(Additional material relevent to "Increase of human over natural erosion rates in tropical highlands constrained by cosmogenic nuclides" by Hewawasam et al., 2003)

Tilak Hewawasam
Isotope Geology, University of Berne, Erlachstrasse 9a, 3012 Berne, Switzerland.

Friedhelm von Blanckenburg
Institut für Mineralogie, Universität Hannover, Callinstrasse 3, 30167 Hannover, Germany.

Mirjam Schaller
Department of Earth Sciences, University of Cambridge, Downing Street,
Cambridge CB2 3EQ, England.

Peter Kubik
Paul Scherrer Institute, c/o Institute of Particle Physics, ETH Hönggerberg, 8093 Zürich, Switzerland.

Appendix DR1: Cosmogenic Nuclide Analysis and Data Processing

Sand samples were taken from the beds of creeks, streams and trunk streams. Surface soils are single location grab samples from small catchments that were collected on slopes adjacent to creeks, usually not taken more than 50 m distances from the creek. Ca. 50 g of pure quartz were used for measurement of cosmogenic nuclides. Sample processing and AMS analysis are after Schaller et. al. (2001). Analysis of grain size fractions in the Mahaweli trunk stream and its tributaries shows that between 25 and 40% of the bed material is composed of the size fraction 0.6-1.4 mm (Irrigation Department of Sri Lanka, personal communication). Tests on two samples with grain sizes ranging from 0.25 mm to 20 mm showed that nuclide concentrations are remarkably independent of grain size for all fractions in the sample of M-PER. In sample AO-2, fractions <1 mm yield uniform concentrations, whereas the concentrations only double towards the 20 mm fraction (see in Table DR2). This relationship is the opposite of the correlation observed in Puerto Rico (Brown et al., 1998), but is much smaller in magnitude. Overall, the size fraction of 0.5-1 mm was used as the representative sample for nuclide concentration determination.

Erosion rates were calculated following the approach described by Schaller et. al. (2001), using a recently revised set of scaling laws (Schaller et al., 2002). In their calculation, representation of nucleonic, stopped muonic and fast muonic contributions was taken into account separately. This is important in erosion rate studies because material has been denuded from great depths, which are effecting the muonic contribution. The latitudinal effect on muonic production is negligible for the latitudes above 40∀N (Schaller et al., 2002). We estimated this effect for our samples based on Allkofer (Allkofer, 1975). Documented paleomagnetic changes within the cosmogenic time scale, which are much more important closer to the equator than high latitudes, were also taken into consideration (Masarik et al., 2001). The production rates were determined from the catchments' mean altitudes instead of averaging the production rates derived from the actual basin hypsometry. The advantage of this approach is that production rates can be readily recalculated from the altitudes and latitudes given (Table 1 and Table DR2). This simplification can be justified because the differences introduced into production rates are typically less than 0.5%. Even for catchments with high relief the difference in production rate is only 1.7%.

The erosion rate and sediment generation rate uncertainties in Table 1 and Table DR2 combine (i) the total analytical error of the measured ^{10}Be concentration (based on 1ω uncertainties for the various contributions), (ii) an estimated upper limit for the uncertainty from the altitude determination, (iii) an error for the scaling factor, and (iv) the uncertainty of the SLHL production rate. Correction of erosion rates for quartz enrichment in regolith through dissolution may be important in cosmogenic nuclide-derived erosion rate assessments (Riebe et al., 2001; Small et al., 1999), but our rates were not corrected for quartz enrichment and hence indicate the minimal rate of erosion.

TABLE DR1. SHORT-TERM SEDIMENT YIELDS, UPPER MAHAWELI CATCHMENT, SRI LANKA

Large catchment	Area (km^2)	Sediment yield[*] (t.km^{-2}.yr^{-1})	Record period	Record length (yr)	Weathering flux[†] (t.km^{-2}.yr^{-1})	Short-term sed. yield[§] (t.km^{-2}.yr^{-1})
Derived from sediment gauging						
Atabage oya	44	325	1997-2000	03	34	359
Nilambe oya	62	115	1991-2000	09	19	134
Huluganga	123	209	1993-2000	07	15	224
Maha oya	107	347	1994-2000	06	48	395
Belihul oya	146	516	1995-2000	05	37	553
Uma oya	98	1583	1993-2000	06	29	1612
Peradeniya	565	417	1950-1982	33	30	447
Derived from sediment trapping						
Uma oya	740	2090	1991-1994	03	30	2120
Pologolla	721	375	1976-1993	17	30	405
Victoria	16	480	1985-1993	07	30	510

[*] Mean annual sediment yield, derived from river gauging and reservoir filling measurements. Trap efficiency of reservoirs has been taken into account to calculate sediment yield from survey results (sediment gauging data by the Mahaweli Authority and the Irrigation Department of Sri Lanka, personal communication). Unmeasured bed material was taken to be 10% of the total sediment yield (Summerfield and Hulton, 1994).

[†] Mean annual weathering flux, derived from the measured dissolved load for the six catchments over one hydrological year since March 2000. The dissolved load was corrected for non-weathering source using factors given by Berner and Berner (1987) in continental scale. An average annual weathering flux of 30 t.km^{-2}.yr^{-1}, based on chemical mass balance of the six catchments, is considered for unmeasured catchments.

[§] Short-term sediment yield, sum of sediment yield[*] and weathering flux[†].

TABLE DR2. COSMOGENIC NUCLIDE-DERIVED EROSION RATES AND SAMPLE DESCRIPTION, UPPER MAHAWELI CATCHMENT, SRI LANKA

Catchment	Sample	Area (km^2)	Alti. (m)	Max. alti. (m)	Mean alti. (m)	^{10}Be conc.[*] X10^5	App. age (k.y.)	Erosion rate (mm/k.y.)	Sediment gene. rate (t.km^{-2}.yr^{-1})
Sediment (s) and soil (b) from small catchments									
Galaha	GH(F)-1 (s)	0.04	1540	1610	1560	9.48 ∂ 0.53	91	8.0 ∂ 0.7	21.6 ∂ 1.9
(Forest)	GH(F)-2 (s)	0.01	1580	1610	1600	15.84 ∂ 0.30	147	4.7 ∂ 0.3	12.7 ∂ 0.8
	GH(F)-3 (b)	-	1580	1580	1580	14.67 ∂ 0.55	137	5.1 ∂ 0.4	13.8 ∂ 1.1
Galaha	GH(T)-1 (s)	0.25	1410	1610	1510	11.44 ∂ 0.90	113	6.3 ∂ 0.7	17.0 ∂ 1.9
(Tea)	GH(T)-2 (s)	0.18	1400	1560	1500	14.05 ∂ 0.30	139	5.0 ∂ 0.4	13.5 ∂ 1.1
Hakgala	HG(F)-3 (s)	0.15	1700	1800	1780	8.20 ∂ 0.22	68	10.8 ∂ 0.7	29.2 ∂ 1.9
(Forest)	HG(F)-3 (b)	-	1700	1700	1700	7.45 ∂ 0.22	65	11.4 ∂ 0.8	30.8 ∂ 2.2
	HG(F)-4 (s)	1	1750	2080	1900	8.69 ∂ 0.22	67	10.9 ∂ 0.7	29.4 ∂ 1.9
	HG(F)-4 (s)-D.S.	1	1750	2080	1900	9.11 ∂ 0.44	70	10.4 ∂ 0.8	28.1 ∂ 2.2
	HG(F)-4 (b)	-	1750	1750	1750	10.71 ∂ 0.47	91	7.9 ∂ 0.6	21.3 ∂ 1.6
Hakgala	HG(T)-1 (s)	1	1510	1800	1700	7.64 ∂ 0.22	67	11.1 ∂ 0.7	30.0 ∂ 1.9
(Tea)	HG(T)-2 (s)	0.3	1510	1710	1680	6.01 ∂ 0.25	53	14.2 ∂ 1.0	38.3 ∂ 2.7

Sediments from large catchments									
Atabage oya	AO-1	44	590	2080	1110	3.13 ∂ 0.19	41	20.2 ∂ 1.7	54.5 ∂ 4.6
	AO-2(i)	30	810	2080	1240	4.08 ∂ 0.15	49	16.5 ∂ 1.1	44.6 ∂ 3.0
	AO-2	30	810	2080	1240	3.49 ∂ 0.53	42	19.5 ∂ 3.6	52.7 ∂ 9.7
	AO-2(ii)	30	810	2080	1240	5.22 ∂ 0.27	63	12.5 ∂ 1.0	33.8 ∂ 2.7
	AO-2(iii)	30	810	2080	1240	6.46 ∂ 0.21	77	9.9 ∂ 0.7	26.7 ∂ 1.9
	AO-2(iv)	30	810	2080	1240	6.02 ∂ 0.30	72	10.7 ∂ 0.8	28.9 ∂ 2.2
	AO-2(v)	30	810	2080	1240	7.13 ∂ 0.30	85	8.9 ∂ 0.7	24.0 ∂ 1.9
Nilambe oya	NO-1	62	610	1700	945	2.66 ∂ 0.16	39	21.7 ∂ 1.8	58.6 ∂ 4.9
	NO-2	23	640	1700	1070	2.57 ∂ 0.13	35	24.0 ∂ 1.7	64.8 ∂ 4.6
Hulu ganga	HUG-1	123	470	1880	1045	2.64 ∂ 0.16	37	23.1 ∂ 1.9	62.4 ∂ 5.1
	HUG-2	10	700	1880	1165	2.07 ∂ 0.30	27	31.6 ∂ 5.4	85.3 ∂ 14.6
Maha oya	MO-1	107	570	2120	1090	2.41 ∂ 0.21	32	26.0 ∂ 2.9	70.2 ∂ 7.8
	MO-1-D.S.	107	570	2120	1090	2.14 ∂ 0.17	29	29.4 ∂ 2.9	79.4 ∂ 7.6
	MO-2	10	1200	2120	1650	10.20 ∂ 0.26	92	7.9 ∂ 0.5	21.3 ∂ 1.4
	MO-2-D.S.	10	1200	2120	1650	11.20 ∂ 0.28	100	7.2 ∂ 0.5	19.4 ∂ 1.4
	MO-3	6	1100	2120	1515	2.45 ∂ 0.13	25	32.3 ∂ 2.5	87.2 ∂ 6.8
Belihul oya	BO-1	146	240	2520	1165	1.45 ∂ 0.16	19	45.4 ∂ 5.7	122.6 ∂ 15.4
	BO-2	72	665	2520	1510	2.30 ∂ 0.17	24	34.4 ∂ 3.3	92.9 ∂ 8.9
Uma oya	UO-1	740	150	2510	1190	2.57 ∂ 0.26	32	25.7 ∂ 3.1	69.4 ∂ 8.4
	UO-2	98	1030	2510	1620	4.00 ∂ 0.78	37	21.0 ∂ 9.2	56.7 ∂ 24.8
	UO-3	48	1090	2510	1835	2.58 ∂ 0.34	22	36.6 ∂ 5.9	98.8 ∂ 15.9
Peradeniya	M-PER	565	470	1710	840	3.92 ∂ 0.20	62	13.3 ∂ 1.1	35.9 ∂ 3.0
	M-PER(ii)	565	470	1710	840	4.68 ∂ 0.18	74	11.0 ∂ 0.8	29.7 ∂ 2.2
	M-PER(iii)	565	470	1710	840	4.82 ∂ 0.25	76	10.6 ∂ 0.9	28.6 ∂ 2.4
	M-PER(iv)	565	470	1710	840	3.73 ∂ 0.25	59	14.1 ∂ 1.3	38.1 ∂ 3.5
	M-PER(v)	565	470	1710	840	3.22 ∂ 0.20	51	16.6 ∂ 1.5	44.8 ∂ 4.1
Haragama	M-HAG	844	430	1710	755	2.16 ∂ 0.15	37	24.2 ∂ 2.2	65.3 ∂ 5.9
Victoria	M-VIC	16	240	1110	525	1.03 ∂ 0.10	21	45.0 ∂ 5.2	121.5 ∂ 14.0
Minipe	M-MIN	778	115	2510	1090	2.05 ∂ 0.12	28	30.5 ∂ 2.4	82.4 ∂ 6.5

Note: (i) = grain size : 0.25-0.5 mm, (ii) = grain size : 1-2 mm, (iii) = grain size : 2-3 mm, (iv) = grain size : 3-6 mm, (v) = grain size : 12-20 mm, no number with index = grain size: 0.5-1 mm, F = Forested, T = Tea planted, D.S. = Duplicate sample). Mean latitude for all samples is 7°N.

* Units: Atoms of ^{10}Be per 1 g of quartz.

REFERENCES CITED

Allkofer, O.C., 1975, Introduction to Cosmic Rays: München, Verlag Karl Thiemig.

Berner, E.K., and Berner, R.A., 1987, The Global Water Cycle, Prentice-Hall, 397 p.

Brown, E.T., Stallard, R.F., Larsen, M.C., Bourlès, D.L., Raisbeck, G.M., and Yiou, F., 1998, Determination of predevelopment denudation rates of an agricultural watershed (Cayaguás River, Puerto Rico) using in situ-produced ^{10}Be in river-borne quartz: Earth and Planetary Science Letters, v. 160, p. 723-728.

Masarik, J., Frank, M., Schäfer, J.M., and Wieler, R., 2001, Correction of in situ cosmogenic nuclide production rates for geomagnetic field intensity variations during the past 800,000 years: Geochimica et Cosmochimica Acta, v. 65, p. 2995-3003.

Riebe, C.S., Kirchner, J.W., and Granger, D.E., 2001, Quantifying quartz enrichment and its consequences for cosmogenic measurements of erosion rates from alluvial sediment and rogolith: Geomorphology, v. 40, p. 15 - 19.

Schaller, M., von Blanckenburg, F., Hovius, N., and Kubik, P.W., 2001, Large-scale erosion rates from in situ-produced cosmogenic nuclides in European river sediments: Earth and Planetary Science Letters, v. 188, p. 441-458.

Schaller, M., von Blanckenburg, F., Veldkamp, A., Tebbens, L.A., Hovius, N., and Kubik, P.W., 2002, A 30,000 yr record of erosion rates from cosmogenic ^{10}Be in Middle European river terraces: Earth and Planetary Science Letters, v. 204, p. 307-320.

Small, E.E., Anderson, R.S., and Hancock, G.S., 1999, Estimates of the rate of regolith production using ^{10}Be and ^{26}Al from an alpine hillslope: Geomorphology, v. 27, p. 131-150.

Summerfield, M.A., and Hulton, N.J., 1994, Natural controls of fluvial denudation rate in major world drainage basins: Journal of Geophysical Research, v. 99, p. 13871-13883.