LBA-ECO ND-06 Land Use Effects on Soil Nutrients: A Review of Studies 1950-2001

Summary:

This data set provides measurements of soil properties compiled from 39 studies on nutrient dynamics in natural forests and forest-derived land uses (pasture, shifting cultivation and tree plantations) conducted in Amazonia over the period of 1950-2001. The initial literature survey for the data consisted of more than 100 studies conducted during this period.

The objectives of this project were to compare soil data from major land uses across Amazonia and identify gaps in present knowledge that offer direction for future research. Five widely cited hypotheses were tested concerning the effects of land-use change on soil properties by analyzing data compiled from 39 studies in multi-factorial ANOVA models:

- effective cation exchange capacity (ECEC), and exchangeable calcium (Ca) concentrations rise and remain elevated following the slash-and-burn conversion of forest to pasture or crop fields
- soil contents of total carbon (C), nitrogen (N), and inorganic readily (i.e., Bray, Mehlich I or resin) extractable phosphorus (Pi) decline following forest-to-pasture conversion
- soil concentrations of total C, N, and Pi increase in secondary forests with time since abandonment from agricultural activities
- soil nutrient conditions under all tree-dominated land-use systems (natural or not) remain the same
- higher efficiencies of nutrient utilization occur where soil nutrient pools are lower

There is one comma-delimited ASCII file (.csv) with this data set and a list of the 39 studies used in this data set provided as a companion file in text format.

Data Citation:

Cite this data set as follows:

McGrath, D., C.K. Smith, H.L. Gholz, and F.A. Oliveira. 2012. LBA-ECO ND-06 Land Use Effects on Soil Nutrients: A Review of Studies 1950-2001. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

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Data users should use the Investigator contact information in this document to communicate with the data provider. Alternatively, the LBA Web Site [http://lba.inpa.gov.br/lba/] in Brazil will have current contact information.

Data users should use the Data Set Citation and other applicable references provided in this document to acknowledge use of the data.

Table of Contents:

1. Data Set Overview:

Project: LBA (Large-Scale Biosphere-Atmosphere Experiment in the Amazon)

Activity: LBA-ECO

LBA Science Component: Nutrient Dynamics

Team ID: ND-06 (Gholz / Oliveira)

The investigators were Gholz, Henry L.; Oliveira, Francisco de Assis and Smith, Charles (Ken) Kenneth. You may contact McGrath, Dr. Deborah A. (dmcgrath@sewanee.edu)

LBA Data Set Inventory ID: ND06_LandUse_Studies

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2. Data Characteristics:

Data are provided in a single comma-delimited ASCII file:
ND06_soil_properties_literature_survey.csv

These soil data were compiled from 39 studies conducted between 1950 and 2001 in Amazonia. The list of the 39 study references is provided as a companion file in text format.

Column	Heading	Units/format	Description
1	Region		Regional abbreviations as follows: Amazonas, Brazil; Caqueta, Colombia; Anangu, Ecuador, Mabura Hill, Guyana; Rondonia, Brazil; San Carlos de Rio Negro, Venezuala; Yurimaguas, Peru
2	N_sites		Number (n) of sites per study averaged
3	Land_use		Land use: primary forest (p. for), secondary forest (s. for), pasture (pas), shifting cultivation (cul), tree plantation or agroforest (pln)
4	Age_class	years	Age class of land use: <= (less than or equal to) 5 years, <=10 years, <=20 years, <=30 years, or unknown (primary forest age not known)
5	Soil_order		Soil orders: Ult (US-Ultisol; FAO-Acrisols; Brazil-red-yellow Podzolics) and Ox (US-Oxisol; FAO-Ferrasols; Brazil-yellow and red-yellow Latisols)
6	Depth	cm	Soil depth in centimeters
7	pH_H2O		pH
8	Bd	g/cm3	Soil bulk density expressed as g/cm3
9	C_total	g C /kg	Total carbon assayed using (a) gas chromatography after dry combustion in a C and N analyzer or (b) Walkley-Black method (low Ca soils only; Nelson and Sommers 1982) expressed as g C/kg. Soil contents of C in top 10 cm are the product of bulk density (Bd) and C_total for each observation
10	N_total	g N/kg	Total nitrogen assayed using (a) gas chromatography after dry combustion in a C and N analyzer or (b) a Kjeldahl procedure (Bremmer and Mulvaney 1982) expressed as g N/kg. Soil contents of N in top 10 cm are the product of bulk density (Bd)
11	P_total	mg P/kg	Total phosphorus measured (a) colorimetrically or (b) using inductively coupled argon plasma (ICAP) spectroscopy after acid digestion (Olsen and Sommers 1982) expressed as mg P/kg
12	P_ext	mg P/kg	Extractable phosphorus (ext-Pi) measured colorimetrically or using ICAP after (a) Mehlich double-acid, (b) Bray, or (c) resin extraction (Olsen and Sommers 1982) expressed as mg P/kg
13	Ex_Ca	cmol /kg	Exchangeable Ca assayed using ICAP or atomic absorption spectroscopy (AA) following extraction in 1.0 M NH4OAc (pH 7) or a Mehlich I or III double-acid solution (Thomas 1982). Expressed as cmol /kg
14	ECEC	cmol /kg	Effective cation exchange capacity - sum of base cations (extracted

			and assayed as described for Ex_Ca) - exchangeable A1 (extracted in 1M KCl and assayed using ICAP or AA). Expressed as cmol /kg
15	Clay	%	Percent clay
16	Ref_num		References of studies cited denoted by numbers below. See companion file References.csv for complete citation
Note: missing values are represented as -9999			

Example data records:

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Region,N_sites,Land_use,Age_class,Soil_order,Depth,pH_H2O,Bd,C_total,N_total,P_total,P_ext,Ex_Ca,ECEC,Clay, Ref_num,
"Acre, Brazil",8,p. for,,Ult,20,4.3,-9999,15.3,1.6,360,1.5,0.5,3.1,41,1,
"Acre, Brazil",8,pln,10,Ult,20,4.9,1.02,16.2,1.7,410,1.1,2,4.4,46,"1,2",
"Acre, Brazil",5,cul,5,Ult,20,5.9,1.1,10.1,0.9,-9999,8.1,1.8,3.38,-9999,3,
"Acre, Brazil",5,p. for,,Ult,20,4.7,1.1,8.1,0.8,-9999,2.8,0.81,2.22,-9999,3,
"Acre, Brazil",5,pas,20,Ult,20,5.4,1.3,10.3,1,-9999,4.6,3.07,4.95,-9999,3,
"Amazonas, Brazil",5,p. for,,Ult,10,4.1,-9999,34.6,1.9,-9999,2.3,0.1,3.3,51,4,
"Amazonas, Brazil",1,p. for,,Ox,5,3.6,-9999,61.7,3.8,-9999,-9999,-9999,-9999,70,5,
"Amazonas, Brazil",1,pas,5,Ox,5,4.7,-9999,94.1,4.1,-9999,-9999,-9999,-9999,-9999,5,
"Amazonas, Brazil",1,pas,10,Ox,5,4.5,-9999,76.4,4.8,-9999,-9999,-9999,-9999,-9999,5,
"Caqueta, Columbia",4,p. for,,Ult,20,4.1,1.02,12.2,1.1,200,2.5,0.2,4.05,19,"6,7",
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Site boundaries: (All latitude and longitude given in decimal degrees)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Geodetic Datum
Amazon Basin (Amazon Basin)	-80	-35	5	-18	World Geodetic System, 1984 (WGS-84)

Time period:

- The data set covers the period: 1950/01/01 to 2001/05/14
- Temporal Resolution

Platform/Sensor/Parameters measured include:

- SOIL SURVEY / HUMAN OBSERVER / SOIL CHEMISTRY
- SOIL SURVEY / HUMAN OBSERVER / SOIL BULK DENSITY
- SOIL SURVEY / HUMAN OBSERVER / SOIL MOISTURE/WATER CONTENT
- SOIL SURVEY / HUMAN OBSERVER / SOIL NUTRIENTS

3. Data Application and Derivation:

Historic soil properties data can be used to validate models and as a baseline of comparison for more recently collected data.

4. Quality Assessment:

Not applicable.

5. Data Acquisition Materials and Methods:

Data acquisition

We reviewed over 100 studies of soil and plant nutrient dynamics in native forests and forest-derived land uses conducted in the Amazon Basin over the past 4 decades. The final data set used in our analyses was comprised of 39 studies representing five major land uses (primary forest, secondary forest, pasture, annual crops, and tree plantations) across Amazonia.

To facilitate comparisons across studies, we developed specific criteria for including a study in our analysis.

1. First, to minimize variation due to inherent differences among soil orders, only data from sites with soils identified as Ultisols or Oxisols were used. Together, Ultisols and Oxisols represent 60% to 75% of the region's soils (Sanchez et al.,1982; Moraes et al.,1995; Cerri et al., 2000). Excluded from our analysis were Amazonian forest and agricultural sites on sandy Spodosols and more eutrophic Alfisols.
2. Second, the depth of soil sampling in each study was placed into one of three categories (0-5 cm, 0-10 cm, and 0-20 cm); studies in which sampling occurred deeper in the soil profile were not included because the sample size was so small.
3. Third, methods of soil analysis in each study were carefully examined, and only data derived using the same, or very similar, laboratory procedures were included (the analytical procedures used are footnoted in the Appendix of McGrath, et al. 2001).

Specific soil properties examined include concentrations of total C, N, P, extractable inorganic phosphate (Pi), and exchangeable Ca, ECEC, C:N ratios, and topsoil contents of C and N (0-10-cm depth), as well as pH and bulk density (Bd). Extractable Pi refers to inorganic phosphate extracted using either a Bray, Mehlich (I or III), or resin extraction, which, to date, are the most common procedures reported in Amazonian studies (McGrath, et al. 2001). These procedures all extract relatively similar quantities of Pi, which are presumably related to the most immediately plant available soil pool (McGrath et al. 2001). Contents of total C and N in the top 10 cm of soil were estimated as the product of Bd and elemental concentrations for each observation that included these parameters. This depth was selected for estimating C and N contents because it was used in the majority of studies we reviewed.

The age of forest-derived land-use sites was also classified (5 years or less, 6-10 years, 10-20 years, and more than 20 years). We assumed that primary or old-growth forests were over 100 years old, because the age of these systems is generally not reported. We defined secondary forests as successional regrowth of native vegetation following abandonment from annual cropping, cattle ranching, or logging, and we assumed that the age reported for a secondary forest indicated the time since abandonment of agricultural activities. In our data set, all but one secondary forest originated from abandoned annual crop fields, often referred to as fallows.

"Plantations" refers to perennial crop-based agroforests, as well as stands of native or exotic timber species. When possible, we calculated means on a per study basis for each land use within the same soil order and, age and depth class to prevent a single study with multiple sites from disproportionately influencing our analysis.

Data analysis:

The data set compiled was analyzed in single-and two-stage ANOVA models with variable classes of (a) land use, (b) soil order, (c) age of land use, and (d) sampling depth, plus their interactions. After we

determined that age of land use and sampling depth had the least effect on soil properties, these variable classes were dropped from our final analysis, which used a two-stage sequential ANOVA model with factors of land use, soil order, and their interaction to calculate the probability (P) values.

Our analysis assumes that studies of all forest-derived land uses were conducted on sites established after clearing primary or old-growth forest for the first time, thus enabling us to make conclusions about the effect of land-use change on soil fertility and nutrient pools. After examining significant land use by soil order interactions, we used a Tukey's studentized range test to determine which of the five land uses differed with respect to soil characteristics, as recommended by Zar (1999). This more conservative multiple-comparison procedure was chosen because it controls type I error rates on an experimental basis and accounts for unequal sample sizes (Ott 1988). Specifically, we used this test to determine if soil properties differed among (a) primary forest vs other land uses, (b) pasture vs forest, and (c) secondary forest vs other land uses.

To test the hypothesis that higher efficiencies of nutrient use occur where soil nutrient pools are smaller, we regressed an index of nutrient-use efficiency (NUE) (inverse of litterfall N, P, or Ca content) as a function of soil concentrations of total N, extractable Pi, and exchangeable Ca, when paired data were available for any of the forest and nonforest land uses. This analysis was also performed on log-transformed data. All analyses were performed using SAS (SAS Institute, Inc., Cary, NC, USA).

6. Data Access:

This data is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Data Archive Center:

Contact for Data Center Access Information:
E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

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- McGrath D.A., C.K. Smith, H.L. Gholz, and F.D. Oliveira. 2001. Effects of land-use change on soil nutrient dynamics in Amazonia, Ecosystems, 4(7):625-645. (LBA-ECO Pub ID = 199)