Supplementary Information for A NEW HYPOTHESIS FOR THE ORIGIN OF AMAZONIAN DARK EARTHS by SILVA et al.

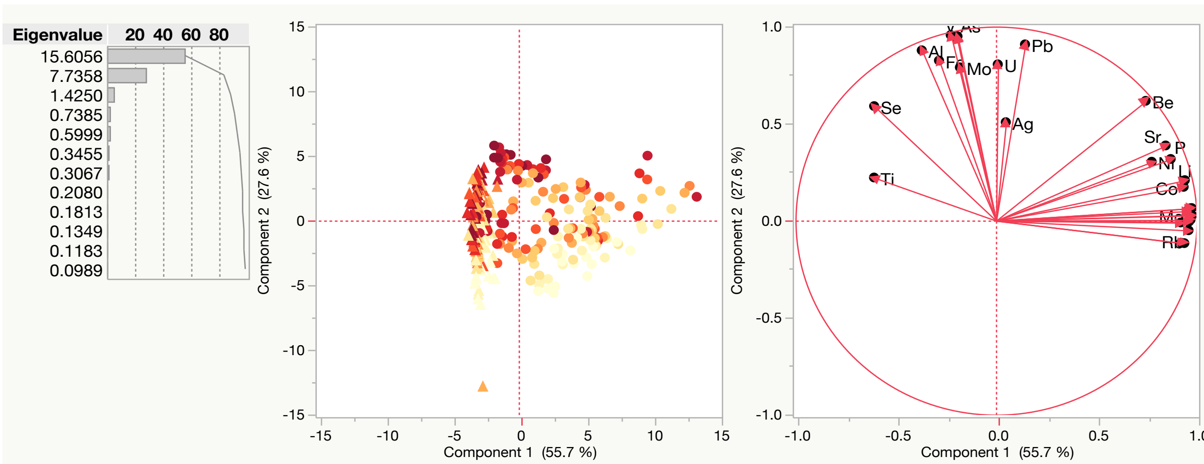
Table S1. Correlations between the total concentration of 28 elements measured in all maximum contrast ADE and Ultisol soil samples.

	Mg	P	K	Ca	Ti	Li	Be	Al	V	Cr	Mn	Fe	Co	Ni
Mg	1.0000	0.8102	0.9275	0.8925	-0.5655	0.9128	0.7412	-0.3370	-0.2011	-0.1635	0.9315	-0.2783	0.9285	0.7538
P	0.8102	1.0000	0.8179	0.8063	-0.5348	0.8981	0.8302	-0.0555	0.1312	0.1343	0.7175	0.0391	0.8156	0.7654
K	0.9275	0.8179	1.0000	0.8357	-0.4962	0.9356	0.7682	-0.2856	-0.1659	-0.1231	0.8736	-0.1931	0.9260	0.7163
Ca	0.8925	0.8063	0.8357	1.0000	-0.5821	0.8345	0.6699	-0.3561	-0.2236	-0.2050	0.8560	-0.2685	0.8228	0.6851
Ti	-0.5655	-0.5348	-0.4962	-0.5821	1.0000	-0.5251	-0.3481	0.5229	0.3415	0.3754	-0.5532	0.5234	-0.4521	-0.4653
Li	0.9128	0.8981	0.9356	0.8345	-0.5251	1.0000	0.8604	-0.1729	-0.0085	0.0252	0.8528	-0.1258	0.9403	0.7882
Be	0.7412	0.8302	0.7682	0.6699	-0.3481	0.8604	1.0000	0.2557	0.4206	0.4420	0.6281	0.2554	0.8287	0.7705
Al	-0.3370	-0.0555	-0.2856	-0.3561	0.5229	-0.1729	0.2557	1.0000	0.9329	0.9054	-0.4792	0.9212	-0.2003	-0.0451
V	-0.2011	0.1312	-0.1659	-0.2236	0.3415	-0.0085	0.4206	0.9329	1.0000	0.9645	-0.3452	0.8808	-0.0602	0.1128
Cr	-0.1635	0.1343	-0.1231	-0.2050	0.3754	0.0252	0.4420	0.9054	0.9645	1.0000	-0.2771	0.8376	-0.0000	0.1349
Mn	0.9315	0.7175	0.8736	0.8560	-0.5532	0.8528	0.6281	-0.4792	-0.3452	-0.2771	1.0000	-0.4221	0.9125	0.6819
Fe	-0.2783	0.0391	-0.1931	-0.2685	0.5234	-0.1258	0.2554	0.9212	0.8808	0.8376	-0.4221	1.0000	-0.1779	-0.0207
Co	0.9285	0.8156	0.9260	0.8228	-0.4521	0.9403	0.8287	-0.2003	-0.0602	-0.0000	0.9125	-0.1779	1.0000	0.7670
Ni	0.7538	0.7654	0.7163	0.6851	-0.4653	0.7882	0.7705	-0.0451	0.1128	0.1349	0.6819	-0.0207	0.7670	1.0000
Cu	0.9272	0.8657	0.9361	0.8751	-0.5279	0.9236	0.7298	-0.3123	-0.1874	-0.1534	0.9120	-0.2075	0.9156	0.7560
Zn	0.9309	0.8374	0.9167	0.9013	-0.5149	0.9049	0.7109	-0.3282	-0.2134	-0.1790	0.9103	-0.2270	0.9062	0.7499
As	-0.1708	0.1645	-0.1612	-0.2006	0.2207	0.0000	0.4272	0.8744	0.9658	0.9263	-0.3095	0.8232	-0.0466	0.1386
Se	-0.5374	-0.4456	-0.5565	-0.5093	0.4850	-0.4581	-0.0675	0.6867	0.6463	0.6436	-0.5545	0.5408	-0.4017	-0.2949
Rb	0.9298	0.8119	0.9607	0.8414	-0.4990	0.8837	0.6705	-0.3734	-0.2564	-0.2111	0.9026	-0.2537	0.8984	0.6873
Sr	0.8257	0.8883	0.7985	0.8389	-0.4319	0.8556	0.8362	0.0662	0.1848	0.1750	0.7066	0.1508	0.8029	0.7276
Mo	-0.1787	0.1661	-0.1297	-0.1609	0.4302	-0.0230	0.2946	0.8164	0.8139	0.7978	-0.3226	0.8440	-0.0827	0.0756
Ag	0.0984	0.1413	0.0642	0.0525	-0.0442	0.1365	0.3603	0.3539	0.3840	0.3978	0.0440	0.2902	0.1491	0.1722
Cd	0.9037	0.8402	0.8977	0.9419	-0.5354	0.8879	0.7050	-0.3443	-0.2253	-0.1980	0.9020	-0.2433	0.8888	0.7225
Cs	0.8786	0.7559	0.9091	0.8034	-0.4512	0.8184	0.5884	-0.3888	-0.3069	-0.2770	0.8656	-0.2589	0.8410	0.6374
Ba	0.9289	0.8593	0.9120	0.9074	-0.5350	0.8937	0.7411	-0.2748	-0.1533	-0.1322	0.8869	-0.1643	0.8993	0.7518
Tl	0.9565	0.8592	0.9350	0.8945	-0.5766	0.9346	0.7758	-0.3263	-0.1623	-0.1113	0.9462	-0.2485	0.9351	0.7597
Pb	0.1711	0.4208	0.1512	0.1391	-0.0907	0.3368	0.7051	0.6686	0.8232	0.8108	0.0512	0.5738	0.3002	0.4064
U	0.0848	0.1872	0.0230	-0.0262	0.0610	0.1948	0.5250	0.6057	0.7226	0.7576	0.0201	0.4406	0.2265	0.2709

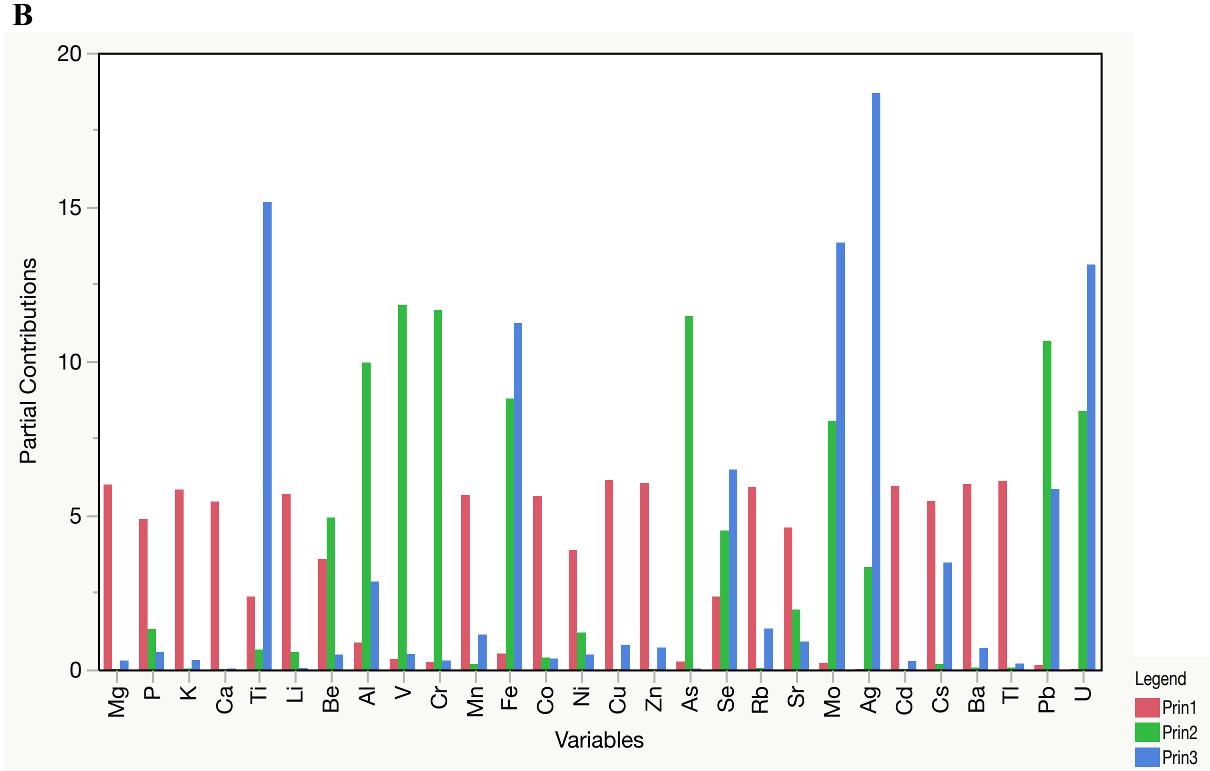
	Cu	Zn	As	Se	Rb	Sr	Mo	Ag	Cd	Cs	Ba	Tl	Pb	U
Mg	0.9272	0.9309	-0.1708	-0.5374	0.9298	0.8257	-0.1787	0.0984	0.9037	0.8786	0.9289	0.9565	0.1711	0.0848
P	0.8657	0.8374	0.1645	-0.4456	0.8119	0.8883	0.1661	0.1413	0.8402	0.7559	0.8593	0.8592	0.4208	0.1872
K	0.9361	0.9167	-0.1612	-0.5565	0.9607	0.7985	-0.1297	0.0642	0.8977	0.9091	0.9120	0.9350	0.1512	0.0230
Ca	0.8751	0.9013	-0.2006	-0.5093	0.8414	0.8389	-0.1609	0.0525	0.9419	0.8034	0.9074	0.8945	0.1391	-0.0262
Ti	-0.5279	-0.5149	0.2207	0.4850	-0.4990	-0.4319	0.4302	-0.0442	-0.5354	-0.4512	-0.5350	-0.5766	-0.0907	0.0610
Li	0.9236	0.9049	0.0000	-0.4581	0.8837	0.8556	-0.0230	0.1365	0.8879	0.8184	0.8937	0.9346	0.3368	0.1948
Be	0.7298	0.7109	0.4272	-0.0675	0.6705	0.8362	0.2946	0.3603	0.7050	0.5884	0.7411	0.7758	0.7051	0.5250
Al	-0.3123	-0.3282	0.8744	0.6867	-0.3734	0.0662	0.8164	0.3539	-0.3443	-0.3888	-0.2748	-0.3263	0.6686	0.6057
V	-0.1874	-0.2134	0.9658	0.6463	-0.2564	0.1848	0.8139	0.3840	-0.2253	-0.3069	-0.1533	-0.1623	0.8232	0.7226
Cr	-0.1534	-0.1790	0.9263	0.6436	-0.2111	0.1750	0.7978	0.3978	-0.1980	-0.2770	-0.1322	-0.1113	0.8108	0.7576
Mn	0.9120	0.9103	-0.3095	-0.5545	0.9026	0.7066	-0.3226	0.0440	0.9020	0.8656	0.8869	0.9462	0.0512	0.0201
Fe	-0.2075	-0.2270	0.8232	0.5408	-0.2537	0.1508	0.8440	0.2902	-0.2433	-0.2589	-0.1643	-0.2485	0.5738	0.4406
Co	0.9156	0.9062	-0.0466	-0.4017	0.8984	0.8029	-0.0827	0.1491	0.8888	0.8410	0.8993	0.9351	0.3002	0.2265
Ni	0.7560	0.7499	0.1386	-0.2949	0.6873	0.7276	0.0756	0.1722	0.7225	0.6374	0.7518	0.7597	0.4064	0.2709
Cu	1.0000	0.9669	-0.1677	-0.6050	0.9577	0.8372	-0.1143	0.0309	0.9523	0.9413	0.9667	0.9488	0.1251	-0.0075
Zn	0.9669	1.0000	-0.1954	-0.5917	0.9337	0.8339	-0.1296	0.0171	0.9568	0.9111	0.9571	0.9364	0.1077	-0.0343
As	-0.1677	-0.1954	1.0000	0.6293	-0.2335	0.1994	0.7618	0.4192	-0.2098	-0.2927	-0.1304	-0.1309	0.8584	0.7494
Se	-0.6050	-0.5917	0.6293	1.0000	-0.6478	-0.3214	0.4171	0.4014	-0.5620	-0.6737	-0.5531	-0.5375	0.5209	0.6198
Rb	0.9577	0.9337	-0.2335	-0.6478	1.0000	0.7805	-0.1630	-0.0170	0.9102	0.9661	0.9327	0.9411	0.0367	-0.0671
Sr	0.8372	0.8339	0.1994	-0.3214	0.7805	1.0000	0.1977	0.2046	0.8284	0.7511	0.8833	0.8195	0.4513	0.2449
Mo	-0.1143	-0.1296	0.7618	0.4171	-0.1630	0.1977	1.0000	0.2110	-0.1477	-0.1703	-0.0922	-0.1386	0.5583	0.4266
Ag	0.0309	0.0171	0.4192	0.4014	-0.0170	0.2046	0.2110	1.0000	0.0354	-0.0841	0.0498	0.1123	0.4981	0.5043
Cd	0.9523	0.9568	-0.2098	-0.5620	0.9102	0.8284	-0.1477	0.0354	1.0000	0.8842	0.9533	0.9329	0.1166	-0.0391
Cs	0.9413	0.9111	-0.2927	-0.6737	0.9661	0.7511	-0.1703	-0.0841	0.8842	1.0000	0.9229	0.8757	-0.0531	-0.1431
Ba	0.9667	0.9571	-0.1304	-0.5531	0.9327	0.8833	-0.0922	0.0498	0.9533	0.9229	1.0000	0.9306	0.1677	0.0051
Tl	0.9488	0.9364	-0.1309	-0.5375	0.9411	0.8195	-0.1386	0.1123	0.9329	0.8757	0.9306	1.0000	0.2105	0.0871
Pb	0.1251	0.1077	0.8584	0.5209	0.0367	0.4513	0.5583	0.4981	0.1166	-0.0531	0.1677	0.2105	1.0000	0.8519
U	-0.0075	-0.0343	0.7494	0.6198	-0.0671	0.2449	0.4266	0.5043	-0.0391	-0.1431	0.0051	0.0871	0.8519	1.0000

Supplementary Figure 1. (A) Principal component analysis of total concentrations (28 elements) ordinated by soil type (Ultisol = triangles and ADE = circles), clustered primarily along principal component 1 (X axis) and depth (red = 100 cm and yellow = 10 cm), clustered primarily along principal component 2 (Y axis). **(B)** Contribution of each element toward separation along the top three ranked principal components (PC 1, 2, 3).

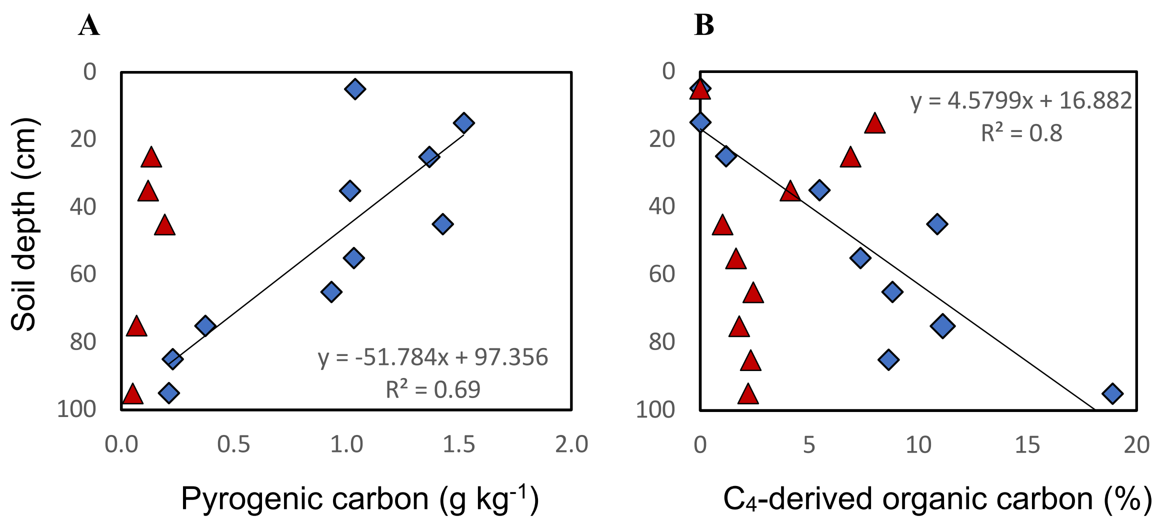
A



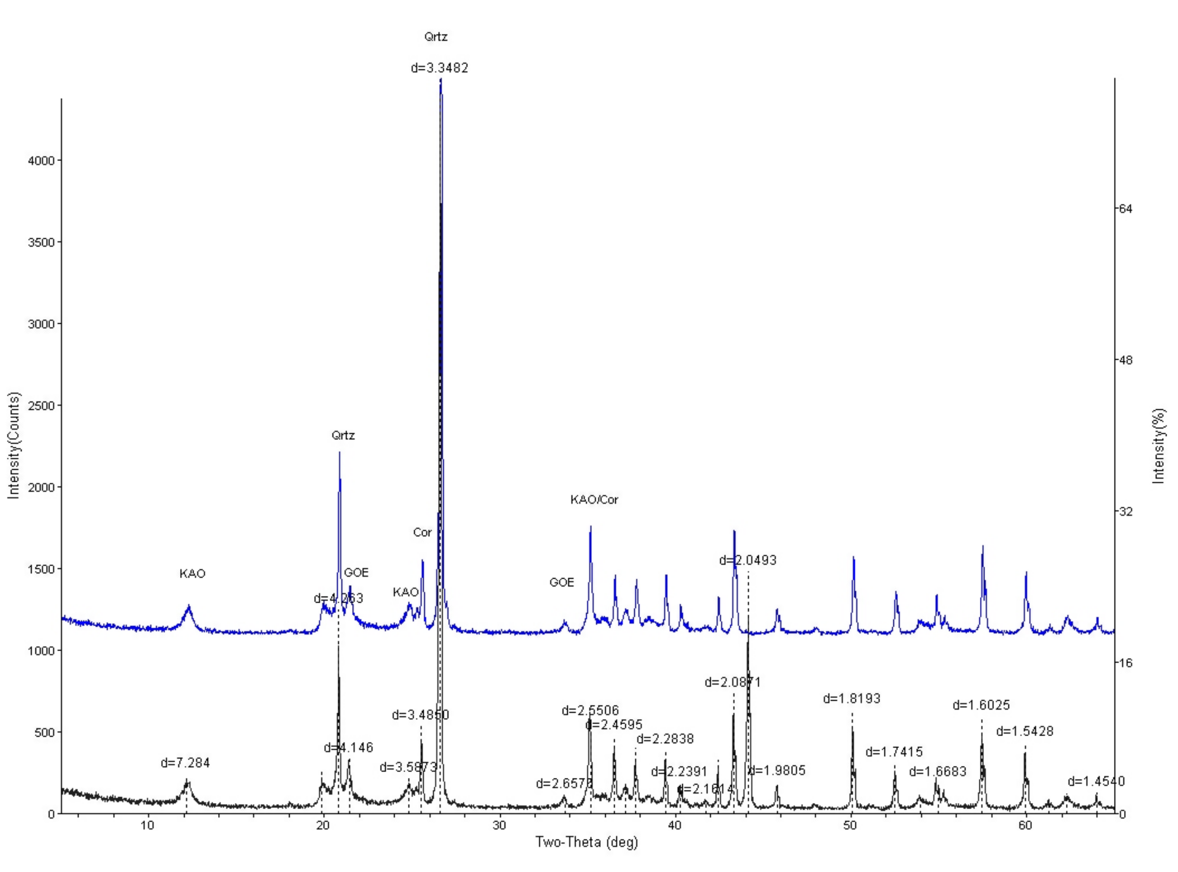
B



Supplementary Figure 2. (A) Mass of pyrogenic charcoal in ADE and Ultisol profiles extracted through acid-peroxide digestion. **(B)** Relative contribution of C_4 grass biomass to the total soil organic carbon calculated from the average stable carbon isotope ratios of ADEs and Ultisol profiles. Standard errors around the mean are shown in Figure 4. Regression lines show statistically significant trends with soil depth for ADE only (blue symbols).

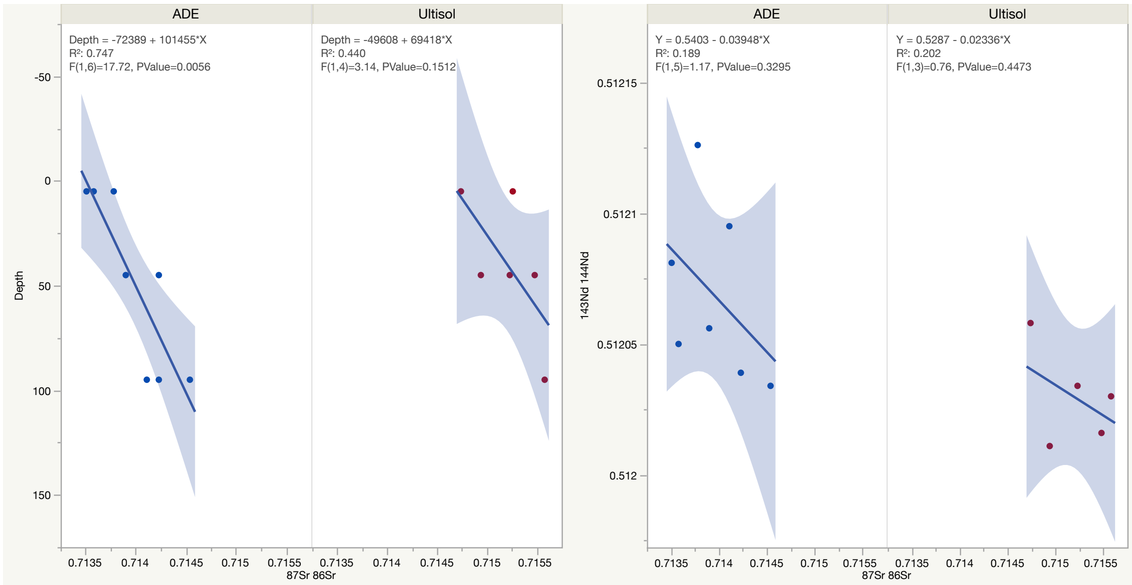


Supplementary Figure 3. Clay mineralogy characterization of a typical ADE and a typical Ultisol sample (40-50 cm depth) using quantitative X-ray diffraction (XRD) spectra following organic carbon removal and analysis of fine fraction. The spectra indicate similar mineralogy, which implies that differences in fertility were caused by exogenous input rather than local pedogenic processes. The analysis was performed using a Rigaku Ultima IV X-ray diffractometer (Tokyo, Japan) with a Cu tube at 40 kV and 40 mA at a scan rate of 2 degrees 2θ min^{-1}, with a Jade 9 (MDI, Livermore, CA) software for mineral identification of the clay fractions, in which gibbsite is identified by peaks at 4.85 Å and 4.38 Å and kaolinite is identified by a characteristic peak at 7.0 Å[1].

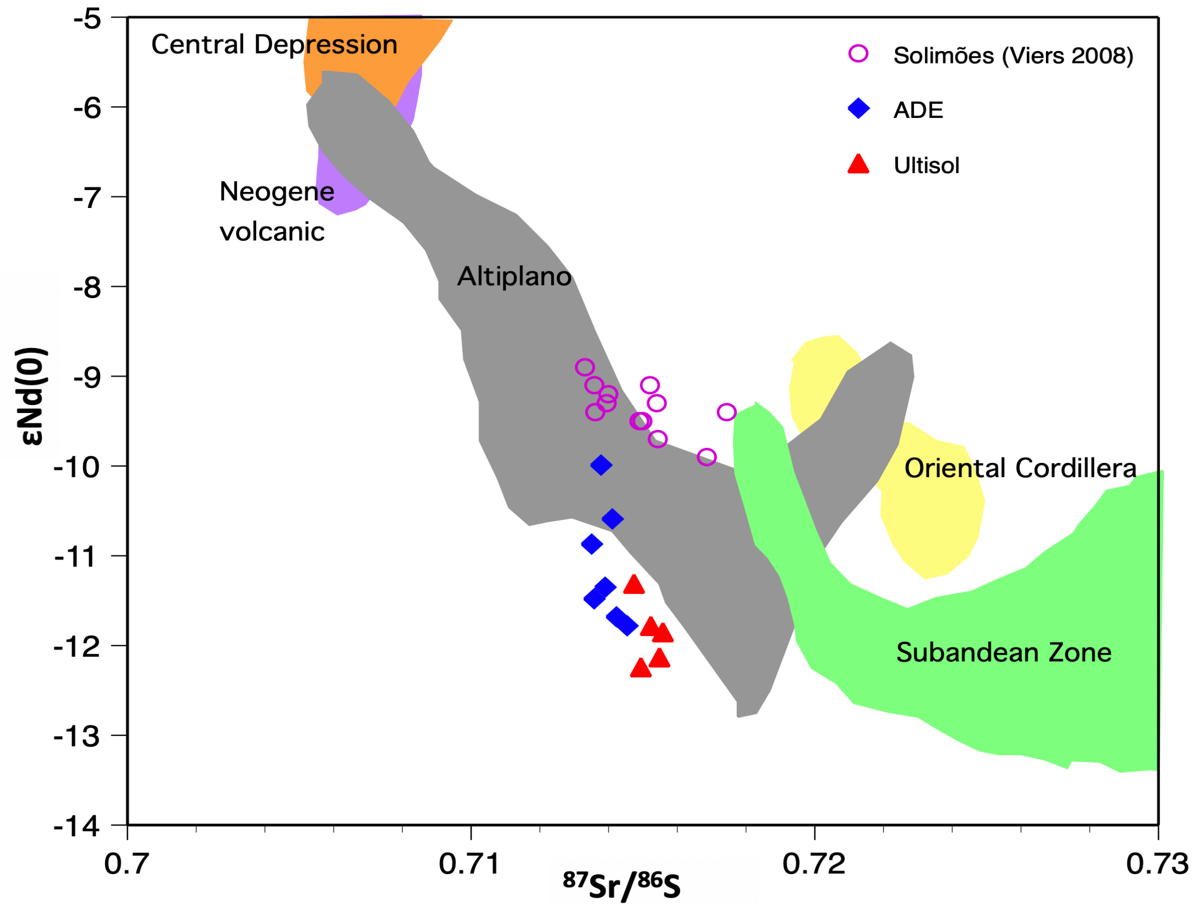


Supplementary Figure 4. **(A)** Isotopic ratios of strontium (Sr) as a function of soil depth and in relation to neodymium (Nd) isotope ratios. (**B)** Typical isotopic signatures of Sr and the radiogenic isotope of Nd εNd(0) - deviation from reference chondrite - across the Amazonian floodplain[2], which indicate exogenous alluvial inputs to ADE profiles but not to the adjacent Ultisol.

A



B



Supplementary References

1. Aburto, F. A. & Southard, R. J. Thermal analysis mineral quantification and applications as a relative dating tool in moraine chronosequences. *Soil Sci. Soc. Am. J.* **80**, 502–515 (2016).
2. Roddaz, M. *et al.* Evidence for the control of the geochemistry of Amazonian floodplain sediments by stratification of suspended sediments in the Amazon. *Chem. Geol.* **387**, 101–110 (2014).