites were located over the Kalahari sands, along a precipitation gradient (from 970 to 230 mm mean annual rainfall) and located at least 5 km from significant human settlements and major roads (Scholes et al., 2002).

The mean annual rainfall for Vastrap was derived from a 23-year rain gauge data set collected on an adjacent farm approximately 5 km from the field site (T. Botha, pers. comm.). The Sandveld value was derived from the 27-year data set collected at the research station immediately adjacent to the field site. Data provided by the Zambian Department of Agriculture were used to derive values for the Maziba, Senanga, and Lukulu sites. The Maziba value was linearly interpolated from data collected at Sesheke (43-year record, 85 km from the site) and Senanga (42-year record, 78 km from the site). Similarly the value for the Senanga site was interpolated using data from Senanga (28 km from the site) and Mongu (44-year record, 74 km from the site). The mean annual rainfall used for the Lukulu site was calculated as an inverse-distance weighted mean of values from Mongu (44 years), Kaoma (42 years), Zambezi (38 years), and Kabompo (31 years) with distances of these stations from the field site ranging between 93 and 138 km (Swap et al., 2004). Mean annual precipitation of the Sua Pan was calculated from

data from the Botswana Meteorological Department.

The 'Mongu-D' site is located near Mongu, in seasonally waterlogged grassy depressions, which are intentionally burned from July to October. The floodplains near the Zambezi River are flooded every year between January and June.

Land-use gradients in the Kalahari

During the 2000 field campaign, sites with different disturbance intensities were selected in areas near the main research sites along the precipitation gradient. The numbers 0 to 4 in the site names in the data files indicate disturbance intensity, with 0 being the lowest intensity and 4 being the highest.

An additional site north of the Mongu research site along the precipitation gradient (approximately 500 m away) was selected as the 'disturbed' site to be compared to the relatively undisturbed, main research site of the Kalahari transect ('Mongu'). This area, named 'Mongu-1' in the data set, was substantially disturbed by deforestation and clearing for agriculture, and then abandoned after a few years and rapidly re-invaded by shrubs such as *Baphia massaiensis* and *Bauhinia* spp (Frost, 2000).

Three additional sites were sampled close to the main research site of the Kalahari transect in Maun (Botswana). The 'Maun-0' or 'Wildlife' site had lower human disturbance intensities, and was located approximately 26 km from the town, inside the Northern Botswana Veterinary Fence system. Another site, 'Maun-3' or 'Maun village', was chosen within 1 km of the main road to represent land under a more intense land use regime. This site was also near several homesteads and hosted an unused cattle corral. Only 2 samples from another site, 'Maun-1' (for Maun tower site), are available. This site and the main research site of the Kalahari transect (Maun) were very close and had similar disturbance intensities (although they seemed higher in Maun then in Maun-1), but the Maun-1 site had taller trees.

The third land use gradient was located near Okwa. Approximately 20 km south of the Okwa river site, we made use of a cattle station located 4 km from the Trans-Kgaligadi Highway. The station supports its own population of cattle and also receives cattle from other boreholes. With the intention to capture a gradient in grazing pressure, we sampled at distances of 3 km, 2 km, 1 km, and 100 m from

the pens (Okwa-1, -2, -3, and -4, respectively). However, the site Okwa-1 was also located about a kilometer from the road, receiving cattle from other boreholes, and showing signs of intense grazing (Feral et al., 2002). The Okwa-G site corresponds to all the other grazing sites (Okwa 1 to 4), but the exact location of the sample along the gradient was not recorded.

The fourth land use gradient was located near Tshane. The main research site was located at approximately 10 km from the village of Tshane (named 'Tshane' in this study). A disturbed site, 'Tshane-2' was located around the Tshane village (~500 m), and it was heavily grazed, mainly by goats. A third site, 'Tshane-1', was located between the other two sites, and it was selected as a site with intermediate grazing pressure.

Fire gradients in the Kruger National Park

In this study, experimental plots with different fire frequencies, as indicated in the data file (**kt_plants _C_N_iso.csv**) were sampled to represent fire gradients. The plots selected included controls (where fire has been suppressed since the establishment of fire trails, about 50 years), triennial (burned every three years in winter), and annual (burned every year in winter) treatments. A sexennial burn (burned every 6 years in spring) in Satara was also sampled to analyze a low fire frequency treatment.

Measurements

Soil and plant samples were analyzed for %C, %N, d13C and d15N with an Optima isotope ratio mass spectrometer (IRMS) coupled to an elemental analyzer (EA) at the Department of Environmental Sciences, University of Virginia, USA.

The stable isotope ratios are expressed using standard delta notation in units per mil. The isotope ratios are expressed relative to the international standard, PDB for carbon and atmospheric N_2 for nitrogen samples. The carbon and nitrogen content are expressed in percentage weight of the dry sample.

Sample Processing

Plant Samples

1. Plant samples were collected at the same height for each functional type (10 to 15 leaves per plant, which were composited into one sample for each individual plant).
2. Samples were air dried in the field and transported to the laboratory.
3. Samples were oven dried at 60 degrees Celsius.
4. Samples were ground in a Willey mill to pass a 40 mesh screen.
5. Samples were analyzed in IRMS coupled with EA.
6. Sample data were transferred to a database.

Soil Samples

1. Soil samples collected with soil cores; the cores were passed through a 2 mm sieve to remove coarse roots.
2. Samples were air dried in the field and transported to the laboratory.
3. Samples were oven dried at 60 degrees Celsius.
4. Algal filaments were separated (only for the soil crust samples from Tshane) with sonicator and centrifuge; oven dried filaments (60 degrees Celsius).
5. Samples were acidified with 20 % HCl (hydrochloric acid) to remove carbonates.
6. Samples were analyzed in IRMS coupled with EA.
7. Sample data were transferred to a database.

Julieta Aranibar (left) and Luanne Otter extracting a soil sample at the Tshane site. Photo provided by Bob Scholes.

Error Sources

The instrument precision was 0.3 per mil for C and N isotope ratios. The calculated standard error of citrusí leaves standards was 0.02 (average %N=2.8) for %N and 0.1 (average %C=41.9) for %C. This error includes instrument precision, experimental error when weighing the samples, and variability of C and N content among all the citrusí samples.

Known Problems with the Data

There are a low number of replicates at some of the sites and no replication during different years for the same site.

Acknowledgments

The authors wish to express their gratitude to those who provided us with samples collected during their field campaigns: Robert Scholes, Dirk Parson, Peter Dowty,

Susan Ringrose, Warren Wood, Frank Eckardt, Christelle Hely, and Kaycie Billmark.

This study was part of the Southern African Regional Science Initiative (SAFARI 2000), and was funded by the National Aeronautic and Space Administration (grants 7956 - Kalahari Transect; 7266 - SAVE; 7862 - SAFARI 2000; 9357 - IDS); the Department of Environmental Sciences (Moore award and Dupont fellowship to J. Aranibar); and SysTem for Analysis Research and Training (START).

Additional Sources of Information

Additional related data sets collected during the Kalahari Transect Wet Season Field Campaign are archived by ORNL DAAC. A list of these data sets is available at: http://www.daac.ornl.gov/S2K/safari.html.

References

Aranibar J. N., L. Otter, S. A. Macko, C. J. W. Feral, H. E. Epstein, P. R. Dowty, F. Eckardt, H. H. Shugart, and R. J. Swap. 2004. Nitrogen cycling in the soil-plant system along a precipitation gradient in the Kalahari sands. Global Change Biology, 10(3): 359-373.

Aranibar J. N., S. A. Macko, I. C. Anderson, A. Potgieter, R. Sowry, and H. H. Shugart. 2003. Nutrient cycling responses to fire frequency in the Kruger National Park (South Africa) indicated by stable isotopes. Isotopes in Environmental and Health Studies, 39: 141-158.

Aranibar, J. N., I. C. Anderson, S. Ringrose, and S. A. Macko. 2003. Importance of cyanobacterial crusts as a source of nitrogen of Southern African arid ecosystems, as indicated by acetylene reduction and stable isotopes. Journal of Arid Environments, 54: 345-358.

Buermann, W. and M. Helmlinger. 2004. SAFARI 2000 LAI and FPAR Measurements at Sua Pan, Botswana, Dry Season 2000. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Feral, C. J. W., H. E. Epstein, L. Otter, J. N. Aranibar, H. H. Shugart, S. A. Macko, and J. Ramontsho. 2002. Carbon and nitrogen in the soil-plant system along rainfall and land-use gradients in southern Africa. Journal of Arid Environments, 54: 327-343.

Frost, P. G. H. 2000. Vegetation structure of the MODIS validation site, Kataba Forest Reserve, Mongu, Zambia. Report prepared for the NASA Southern African Validation of EOS (SAVE) project, IGBP Kalahari Transect program, and SAFARI 2000. Typescript, 13 pp.

Hipondoka, M. H. T., J. N. Aranibar, C. Chirara, M. Lihavha, and S. A. Macko. 2003. Vertical distribution of grass and tree roots in arid ecosystems of Southern Africa: niche differentiation or competition? Journal of Arid Environments, 54: 319-326.

Midgley, G. F., J. N. Aranibar, K. B. Mantlana, and S. A. Macko. 2004. Photosynthetic and gas exchange characteristics of dominant woody plants on a moisture gradient in an African savanna. Global Change Biology, 10(3): 309-317.

Otter L.B., R. J. Scholes, P. Dowty, J. Privette, K. Caylor, S. Ringrose, M. Mukelabai, P. Frost, N. Hannan, O. Totolo, and E. M. Veenendaal. 2002. The Southern African Regional Science Initiative (SAFARI 2000): Wet season campaigns. South African Journal of Science, 98, 131-137.

Scholes R. J., P. R. Dowty, K. Caylor, D. A. B. Parsons, and H. H. Shugart. 2002. Trends in savanna structure and composition along an aridity gradient in the Kalahari. Journal of Vegetation Science, 13: 419-428.

Swap R. J. , J. N. Aranibar, P. R. Dowty, W. P. Gilhooly, and S. A. Macko. 2004. Natural abundance of 13C and 15N in C3 and C4 vegetation of Southern Africa: Patterns and Implications. Global Change Biology, 10(3): 350-358.

Point of Contact:

Julieta Aranibar
Formerly of University of Virginia
Now at:
Department of Global Ecology
Carnegie Institution of Washington
260 Panama Street

Stanford, CA 94305 USA
E-mail: aranibar@catalase.stanford.edu
Phone: +01-650-325-1521
Fax: +01-650-325-6857

Stephen A. Macko
Department of Environmental Sciences
Clark Hall
291 McCormick Rd
PO Box 400123
Charlottesville, VA 22904-4123 USA
E-mail: sam8f@virginia.edu
Phone: +01-434-924-6849
Fax: +01-434-982-2137

Revision Date: Tuesday, January 11, 2005